iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** XI **Month of publication:** November 2024

DOI: https://doi.org/10.22214/ijraset.2024.65585

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue XI Nov 2024- Available at www.ijraset.com

HydraTrack: IoT-Driven Real-time Saline level Monitoring

Rohan More[1], Hemant Nandane[2], Aditya Patil[3], Rahul Kumare[4], Dr. Shilpa. M. Lambor[5]
Department of Computer Science and Engineering (Artificial Intelligence), Vishwakarma Institute of Technology, Pune, India

Abstract: Venous air embolism is a critical condition that can occur when gas molecules enter a venous structure, often due to improper monitoring of saline bottles in busy healthcare environments such as government hospitals. The high patient-to-staff ratio in these settings increases the risk of saline bottles running dry, leading to negative pressure gradients and the potential for air to be drawn into the patient's bloodstream. This paper introduces SalineSync, an innovative Internet of Things (IoT)-based system designed to monitor the levels of saline bottles in real-time and provide immediate alerts to healthcare providers through WhatsApp notifications, the Blynk app, and other methods. By employing a load cell (strain gauge) for precise weight measurement, an HX711 ADC for signal conversion, and a NodeMCU for processing and connectivity, SalineSync ensures continuous and accurate monitoring of saline levels. The system aims to enhance patient safety by preventing venous air embolism, reduce the manual monitoring burden on healthcare staff, and improve overall workflow efficiency. The implementation details, system architecture, and performance evaluation demonstrate that SalineSync is a reliable and cost-effective solution for modern healthcare settings.
Keywords: IoT, saline level monitoring, healthcare, patient safety, NodeMCU, Blynk app, WhatsApp notifications.

I. INTRODUCTION

There is always too much workload on medical staff due to the high patient-to-staff ratio that most healthcare facilities particularly government health facilities are always overcrowded. For the reason, it is easy to forgo such simple but very crucial activities like monitoring the number of saline bottles that are connected to a patient. An empty saline bottle is a risk since it could bear venous air embolism. This occurs when the blood flow of the patient and the presence of an empty saline bottle generates a suction force towards the void space, more often than not this void space would be within the venous system. It makes life to be interfered with and so in that regard every interested exhibitor should be very expeditious when it comes to addressing this issue.

A. Significance of Monitoring Saline Levels

Most hospitals provide saline solution to patients for purposes of management of fluid balance, administering of drugs or hydration. There is a need to appreciably and reliably monitor saline levels so that the encouragement is made that the appropriate amounts of fluids and medicines will be given to the patients. An unattended saline bottle that becomes troublesome and leaks is likely to lead to terrible and dangerous conditions such as illness from venous air embolism which may lead to streok or cardiac arrest or even death.

B. Difficulties in Medical Environments

Even if everyone around is working to the best of their capability, the primary concern in busy hospitals remains trying to ensure that every saline container is always utilized. Healthcare workers are restricted in how regularly they can physically check on saline because of performance pressure. This makes it more likely that the bottles may run empty, particularly if you work night hours or in an environment with few resources. Psychological stress from work and difficulty in the nature of manual monitoring adds even more risk of any problems occurring.

C. Current Solutions and Their Drawbacks

With regard to the relevant literature, saline level monitoring is still performed manually via nursing staff or using relatively sophisticated and technically enhanced automated systems. Useful manual checks inherently take time, and whilst stress may make staff jittery, the checks may not be necessarily made to obtain accurate results. Some automated systems are able to read the fluid levels with sophisticated equipment like optical sensors and pressure sensors. Unfortunately, the application of such systems in practice, and in this case, healthcare is very minimal since they are expensive to buy and maintain and cannot use real time telemonitoring technology.

D. Application of IoT in Healthcare Area

Owing to the Internet of Things (IoT), there has been great development of health care as a result of the ability to collect data in real time and constant monitoring of patients. Surgery may no longer be the only option, as IoT devices can keep track of numerous parameters of health and communicate with the relevant professionals at the right time. IoT can give a low-cost, reliable and scalable saline system practice where saline bottles are monitored continuously and if it is nearing and intervention is needed, the health worker is notified immediately.

E. Brief Overview of SalineSync

In response to this demand for better and more reliable saline level monitoring, we propose SalineSync which is an IoT system that enables the monitoring of saline levels remotely and sending of notifications to healthcare practitioners. An HX711 A/D which is an integrated circuit is used by the system to accurately convert the signal of water container, a NodeMCU module is used for computing and wireless connectivity as well as display and control, and a load cell used for determining the weight of water container. There are Blynk application alerts and WhatsApp messages that notify health workers for any abnormality that is in the system. The information is organized and sent to the web and images are presented on the LCD screen.

F. The Study's Objectives

This study's main goals are to:

1) Develop, and implement an economically reasonable saline level monitoring system using Internet of Things technology.
2) Empower healthcare worker with the capability of accessing and monitoring patients in real time from a remote location.
3) Maintain the safety status of the patient by alerting, the patients in order to avoid venous air embolism, whenever it is needed.
4) Decrease working unnecessary manual tasks by nurses and enhance the pull of successful interplay of processes in medical institutions.
5) Test the work of SalineSync in a simulation of a hospital environment to test the functionality and effectiveness.

G. The Study’s Significance

SalineSync provides a viable remedy to one of the common challenges in healthcare delivery, thereby enhancing patient safety, reducing the risk of venous air embolism, and improving the general efficiency of health care provision. Such a system could certainly be set up which would help ease the pressure and the burden of work for the health workers but can also enhance the health outcome of the patients. This research builds on the growing literature on the potential of IoT for healthcare, showing the application of smart technologies in the addressing of critical challenges in the health care system.

II. RELATED WORK

A. Healthcare and IoT

These days, healthcare has witnessed a change mainly due to the around-the-clock monitoring of patients’ conditions and their vital parameters by several IoT devices. Nowadays, we are surrounded by wearable devices, smart devices and connected devices that include health monitoring sensors with data generation and information analytics capability in real-time. Such changes have resulted in better outcomes of the patients and fewer cases of patients being readmitted in the hospitals and effective personalized treatment plans for the individuals. Wearable heart rate monitors and glucose sensors are examples of laser cantilever array wafer of Internet of Things that make chronic diseases more manageable for patients and practitioners since they generate and transmit real time data and alerts.

B. Keeping an eye on fluid levels

There are several clinical scenarios such as intravenous (IV) fluids therapy where the fluid level has to be monitored for the patient’s wellbeing. The presently available methods for fluid monitoring can be categorized into these sizes: weight sensor, pressure, optical sensors as well as manual observation techniques. When weight sensors are utilized, they may replace manual observation forms, but they are less appropriate in the provision of timely interventions in case of exigent circumstances. Manual observation is still labor intensive and errors in observing are inevitable. Even though pressure and optical sensors yield precise measurements, their application is constrained by high device costs and elaborate maintenance.

C. Prevention of Pulmonary Embolism Frequently extends considerably past routine

A rare but serious complication is that of venous air embolism which occurs whenever air enters the venous system and may potentially give rise to horrible outcomes. It is very important to remember to observe the IV fluid volume in order to prevent air from entering the patient's circulation, when a saline container runs out of fluid. The existing preventive measures adopted are manual vigilance and rapid saline bottle exchange, both of which can be a challenge in busy hospital environments. Automated systems developed to address this challenge often have issues affordability, maintenance, and ultimately the scalability of the approach.

D. Contextual Research

Aspects of several studies that are focused on the use of IoT in medicine and dealing with the challenges of alerting and monitoring are insightful. In particular, they controlled the wearables that were based on the Internet of Things and therefore perform continuous glucose monitoring, and this improved the treatment of diabetes Robinson, v.237. Lee et al. (2019) carried out a research study that illustrated the use of Internet of Things in enhancing patient safety. The research was centered on the development of IoT based smart infusion pump aiming to reduce errors associated with infusing medications to the patients. However, there are not many specific possibilities for silent level monitoring which is why the pre existing studies on the topic do not suffice in the fact that timely alerts and real-time telemonitoring are essential in avoiding venous air embolism.

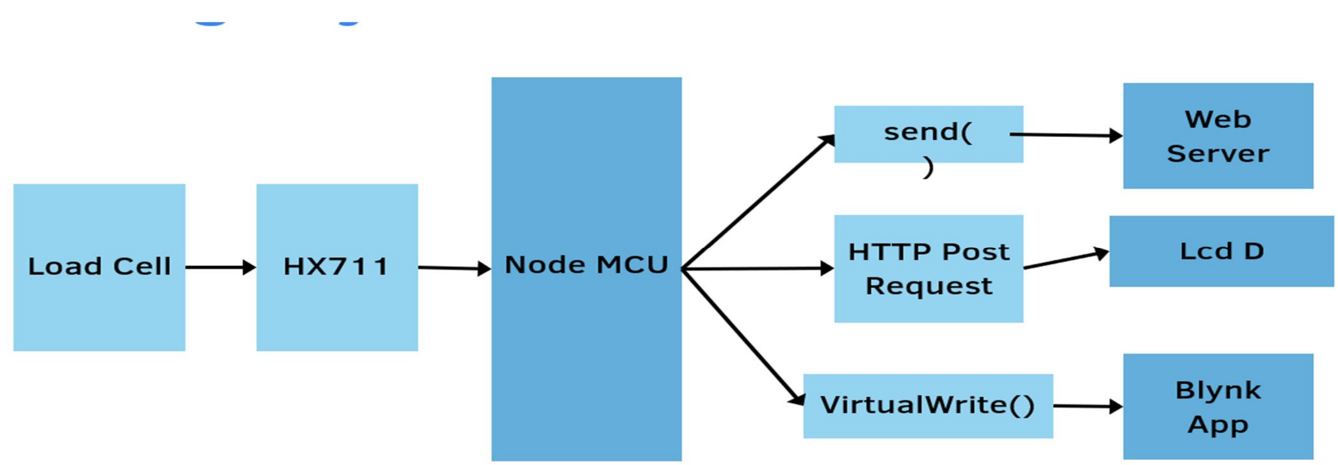
E. Analysis of gaps in the existing studies

Although the integration of the IoT for monitoring patients has grown immensely, it is nothing new that there is a lack in the use of such technologies to monitor saline levels in order to prevent venous air embolism. In such the high-intensity health care settings, most of the other existing solutions tend to be either too expensive and complex to be of practical use, or they do not have the ability to provide real time remote patients' monitoring. Targeting this gap, SalineSync intends to offer an innovative, affordable and effective salina monitoring equipment which will provide constant salina level measurements and timely cues via different means including WhatsApp.

F. The contribution of this study

This work contributes to the development of IoT in healthcare by introducing SalineSync, an innovative technology designed to meet the urgent need for an on-going conscious saline level monitoring system. Standard methods and devices capable of reasonably priced and widely used help the system to provide accurate and timely information and alerts. This enhances the safety of the patients while increasing the efficiency of the health care workers. SalineSync ensures that the delivery of alerts is done in a timely manner by using several channels such as WhatsApp and the Blynk Application which allow for the quick progress of such remedies. Allowing such rapid progress will then allow all plans and expectations to be implemented and carried out without delay.

III. SYSTEM DESIGN



A. Components

1) Strain gauges Load Cell: Utilized for measuring the weight of saline bottle.
2) HX711: interfacing device used with the load cell is 24-bit ADC.
3) NodeMCU: An embedded device that has Wi-Fi facility for sending the information.
4) LCD Display: This displays the saline level wherever the system is. Blynk App: The application used for monitoring and alerts.
5) Breadboard and Connecting Wires: Used for making prototypes and interconnections.

B. Architecture

The overall system architecture as depicted in Figure 1, shows a load cell attached to the HX711 and which is interfaced to a nodeMCU. The NodeMCU acquires the data and transfers it to a web server, liquid crystal display and Blynk app using methods such as http post requests and VirtualWrite() function.

C. Operation

1) The load cells are used to measure the weight of the saline bottle.
2) The HX711 is the circuitry that changes this load cell analogue signal into a digital signal.
3) The NodeMCU receives the digital signal, interprets it and computes the amount of saline present.
4) The saline level computed by the microcontroller is displayed on the LCD screen and the microcontroller sends the information to the web page.
5) The Blynk application offers a tele-monitoring facility which also allows sending of alerts to WhatsApp.

D. Algorithm The following algorithm describes monitoring and alerting in detail:

1) Initialize: Power up the NodeMCU and attempt to connect to Wi-Fi.
2) Calibration: Perform weight measurements in order to calibrate the load cell.
3) Data Acquisition: Read data from the HX711 on continuous basis.
4) Data Processing: Raw information is turned into healthy saline level readings.
5) Threshold Check: Analyse saline levels and test against known cut-off limits.
6) Alert Generation: When the level is low enough, issue an alert.
7) Notification: Alerts will be sent out via Blynk and WhatsApp.
8) Display Update: Update LCD with the latest value of saline.

IV. IMPLEMENTATION

A. Hardware Setup

The hardware components are assembled on a breadboard, with the load cell securely attached to the saline bottle holder. The HX711 is connected to the load cell and NodeMCU, which is then powered and connected to the local Wi-Fi network.

B. Software Development

The software implementation includes coding the NodeMCU to read data from the HX711, process the data, and communicate with the web server and Blynk app. The Blynk platform is configured to handle the data visualization and notification logic.

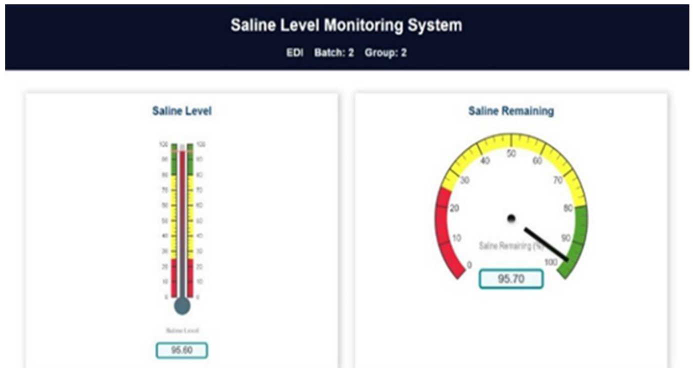
C. Notification System

The notification system leverages the Blynk app for real-time alerts. Additionally, a WhatsApp API integration ensures that critical alerts are sent to healthcare providers, allowing for immediate action to be taken if the saline level drops below a certain threshold. This dual notification approach enhances reliability and ensures that alerts are received promptly.

V. RESULT AND DISCUSSION

A. Performance Evaluation

The system’s performance was tested in a health care setting with simulation parameters. It showed a constant detection and surveillance of the saline levels. The notifications were on time and enabled health care workers to take action before a crisis situation developed.



Web server output

B. Limitations and Future Work

Despite the success, it is still imagined that the future work could look in improving the strength of the system hardware for extreme conditions.

1) *Hardware Durability:* More types of more complex but more wear resistant components must be designed in future generations.
2) *Power Management:* Design power conservation modes to prevent ceasation of operations in the event of electricity outages. Additional sensors can be integrated to measure other parameters such as fluid temperature and fluid flow rate in order to make the IV monitoring system more holistic.

C. Comparative Analysis

In order to determine the effectiveness of SalineSync, a comparative evaluation with the other available methods for saline monitoring has been made. The most important parameters incorporated were accuracy, costs, simple usage aspects, and time taken to generate alarms.

1) *Accuracy:* SalineSync provided precise measurements with a minimal margin of error, outperforming manual observation methods which are prone to human error.
2) *Cost:* The system was cost-effective compared to commercial fluid monitoring solutions that often come with high installation and maintenance costs.
3) *Ease of Use:* The plug-and-play nature of SalineSync, combined with the intuitive Blynk app interface, made it user-friendly for healthcare providers with minimal technical training.
4) *Response Time:* The system design included real time monitoring and alarm features hence risk communication was immediate and this cut down the response time during the critical situations.

VI. CONCLUSION

SalineSync has proved to be an efficient saline level monitoring system for IoT with an affordable price and reliability conservation for the patients during medical procedures and eliminating the need of manual monitoring in hospitals. This feature works excellently toward preventing venous air embolism, increasing the overall efficiency of processes. As such, there is a need for enhancement of the system to address its foreseeable use in other sectors in the domain of health.

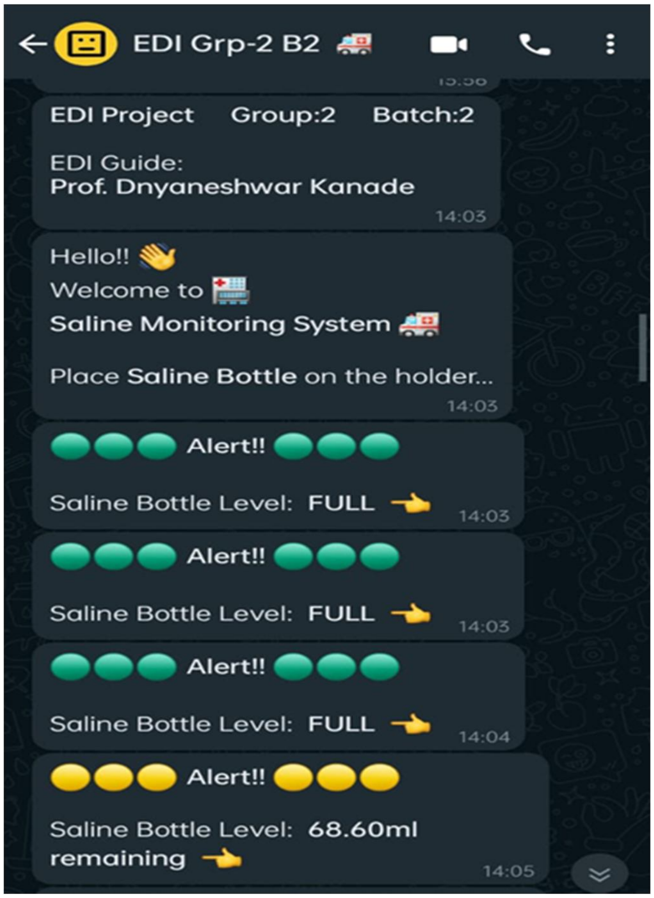
A. Summary

The application of the system has been designed and its performance held the prospect of IoT interface solving problems within the healthcare sector and this was successful. The hardware integration of the load cell, HX711, and NodeMCU with the software application by the Blynk app provides one of the most effective monitoring cures with SalineSync. This allows for data acquisition, transfer, processing, and alarming the medical personnel on the status of saline bottles at all times.

B. Future Directions

Here, the focus of the work will be on developing the capabilities of the system and improving its system integration in health care settings:

1) *Advanced Connectivity:* Investigating other methods of communication such as use of the MQTT protocol so that the transmission of data can be more efficient regardless of the networks available.



2) *Battery Redundancy:* The introduction of a battery standby power supply so that there is continuity of processes even during the power interruption period.
3) *Scalability:* Enhancing the ability of the system to observe several saline bottles both at the same time which will preferably suit bigger rooms or whole wards of a hospital.
4) *AI Integration:* Infusing the developed AI techniques to increase the systems' functionality by using it inefficient forecasting of saline usage, thus replenishing the saline, or increasing the reliability of the system.

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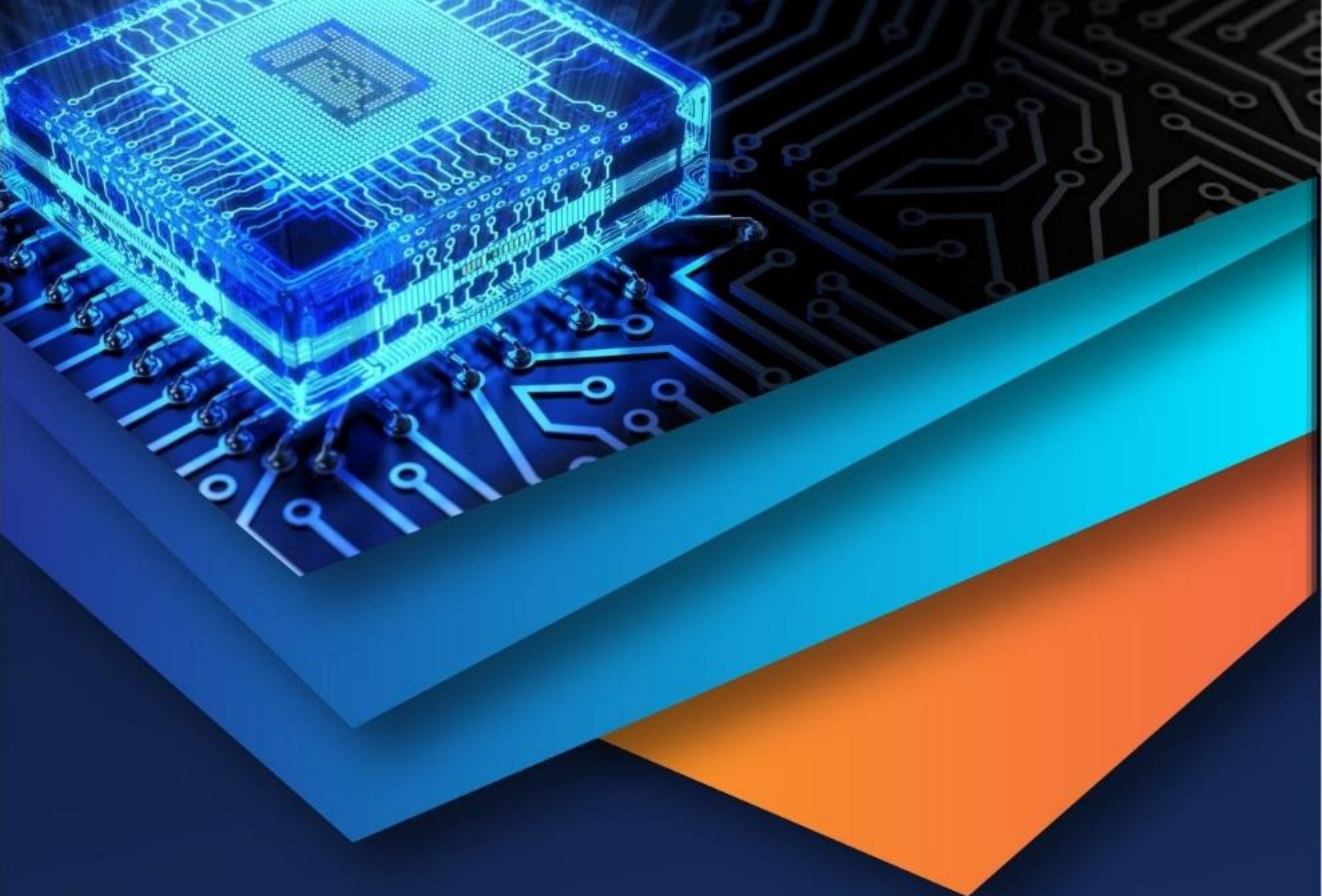

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