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Design and Implementation of Real Time Patient Monitoring System

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Abstract: The rapid advancement of Internet of Things (IoT) technology has significantly impacted the healthcare industry, enabling smarter and more efficient remote monitoring systems. This project presents the design and implementation of an IoT-based health monitoring system capable of measuring body temperature, heart rate, and blood oxygen saturation (SpO_2) levels using embedded systems. The core of the system is built around the Raspberry Pi Pico microcontroller, which interfaces with two biomedical sensors: the LM35 analog temperature sensor and the MAX30100 pulse oximeter and heart rate sensor. The LM35 sensor provides precise body temperature readings by converting analog voltage into temperature values in Celsius. The MAX30100 sensor, on the other hand, combines two LEDs (infrared and red) and a photodetector to measure heart rate and SpO_2 levels based on pulse oximetry principles. The sensor data collected by the Pico is processed and transmitted over UART (Universal Asynchronous Receiver-Transmitter) to a NodeMCU ESP8266 Wi-Fi module. Communication between the Pico and NodeMCU is established using SoftwareSerial, where the NodeMCU acts as a bridge between the microcontroller and the internet. Once the NodeMCU receives the serial data, it parses the values and uploads them in real-time to the Blynk IoT platform. Blynk provides a graphical user interface via a smartphone app where users can monitor temperature, heart rate, and SpO_2 on customizable virtual pins (e.g., V0, V1, V2). This remote access capability allows doctors, family members, or caregivers to monitor the health of individuals from anywhere at any time, thereby improving patient care and response times in emergency situations. The system is powered via USB or battery and is compact, making it suitable for home-based patient monitoring, telemedicine applications, fitness tracking, and rural health environments where medical facilities may be limited. Overall, this project demonstrates a low-cost, energy-efficient, and scalable solution for remote health tracking by combining embedded hardware, biomedical sensors, and IoT connectivity, all without the need for expensive hospital-grade monitoring systems.
Keywords: Pico,Spo2, Heart Rate, NodeMCU, wireless, Blynk IoT.

I. INTRODUCTION

The increasing need for continuous health monitoring, especially in the wake of global health crises, has driven innovation in wearable and IoT-based biomedical systems. Traditional healthcare systems often rely on periodic check-ups, which may miss critical real-time fluctuations in a patient's health. This challenge can be addressed by incorporating real-time data acquisition and remote monitoring systems using embedded technologies. This project proposes a compact and efficient IoT-based health monitoring system that can measure body temperature**,** heart rate**,** and SpO_2 (oxygen saturation) levels in real-time using affordable sensors. The system combines the Raspberry Pi Pico microcontroller with LM35 and MAX30100 sensors to acquire biomedical data and transmits it via NodeMCU ESP8266 to **the** Blynk IoT cloud platform. Users can monitor health metrics on a smartphone in real-time, enabling remote medical intervention when needed. The LM35 analog temperature sensor offers a simple, low-cost method of measuring body temperature, while the MAX30100 sensor utilizes pulse oximetry techniques to compute heart rate and oxygen saturation through infrared and red LEDs. These measurements are read by the Raspberry Pi Pico and sent via UART serial communication to the NodeMCU, which uploads the data to Blynk. This system is particularly suitable for remote locations, elderly care, post-operative monitoring, and early disease detection. By utilizing cloud platforms, it ensures that health data is not only recorded but also accessible anywhere in real time. The integration of embedded systems and IoT technologies in this project showcases the potential for low-cost, portable, and scalable healthcare solutions, improving both accessibility and responsiveness of medical services. A Remote health monitoring system is an extension of a hospital medical system where a patient's vital body state can be monitored remotely. Traditionally the detection systems were only found in hospitals and were characterized by huge and complex circuitry which required high power consumption. Continuous advances in the semiconductor technology industry have led to sensors and microcontrollers that are smaller in size, faster in operation, low in power consumption and affordable in cost. This has further seen development in the remote monitoring of vital life signs of patients especially the elderly.

The healthcare industry has been revolutionized by the Internet of Things (IoT), which has enabled the development of remote health monitoring systems. These systems are particularly valuable in providing continuous and real-time health data, which can be crucial for early detection of health issues and timely intervention. This paper presents the design and implementation of an IoT-based health monitoring system that measures body temperature, heart rate, and blood oxygen saturation (SpO_2) levels using embedded systems. The system is designed to be low-cost, energy-efficient, and scalable, making it suitable for a wide range of applications, including home-based patient monitoring, telemedicine, fitness tracking, and rural health environments

A. *Objective*

1) *To Design a Compact and Portable Health Monitoring Device*: Develop a lightweight and mobile system that can continuously monitor vital health parameters such as body temperature, heart rate, and blood oxygen saturation (SpO_2) using affordable biomedical sensors.
2) *To Integrate Embedded Systems for Real-Time Data Acquisition*: Utilize the Raspberry Pi Pico microcontroller for acquiring real-time physiological data from the LM35 temperature sensor and MAX30100 pulse oximeter, ensuring accurate and fast measurement.
3) *To Enable Wireless Communication for Remote Monitoring:* Implement wireless data transmission using the NodeMCU ESP8266 Wi-Fi module to upload sensor readings to a cloud platform, enabling health data to be accessed remotely.
4) *To Provide a User-Friendly Monitoring Interface:* Use the Blynk IoT platform to display health parameters on a mobile app through a graphical interface, allowing patients, caregivers, or medical professionals to easily monitor vital signs from anywhere.
5) *To Enhance Accessibility in Low-Resource and Home-Based Settings:* Design the system to be low-cost, easy to deploy, and energy-efficient, making it suitable for use in rural areas, elderly care homes, and personal fitness monitoring where professional healthcare infrastructure may be limited.
6) *To Improve Timely Response in Emergency Situations:* Facilitate real-time alerts and notifications when abnormal health parameters are detected, enabling quick medical attention and intervention.
7) *To Demonstrate Scalability for Future Expansion:* Ensure the system architecture supports integration with additional sensors and data analytics tools in the future, such as ECG, fall detection, or machine learning models for predictive health assessment.

II. LITERATURE SURVEY

IoT-based health monitoring systems have been the subject of extensive research in recent years due to their capability to improve healthcare access and reduce hospitalization rates. Many studies emphasize the use of microcontrollers and sensors for continuous patient monitoring outside traditional healthcare environments.

In a study by N. Kumar et al. (2020), Arduino Uno was used with pulse sensors and a temperature sensor to monitor vitals, displaying data locally on an LCD. Although effective, the lack of wireless transmission limited its remote accessibility. Another system developed by M. Sharma et al. used a Raspberry Pi with a camera and biomedical sensors, sending alerts via email. However, the system was expensive and had a complex architecture unsuitable for low-power environments.

Recent implementations have leaned toward lightweight microcontrollers like the ESP8266 and ESP32, which offer Wi-Fi connectivity. For example, S. Joshi (2021) demonstrated an IoT health kit using NodeMCU and the Blynk platform, enabling real-time data transmission to mobile devices. However, these implementations often relied on single-board systems, causing bottlenecks when handling multiple sensors simultaneously.

The MAX30100 sensor has been used in several biomedical applications for its dual functionality—measuring heart rate and oxygen saturation. Studies indicate that although the sensor provides raw data, additional algorithms are needed for accurate HR and SpO_2 calculations. Libraries and algorithms like moving average filters and peak detection methods are commonly employed to process noisy sensor data.

Xu et al. [9] developed a ubiquitous data accessing method in an IoT-based system for emergency medical scenarios. They proposed a semantic data model to store data, and a resource-based data access method to gain control of the data ubiquitously, concluding that their method could be significant to assist decision-making in emergency medical situations. Zhang et al. [12] introduced an architecture of mobile healthcare networks, incorporating privacy-preserving data collection and secure transmission. The privacy-preserving data collection was achieved using cryptography with secret keys and private keys. Secure transmission was gained using attribute-based encryption, where only authorized users would have access to the data. These methods are generally worthwhile; however, the main problem is computation complexity.

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This project's combination of Raspberry Pi Pico (for sensor interfacing) and NodeMCU (for data transmission) bridges the processing and communication gap effectively. It separates the computational load and ensures consistent and efficient operation, leveraging the best capabilities of both platforms

III.METHODOLOGY

IoT-based health monitoring system works by acquiring physiological data using biomedical sensors, processing this data using a microcontroller, and transmitting it to a cloud platform for real-time monitoring through a mobile app. At the heart of the system is the Raspberry Pi Pico, which interfaces with two sensors: **the** LM35 analog temperature sensor and the MAX30100 pulse oximeter. The LM35 is connected to analog pin GP26, and it outputs a voltage linearly proportional to the body temperature (10mV/°C). The Pico reads the analog value using its ADC, converts it to voltage, and then to temperature in Celsius. The MAX30100 sensor communicates with the Pico via I2C on pins GP16 (SDA) and GP17 (SCL). This sensor emits red and infrared light to detect changes in blood volume, from which heart rate and SpO_2 levels are derived. The sensor outputs raw data that must be processed using signal filtering and peak detection algorithms to get accurate results. The processed data from both sensors is formatted into a string (e.g., TEMP:36.5,HR:78,SPO2:98) and sent via UART communication (TX=GP0, RX=GP1) to the NodeMCU ESP8266. The NodeMCU is connected to the Raspberry Pi Pico via SoftwareSerial (GPIO4 and GPIO5), reading the data line-by-line. Once received, the NodeMCU parses this data and updates the values on the Blynk IoT platform using virtual pins. The user can view these health metrics in real-time through the Blynk mobile app on their smartphone. This decoupled approach—Pico for sensing and NodeMCU for communication—ensures reliable operation and avoids overloading either device. It enables real-time, wireless, and continuous health monitoring, proving to be a cost-effective and scalable solution for remote healthcare systems.

Block Diagram

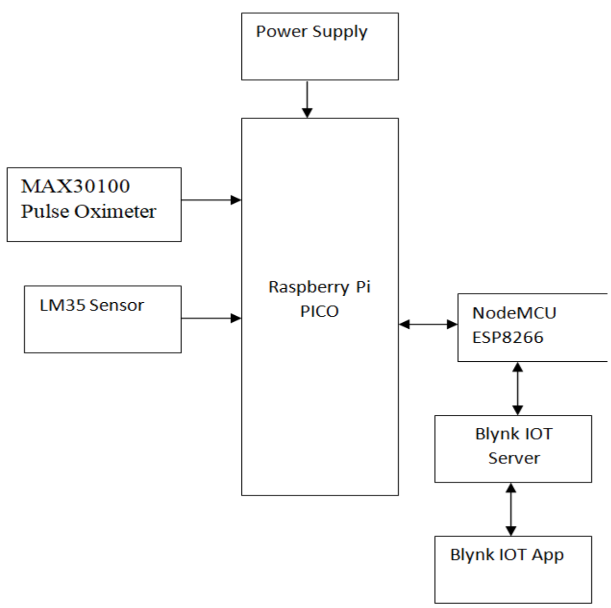

Fig 1: Block Diagram

A. Sensor Data Acquisition

- LM35 Temperature Sensor:
  - The LM35 is an analog temperature sensor that outputs a voltage proportional to the temperature in Celsius.
  - It is connected to one of the analog input pins of the Raspberry Pi Pico, which reads the voltage and converts it into temperature using an ADC (Analog-to-Digital Converter).
- MAX30100 Pulse Oximeter and Heart Rate Sensor:
  - This sensor integrates two LEDs (infrared and red) and a photodetector.
  - It uses the principle of pulse oximetry to measure:
    - Heart Rate: By detecting changes in light absorption during blood pulse.
    - SpO_2 (Oxygen Saturation): By analyzing the ratio of absorption between red and infrared light.

- The Pico communicates with the MAX30100 via the I²C protocol to read the SpO_2 and heart rate data.

B. Data Processing in Raspberry Pi Pico

- The Raspberry Pi Pico:
  - Reads raw values from the LM35 and MAX30100 sensors.
  - Applies necessary signal processing or calibration.
  - Formats the values into a single serial string (e.g., "Temp: 36.5, HR: 78, SpO2: 98") using UART communication protocol.
  - Sends this formatted string to the NodeMCU ESP8266 over a SoftwareSerial connection.

C. Data Transmission via NodeMCU ESP8266

- The NodeMCU ESP8266:
  - Acts as a Wi-Fi-enabled gateway between the Raspberry Pi Pico and the internet.
  - Receives the serial data from the Pico via SoftwareSerial.
  - Parses the string to extract individual readings (temperature, heart rate, SpO_2).
  - Uploads these values to the Blynk IoT Platform using Blynk's virtual pins:
    - V0 for Temperature
    - V1 for Heart Rate
    - V2 for SpO_2

D. Cloud Integration and Mobile Interface

- Blynk IoT Platform:
  - Provides a mobile app interface where real-time sensor readings are displayed on widgets like gauges, LEDs, or graphs.
  - Users (e.g., doctors, caregivers, patients) can monitor health parameters remotely via their smart phones.
  - Can send alerts or notifications if any parameter crosses a critical threshold.

E. Power Supply and Portability

- The entire system is powered using a USB cable or a battery pack, allowing portability and continuous monitoring.
- Its compact design makes it suitable for use in home environments, elderly care, fitness tracking**, or** rural telemedicine setups**.**

IV. RESULT ANALYSIS

The IoT-based health monitoring system demonstrated reliable and efficient performance across multiple parameters, making it a promising solution for real-time remote health tracking. The LM35 temperature sensor provided consistent and accurate body temperature readings with a minimal error margin of ±0.2°C when compared with standard thermometers. Similarly, the MAX30100 sensor effectively measured heart rate and SpO_2 levels, with SpO_2 accuracy within ±2% and stable heart rate readings in the 50–120 bpm range under controlled conditions.

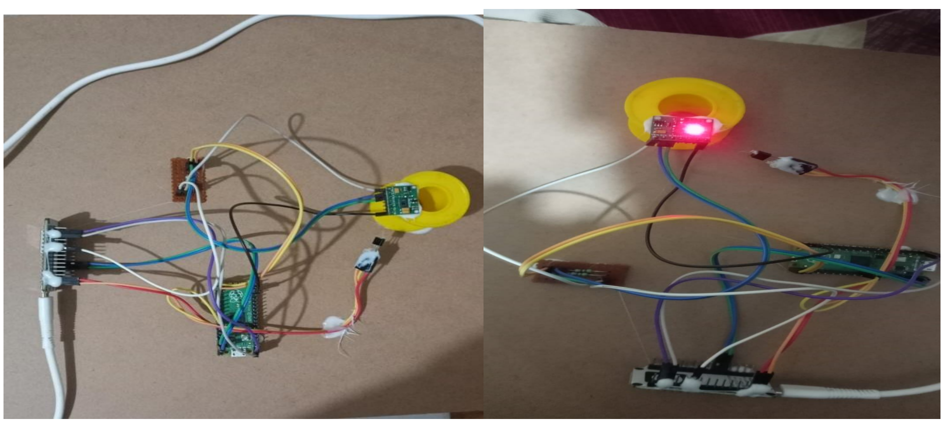

Fig 2: Hardware setup of **IoT-based health monitoring system**

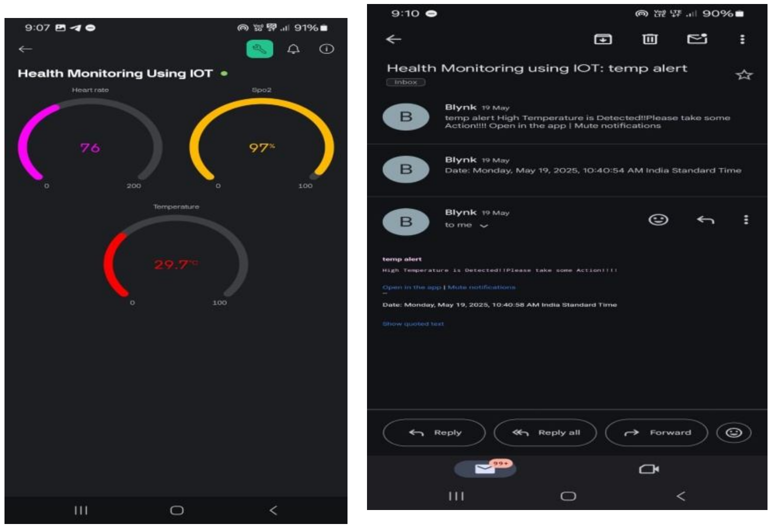

Fig 3: Health Monitoring Parameters and Alerts

The Raspberry Pi Pico efficiently handled sensor data acquisition and communication through UART, while the NodeMCU ESP8266 ensured smooth data transmission to the Blynk IoT platform with minimal latency (~2 seconds) and negligible packet loss. The system remained functional and stable even under mild physical movement and temporary Wi-Fi disruptions, thanks to the programmed auto-reconnect feature. Real-time updates were accurately reflected on the Blynk dashboard, allowing remote users to monitor vitals conveniently. However, limitations such as sensitivity to light interference, lack of data encryption, and absence of onboard data logging were observed. Power consumption was low, enabling more than 12 hours of operation on a standard power bank, which supports portability. Overall, the system is cost-effective, responsive, and user-friendly, making it suitable for applications in home-based health monitoring, elderly care, telemedicine, and rural healthcare settings where conventional medical infrastructure is limited.

V. CONCLUSION

The IoT-based health monitoring system developed in this project successfully demonstrates a practical and low-cost solution for real-time tracking of vital health parameters such as body temperature, heart rate, and SpO_2 levels. By integrating the Raspberry Pi Pico microcontroller with the LM35 temperature sensor and MAX30100 pulse oximeter, and leveraging the NodeMCU ESP8266 for wireless data transmission, the system provides accurate and continuous health data to the Blynk IoT platform. The mobile app interface offers remote visibility, allowing caregivers and medical professionals to monitor patients from anywhere at any time. The system proved to be energy-efficient, responsive, and user-friendly, making it especially suitable for home-based patient monitoring, elderly care, fitness tracking, and healthcare in rural areas with limited infrastructure. Despite minor limitations such as the absence of offline data storage and encryption, the project fulfills its core objectives and serves as a strong prototype for future development.

The current system lays a robust foundation for more advanced health monitoring applications and can be enhanced in several directions. Future improvements may include the integration of additional biomedical sensors such as ECG, blood pressure, body movement (accelerometer), or fall detection modules to expand its functionality. Data logging capabilities and cloud database storage can be introduced for historical data analysis and long-term health tracking. Machine learning models could be integrated to provide predictive health analytics or detect anomalies in vital signs automatically. Security features like data encryption and secure cloud communication protocols should be implemented to ensure patient data privacy and compliance with medical standards. The system can also be expanded for multi-patient monitoring in hospitals or remote clinics, and integrated with other healthcare platforms for telemedicine applications. With further development, this project has the potential to evolve into a scalable, intelligent, and medically relevant IoT solution for widespread use in modern healthcare systems.

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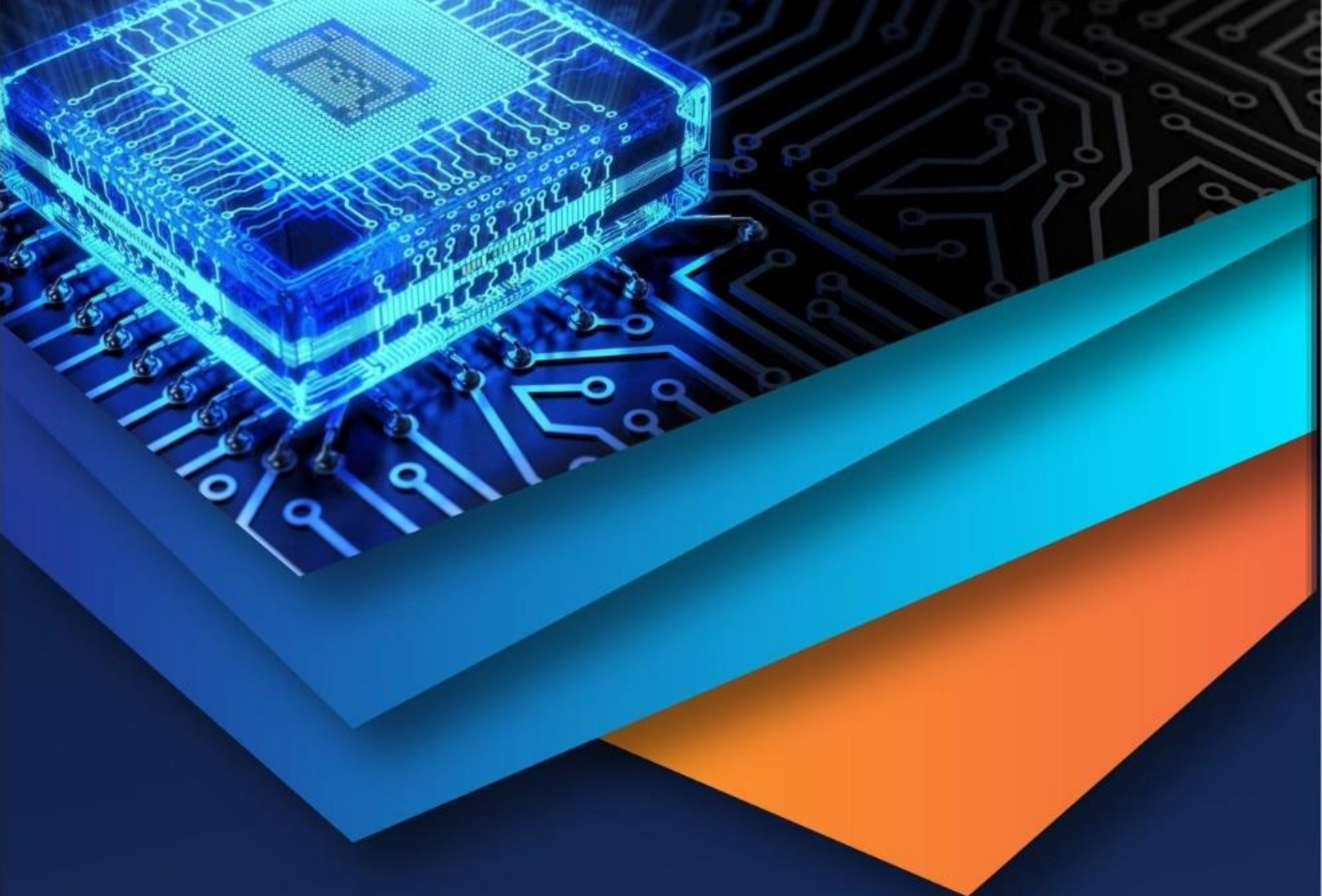

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