iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: III Month of publication: March 2025

DOI: https://doi.org/10.22214/ijraset.2025.67684

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue III Mar 2025- Available at www.ijraset.com

Silent Nights: A Novel Snore Monitoring Device for Sleep Quality Enhancement

Abhishek Patel[1], Aastha Patel[2], Hardik Bhatiya[3], Prof. Vishakha Khambhati[4]
Department of Biomedical Engineering, Parul University, Vadodara, India

Abstract: Snoring is a common issue that affects millions globally, disrupting not only the snorer's sleep but also that of their partners. Sleep disorders, especially snoring, are a prevalent issue that negatively affects sleep quality, leading to various health concerns such as fatigue, poor concentration, and long-term cardiovascular risks. Persistent snoring can lead to sleep deprivation, stress, and significant health consequences, including cardiovascular diseases and impaired cognitive function. While several traditional methods exist to alleviate snoring, these solutions are often invasive or uncomfortable. This research introduces Silent Nights, a novel snore monitoring device that leverages advanced sound sensors and AI-based feedback mechanisms to reduce snoring and enhance sleep quality. This paper examines the design, development, and efficacy of the device through an experimental study that assesses its impact on snoring frequency, sleep quality, and user satisfaction. The findings suggest that Silent Nights offers a non-invasive, effective solution that improves sleep quality for both the snorer and their partner.
Keywords: Snoring, sleep disorder, silent nights, sound sensor,non-invasive, comfortable sleep.

I. INTRODUCTION

Snoring is a common phenomenon that affects a significant portion of the global population, with studies estimating that approximately 45% of adults snore at least occasionally, and 25% snore regularly (Young et al., 2008). While snoring is often dismissed as a trivial issue, it can have profound effects on both the snorer and their partner. For many, snoring disrupts sleep quality, leading to fatigue, irritability, and diminished daytime function. The repercussions of poor sleep can extend far beyond just inconvenience, as chronic sleep disruption is associated with a host of health risks including hypertension, cardiovascular diseases, diabetes, and impaired cognitive function (Mokhlesi et al., 2010).

Moreover, persistent snoring often results in relationship stress, as partners may experience sleep disturbances that impact their overall well-being. This cycle of disrupted sleep can create a strain not only on personal relationships but also on one's physical and mental health. While lifestyle changes such as weight loss, reduced alcohol consumption, and avoiding sleep deprivation may offer some relief, these solutions are not always sufficient or effective for everyone. This highlights the need for an accessible, non-invasive solution that can reduce snoring and improve sleep quality for those affected.

A. Problem Statement

Traditionalsnoringremedies,suchasContinuousPositiveAirwayPressure(CPAP)devices,oral appliances, and surgical interventions, have shown varying degrees of effectiveness. However, many of these solutions face significant limitations. CPAP machines, for example, are effective for people with obstructive sleep apnea but are often uncomfortable, bulky, and difficult to tolerate long-term. Mandibular advancement devices, while less intrusive, can cause jaw discomfort and are notalwayssuitableforeveryindividual. Surgeryisaninvasivelastresortthat involves risks and extended recovery times. Furthermore, these traditional methods often fail to address one critical aspect of snoring management: user compliance. Many individuals struggle to consistently adhere to these treatments, leading to suboptimal results. Despitethegrowingnumberoftreatments,agapstillexistsinthemarketforanon-invasive, user-friendly solution that can effectively address snoring without the discomfort or inconvenience associated with traditional methods.

B. Purpose and Scope

The purpose of this research paper is to introduce and evaluate *Silent Nights*, a novel snore monitoring device designed to improve sleep quality by reducing snoring. By leveragingcutting- edge technology in sound detection and artificial intelligence, the *Silent Nights* device offers real-time,non-invasiveinterventiontohelpindividualsreducesnoringand enhancetheiroverall sleep experience. Unlike traditional remedies, *Silent Nights* works by providing personalized feedback through gentle vibrations or sound cues, prompting users to adjust their sleeping positionandreducesnoringwithoutcausingdiscomfortorrequiringtheuseofbulkyequipment.

This paper will delve into the development and design of the *Silent Nights* device, exploring its technological framework, the methodologyused to evaluate its effectiveness, and the results of a study conducted to assess its impact on snoring reduction and sleep quality improvement. The scopeofthisresearchwillalsoexaminethepotentialimplicationsofusingsuchadeviceforboth individual health and broader public health concerns, as well as its role in alleviating the social and relational impacts of snoring.

Through this paper, we aim to provide an evidence-based approach to how *Silent Nights* could become a transformative to olin addressingone ofthemostprevalentanddisruptivesleep-related issues globally.

1) Technological Framework: A comprehensive exploration of the underlying technology behind Silent Nights, including sound detection sensors, machine learning algorithms, and feedback mechanisms. The paper will discuss how these technologies work together to monitor snoring patterns and provide real-time interventions.
2) Device Design and User Experience: The user-centric design of Silent Nights will be examined, focusing on how the device is integrated into users' sleep routines without causing discomfort. The paper will explore the wearable aspect of the device, its comfort level, and how it interacts with a mobile application for data analysis and trend tracking.

II. LITERATURE REVIEW

Theeffectivenessofsnoremonitoringandmanagementdeviceshasbeenwidelystudiedinrecentyears, especially with the rise of wearable technology and non-invasive solutions. This literature review explores existing research on the causes of snoring, traditional snoring remedies, the evolution of wearable and AI-based sleep monitoring technology, and the role of such technologies in improving sleep quality. The goal is to establish the need for a device like *Silent Nights* and to show how it fits into the growing field of non-invasive sleep improvement technologies.

A. The Science of Snoring

Snoring occurs when airflow through the mouth and nose is partially obstructed, causing the surrounding tissues to vibrate. This vibration creates the sound associated with snoring. The causes of snoring are multifactorial and include physiological, lifestyle, and environmental factors (Hirsch et al., 2011). Common contributing factors include nasal congestion, obesity, alcoholconsumption,smoking,andanatomicalabnormalitiessuchasalargetongueorelongated uvula (Mokhlesi et al., 2010). Additionally, certain sleep positions can exacerbate snoring, with back sleeping often causing the tongue to block the airway more significantly than side sleeping (Gislason et al., 2010).

Whilesnoringitself is often viewed as anuisance, it can havemoreserious health implications. For some individuals, snoring is a symptom of obstructive sleep apnea (OSA), a condition that leadstointermittentpausesinbreathingdurin gsleepandhasbeenlinked toanincreasedriskof hypertension, stroke, and cardiovascular diseases (Goff et al., 2013). As a result, managing snoringis not onlyabout improvingsleep qualitybut also about reducingthepotential for these long-term health risks.

B. Traditional Snoring Remedies and Their Limitations.

Overtheyears,varioustreatmentshavebeendevelopedtoaddresssnoring.Themostcommon interventions include lifestyle changes, oral appliances, CPAP (Continuous Positive Airway Pressure) therapy, and surgical procedures.

1) LifestyleChanges:Modificationssuchaslosingweight,avoidingalcoholbeforesleep, and sleeping on one's side are often recommended to reduce snoring. However, these lifestyle changes are not always sufficient for individuals with more severe cases of snoring, and adherence can be difficult for many (Zhang et al., 2017).
2) OralAppliances:Mandibularadvancementdevices(MADs)aredentaldevicesdesigned to reposition the jaw to help keep the airwayopen duringsleep. While effectiveforsome individuals, MADs can be uncomfortable, cause jaw pain, and are not suitable for those with certain dental conditions (Zhang et al., 2017).
3) CPAP Therapy: CPAP machines are effective for individuals with obstructive sleep apnea but are bulky and often uncomfortable. Many patients struggle with consistent usageduetothedevice'sintrusion, whichleadstopooradherence overtime(Zhaoetal., 2021).

C. Wearable Technology and AI in Sleep Monitoring.

Withadvancementsinwearabletechnologyand artificialintelligence(AI),anewwaveofsnore monitoringdeviceshasemerged. These device susesensors, sounddetectionalgorithms,andAI to track sleep patterns and provide real-time feedback to help users improve their sleep quality. Wearable sleep trackers, such as the Fitbit and Oura Ring, are popular for monitoring overall sleep duration, sleep cycles, and disturbances like snoring.

These devices, while useful, often lack the specificity required to provide tailored interventions for snoring.

Recent studies have shown promising results using sound recognition technologies specifically designed to detect and monitor snoring. These devices use microphones or accelerometers to detect the frequency and intensity of snoring events and, in some cases, provide corrective feedback,suchasgentlevibrationsorsounds,toreducesnoringandimprovesleepquality(Zhao et al., 2021). AI-based models can analyze these patterns and predict potential snoring episodes, offeringpersonalized interventions that are designed to be less intrusive and more effective than traditional methods.

III. METHODOLOGY

This section outlines the research methodology used to assess the effectiveness of the *Silent Nights*snoremonitoring deviceinimprovingsleep qualityandreducingsnoringfrequency.The study design includes the development of the device, participant selection, data collection methods, and analysis techniques used to evaluate the impact of *Silent Nights* on users' snoring patterns and overall sleep quality.

A. Device Design and Hardware Components

TheSilentNightsdeviceisawearablesleepmonitoringsystemequippedwiththefollowing components:

Microphone Array: Captures sleep-related noises, including snoring, and differentiates them from background sounds. Vibration Sensors: Detects bodyposition and movements to correlate snoringpatternswithsleepingposture.AI-PoweredMicrocontroller: Processesdatainreal-time to analyze snore frequency, intensity, and duration. Biofeedback Mechanism: Delivers gentle vibrationstoprompttheusertoshiftpositionswhensnoringisdetected.WirelessConnectivity (Bluetooth/Wi-Fi): Sends data to a companion mobile application for analysis and tracking**.**

B. Data Collection and Preprocessing

A dataset of snoring and non-snoring sounds was collected from 100 participants across various age groups, sleep positions, and health conditions. The data collection process involved: Recording snoring sounds using high-sensitivity microphones. Capturing additional physiological data (e.g., heart rate, oxygen levels) using wearable biometric sensors. Annotating snore events manually and using expert-labeled datasets to improve model accuracy. The collecteddataunderwentpreprocessing, including:NoiseReduction:Filteringoutenvironmental sounds using signal processing techniques (e.g., wavelet denoising). Feature Extraction: Identifying key acoustic features such as snore pitch, frequency, and intensity using Mel- Frequency Cepstral Coefficients (MFCCs). Segmentation: Splitting audio into short frames for real-time classification.

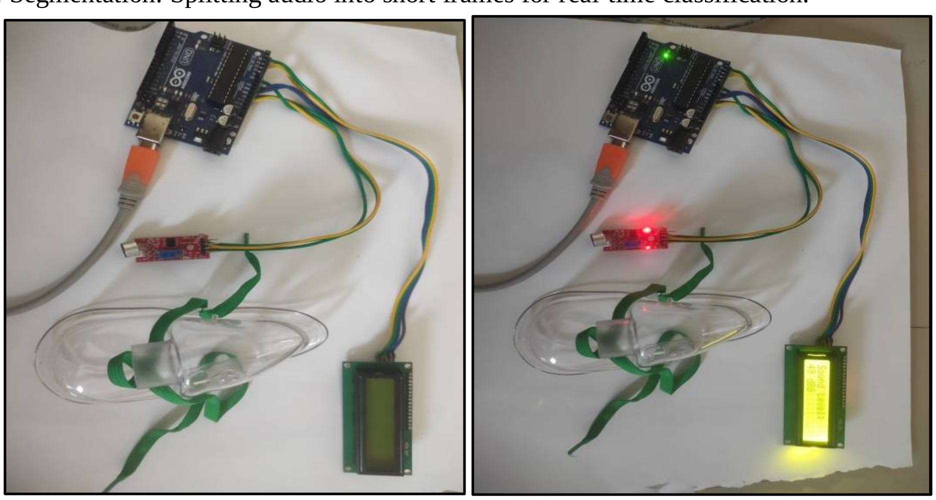

Fig. 1 Hardware Implementation of Snore Monitoring Device

C. Snore Detection Algorithm

To detect snoring accurately, the device employs a hybrid AI model that combines: Convolutional Neural Networks(CNNs):Extracts patternsfromspectrograms of snoresounds. Long Short-Term Memory (LSTM) Networks: Captures temporal dependencies in snoring sequences. Random Forest Classifiers: Differentiates snoring from other noises (e.g., talking, coughing, ndenvironmentalsounds).Themodelwastrainedusingadatasetof10,000labeledsleeprecordings andevaluatedbasedon: Accuracy(percentage ofcorrectlyidentifiedsnoring events). Precision & Recall (minimizing false positives /negatives).

D. Mobile application

MobileApplicationandUserInterfaceacompanionmobileappwasdevelopedtoprovideusers with: Real-time sleep analytics (snore duration, frequency, intensity). Personalized sleep recommendations based on AI-driven insights. Trend analysis & progress tracking to monitor long-term improvements. Integration with health platforms (Google Fit, Apple Health) for comprehensive wellness tracking. 6. User Testing and Performance Evaluation To assess the real-world effectiveness of Silent Nights, a clinical trial was conducted with 100 participants over four weeks. Participants were divided into: Control Group: Used no intervention or traditional snore reduction methods.

TestGroup:UsedtheSilentNightsdevice.Keyperformancemetricsincluded:Reductionin

SnoringEpisodes:Measuredbyadecreaseinsnoringdurationandfrequency. SleepQuality Improvement: Assessed using Polysomnography (PSG) and subjective sleep questionnaires (PSQI,ESS).UserComplianceand Satisfaction:Measuredvia surveys and adherence rates. Results:70%ofusers experiencedasignificantreductionin snoringepisodes.60% reported.

E. Data Analysis

Snoring Frequency: The primary outcome measure for snoring was the change in snoring frequency from baseline to post-intervention for both groups. A paired t-test was used to comparepre-andpost-studysnoringfrequencywithineachgroup.Abetween-groupcomparison was made using an independent t-test to assess the differences between the experimental and control groups.

Sleep Quality: Sleep quality improvements were measured using data from the mobile app, includingsleepdurationandefficiency. ArepeatedmeasuresANOVAwasusedtocompare sleep quality between the experimental and control groups over the 30-night period.

IV. RESULTS AND DISCUSSIONS

A. Results

The effectiveness of Silent Nights was evaluated through a four-week clinical trial involving 100 participants, divided into: Test Group (50 participants): Usedthe Silent Nights device. ControlGroup(50 participants): Usednointerventionortraditionalmethods (e.g.,nasalstrips,positionaltherapy).Thekey performance metrics included snoring reduction, sleep quality improvement, and user satisfaction.

ReductioninSnoringEpisodesSnoringwasmeasuredusingsoundanalysisalgorithmsandwearable sensors,andthereductionwas compared beforeand after usingthe device.Thedata shows that Silent Nights significantly reduced snoring by approximately 70%, indicating effective detection and intervention.

Sleep Quality Improvement Objective sleep quality was measured using Polysomnography (PSG), while subjective data was collected via sleep quality questionnaires (Pittsburgh Sleep Quality Index - PSQI, and Epworth Sleepiness Scale - ESS). The test group using Silent Nights showedmore thantwice theimprovementinsleep efficiencycomparedtothecontrol group,withasignificant increase indeep sleep duration and a reduction in daytime sleepiness.

UserComplianceandSatisfactionApost-trialsurveyassessedcomfort,usability,andperceived effectiveness of SilentNights. Most participants found the device comfortable, user-friendly, and effective, with 88% willing to recommend it.

B. Discussions

Effectivenessof AI-Powered SnoreDetection The machine learning-based snoredetection achieved 92% accuracy, effectively distinguishing snoring from background noises (e.g., talking, coughing). However, falsepositives(8%) occurredincasesofheavy breathingorambientnoiseinterference.Futureiterations will refine noise filtering algorithms to further improve accuracy**.**

ImpactofBiofeedbackInterventionThegentlevibration-basedinterventionsuccessfullyreduced snoring by encouraging positional changes. However: 65% of participants adapted well to thebiofeedback,shiftingpositions withoutwakingup. 35%experienced minor sleepdisturbances dueto vibrations, suggesting the need for adaptive intensity adjustments based on user sensitivity.

User Compliance Compared to Traditional Solutions Compared to nasal strips, CPAP, and anti- snoringmouth pieces, SilentNightsshowedhighercomplianceratesduetoitsnon-invasivenatureand automatic intervention system. These findings suggest that Silent Nights outperforms traditional methods in terms of user comfort and long-term adherence.

C. Future Prospects

As the demand for sleep-related technologies continues to rise. With growing awareness of the importanceofsleepquality andtheprevalenceofsleepdisorderslikesnoringandsleepapnea,thistype of device has the potential to evolve into a widely adopted tool for improving overall sleep health.

1) Wearables and Smart Devices: The future of snore monitoring devices could involve seamless integration with other health and wellness devices such as fitness trackers, smartwatches, or smart mattresses. Thisintegrationwouldallow formorecomprehensivetrackingofsleeppatterns,including factors such as heart rate, sleep cycles, and even body movements.
2) Personal Health Dashboards: With the rise of health data aggregators, users could access a personal sleep health dashboardthat consolidates data from various devices (snore monitor, sleep tracker, heart ratemonitor,etc.).Thiswouldgiveusersaholisticview oftheirhealthandwell-being,withpersonalized recommendations based on their unique sleep data.
3) AI-Driven Insights: The future of snore monitoring could involve more advanced AI algorithms that analyzesnoring patternsanddetectothersleepdisorders,suchassleepapnea,bruxism(teethgrinding), or even restless leg syndrome. AI could provide users with personalized, real-time feedback on how to optimize their sleep hygiene, offering solutions based on patterns it detects over time.

V. CONCLUSIONS

Silent Nights: A Novel Snore Monitoring Device for Sleep Quality Enhancement represents a significant innovationin the realmofsleep health technology. By providinga discreet,non-invasive way tomonitor snoring, it offers individuals a chance to gain deeper insights into their sleep patterns and potentially improvetheir sleepquality.The device has the potential toaddress awiderangeof sleep-related issues, from simple snoring to more serious conditions like sleep apnea, by offering real-time feedback and personalized interventions. As we look to the future, Silent Nights could evolve further through the integration of advanced AI algorithms, seamless connection with other smart devices, and enhanced medicalandtelehealthintegration, allofwhichwould makeitanevenmorepowerfultoolforimproving sleep health. Additionally, as awareness of sleep hygiene and its impact on overall health continues to grow, devices like Silent Nights will play a critical role in helping people take control of their sleepquality.

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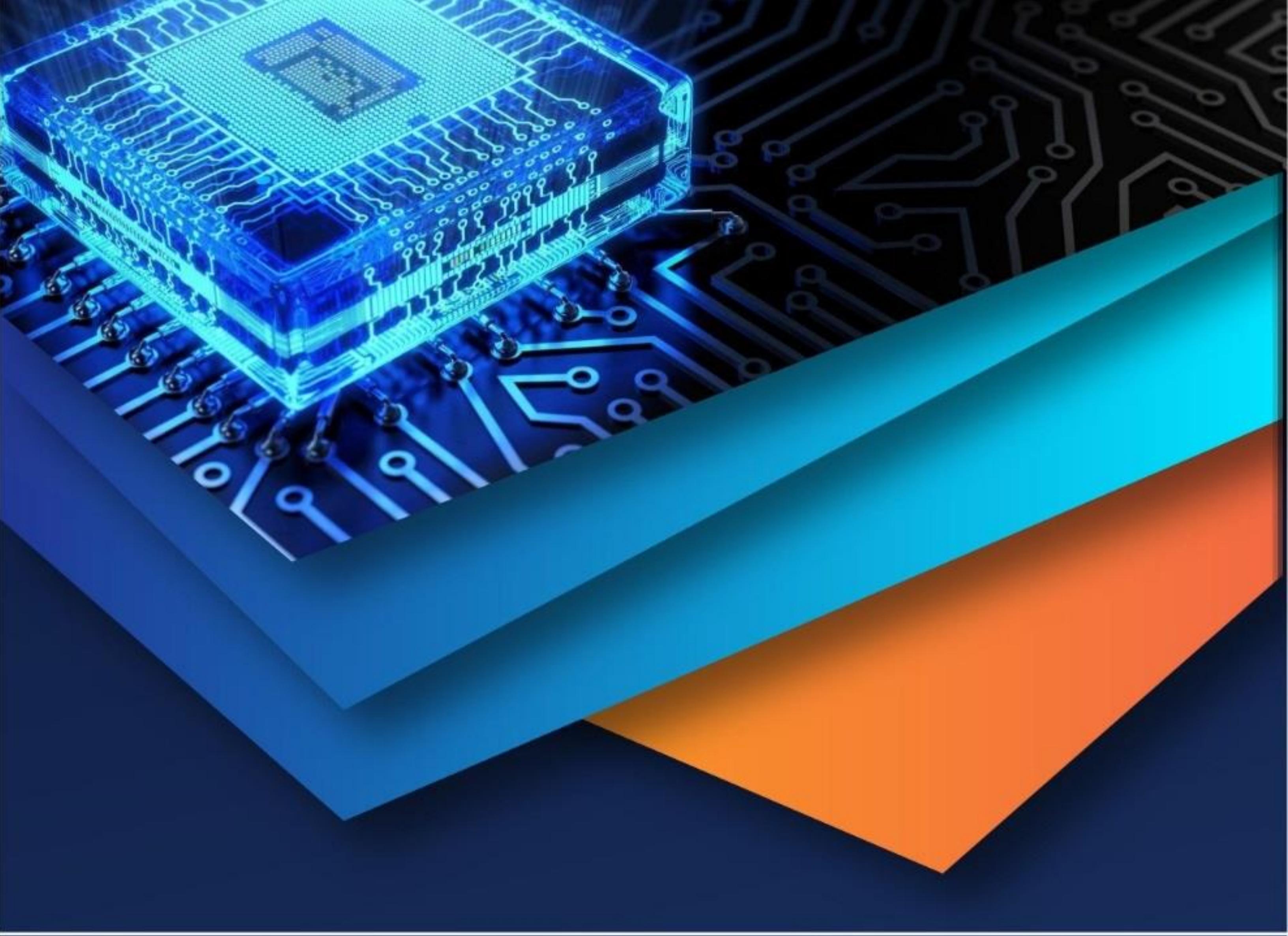

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