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IoT Based Automatic Air Pollution Monitoring and Purification System

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Abstract: Degradation of air quality, like climate change and global warming, has become an all-encompassing existential hazard to humanity and natural life. Exposure to severely polluted air on a regular basis causes pulmonary disorders and contributes to severe allergies and asthma. According to studies, more than 10 million people die each year as a result of irregularities produced directly or indirectly by air pollution. The work of Lelieveld et al. [1] sheds light on the gravity of the problem. It is estimated that by 2050, the worldwide premature mortality from air pollution will exceed 6.6 million fatalities per year (358000 from ozone, the rest from PM 2.5) [1]. As a result, we decided to focus our study on improving indoor air quality. Despite the fact that there are numerous indoor air purifiers on the market, their cost belies their effectiveness, and the effective ones are far too expensive for working-class people to afford [2]. In order to address this issue, we created an automated Internet of Things (IoT) based air filtration system that uses an automated air purifier which is triggered when air quality falls below WHO criteria. Our initiative intends to improve indoor air quality by utilizing the most cost-effective and efficient modules available.

Keywords: Indoor Air Pollution, Air Purifier, IAQ, Sharp Dust Sensor GP2Y1010AU0F, IoT, Particulate Matter (PM), HEPA Filter

I. INTRODUCTION

Particulate Matter or Particulates are microscopic solid and liquid matter particles suspended in the air. Smog, soot, cement dust, virus, pollen, and other pollutants are examples of PM. The diameter of harmful particulate matter ranges from 1 micron (1- micron = 10-6 metre) to 100 microns. Large particles are defined as those with a diameter of 2.5 microns to 10 microns, while small particles are defined as those with a diameter of 2.5 microns or less. A typical human hair is 50 times larger than 2 micron particles. Inhaling such particle matter for an extended length of time produces a variety of health problems. Such issues vary from breathing ailments to severe lung malfunctions. We used to conceive of PM pollution as something that happened outside, but that is no longer the case. Indoor air quality in the world's most polluted cities (such as Delhi and Beijing) is substantially worse than outside air quality in moderately polluted cities, according to scientific evidence. Indoor air pollution is a serious issue that should not be overlooked. For many irrespirable particulate particles, global indoor pollution exceeds global outdoor pollution (Smith, 1993) [3].

Indoor air pollution has been increased by modifications in building designs intended to enhance energy efficiency. Modern homes and businesses are more airtight than older designs as a result of these changes. Furthermore, developments in construction technology have increased the usage of synthetic building materials significantly [4]. While these developments have resulted in more convenient structures with reduced construction and operating costs, their airtight rooms produce far greater PM concentrations than those found outside. Carbon monoxide, particulate matter, and aerosols including sulphur and nitrogen oxides from cooking stoves, space heaters, cigarettes, incense, and mosquito coils are all major contributors of indoor air pollution [5]. Cleaning supplies, paints, pesticides, and building materials such as asbestos and fibreglass all have a negative impact on indoor air quality and can cause headaches, dizziness, and weariness, especially in rooms with poor ventilation [6]. Legionella bacteria, which can cause pneumonia, can develop in rooms with poorly maintained air conditioning and heating [6]. Household moisture and mould can aggravate lung diseases and cause breathing difficulties [7]. There was no significant difference in the pulmonary function of smoking and non-smoking women who were similarly exposed to domestic smoke, according to research conducted on the outskirts of Kathmandu valley, which is devoid of industrial pollution [8]. As the statement goes,"Prevention is better than cure," an effective air filtration system is required but not at the expense of a significant financial outlay.

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II. PROBLEMS WITH CURRENT MODELS

Many air quality monitoring and purification devices claim to be highly effective, but they are prohibitively expensive for people of heavily polluted and underdeveloped nations to afford. Rich and industrialized countries' air quality measurement systems have been found to be unreliable [2]. So to produce accurate data, a more efficient system (in terms of power consumption, portability, and efficacy) should be created by the utilization of low-cost but effective sensors..

According to the literature, low-cost, high-quality particle detectors exist, but they are difficult to find on the market due to manufacturing issues [9]. Fast, small, portable, and low-cost gadgets to monitor and enable research should be created for underdeveloped countries [10]. The purifiers available in the market consume relatively high amount of electricity, which can be burdensome for people of global south. Due to such heavy prices and power consumption issues, these expensive models have not yet found their way into developing countries, where dangers of air pollution loom ever more threateningly.

III.SOLUTION

Considering the danger of air quality degradation and current paucity of efficiency and affordability in modern air purifiers, we have devised to create a cheaper, more sustainable and efficient system. Our product consumes one third as much power as consumed by an average modern air purifier. We have employed IoT, mathematical calibration and database servers to create a product that can do air purifying, data recording, and accurate data reading under a budget of 30 US$.

A. Required Components

1) *Arduino UNO Rev3:* Arduino UNO Rev3 is the micro-controller based on the ATmega328P. It controls the operations and employs the necessary algorithms and equations to provide the accurate reading. Other models of Arduino as well as other kinds of microprocessors like Raspberry Pi can also be used. It has 14 Digital Input/Output pins that is used to connect all the components of the system.
2) *Sharp Dust Sensor GP2Y1010AU0F:* This sensor uses is used for the detection of particles in the air. It is compact and thin (46*30*17.6mm). This sensor has high sensitivity to dust conditions and fast response time between the Arduino and itself. (More detailed explanation in Working mechanism)
3) *Automotive Filter:* The serrated walls of the filter, built by microscopic fibres, trap the dust on the outer layer so that only clean air enters the inside of the filter.
4) *Relay Module (5 Volt 1 Channel):* The relay is electrically operated switch. It can be turned on and off, depending on whether to let the electricity flow or not. When the air quality deteriorates below a certain level, the relay closes the connection and current flows into the purifying module.
5) *OLED Display:* OLED stands for Organic Light Emitting Diodes that produces light through organic molecules. It can be operated by the help of Arduino UNO to view the PM density readings in real-time. It has fast response speed and low power consumption.

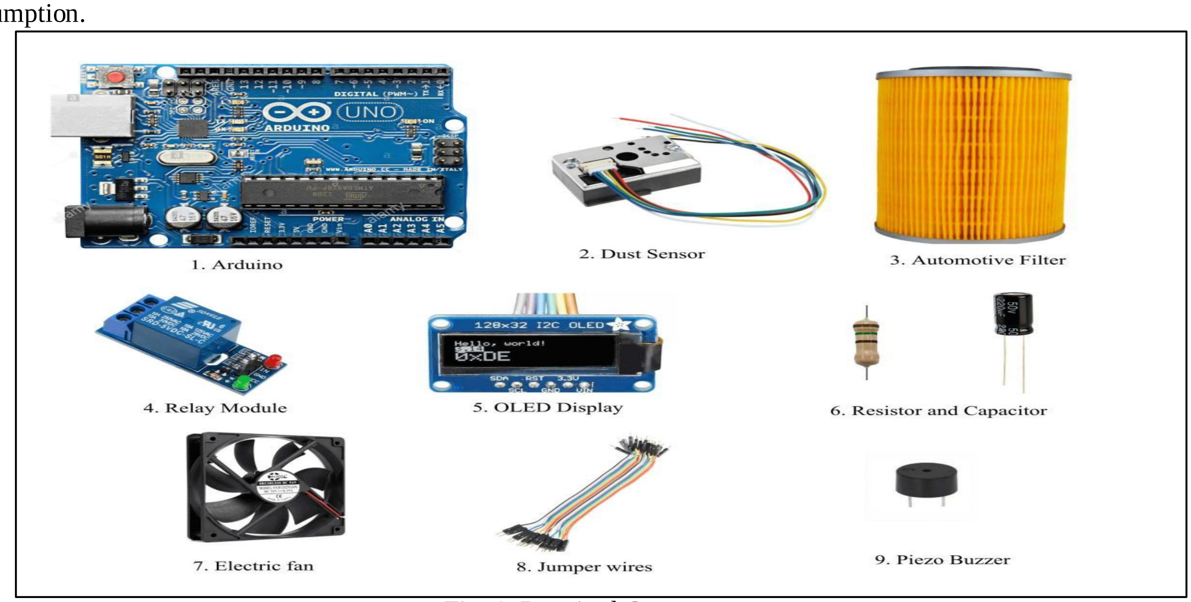

Fig. 1 Required Components

6) *150Ω Resistor and 220μF Capacitor:* Resistors and capacitors have been used to control the flow of current and regulate the voltage of the operating current.
7) *12V Electric Fan (D.C):* Used exclusively in the purifier module, the fan creates a partial vacuum inside the air filter that forces air into the walls of the filter. Purified air enters the inside of the air filter due to the upward thrust generated by it.
8) *Jumper Wires:* Jumper wires electrically connect different modules to the Arduino. It has 2 connector pins at each ends that is used to join 2 points electrically without the need of soldering.
9) *Piezo Buzzer:* A "piezo buzzer" is a tiny speaker that can be directly connected to Arduino and works on the basis of piezoelectricity. It is an effect where certain crystals will change shape when you apply electricity to them. By applying an electric signal at the right frequency, the crystal can make sound. From the Arduino, you can make sounds with a buzzer. This is used as an alert for unhealthy air quality.

IV. WORKING MECHANISM

The Proposed system's framework is based on IoT. The IoT is a network of interconnected computing devices, mechanical and digital equipment that can send and receive data without the need for human intervention. Micro-controllers, sensors, and communication devices make up an IoT ecosystem, which collects, sends, and acts on data collected from their surroundings [11]. Our "IoT Based Automatic Air Purification And Monitoring System" is a cost-effective and portable gadget that includes modern technology for machine-to-machine communication without the need for human intervention.

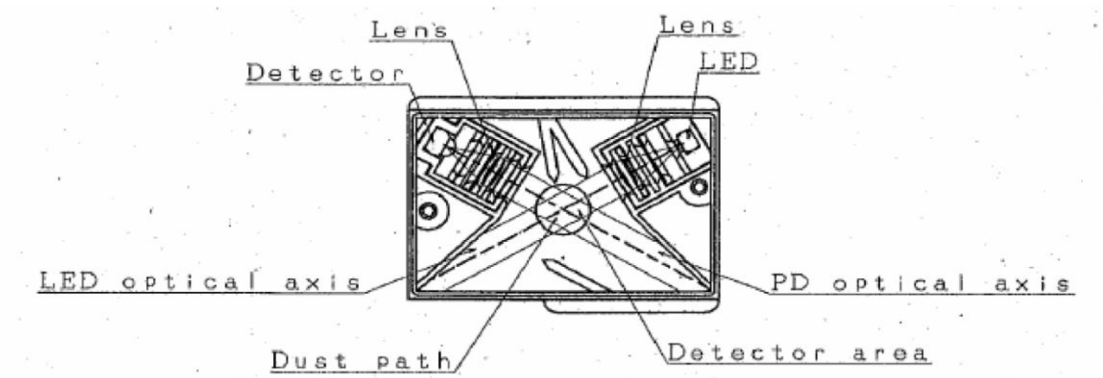

Fig. 2 Inner framework of the Dust sensor

The SHARP GP2Y1010AU0F Optical Dust Sensor is a key component of this project. This sensor detects microscopic particles in the air. Light-emitting diode (LED) and Photo-diode (PD) make up the majority of the sensor. Light waves are continuously emitted by the LED. Dust particles reflect, refract, or deflect light waves when they come into contact with them (See Fig. 3). The photo-diode detects these waves and generates an equivalent current based on the detected light waves. After the amplifier circuit amplifies the current from the photo-diode, the device produces analogue voltage output.

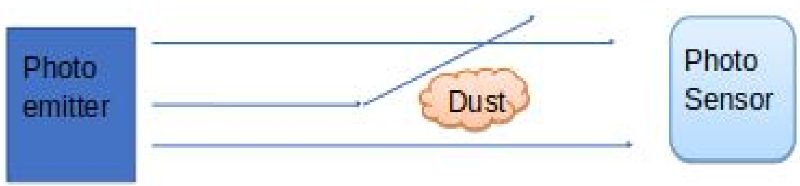

Fig. 3 Reflection, Refraction, and Deflection of light waves by Dust particles

The sensor then communicates the voltage data to the Arduino, which uses a theoretically proved equation calibrated to match the sensor to calculate the Indoor Air Quality(IAQ) (unit: $\mu g/m^3$). Following that, the Arduino performs a logical comparison and decides whether or not to start the Air purifier. If the computed IAQ exceeds the threshold recommended by the WHO, (https://www.who.int/tools/air-quality-standards),the Arduino signals the Relay module to close the connection that will power the Purifier module. The Arduino also relays current to the piezo buzzer that alerts the household member for unhealthy indoor air pollution level.
Air purifier will run until the IAQ falls below or equals the threshold recommended by WHO (https://www.who.int/tools/air-quality-standards).

Fig. 4 Working module of the system

The Air purifier removes contaminants from the air. A normal automotive air filter is used in the purifying module. The filter is a very fine fiber-like material that has been folded into a zigzag shape (like the shape of an accordion). This shape creates a large surface for filtering air. Air must be passed through the filter for it to be purified.

In the purification chamber, a 12V DC Fan is positioned on top that draws air into the Air Filter. The fan aids in the creation of a pressure difference between the interior and outside of the purification chamber. Due to the low air pressure inside the chamber, dust particles are drawn in via the fan and are adsorbed on the microscopic layers of filter's wall. Finally, the fan releases filtered air progressively into the environment.

V. BLOCK DIAGRAM AND CIRCUIT CONNECTION

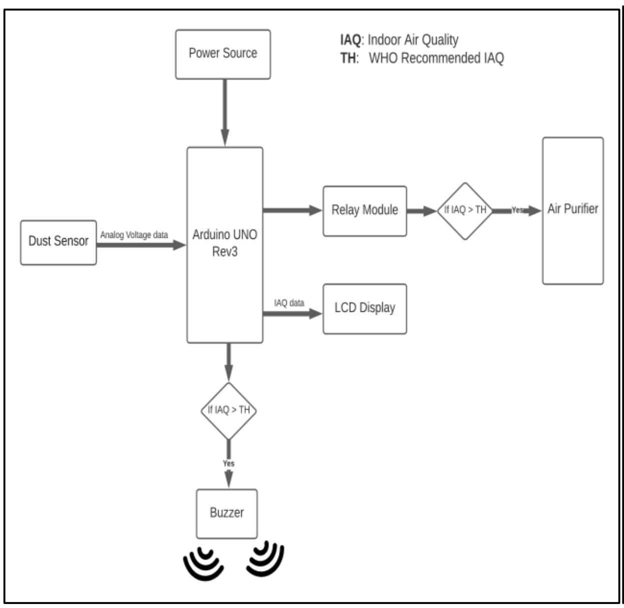

Fig. 5 Block diagram of the system

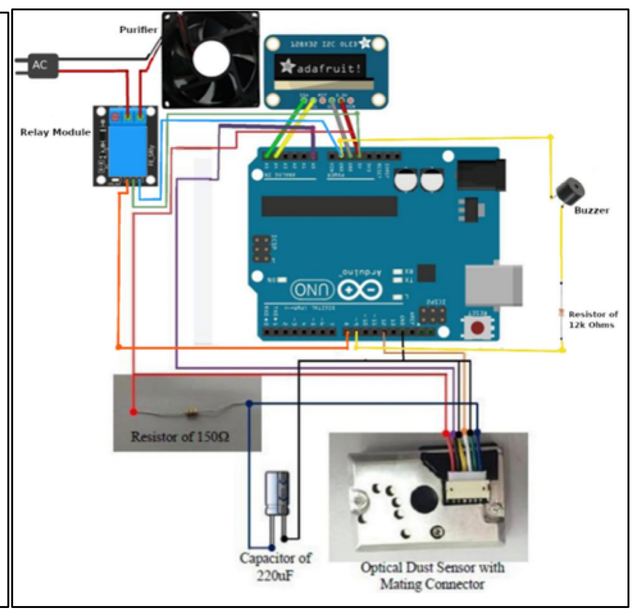

Fig. 6 Circuit connection of the system

VI. RESULTS AND DISCUSSION

The device was used in several sites throughout Kathmandu The purifier immediately started running at locations with evident air pollution (enough to be seen by naked eyes). Furthermore, the result can be seen as a digital dust density value (Fig. 7), a graph of dust density vs. Time (Fig. 8), or an analog meter (Fig. 9). It can be viewed in display screens like: Thin Film Transistor (TFT) LCD, White OLED. Data can also be received in electronic devices by connecting with Arduino.

The numbers we got were quite close to the seasonal averages, which are determined with the use of sophisticated sensors and computers. From the experiments conducted, we were able to substantiate the poor indoor air quality that prevailed in our houses too.

To further test the effectiveness of the purifying mechanism, we recorded the air quality of a room and then discharged aerosols and cement dust into the room. The automated air purifier kicked in as soon as PM was placed in the room. After about 54 minutes, the air quality in a 7*12*10 cubic ft. room reached healthy levels.

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The table below shows the Air Quality Index(AQI) of the various sites in Kathmandu.

TABLE I
Data Collected At Various Sites in Kathmandu (City)

Location	Air Quality Index ($\mu g/m^3$)
Pulchowk Campus, Institute of Engineering, Kathmandu, Nepal	61.5
Maitighar, Kathmandu, Nepal	179
Trintiy International College, Dillibazaar, Kathmandu, Nepal	63
Sundhara, Kathmandu, Nepal	143
Ratnapark, Kathmandu, Nepal	151
Royal Nepal Airlines, Kathmandu, Nepal	175

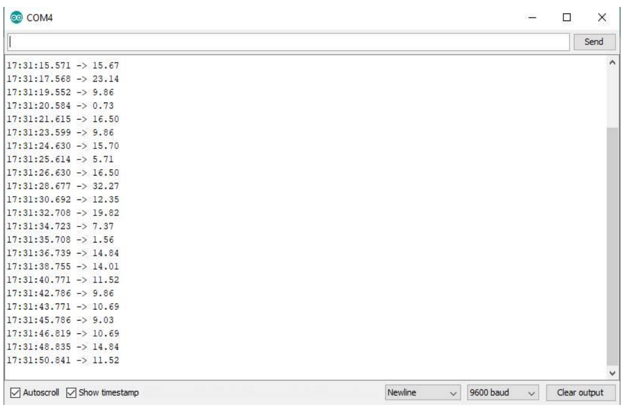

Fig. 7 Digital value of AQI as detected by sensor (displayed with time-stamp)

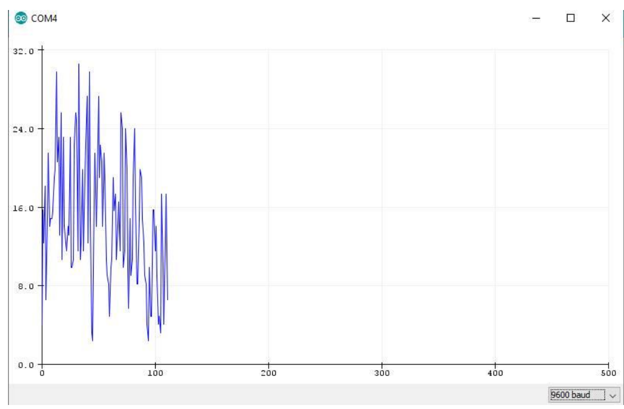

Fig. 8 Graph of pm-concentration versus time

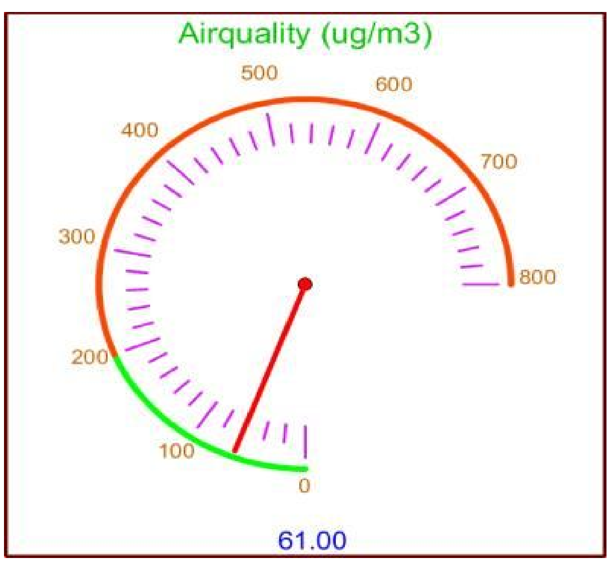

Fig. 9 IAQ displayed using Analog-meter in Arduino IDE

VII. CONCLUSION AND FUTURE PROSPECTS

Using Arduino UNO, Optical Dust Sensor, Air Filter, and other components, we created, economically, a Air Pollution Monitoring and Purification system. Using the Sharp Dust Sensor GP2Y1010AU0F, our project can efficiently detect exceeding the threshold of Indoor Air Pollution and warn the user by alerting, recording, and displaying pollution data. It also filters the air when pollution level reaches unhealthy level. Thus, our project will show to be a crucial necessity for both households and low air quality work environments.

Because we used low-cost materials, we may upgrade the project and improve even further. We can employ far more efficient air filters like: HEPA Filter which can theoretically remove at least 99.97% of dust, pollen, mold, and bacteria and Activated Carbon filter to remove volatile organic gases[6].We also can improve data accuracy by applying mathematical models and other more precise sensors. AI learning algorithms can be implemented in the micro-controller to self-predict the possibility of unhealthy Indoor air pollution and start the purification process accordingly. The data can be accessed via the display screen and SD Card for additional research. To filter the air and reduce potential health hazards, this system can be used in any room, office, or other indoor area.

VIII. NOMENCLATURE

PM	Particulate Matter
IAQ	Indoor Air Quality
IoT	Internet of Things
WHO	World Health Organization
HEPA	High Efficiency Particulate Air (filter)
IDE	Integrated development environment
LED	Light Emitting Diode
PD	Photo Diode
OLED	Organic Light-Emitting Diode
LCD	Liquid Crystal Display
DC	Direct Current
AQI	Air Quality Index
AI	Artificial Intelligence
SD	Secure Digital

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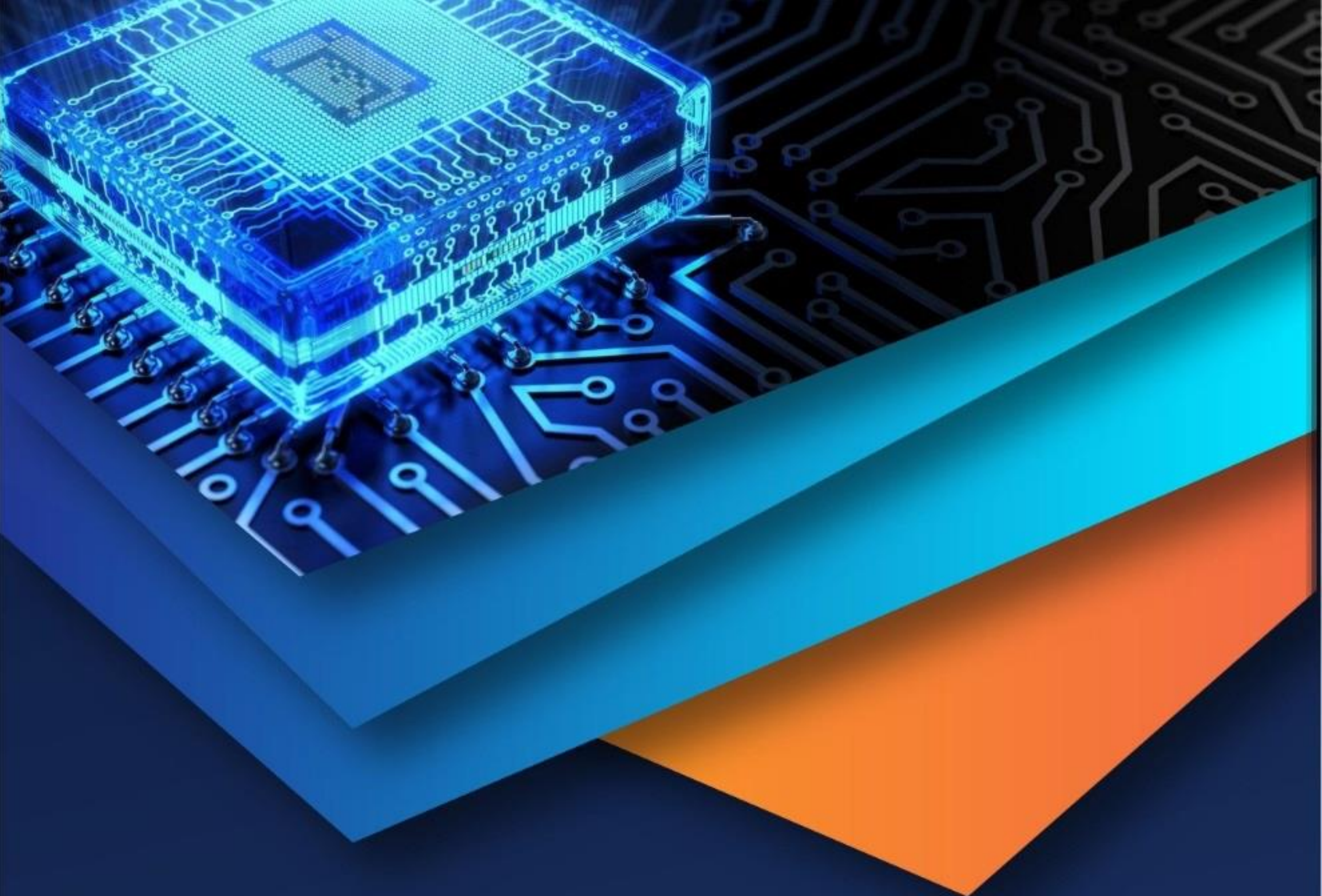

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