Potential Use of Waste Heat from the Projectors for Low Power Applications

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Abstract - *The need for many systems to reject heat as a by-product of their operation is fundamental to the law of thermodynamics. Waste heat has lower utility. So, the effective use of this waste heat can be a source for an alternative energy. An analysis of the effective use of waste heat from the Projectors, based on Seebeck effect is done. A power convertor (boost convertor) is used to enhance the power so that it can be used in various low power applications.*

1.INTRODUCTION

The generation of electrical energy from the waste heat is an interesting area under study. Waste heat is generated from many electronic devices. In general waste heat is produced in any process where work is done. Conventional methods of conversion of heat to electricity can be employed only for very high intensity sources. A general overview of conversion of heat from low and medium level intensity sources using thermoelectricity is discussed. The advantage of this method is that it does not require high investment and regular maintenance which is needed in the case of conventional methods. In order to demonstrate the effective use of waste heat, the generation of electrical energy from a projector is analyzed. This obtained electrical energy can be used in various low power applications. The need of the project is that Today, the major source for electrical energy is the fossil fuel, which is renewable type of energy. The availability of these energy sources are continuously declining due to the excessive use and increase in population. Therefore, there is a large need for alternative energy sources that provide small amount of electricity which is nonrenewable. Vast amount of heat is discharged into the atmosphere from the various sources and evidently, it would be beneficial to recover some amount of this waste heat and convert them into useful electrical energy. Unfortunately, large amount of waste heat that has been emitted has a temperature less than 140 'C and hence the conventional methods such as the steam turbines cannot be employed. Two other methods such as thermoelectricity and Rankine cycle can be employed. Though Rankine cycle has a higher efficiency, it is not used as it involves the use of hazardous chemicals such as ammonia and is less reliable and hence thermoelectric generators are used in this conversion. The advantage of thermoelectric generators is that it consists of no moving parts, easier integration with devices and cost effective.

2.PROPOSED SYSTEM

The proposed system is discussed and the operations and functions of the various blocks are explained in detail. There are four blocks and they are,

1.Projector:

2.TEG modules

3.Boost converter

4.Low power application

A projector is an optical device that is used to create an image generally on a projector screen. There are three types of projectors namely DLP, CRT and LCD projectors. A projector is a device that consists of a high intensity lamp for its operation. The supply voltage to the projector is 220volt in which 24volt is required for the operation of the lamp. This lamp produces enormous amount of heat energy that causes damage to the components present inside the projector and hence this heat is removed using a ventilator fan. This type of heat source is called convection, where heat is transferred through air. Thus an apt method for this type of heat source to be converted is thermoelectricity.

Hence, thermoelectric generators are used in this conversion. The heat from the projector is made incident on the thermoelectric generator. Various types of materials are analysed and chosen to provide high output voltage. This energy produced is then amplified by using a boost convertor (power convertor) and used in low power appliances such as mobile charger, to charge a battery etc.,

Various tests have been done in order to evaluate the energy that is possible to recover.

3.METHODS OF CONVERSION

Thermoelectric modules are used in the conversion process. Thermoelectric modules consist of thermocouples and it is based on SEEBECK effect and from the various types of thermocouples a comparison is made and the suitable module is selected. Seebeck effect states that when two dissimilar metals are joined to form a junction and when one side is maintained hot and other side is maintained at a lower temperature, electrical energy is produced in the junctions. The temperature difference is directly proportional to the amount of voltage produced. Fig 1 shows the see beck effect. Fig 2 shows the graph of thermal voltage produced versus temperature.

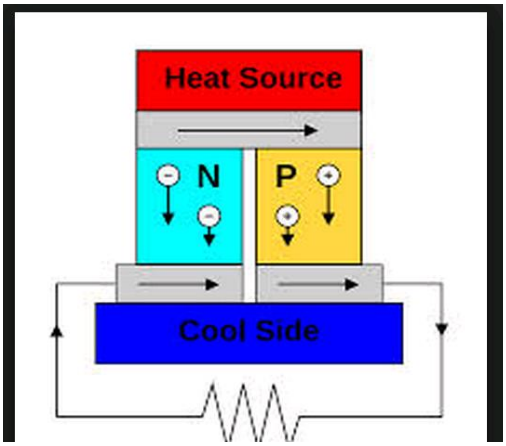

Fig 1: Seebeck effect

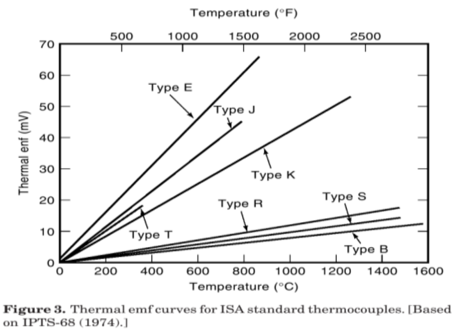

Fig 2: Thermal EMF curves for thermocouples

Thermocouples are generally of two types Base metals and Noble metals. Base metals include type E, J, K, T whereas Noble metals include type S, R, B. Type K thermocouple is Nickel-Chromium/Nickel-Alumel. It is the most common type of thermocouple, it is inexpensive, accurate, reliable and has a wide temperature range. Type J is made of Iron/Constantan is also very common and has a smaller temperature range and a shorter lifespan at higher temperature than the Type K. It is equivalent to Type K in terms of expense and reliability. Type T is Copper/Constantan. It is very stable thermocouple and is often used in extremely low temperature applications such as cryogenics or ultra-low freezers. Type E is made of Nickel-Chromium/Constantan. It has a stronger signal and higher accuracy than the Type K or J at moderate temperature of 1000F and lower. Type N is made of Nicrosil/Nisil. The type N shares the same accuracy and temperature limits as the Type K but Type N is more expensive. Type R is made of Platinum/Rhodium-13%. It is used in extremely high temperature applications which has the highest percentage of Rhodium which makes it more expensive. Type R is very similar to Type S in terms of performance, it is sometimes used in lower temperature applications because of its high accuracy and stability. Type B Platinum/ Rhodium30%. It is used in extremely high temperature applications. It has the highest temperature limit of all the thermocouples. It has high accuracy and stability. Various types of thermocouples were analysed and chosen based on their figure of merit. Noble metals are generally costly and used in very high temperature areas. Whereas type J can be used but the lifetime of these are very less and hence they are not preferred. Type T is used for low temperature areas such as freezers. From table 1 it is observed that type E is much more suitable than type K.

Table 1: Characteristics of various thermocouples

TYPE	OXIDATION RESISTANCE	MAXIMUM TEMP WITHSTANDING CAPABILITY
TYPE K	MORE	MORE
TYPE E	LESS	LESS

4.RESULTS ON TESTING THE MODULES

The testing of various thermoelectric modules were performed in several configurations such as series, parallel, connecting three thermoelectric modules in series and the efficient structure was found. The comparison of these various configurations are explained below

Fig 3: TEG with heat sink on one side

We had initiated our work by just placing the module alone in front of the projector, so when the heat is emitted, the module side facing the projector gets heated up soon and slowly transfers to the other end and so the temperature difference we obtained was negligible. So we just analyzed and figured out a solution of attaching a heat sink on one side (hot side) of the TEG module. So in this case the obtained output voltage was **0.3volt**, which wasn't sufficient to use for low power applications.

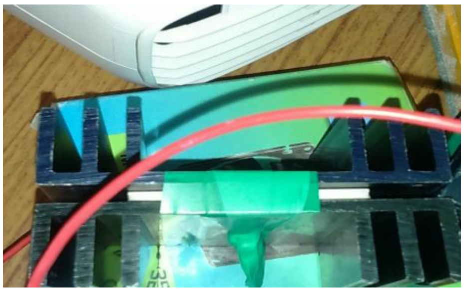

Fig 4: TEG with heat sink on both sides

So in that note we decided to mount heat sink on both the sides of the module, the temperature difference was more or less equal, therefore in order to maintain the required temperature gradient, we had placed a fan near the side so that it pushes away the heat and maintains low temperature. So with this setup we obtained **0.4volt.**

After testing with a single module, several configurations of the thermoelectric modules were tested. When two modules were connected in series the acquired voltage was **0.73volt**. After a certain amount of delay, the voltage was dropped to **0.71volt.** Therefore, we made a small comparison between series and parallel configurations.

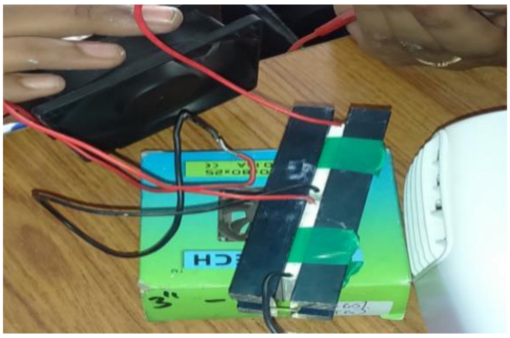

Fig 5: Two TEG modules

For different values of load resistors, the corresponding current has been noted down and a plot of the V-I characteristics is obtained, from which the obtained voltage values are compared. Finally, it is observed that the series configuration is more efficient.

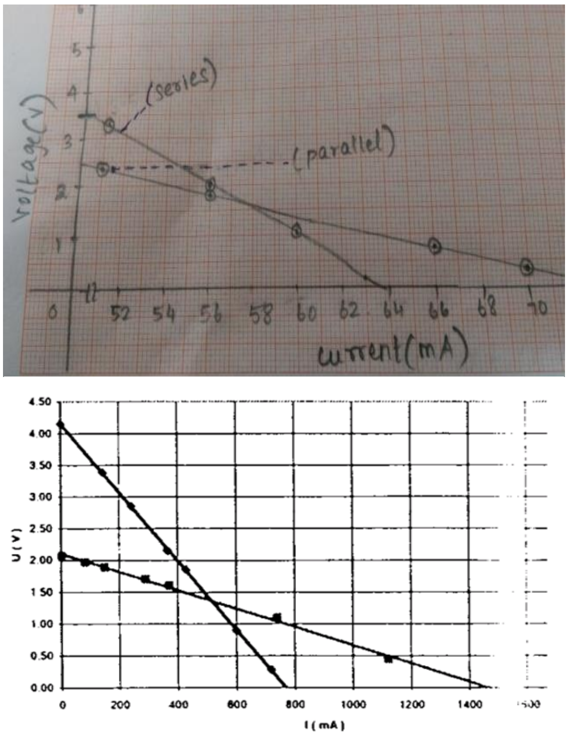

Fig 6: Graph for serial and parallel configuration

When three modules were connected in series, the voltage obtained is **0.44volt.** This is because the modules were placed at an angle of 45degrees, so the heat that is dissipated wouldn't pass through all the modules and obtained voltage is less. The setup of three modules is as shown in the fig 7.

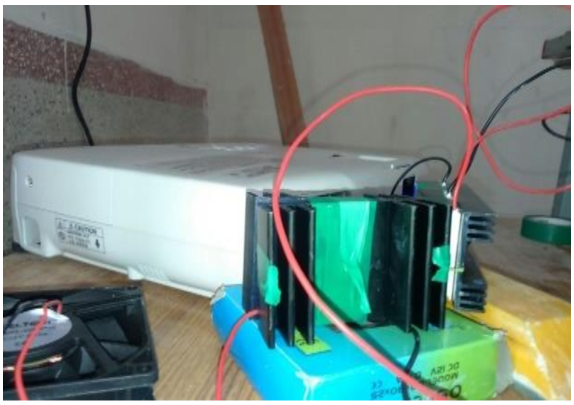

Fig 7: Three TEG modules in series

On the other hand, when four modules have been placed, (two at the top and the other two at the bottom) the emitted heat gets transferred equally and so the obtained voltage was **0.77volt** which is more efficient for usage in low power applications. But when this setup is tested for a fixed amount of time there is a drop in the voltage. The voltage finally obtained is **0.67v.** The results of the various configurations tested are listed in the table 2.

The configuration that is best suited can be understood from the table.

Table2: Results on testing TEG modules

No of modules	Voltage obtained (V)	Voltage obtained after a fixed time (V)
1	0.4	0.34
2	0.73	0.71
3	0.44	0.39
4	0.77	0.67
5	0.5	0.44

From the above table it is evident that the setup of 2 modules connected in series is efficient. When they are connected in parallel the voltage obtained is not sufficient.

5.BOOSTER CIRCUIT

The desired boost convertor circuit is implemented using an IC TPS6122x.Using this IC, the obtained dc voltage of around 0.7volt can be effectively boosted to 5volt.The TPS6122x family devices provide a power-supply solution for products powered by a single-cell, two-cell, one-cell Li-Ion or Li-polymer battery. The TPS6122x is a high performance, high efficient family of switching boost converters. To achieve high efficiency, the power stage is realized as a synchronous-boost topology. For the power switching, two actively controlled low-RDS on power MOSFETs are implemented.

The circuit diagram of booster circuit using IC tps6122x is shown below in fig 8.

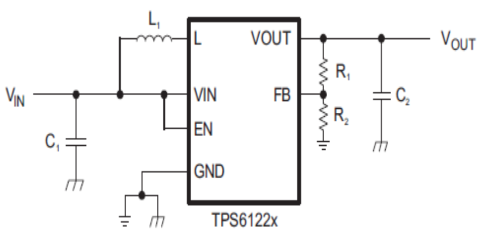

Fig.8: Circuit diagram of the booster circuit

The obtained voltage of 0.7 volt is given to the circuit via capacitor and inductor combination at the input of IC. At the output, a potential divider circuit (R_1, R_2) is used for adjusting the output voltage. The output voltage is coupled via a capacitor. A suitable inductor must be connected between pin VIN and pin L. Inductor value of around 4.7 μH shows good performance due to reduced switching frequency and therefore reduced switching losses. However, using reduced inductor values below 2.2 μH is not recommended. The inductor value can be calculated using the relation

$$L = V_{in} \times (V_{out} - V_{in}) / (f \times V_{out})$$

An input capacitor (C1) value of at least 10 μF is recommended to improve transient behavior of the regulator and EMI behavior of the total power supply circuit. A ceramic capacitor placed as close as possible to the VIN and GND pins of the IC. For the output capacitor C2, small ceramic capacitors are recommended, placed as close as possible to the VOUT and GND pins of the IC. If, for any reason, the application requires the use of large capacitors which cannot be placed close to the IC, the use of a small ceramic capacitor with a capacitance value of around 2.2μF in parallel to the large one is recommended. This small capacitor should be placed as close as possible to the VOUT and GND pins of the IC. A minimum capacitance value of 4.7 μF should be used, 10 μF is recommended. If the inductor value exceeds 4.7 μH, the value of the output capacitance value needs to be half the inductance.

$$C_2 >= L/2$$

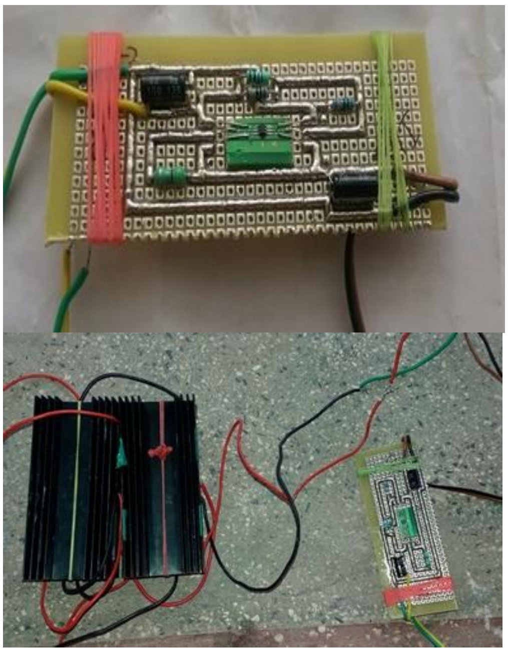

Fig.9: Implementation of the booster circuit

Table 3: Results on testing booster circuits

S.NO	INPUT	OUPUT
1	0.5volt	0.02volt
2	>0.6volt	5.1volt

Thus, the integrated circuit acts a switch which conducts when the input voltage exceeds the threshold (0.6volt), and gives an output voltage of 5.1 volt. The obtained output voltage can be given appropriate application circuits which operates at this voltage level.

6.APPLICATION

On analysis of various low power applications, it is found that a temperature sensor consumes substantially a low power and operates at a very low input voltage of 4volt.The various low power applications that can be used are as follows:

- Heat sink fans:1.2V DC
- Power bank:3.7V to 5 V (0.5 W)
- Battery powered Applications
- Mp3 recharger:0.25-0.4W
- White or status LEDs
- Sensors.

7.CONCLUSION AND FUTURE WORKS

Thus, the excess heat energy obtained from the projector is effectively converted to electrical energy using thermoelectric modules. It is found that two modules connected in series is the best setup where we obtained 0.7volt. It was boosted with a boost convertor which produced 5.1volt which is sufficient to power low power applications. The results obtained are close to reaching the objective proposed. The exploration of the potential use of waste heat is a promising field under development. Further works to be done are to match the impedance of the output of the thermoelectric generator and the input of the boost convertor. Due to impedance mismatch, at some instance there is a corresponding voltage drop at the input end of the boost convertor. By proper impedance matching this can be rectified. It can be employed in various large scale industries as it involves large machines which dissipate heat as their by-product. The domestic and service sectors have been identified as the areas that would most likely benefit due to the range of temperatures of waste heat sources.

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