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Air Conditioning System in Car Using Thermoelectric Effect

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Abstract: in present scenario, hvac system (commonly used in the air conditioners) is very efficient and reliable but it has some demerits. It uses refrigerants like freon, ammonia, etc. Due to the use of such refrigerants maximum output can be obtained but it leads to much harmful effect to our environment i.e. The global warming. That leads to the emergence of finding an alternative of the conventional hvac system, i.e. Thermoelectric cooling and heating system. The present paper deals with the study of thermoelectric air conditioner using tec module. Thermoelectric cooling system have advantages over conventional cooling devices, such as compact size, light in weight, low cost, high reliability, no mechanical moving parts and no working fluids.

Key words: peltier module, thermoelectric air conditioner.

I. INTRODUCTION

In thermoelectric material, electrical energy can be directly converted into thermal energy and vice versa. This direct conversion of energies is possible due to the two important thermoelectric effects: the SEEBECK EFFECT and the PELTIER EFFECT [7]. The Seebeck effect refers to the existence of an electric potential across a thermoelectric material subjected to temperature gradient. The Peltier effect refers to the absorption of heat into one end of a thermoelectric material and the release of heat from the opposite end due to a current flow through the material.

A conventional cooling system contains three fundamental parts- the evaporator, compressor and condenser. In evaporator, the pressurized refrigerant is allowed to expand, boil and evaporate. During this change of state from liquid to gas, energy (heat) is absorbed. The compressor acts as the refrigerants pump and recompresses the gas to liquid. The condenser expels the heat absorbed in the environment plus the heat produced during compression, into the atmosphere [1]. In thermoelectric material, at cold junction energy(heat) is absorbed by electrons as they pass from a low energy level in the p-type semiconductor element, to a higher energy level in the n-type semiconductor element [2]. The power supply provides the energy to move the electrons through the system. At the hot junction, energy is expelled to the heat sink as electrons move from a high energy level element (n-type) to a lower energy level element (p-type)[6].

This HVAC system uses various refrigerants such as Freon and Ammonia, by which maximum output can be obtained but emission of these gases leads to most undesirable effect i.e. global effect.

The introduction of the new HVAC system using thermoelectric couple shall overcome all the disadvantages of the present HVAC system. The advantages would be high reliability, no moving parts, compact size, no working fluid, low cost and light weight[9].

II. MATHEMATICAL MODELLING

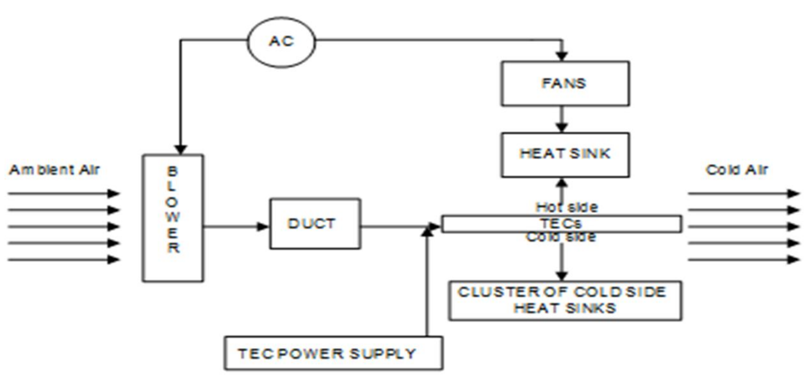

Fig.1. Cooling fan using thermoelectric module

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A. The cooling systems mainly consist of the following modules

1) Car Blower which acts as the primary source of air.
2) Duct which conveys the air from the blower to cluster of Al cold heat sinks.
3) One long heat sink is fitted to the hot side of TEC to absorb heat
4) 2 Aluminium heat sinks that are attached to the cold side
5) 2 TECs are sandwiched between cold and hot heat sinks
6) A DC source which is used to power the fans and blower
7) DC power supply is used to drive the TECs

B. Assumptions

1) No heat loss takes place from or to the system.
2) Thermos physical properties such as Resistivity, conductivity, etc do not change with temperature.
3) Heat transfer takes place only through the p-type and n-type semiconductor.

A thermoelectric device will create a voltage when there is temperature difference on each side of the device. On the other hand, when a when a voltage is applied to it, a temperature difference is created. The temperature difference is also known as Peltier effect. Thus, TEC operates by the Peltier effect, which stimulates a difference in temperature when an electric current flows through a junction of two dissimilar materials. A good thermoelectric cooling design is achieved using a TEC, which is solid state electrically driven heat exchanger

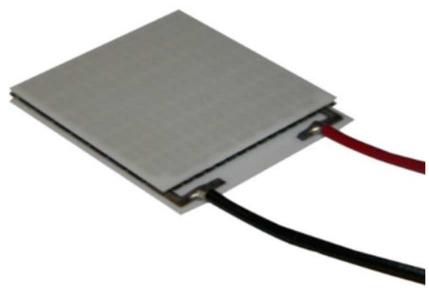

Fig.2. Single stage thermoelectric module

A standard module consists of any number of thermocouples connected in series and sandwiched between two ceramic plates. By applying a current to the module one ceramic plate is heated while the other is cooled. The direction of the current determines which plate is cooled. The number and size of the thermocouples as well as the materials used in the manufacturing determine the cooling capacity. Cooling capacity varies from fractions of Watts up to many hundreds.

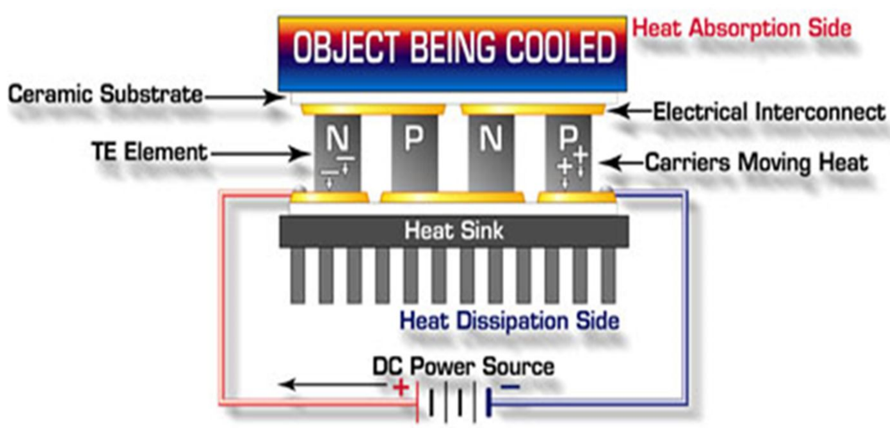

Fig.3. Thermal network model of tec

When current is passed through dissimilar materials, heat is absorbed or liberated at the junction, this is known as Peltier effect.

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Various equations for calculating different parameters are listed below-

4) Temperature Difference

$$\Delta T = T_h - T_c$$

T_h = hot side temperature

T_c = cooling side temperature

(Actual ΔT is not always same as the system ΔT .)

5) Cooling Load

$$Q_c = \dot{m} C_p \Delta T$$

Density of air at 30 ℃ was taken as 1.164 kg/ m^3. Q was obtained by multiplying velocity of air pass through the rectangular duct of heat sinks and the cross-section area of a heat sink. It is denoted by the equation (Q =V*A). Velocity of the air passing through the duct was measured using an anemometer and resulted in a reading of 5 m/s^2 Cross sectional area of the rectangular duct (W*H) was calculated as 0.0054128 m^2 and the volume flow rate was 0.02706 m^3/s. Specific heat of air (Cp) at 30℃ was taken a s1007 J/ kgK.

6) Heat Sink Selection

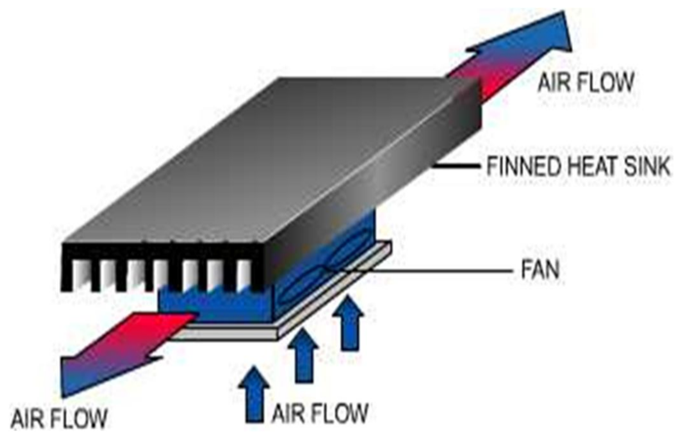

fig.4. forced convection heat sink system

$$R = \frac{T_h - T_\infty}{Q_h}$$

R is the thermal resistance (in ^0C/W or K/W) and T_h, T_∞ is the hot side temperature and ambient temperature respectively. Q_h is the heat load into the heat sink which is the sum of TEC power P_e and heat absorbed.

$$Q_h = Q_c + P_e$$

7) Coefficient Of Performance

$$COP = \frac{Q_C}{P_e}$$

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III. TESTING

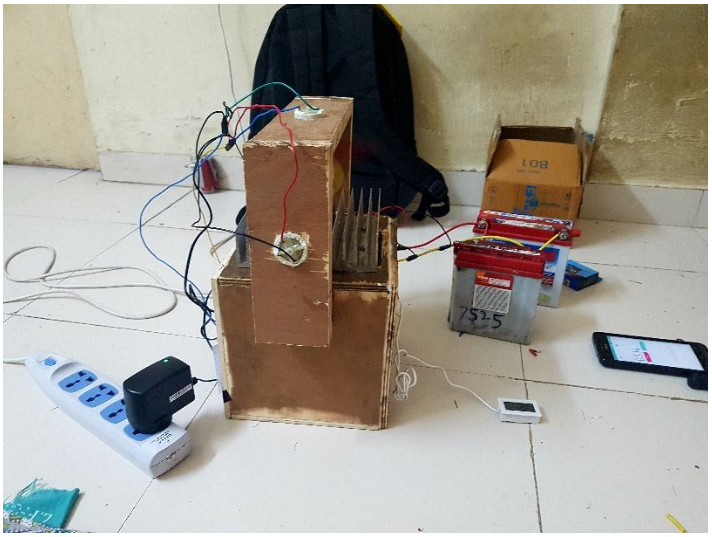

Fig.5. PROTOTYPE

The setup was run for certain duration of time and the initial and final temperature inside enclosure was observed using a digital thermometer. Five runs were conducted for testing the prototype. The first run was 4 minutes' duration run and was conducted to check the working of TECs and fans. The next 5 runs were conducted to test the capacity of the TECs for 15 minutes. Following results were obtained:

TRIAL 1	
TIME(minutes)	TEMPERATURE (℃)
0	35.2
5	32.3
10	31.1
15	30.2

TRIAL 2	
TIME(minutes)	TEMPERATURE (℃)
0	34.8
5	32.1
10	31.2
15	30.0

TRIAL 3	
TIME(minutes)	TEMPERATURE (℃)
0	34.2
5	31.8
10	30.8
15	30.1

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TRIAL 4	
TIME(minutes)	TEMPERATURE (°C)
0	35.3
5	33.1
10	31.2
15	30.0

TRIAL 5	
TIME(minutes)	TEMPERATURE (°C)
0	35.8
5	33.1
10	31.2
15	29.9

IV. RESULTS OF TESTING

After conducting trial, it was found, there was a drop of temperature of 5 degrees than surrounding temperature. The overall efficiency of the system can be improved using heatsink with circulating water or other liquid for better cooling of hot side heatsink.

V. SOFTWARE ANALYSIS

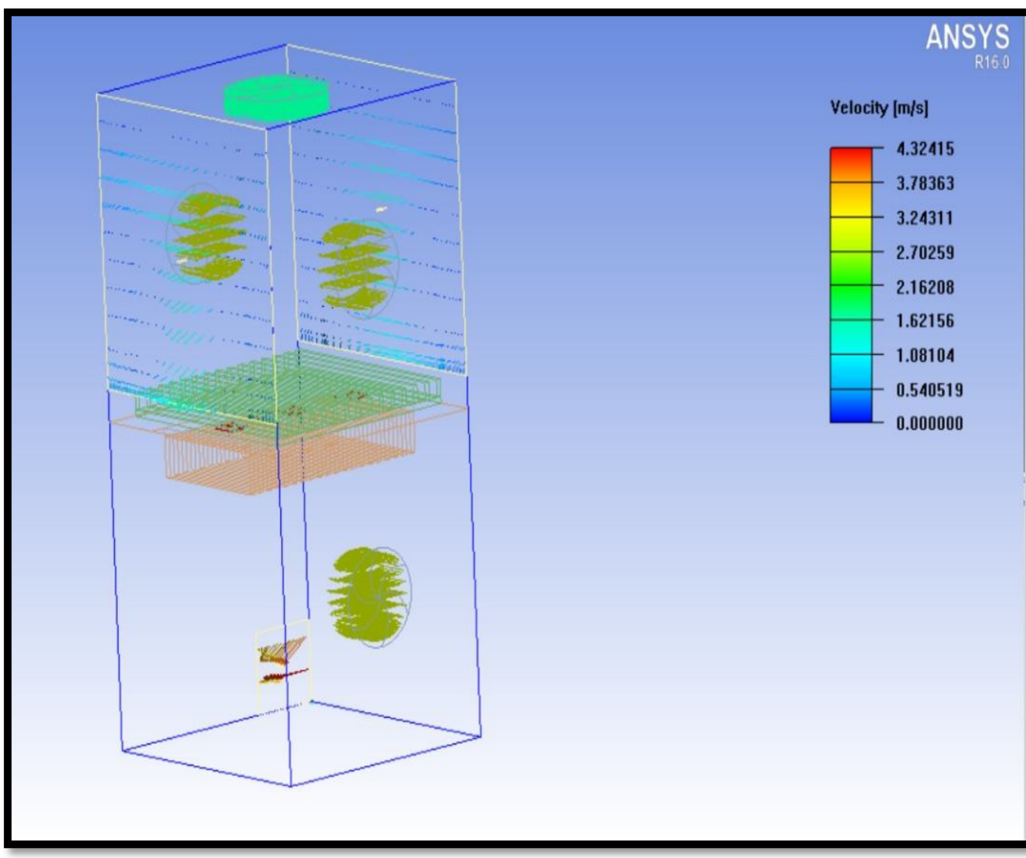

FIG.6. AIR FLOW IN THE PROTOTYPE

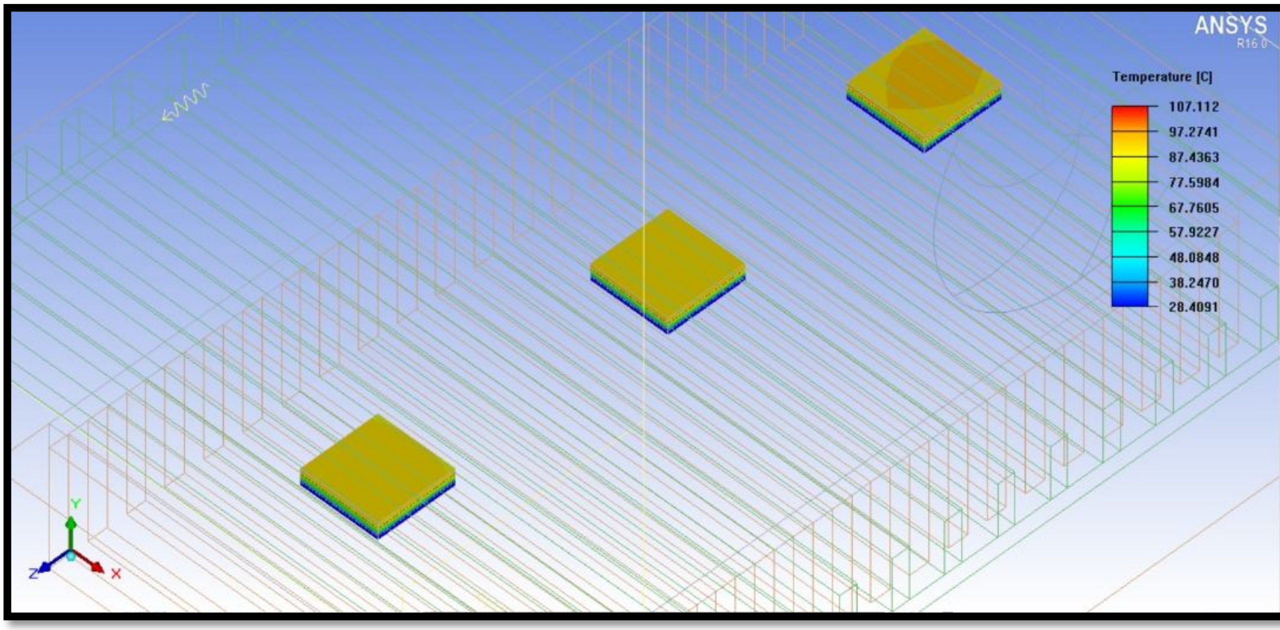

Fig.7. TEC TEMPERATURE

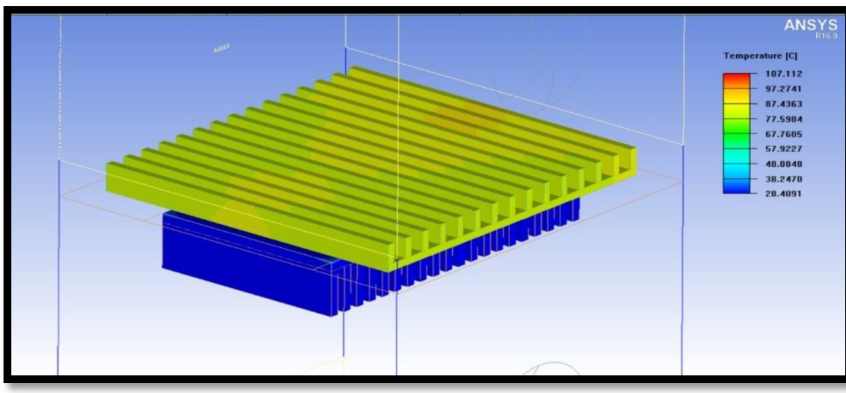

Fig.8. TEMPERATURE DISTRIBUTION

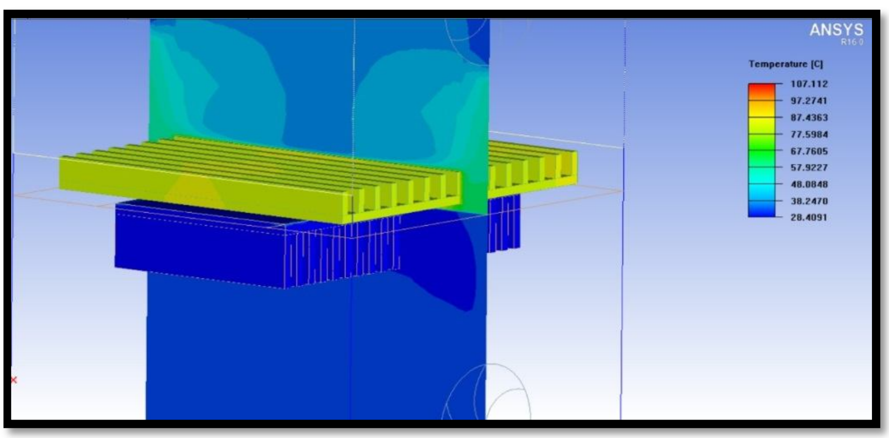

Fig.9. FINS ARRANGEMENT

VI. CONCLUSION

The aim of the project was to design and build an air cooling system comprising of Thermoelectric modules and to achieve a temperature drop of around 5-7^0 C. We have achieved a temperature drop of around 5^0 C in the experimental setup.

In this project, we as a team have studied various concepts of TEC cooling such as thermoelectric effect, selection of TEC modules as per application, selection of heatsinks. The project had two phases design/simulation and prototype testing. The prototype was fabricated using various components available in market. We have resolved various issues we faced during initial testing phase.

This project has been a challenging experience for the group. During the course of evolution of the project many facets of electronic, electrical and mechanical matters were referred to and executed. In the ultimate analysis, we have assimilated much knowledge and experience from the project due to its broad spectrum of multifarious engineering. The project has led us to acquire problem solving skills, presentation skills which cannot be underestimated. The evolution of engineering ideas and fundamental theory into practical product has also enhanced us as engineers.

VII. FUTURE SCOPE

During the project, we as a group always have tried our best to create a better operating cooling system although much work is needed in this field. The cooling system can be improved by incorporating PCM (Phase Change Material) cooling system and can be made much compact by use of efficient fans and heat sinks. Temperature control can be added using a closed loop circuit and feedback network. The cooling system can be further improved by use of TEC modules having higher capacity.

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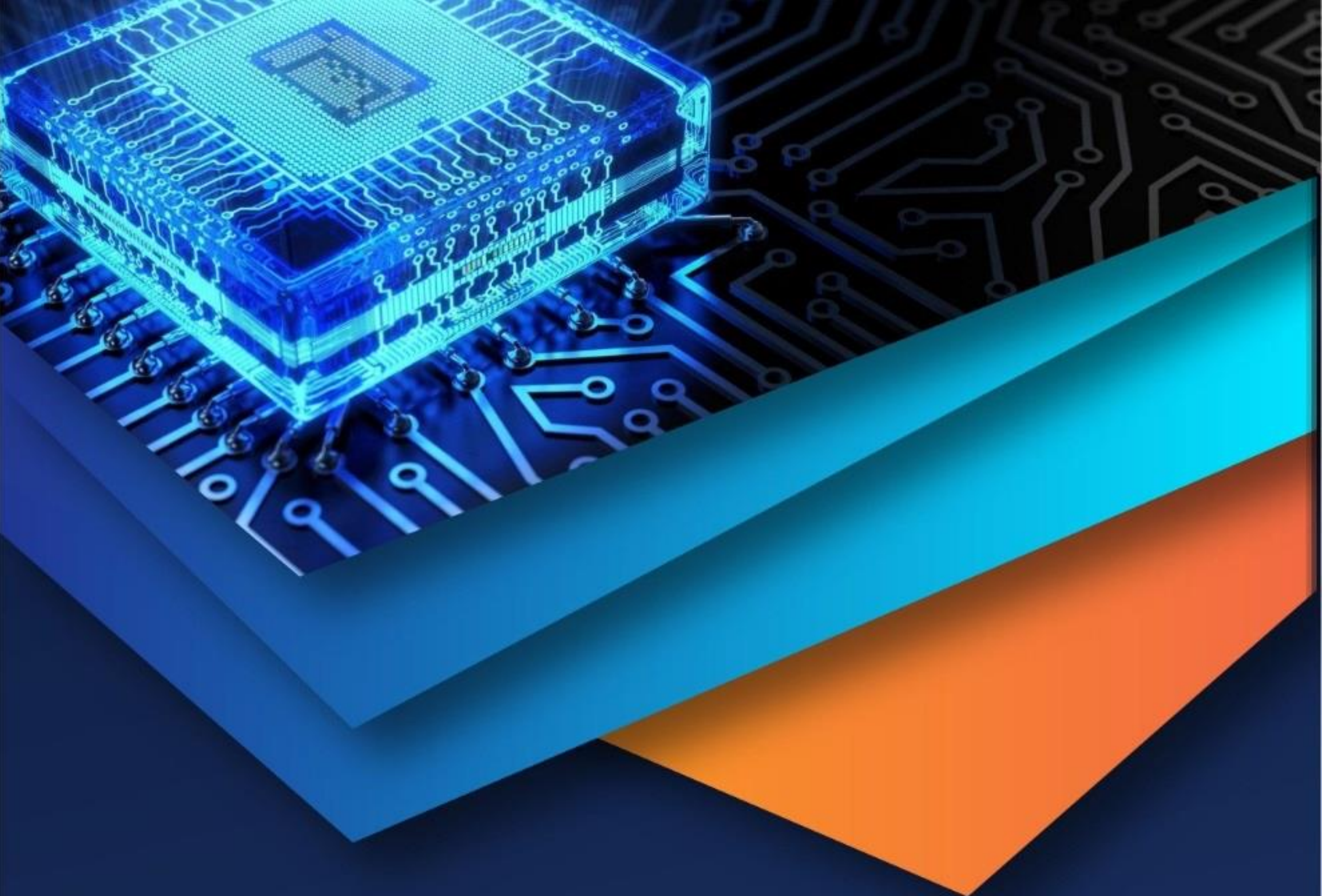

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