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# Resource Optimization in Smart Parking System

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***Abstract: The persistent rise in vehicle ownership has intensified the demand for orderly and efficient parking management, especially in urban and semi-urban settings where available space is often limited. In many such environments, conventional parking***
***arrangements continue to suffer from the absence of real-time monitoring, resulting in avoidable delays, disorganized vehicle flow, and underutilization of available slots.***
***This paper presents the development of a smart parking system built around the ESP8266 microcontroller. The parking layout is divided into four organized blocks, each containing three slots, thereby enabling structured observation and easier interpretation of slot status. By employing shift registers for sensor input collection, the design reduces hardware requirement and wiring complexity while preserving functional efficiency.***
***The system further incorporates a local display interface and a browser-accessible web server for live parking updates. In addition, an ultrasonic sensor and servo-assisted entry gate are integrated to regulate vehicle admission in accordance with slot availability. Taken together, the developed model offers a practical, economical, and technically coherent solution for small to medium-scale smart parking applications.***
***Keywords—Smart Parking, ESP8266, Infrared Sensors, 74HC165 Shift Register, Web Server, Embedded Automation, Real-Time Monitoring***

## I. INTRODUCTION

The growing concentration of vehicles in daily life has placed considerable strain on existing parking infrastructure. In many institutions, residential complexes, and commercial premises, drivers spend unnecessary time locating vacant spaces, a situation that contributes not only to congestion but also to avoidable fuel consumption and operational inefficiency.

As noted by J. A. Abdulsaheb et al. (2020), traditional parking facilities are often unable to cope with the influx of vehicles, creating a pressing need for effective, real-time management systems [1]. To mitigate these issues, researchers have increasingly turned to the Internet of Things (IoT). By connecting physical parking infrastructures with wireless communication technologies, these intelligent systems can provide real-time availability updates to drivers before they enter a facility, thereby streamlining traffic flow and minimizing carbon emissions.

A critical component of any smart parking architecture is the reliable detection of vehicle presence, which is most commonly achieved through infrared (IR) or ultrasonic transducers. H. Tanti et al. (2019) successfully demonstrated the use of IR sensors for individual slot monitoring, noting their cost-effectiveness and rapid binary detection capabilities [2]. Similarly, J. A.
Abdulsaheb et al. (2020) utilized multiple IR sensors to govern both slot occupancy and gate operations [1]. Conversely, N. M.
F. A. Azmi et al. (2018) and P. M. Sai et al. (2021) relied heavily on ultrasonic sensors to track vehicle distances and occupancy [3], [4]. Furthermore, Andie et al. (2022) explored a hybrid approach, combining HC-SR04 ultrasonic sensors with LDR and laser modules to accurately count vehicles passing through an entrance gate [5].

To process this sensor data and provide seamless user experiences, recent literature heavily emphasizes the balance of computing power and cloud connectivity. H. Tanti et al. (2019) and J. A. Abdulsaheb et al. (2020) highlight the NodeMCU ESP8266 as an optimal processing core due to its built-in Wi-Fi and cloud integration capabilities [1], [2]. While N. M. F. A. Azmi et al. (2018) explored Raspberry Pi with MQTT protocol, and P. M. Sai et al. (2021) utilized Arduino with ThingSpeak, the consensus remains that a combination of local display systems and remote web dashboards is essential for an efficient user interface [3], [4].

Traditional parking systems generally lack dynamic monitoring capability and therefore fail to provide immediate information regarding occupancy status. While several IoT-enabled parking models have been proposed in recent years, many of them depend on comparatively expensive hardware arrangements or require complex deployment conditions, which may not be suitable for modest-scale environments.

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In response to these limitations, the present work proposes a smart parking framework that emphasizes structural simplicity, reduced hardware burden, and real-time accessibility. The objective is not merely to automate slot detection, but to establish a reliable and interpretable system that remains feasible for practical implementation without excessive infrastructural demands.
Prototype of the developed model is shown in Fig. 1.


Fig.1 Image of prototype of our Smart Parking System

While existing ESP8266-based solutions effectively demonstrate remote monitoring and automated access control, scaling these systems exposes a significant hardware limitation regarding General Purpose Input/Output (GPIO) pin availability. Monitoring multiple individual slots quickly exhausts the available pins on standard microcontrollers. To address this specific gap, the proposed system introduces a highly optimized, block-wise architecture (Blocks A, B, C, and D) managing twelve separate IR sensors. By integrating two 74HC165 shift registers, the design efficiently condenses the data array, allowing the ESP8266 to read all twelve sensors using only three GPIO pins. Coupled with an automated servo gate governed by an ultrasonic sensor to manage physical entry, and a dual-display output mechanism featuring a local 16x2 LCD alongside a Wi-Fi-enabled web interface, this approach provides a scalable, resource-efficient framework that successfully overcomes the hardware constraints prevalent in earlier IoT parking designs.

## II. PROPOSED SYSTEM

The proposed architecture organizes the parking region into four distinct blocks, denoted as A, B, C, and D. Each block contains three slots, allowing the availability status to be represented in a segmented and readable form. Such block-wise representation improves interpretability and supports faster understanding of space distribution as shown in Fig. 2.

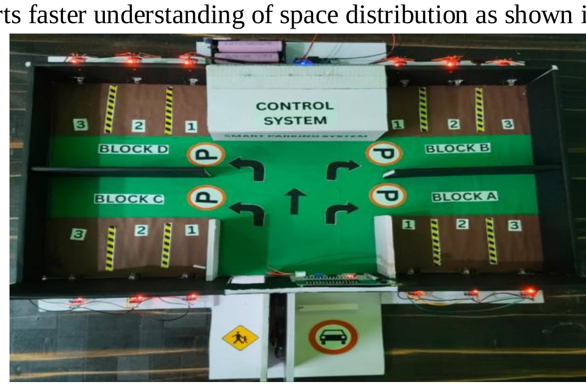


Fig. 2 Block-wise representation of Smart Parking System

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Infrared sensors are assigned to individual parking slots for occupancy detection. Because the number of sensing points increaseswith the number of parking spaces, direct wiring of every sensor to the microcontroller would essentially increase circuit complexity. To address this issue, the 74HC165 shift register is employed as a parallel-in serial-out device, enabling multiple sensor signals to be consolidated and transmitted efficiently to the ESP8266. This arrangement significantly reduces the number of direct microcontroller connections required, thereby simplifying implementation and enhancing scalability within the intended operational range.

At the center of the design lies the ESP8266 microcontroller, which performs data acquisition, slot analysis, and communication control. Once the system identifies available spaces in each block, the processed information is displayed locally and transmitted through a web server. This dual-mode reporting mechanism strengthens usability by supporting both on-site observation and browser-based access.

An automated gate mechanism is also integrated into the system. An ultrasonic sensor installed near the entrance detects the arrival of a vehicle. The controller then verifies whether any parking slot is available. If space exists, the servo motor actuates the gate to allow entry; if the lot is full, the gate remains closed. This logic helps prevent unnecessary internal congestion and improves entry management.

## III. SYSTEM DESIGN

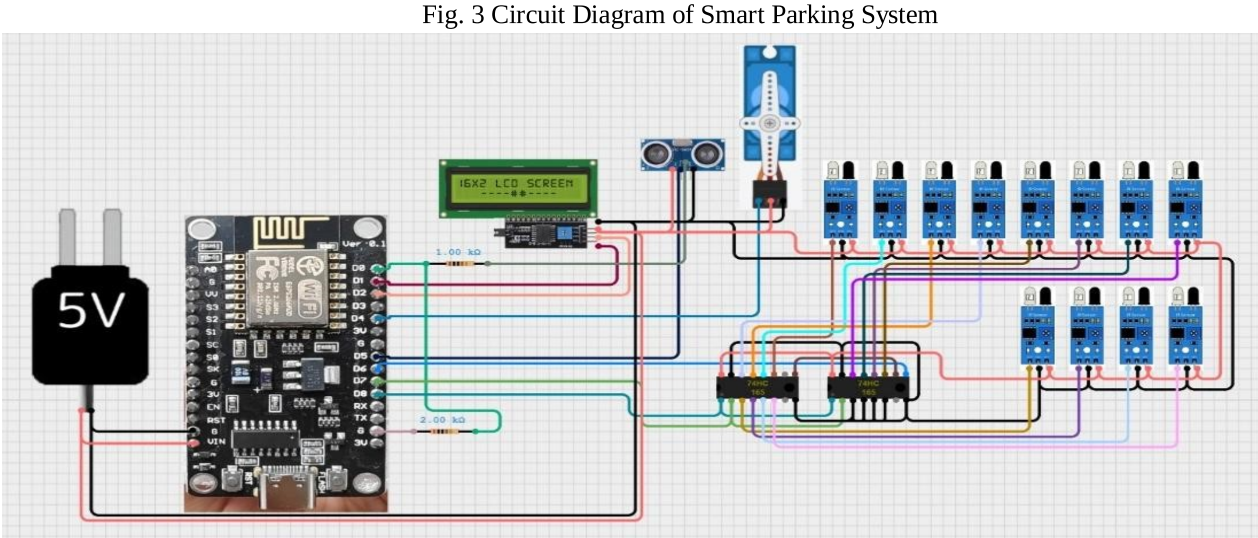
The ESP8266 functions as the central processing element of the system[6]. Its role extends beyond simple control, as it handles sensor-derived data, determines occupancy conditions, and hosts a Wi-Fi-enabled web interface for real-time status transmission. Infrared sensors form the primary detection layer. Their working principle relies on emission and reflection of infrared radiation, making them suitable for identifying vehicle presence within designated slots. Their practical advantages include fast response and relatively straightforward integration into embedded designs.

The 74HC165 shift register plays a crucial role in reducing the number of GPIO pins required by the controller. By collecting multiple parallel sensor inputs and forwarding them serially, it enables an efficient interface between a multi-sensor parking layout and a compact microcontroller platform [7].

The LCD module serves as the local display unit and presents block-wise parking information in a clear format. This makes the current slot condition readily understandable even without accessing the web interface.

The ultrasonic sensor and servo motor together form the gate control subsystem. The ultrasonic sensor [8] detects the presence of an approaching vehicle, while the servo motor executes the opening and closing of the entrance barrier in accordance with availability status determined by the controller.The servo motor controls the gate mechanism. When the system detects an incoming vehicle and confirms availability, the motor rotates to open the gate. After the vehicle passed, it returns to its original position to close the gate. The circuit diagram in Fig. 3 shows the connection of all the sensors with the shift registers and the connection of the shift registers and display unit with the ESP8266 microcontroller. The actual circuit of the control unit is depicted in Fig. 4.

Fig. 3 Circuit Diagram of Smart Parking System



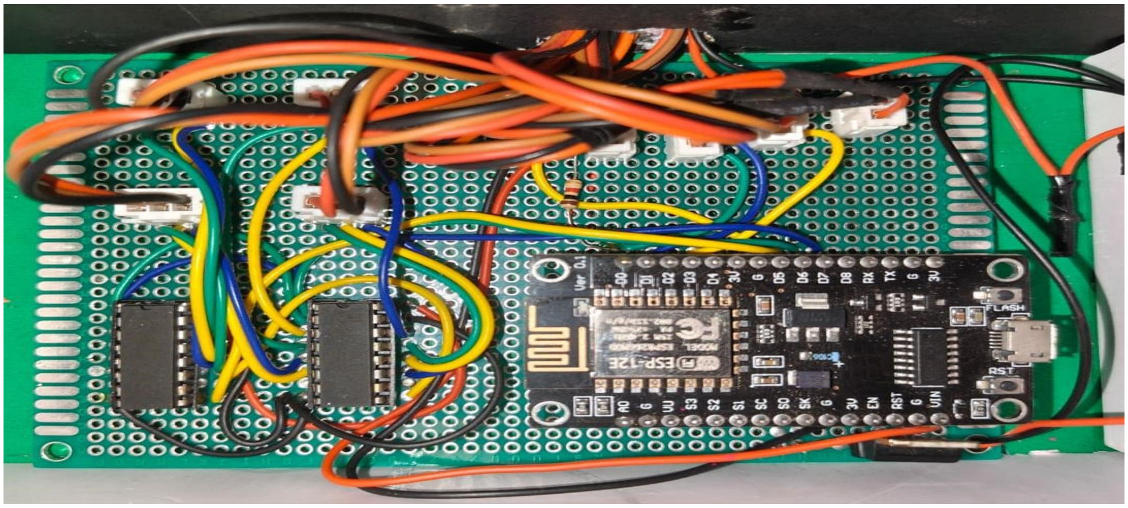


Fig. 4 Circuit of the Control Unit

## IV. WORKING METHODOLOGY

The system operates through a continuous monitoring cycle. Initially, infrared sensors detect whether each slot is occupied. The resulting digital signals are collected by the shift registers and transmitted to the ESP8266 for interpretation.

The controller processes this information and determines the number of vacant slots in each parking block. The computed results are then shown on the LCD and updated on the web server interface, ensuring simultaneous visibility across both output channels. The web server hosted by the ESP8266 can be accessed through a browser by users connected to the same network. It displays real-time information regarding occupied and free slots, block status, and the overall condition of the parking area. This arrangement extends system usability beyond the immediate hardware setup and makes monitoring more convenient.

From an operational standpoint, the methodology follows a structured sequence: vehicle detection, data consolidation, controllerside processing, result display, and gate regulation. The coherence of these stages ensures that the system remains responsive and functionally synchronized during use as shown in Fig.5.

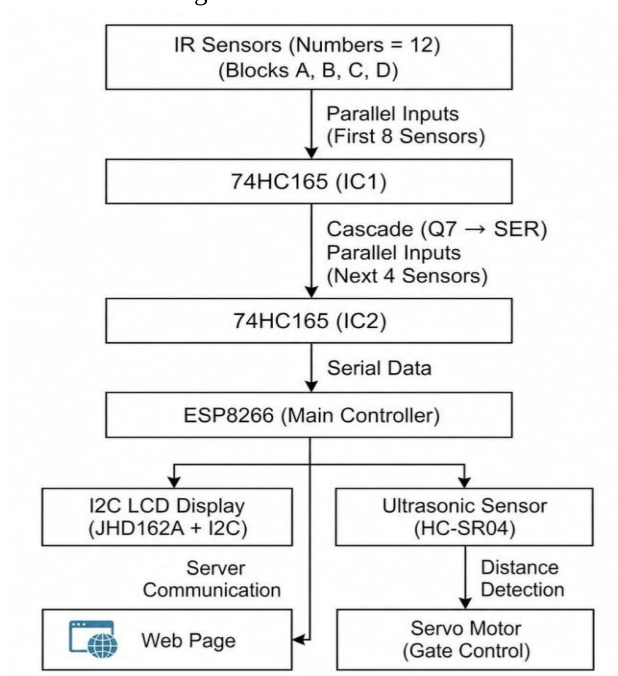



Fig. 5 Work Flow Diagram of Smart Parking System

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In the proposed parking system, there are 12 IR sensors to monitorone per parking slot. Since the ESP8266 doesn't have enough pins to read all 12 directly, two 74HC165 chips are linked together in series.

The first chip handles sensors 1 through 8, and the second chip takes care of sensors 9 through 12. Any unused inputs on the second chip are simply grounded. Both chips share the same clock and load signals coming from the ESP8266.

The output of the IC1 feeds directly into the input of the IC2. So when the ESP8266 reads data, it gets a single stream of 16 bits total 8 from each chip arriving one after another. During a reading cycle the ESP8266 briefly pulls the load pin LOW this tells both chips to simultaneously "freeze" and record the current state of all 12 sensors. The ESP8266 then sets the pin HIGH again and starts sending clock pulses.

With each clock pulse, the chips push out one bit the state of one sensor which the ESP8266 reads and stores. After 12 pulses (or 16 if the unused inputs are counted), the ESP8266 has a complete picture of every parking slot.

## V. RESULTS

The developed model demonstrates that a structured parking management system can be achieved with relatively limited hardware resources when sensing, data compression, and wireless communication are integrated effectively. The use of infrared sensors enabled slot-level occupancy identification, while the 74HC165 shift register simplified multi-sensor interfacing without compromising the continuity of data acquisition.

The ESP8266 successfully performed centralized processing and real-time status dissemination through both the LCD and the web-based interface as shown in Fig. 6 and Fig. 7. This dual-output behavior improved accessibility of parking information and reduced dependence on manual observation. The inclusion of the automated gate subsystem further enhanced operational discipline by permitting entry only when space was available.

From an implementation perspective, the system proved suitable for small and medium parking environments where economical deployment and straightforward maintenance are important considerations. The block-wise layout also improved readability of status information, making the design more practical for institutional and localized use cases.

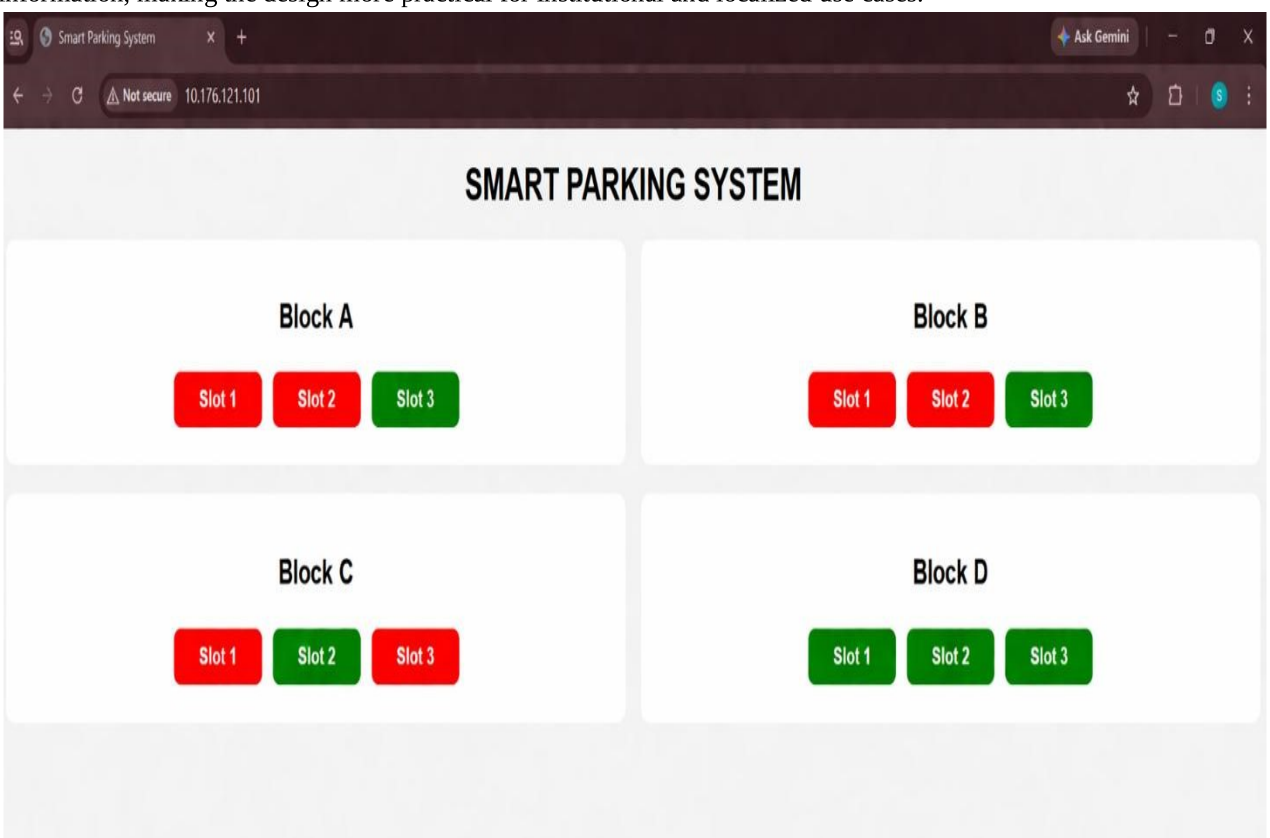


Fig. 6 Web-based Interface of Smart Parking Syatem

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Fig. 7 LCD Interface of Smart Parking System.

## VI. DISCUSSION

The developed parking system can be adopted in educational institutions, residential buildings, private parking zones, and small commercial premises where organized vehicle management is required. Because the design is structurally simple and modular in nature, it can be adapted for a range of similar environments with limited modification.The system offers several practical benefits:

- It reduces wiring complexity by using shift registers for multi-sensor input handling .
- It provides real-time parking updates through both a local display and a web interface.
- It introduces structured block-wise slot representation, which improves clarity for users.
- It supports automated entry control, thereby improving traffic regulation at the parking gate.
- It remains cost-effective and implementation-friendly for modest-scale deployments.

## VII. LIMITATION AND FUTURE SCOPE

Despite its practical utility, the system is not without limitations. The detection accuracy of infrared sensors may be influenced by environmental factors such as dust accumulation, excessive ambient light, or misalignment of sensing units, all of which can affect reliability under non-ideal conditions.

In addition, the present design is primarily intended for small to medium-scale deployment. Expanding the same framework to a substantially larger parking area would require additional hardware, more sophisticated data handling, and broader coordination across sensing modules.

The proposed system offers multiple directions for future enhancement. Integration with mobile applications could improve user convenience. Further refinement may also involve camera-assisted detection, data analytics, or artificial intelligence-based forecasting of parking demand. Such additions could transform the present model from a localized embedded solution into a more intelligent and scalable smart infrastructure system.

## VIII. CONCLUSION

The smart parking system developed in this work provides a coherent and efficient solution to the persistent challenge of parking space management. By combining infrared sensing, 74HC165-based input handling, and ESP8266-centered control, the model achieves reliable slot monitoring, streamlined processing, and practical real-time communication.

The web server component significantly improves user accessibility by allowing slot information to be viewed through a browser, while the automated gate mechanism adds a further layer of functional intelligence to the system. As a result, the proposed design emerges as a cost-conscious and operationally effective parking solution for controlled environments.

With suitable enhancements in connectivity, sensing precision, and predictive intelligence, the system has the capacity to evolve into a more advanced smart parking framework aligned with the demands of smart city infrastructure.

## IX. ACKNOWLEDGMENT

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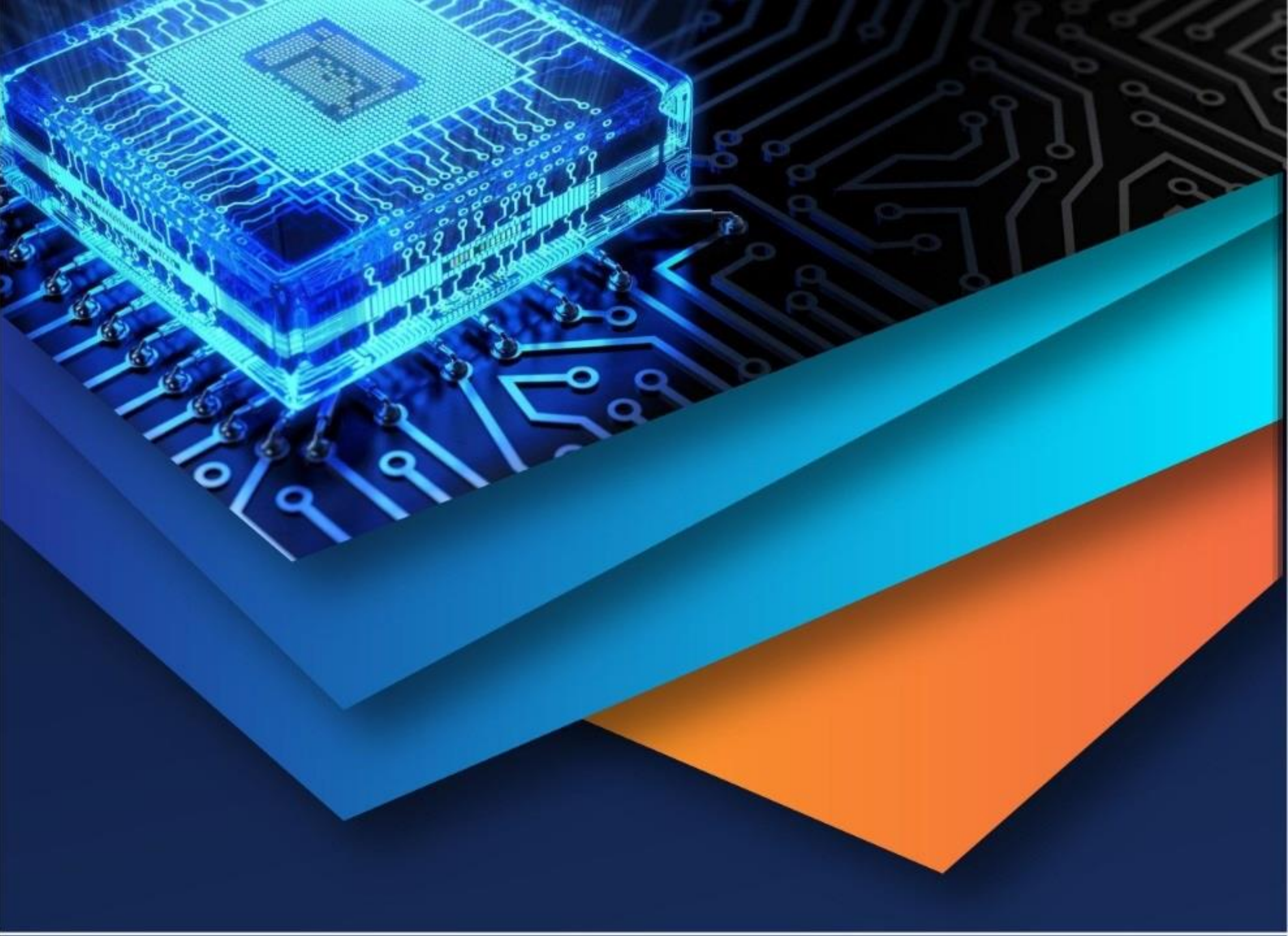

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