# Fabrication Of Solar Operated Thermoelectric Refrigerartion System

Veerandra Patil, Dr. Manoj Modi, Rahul Mandloi, Sanjay Gautam, Swapnil Mukati, Vivek Verma

**Abstract**— In this research article, prototype of thermoelectric refrigeration system working has been designed and fabricated. This fabricated system is working on DC voltage, which is generated by the photo voltaic cells. The developed experimental prototype is having a refrigeration space of 1 liter capacity, which is refrigerated by using four numbers of Peltier module (Supercool : PE-063-10-13, $Q_{max}$=19W) and a heat sink fan assembly used (Model No: TDEX6015/TH/12/G, $R_{th}$=1.157$^{o}$C/W ) to increase the heat dissipation rate from hot side of Peltier module. In the recent years, we have many problem such as energy crises and environment degradation due to the increasing emission of $CO_2$ and ozone layer depletion has become the primarily concern in both the developed and developing countries. Our project utilizes the solar energy for its operation. Solar refrigeration using thermoelectric module is going to be one of the most cost effective, clean and environment friendly system. This project does not need any kind of refrigerant and mechanical device like compressor, prime mover, etc for its operation. The main purpose of this project is to provide refrigeration to the remote areas where power supply is not possible.

**Index Terms**—Photo voltaic cells, Peltier module, Solar energy, Thermoelectric refrigeration.

## 1 INTRODUCTION

### 1.1 Background of Thermoelectric Refrigeration

This invention relates to produce the refrigeration effect with the use of solar energy and peltier module. We use solar panel here to save energy and peltier module to eliminate most of the moving parts in common refrigeration system. Generally we see that common refrigeration system has compressor, refrigerant which required electric energy to run which is also a noisy operation. So we use pettier module to reduce such type of problem.Xi et al.1 presented in their study that thermoelectric refrigeration emerges as alternative green refrigeration technology due to their distinct advantages as noiseless and wearless due to no moving parts, reliable, portable and compatible with Solar PV cell generated DC power, making them complete environment friendly. A detailed comparative study of vapour compression, thermoelectric and absorption refrigeration system has been conducted by Bansal et al.2 to compare the development cost, energy consumption, noise intensity production and COP for these three refrigeration systems. Thermoelectric cooling works on the principle of Peltier effect, when a direct current is passed between two electrically dissimilar materials heat is absorbed or liberated at the junction. The direction of the heat flow depends on the direction of applied electric current and the relative Seebeck coefficient of the two materials. A Peltier module or thermoelectric cooling module Fig.1 is a solid-state active heat pump which consist a number of p- and n- type semiconductor couples connected electrically in series and thermally in parallel are sandwiched between two thermally conductive and electrically insulated substrate.

### 1.2 Basic Concept of Thermoelectric Refrigeration

In 1821-31 Thomas Johann Seeback found that a circuit made from two dissimilar metals, with junctions at different temperatures would deflect a compass magnet.
However, it was quickly realized that a "Thermoelectric Force" induced an electrical current, which by Ampere's law deflects the magnet. More specifically, the temperature difference produces electric potential (voltage) which can drive an electric current in a closed circuit. Today, this is known as the Seeback effect.

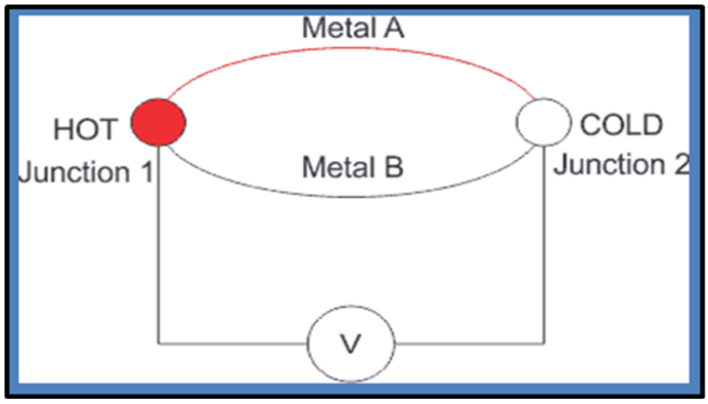


*Figure 1.1: Thomas Effect*

### 1.3 Principle and characteristics of Thermoelectric Refrigeration

Thermoelectric coolers operate by the Peltier effect. The device has two sides, and when a DC electric current flows through the device, it brings heat from one side to the other, so that one side gets cooler while the other gets hotter. The "hot" side is attached to a heat sink so that it remains at ambient temperature, while the cool side goes below room temperature. In some applications, multiple coolers can be cascaded together for lower temperature. Thermoelectric refrigeration work on the principle of seebeck effect in which the voltage is applied between two different combination of metal and due to effect of seebeck the cooling and heating phenomena is happened which can be used accordingly for


- *Veerandra Patil, Acropolis Institute of Technology & Research Indore, India, E-mail: virgipatil@mail.com*
- *Dr. Manoj Modi, Acropolis Institute of Technology & Research Indore, India,*
- *E-mail: manojmnitjaipur1@gmail.com*

different purpose.

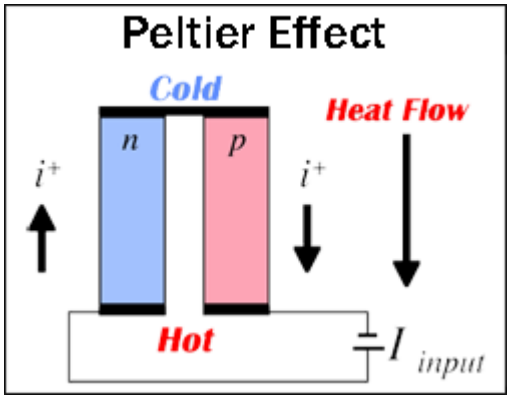


*Figure 1.2-Peltier effect*

Following are the characteristics:

- Save energy by using solar energy, which is renewable source of energy.
- Does not produce harmful gases like CFC's.
- Noiseless operation
- No moving parts ,no friction.
- Portable.

## 2 LITERATURE REVIEW

On by reviewing the literatures on solar operated thermoelectric refrigeration of the various researchers, the literatures here described as:

[1] Sujith G. et al.(2016)
In this paper author design and fabricated the Thermoelectrical Refrigeration to cool a volume of 40L using principle of Peltier effect to cool and maintain temperature range of 5°C to 25°C and the project is used only for light heat load to lower its temperature to particular temperature. One of the advantage of this project is it takes low power to drive the refrigerator.

[2] Bharat M. Jibhakate et al.(2016)
The study show that a Thermoelectric Refrigeration model is design and fabricated in place of compressor and it is based on principle of Peltier effect to maintain effectiveness of both heating and cooling side also the simulation is done to on thermoelectric refrigeration to maintain it at 40°C. The designed is environmental friendly also it has various applications in medical and pharmaceutical equipments.

[3] Sivakumar.N.et al. (2018)
In the literature the author designed the Thermoelectric Refrigeration in place of prime movers, compressor or any type of refrigerant as this designed is applicable in such areas where the electricity not available and also environmental friendly as CFC, $CO_2$ etc. produce in other refrigeration system. As per the experimental result on thermoelectric refrigeration the minimum temperature 15°C for cooling and maximum temperature 65°C for heating was obtained. Also comparisons of results done on effect of cooling on AC and DC supply and COP of systems.

[4] Mr. Swapnil B. Patond et al.(2015)
In this research a thermoelectric module is designed to analysis the heating and cooling system by using solar energy and which is based on peltier effect. This system is different from other refrigeration system where heating and cooling is done with the help of mechanical devices and by using refrigerants. Experimental study is done for small scale solar operated thermoelectric heating and cooling, the graph is plotted from obtained results from experiment for different metals, fruits & water to analyse the heating and cooling rates in various modes. This system is free from maintenance.

[5] D. Rajani et al.(2018)
In the literature the author fabricated a prototype of solar operated thermo electric cooling system based on peltier effect and its working on solar photo voltage cell generated DC voltage. Through the experiments the performance parameter (heat absorption, energy supply and coefficient of friction) are analysed the result show that the COP of the system increases with time interval. Through the system high COP on low cost obtained. It also having applications in Military and medical equipments.

[6] Abhijith Raju et al.(2016)
In this paper the authors objective is to design and develop solar operated thermoelectric refrigeration to produce small amount of refrigerating effect using solar energy this system is working on the principle of peltier effect. Its results from experiments shows that the COP about 0.17 when the atmosphere temperature was 27°C and 500ml water kept inside the refrigerated space for 50 minutes it shows that the reduction of temperature from 27°C to 15°C. and through the results of experiment shows that the system work continuously if we full charged it with solar panel for 15 hours.

## 3 COMPONENTS DETAILS

In this research we are fabricating a thermoelectric system using solar energy. It is an eco-friendly project, made by using thermoelectric module. The project supports both heating and cooling. The construction set up for this system requires following parts:

1. Solar panel
2. Charge controller
3. Battery
4. Fins,
5. Thermister
6. Exaust fan,
7. Circuit kit
8. Thermoelectric module.
9. Thermocol box

### 3.1 SOLAR PANEL

Solar panel refers either to a photovoltaic module, a solar hot water heater, or to a set of solar photovoltaic (PV) modules electrically connected and mounted on a supporting structure. A PV module is a packaged, connected assembly of solar cells. Solar panels can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each module is rated

by its DC output power under standard test conditions (STC), and typically ranges from 100 to 320 watts.

**SPECIFICATION OF SOALR PENAL**

| | |
|---|---|
| Panel Size | 1 ¼ " x 1" |
| Cost of the Panel | Rs.700 - Rs.1,000/- |
| Weight of the Panel | 1kg |
| Voltage | 12 volt |
| Current | 5 A |
| Power | 12 watt |

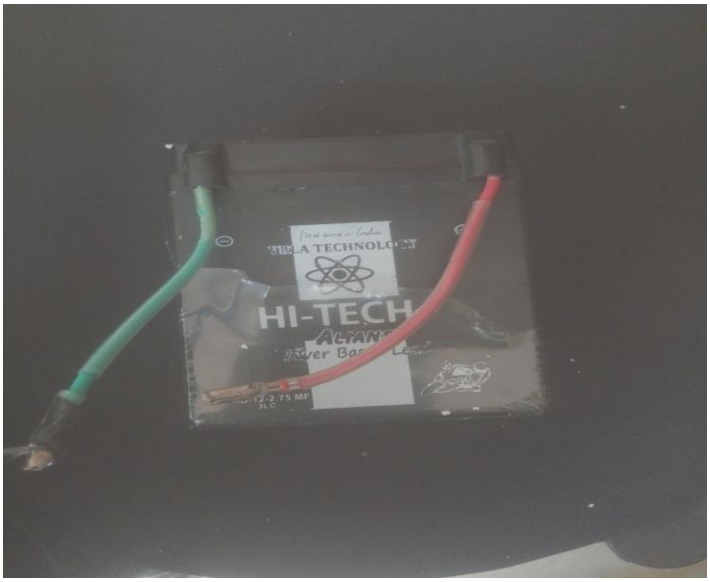


*Figure 3.1: Solar Panel*

### 3. 2 BATTERY

The device consist of lead-acid cell Sulphuric acid is used as electrolyte. Gives high load current of current rating (100-300) A-hr .The following chemical phenomena takes place -

$PbO_2 + 2H_2SO_4 \rightarrow 2PbSO_4 + 2H_2O$

In the project we use 12v battery. Battery is used for storage of electric energy we use here battery of 12v to run the fan of working on 12v

**SPECIFICATION OF BATTERY**

| | |
|---|---|
| Weight of the battery | 2 kg |
| Cost of the battery | Rs.500 – 600 |
| Output power | 86.4 watt |
| Operating voltage | 12 V |
| Current | 7.2 A |

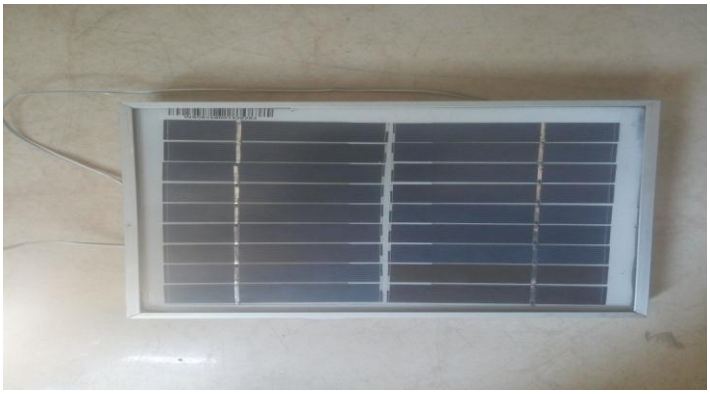

*Figure 3.2: Battery*

### 3. 3 PELTIER MODULE

Thermoelectric device are pair of two dissimilar metal semiconductors or conductor with semiconductor.In this system the device is made of extrinsic semiconductor having p-n junction in series with required no of cells.The energy difference of conduction band of material should be high for higher refrigeration.

**SPECIFICATION OF PELTIER MODULE**

| | |
|---|---|
| Model number: | TEC1-12706 |
| Voltage : | 12V |
| Umax (V) : | 15.4V |
| Imax (A) : | 6A |
| QMax (W) : | 92W |
| Internal resistance: | 1.98 Ohm +/- 10% |
| Dimensions : | 40mm x 40mm x 3.6mm |
| Power Cord : | 350mm |
| HS Code: | 854150 |
| Certification: | RoHS |
| Type: | Cooling Cells |
| Usage: | Refrigerator/Warmer |

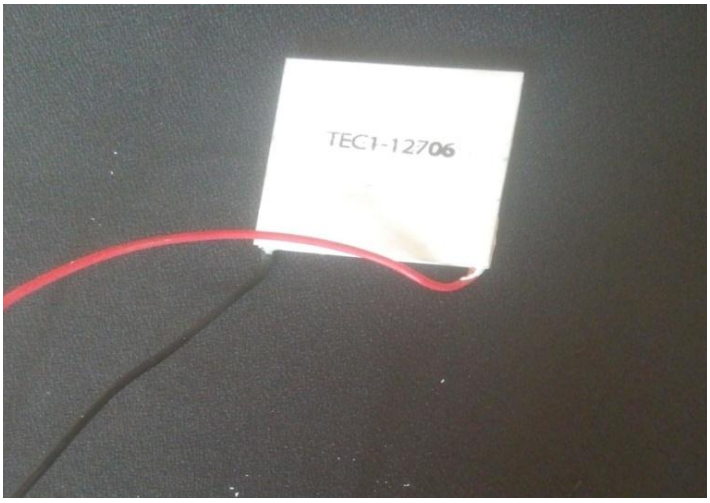


*Figure 3.3-Peltier Module*

### 3. 4 THERMISTOR

Thermistors are thermally sensitive resistors whose prime function is to exhibit a large, predictable and precise change in electrical resistance when subjected to a corresponding change in body temperature. Negative Temperature Coefficient (NTC)

thermistors exhibit a decrease in electrical resistance when subjected to an increase in body temperature and Positive Temperature Coefficient (PTC) thermistors exhibit an increase in electrical resistance when subjected to an increase in body temperature.

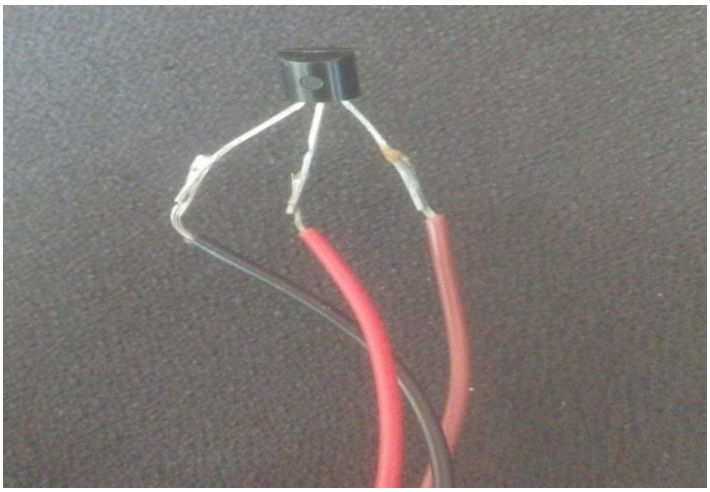

*Figure 3.4-Thermister*

### 3. 5 THERMOCOL BOX

In this we use thermocol box as a cabin or space too be cooled. EPS features a closed cell structure and thus supports low thermal conductivity. It is highly preferred for thermal insulation. Other materials possess an open cell structure and are thus incompetent when subject to moisture. Secondly, thermocol is tasteless, odorless and fungi-resistant. It is one of the most reliable and cost-effective means to protect your goods from transit damage. It is extremely light. It can be moulded into any desired shape and is yet sufficiently rigid to absorb shocks and physical impact.

1. It is light in weight.
2. It has low thermal conductivity.
3. It is tasteless, odorless and fungi resistance.
4. Reliable.

**SPECIFICATION OF THERMOCOL BOX**

| | |
|---|---|
| Capacity | 8 Liters |

*Figure 3.5-Thermocol Box*

### 3.6 FAN

Fan is used for throwing heat from peltier module to increase the efficiency of refrigeration effect. It is used because one side other than cooling side get heated which needs to be cooled down. To cool the other side the fan is uses to throw heat to the environment

**SPECIFICATION OF COOLING FAN**

| | |
|---|---|
| Brand: | OGC |
| Voltage : | 12V |
| Imax (A) : | 16A |
| Dimensions : | 10cm x 10cm x 8cm |
| Speed : | 2500rpm |
| Air Flow: | 34.65CFM |


*Figure 3.6-Cooling Fan*

### 3. 7 DIGITAL TEMPERATURE DISPLAY CIRCUIT

In this we use temperature display unit through which we record the temperature for calculation .it is connected with thermister in which voltage changes cause the change the resistance in it and transfer the signals to display unit which convert change the resistance in temperature unit.

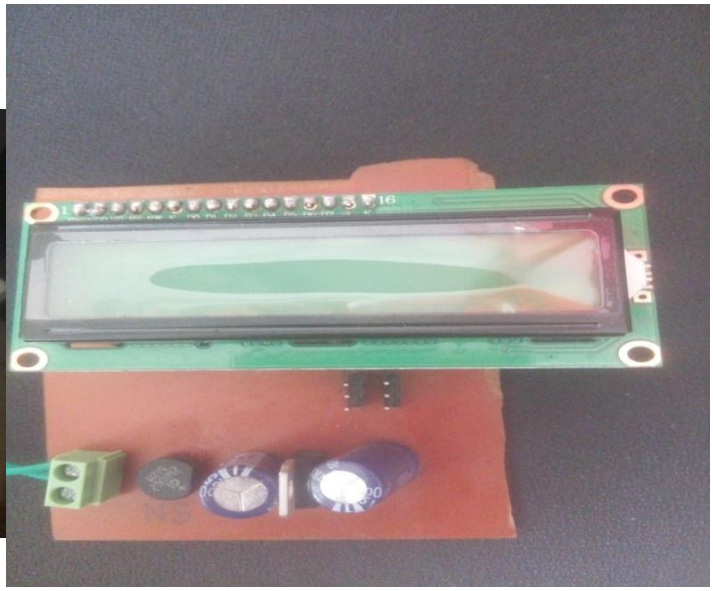

*Figure 3.7-Digital Temperature Display*

### 3. 8 FINAL ASSEMBLY OF RESEARCH MODEL

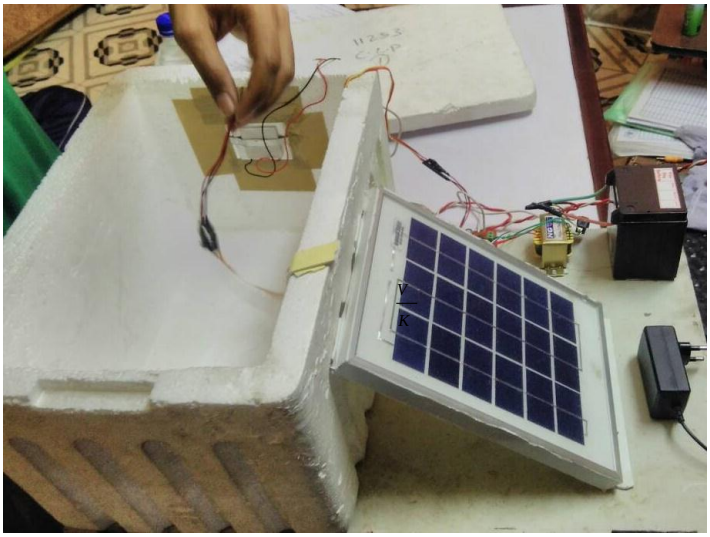

*Figure 3.8: Final Research Model*

## 4 PROBLEM DEFINITION

Generally we see that refrigeration process uses electric energy which is not available at most of the remote places in our country .we know that sun energy is available everywhere which also green energy and renewable energy source. We also save electric energy here. From last century till now refrigeration has been one of the most important factors of our daily life. The current tendency of the world is to look at renewable energy resources as a source of energy. This is done for the following two reasons; firstly, the lower quality of life due to air pollution; and, secondly, due to the pressure of the ever increasing world population puts on our natural energy resources. From these two facts comes the realization that the natural energy resources available will not last indefinitely. The basic idea is implementation of photovoltaic driven refrigerating system powered from direct current source or solar panel (when needed) with a battery bank. The Seebeck, Peltier and Thomson effects, together with several other phenomena, form the basis of functional thermoelectric modules. Thermoelectric Refrigeration aims at providing cooling effect by using thermoelectric effects rather than the more prevalent conventional methods like those using the 'vapour compression cycle' or the 'gas compression cycle'.

## 5 METHODOLOGY

In this we first explain the definition of the problem than plan and conducted the market research and prepared the bill of materials with this make space for Peltier module and calculate the specification of module than made the circuit connection and assemble the parts.

## 6 MANUFACTURING PLAN

In this first we prepare a process plan and work accordingly the steps of the process are:

1. Make cavity for fan and peltier module in box
2. Fit the fan in box
3. Connected the circuit and make the connection of diode with solar panel and Connect battery to solar panel
4. In this step we made three connections with battery
   a) Battery to display unit
   b) Battery to peltier module
   c) Battery to fan
5. In this step we finally assemble the all parts and thus the model is prepared.

### 6. 1 FABRICTION PLAN

STEP1: First we have the thermocol box of 8 liters.
STEP2: Then we make section in it with equal dimension of fin to make fit in it.
STEP3: Fit the peltier module on back side of heat sink (fin).
STEP4: Place the fin ,peltier ,and fan in the section.
STEP5: Connect all to the battery.
STEP6: Check the proper working of all the components and do the calculation according to it.

### 6.2 BILL OF MATERIAL

| S .No. | ITEMS | SPECIFICATIONS | QUANTITY |
|---|---|---|---|
| 1 | Thermocol box | Capacity 8 litre | 1 |
| 2 | Peltier module | Model number : TEC1-12706<br>Voltage :12V<br>Imax (A) : 6A<br>QMax (W) : 92W | 1 |
| 3 | Fan | 12V , 2500rpm | 1 |
| 4 | Battery | 12v, 7.2 amp | 1 |
| 5 | Solar panel | 12v | 1 |
| 6 | Temperature display | Reading in degree Celsius | 1 |

### 7 OBSERVATION AND CALCULATIONS

Theoretically the cold side temperature of peltier module was 9°C but it been found that the temperature of cold side is reduce to 15 °C due to circuit resistance. We also found that the circuit voltage is 5V and current is 1.95A due to which the voltage given by battery is reduce and reduction in voltage cause the reduction in cooling effect which is low. We also observed that the theoretical cop of system is 1.84, where heat absorb rate of peltier is found 6.21.

### 7.1 CALCULATION OF PELTIER MODULE SPECIFICATION:

Given specification of peltier module (Supercool: PE-063-10-13) from datasheet are :

$Q_{max}$=19 W  $T_{hot}$ = 25°C  $I_{max}$ =3.9 A
m =1  $V_{max}$ =7.8 V  $T_{h\,max}$=80° C
($\Delta T_{max}$) =74° C  $T_c$=15°C  dt = 9.6 J/S

- **Device seebeck voltage**

**=** 0.261

- **Device electrical resistance**

- **Device thermal conductance**

  =0.007W/K

- **Theoretical COP**

= (0.0261 X 1.95 X 282)-1/2(1.95²)(1.5)-(0.007)(25-15)
=11.43W
=0.0261X1.95 (25-15)+(1.95²X1.95)
= 6.21W

$$R_m = \frac{(\Delta T_{max} - T_h)}{T_h} \frac{V_{max}}{I_{max}}$$

$$R_m = \frac{(347 - 298)}{298} = \frac{7.8}{3.9} = 1.5 \text{ ohm}$$ COP=

=1.84

$$R_m = \frac{(\Delta T_{max} - T_h)}{2\Delta T_{max}} \frac{V_{max} I_{max}}{T_h}$$

$$R_m = \frac{(347 - 298)}{2 \times 347} \frac{7.8 \times 3.9}{298}$$

- **Actual heat calculation**

$$Q_c = \alpha_m T_c I - \frac{1}{2}(I^2 R_m) - K_m (T_h - T_c)$$

## 8 Result and Discussion

The experimental result shows that temperature is reduced to 15°C without any heat load and to 18°-19°C with 100 ml water kept inside refrigeration space in 90 minute with respect to 28°C ambient temperature. Also the actual COP of refrigeration cabinet has been calculated with heat load and it is 0.7. The developed thermoelectric refrigeration system is having potential application of storage and transportation of life saving drugs and biological materials at remote areas of our country where grid power is unavailable.

### 8. 1 ADVANTAGES

$$Q_{actual} = \frac{mC_p \Delta T}{dt} = \frac{1 \times 4.18 \times (28 - 18)}{9.6} = 4.36\ W$$

1. Light weight and compact for very small heat loads.
2. No moving parts, eliminating vibration, noise, and problems of wear.
3. Reversing the direction of current transforms the cooling unit into a heater.
4. Operates in any orientation. Not affected by gravity or vibration
5. Very low cost device for cooling in small appliances.
6. Precision temperature control capability

$$COP = \frac{Q_{actual}}{W} = \frac{4.36}{6.21} = 0.7$$

7. High reliability - We guarantee 200,000 hours of no failures.
8. Eco-friendly C-pentane, CFC free insulation.

### 8. 2 LIMITATIONS

1. Limited to very small refrigeration volume.
2. Compared to conventional refrigerators cooling achieved is less.
3. Heat sinks required to conduct heat to and from the thermoelectric modules become very heavy and bulky as the refrigeration capacity increases.
4. C.O.P. is less as compared to conventional refrigeration system

### 8. 3 APPLICATIONS OF SOLAR OPERATED THERMOELECTRIC REFRIGERATION

- **Use of green energy**

In this project we use solar panel to use sun energy and avoid the use of electric energy which cost us. So by the use of solar energy we save electric energy .

- **Environment friendly**

Generally we see that common refrigerators produce CFCs which harms the environment but peltier module does not produce any harmful gases.

- **CPU coolers**

Peltier module can be use in CPU to maintain the lower temperature of processor.

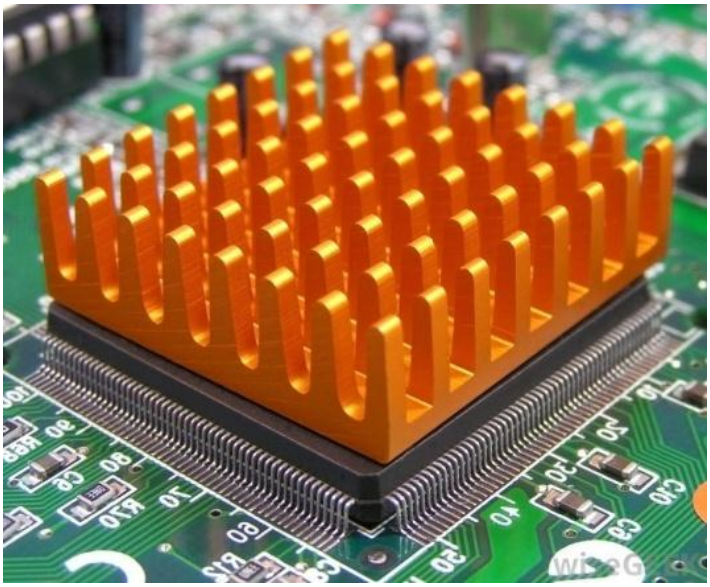

*Figure 8.1: CPU (Motherboard)*

## 9 Future Enhancement

As we observed that the theoretical minimum temperature that could be achieve was 9°C given by manufacturer but practically we get lowest temperature of 15 °C.

- Research in `the field of thermoelectricity and

experimentation with different materials is required to improve the COP of the TE cooler.

- We can increase the efficiency by increasing number the peltier module .
- Increase size of module by manufacture can help to increase cooling effect for more area.
- Effective wire with low resistance can improve peltier effect.

## 10 CONCLUSION

The TE devices can act as coolers, heat pumps, power generators, or thermal energy sensors and are used in almost all the fields such as military, aerospace, instrument, biology, medicine, industrial or commercial products. The major challenge faced in TE cooling is lower COP especially in large capacity systems. However, as the energy costs are elevating and environmental regulations regarding the manufacture and release of CFCs have become more firm with time, the scope of TE effect has revived, especially in the developing countries or the third world where the energy is not surplus. TE chilling of beverage can be done at the farm level to inhibit any enzymatic or microbial change in quality of the beverage. Research in `the field of thermoelectricity and experimentation with different materials is required to improve the COP of the TE cooler. In the coming years thermoelectricity has a lot of potential to create energy saving and effective solutions for the industry and commercially as well. The minimum temperature achieved was found to be 15°C for cooling

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