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A Smart Helmet for Air Quality and Hazardous Event Detection for the Mining Industry

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Abstract : ***A smart helmet has been developed that is able to detect of hazardous events in the mines industry. In the development of helmet, we have considered the four main types of hazard such as air quality, helmet removal, fire and mercury sensor . The first is the concentration level of the hazardous gases such as CO, SO2, NO2, and particulate matter. The second hazardous event was classified as a miner removing the mining helmet off their head. An IR sensor was developed unsuccessfully but an off-the shelf IR sensor was then used to successfully determine when the helmet is on the miner's head. The third hazardous event is fire sensor , it is used as a simple and compact device for protection against fire. The module makes use of IR sensor and comparator to detect fire up to a range of 1 metre. The fourth hazardous event is Mercury sensor, which is a very toxic element that is widely spread in the atmosphere, lithosphere, and surface water. Presently mining safety helmets only have the purpose of protecting the miner's head against potential hazardous bumps. The safety helmets do not have any technology added to it to let miners know when a fellow miner has encountered a hazardous event. In recent years, harvesting technology has played an important role in the area of mine applications. The literature on mines technology is available but very limited.***
Keywords: air quality ; mining ; safety ; ZigBee ; wireless sensor Networks .

I. INTRODUCTION

South Africa is known for its extensive and diverse mineral resources and large mining industry [1]. Supervisors are held responsible for all injuries sustained under their supervision, and should therefore be aware of potentially risky situations [1]. The problem addressed in this paper was the improvement of a mining helmet in order to ensure more safety awareness between miners. When working with noisy equipment, being aware of one's surroundings can sometimes be challenging [2]. In the mining industry miners tend to remove some of their safety gear because the gear is too heavy, warm or uncomfortable to work with. However, miners generally do not remove their helmets. Presently mining safety helmets only have the purpose of protecting the miner's head against potential hazardous bumps. The safety helmets do not have any technology added to it to let miners know when a fellow miner has encountered a hazardous event. Therefore the purpose of the project described in this paper was to modify an existing mining safety helmet to make the helmet even safer by adding a wireless sensor node network. The task was extended to designing the system small enough to fit into the safety helmet and last long enough while running on battery power. A further challenge was to modify the helmet without changing its physical structure. The added weight had to be kept to a minimum. A mining helmet needs to be modified to improve miner safety by adding intelligence to the helmet. When a miner removes his helmet he needs to be warned. If an object falls on a miner even when wearing his helmet he can become unconscious or immobile. The system must determine whether or not a miner has sustained a life-threatening injury. These two events are defined as hazardous events. Thirdly, dangerous gases need to be detected and announced. In the area of mining technology, real-time monitor and control of mine hazard are more complex. Mine safety modules are configured to communicate to ground control or a central station. A real critical issue in mines is hazardous gases. Systems used in a mine can create intense vibrations and increase the level of hazardous gases such as CO, SO2, NO2 and particulate matter. The working conditions can be very noisy and miners don't watch each other constantly. Miners tend to stay in groups and will be no more than 5 meters (m) from each other. A warning system needs to be incorporated that will warn miners within a 5 m radius that a miner is experiencing a hazardous event. This system needs to process and transmit the event within 1 second (s). These systems measure the environment around the miner with gas sensors and are then used to implement evacuations. These do not alert the miner at all or only alert the miner in an audible way. These systems warn miners, but when a miner is obstructed or injured, an external input is required from ground control [3]- [5]. In recent years, harvesting technology has played an important role in the area of mine applications. The literature on mines technology is available but very limited. Nutter, et al. proposed a methodology for identifying safety hazards inherent in underground monitoring and control. They

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also designed potential safety hazard equipment. They developed methodologies based on analytical electronics and computer based hardware/software systems [6]-[8]. Kock, et al. developed the technology in terms of health, safety, and productivity for the South African coal mining industry. They also investigating the coal interface detection (CID), productivity, communication channels (infrared, power line, optical fibers, and radio) [9]. Misra et al. presents a case study for mines. They reviewed on communication techniques such as through the wire (TTW), through the air (TTA), and through the earth (TTE) [10]. Forooshani, et al. presents a compressive.

II. RELATED WORK

Hazard Evaluation Methodology for Computer-Controlled Mine Monitoring/Control Systems :

A methodology for identifying safety hazards inherent in underground monitoring and control equipment will be given. Under a US Bureau of Mines contract, a methodology has been developed for determining the inherent design items that affect safety hazards. Though serious consideration has already been given to the normal intrinsic safety and explosion-proof characteristics of a system, the problem may be the system itself rather than the more immediately noticeable system components. In monitoring or controlling items located in underground coal mines, the hardware reliability of a system is seldom recognized as a potential safety hazard. As a result of the developing methodology, a set of design guidelines has been developed to ensure that known system design difficulties can be identified from the outset for designers of new mine monitoring/control systems. This technique could prove valuable to other system design engineers as well.

Experimental Link Quality Characterization of Wireless Sensor Networks for Underground Monitoring :

The aim of this paper is to experimentally investigate the link quality characteristics of the three communication channels available in WUSNs for underground pipeline monitoring to gain further insight into protocol development for WUSNs. To this end, received signal strength (RSS), link quality indicator (LQI), and packet reception ratio (PRR) are characterized for the three communication channels in WUSNs. The RSS and PRR results show that the underground-to-underground channel is highly symmetric and temporally stable,but its range is severely limited, and that the aboveground-to-underground/underground-to- underground channels are asymmetric and exhibit similar temporal properties to over-the-air communication channels. Interestingly, the results show that RSS is a better indicator of PRR than LQI for all three channels under consideration.

III.PROPOSED METHOD

A smart mining helmet was developed that is able to detect Four types of hazardous events such as as air quality, helmet removal, fire and vibration sensor . In order to explain the entire system, the system is divided into six units. Helmet remove sensor, which is used to detect the miner, is wearing the safety helmet or not this is achieved through the IR sensors. Air quality sensor, which is used to detect Air pollution from coal mines. It is mainly due to emissions of particulate matter and gases include methane (CH4) and carbon monoxide (CO). Data processing unit the micro controller which is used to get all the data from the above all sensor and concludes whether need any intimation to wireless unit or the user wearing it. Wireless transmission and alerting unit is used to transfer the data obtained from the processing unit. It is achieved through Zigbee .The Block Diagram for mine worker helmet and for supervisor is show in below figure 4 (a)and (b) respectively.

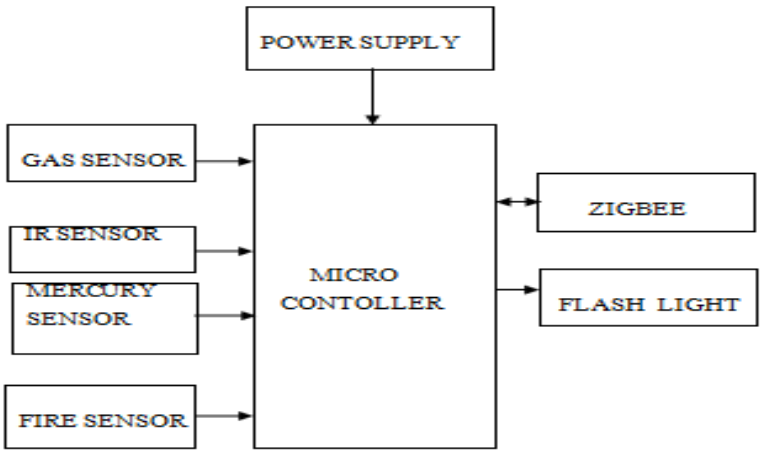

Fig. 1(a): Mine worker Helmet Figure

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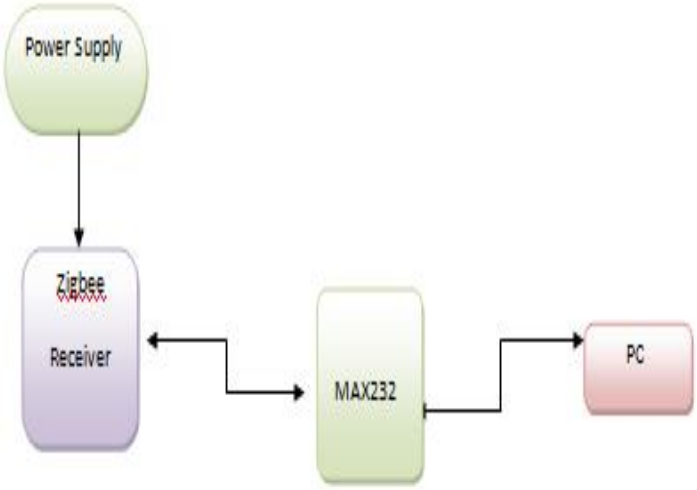

Fig.1(b): Supervisor

A. Arduino Uno

Arduino Uno is a microcontroller, the central controller for the whole unit of smart cart. Arduino Uno based on the ATmega328. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, and a reset button. The board can be programmed with Arduino Software (IDE). The board can operate on an external supply from 6 to 20 volts. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts. The ATmega328 has 32 KB flash memory. It also has 2 KB of SRAM and 1 KB of EEPROM.

B. Air Polution Sensor

Air pollution from coal mines is mainly due to emissions of particulate matter and gases include methane (CH4), sulphur dioxide (SO2), and oxides of nitrogen (NO2), as well as carbon monoxide (CO). From different studies, it is well known that when human being comes in contact these chemicals/pollutants it could have adverse effect on their health. MQ-2 gas sensor is used to detect hazardous gases,it has high sensitity to Propane, Butane and LPG, also response to Natural gas. The sensor could be used to detect different combustible gas, especially Methane, it is with low cost and suitable for different application.

C. Helmet Removal Sensor

For detecting the removal of the helmet a few different approaches were considered. The comparison, advantage, and disadvantage of the proposed approaches in the literature was reported in [1]-[11]. For this study, the IR beam based helmet remove sensor technique was considered better among other available techniques such as a switch, analogue distance sensor, and digital distance sensor. The IR beam can be designed to use low amounts of power. An off-the-shelf IR distance detector was used for this application. The IR sensor was designed to send a constant signal from the one side of the helmet to the other side with the circuit

D. Vibration Sensor (Mercury sensor)

The Vibration sensor is used for measuring, displaying, and analyzing linear velocity, displacement and proximity, or acceleration. The vibration sensor, which is useful for a variety of different fields, has the ability to detect vibrations in a given area. This can help to alert someone to trouble with a system. Within the coal, mining and quarrying industries, it is common for machinery to run 24/7, often under extreme environmental conditions, with high levels of dust, moisture and temperature, and in areas where access for maintenance or repair is difficult. Vibration monitoring is key to the success of a preventative maintenance programme. Its use has been accepted and proven for the detection of faults that include bearing wear, misalignment of shafts and out of balance fans.

E. Fire sensor

Fire sensor is a simple and compact device for protection against fire. The module makes use of IR receiver sensor and comparator to detect fire up to a range of close proximity. The device, weighing about 5 grams, can be easily mounted on the device body . It gives a high output on detecting fire.

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F. LCD

A liquid-crystal display (LCD) is optical device that uses the light-modulating properties of liquid crystals. Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome. LCDs are used in a wide range of applications including computer monitors, televisions, instrument panels, aircraft cockpit displays, and indoor and outdoor signage. Small LCD screens are common in portable consumer devices such as digital cameras, watches, calculators, and mobile telephones, including smartphones. LCD screens are also used on consumer electronics products such as DVD players, video game devices and clocks. Results are displayed on LCD.

G. Wireless Transmission

ZigBee was created to be a low power, lowdata rate and a low-cost device. ZigBee has all the same benefits as a Wi-Fi system. ZigBee is based on the IEEE 802.15.4 standard [13], [16]. A ZigBee module is also more useful for creating larger mesh networks than Bluetooth and is therefore the better option when routers and access points cannot be implemented. In [3] all the components are attached to the safety helmet with Velcro. Some of the components are placed inside the helmet, while this helps to protect the components from bumps and gasses, this can result in electronics being embedded into the head of a miner if a seriously hard bump is experienced. In [4] ZigBee modules are the chosen wireless chip because its signals are able to penetrate walls and work very well in mines. Wireless or more specifically Wi-Fi, is sometimes used in mines, but it needs cabling throughout the mine to the routers, that can be damaged [13].

H. Piezo Buzzer

Piezo buzzer is the handy sound generator used in electronic circuits to give audio indication .It is widely used as alarm generator in electronic devices. A Piezo buzzer has a Piezo disc and an oscillator inside. When the buzzer is powered, the oscillator generates a frequency around 2-4 kHz and the Piezo element vibrates accordingly to produce the sound. An ordinary Piezo buzzer works between 3 – 12 volts DC.

IV. RESULTS

The helmet removal test was done using Ir sensors used in our project by using different sizes, shapes and different colors sensor given satisfactory and 100% results is obtained as shown in figure 3 and all various kinds of testing done during performance test of helmet sensor program done in Arduino controller done using digital pins run very well displayed helmet value on LCD as well as send to receiver using zigbee communication 9600bits/sec to a range of nearly 10mts with line of sight and without line of sight at constant 5v.

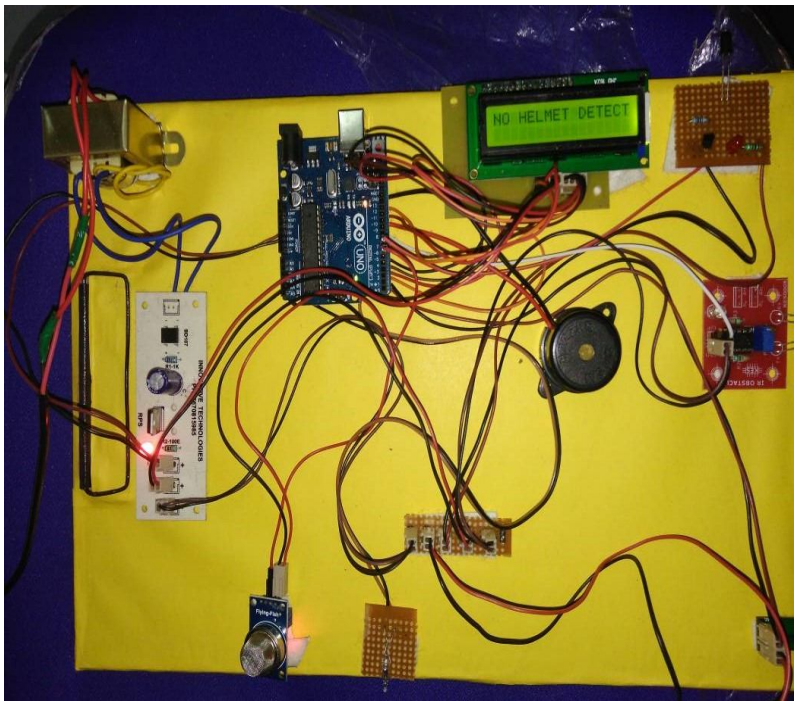

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Fig. 3: No helmet detected.

Gas sensor in our project used is MQ-2 measures a wide range of gases like LPG, CO2, also alcohol this sensor has been tested under extreme condition of high and low chemical and dangerous possinous which are hazardous for human health . The sensors values are accurate when tested and prosseds and results are displayed on LCD as shown in figure 4.

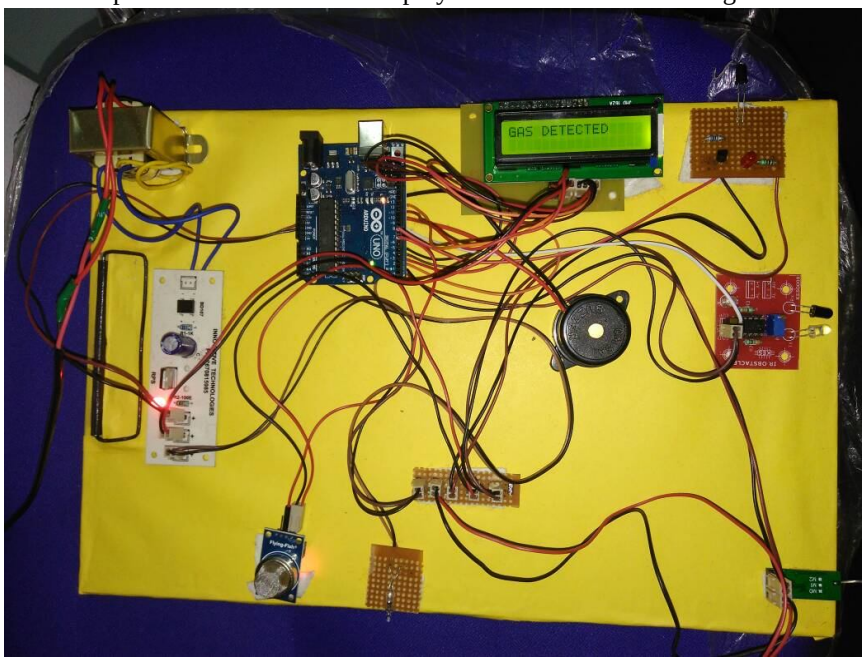

Fig. 4: Hazardous Gases are detected.

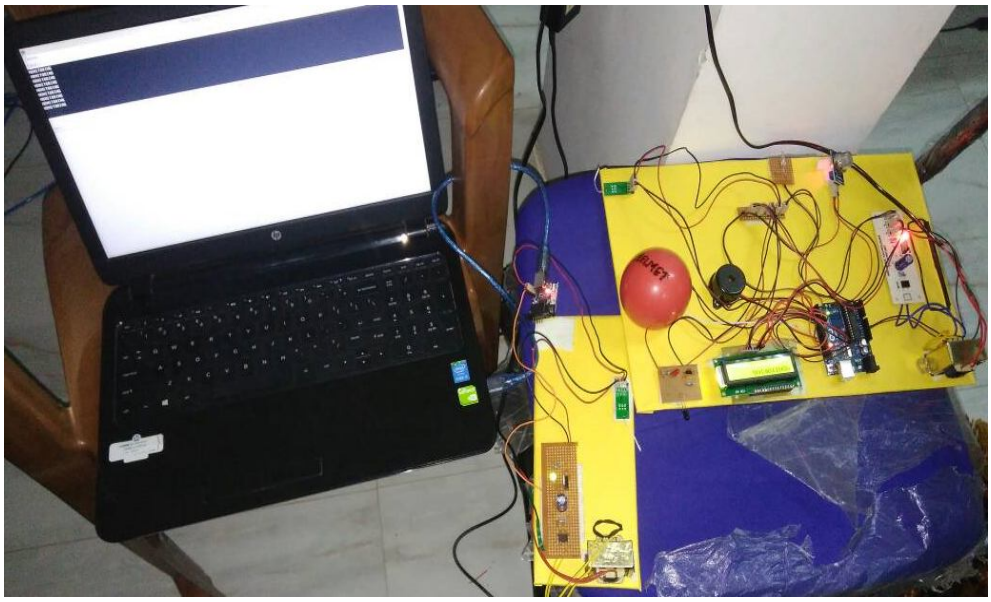

Fig. 4: Hazardous Gases are detected.

V. CONCLUSION

A smart mining helmet was developed that is able to detect Four types of hazardous events such as as air quality, helmet removal, fire and vibration sensor . The First hazardous events were classified as a miner removing the mining helmet off their head. An off-the-shelf IR sensor was then used to successfully determine when the helmet is on the miner's head.The Second concentration level of the hazardous gases such as CO, SO2, NO2, Alcohol and particulate matter. The third hazardous event is fire sensor , it is used as a simple and compact device for protection against fire. The fourth hazardous event is vibration sensor, here a mercury sensor is

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used which is a very toxic element that is widely spread in the atmosphere, lithosphere, and surface water,used to check the availability of water under the ground

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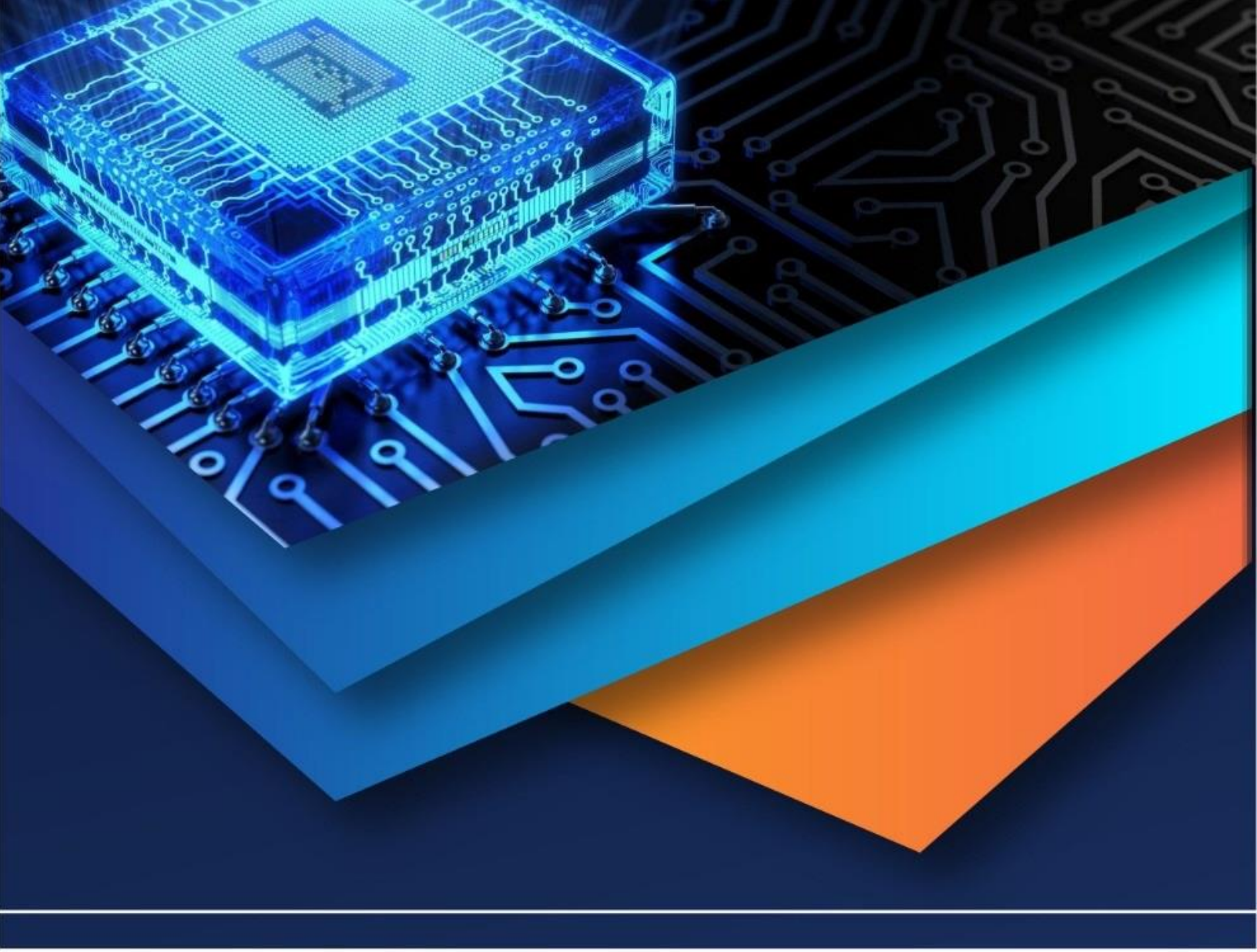

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