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Detection of Snoring Events for the Treatment of Obstructive Sleep Apnea

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Abstract: Obstructive sleep apnea (OSA) is one of the most common disorders which affects the people, mainly in the age of 30 to 70. In current population, the percentage of this disorder gets increased and death rate also increases. It is one of the under diagnosed and under treated disorder. In our project, we introduce a low-cost, easily usable and wireless prototype device to diagnose and to treat obstructive sleep apnea. The developed device used to track the level of respiration and snoring episodes. When a snoring episode is detected, we deliver a small electric current to pharyngeal muscles by use of pen like electrical stimulators that make them to regain their muscle tone, thus obstructive sleep apnea can be treated. And also, this device communicates with an IOT to keep a recording of respiration and apnea data to enable further studying of data by medical professionals and researchers.

***Keywords*: obstructive sleep apnea, electrical stimulator, snoring, pharyngeal muscle, IOT**

I. INTRODUCTION

Sleep apnea can be defined as pauses in breathing and temporary cessation of breath while sleeping. The breathing pauses can last from a few seconds to a minute. Here are several types of sleep apnea they are, i) Obstructive sleep apnea, ii) Central sleep apnea, and iii) Mixed sleep apnea.

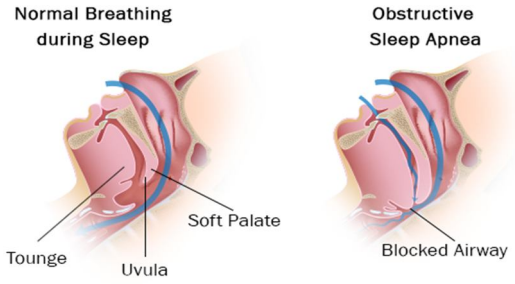

Figure.1 Anatomy of OSA

But the most common is obstructive sleep apnea. This type of apnea occurs when your throat muscles intermittently relax and block your airway during sleep. A noticeable sign of obstructive sleep apnea is snoring. Which is the harsh sound that occurs while sleeping when the breathing is partially obstructed.

The pharyngeal muscles are of particular importance in respiratory function. Poor pharyngeal muscle responsiveness during sleep is another physiologic feature contributing to OSA. Inadequate responsiveness of the upper airway dilator muscles during sleep is recognized by minimal increase in EMG activity to negative pharyngeal pressure

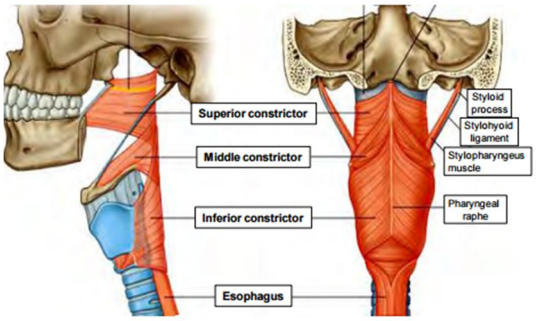

Figure.2 Anatomy of Pharyngeal muscle

A. Causes

1) Old age
2) Brain injury (temporary or permanent)
3) Decreased muscle tone. This can be caused by drugs or alcohol, or it can be caused by neurological problems or other disorders.
4) Long-term snoring may induce local nerve lesions in the pharynx.
5) Obstructive sleep apnea occurs when the muscles in the back of your throat relax too much to allow normal breathing. This may lower the level of oxygen in your blood and cause a build-up of carbon dioxide.
6) Some adults show an increase in pharyngeal tissue which cause respiratory obstruction during sleep. Adults with normal body mass indices (BMIs) often have decreased muscle tone causing airway collapse and sleep apnea.

B. Signs and symptoms

1) Loud snoring
2) Observed episodes of stopped breathing during sleep
3) Awakening with a dry mouth or sore throat
4) Morning headache
5) Excessive daytime sleepiness
6) High blood pressure

C. Risk factors

1) *Excess Weight:* Fat deposits around the upper airway may obstruct breathing. Medical conditions that are associated with obesity, such as hypothyroidism and polycystic ovary syndrome, also can cause obstructive sleep apnea.
2) *Narrowed Airway:* It may inherit naturally narrow airways. Or your tonsils or adenoids may become enlarged, which can block your airway.
3) *High Blood Pressure (Hypertension):* Obstructive sleep apnea is relatively common in people with hypertension.
4) *Chronic Nasal Congestion:* Obstructive sleep apnea occurs twice as often in those who have consistent nasal congestion at night, regardless of the cause. This may be due to narrowed airways.
5) *Smoking:* People who smoke are more likely to have obstructive sleep apnea.
6) *Diabetes:* Obstructive sleep apnea may be more common in people with diabetes.
7) *Asthma:* Research has found an association between asthma and the risk of obstructive sleep apnea.

D. Complications

1) *Daytime Fatigue And Sleepiness:* People with obstructive sleep apnea often experience severe daytime drowsiness, fatigue and irritability. They may also be at higher risk of work-related accidents.
2) *Cardiovascular Problems:* Sudden drops in blood oxygen levels that occur during obstructive sleep apnea increase blood pressure and strain the cardiovascular system. The more severe the obstructive sleep apnea, the greater the risk of coronary artery disease, heart attack, heart failure and stroke. It also increases the risk of abnormal heart rhythms (arrhythmias). These abnormal rhythms can lower blood pressure. these repeated multiple episodes of arrhythmias could lead to sudden death.
3) *Complications With Medications And Surgery:* Obstructive sleep apnea also is a concern with certain medications and general anaesthesia. These medications, such as sedatives, narcotic analgesics and general anaesthetics, relax your upper airway and may worsen your obstructive sleep apnea. People with obstructive sleep apnea may be more prone to complications after surgery.
4) *Eye Problems:* Some research has found a connection between obstructive sleep apnea and certain eye conditions, such as glaucoma. Eye complications can usually be treated.

E. Diagnosis

Tests to detect obstructive sleep apnea include:

1) *Polysomnography:* During this sleep study. If patient hooked up to equipment that monitors your heart, lung and brain activity, breathing patterns, arm and leg movements, and blood oxygen levels while you sleep. If patient diagnosed with obstructive

sleep apnea, staff may wake you and give you continuous positive airway pressure for the second half of the night. Polysomnography can help your doctor diagnose obstructive sleep apnea and adjust positive airway pressure therapy.

2) *Home Sleep Apnea Testing:* At-home version of polysomnography to diagnose obstructive sleep apnea. This test usually involves measurement of airflow, breathing patterns and blood oxygen levels, and possibly limb movements and snoring intensity.

F. Therapies

1) *Positive Airway Pressure:* In this treatment, a machine delivers air pressure through a piece that fits into your nose or is placed over your nose and mouth while you sleep. The most common type is called continuous positive airway pressure, or CPAP.
2) *Bilevel Positive Airway Pressure (BPAP):* Another type of positive airway pressure, delivers a pre-set amount of pressure when you breathe in and a different amount of pressure when you breathe out.
3) *Surgery or Other Procedures*

a) *Surgical Removal of Tissue:* Uvulopalatopharyngoplasty (UPPP) is a procedure in which your doctor removes tissue from the back of your mouth and top of your throat. These procedures don't treat obstructive sleep apnea, but they may reduce snoring.
b) *Upper Airway Stimulation:* This new device is approved for use in people with moderate to severe obstructive sleep apnea who can't tolerate CPAP or BPAP.A small, thin impulse generator (hypoglossal nerve stimulator) is implanted under the skin in the upper chest. The device detects your breathing patterns and, when necessary, stimulates the nerve that controls movement of the tongue.
c) *Jaw surgery (Maxillomandibular Advancement):* In this procedure, the upper and lower parts of your jaw are moved forward from the rest of your facial bones. This enlarges the space behind the tongue and soft**.**
d) *Surgical Opening in the Neck (Tracheostomy):* During a tracheostomy, your surgeon makes an opening in your neck and inserts a metal or plastic tube through which you breathe. Air passes in and out of your lungs, bypassing the blocked air passage in your throat.
e) *Implants:* This minimally invasive treatment involves placement of three tiny polyester rods in the soft palate. These inserts stiffen and support the tissue of the soft palate and reduce upper airway collapse and snoring. Nasal surgery to remove polyps or straighten a crooked partition between your nostrils.

II. METHODOLOGY

A. Block Diagram

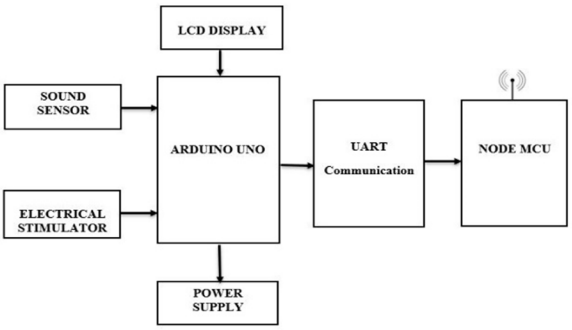

Figure.3 Block Diagram

B. Embedded Systems

An embedded system is a special-purpose computer system, which is completely encapsulated by the device it controls. An embedded system has specific requirements and performs pre-defined tasks, unlike a general-purpose personal computer. An embedded system is a programmed hardware device. A programmable hardware chip is the 'raw material' and it is programmed with particular applications. This is to be understood in comparison to older systems with full functional hardware or systems with general purpose hardware and externally loaded software. Embedded systems are a combination of hardware and software which facilitates mass production and variety of application. A combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a dedicated function.

C. Arduino Uno

Arduino/Genuine Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again.

D. Power

The Arduino Uno board can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm centre-positive plug into the board's power jack. Leads from a battery can be inserted in the GND and Vin pin headers of the POWER connector.

The board can operate on an external supply from 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may become unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

E. Memory

The ATmega328 has 32 KB (with 0.5 KB occupied by the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

F. Communication

Arduino/Genuino Uno has a number of facilities for communicating with a computer, another Arduino/Genuino board, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). The Arduino Software (IDE) includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A Software Serial library allows serial communication on any of the Uno's digital pins. The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino Software (IDE) includes a Wire library to simplify use of the I2C bus. For SPI communication, use the SPI library.

G. Sound Sensor

The sound sensor is one type of module used to notice the snoring. Generally, this module is used to detect the intensity of snoring. This sensor employs a microphone to provide input to buffer, peak detector and an amplifier.

This sensor notices a snoring, & processes an o/p voltage signal to a microcontroller. This module allows you to detect when snoring has exceeded a set point you select. Snoring is detected via a microphone and fed into an LM393 op amp

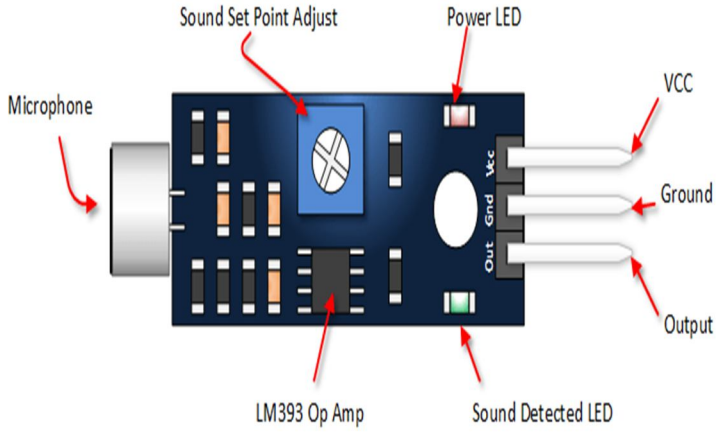

Figure.4 Sound Sensor

H. LCD Display

The most commonly used Character based LCDs are based on Hitachi's HD44780 controller or other which are compatible with HD44580.

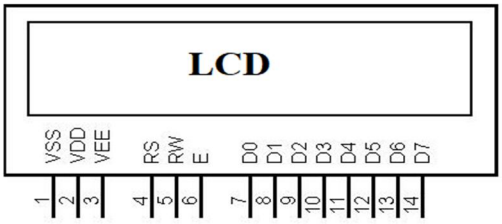

Figure.5 LCD Display

I. Node MCU

NodeMCU is an open source IoT platform. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module. The term "NodeMCU" by default refers to the firmware rather than the dev kits. The firmware uses the Lua scripting language. It is based on the eLua project, and built on the Espressif Non-OS SDK for ESP8266. It uses many open source projects, such as lua-cjson, and spiffs

The ESP8285 is an ESP8266 with 1 MB of built-in flash, allowing for single-chip devices capable of connecting to Wi-Fi. The successor to these microcontroller chips is the ESP32.

J. Ubidots

Ubidots is an IoT Platform empowering innovators and industries to prototype and scale IoT projects to production. Use the Ubidots platform to send data to the cloud from any Internet-enabled device. You can then configure actions and alerts based on your real-time data and unlock the value of your data through visual tools. Ubidots offers a REST API that allows you to read and write data to the resources available: data sources, variables, values, events and insights. The API supports both HTTP and HTTPS and an API Key is required.

Your data will be protected with two more replication, encrypted storage and optional TLS/SSL data support. You can also customize permission groups to each module of the platform.

K. Power Supply Unit

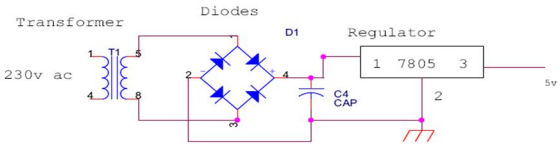

Figure.6 Power supply unit

L. Step Down Transformer

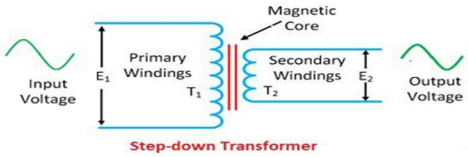

Figure.7 Step down Transformer

The Step-down Transformer is used to step down the main supply voltage from 230V AC to lower value. This 230 AC voltage cannot be used directly, thus it is stepped down. The step-down voltage is 12V.The Transformer consists of primary and secondary coils. To reduce or step down the voltage, the transformer is designed to contain a smaller number of turns in its secondary core.

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The output from the secondary coil is also AC waveform. Thus, the conversion from AC to DC is essential. This conversion is achieved by using the Rectifier Circuit/Unit.

M. Rectifier

The Rectifier circuit is used to convert the AC voltage into its corresponding DC voltage Rectifier having three types,

1) Half wave rectifier.
2) Full wave rectifier
3) Bridge rectifier

The most important and simple device used in Rectifier circuit is the diode. This project used to bridge rectifier. A bridge rectifier makes use of four diodes in a bridge arrangement to achieve full-wave rectification. This is a widely used configuration, both with individual diodes wired as shown and with single component bridges where the diode bridge is wired internally. below diagram is bridge rectifier

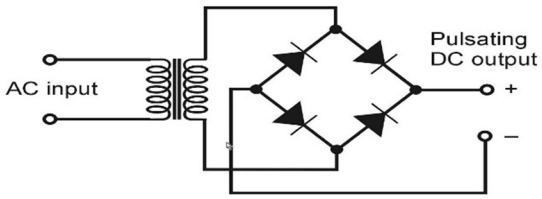

Figure. 8 Bridge Rectifier

The simple function of the diode is to conduct when forward biased and not to conduct in reverse bias. The Forward Bias is achieved by connecting the diode's positive with positive of the battery and negative with battery's negative. The efficient circuit used is the Full wave Bridge rectifier circuit. The output voltage of the rectifier is in rippled form, the ripples from the obtained DC voltage are removed using other circuits available. The circuit used for removing the ripples is called Filter circuit.

The simple capacitor filter is the most basic type of power supply filter. The application of the simple capacitor filter is very limited. It is sometimes used on extremely high-voltage, low-current power supplies for cathode-ray and similar electron tubes, which require very little load current from the supply. The capacitor filter is also used where the power-supply ripple frequency is not critical; this frequency can be relatively high. The capacitor (C1) shown in figure 4-15 is a simple filter connected across the output of the rectifier in parallel with the load.

Capacitors are used as filter. The ripples from the DC voltage are removed and pure DC voltage is obtained. And also, these capacitors are used to reduce the harmonics of the input voltage. The primary action performed by capacitor is charging and discharging. It charges in positive half cycle of the AC voltage and it will discharge in negative half cycle. Here we used 1000µF capacitor. So, it allows only AC voltage and does not allow the DC voltage. This filter is fixed before the regulator. Thus, the output is free from ripples.

N. Regulator

Regulator regulates the output voltage to be always constant. Regulator having two types.

1) Positive regulator (78XX)
2) Negative regulator (79XX)

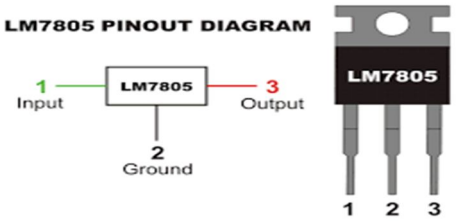

Figure. 9 Regulator (LM7805)

The output voltage is maintained irrespective of the fluctuations in the input AC voltage. As and then the AC voltage changes, the DC voltage also changes. Thus, to avoid this Regulators are used. Also, when the internal resistance of the power supply is greater than 30 ohms, the output gets affected.

Thus, this can be successfully reduced here. The regulators are mainly classified for low voltage and for high voltage. Here we used 7805 positive regulator. It reduces the 12V dc voltage to 5V dc.

The Filter circuit is often fixed after the Regulator circuit. Capacitor is most often used as filter. The principle of the capacitor is to charge and discharge. It charges during the positive half cycle of the AC voltage and discharges during the negative half cycle. So, it allows only AC voltage and does not allow the DC voltage.

This filter is fixed after the Regulator circuit to filter any of the possibly found ripples in the output received finally. Here we used 0.1µF capacitor. The output at this stage is 5V and is given to the Microcontroller In the power supply circuit two regulators are used. 7805 regulator is used to produce positive 5V dc. Microcontroller and sensors are operated at 5V dc voltage. The output of the 7805 regulator is connected to NODE MCU.

O. Software Requirement

1) Arduino IDE: The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them.

III. RESULT AND DISCUSSION

In our proposed system we design a protocol that uses sound sensor to predict the snoring events. This sound sensor is a module that can detect intensity of sound by taking input via microphone and it will detect it as snoring using peak detector and LM393 opamp that can produce value with certain threshold we fix, finally detected value is sent as output to microcontroller. The snoring events are classified based on time stamps. Using this classification, we make graphical representation drawn between amplitude (vs) time that analyse OSA. This output can be retrieved and also stored in cloud by Iot using Ubidots website for future remedies and references.

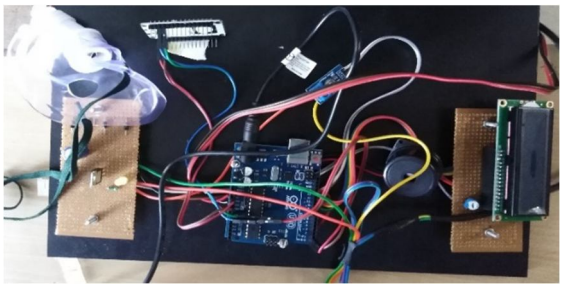

Figure.10. Proposed model

And also, for treatment of OSA we do muscular stimulation using pen like stimulator in the region of pharyngeal muscle by passing a certain current of frequency range 30-40 Hz and amplitude of 2 -4 V and pulse duration can be range from 0.2-1.0 ms. This method can be safer and accurate one.

IV. CONCLUSION

Thus, we come to the conclusion that OSA will lead to temporary breathing problem at early stages and this situation get worse when it became unnoticed. The problem like hypertension, stroke and heart failure will be the major cause. So, our proposed prototype can be accurate, flexible and cost effective and with electrical stimulator can prevent OSA problem. This prototype can be made commercially available in areas like home care unit, medical centres and medical institutions. The physician can get data of patient at anywhere and anytime.

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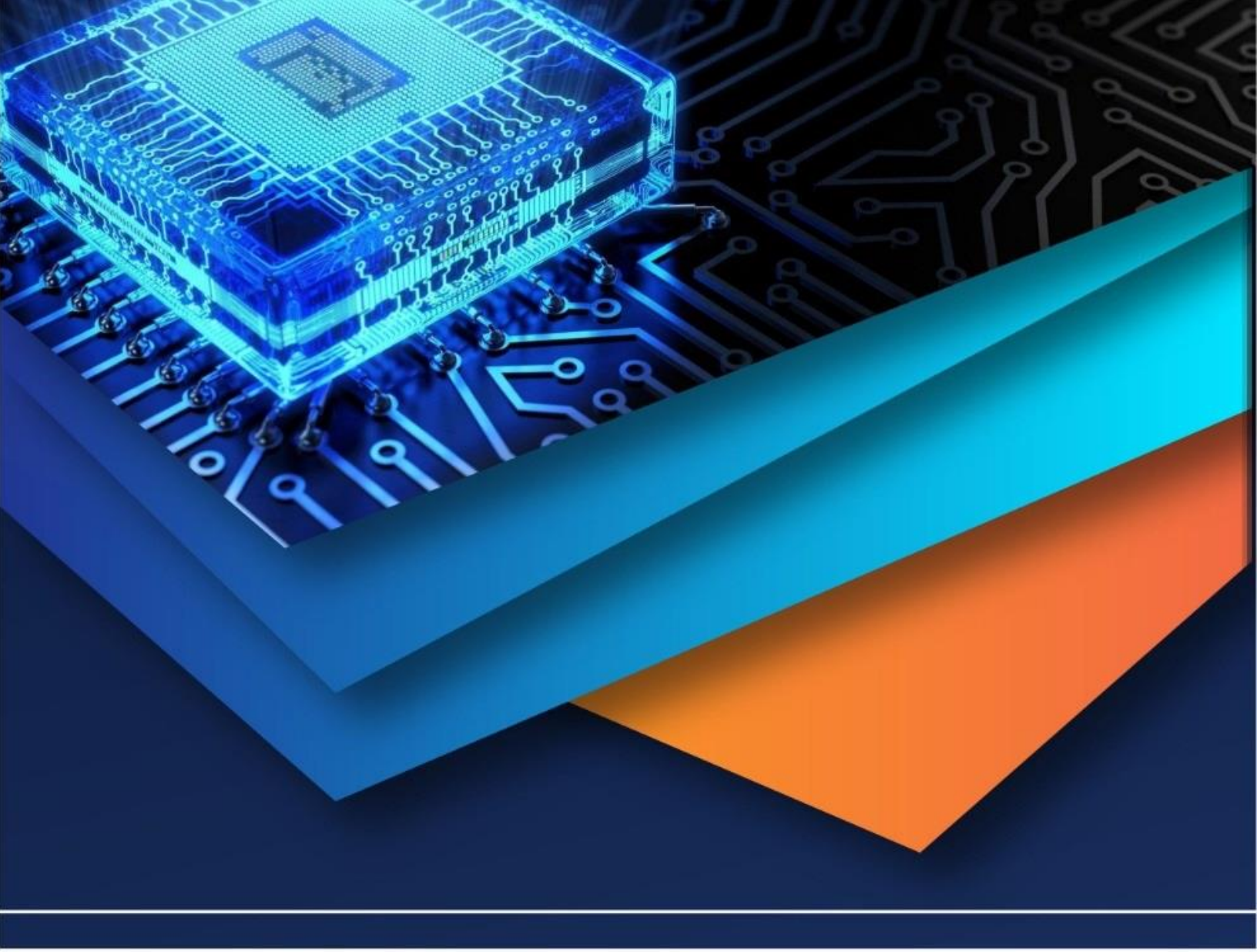

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