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Fabrication And Testing of Advance Air Purifier with Viral Filter

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Abstract: The increasing concerns over air pollution, allergies, and airborne viruses have heightened the need for efficient air purification systems. Air pollution occurs when harmful or excessive quantities of substances including gases, particles, and biological molecules are introduced into Earth's atmosphere. It may cause diseases, allergies and even death to humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment. Both human activity and natural processes can generate air pollution.

This project focuses on the fabrication and testing of an advanced air purifier integrated with a viral filter to combat these challenges. The proposed air purifier utilizes a multi-stage filtration process that includes HEPA filters, activated carbon, UV-C rod and a specialized viral filter designed to trap and neutralize viral particles. The key parameters such as airflow rate, filter life, energy consumption, and purification efficiency are measured during the testing phase. The results of this study provide valuable insights into the practical applications of advanced air purifiers with viral filters in improving indoor air quality and safeguarding public health.

Keywords: Hepa Filter, UV-C Rod, Viral Filter, Activated Carbon Filter, Air Flow Rate, Energy Consumption, Filter Life, Purification Efficiency.

I. INTRODUCTION

Air pollution has become a significant concern across the globe, particularly due to its harmful effects on human health. Recent advancements in air purification technology have made it possible to reduce airborne pollutants, but the need for enhanced filtration to capture pathogens like viruses has emerged as a necessity.

Pollution has rocked the world with skyrocketing pollution levels. Though the long-term solution to the pollution problem lies in finding and minimizing pollution sources, we need to bring the current pollution levels under control by the time. The best way of controlling pollution is by using air purifiers.

The purpose of this project is to create an efficient air purification system for both residential and industrial applications, which can reduce the risk of airborne transmission of infectious diseases.

In this project we use six stage purification, the first one being pre filter and second is air filter. The combination of these 2 filters leads to dual filtration using a centrifugal air force to suck amount of air and purify it of dust particles, fourth layer is UVC protection.

A. Impurities in Air

Impurities in air refer to unwanted substances present in the atmosphere that can have harmful effects on health, the environment, and materials. These impurities can be classified into different types:

1) Natural Impurities:

- Dust and Pollen – Produced by soil erosion, plant reproduction, and volcanic activity.
- Smoke and Ash – From wildfires and volcanic eruptions.
- Gases – Such as methane from wetlands and carbon dioxide from respiration.

2) Man-Made Impurities (Pollutants):

- Particulate Matter (PM2.5, PM10) – Tiny solid or liquid particles from industries, vehicles, and burning fuels.
- Carbon Monoxide (CO) – Released by incomplete combustion of fuels in vehicles and factories.
- Sulfur Dioxide (SO_2) – Emitted by burning fossil fuels, especially coal.

- Nitrogen Oxides (NO_x) – Produced by vehicle engines and industrial processes.
- Volatile Organic Compounds (VOCs) – Emitted from paint, gasoline, and household products.
- Ozone (O_3) – A secondary pollutant formed by chemical reactions between NO_x and VOCs under sunlight.

II. LITERATURE REVIEW

Rushikesh Kadam: Worked on Solar Powered Air Purifier for improving Air Quality Index, Fabricated model consists of a Solar panel, MQ135 sensor, and air purifier filters i.e., HEPA filter & Activated carbon filter and other miscellaneous components for filtering the polluted air to survive. This model can capture carbon polluted particles, dust particles and smoke molecules.

Perumal: Designed Solar Indoor Air-Purifier with Air Quality Monitor System as shown in fig 2.2. In this model it consists of Solar panel for energy supply), power-wall battery technology for storing power generated from the solar panel for later use), air purifier which has hybrid filtering system and air quality monitoring system to give the air composition data. A hybrid filtering system made up of three filtering sections, primary filtering section has pre-filter (HEPA filter). A pre-filter captures the largest particles before they reach the more expensive HEPA filter.

Manjeet Kumar: Designed Solar Powered Air Purifier as shown in fig 2.10. This research work emphases on design and fabrication of an air purifier which is powered by solar energy and testing the effectiveness of the system to curb the air pollution. The focus is on extracting the suspended particulate matter from the air which are the major contributors in the pollution of air in many urban cities. It works on a non-conventional method and intents to achieve best possible air purification results using eco-friendly and economical method. It works on the basic principle of adhesion of the suspended particles in the air with the liquid and settles down due to being heavier than air and gets separated from the air helping us to achieve better air quality index.

III. METHODOLOGY

The methodology can be divided into several stages, ranging from design to construction, testing, and evaluation. The goal is to create a device that can efficiently remove particulate matter, viruses, and other harmful pathogens from the air. Below is an outline of the methodology that includes both fabrication and testing aspects.

A. Design Phase

1) Conceptualization and Requirements

- Objective**:** To design an air purifier that effectively removes viruses and other harmful airborne particles.
- Specifications**:**
  - Filtration efficiency for particulate matter (PM2.5, PM10) and pathogens (viruses, bacteria).
  - Airflow rate: Typically, air purifiers are designed based on airflow rate (e.g., 100-300 CFM).
  - Power consumption.
  - Size and portability.
  - Noise level.
  - Cost-effectiveness.
- Target Viruses: The design should focus on filtration technologies that can target both large particles and smaller aerosols where viruses like SARS-CoV-2, Influenza, etc., might be found.

2) Selection of Filtration Technology

- UV-C Light: Used to deactivate microorganisms like bacteria and viruses by damaging their DNA or RNA.
- Activated Carbon Filters: Used for removing volatile organic compounds (VOCs), odors, and certain gases.
- Dust Filter: Captures larger dust particles to improve air quality and protect other filters.
- Air Filter: A general filter that removes particles from the air.
- Viral Filters: A filter specifically designed to capture particles as small as viruses, including COVID-19.
- Airflow Circuit: Design an optimal airflow path that ensures maximum contact between the air and filter materials.
- Fan and Motor: Select a motor with sufficient capacity to maintain a consistent airflow.
- Size and Housing: The housing should be designed for easy installation, filter replacement, and maintenance. Material selection for the housing should also be considered to avoid off-gassing and ensure durability.
- Control System: Consider implementing sensors (e.g., particle sensors, gas sensors) to monitor air quality.

- Integration of Viral Filter: The viral filter is an additional layer, possibly integrated with UV systems to target specific viral pathogens.

B. Fabrication Phase

1) Material Selection

- Filter Materials**:**
  - filters with a 99.97% efficiency for particles as small as 0.3 microns.
  - Activated carbon sheets for VOC adsorption.
  - Antimicrobial treatments (e.g., copper-based coatings, silver ions) for enhanced viral filtration.
- Casing Material: Non-toxic, non-reactive plastic or metal (stainless steel or aluminum) with durability and ease of maintenance in mind.
- Fan and Motor: Choose a low-noise, efficient fan that meets the desired airflow rate.
- UV-C Lamp: If UV-C is included, use certified UV-C lamps that emit the required wavelength for microbial inactivation (typically around 254 nm).

2) Assembly Process

- Fabricate the Housing: Design and fabricate the outer casing.
- Install Fan and Motor: Secure the motor and fan system, ensuring proper airflow and noise reduction features.
- Install Filters: Assemble layers of filters (activated carbon, air filter, dust filter viral filters) in a manner that allows air to pass through them efficiently.
- Integrate UV-C System: Position the UV-C light (if included) inside the purifier such that it treats the air passing through the filter.
- Sensor Integration: Install particle and gas sensors, along with a control board to regulate the system based on air quality readings.
- Power Supply: Set up the power supply and control circuits, including user interfaces like switches.

C. Testing Phase

1) Performance Testing

- Filtration Efficiency Testing:
  - Test the air purifier's ability to remove particulate matter (PM2.5, PM10) using a particle counter.
  - Test viral filtration efficiency by simulating airborne viruses and checking how effectively the purifier reduces virus concentration.
- Airflow Rate: Measure the airflow rate to ensure it meets the required standards.
- CADR (Clean Air Delivery Rate): Test the CADR for dust, smoke, and pollen to confirm the efficiency of the air purifier in real-world conditions.

2) Noise and Power Consumption Testing

- Noise Level**:** Measure the noise output (in decibels) to ensure the air purifier operates quietly under normal conditions.
- Power Consumption**:** Measure the power consumption during various operating modes to ensure it meets the energy-efficiency requirements.

3) Durability and Safety Testing

- Material Durability: Test for the longevity of filters (viral filter, activated carbon) by subjecting them to multiple cycles of filtration.
- Safety Standards: Ensure that the system adheres to local safety standards.

D. Optimization Phase

- Based on the initial testing results, optimize the airflow system, filter material, and fan motor for greater efficiency.
- Adjust the design or features (e.g., UV-C exposure time, motor speed) to enhance performance based on testing feedback.

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E. Final Evaluation

Conduct real-world testing in various environments (e.g., offices, homes, hospitals) to evaluate the purifier's performance over time and under different conditions.

IV. FLOW CHART OF WORK FLOW

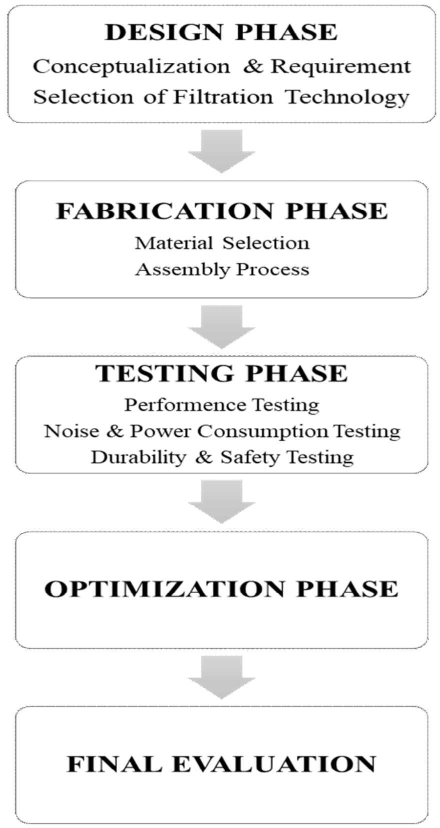

Fig 1: Flow Chart

V. CALCULATION

A. Air Flow Rate (Cfm) Calculation:

Flow Rate (CFM) = Fan Area* Air Velocity (ft/min)

CFM = 0.0763* 700 = 53.4 CFM

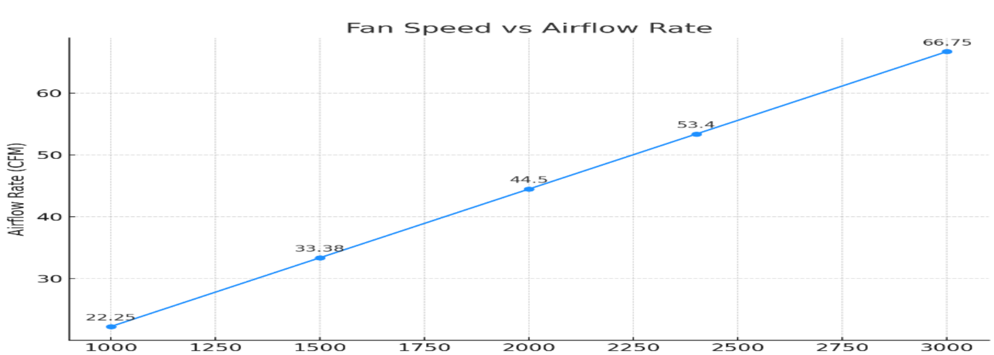

Fig 2: Fan speed vs Air flow curve

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B. Filter Efficiency:

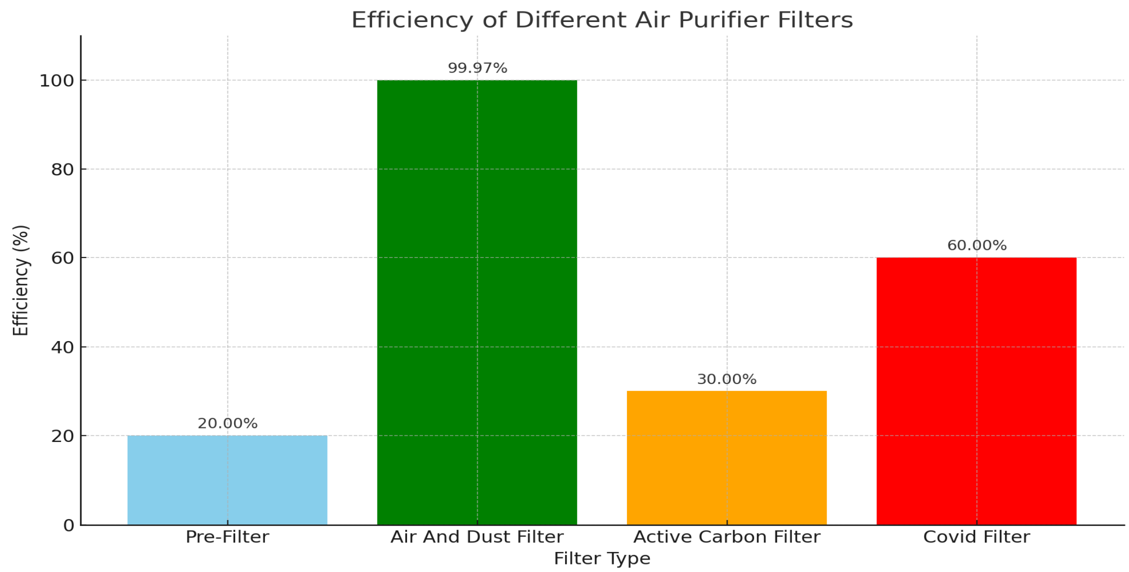

Fig 3: Efficiency comparison of Different Air Purifier Filters

C. Pressure Drop Across Filter:

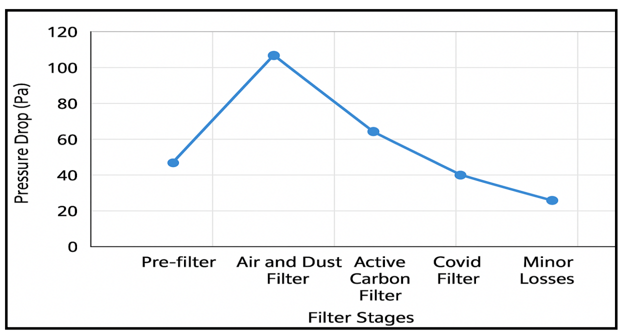

Fig 4: Pressure Drop Curve

D. Power Consumption:

$$\text{Power (W)} = \text{Voltage (V)} \times \text{Current (A)}$$

1) DC Fan-

Voltage = 24V
Current ≈ 0.3A
P = 24×0.3 = 7.2 WP

2) UV-C Lamp-

P=8 W

3) Sensors (MQ135, MQ7, MQ2)-

Table 1: Power Consumption Chart for Sensors

Sensor	Avg. Voltage	Current (A)	Power (W)
MQ135	5V	0.15A	0.75 W
MQ7	5V	0.15A	0.75 W
MQ2	5V	0.15A	0.75 W

Total Sensor Power = 0.75 × 3 = 2.25 W

4) Microcontroller-

Voltage: 5V
Current: ~50mA
Power: 0.25 W

5) LED-

P = 0.5W

Total Power Consumption= 18.2 W

6) Power Consumption Per Hour:

Energy Consumption per hour=18.2W⇒18.2Wh

Per day (8 hrs usage);

18.2×8=145.6Wh/day ≈0.107 kWh

VI. RESULT

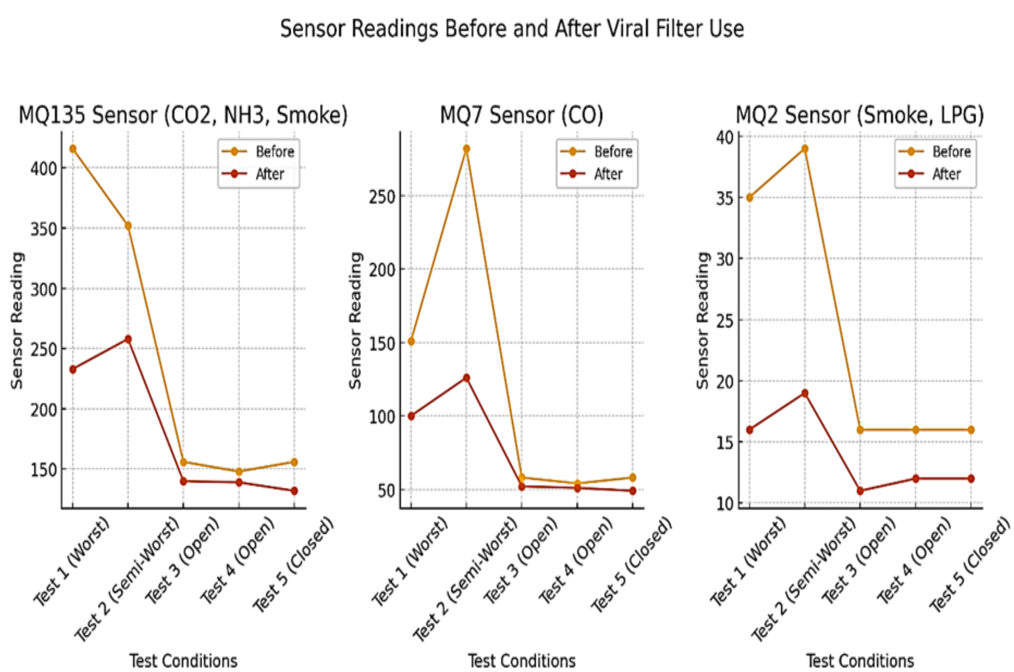

Fig 5: AQI analysis curve for different conditions for sensors

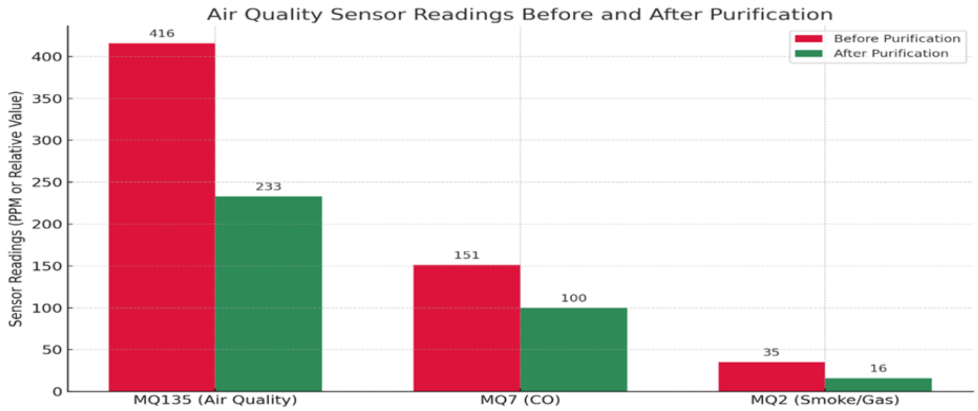

Fig 6: AQI analysis bar graph for different conditions for sensors

Table 2: Comparison with different purifiers available in market

Feature	Our Advance Air Purifier	Other Advanced Purifiers available in market
Filtration Stages	6- Stage (Pre-filter, Air Filter, Covid filter, UV, Dust Filter, Active carbon filter)	2-3 Stage (HEPA + carbon, rarely UV)
Customizability	High	Low
UV Sterilization	Yes	Rare
Fan Type	Axial Fan	Blower type or low rpm fan
Sensor Integration	MQ135, MQ7, MQ2	Some have PM2.5 sensor, gas sensor
Build Material	Metal Body	Plastic body
Energy Consumption	Very Low	30-60W typically
Maintenance Cost	Low	High
Cost	Much Cheaper to Build	20000-60000 depending on brand
Target Area	Medium-Large room	Small-medium room mostly

A. Air Quality Index (AQI)

Table 3: Color coding for different AQI ranges

Air Quality Index	Level of Health Concern	Colors
0-50	Good	Green
51-100	Moderate	Yellow
101-150	Unhealthy for sensitive groups	Orange
151-200	Unhealthy	Red
201-300	Very Unhealthy	Purple
301-500	Hazardous	Maroon

VII. CONCLUSION AND FUTURE SCOPE

The development of this multi-stage air purifier represents a significant stride toward addressing the increasing concerns surrounding indoor air quality, particularly in the wake of global health crises caused by airborne pathogens. The system integrates a comprehensive filtration process that includes a pre-filter for large particulate matter, air filter, an activated carbon filter for chemical and odour adsorption, and an optional UV-based sterilization stage aimed specifically at deactivating viruses and bacteria.

1) IoT integration for real-time monitoring.
2) Adaptive airflow control.
3) Make this purifier based on renewable energy with the help of solar panel and batteries.
4) Installed AQI with purifier at every stage of filtrations.

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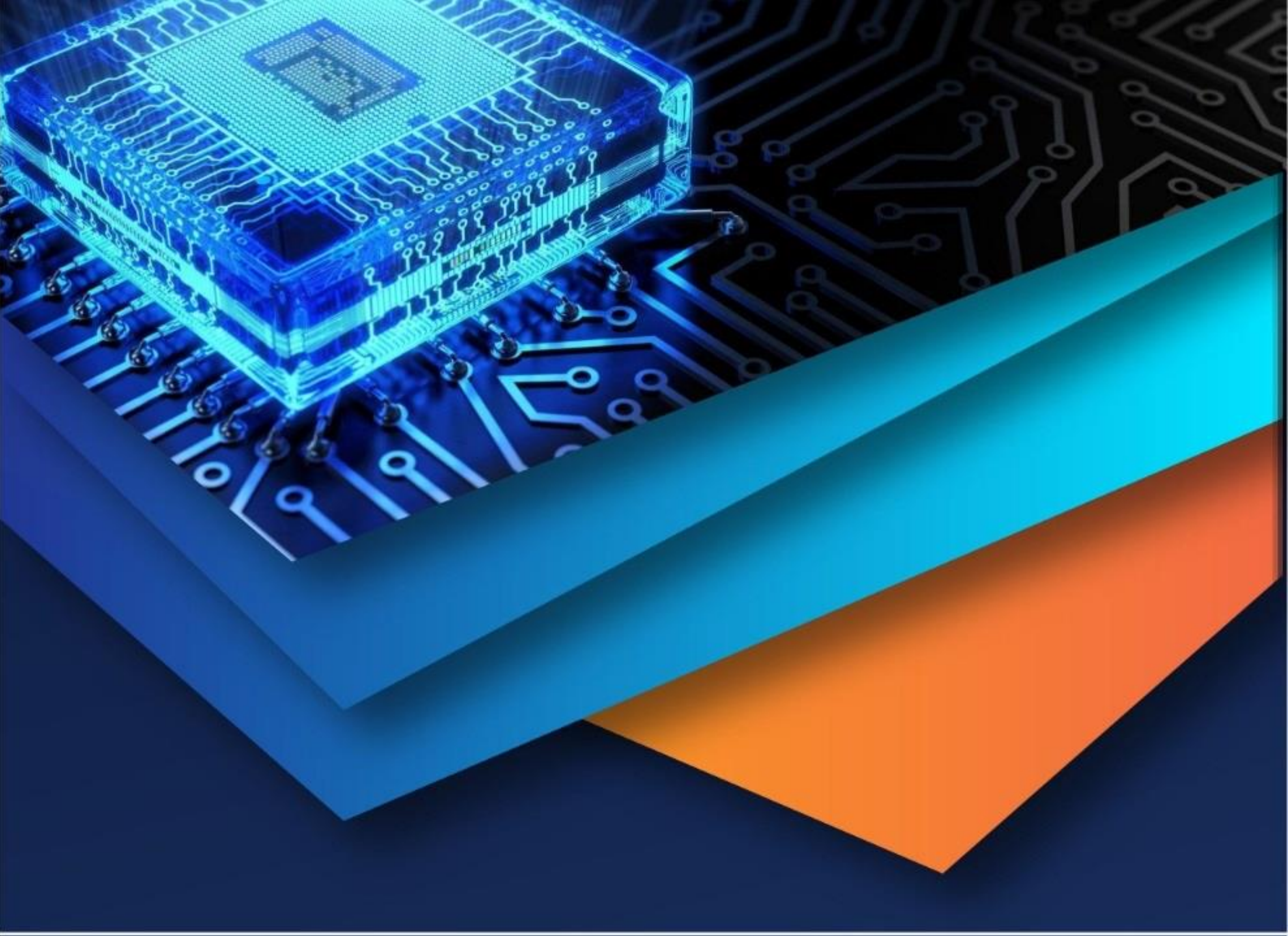

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