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Photovoltaic Powered Dual Thermoelectric Air Conditioning System

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Abstract: ***Nowadays energy efficient and environment friendly systems are among the emerging technologies, due to growing concerns about climate change and sustainability. According to the present scenario, the renewable energy resources are becoming the source of energy due to the decrease in non-renewable energy resources (Fossil fuels). So we presented a "Photovoltaic-Powered Dual Thermoelectric Air Conditioning System" that incorporates Peltier modules(thermoelectric material) which works on peltier effect known for their eco-friendly characteristics. Harnessing solar energy through a high-efficiency PV array, this system aims to provide efficient and sustainable air conditioning while minimizing the reliance on traditional power sources. The additional benefit of this system is that it provides year round comfort i.e. cooling and heating facility in one system.***

Keywords: Thermoelectric; Peltier module; Peltier effect; Photovoltaic;

I. INTRODUCTION

Air conditioning refers to the regulation of air quality for human comfort. While conventional air conditioning systems are effective in providing comfortable environment, but they have some drawbacks too. The conventional air conditioning systems consume large amount of energy contributing to elevated electricity bills and placing strain on power grids during peak demand periods. One of the major drawbacks of conventional air conditioning systems is that they release harmful gases that have been causing damage to the environment over the years, contributing to global warming. However, with the utilization of peltier technology (which makes use of peltier effect) it is possible to control indoor temperature. Unlike conventional air conditioning systems that use refrigerant like Freon and CFCs gases that harm the ozone layer. The Photovoltaic-Powered Dual Thermoelectric Air Conditioning System integrates solar energy and advanced thermoelectric modules, offering a sustainable and energy-efficient solution to control indoor temperature without any environment degradation. Additionally this air conditioning system provides both cooling and heating facility into one system. The integration of photovoltaic panels with a Peltier-operated air conditioner is designed to fulfil goals related to energy efficiency and environmentally conscious heating and cooling. This air conditioning system is ideal for remote areas or locations also, offering independence from centralized energy sources. This paper is related to provide energy efficient and environment friendly solution to control indoor temperature that can replace conventional air conditioning systems, which consume a significant amount of electricity.

II. LITERATURE SURVEY

A.Josh, and A.D.Souza [1] Considered that thermoelectric cooling uses Peltier module that operates on peltier effect. Peltier module, a semiconductor-based material (P-type & N-type) has two sides where heat is absorbed from one side and dissipated on another side. Peltier module consists of several thermocouples sandwiched between two layers of ceramic substrates. The ceramic substrates have high thermal conductivity so that there is minimal conduction resistance across the layer of the substrate but very low electrical conductivity to avoid any leakage current flow through the substrate. When the inside temperature reaches the required condition then thermostat is used to control the inside temperature and power supply to Peltier module will stop.

M. Khalid, A.M.I. Ahmed, [2] The study highlights the development of an intelligent air conditioning system using Peltier modules, which operate based on thermoelectric cooling principles. These modules serve as eco-friendly alternatives to traditional air conditioners by leveraging semiconductor technology to transfer heat from one side to another when a low voltage DC power source is applied. The system incorporates sensors, a microcontroller, and IoT technology for temperature monitoring and control. The study underscores the environmental friendliness and efficiency advantages of Peltier modules over vapour compressor systems.

Baiyang Zhao, Zhigang Zhao, Meng Huang, Xuefen Zhang, Yong Li, Ruzhu Wang [3] Describes that the integration of solar photovoltaic (PV) technology with vapour compression air-conditioning, termed solar PV-powered air-conditioners, presents an appealing and eco-friendly solution for peak load reduction.

This synergy capitalizes on the direct correlation between building cooling needs and solar radiation. Simultaneously, electric utilities acknowledge the advantages of cooling energy storage as a viable strategy for reshaping electric loads in response to building cooling demands, especially for demand response purposes.

Ryszard Buchalik , Grzegorz Nowak [4] analyses a thermoelectric air conditioning system's efficiency through performance simulations, emphasizing cooling capacity, COP, and economic optimization. It utilizes environmentally friendly thermoelectric modules with inert liquids and radiators for heat transfer, ensuring simplicity and controllability. Economic efficiency is assessed using the ETCC indicator, which factors in investment and operational costs.

Rescue robots face difficulties in cooling due to harsh environmental conditions, leading to the need for alternative cooling methods like thermoelectric cooling to optimize energy consumption and ensure efficient operation during rescue missions. Due to two primary limitations—restricted energy resources and hazardous environmental conditions—traditional cooling methods prove inefficient, if not harmful, for these robots. paper suggests employing thermoelectric cooling coupled with Model Predictive Control to achieve efficient cooling. Computational Fluid Dynamics simulations endorse this strategy, indicating the possibility of minimizing energy usage. [5]

Raj Shekhar Srivastava, Anuruddh kumar, Harishchandra Thakur [6] vehicles left in open spaces experience notable temperature changes, requiring air conditioning to ensure passenger comfort. These fluctuations are especially problematic during summer, causing cabins to become excessively hot, and in winter, leading to uncomfortably cold interiors. Traditional air conditioning methods contribute to higher fuel usage and emissions. This paper suggests a solar-powered thermoelectric cooling/heating system as an eco-friendly alternative. While past solutions mainly rely on solar energy, their intricate designs and need for frequent maintenance make them less practical. Thermoelectric technology presents a simpler, self-sustaining option for both cooling and heating, directly fuelled by solar power

III.PROPOSED SYSTEM

The system utilizes a Peltier module for cooling & heating, with an IR receiver for adjusting the desired temperature through an IR remote. It incorporates a temperature sensor to detect the surrounding temperature, and an Arduino to control all the devices by sending pre-coded commands. In cooling mode the cold side of peltier is placed inside the room and the hot side is connected to a radiator for heat dissipation. In case of heating mode the cold side of peltier is placed outside the room and hot side is placed inside the room providing heating effect. By providing solar power, the module absorbs heat from the surroundings, resulting in a cooler space & in the latter case radiates heat into the surrounding resulting in warm space. This compact and lightweight system offers efficient cooling and energy efficient capabilities.

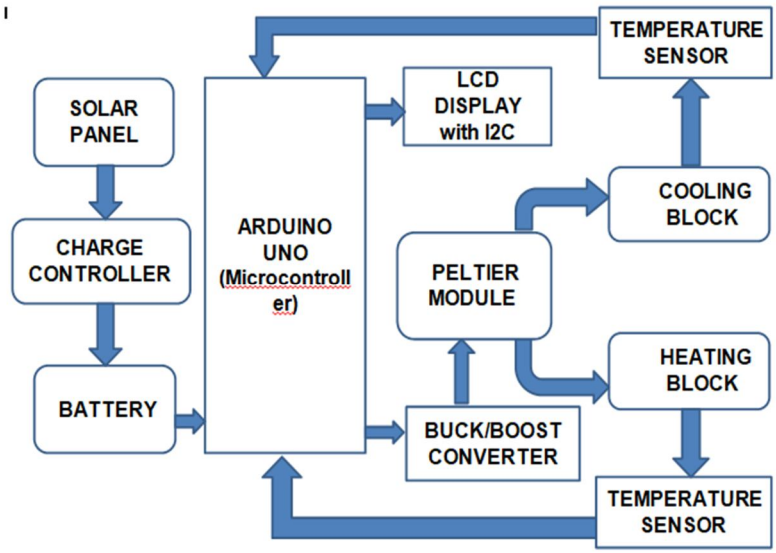

Fig 1.Block Diagram

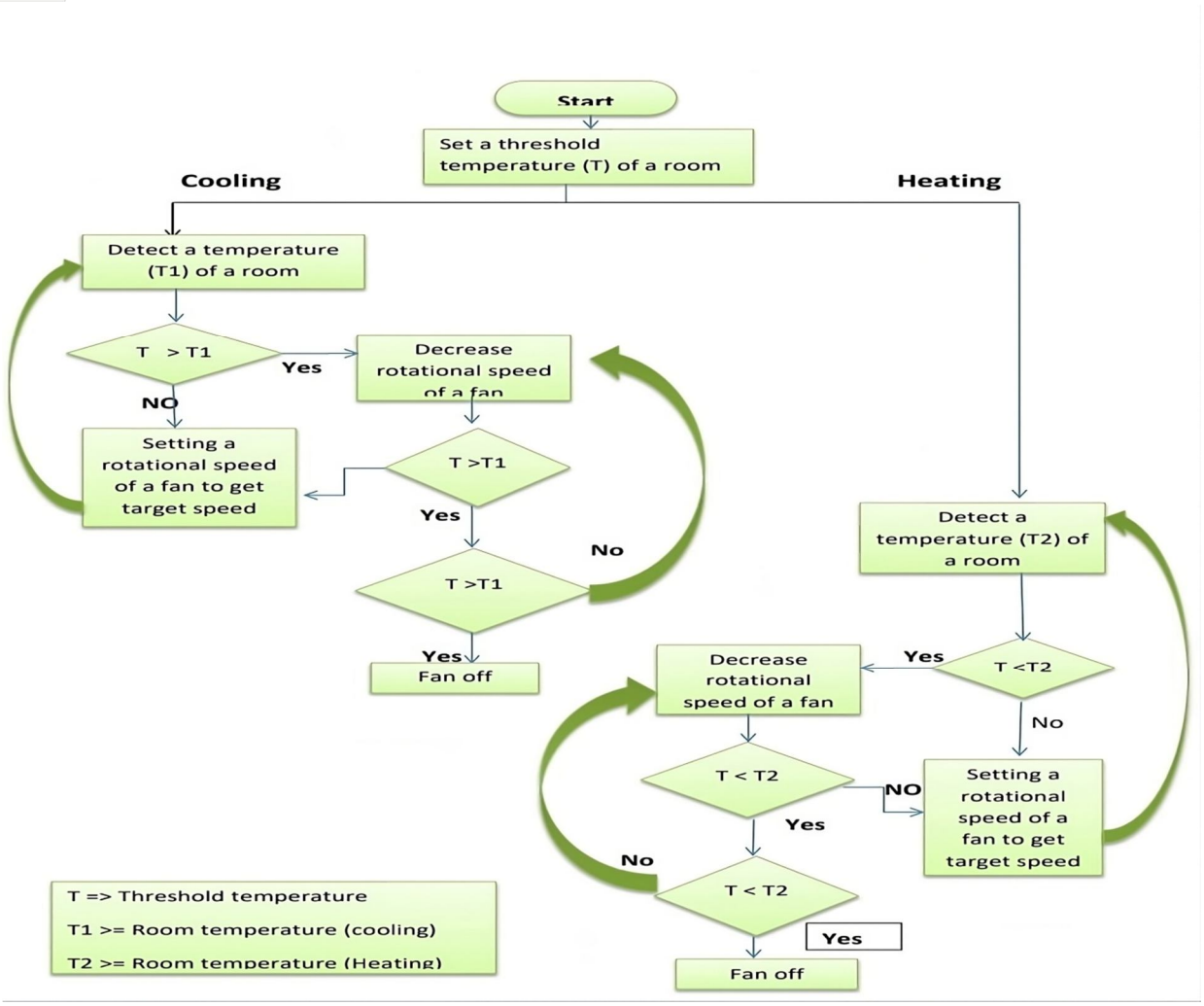

Fig 2. Flowchart of proposed system

IV. PRINCIPAL COMPONENTS OF THE SYSTEM

A. *Arduino Uno:* Uno is a microcontroller based on 8-bit ATmega328P microcontroller. It consists of components such as crystal oscillator, serial communication, voltage regulator etc. to support the microcontroller. It operates at 5 volts and typically accepts input voltages ranging from 7 to 12 volts, with a limit of 6 to 20 volts, with 14 digital I/O pins, including 6 PWM outputs, and 6 analog input pins, it offers flexibility for various projects. Each I/O pin can handle up to 20 mA of DC current, with the 3.3V pin supporting up to 50 mA. The Uno boasts 32 KB of flash memory, with 0.5 KB reserved for the bootloader, along with 2 KB of SRAM and 1 KB of EEPROM. This board comes with features required to run the controller and can be directly connected to computer through USB cable to the controller using IDE (integrated development environment) software.

B. *Solar panel:* Photovoltaic panels (PV) are devices that convert sunlight into electricity. They are made up of silicon. When sunlight hits these cells, it creates an electric field across the layers, causing electricity to flow. It consists of monocrystalline solar cell that provides an operating voltage of 12v. The electricity generated by solar panels can be used immediately, stored in batteries for further uses. Solar panels produce clean, renewable energy without emitting greenhouse effects or pollutants.

C. *Peltier Module:* A Peltier module, also known as a thermoelectric cooler or TEC module, is a semiconductor device used for heating or cooling applications based on the Peltier effect. When an electric current flows through the module, heat is transferred from one side to the other, creating a temperature differential. This effect can be utilized to either remove heat from one side (cooling) or generate heat on the other side (heating), depending on the direction of the current flow. The Peltier Module, designated as TEC-12706, operates at a nominal voltage of 12 volts, with a maximum allowable voltage of 15.4 volts. It can handle a maximum current of 6 amps and dissipate heat up to a maximum of 92 watts.

IV.SIMULATION & IMPLEMENTATION OF THE PROTOTYPE

Before implementing the software, we simulated the system to know whether it works properly or not. At first we have done coding by using Arduino IDE software and coding was accurate. The Arduino IDE, or Integrated Development Environment, is a software tool utilized for coding arduino microcontrollers. It features a text editor for writing code, a compiler for converting code into machine-readable instructions, and a uploader for transferring code to Arduino boards. It is an open source software which means that its source code is freely available for anyone to view, modify, and distribute. After coding, the simulation was done using Proteus design suit version 8.14 .In Proteus design suit there is no peltier module so we used motor to show the working of peltiers. It has two motors, one is used to show cooling operation and other is used to show heating operation. The circuit operates in two modes i.e. manual and automatic. In automatic mode when room temperature is greater than 27 degree Celsius, it starts cooling and when room temperature is less than 14 degree Celsius, it starts heating. In manual mode we can set the temperature according to our preference.

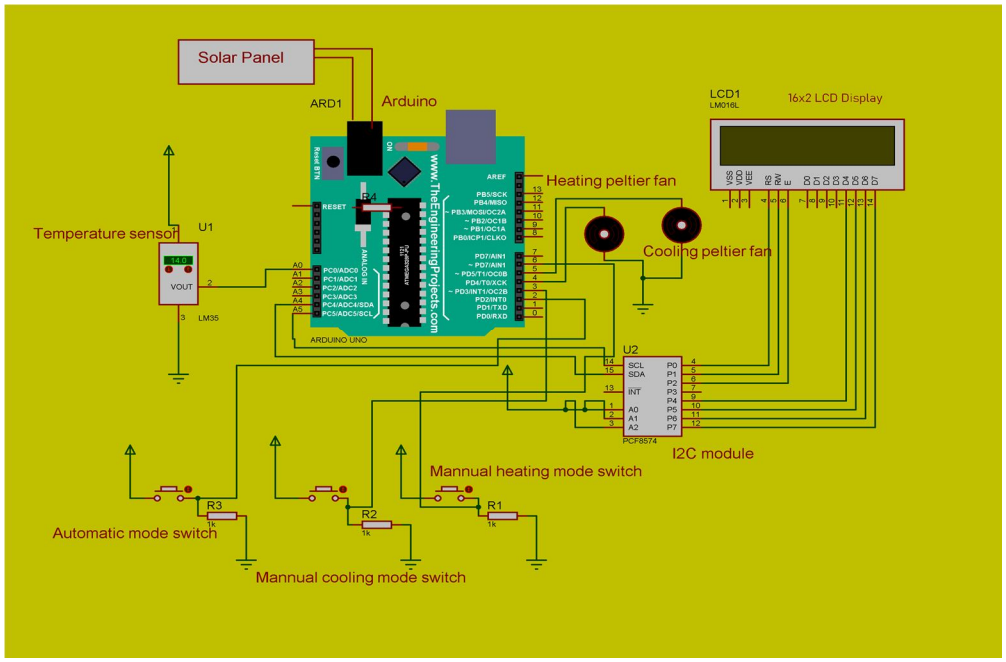

Fig 3.Schematic diagram of proposed system

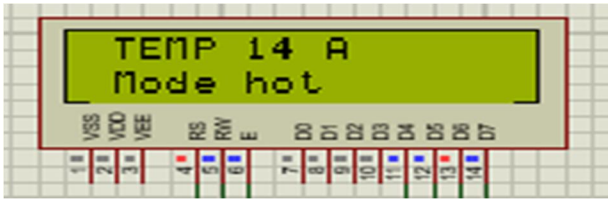

Fig 4.Circuit for automatic heating mode

In fig 4 circuit diagram is shown. Here "A" represents automatic operation of the system. We have done coding in such a way that if room temperature is less than 15 degree Celsius, it will start heating the room.

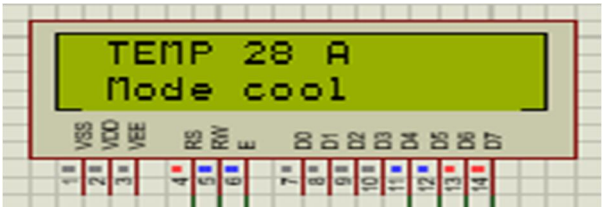

Fig 5.Circuit for automatic cooling mode

In fig 5 circuit diagram is shown. Here in automatic cooling mode of operation when the temperature is greater than 27 degree Celsius, it will start cooling the room.

Fig 6.Circuit for manual heating mode

In fig 6 circuit diagram is shown.Here "M" represents mannual mode of operation, user can set the temperature according to the preference.

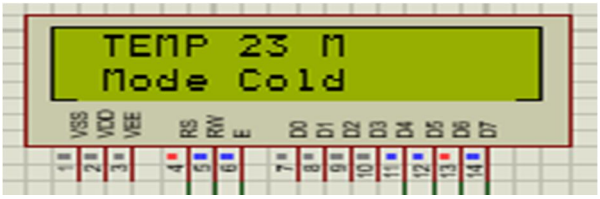

Fig 7.Circuit for manual cooling mode

V. RESULT & ANALYSIS

When practically implemented the photovoltaic powered dual thermoelectric air conditioning system it is observed that minimum cooling temperature obtained is 22 degree Celsius in cooling mode while in heating mode maximum heating temperature obtained is 31 degree Celsius with reference to room temperature.

A. Comparison

Conventional system	Proposed system
Emit harmful gases	No harmful gases are released since no refrigerants are used
Consume more power	Energy efficient as solar power is used
Conventional air conditioning systems are bulky	This system is compact and light weight
These systems are not durable	Proposed system is durable because solar panel and thermoelectric components have long life span.

VI.CONCLUSION

Our main objective of this research paper was to introduce an environment friendly and energy efficient air conditioning system. The proposed air conditioning system reduces carbon emissions and dependency on fossil fuels. This system can be deployed in diverse settings, from residential homes to commercial buildings, off-grid locations, and even in vehicles, offering flexibility in addressing cooling /heating needs.

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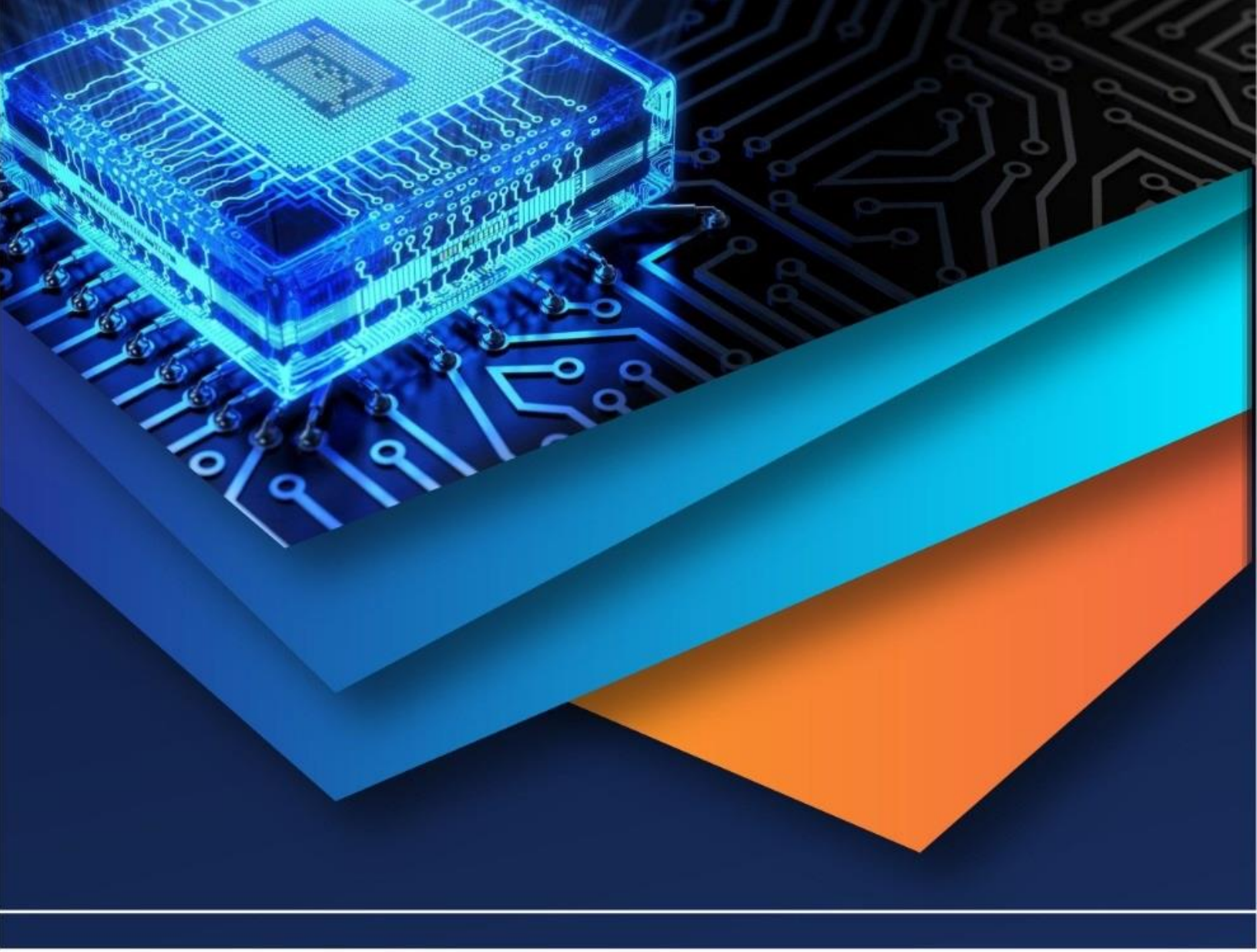

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