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Smart Assistive System for Paralysis People

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Abstract: Mobility impairments due to paralysis present significant challenges, limiting independence and daily activities. This research focuses on developing an Electrooculography (EOG)-Based Blink-Controlled Wheelchair, enabling hands-free movement using eye blinks as the primary input. The system utilizes the Bio Amp EXG Pill to capture EOG signals, which are processed by an ESP32 microcontroller to detect voluntary eye blinks. A single blink triggers forward movement, while the absence of a blink stops the wheelchair. To enhance usability, an HTML-based web interface has been integrated, allowing users or caregivers to control the wheelchair in all directions remotely. The system employs an L298N motor driver to regulate two BO motors, ensuring efficient and reliable motion control. The proposed solution offers a cost-effective, power-efficient, and user-friendly alternative to traditional joystick or voice-controlled wheelchairs. The combination of blink-based control for autonomous movement and web-based remote control provides enhanced accessibility and flexibility. Future improvements may include machine learning algorithms for better blink detection, wireless connectivity for remote monitoring, and adaptive calibration for different users. This research contributes to the advancement of assistive mobility solutions, empowering individuals with paralysis to navigate their surroundings independently.
Keywords: Electrooculography, EOG, Blink-Controlled Wheelchair, ESP32-based Assistive Technology, Paralysis Mobility Solution, Web-based Wheelchair Control

I. INTRODUCTION

Mobility impairment due to paralysis significantly affects an individual's independence and quality of life. Traditional wheelchairs often require manual operation through joysticks or voice commands, which may not be accessible to individuals with severe motor disabilities. To address this challenge, assistive technologies based on Electrooculography (EOG) have gained attention for enabling hands-free control of mobility devices. This research presents a blink-controlled EOG-based wheelchair, which utilizes eye blinks as the primary input for movement. The system employs the Bio Amp EXG Pill to acquire EOG signals, which are then processed by an ESP32 microcontroller to detect voluntary eye blinks. A single blink initiates the forward motion of the wheelchair, while the absence of a blink stops it.

This approach provides a simple and effective solution for individuals with severe physical limitations. In addition to blink-based control, a web-based HTML interface has been integrated to allow manual control of the wheelchair in all directions. This feature ensures that caregivers or users can remotely operate the wheelchair when necessary, enhancing flexibility and usability. The L298N motor driver is used to regulate two BO motors, ensuring smooth and precise movement. The proposed system is cost-effective, power-efficient, and user-friendly, making it a viable alternative to existing wheelchair control mechanisms. Future advancements may include machine learning-based blink filtering for improved accuracy, wireless connectivity for remote monitoring, and adaptive calibration to accommodate different user needs. This research aims to contribute to the field of assistive mobility technologies, offering a novel and accessible solution for individuals with severe motor impairments.

II. LITERATURE SURVEY

1) Brain-Computer and EOG-Based Assistive Technologies

Brain-Computer Interfaces (BCIs) and Electrooculography (EOG)-based control systems have been extensively studied to aid individuals with severe motor impairments. Katona et al. (2021) created a BCI system utilizing the NeuroSky MindWave EEG headset to manage the speed of a mobile robot. Their research showcased the potential of brainwave-based control, although it was constrained by the need for extensive calibration of EEG signals. In a similar vein, Keutayeva et al. (2023) presented a compact convolutional transformer model aimed at enhancing subject-independent EEG-based BCI performance, emphasizing the difficulties posed by inter-subject variability in bio-signal processing. While these EEG-based systems hold promise, EOG-based methods offer a more straightforward and efficient approach for eye-controlled assistive devices, making them a more viable option for wheelchair control.

2) Eye Blink and Eye Movement Detection Techniques

EOG signal processing serves as an effective technique for identifying voluntary eye movements, which can facilitate hands-free operation of assistive devices. Yathunanthan et al. (2022) introduced an EOG-based wheelchair control system that processes eye movement signals directly on a microcontroller, thus eliminating the need for external computers and lowering system costs. Their system achieved an impressive 99% classification accuracy for commands based on eye movements (forward, reverse, left, and right), underscoring the reliability of EOG for wheelchair navigation. Likewise, Nakanishi et al. (2021) concentrated on distinguishing between voluntary (double blink, wink) and involuntary blinks, achieving a detection accuracy of 98.28%. These studies validate that EOG signals can be effectively utilized to detect eye blinks with high accuracy, reinforcing the practicality of an EOG-controlled wheelchair system.

3) Wheelchair Control Mechanisms

Traditional wheelchairs are mainly operated through joysticks or voice commands, which can be challenging for individuals with severe motor disabilities. Yathunanthan et al. (2022) introduced an eye movement-based control system that enables users to navigate in various directions (forward, backward, left, right) using EOG signals. Similarly, Nakanishi et al. (2021) developed a method for detecting voluntary blinks to control wheelchairs, demonstrating that different blink types can correspond to specific commands. However, while both studies concentrated on multi-directional control, a straightforward blink-based forward-motion system (like the one in our project) could provide a more intuitive and reliable solution.

4) System Implementation

Current EOG-based wheelchair systems typically utilize analog filtering and signal processing methods to capture eye movement signals. Yathunanthan et al. (2022) created a low-cost, microcontroller-driven EOG signal processing system, which significantly simplified hardware requirements. In contrast, Nakanishi et al. (2021) employed brain-machine interface (BMI) techniques to improve voluntary blink detection. Our project builds on these foundations by using the BioAmp EXG Pill for signal acquisition and the ESP32 microcontroller for processing, resulting in a cost-effective and efficient solution. Furthermore, our system features a web-based control interface, providing flexibility for manual operation when necessary.

5) Research Gaps and Future Scope

Despite progress in EOG-based assistive technologies, several challenges persist. Most existing research emphasizes eye movement detection but often overlooks issues like false blink detection and inconsistent eye movement triggers. Our project seeks to improve blink detection accuracy through signal filtering techniques to minimize unintended movements. Additionally, incorporating wireless connectivity for remote monitoring and machine learning-based adaptive blink filtering could enhance system performance.

III. PROBLEM STATEMENT, OBJECTIVES AND METHODOLOGY

A. Problem Statement

People with serious motor disabilities, e.g., those suffering from paralysis, ALS (Amyotrophic Lateral Sclerosis), or spinal cord injury, are severely handicapped in mobility and autonomy. Conventional wheelchair control devices, such as joysticks or voice commands, can be unsuitable for individuals with poor motor capability. To solve this, an eye-blink-controlled wheelchair based on EOG (Electrooculography) signals is suggested, which allows hands-free operation. The system shall employ ESP32 as the microcontroller and BioAmp EXG Pill for recording and processing eye-blink signals to perform precise and faithful movement control. A web interface shall also be incorporated to afford alternative control in order to afford greater user freedom.

B. Objective

1) Design an eye-blink-based wheelchair using EOG signals in order to bring mobility to patients with severe motor disabilities.
2) Deploy an ESP32-based real-time blink-detection signal-processing system to accurately detect eye blinks with minimal false triggers.
3) Provide stable movement control by correlating detected eye blinks to wheelchair movement (e.g., one blink for forward, lack of blink for stop)
4) .Increase accuracy and reliability by enhancing blink-detection algorithms to differentiate voluntary blinks from involuntary blinks.
5) Add a web-based control interface to offer an alternate means of navigation for caregivers or users.
6) Test and verify the system for responsiveness, accuracy, and usability in varying conditions.

C. Methodology

1) Hardware Setup

- Utilize ESP32 as the main microcontroller.
- Connect BioAmp EXG Pill for acquiring EOG signals due to eye movement.
- Connect the system to an LED (testing) prior to incorporation of a motor driver for wheelchair operation.

2) Signal Processing & Blink Detection

- Obtain raw EOG signals from the front region.
- Apply filtering methods (low-pass and high-pass filters) to remove noise.
- Create an online blink recognition algorithm with the use of thresholding methods in order to recognize voluntary and involuntary blinks.

3) Wheelchair Control Mechanism

- Dedicate individual commands using blink patterns:
- Single blink → Go forward
- No blink → Do not move
- Implement a motor driver circuit for driving the wheelchair according to sensed signals.

4) Web-Based Interface Implementation

- Make an easy-to-use HTML website hosted on ESP32 for internet control.
- Facilitate movement direction options (forward, reverse, left, right) to add flexibility.

5) Testing & Performance Evaluation

- Authenticate system accuracy with real-time eye-blink detection tests.
- Test system response time, false triggers, and accessibility for users with motor impairments.
- Improve blink detection to enhance system stability and reliability.

IV. ENTIRE RESEARCH SETUP OF THE PROJECT

The experimental setup for this eye-blink-driven wheelchair system includes an ESP32 microcontroller as the central processing unit, communicating with the Bio Amp EXG Pill to record EOG signals from electrodes located around the eyes. The recorded signals are filtered in the analog domain and then amplified prior to processing via a blink detection algorithm to identify intended blinks from noise. A motor driver (L298N) is utilized to drive the movement of the wheelchair, whereby a blink of the eye moves the wheelchair ahead and no blinks halt it. A web-based control interface, running on the ESP32, enables remote control of the wheelchair via Wi-Fi. Power is provided by a rechargeable Li-ion battery pack for convenience. For reliability and accuracy, rigorous testing under different motion and lighting conditions is performed to eliminate false activation, refine blink detection thresholds, and confirm response time and handleability of the system. Performance of both web-based manual control and EOG-based control is measured to provide enhanced usability in patients with severe motor impairment.

V. LIST OF HARDWARE AND SOFTWARE

Category	Component	Description
Hardware	ESP32 Microcontroller	Central processing unit for acquiring and processing EOG signals.
	BioAmp EXG Pill	Used for capturing electrooculogram (EOG) signals.
	Electrodes	Placed around the eyes to record EOG signals.
	Motor Driver Module	Controls the wheelchair motors based on processed EOG signals.
	Wheelchair Model / Prototype	The physical system for movement testing.
	LiPo Battery	Provides power for the entire setup.
Software	Arduino IDE	Used for programming and flashing the ESP32 firmware.
	ESPAsyncWebServer Library	Enables web-based control of the wheelchair.
	Wi-Fi Communication Protocols	Facilitates data transmission between ESP32 and the web interface.

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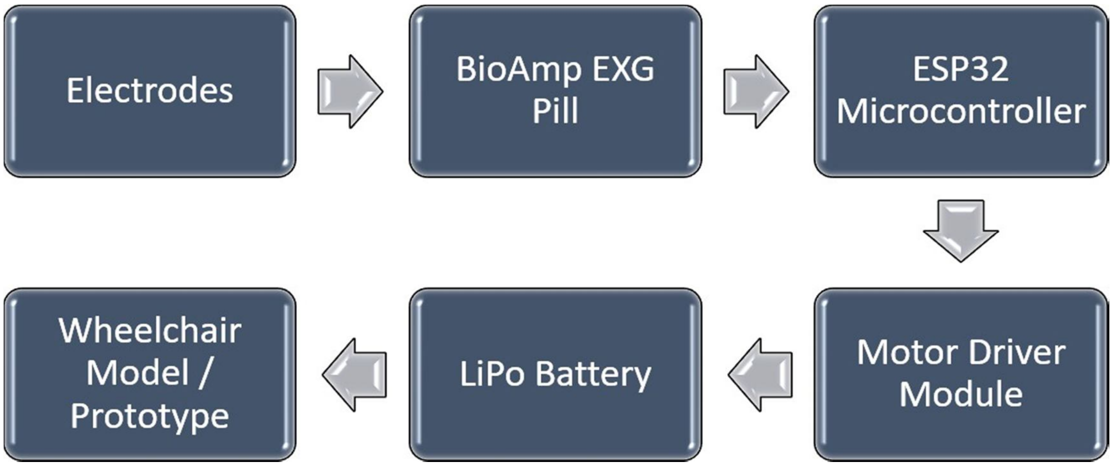
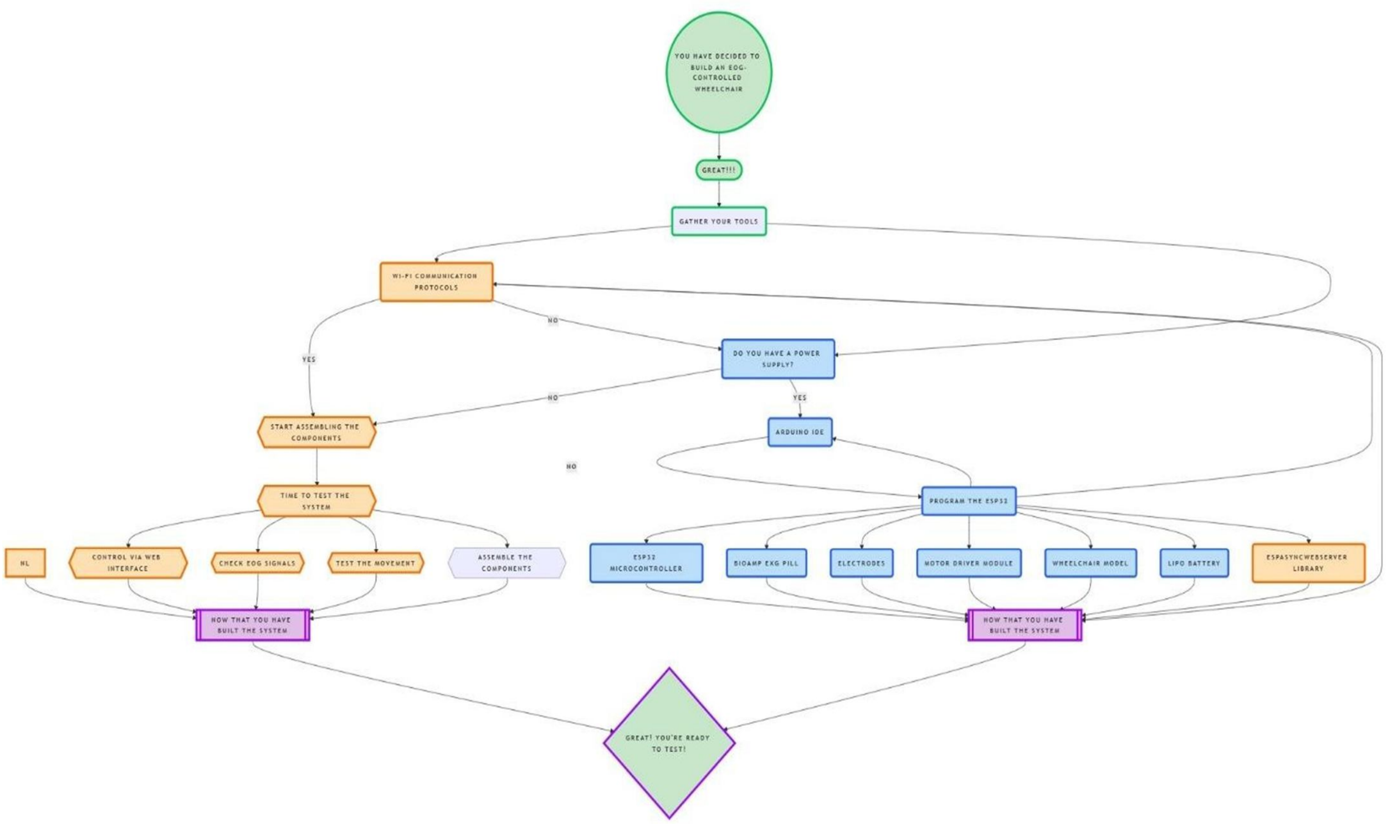
VI. BLOCK DIAGRAM AND FLOW CHART OF THE SYSTEM



A. Explanation Of Block Diagram

1) Electrodes → Capture EOG signals from the user's eye movements or blinks.
2) BioAmp EXG Pill → Amplifies and filters weak EOG signals for processing.
3) ESP32 Microcontroller → Processes EOG signals and sends control commands.
4) Motor Driver Module → Drives the wheelchair motors based on ESP32 signals.
5) LiPo Battery → Provides power to the ESP32, motor driver, and motors.
6) Wheelchair Model / Prototype → Moves in response to control signals.

B. Explanation of Flowchart



1) Decision to Build the Wheelchair: You have decided to build an EOG-controlled wheelchair.
2) Gather Your Tools: Collect all necessary hardware and software components.
3) Wi-Fi Communication Protocols: Ensure Wi-Fi communication is set up for web-based control.
   a. Check Power Supply:
      Yes → Proceed to programming.
      No → Get a power supply before proceeding.
- Arduino IDE: Use Arduino IDE to write and upload the firmware to ESP32.
- Program the ESP32: Flash the ESP32 with code to process EOG signals and control the wheelchair.
   b. Assemble the Components Connect all hardware:
      ESP32 Microcontroller Bio Amp EXG Pill Electrodes
      Motor Driver Module Wheelchair Model LiPo Battery.
- ESP Async Web Server Library: Integrate the ESPA sync Web Server library for web-based wheelchair control.
- System is Built: All components are connected, and the system is ready for testing.
   c. Testing the System: Perform three major tests: Check EOG signals – Validate blink detection.
      Test the movement – Ensure the wheelchair responds correctly. Control via web interface – Confirm remote control works.
- Final Confirmation: Great! You're ready to test! – The system is fully functional and operational.

VII. RESULT AND ANALYSIS

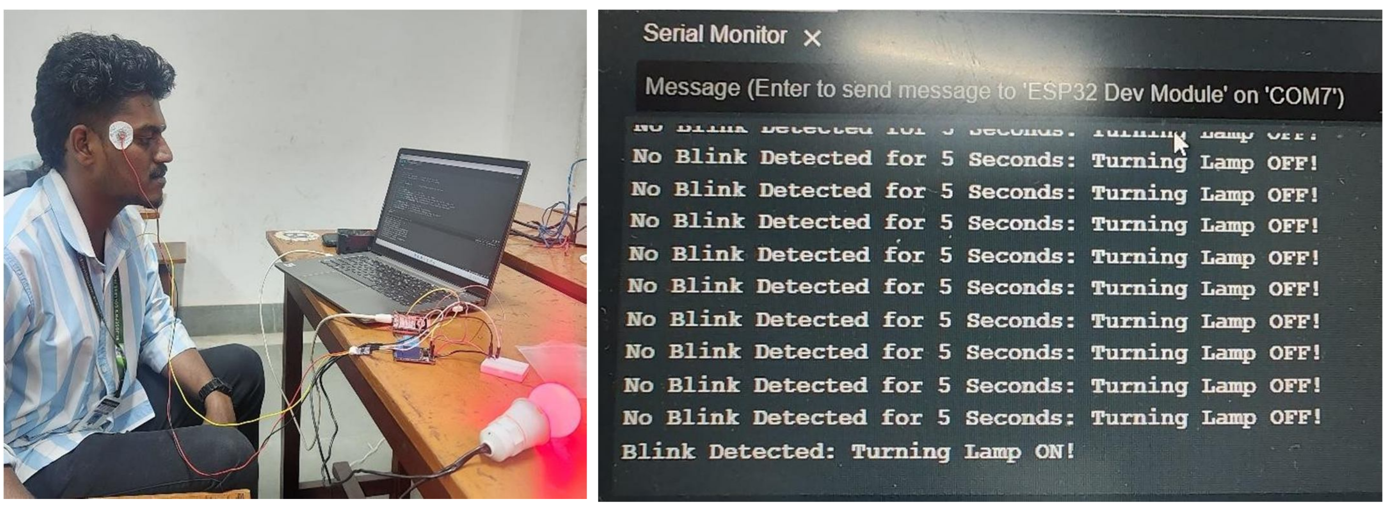


Fig 1: Blink Detection And Response Mechanism

The blinking recognition system identifies purposeful blinking and adjusts the lamp accordingly. As blinking is sensed, the system processes the signal instantaneously to turn on the lamp. System response time is minimal to aid in real-time performance. If no blinking is sensed in five seconds, power consumption is decreased by turning off the lamp. The system was tested in diverse lighting conditions and distances with accurate blinking recognition and minimal false alarms to indicate true processing. The response of the lamp was stable with no visible delay or flickering. Robustness was enhanced by testing by changing eye closure lengths to differentiate between eye movements and intentional blinking. Long-term testing was conducted to monitor stability and performance during extended run. In general, the system demonstrates potential to utilize eye blinking as an additional controlling device.

Adaptive learning algorithms can be included in future development to calibrate recognition to each user. Enhanced algorithms in blinking recognition can minimize false alarms. Expanding the system to be compatible with more smart home equipment can further aid in practical uses.

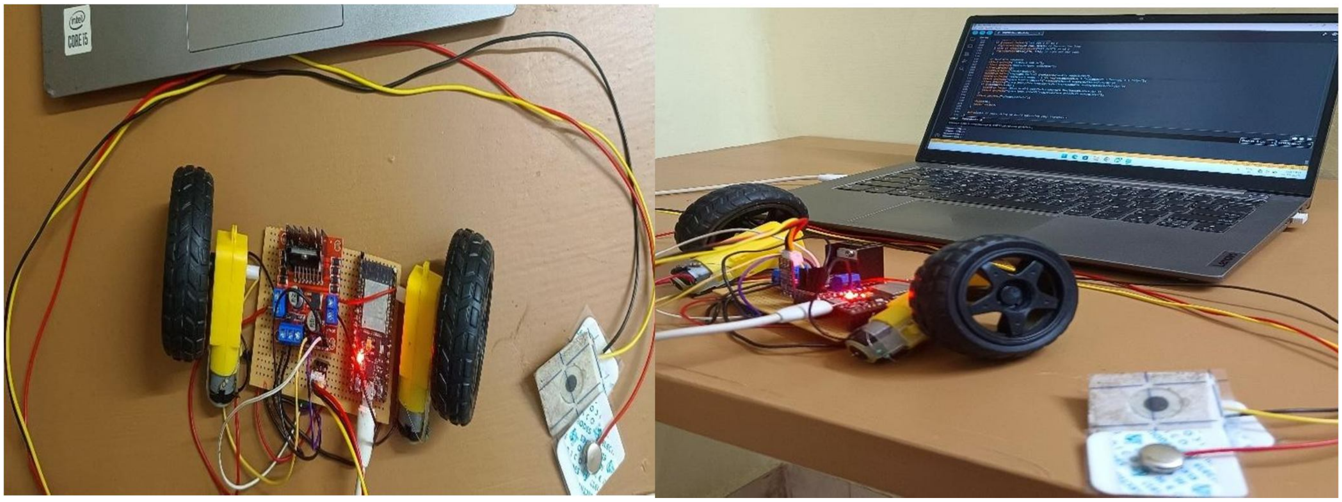


Fig 2: Prototype of Blink Detection-Based Motor Control

The blink detection-based motor control system is designed to assist paralyzed individuals by enabling hands-free movement through voluntary eye blinks. The system captures EOG (Electrooculography) signals through electrodes, which are processed by the ESP32 microcontroller to detect voluntary blinks. Upon detection of a blink, the microcontroller triggers the motor driver module, energizing the motors to move the wheelchair forward. In case of no blink for five seconds, the system automatically disables the motors to prevent undesired movement. The inclusion of Wi-Fi communication allows remote monitoring and control via a web interface, thus enhancing accessibility. The accuracy in blink detection is refined through signal filtering methods to minimize false triggers from spontaneous eye movements. The system is tes ted under varying conditions to ensure reliable performance under real-world scenarios. By providing an intuitive and efficient control method, the technology increases mobility and independence for individuals with motor disabilities. The system performance is measured in terms of blink detection accuracy, motor response time, and overall usability of the system. Potential future improvements include multi-directional control through additional blink patterns or an adaptive learning model for enhanced responsiveness.

VIII. CONCLUSION

The blinking recognition system is proving to be efficient in making purposeful eye blinking an actuating system. Under diverse lighting conditions and distances, through rigorous testing, the system has been stable with minimal false alarms and stable responses to the lamp. The system is also improved by separating purposeful blinking from eye movements. Long-term testing has also confirmed stability and effectiveness in continuous system operation. While available in an implemented shape with promising results, future work can focus on optimizing blink recognition algorithms to prevent spurious activations better. Adaptive learning algorithms can be added to adjust system response to user patterns. Making it increasingly compatible with other smart products can further support making it functional. Besides being employed in home automation, this system can be used in assistive technology in individuals with mobility limitations. As this system is developed further and used in conjunction with other smart control interfaces, this can be developed into an even more universal system accessible to everyone. This work is an introduction to future work in hands-free systems to newer and improved methods of interacting.

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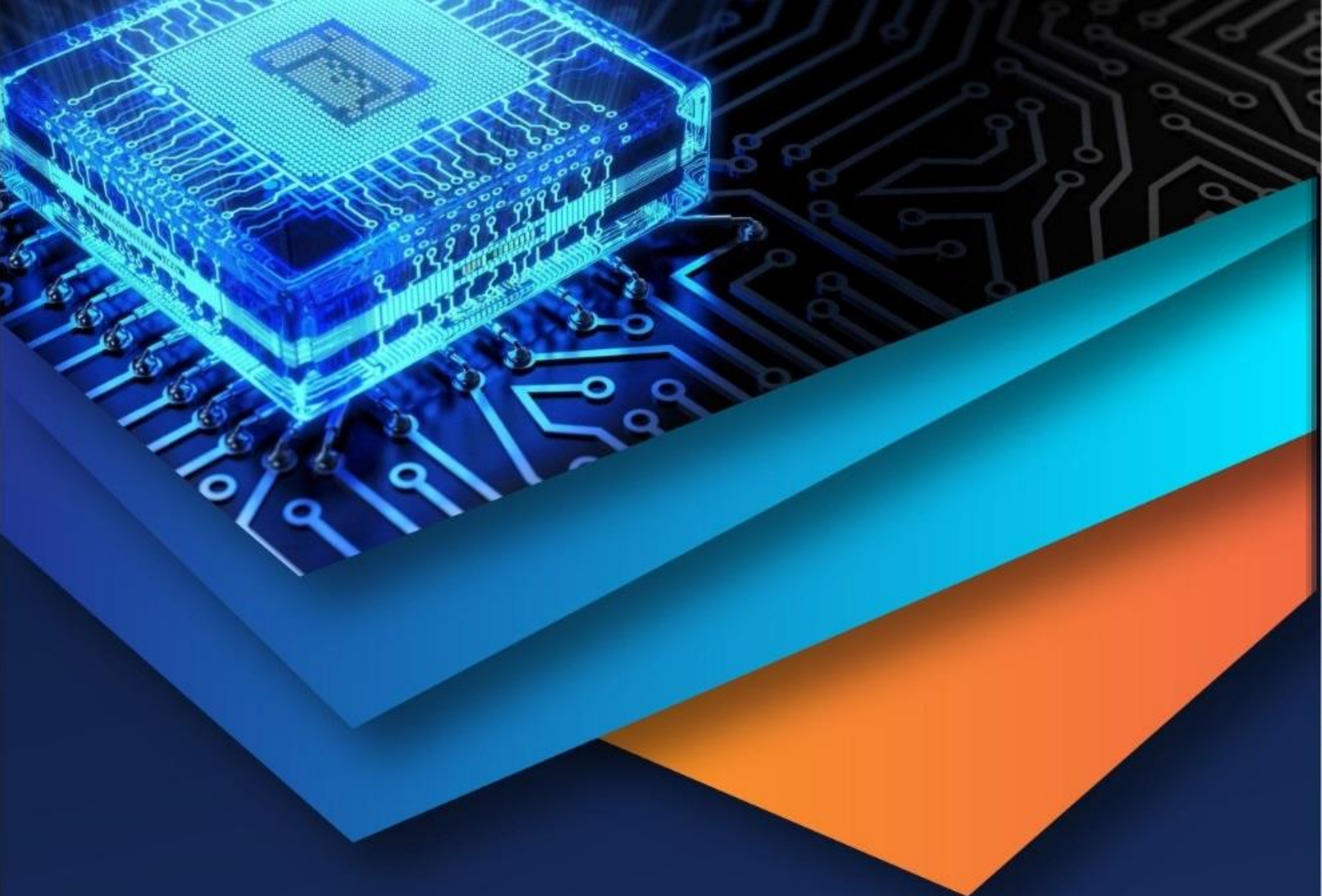

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