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Development of Low-Cost Portable Mastitis Screening Device

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***Abstract:** Mastitis is one of the most common and economically significant diseases affecting dairy cattle, leading to reduced milk yield, poor milk quality, and increased veterinary treatment costs. Early detection of mastitis is essential to prevent severe infection, minimize economic losses, and improve overall herd health management. Conventional diagnostic techniques such as the California Mastitis Test (CMT), somatic cell count analysis, and microbial culture require laboratory facilities, trained personnel, and considerable processing time, making them less suitable for routine on-farm monitoring.*

To address these limitations, this study proposes the development of a low-cost portable mastitis screening device capable of providing rapid and on-site detection using sensor-based monitoring and IoT technology. The system operates through a two-stage detection approach. Initially, the udder surface temperature is measured using a DS18B20 digital temperature sensor to identify abnormal thermal variations caused by inflammation. Subsequently, milk samples are analyzed using pH and electrical conductivity (EC) sensors to detect biochemical changes associated with mastitis infection. These sensor outputs are processed using an ESP32 microcontroller, while an ADS1115 analog-to-digital converter improves the accuracy of analog signal readings. The processed results are displayed on a LCD display and simultaneously transmitted to a web-based monitoring system through Wi-Fi connectivity for real-time remote observation.

The system incorporates calibration procedures and threshold-based algorithms to classify mastitis conditions into normal, moderate risk, and high-risk categories. Experimental testing demonstrated observable increases in udder temperature, milk pH, and electrical conductivity in suspected mastitis conditions, validating the effectiveness of the selected biological indicators. The developed prototype offers a reliable, affordable, and farmer-friendly solution for early mastitis detection and digital herd health monitoring. This technology has the potential to support preventive dairy management, reduce economic losses, and contribute to smart and sustainable dairy farming practices.

***Keywords:** Mastitis Detection, Dairy Cattle Health Monitoring, Electrical Conductivity Sensor, Milk pH Sensor, ESP32, IoT-Based Dairy Monitoring.*

I. INTRODUCTION

Dairy farming plays a vital role in global agriculture by providing milk and dairy products that contribute significantly to food security and rural livelihoods. Maintaining the health of dairy cattle is essential for ensuring consistent milk production and quality. Among the various diseases affecting dairy animals, mastitis is one of the most common and economically significant conditions. Mastitis is an inflammation of the mammary gland primarily caused by bacterial infection, leading to reduced milk yield, deterioration in milk quality, and increased veterinary treatment costs. Early detection of mastitis is therefore crucial to prevent severe infection, minimize economic losses, and maintain overall herd health.

Traditional mastitis detection methods include visual inspection, the California Mastitis Test (CMT), somatic cell count analysis (SCC), and microbial culture techniques. Although these methods provide reliable results, they often require laboratory facilities, specialized equipment, and trained personnel. In many dairy farms, particularly small and medium-scale operations, access to such facilities is limited. As a result, mastitis is often detected at later stages when symptoms become visible, leading to delayed treatment and increased damage to the udder.

Advances in sensor technology and embedded systems have created opportunities for developing portable diagnostic devices that assist farmers in monitoring animal health directly on the farm. Sensor-based detection systems measure biological indicators associated with mastitis, such as udder temperature, milk electrical conductivity, and milk pH. These parameters change significantly when infection occurs in the mammary gland. By monitoring these indicators, mastitis can be identified at an early stage without relying on laboratory analysis. Therefore, this study focuses on the development of a low-cost portable mastitis screening device that detects early signs of mastitis using temperature, pH, and electrical conductivity sensors integrated with a microcontroller-based monitoring system.

II. LITERATURE REVIEW

Mastitis is one of the most common diseases affecting dairy cattle, leading to significant economic losses due to reduced milk yield, poor milk quality, and increased treatment costs. Several studies have focused on identifying reliable indicators for early detection of mastitis. Zalewska et al. (2025) analyzed milk samples from Polish Holstein-Friesian cows and reported that subclinical mastitis significantly affects milk composition, clotting time, and curd firmness. Their findings showed that increased somatic cell count (SCC) due to infection negatively influences milk processing properties, emphasizing the need for early detection methods to maintain milk quality. Infrared thermography (IRT) has emerged as a promising non-invasive technique for detecting mastitis by monitoring udder surface temperature. Korelidou et al. (2024) and Gayathri (2024) demonstrated that inflammation in the udder causes localized temperature variations, which can be captured using thermal imaging systems. These studies confirmed that IRT enables early detection of mastitis before visible clinical symptoms appear. Similarly, Deeksha and Sindhu (2021) highlighted that thermography allows rapid on-field monitoring of udder health without the need for laboratory analysis, making it a practical tool for dairy farm management. Electrical conductivity (EC) of milk has also been widely studied as an indirect indicator of mastitis. Singh et al. (2023) reported that mastitis causes an increase in sodium and chloride ions in milk, resulting in higher electrical conductivity values. Earlier studies by Norberg and Hogeveen (2004) and Nielen (1992) also confirmed that EC measurements correlate strongly with somatic cell count and udder inflammation. These studies suggest that EC sensors can provide a rapid and cost-effective approach for monitoring milk quality and detecting mastitis at an early stage.

Milk pH has been investigated as another useful parameter for mastitis detection. Sharma et al. (2018) explained that mastitis causes changes in milk composition that increase its pH beyond the normal range. Similarly, Ndirangu et al. (2019) developed a simple pH-based pen-side test for detecting subclinical mastitis, demonstrating that pH measurement can serve as a rapid and low-cost screening method for field conditions.

Recent research has also explored the integration of multiple sensing techniques to improve detection accuracy. Rukmana et al. (2021) developed a mastitis detection system that combines electrical conductivity and pH sensors with a fuzzy inference algorithm to classify milk samples into healthy or infected categories. Zhang et al. (2023) further enhanced mastitis detection using thermal infrared imaging combined with deep learning algorithms, achieving high accuracy in identifying infected regions.

III. EXISTING SYSTEM

The existing mastitis detection systems used in dairy farms are mainly based on traditional diagnostic techniques and laboratory testing methods. These systems are commonly used to identify mastitis infection in dairy cows by analyzing milk samples and observing physical symptoms. Although these methods provide reliable results, they usually require laboratory facilities, trained personnel, and significant time for analysis. As a result, early detection of mastitis becomes difficult for farmers, particularly in small-scale dairy farms where advanced diagnostic equipment is not easily available.

A. Laboratory-Based Detection Methods

Traditional mastitis detection methods include somatic cell count (SCC), bacteriological culture, and the California Mastitis Test (CMT). These techniques are widely used to confirm the presence of mastitis by examining milk samples in laboratory conditions. While these methods provide accurate results, they require sample collection, chemical reagents, and skilled technicians. Additionally, the testing process may take several hours or even days, which delays early disease identification and treatment.

B. Conventional Monitoring Techniques

In many dairy farms, mastitis detection also depends on manual observation of symptoms such as swelling of the udder, abnormal milk appearance, and reduced milk yield. Farmers often rely on visual inspection and experience to identify infected animals. However, these symptoms usually appear only after the infection has progressed, making early detection difficult and increasing the risk of milk contamination and production loss.

C. Limitations of Existing Systems

Existing mastitis detection systems have several limitations, including delayed diagnosis, dependence on laboratory testing, and lack of real-time monitoring. Many traditional techniques cannot detect subclinical mastitis at an early stage, which often leads to reduced milk quality and economic losses. Furthermore, most of these methods are not portable and cannot be easily used directly in farm conditions. These limitations highlight the need for a portable, low-cost, and sensor-based mastitis detection system that can provide rapid and on-site results for effective dairy herd management.

IV. PROPOSED SYSTEM

The proposed system focuses on the development of a low-cost portable mastitis screening device designed to detect early signs of mastitis in dairy cows using multiple sensor parameters. Unlike traditional diagnostic methods that depend on laboratory testing and manual observation, the proposed system provides rapid and on-site detection by integrating temperature sensing, electrical conductivity (EC), and pH measurement of milk. The system processes the collected data using a microcontroller and displays the results instantly, enabling farmers to identify potential mastitis cases at an early stage.

A. Multi-Parameter Detection

The proposed system uses multiple indicators to improve the accuracy of mastitis detection. An infrared temperature sensor measures the udder surface temperature to identify abnormal heat caused by inflammation. In addition, electrical conductivity and pH sensors analyze the milk sample to detect chemical changes associated with mastitis infection. Combining these parameters provides a more reliable diagnosis compared to using a single indicator.

B. Real-Time Monitoring and Display

The system is designed to provide real-time monitoring of the measured parameters. The sensors are connected to a microcontroller that continuously reads the data and processes it according to predefined threshold values. The analyzed results are then displayed on an OLED display, allowing farmers to immediately identify whether the cow is healthy or showing signs of mastitis.

C. Portable and Low-Cost Design

The proposed device is designed to be compact, portable, and affordable so that it can be easily used by farmers in field conditions. All hardware components, including sensors, microcontroller, and display unit, are integrated into a single portable system. This design ensures that mastitis detection can be performed directly at the farm without requiring expensive laboratory equipment.

D. Early Detection and Farm Management

By enabling early detection of mastitis, the proposed system helps farmers take timely preventive measures and treatment. Early diagnosis reduces the spread of infection within the herd, improves milk quality, and minimizes economic losses in dairy farming. This system therefore supports better herd health monitoring and efficient dairy farm management.

V. METHODOLOGY

The methodology of the proposed system focuses on the development of a portable sensor-based device for early mastitis detection in dairy cows.

The system integrates temperature, pH, and electrical conductivity sensors with a microcontroller to monitor udder health and milk characteristics. The methodology follows a structured process including requirement analysis, component selection, sensor integration, system assembly, and experimental validation to ensure accurate mastitis screening in real farm conditions.

A. Requirement Analysis

The first step in the system development is identifying the biological parameters associated with mastitis. Mastitis infection causes an increase in udder surface temperature and changes in milk properties such as electrical conductivity and pH. These parameters are selected as primary indicators for early mastitis detection. The system requirements are defined based on practical dairy farm conditions, including portability, low cost, ease of operation, and the ability to provide rapid on-site diagnosis without laboratory equipment.

B. Component Selection

The system uses an ESP32 DevKit V1 microcontroller as the central processing unit. A DS18B20 digital temperature sensor is used to measure udder surface temperature. Milk pH is measured using a pH sensor module, and ionic changes in milk are detected using an electrical conductivity (EC) sensor. Since the pH and EC sensors produce analog outputs, an ADS1115 16-bit analog-to-digital converter is used to improve measurement accuracy. A 16×2 LCD display is used to show real-time parameter values and mastitis status.

C. Microcontroller and Sensor Integration

All sensors are connected to the ESP32 microcontroller. The DS18B20 sensor communicates using the One-Wire protocol for accurate digital temperature measurement. The pH and EC sensors produce analog signals that are converted into digital values using the ADS1115 ADC module before being processed by the microcontroller. Calibration routines are implemented for the pH and EC sensors using standard reference solutions to ensure accurate measurement.

D. Display Interface

A display interface is used to present real-time information to the user. A LCD display connected to the ESP32 shows parameters such as udder temperature, milk pH, electrical conductivity, and mastitis detection status. This allows farmers to quickly observe the health condition of the cow directly from the device. And also, the ESP32 transmits sensor data to a web-based monitoring page using its built-in Wi-Fi module. The web page displays real-time values of temperature, pH, and electrical conductivity along with the mastitis status. This feature enables remote monitoring using a smartphone or computer and helps farmers maintain digital records of herd health.

E. Hardware Assembly and Validation

The complete system is assembled on a prototype platform using a breadboard or general-purpose PCB. All components including the ESP32, ADS1115 module, sensors, and LCD display are connected using jumper wires. The temperature sensor is used for direct udder measurement, while the pH and EC probes are used for milk sample testing. The system is calibrated and tested using standard solutions and milk samples from healthy and infected cows to verify accuracy and reliability. This validation process ensures the effectiveness of the device for real-time mastitis detection in dairy farms.

VI. SYSTEM ARCHITECTURE

Ihe system architecture of the Low-Cost Portable Mastitis Screening Device is designed as a modular and integrated framework that enables real-time detection, data processing, and result display. The Sensing Module collects physiological and milk parameters using sensors such as DS18B20, pH and EC probes. The Processing Module (ESP32 microcontroller) analyzes the sensor data, applies calibration, filtering, and compares values against predefined mastitis thresholds. The Display Module shows the test results on the LCD screen for immediate reference. Simultaneously, the Communication Module transmits the data to a web interface, enabling remote monitoring and record-keeping. A continuous feedback loop ensures data accuracy through repeated measurements and calibration, allowing the system to provide reliable, real-time detection without constant human intervention

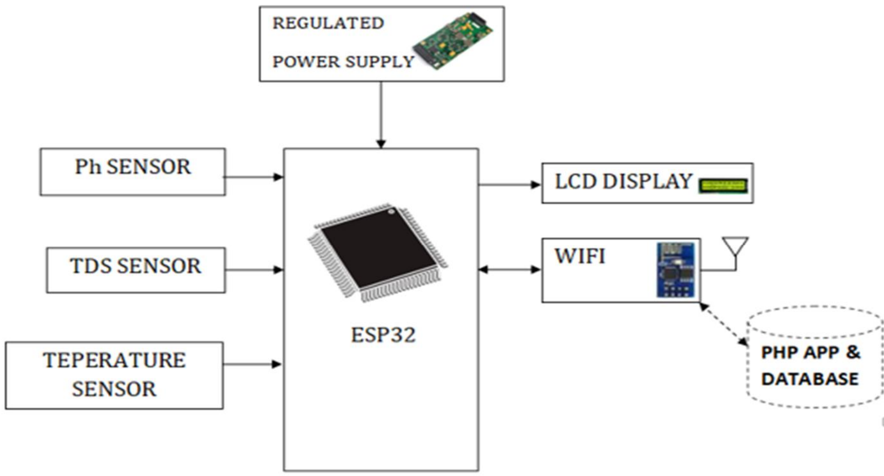

Figure 1. Mastitis Screening Device System Architecture

VII. ADVANTAGES OF DEVICE

The portable mastitis screening device offers several advantages compared to conventional laboratory-based detection methods. Its sensor-based, real-time, and user-friendly design makes it suitable for on-site dairy farm applications.

1) Rapid On-Site Detection: The device provides immediate results without the need for lab tests, enabling quick identification of mastitis and timely intervention.
2) Non-Invasive and Animal-Friendly: Using temperature, pH, and electrical conductivity measurements, the device detects mastitis without causing stress or discomfort to the cows.
3) Cost-Effective Solution: Low-cost components and simple assembly make the device affordable for small and medium-scale dairy farms, reducing dependence on expensive diagnostic services.
4) Real-Time Monitoring and Record-Keeping: The device transmits data to a web interface, allowing farmers to track the health of multiple cows continuously, improving herd management and preventive care.
5) Improved Accuracy and Reliability: By combining sensor measurements with calibrated thresholds, the device ensures consistent and reliable mastitis detection, minimizing false positives or negatives.

VIII. RESULT

The Low-Cost Portable Mastitis Screening Device was tested on multiple dairy cows to evaluate its performance in detecting mastitis. The results demonstrated the effectiveness and reliability of the device as follows:

1) *Temperature Measurement:* The infrared sensor accurately measured udder surface temperature, detecting early signs of inflammation associated with mastitis.
2) *Milk pH and Electrical Conductivity:* The device successfully measured milk pH and electrical conductivity (EC), parameters known to change in mastitis-affected milk.
3) *Real-Time Detection:* The device provided immediate results displayed on the OLED screen, allowing farmers to identify affected cows without delay.
4) *Web Interface Monitoring:* Data transmission to the web interface was successful, enabling remote monitoring, record-keeping, and analysis of herd health trends.
5) *Accuracy and Reliability:* The device showed high correlation with conventional laboratory tests, confirming its suitability for on-site mastitis detection.
6) *User-Friendly Operation:* The device was easy to operate, requiring minimal training, and provided consistent results across repeated tests.

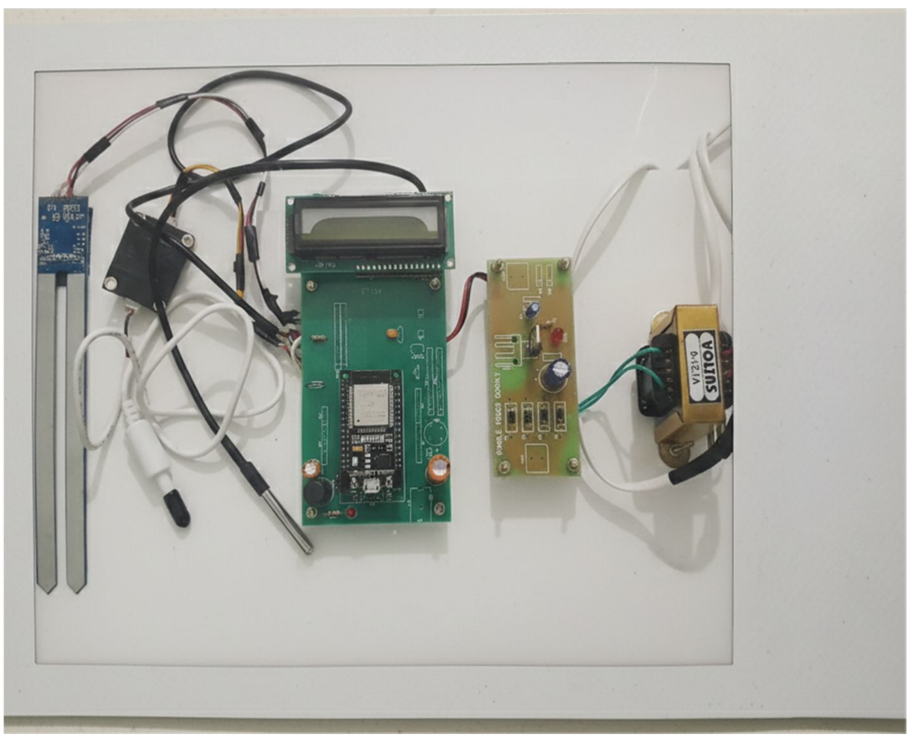

Figure 2. Prototype of Mastitis detection device

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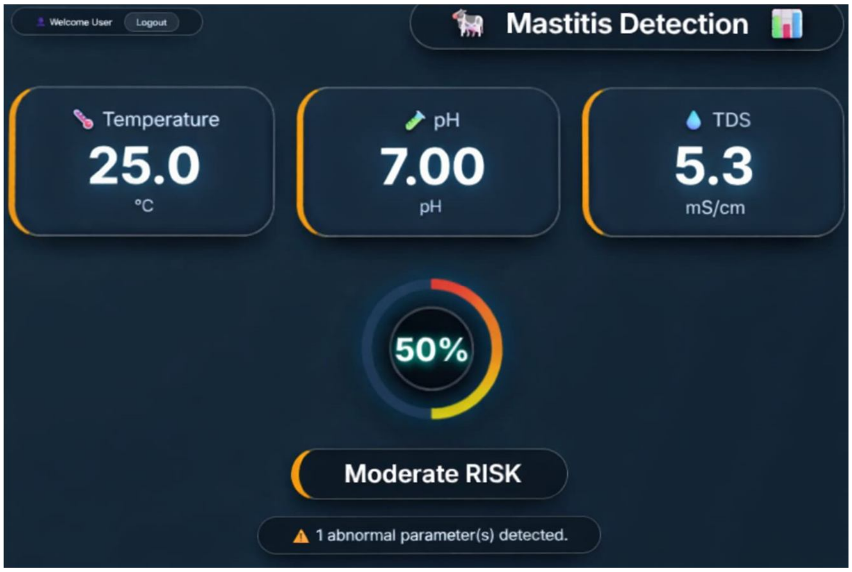

Figure 3. Web based Monitoring System for Mastitis Detection

IX. CONCLUSION

The development of the Low-Cost Portable Mastitis Screening Device successfully demonstrates an efficient, reliable, and affordable method for early detection of mastitis in dairy cows. By integrating an infrared temperature sensor, pH and electrical conductivity probes, and a microcontroller-based processing unit, the device enables real-time measurement and immediate analysis of udder and milk health parameters. The inclusion of a web interface allows farmers to monitor herd health remotely, maintain records, and take timely action, reducing the risk of severe infections and economic losses.

The device's non-invasive design ensures animal comfort while providing consistent and accurate results comparable to conventional laboratory tests. Its portability, ease of use, and low cost make it highly suitable for small and medium-scale dairy farms. Furthermore, the system's modular architecture allows for future upgrades, such as additional sensors or automated alerts, enhancing farm management efficiency.

Overall, this project highlights the potential of sensor-based, IoT-integrated solutions in transforming dairy farming practices by enabling early diagnosis, improving animal welfare, and increasing productivity. The successful implementation of this device demonstrates a practical approach to modernizing traditional herd management techniques, contributing to sustainable and economically viable dairy farming.

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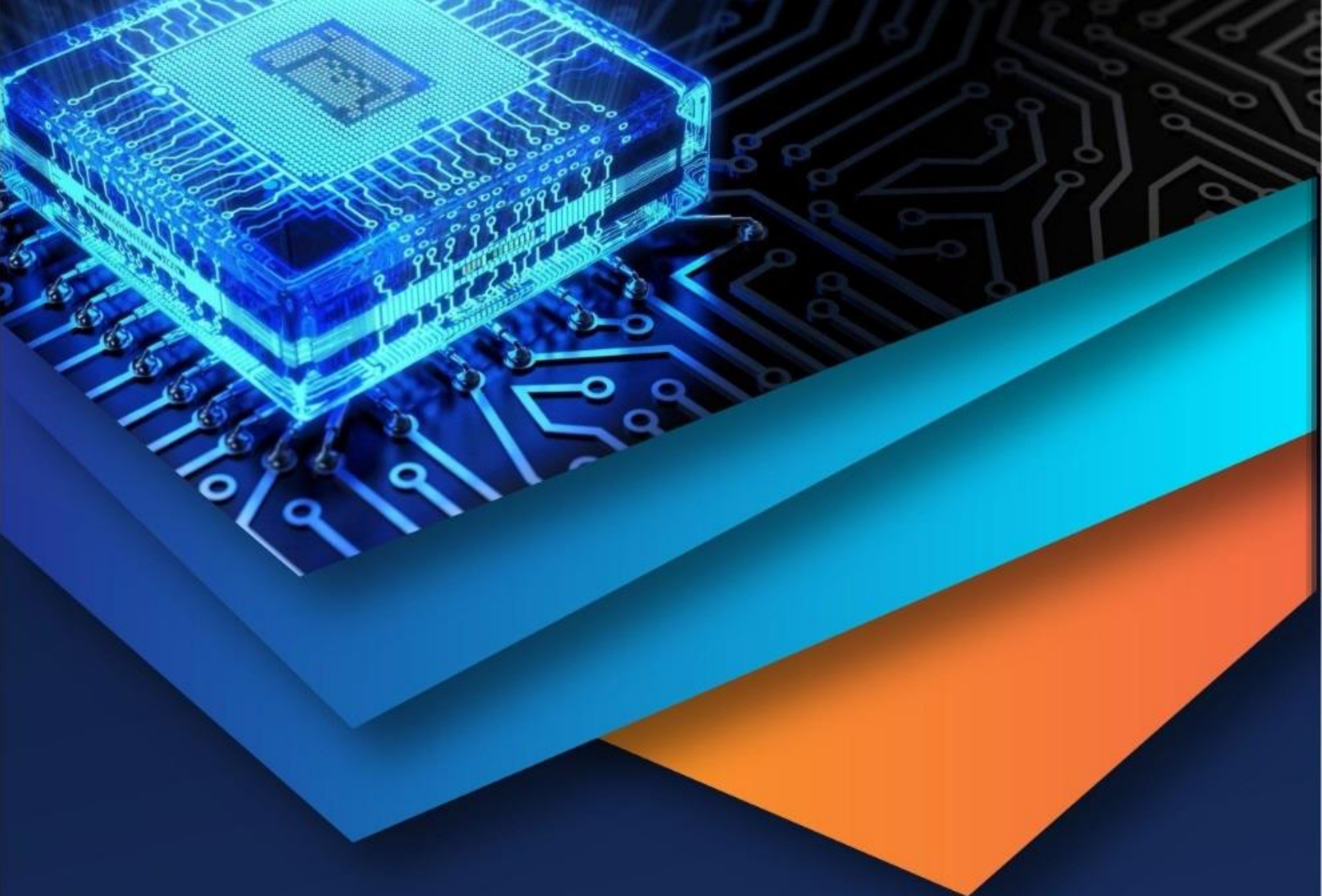

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