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# Implementation of Electronic Nose with TGS Gas Sensors

Chiranjeevi

***Abstract: Nowadays, requirements for detecting fresh milk from farms are restricted by traditional testing methods and expensive imported detecting instruments, which is going against the improvement of fresh milk's quality. The proposed prototype is an ARM based monitoring unit which monitors the unwanted ingredients presents in the test milk. The concentration of VOCs present in the headspace of raw milk varied drastically when it was contaminated by bacterial metabolism, ageing, photo-oxidation and presence of provident metals such as copper, iron and nickel. Milk from a healthy cow contains only few bacteria which may multiply and the rate of multiplication will increase as time passes from the time of milking to the time of processing it also depends on the standard of milking, handling practices and storage. These bacterial growths lead to the spoilage of milk with the production of off-flavor. As the microbial spoilage of starting milk severely affects the industrial quality due to undesirable aroma, physical defects and metabolic toxicity, identification of milk spoilage before production of products becomes mandatory. Likewise, spoilage of milk due to various other factors should also be identified at the initial phase to avoid complications and complaints in the final product.***
***Keywords: ARM 7, ZigBee, TGS sensors.***

## I. INTRODUCTION

In the fast moving world fuelled by rapid strides in technological evolution, globalization and urbanization, there is a promising trend in terms of increase in the degree of awareness on monitoring environmental pollution and food quality assessment. Among the quality control of highly perishable food products, the quality control of starting milk is one of the most important tasks in the production of dairy products. Since chemical analysis of milk remains a great challenge to the sensory evaluation panel for many decades due to its heterogeneous nature, need for a rapid and cost effective tool for quality discrimination of milk and dairy products became substantial. Milk obtained from a healthy cow contains only few bacteria that may multiply, and makes rate of multiplication that will increase as time lapses from the time of milking to the time of processing, it also depends on the particular standard of the milking, as well as handling practices followed and storage. As we seen these bacterial growths lead to the spoilage of milk with the heavy production of the off-flavor that leads to the microbial spoilage of initial milk that severely affects the industrial quality due to undesirable issues, like physical defects and also metabolic toxicity, se we need to plan identification of milk spoilage before production of products becomes compulsory. In the same manner spoilage of milk due to several other factors should also be identified at the initial stage to avoid complications and complaints in the end product. Therefore in order to achieve this we need of early detection of VOCs at headspace generated during spoilage only. For example, milk spoilage due to microbial/bacterial contamination can be identified from the presence of acetaldehyde, acetic acid and ethanol present in the headspace of the milk, that were absent in raw milk before it gets spoilage. Likewise hex anal, pent anal and dim ethyl disulfide is good indicators of fluorescent light damaged products.

Table 1 Dairy products and typical types of spoilage microorganisms or microbial activity

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| Food | Spoilage microorganism or microbial activity |
|---|---|
| Raw milk | A wide variety of different microbes |
| Pasteurized milk | Psychrotrophs, sporeformers, microbial enzymatic degradation |
| Concentrated milk | Spore-forming bacteria, osmophilic fungi |
| Dried milk | Microbial enzymatic degradation |
| Butter | Psychrotrophs, enzymatic degradation |
| Cultured buttermilk, sour cream | Psychrotrophs, coliforms, yeasts, lactic acid bacteria |
| Cottage cheese | Psychrotrophs, coliforms, yeasts, molds, microbial enzymatic degradation |
| Yogurt, yogurt-based drinks | Yeasts |
| Other fermented dairy foods | Fungi, coliforms |
| Cream cheese, processed cheese | Fungi, spore-forming bacteria |
| Soft, fresh cheeses | Psychrotrophs, coliforms, fungi, lactic acid bacteria, microbial enzymatic degradation |
| Ripened cheeses | Fungi, lactic acid bacteria, spore-forming bacteria, microbial enzymatic degradation |

A short summary of the types of dairy products and typical spoilage microorganisms associated with them is shown in Table 1.
While pent anal, hex anal and isopentanal indicate copper induced oxidation in milk, ageing of milk can be significantly identified through the presence of dim ethyl sulfide, pent anal, etc. AMPEHUO et al. observed that the headspace of milk from the cow bearing genetic defect contains trim ethyl amine. Hence by detecting the VOCs responsible for the off-flavor, quality of raw milk can be identified.

## II. RELATED WORK

The proposed system is designed with an array of available commercial metal oxide semiconductor based sensing units for the purpose of real time quality analysis of raw milk products. The sensors were formulated and calibrated to a various concentrations of volatile organic compounds which were responsible for volatile milk flavors. The proposed prototype is an ARM based monitoring unit which monitors the unwanted ingredients presents in the test milk.

## III. E-NOSE MONITORING UNIT

Our proposed system consists of various sensors and RF wireless units as depicted in fig.1.Here the sensor array was exposed directly to the headspace of milk samples at 3 cm distance from the milk surface and the response of each sensor was observed.
The TGS Sensors collects data samples from the Spoiled raw milk and it is taking data in the form of gas molecules and if the input data of the gas molecules in the form of (parts per million) to voltage by using the heating elements.
The heating element is heating as per the concentration of the molecules and it depends on the molecules levels to convert vapor gas in the form of voltage.
The voltage values are varying continuously according to the concentration of the spoiled milk vapor gas molecules parts per million.
The TGS sensors are connected to the LPC 2148 IC and if the processing of the data values in the form of voltages and it display by using the LCD Module.
The maximum voltage is produce at the LCD display the more chemical concentration factors are available in the test milk.
The test raw milk is spoilage it is to decide the compare of the good raw milk voltage levels and spoilage raw milk voltage levels.
If the minimum voltage levels are available the raw milk is good and if the maximum voltage levels are available the raw milk is spoilage.
If the maximum voltage levels are available to indicates the indicators by using the LED’s.
The total data can be monitoring in the PC by using the RF ZigBee module where its role is to transferring the data from ARM 7 unit to remote PC by using the peer to peer protocol.

 

The data can be displayed on to the PC terminal window that can be achieved by flash magic tool, also periodical data updation of all sensors can be continuously monitored and recording in PC.

*A. TGS Sensors*

*1) TGS 813:* The sensing element of Figaro gas sensors is a tin dioxide ($SnO_2$) semiconductor which has low conductivity in clean air.

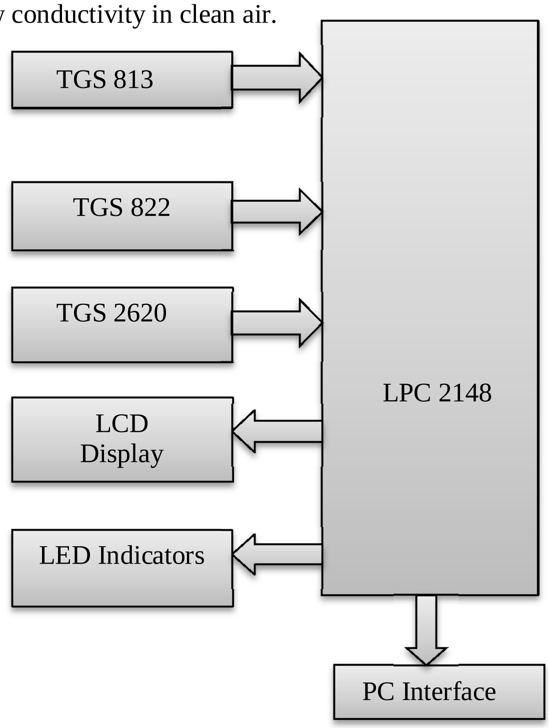


Figure 1.Block diagram of system

If we find any of a detectable gas, the sensor's conductivity immediately increases that depends on the gas concentration in the air. Here is a simple electrical circuit that can convert the change in conductivity to an output signal that in turn corresponds to the gas concentration.

Generally TGS 813 sensor has high sensitivity to methane, propane, and also butane, so that it ideal for natural gas as well as LPG monitoring. As far as sensor can detect a wide range of gases, that in turn makes excellent, low cost sensor for a wide variety of industrial applications.


Basically numbers shown around the sensor symbol in the circuit diagram at the right correspond with the pin numbers as shown in the sensor's outer body drawing. As depicted the sensor is connected as shown in the required circuit, the output across the Load Resistor (VRL) increases rapidly as the sensor's resistance (Rs) decreases, which is depending on gas concentration present over

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their.
Sensing Element: SnO2is sintered to form a thick film on the surface of an alumina ceramic tube which contains an internal heater.
Cap: Nylon 66
Sensor Base: Nylon 66
Flame Arrestor: 100 mesh SUS 316 double gauze

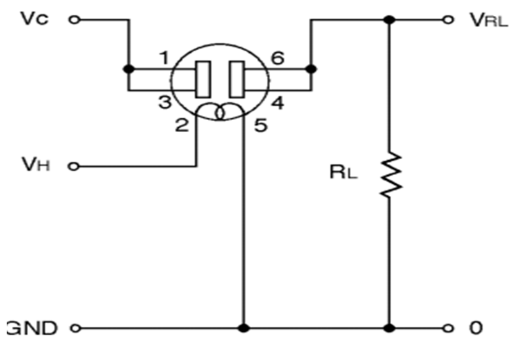


Figure 2 Circuit diagram of TGS 813

| Item | Symbol | Related Values | Remarks |
|---|---|---|---|
| Heater Voltage | $V_H$ | 5.0 +/- 0.2V | AC or DC |
| Circuit Voltage | $V_C$ | Max. 24V | DC only $P_s$<15mW |
| Load Resistance | $R_L$ | Variable | 0.45kΩ min |

Table 3 Circuit conditions of TGS 813

*2) TGS 822:* As sensing element of particualar Figaro gas sensors is a tin dioxide (SnO2) semiconductor that has very low conductivity in presence of clean air. We know that in presence of a detectable gas, the sensor's conductivity increases rapidly depending on the gas concentration in the air.


A simple electrical circuit can convert the change in conductivity to an output signal which corresponds to the gas concentration. The TGS 822 has high sensitivity to the vapors of organic solvents as well as other volatile vapors. It also has sensitivity to a variety of combustible gases such as carbon monoxide, making it a good general purpose sensor.

*3) TGS 2620:* The sensing element is comprised of a metal oxide semiconductor layer formed on an alumina substrate of a sensing chip together with an integrated heater. In the presence of a detectable gas, the sensor's conductivity increases depending on the gas concentration in the air.

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A simple electrical circuit can convert the change in conductivity to an output signal which corresponds to the gas concentration.

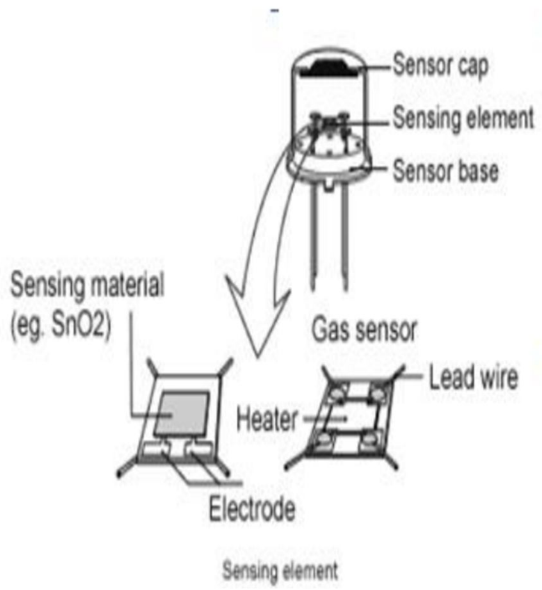


Fig. 3 Sensor structure

As shown in Figure. 3 depict gas sensor structure of TGS 26XX series sensors. As we know gas sensor is composed of sensing element, sensor base and sensor cap. The sensing element consists of sensing material and heater to heat up sensing element (e.g. 400°C). Now depending on the target gas, the sensing element will employs different materials like Tin dioxide ($SnO_2$) , Tungsten oxide ($WO_3$) , etc.

*B. LPC 2148 Processor*

This is a 32-bit ARM7-TDMI-S microcontroller with 32kB of on-chip static RAM and 512 KB of on-chip flash memory. It has 128-bit wide interface/accelerator that enables 60MHz of operation. Also it supports In-System Programming by having on-chip boot loader software, as well as 400ms of full chip erase capability and 256 Bytes of programming in 1ms. For interfacing of sensors, it has 10-bit ADC with 8 analog inputs and a conversion time as low as 2.44µs per channel. CPU operating voltage is ranging from 3V to 3.6V only. As in our proposed system requires only lower power consumption as the same mentioned before. The Architecture is based on RISC principles and its simplicity yields in a high instruction throughput and real-time interrupt response form a small and cost effective processor core. It also has another architectural strategy such as 16-bit Thumb instruction set along with 32-bit ARM instruction set that enhances the code density in restricted memory conditions while returning most of the ARM's performance effectively.

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| | | | | |
|---|---|---|---|---|
| Model number | | | TGS 2620-C00 | |
| Sensing element type | | | D1 | |
| Standard package | | | TO-5 metal can | |
| Target gases | | | Alcohol, Solvent vapors | |
| Typical detection range | | | 50 ~ 5,000 ppm | |
| Standard circuit conditions | Heater Voltage | $V_H$ | 5.0±0.2V DC/AC | |
| | Circuit voltage | $V_C$ | 5.0±0.2V DC/AC | $P_S \leq$ 15mW |
| | Load resistance | $R_L$ | Variable | 0.45kΩ min. |
| Electrical characteristics under standard test conditions | Heater resistance | $R_H$ | 83Ω at room temp. (typical) | |
| | Heater current | $I_H$ | 42 ± 4mA | |
| | Heater power consumption | $P_H$ | approx. 210mW | |
| | Sensor resistance | Rs | 1 ~ 5 kΩ in 300ppm ethanol | |
| | Sensitivity (change ratio of Rs) | | 0.3 ~ 0.5 | $\frac{Rs\ (300ppm)}{Rs\ (50ppm)}$ |
| Standard test conditions | Test gas conditions | | Ethanol vapor in air at 20±2˚C, 65±5%RH | |
| | Circuit conditions | | $V_C$ = 5.0±0.01V DC<br>$V_H$ = 5.0±0.05V DC | |
| | Conditioning period before test | | 7 days | |

Specifications of TGS 2620

*B. ZIGBEE™ Networks*

ZigBee™ networks are basically based on IEEE 802.15.4standard, and physical layers for low rate wireless personal area networks (LR-WPAN). As depicted in Figure 5 ZigBee™ stack that is operating at low power with large network size is the special feature of ZigBee™. Also in Figure 6 shows the comparison of ZigBee™ network with contemporary wireless technologies like Wi-Fi™ etc.

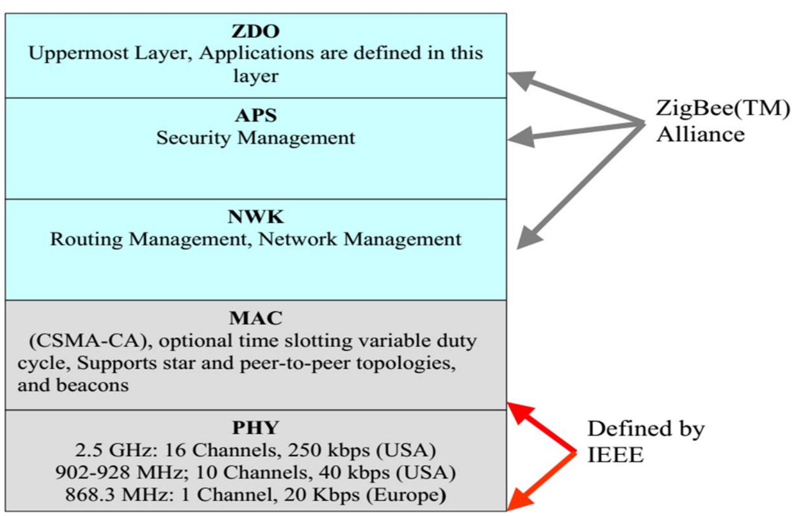


Figure 5 ZigBee(TM) Stack

The XBEE Pro Series1 consists of 20 pins. These are configured accordingly to make them as end devices router as well as coordinator of the system. Now the digital input and output DIO pins are employed for the communication without any change in

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the hardware and are configured using X-CTU software.

| Market Name Standard | ZigBee™ 802.15.4 | GSM/GPRS CDMA/1xRTT | Wi-Fi™ 802.11b | Bluetooth™ 802.15.1 |
|---|---|---|---|---|
| Application Focus | Monitoring and Control | Wide Area Voice and Data | Web, E-mail, Video | Cable Replacement |
| System Resources | 4KB-32KB | 16MB+ | 1MB+ | 250KB+ |
| Battery Life (days) | 100-1000+ | 1-7 | .5-5 | 1-7 |
| Network Size | Unlimited ($2^{64}$) | 1 | 32 | 7 |
| Bandwidth (kBps) | 20-250 | 64-128+ | 11,000+ | 720 |
| Transmission Range (meters) | 1-100+ | 1000+ | 1-100 | 1-10+ |
| Success Matrices | Reliability, Power, Cost | Reach, Quality | Speed, Flexibility | Cost, Convenience |

Figure 6 comparison of ZigBee™ network

The schematic diagram for XBEE Pro series1 is given below in fig 4.

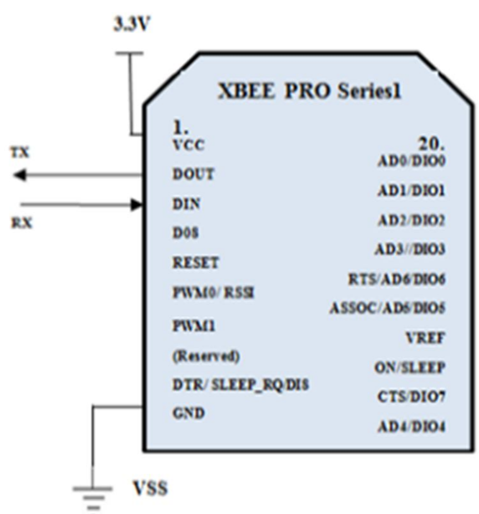


Figure 7 Schematic diagrams for XBEE

## IV. RESULTS OF EXPERIMENT

The efficiency of the developed model in real time quality analysis was studied by collecting milk samples from local farms without added preservatives and treatments. The sensor array was exposed directly to the headspace of milk samples at 3 cm distance from the milk surface and the response of each sensor was observed.

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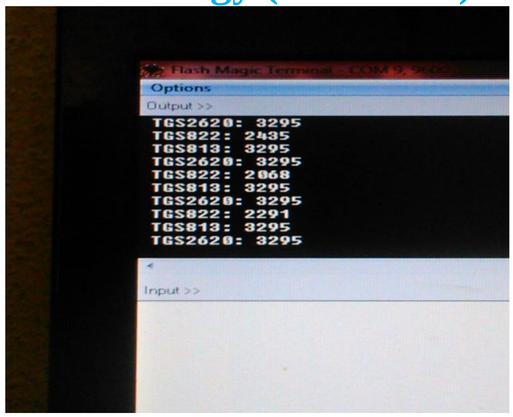

Figure 8 Flash Magic Output

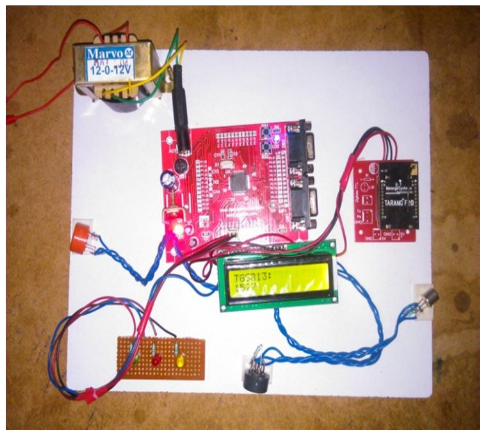

Figure 9 Experimental Setup

| CHEMICAL | REACTIVE SENSOR | VARIED VOLTAGE | MAXIMUM VOLTAGE |
|---|---|---|---|
| ETHANOL | TGS 2620,TGS 813, TGS 822 | 2481, 1736, 2390 | 3295 |
| ACETALDEHYDE | TGS 813 | 1785 | 3295 |
| ACETIC ACID | TGS 822 | 1919 | 2503 |
| DYMETHYL SULPHIDE | TGS 822 | 1835 | 2729 |
| HEXANE ALDEHYDE | TGS 2620, TGS 813, TGS 822 | 2645,1715,1923 | 3295 |

Figure 10 Observed voltages of sensors

## V. CONCLUSION

An RTOS based embedded e-nose was developed with metal oxide semiconductor based sensor array for real time quality discrimination of raw milk. A novel methodology was followed for decision making, a look-up table was formed using the calibrated data and the threshold limit was fixed to detect the presence of VOCs, which are the major contributor for off-flavors in the milk. PCA and GC were carried out to confirm the performance and the results were in convergence with the developed e-nose

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prototype. The same was validated in the local dairy farm with the experts committee. Therefore, it was concluded as a portable, simple to use and cost-effective e-nose prototype, with improved response and appreciable selectivity against the conventional techniques.

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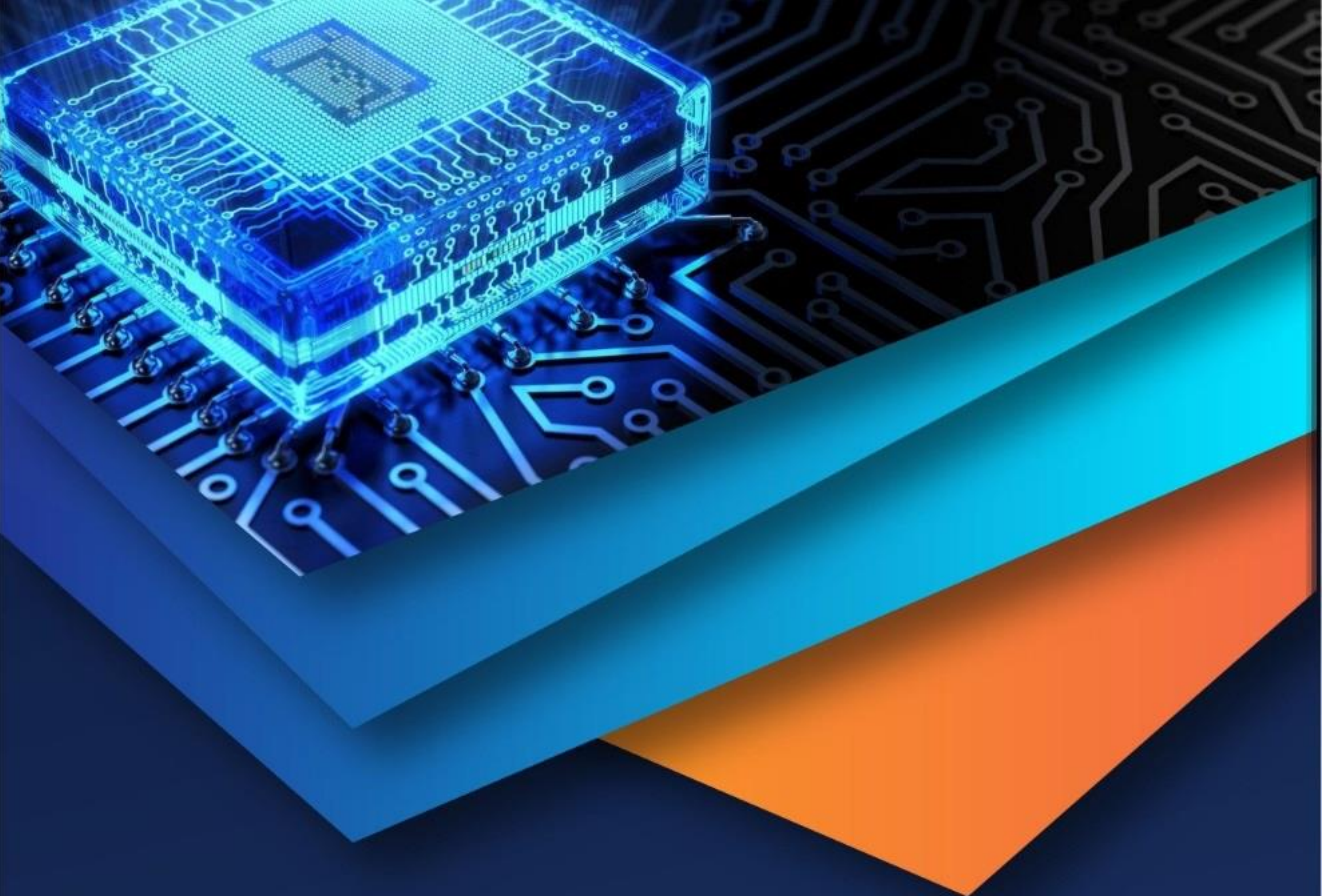


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