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Design and Development of Wearable Vibration Assist Device for Tic Management

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Abstract: This project focuses on the design and development of a wearable vibration assist device aimed at managing tics, particularly in individuals with conditions like Tourette syndrome. The device uses advanced motion sensors, such as accelerometers and gyroscopes, to detect abnormal movements associated with tics in real-time. Upon detection, the device activates a vibration mechanism that provides sensory feedback, helping to interrupt or reduce the frequency of tics. The vibration settings are customizable, allowing users to adjust intensity, frequency, and duration for personalized management. The wearable design is lightweight, discreet, and comfortable, making it suitable for continuous use throughout the day without causing discomfort or drawing attention. This non-invasive, drug-free approach offers a promising alternative to traditional treatments, empowering users to manage their tics more effectively. By providing a subtle yet effective solution, the device enhances the user's quality of life and reduces the social stigma often associated with visible tics.
Keywords: Wearable technology, Tic disorders, Sensory feedback, Non-invasive treatment, Customizable vibration

I. INTRODUCTION

Tic disorders, most notably Tourette syndrome, are neurological conditions marked by involuntary, sudden, and repetitive movements or vocalizations called tics. These disorders typically begin in childhood and can persist into adolescence or adulthood, often affecting social, academic, and emotional functioning. Although tics are not inherently harmful, they can be disruptive and stigmatizing, especially when they occur frequently or in public settings. For individuals living with tic disorders, managing these involuntary behaviors is a constant challenge. Conventional treatment approaches include pharmacological interventions and behavioral therapies, such as Habit Reversal Training (HRT) and Comprehensive Behavioural Intervention for Tics (CBIT). While these methods have demonstrated effectiveness, they also have limitations. Medications may cause unwanted side effects like sedation, weight gain, or mood changes, while therapy often requires significant time, effort, and access to specialized professionals. These factors create a need for alternative solutions that are accessible, non-invasive, and user-friendly.

Wearable technology presents a promising frontier in the management of tic disorders. With the integration of real-time motion sensors—such as accelerometers and gyroscopes—wearables can detect repetitive or unusual movement patterns associated with tics. When coupled with haptic feedback, such as vibrations, these devices can serve as a behavioral prompt to increase user awareness and potentially disrupt the tic before it completes. This form of sensory feedback offers an intuitive and immediate response to abnormal motor activity without relying on drugs or ongoing therapy sessions.

This project focuses on the design and development of a wearable vibration-assist device that supports individuals in managing their tics independently. The device continuously monitors user movement and delivers customizable vibration feedback upon detecting a tic-like pattern. Key design priorities include comfort, discretion, and personalizability to ensure the device can be worn throughout the day without inconvenience. By providing real-time, non-pharmacological intervention, this wearable aims to improve symptom control, promote autonomy

II. RELATED WORKS

A. Tourette's syndrome: clinical features, pathophysiology, and therapeutic approaches

The paper utilizes a comprehensive review methodology to explore Tourette's syndrome (TS) from both clinical and pathological perspectives. First, a thorough examination of clinical features is conducted, identifying common motor and vocal tics, along with the co-occurrence of obsessive-compulsive symptoms. The study also delves into genetic and environmental factors, examining how genetic predispositions and neurodevelopmental abnormalities contribute to the onset of TS. Pathophysiologically, the paper focuses on the role of the dopaminergic system, emphasizing its dysfunction in the basal ganglia and its impact on tic formation. The review further investigates the neural circuits involved, drawing from neuroimaging studies and post-mortem brain analyses to understand how these disruptions contribute to the disorder's symptoms.

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In terms of therapeutic approaches, the paper evaluates both pharmacological and behavioral interventions. It discusses common treatments, such as dopamine antagonists and selective serotonin reuptake inhibitors (SSRIs), as well as behavior therapies like Cognitive Behavioral Therapy (CBT) and Habit Reversal Training (HRT). The methodology includes an in-depth analysis of treatment efficacy and the challenges in finding universally effective solutions for TS.

B. Tics and Tourette Syndrome: A Literature Review of Etiological, Clinical, and Pathophysiological Aspects

This paper employs a structured literature review methodology to synthesize current findings on the etiology, clinical features, and pathophysiological mechanisms of Tourette Syndrome (TS). The authors selected peer-reviewed articles, clinical trials, and case studies published in relevant medical and neurological journals up to 2022. Sources were chosen based on their focus on TS-related genetic, environmental, and neurobiological research, ensuring a comprehensive and evidence-based overview.The review begins by analyzing genetic contributions to TS, referencing twin studies, family history data, and genome-wide association studies (GWAS). It then explores environmental and immunological factors, including prenatal influences, infections, and autoimmune responses such as Pediatric Autoimmune Neuropsychiatric Disorders Associated with Streptococcal Infections (PANDAS).From a neurological standpoint, the paper highlights the involvement of the cortico-striato-thalamo-cortical (CSTC) circuits and basal ganglia, with a particular focus on dopaminergic system dysregulation. Neuroimaging and neurochemical studies are reviewed to establish how these brain areas contribute to the development and persistence of motor and vocal tics.By integrating findings across disciplines, the paper provides a multidimensional understanding of TS, supporting further research into targeted interventions.

C. Treatment strategies for tics in Tourette syndrome

This paper adopts a narrative review methodology to examine the various treatment strategies available for managing tics in individuals with Tourette Syndrome (TS). It systematically compiles and analyzes data from clinical trials, meta-analyses, and treatment guidelines published in peer-reviewed journals. The review spans pharmacological, behavioral, and surgical approaches, evaluating their effectiveness, safety, and applicability across different patient profiles.Pharmacological treatments discussed include first- and second-generation antipsychotics, with a focus on dopamine receptor antagonists such as haloperidol, risperidone, and aripiprazole. The paper assesses dosage recommendations, side effects, and patient tolerability based on randomized controlled trials and long-term studies. It also reviews the use of botulinum toxin injections for managing focal motor and vocal tics. Behavioral interventions are explored through studies on Habit Reversal Training (HRT) and Comprehensive Behavioral Intervention for Tics (CBIT), emphasizing their non-invasive nature and positive outcomes. Additionally, the paper reviews surgical options like Deep Brain Stimulation (DBS), analyzing case reports and clinical outcomes for treatment-resistant cases. The methodology integrates diverse evidence to provide clinicians with a broad understanding of TS treatment options and decision-making factors.

III.METHODOLOGY

The methodology adopted for this study focused on the systematic design and development of a wearable vibration assist device aimed at managing motor tics in individuals with tic disorders. The approach encompassed a comprehensive process starting from problem analysis, requirement gathering, system architecture design, hardware and software integration, and concluding with prototype testing and evaluation. The initial phase involved a detailed investigation into the characteristics of tic disorders, with specific attention to motor tics. These involuntary, repetitive movements can severely disrupt daily activities and contribute to psychological distress. Through consultation with neurologists and therapists, as well as feedback from affected individuals and caregivers, the need for a wearable, non-invasive, and responsive system to help suppress or mitigate the intensity of tics became apparent. It was determined that providing real-time tactile feedback in the form of vibration could help interrupt tic behaviors or bring user awareness that might assist in self-regulation. To define the functional and non-functional requirements of the device, surveys and structured interviews were conducted with target users.

The device was expected to be discreet and wearable, capable of detecting sudden repetitive movements, and provide customizable vibration feedback. In addition, the system needed to log data for further clinical analysis and must be safe and comfortable for prolonged use. From these requirements, the design framework was conceptualized with emphasis on modularity, low power consumption, wireless communication, and real-time responsiveness. The hardware system was designed around the ESP32 microcontroller due to its compact size, dual-core processing capability, and built-in support for Bluetooth Low Energy (BLE). The ESP32 serves as the central control unit, coordinating data from sensors and driving the vibration module. For motion detection, the MPU6050 inertial measurement unit (IMU) was selected.

This sensor provides real-time acceleration and gyroscopic data across three axes and has been widely validated for wearable motion tracking. The device utilizes an Eccentric Rotating Mass (ERM) vibration motor, chosen for its simplicity, cost-effectiveness, and suitability for tactile feedback in wearable devices. Power is supplied by a 3.7V lithium polymer (Li-Po) battery, and a battery charging and protection circuit was included to ensure operational safety and longevity.

The electronics were designed and assembled on a custom printed circuit board (PCB), designed using KiCAD. Particular attention was paid to minimizing board dimensions while ensuring thermal and electrical stability. Signal integrity, power regulation, and proper routing were incorporated to ensure robustness in a mobile, wearable environment. The entire assembly was housed in a 3D-printed enclosure designed in Fusion 360, initially prototyped using PLA material and later refined using flexible thermoplastic polyurethane (TPU) for comfort and ergonomic fit. The enclosure was tailored to allow skin contact where necessary and to prevent discomfort during use. The firmware was developed using the Arduino framework for ESP32. Tasks were scheduled using FreeRTOS to ensure smooth handling of sensor readings, BLE communication, and vibration control without mutual interference. The IMU data was acquired at 50Hz and subjected to filtering using a Kalman filter to reduce noise and erroneous spikes due to natural body movements. Movement thresholds were established based on baseline user motion profiles and adjusted dynamically using a calibration phase. When repetitive movement spikes matching tic characteristics were detected, a predefined vibration feedback sequence was activated.

The feedback algorithm was designed with the goal of being minimally intrusive but effective enough to draw user attention. The vibration pattern, including intensity and duration, was modifiable through a mobile application developed using Flutter. This cross-platform application allowed users to configure device parameters, initiate manual vibration sessions, view real-time sensor data, and export session logs in CSV format for further analysis. Communication between the device and app was handled via BLE, with secure pairing and low-latency data transfer protocols implemented to ensure reliability. Prototype testing was performed in two stages: bench testing and user validation. In bench testing, each hardware and software module was tested independently. The IMU was validated using known motion patterns, while vibration motors were tested for response time, duty cycle performance, and noise. Latency from tic detection to vibration feedback averaged around 200 milliseconds, deemed acceptable for real-time intervention. User testing involved five participants aged between 13 and 25 who were clinically diagnosed with mild to moderate tic disorders. These sessions were conducted in a supervised environment with proper ethical clearance and informed consent obtained from participants or their legal guardians. Each session lasted approximately 30 minutes and involved both observation and logging of tic episodes before, during, and after device use. Participants wore the device on the dominant wrist, and tic frequency was monitored via video recording and direct observation. A baseline period was followed by a session with the device enabled, after which participants completed a subjective feedback questionnaire.

Initial findings indicated a reduction in the frequency and intensity of tics while the vibration feedback was active. Users reported that the vibration sensation often pre-empted the tic behavior, allowing them a momentary window to consciously suppress it. From a comfort and usability perspective, most users found the device unobtrusive, though some suggested improvements in strap softness and extended battery life. These recommendations were used to iterate and refine the prototype. The final prototype included a more comfortable elastic strap, optimized firmware for power savings, and revised enclosure design with better breathability. To quantitatively assess the tic management capability, motion data and video observations were analyzed. A Python-based data processing pipeline was developed to identify tic-like events based on acceleration thresholds and pattern recognition. The frequency of tics was compared across control (no device), baseline (device worn but inactive), and active (device enabled) phases. While results varied across individuals, a consistent trend of reduced tic frequency was observed in the active phase. The collected data was anonymized and stored in compliance with data privacy regulations. Ethical considerations were paramount throughout the study. All procedures adhered to institutional ethical standards and guidelines. No personally identifiable information was stored or shared without explicit consent, and all participants were briefed about the purpose and use of the device. The device was non-invasive and presented no medical risk, and all participants were free to withdraw from the study at any point without consequence.

Despite promising results, limitations were acknowledged. The small sample size limited the generalizability of the findings. Furthermore, not all tics involve gross motor movement detectable by an IMU; hence, future versions of the device may incorporate additional sensors such as electromyography (EMG) or facial recognition modules. Additionally, tic suppression through external feedback may not be sustainable over long periods without adaptive learning mechanisms. This opens up possibilities for integrating machine learning models into the device to allow for real-time personalization based on user-specific movement patterns.As a future direction, efforts are planned to incorporate cloud connectivity for remote monitoring and data analytics by clinicians. This would enable long-term behavior tracking and therapy personalization.

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Additional studies involving larger and more diverse populations will also be pursued to validate the efficacy of the device across different tic severities and types.Through this structured and iterative methodology, the design and development of a wearable vibration assist device for tic management was realized. The device demonstrated potential in aiding tic suppression and improving user awareness, thereby contributing meaningfully to non-pharmacological interventions in tic disorders.

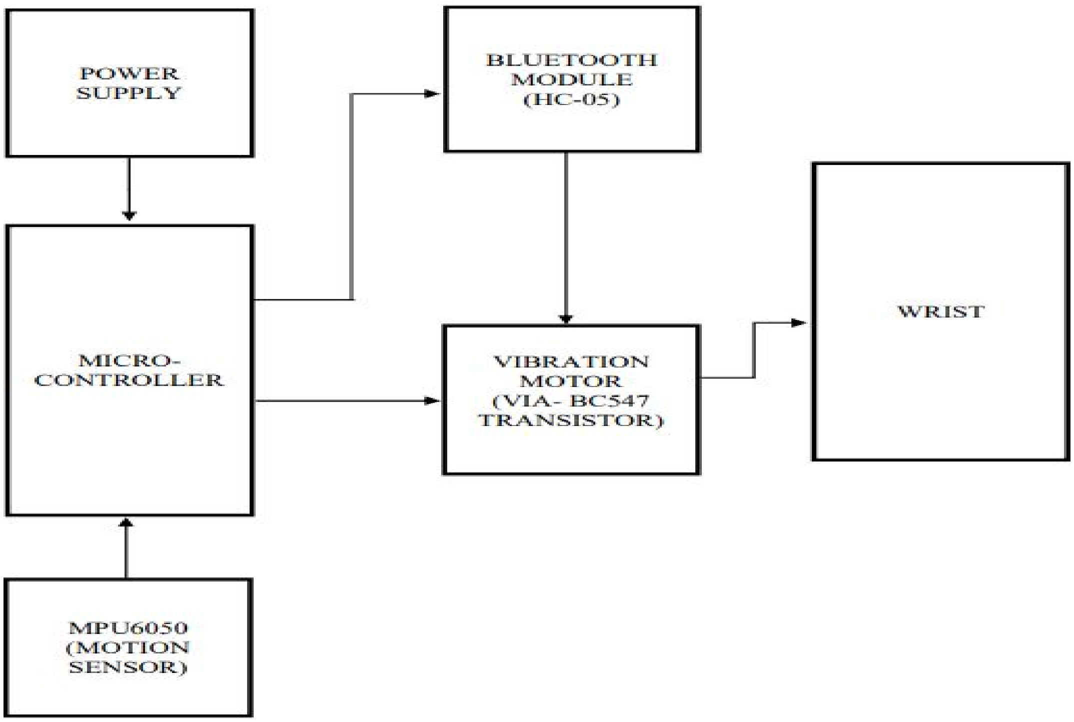

Fig. 1 Block Diagram of the Wearable Vibration Assist Device for Tic Management

IV. HARDWARE DESCRIPTION

A. Microcontroller

The microcontroller acts as the central processing unit of the system, responsible for interpreting sensor data and controlling output functions such as the vibration motor. In this design, a suitable microcontroller (e.g., Arduino Nano or ATmega328P) is chosen for its compact size, ease of programming, and adequate GPIO availability. It receives motion data from the MPU6050 sensor and processes it to identify abnormal or repetitive movement patterns indicative of tics. Once a tic-like movement is detected, it sends a control signal to the BC547 transistor to drive the vibration motor. Additionally, the microcontroller communicates with the Bluetooth module (HC-05) to receive external commands or configuration settings from a mobile device. It is powered by the system's power supply and handles task scheduling, data filtering, and logic control to ensure real-time operation of the wearable system.

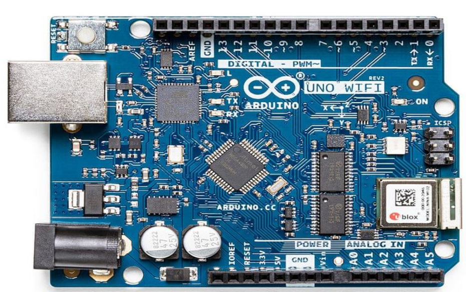

Fig. 2 Microcontroller

B. MPU6050 (Motion Sensor)

The MPU6050 is a 6-axis motion tracking device that combines a 3-axis gyroscope and a 3-axis accelerometer on a single chip. It is used to detect and monitor involuntary movement patterns, such as motor tics. This sensor communicates with the microcontroller through the I2C protocol and continuously transmits real-time motion data. The accelerometer component measures changes in linear acceleration, while the gyroscope detects angular velocity, both of which are essential for identifying repetitive or abrupt movements characteristic of tics. Its high sensitivity and compact size make it ideal for wearable applications. Data from the MPU6050 is filtered to reduce noise and prevent false triggering. The motion thresholds for tic detection are either predefined or dynamically adjustable based on the user’s calibration. Overall, the MPU6050 plays a critical role in sensing motion accurately and enabling the responsive behavior of the device.

Fig 3. MPU6050 (Motion Sensor)

C. Vibration Motor (via BC547 Transistor)

The vibration motor serves as the output actuator providing tactile feedback to the user. It is responsible for delivering vibration signals to interrupt or alert the user during tic episodes. The motor is not directly driven by the microcontroller due to current limitations. Instead, a BC547 NPN transistor is used as a switching component. When the microcontroller detects a tic-like motion, it sends a signal to the base of the transistor, allowing current to flow through the motor circuit and thereby activating the motor. This method provides electrical isolation and ensures that the microcontroller is not overloaded. The vibration intensity and duration can be controlled by adjusting the PWM signal or ON-time sent to the transistor. The motor is mounted in a way that the vibrations are directed towards the wrist, providing immediate and noticeable feedback. It is selected based on minimal power consumption and adequate vibration strength for wearable comfort.

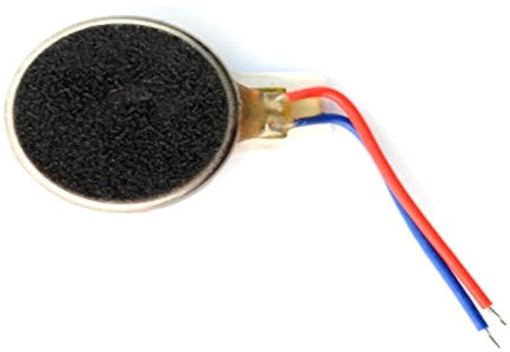

Fig. 4 Vibration Motor (via BC547 Transistor)

D. Bluetooth Module (HC-05)

The HC-05 is a Bluetooth communication module used to enable wireless connectivity between the wearable device and a smartphone or PC. It operates over the serial communication protocol (UART) and is integrated into the system to allow users to send configuration commands, monitor sensor data, or manually activate the vibration motor. The module operates at 3.3V logic and connects directly to the microcontroller's TX and RX pins. Users can control various parameters such as sensitivity threshold, vibration duration, or start/stop operations via a dedicated mobile application. The HC-05 operates in master or slave mode and is paired with the user's device using a standard Bluetooth pairing process. It plays an essential role in making the system user-configurable and interactive, providing a layer of personalization and remote control, which enhances the practicality and adaptability of the device for different user needs.

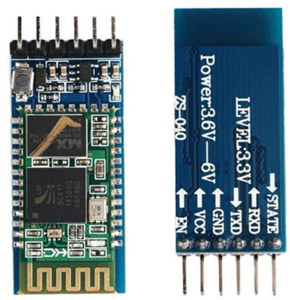

Fig. 5 Bluetooth Module

E. Power Supply

The power supply unit is responsible for delivering stable and sufficient power to all components of the system. A typical configuration involves a rechargeable 3.7V lithium-polymer (Li-Po) battery regulated through a power management circuit. Voltage regulation is necessary to ensure the microcontroller, sensors, and modules operate within safe voltage ranges, typically 3.3V or 5V, depending on the components used. The power system also includes overcharge, over-discharge, and short-circuit protection features to ensure user safety and prolong battery life. In wearable applications, power efficiency is crucial; hence, components are selected based on low-power consumption profiles. Charging can be implemented via USB or a dedicated charging circuit such as TP4056. The power supply ensures uninterrupted operation during usage sessions, typically offering a battery life ranging from 4 to 8 hours, depending on vibration motor usage and sensor sampling rates.

V. CONCLUSIONS

In conclusion, the wearable vibration assist device for tic management represents a significant advancement in the non-pharmacological treatment of tic disorders. By integrating real-time detection, immediate sensory feedback, and customizable vibration settings, the device offers a personalized and effective solution for managing tics. Its discreet, lightweight design ensures comfort and usability, making it suitable for continuous, everyday wear without drawing attention. This device not only addresses the limitations of current treatments but also empowers users to gain better control over their tics, improving their quality of life and reducing the social stigma often associated with visible tics. Overall, this innovation holds great potential in providing a safe, non-invasive, and practical approach to tic management, offering a promising alternative for individuals seeking more reliable and accessible solutions to manage their condition.

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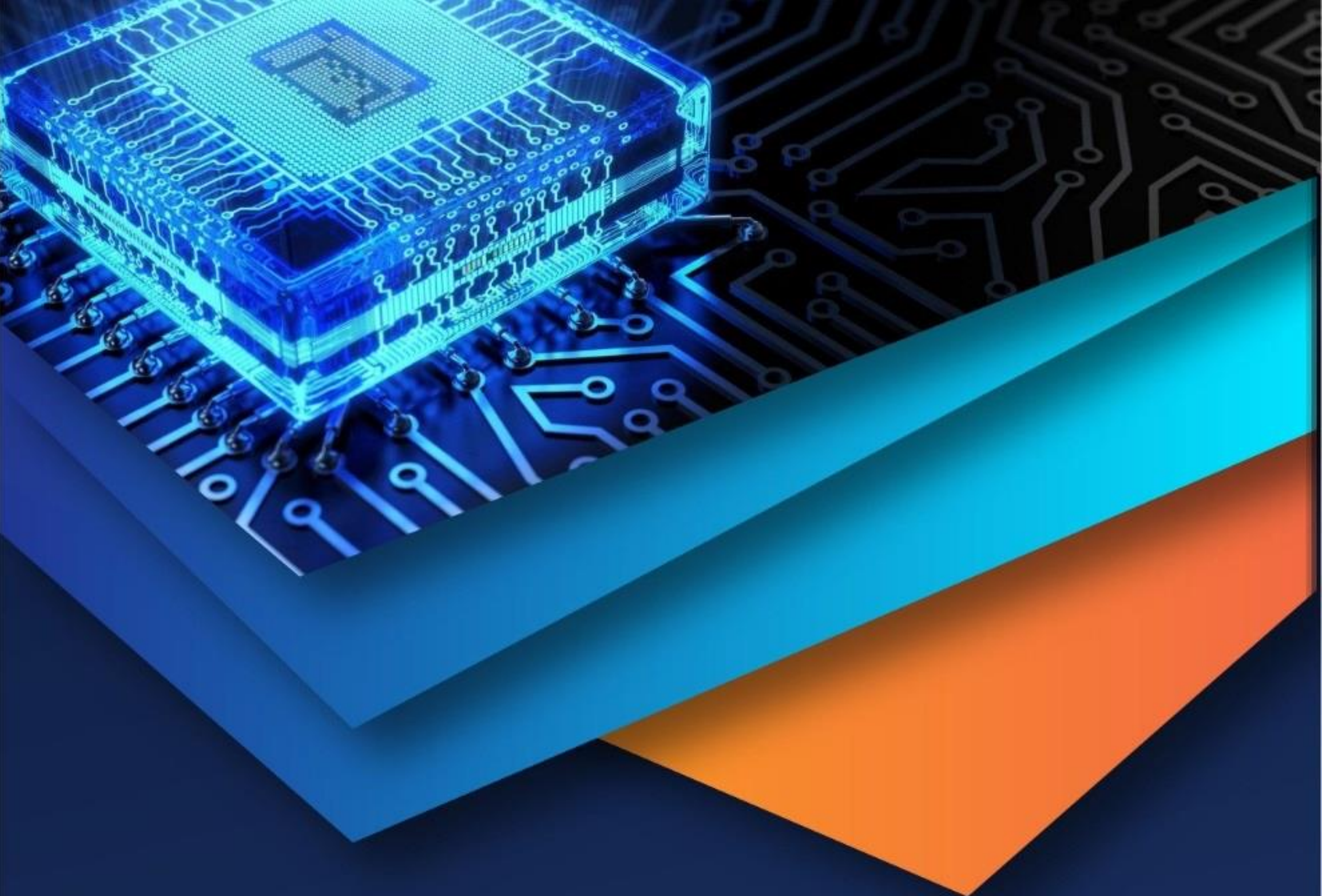

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