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Experimental Thermal Analysis of Pin Fin Heat Sink

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Abstract: This project reviews pin fin heat sinks of different cross- sections, low density versus high density pin configurations and more factors in figuring out what is required for an application. The experiment will be conducted with two different pin fins i.e., a circular cross section and a square cross section in an open circuit suction type wind tunnel, the temperature variations and heat dissipation are compared between both the fins and conclusions are drawn. The experiment is concluded with comparing the results obtained from the experimental setup with that of the analysis of the setup.
Keywords: Pin fins, Wind tunnel, Temperature variations, Heat dissipation, Experimental setup, Analysis.

I. INTRODUCTION

Electronic hardware has made into practically every part of cutting edge life, from toys, PCs to rockets. Each electronic segment relies on upon the entry of electric current to perform and turns into the potential site of heat generation I=P/V. The electronic segments play out an assortment of capacities and, in this way their energy dissemination levels (and warmth area) fluctuate broadly. The range shifts from little semiconductors that disseminate low heat loads like one watt to high-control laser and radio-recurrence gadgets which understudy scatter heat loads up to 1,000 watts. Pin fin heat sinks speak to one such achievement in innovation. As heat scattering increments from microelectronic gadgets and the decrease in general frame variables, dealing with the thermal angles turns into a critical component of item plan in hardware. Both the execution unwavering quality and in addition future of electronic hardware is conversely identified with the temperature of a part in types of gear. The relationship amongst unwavering quality and working temperature of a silicon semiconductor gadget demonstrates that a decrease in temperature compares to a fast increment in dependability and also future of the gadget. Thus, long life and solid execution of a part might be accomplished by powerful control of working temperature in the gadget inside the breaking points set by the gadget configuration engineers. Some coordinated circuits draw such low streams that their intersection temperature is thought to be encompassing air temperature encompassing the gadget, in these cases there would be no heat sink required up to the greatest working temperature of the segment. In any case, the rules expressed above would in any case apply suggesting, having the intersection temperature at 75°C.

A. Major Causes of Electronic Components Failure are

Temperature:55%
Vibration:20%
Humidity:19%
Dust:6%

II. PROBLEM DEFINITION

In perspective of expanding the life and unwavering quality of the electronic gadget, monitoring of temperature variations within the desired limits is essential. Thus keeping electronic gadgets cool is a basic undertaking to guarantee their long life and unwavering quality. The Utilization of heat sinks can help accomplish this, however deciding the correct sort and arrangement is a challenging task. Supervision comprises of ordering a procedure and managing its working, supervisory system 3808 used in thermal power plant must ensure that the maximum operating temperature in control equipment. If the temperature crosses the specified limit the circuit will automatically shut down the control system.

In a Thermal power station, 3808 supervisory circuit may work from 40°c to 100°c. Yet, the de-rating factor constrains the maximum operational temperature to 75°c, so if the temperature crosses the limit the device gets damaged. In order to ensure a stable temperature of up to 75°c, the utilization of a heat exchange device is essential, for this situation a pin fin heat sink which can lessen the burden on the operators and maintenance staff in ensuring a stable operational temperature.

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III. DESIGN AND FABRICATION

Some Integrated circuits draw so minimal current that their Junction temperature is thought to be the encompassing air temperature encompassing the gadget, in these cases there would be no heat sink required up to the most extreme working temperature of the part. Nonetheless, the rules expressed above would at present apply suggesting, having the junction temperature at 75°C. [3]

I have selected low density (sparse) and inline pin fin arrangement as shown in data sheet above pin fin for my experiment area of the heat sink is 418x195mm. The electronic component or IC has the capacity to withstand a junction temperature or chip temperature T_C of 75°c.when the temperature crosses 75°c it fails, hence our objective is to maintain the chip temperature T_C within 75°c by changing the pin fin array. Heat sink must be composed so that heat sink guarantees part unwavering quality. The decision of a legitimate heat sink can likewise dispose of or decrease the requirement for fans, which can corrupt system dependability and present perceptible commotion amid system operation. Furthermore, elite warmth sinks can effectively cool segments without consuming up much room.

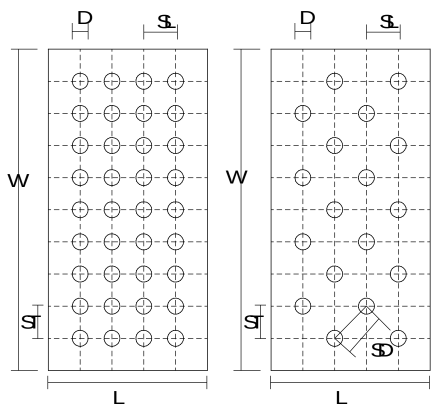

Fig.1 Schematics of inline and staggered pin fin heat sinks

A. *Design Considerations*

The compelling cooling plan for pin fin heat sinks is constrained convection where, constrained air makes huge measure of air in the middle of the pins and upgrading the heat sinks proficiency. Fin spacing for low density pin fin heat sinks is 5.5d-6d and for high density pin fin heat sinks it is 1.5d-2d of the pin fin heat sinks used in this study one with the circular cross section and the other is with the square cross section. The heat sink with foot print of 418*195mm is considered for the experiment where 418mm is the width of the entrance, 195mm is the length measured in the downward direction and 25mm is the thickness of the base plate and is explained in the data sheet.

The low density and inline pin fin arrangement heat sink of size 418x195x25mm with circular cross-section pin fin of Diameter of 0.006m and square cross-section pin-fin of 0.006x0.006 and height of 0.03m with different arrays of 5x5,5x6,5x8,5x10,5x12 with low density stream wise fin spacing of S_L=32mm and span wise S_T=32mm is considered for experiment.

B. *Selection of Material*

After iron, aluminum is currently the second most broadly utilized metal on the planet and also very easy to recycle. For the greater part of cooling situations aluminum heat sinks are ideal over copper heat sinks. Copper heat sinks give just somewhat preferred cooling execution over indistinguishably organized aluminum heat sinks. In any case, the cost for that humble change is a heavier, more-costly heat sink. Aluminum also provides Resistance to corrosion and it is non- toxic.

Regarding cost, copper heat sinks are for the most part offered at a half to 100% premium versus aluminum. With respect to weight, copper is 3.2 times heavier then aluminum. Therefore, copper heat sinks are not regularly suggested exclusively for the thermal resistance they give.

IV. EXPERIMENTAL SETUP

The low density and inline pin fin arrangement heat sink of size 418×195×25mm with pin fin of Diameter of 0.006m and height 0.03m with different arrays of 5×5, 5×6, 5×8, 5×10, 5×12 with low density stream wise fin spacing of S_L=32mm and span wise S_T=32mm was considered for experiment.

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Assumptions
Radiation heat transfer is considered to be negligible.
Temperature differences are small
Body forces are negligible.
The fluid is considered to be in compressible.
Flow is steady and two dimensional.
The fins are uniformly spaced on the base plate.
The fin tip is adiabatic.
Air flow is normal to the fin axis.

A. Pin Fin-Assembly

The first step in solving optimization problems is selection of independent variables. Several factors are considered in choosing these independent variables. Nonetheless the rule is to incorporate just the variables that have high concussion on the heat sink's performance.

The independent variables are pin fin height (H), pin density (N), heat load (Q), chip temperature (T_c) and velocity (V).For optimization the objective is to choose the best heat sink to meet the 418x195mm foot print and not to surpass the ultimate overall height of 300mm.the ultimate height restraint is chosen to perform a typical board pitch in TPS (Thermal power station) 3808 Supervisory Circuit.

The maximum heat load of Q=750Watts is applied at the center of the base plate, which consists of an orderly thickness of 25mm.The atmospheric temperature is taken as 28^0C.The count of fins can be assorted in harmony with the fin spacing. Pin density N is varied for different array of 5×5, 5×6, 5×8, 5×10, 5×12 is considered for our experiment. It can smoothly be detached and put back with studs made out of similar material as that of the assembly base and can be completely screwed in, both the rectangular base as well as the pin-fin are manufactured from real pure aluminum alloy.

B. Temperature Measurement

Temperature plays a very important role in heat sink analysis. Hence at different locations temperature has to be measured, the location where the thermocouples are placed is shown in the figure. The temperature at the surroundings which is the ambient temperature is measured using mercury thermometer with least count of 10°c, and all other locations of the heat sink thermocouples were used as sensors and a digital temperature indicator system was used to convert analog signals directly to degree Celsius. In the present experiment K type thermocouples are used and the specifications are as follows

Type	K
Diameter	0.5mm
Bead size	1.3mm.


Fig.2: Model Setup inside the Wind Tunnel

C. Heating System

The base plate of the heat exchanger is heated almost consistently by two electric resistor strips, which rates at around 500W with regulator, and this happens to be the main heater. The base plate is securely seated to the bottom of the rectangular base and it is ensured of good contact between the main heater and the rectangular base plate. The other surface and sides of the main heater were insulted thermally with glass wool.

Properties of glass wool are,

Temperature	20°c
Density/m^3	24
Specific heat kj/kg k	0.70
Thermal conductivity	0.038

An open circuit suction-type wind tunnel might have been decided should serve concerning illustration a stage should study the heat exchange execution about increased surfaces. The low-speed wind tunnel for a open circuit plan may be made of the taking after sections: (a) a bay segment that incorporates stream conditioners like stream strengtheners and turbulence control screens; (b) a withdrawal cone or spout that accelerates the flow; (c) test segment that holds those model should investigate; (d) An diffuser that lessens the air pace for Similarly as minimal vitality misfortune Concerning illustration possible; (e) a fan driven eventually by a part capacitor engine that is controlled Eventually perusing a AC-V fan speed control.

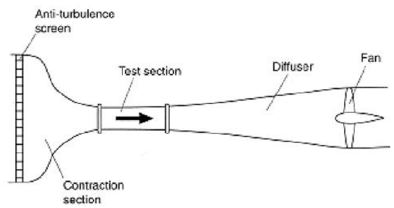

Fig 3: Open Circuit Suction-Type Wind Tunnel [2]

D. Basic Relations

This chapter presents the details about the calculation of "Nusselt number", "Reynolds number" and also "convective heat transfer coefficient" over the plate and across the fins. It also explains the basic relation to calculate the net rate of heat transfer by heat sink. [4]

V. READINGS AND DATA LOGGING

Sl. no	Q in watts	T1 Base Temp	Surface Temp			Fin Temp			T8 ambient Temp
			T2	T3	T4	T5 at L=0.1m	T6 at L=0.2m	T7 at L=0.25m	
1	250	62.7	61.9	62.2	62.1	32.1	28.6	28.2	28
2	500	97.2	91.8	92.1	92.5	36.8	29.3	28.5	
3	750	140.2	135.2	135.2	134.8	42.1	30.2	28.8	

Table 1: Circular cross-sectioned fins 5x12=60fins

Sl. no	Q in watts	T1 Base Temp	Surface Temp			Fin Temp			T8 ambient Temp
			T2	T3	T4	T5 at L=0.1m	T6 at L=0.2m	T7 at L=0.25m	
1	250	60.5	57.2	55.1	53.2	49.7	31.1	27.8	28
2	500	80.6	81.1	80.2	79.8	34.9	29	28.5	
3	750	135.5	129.7	130.1	131.5	38.7	29.6	32.5	

Table 2: Square cross-sectioned fins 5x12=60 fins

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VI. OPTIMIZATION USING ANSYS

There are 3 stages in solving a problem in finite element method. They are **preprocessing, processing and Post processing.** Further step by step process is listed below

Selecting element type and giving material properties

Creation of geometry using modeling command

Finite element mesh generation

Applying boundary conditions like heat flux, convective heat transfer coefficient

Solving the current loaded model

Plotting or listing the results

Various outputs that can be seen are temperature distribution, heat flux variations etc.

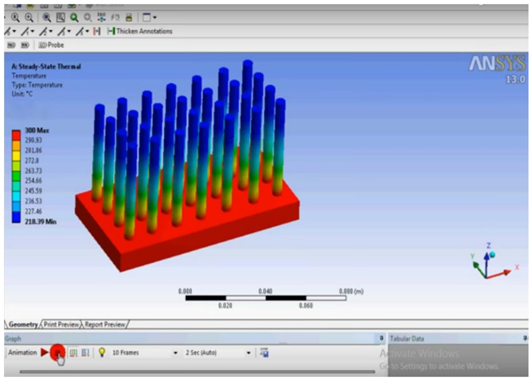

Fig 4: Temperature Distribution in Pin Fin Model

VII. RESULTS AND CONCLUSION

Array	*Over flat plate*		
5x12=60	*Q=250*	*Q=500*	*Q=750*
Re	*55873.9*	*51396.9*	*46428.5*
NU	*69.12*	*66.7*	*63.2*
h1	*9.89*	*9.9*	*9.8*
Q1	*26.56*	*50.05*	*82.8*
Across circular fins			
Re	*1719.2*	*1587.3*	*1428.5*
NU	*19.36*	*18.77*	*17.83*
h2	*90.05*	*90.6*	*90.39*
m	*16.06*	*16.11*	*16.09*
Q2	*215.3*	*395.8*	*644.2*
Q= Q1+ Q2	*241.86*	*457.5*	*745.0*

Table 3: Results for Circular Cross Section Fins

Array	*Over flat plate*		
5x12=60	*Q=250*	*Q=500*	*Q=750*
Re	*55873.9*	*51396.9*	*46428.5*
NU	*69.12*	*66.7*	*63.2*
h1	*9.89*	*9.9*	*9.8*
Q1	*26.56*	*50.05*	*82.8*
Across circular fins			
Re	*1719.2*	*1587.3*	*1428.5*
NU	*19.36*	*18.77*	*17.83*
h2	*90.05*	*90.6*	*90.39*
m	*16.06*	*16.11*	*16.09*
Q2	*215.3*	*395.8*	*644.2*
Q= Q1+ Q2	*241.86*	*457.5*	*745.0*

Table 4: Results for Square Cross Section Fins

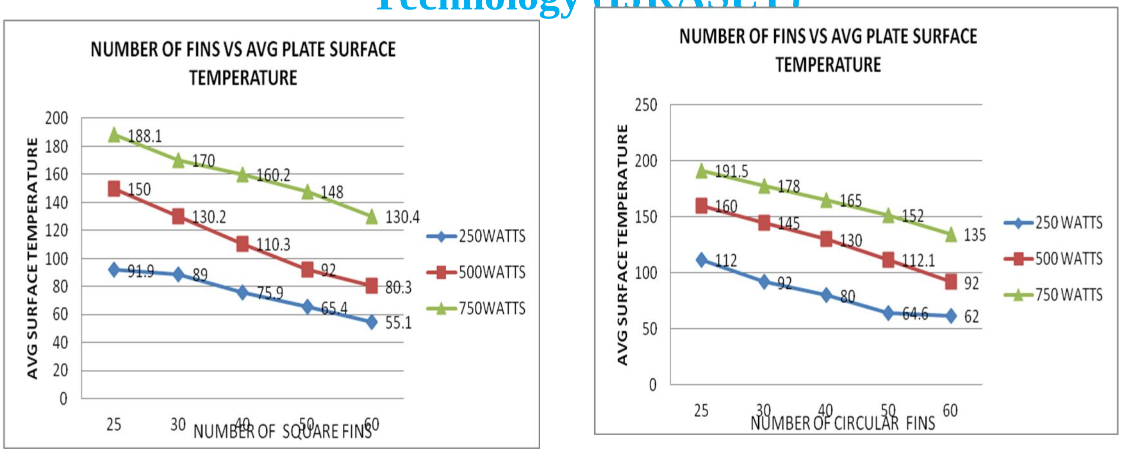

Fig 5: Graph of Number of Fins Vs Average Plate Surface Temperature

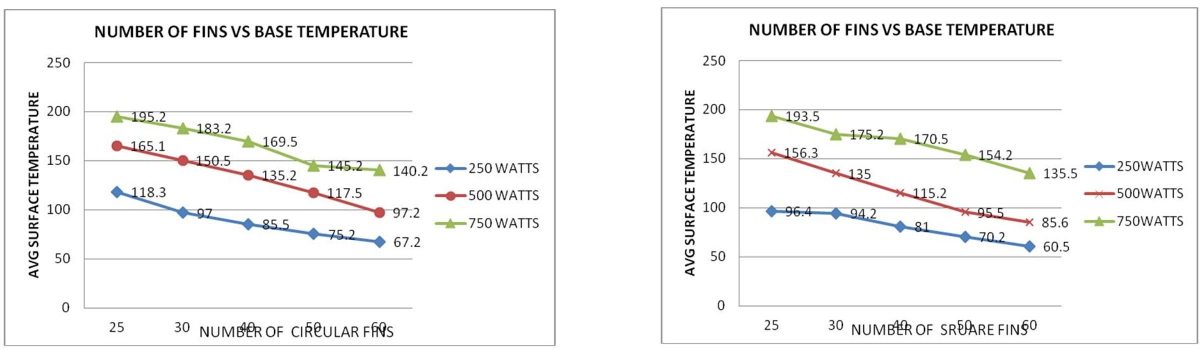

Fig 6: Graph of Number of Fins Vs Base Temperature

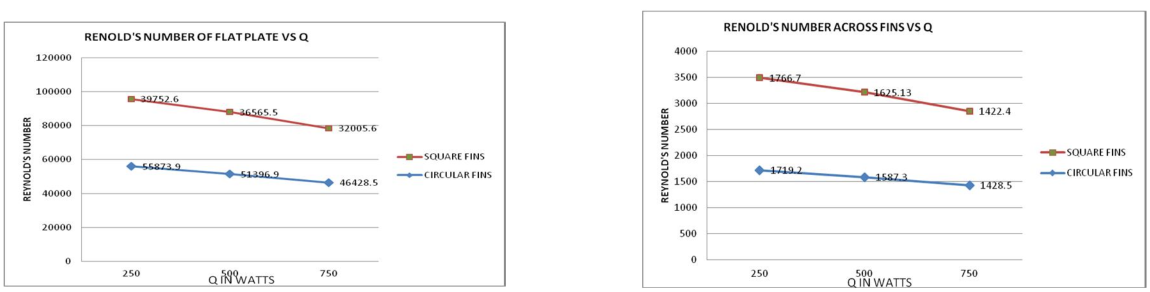

Fig 7: Graph of Reynolds's Number across Fins Vs Heat Transfer

VIII. CONCLUSION

In this study, a thorough heat transfer investigation over a bank of pin fins has been conducted experimentally. The main conclusion drawn from the investigation are presented below

With circular cross-sectioned fins the maximum heat that can be dissipated is 300watts with optimum fin height of 254mm and maintaining the junction temperature within 75^0c.

With square cross-sectioned fins the maximum heat that can be dissipated is 395watts with optimum fin height of 250mm and maintaining the junction temperature within 75^0c.

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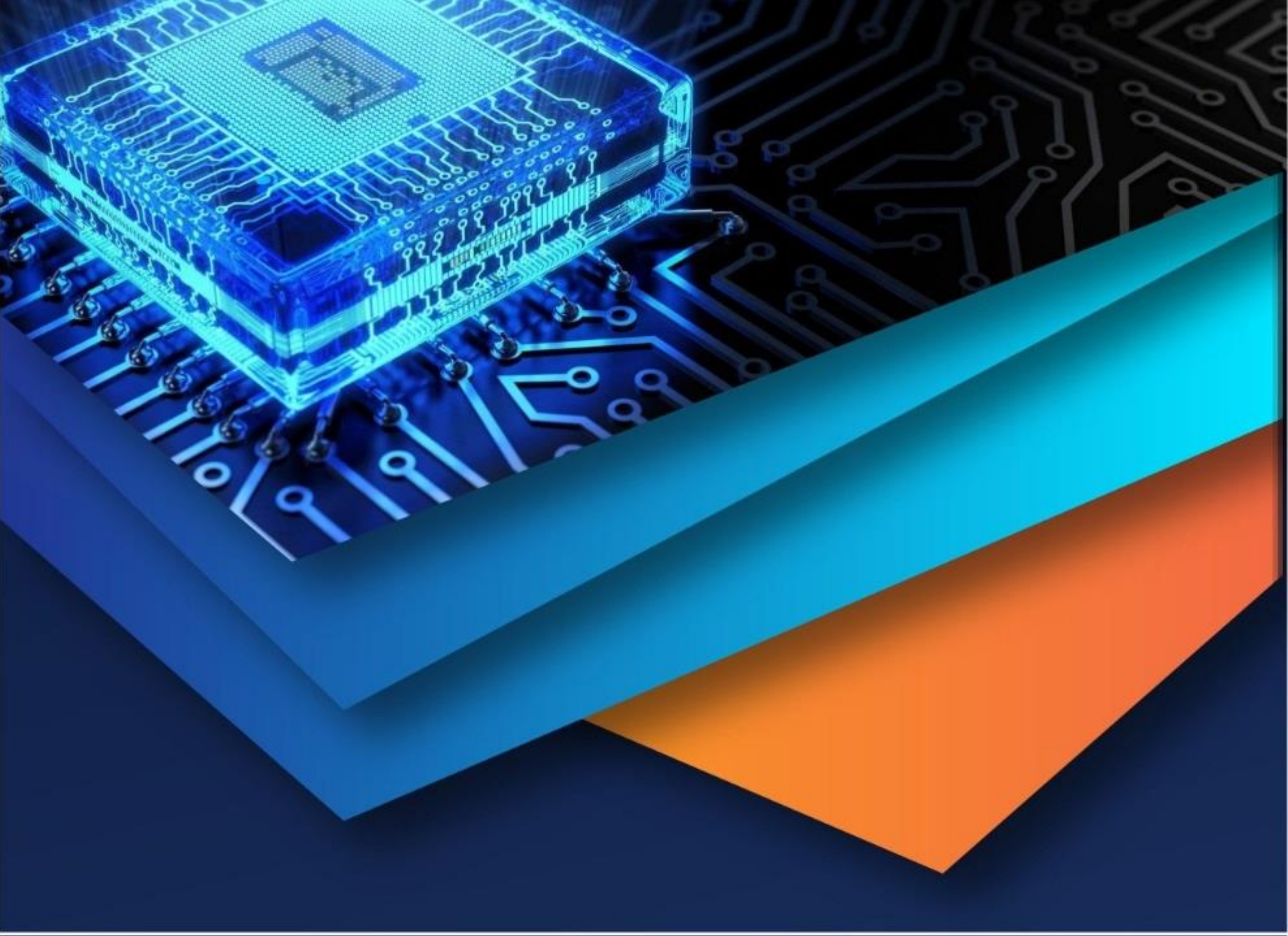

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