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Designing of Wireless Sensor Node for Measurement of Light Intensity of Polyhouse Environment

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Abstract: An ubiquitous Wireless Sensor Network (WSN), consists of spatially distributed autonomous sensor nodes, configured to monitor various physical and environmental parameters. Through the standard protocol supported by IEEE 802.15.4 the sensor nodes are collaboratively connected to the Base station. Basically, the characteristics of sensor node decide the reliability of the WSN. Emphasizing innovative embedded technology a five Wireless Sensor Nodes are designed to measure the intensity of the light, wherein the microcontroller of promising on-chip resources, AVR ATmega8L, is deployed. The microcontroller is employed to ensure the data processing. The deployment of on-chip ADC of 10 bit resolution helps to enhance the preciseness in the results. The photodiode BPW34 is used to detect the light within the polyhouse environment. This sensor is highly sensitive to the visible light. The DAS is wired about operational amplifier TLC 271. Using Code Vision AVR IDE the embedded firmware is developed and ported into on-chip memory of the device. The RF module Zigbee is employed to ensure wireless connectivity. The nodes are implemented to measure light intensity of polyhouse. It is working with high reliability and low power.
Keywords: Wireless Sensor Network, Embedded system, AVR microcontroller, Light intensity, Zigbee RF Module

I. INTRODUCTION

Wireless Sensor Network is an emerging field of electronics and due to promising features, it is becoming more pervasive in the field of sophisticated instrumentation designed for measurement and control of various physical, chemical and environmental parameters [1]. The Wireless Sensor Network is the distributed network, wherein all nodes are collectively collect and disseminate the data about the environmental parameters to the base station [2]. The Wireless Sensor Network has bright salient features like reliability, data security, flexibility in configuration, dynamic reconfigurability, low power consumption, self healing and self insertion of the nodes etc. Many researchers have developed Wireless Sensor Network for plethora of applications [3-5]. It plays the key role in the fields, such as industry, agricultural, biomedical, defense, space application etc.

The socio-economic status of many nations significantly depends upon the developments is agricultural sector. In developed countries the agriculture sector is modernized and agriculturists are availing sophisticated instrumentation for crop cultivation. In developing nations the modernization of the agriculture is the need of the hour. Presently, the agriculturists are employing traditional methods of the agriculture, which causes to reduce the growth rate and crop yield as well. However, recently, the scenario is changing and the agriculturists are attracting towards precision agriculture, wherein the crops are cultivated in controlled environment. The polyhouse agriculture is best example of the precision agriculture. Indeed, the agriculturists are demanding sophisticated electronic instrumentation for controlling environmental as well as soil parameters. Traditionally, the agriculturists are collecting the information of polyhouse parameters through unskilled person and hence this data is less reliable. Moreover, the values of polyhouse parameters are found to be time as well as location sensitive. Therefore, data exhibit the localized effect. Hence, data from the various sites should be collected simultaneously within given time domain. The data collection manually exhibit significant constraints to provide controlled environment. Therefore, the precision agriculturists are demanding the highly sophisticated system to collect and process the environmental data. The Wireless Sensor Network (WSN) is an innovative technology, which could satisfy this need of hour. The WSN is a distributed network, designed using standard wireless network protocols, supporting IEEE 802.15.4 standards, working in globally accepted ISM band at frequency 2.4 GHz, comprising the Wireless Sensor Nodes, which are collectively operating and disseminating data to the base station [6]. The sensor Node plays vital role on reliability and performance of entire WSN. Therefore, the sensor node should have highly promising features. The performance of the sensor Node depends upon the characteristics of sensor employed, features of processing and data storage unit and the wireless unit adopted for establishment data communication. It is found that, the RF module from Zigbee technology is most suitable to ensure the wireless communication [6]. Recently, the microcontrollers of promising features are available, deploying which one can design an embedded system for dedicated applications. Presently, many vendors are contributing in development of the nodes. The Mica2, designed about AVR ATmega128L, is pioneering example of such node. However, it is costly and unaffordable to common agriculturists. Pawar reviewed the field of Wireless Sensor Network and suggested its suitability for environmental paramater [4, 6]. They reported features of both Zigbee as well as Bluetooth technologies. In addition to greenhouse applications, the Wireless Sensor Network technology finds the application in industrial as well as biomedical field. It exhibits the use of Bluetooth to ensure medical applications. Erdongan et al [5] developed Wireless sensor to monitor a pressure inside a tyre of automobiles. Emphasizing the low power requirement of Wireless Sensor Network, Francisco et al have employed WSN for medical applications [7]. Li and Yuan have reported a waste water monitoring system based on Wireless Sensor Network [8]. Merrett et al have attempted to overcome the limitations on designing sensor nodes and reported a algorithm 'Information manageD awarE Algorithm for sensor network' (IDEALS) systems for WSN [9]. Moreover, the researches have also reported different protocols suitable for establishment of Wireless Sensor Network [10-12]. Tziritas et al have extensively studied the Wireless embedded system and reported the constraints of the development [13]. For ground water management the Wireless Sensor Network is developed by Lodel et al [14, 15], wherein real time system is incorporated. They developed WSN for soil moisture measurement, wherein a typically designed moisture sensor is employed. To ensure WSN they availed nodes which are developed about AVR AT mega128 microcontroller [16,17]. Zivkovic has developed wireless smart camera network, wherein Zigbee RF module is used to ensure wireless data communication. Emphasizing the application of renode environmental monitoring the field of WSN is reviewed by Yick et al [18]. By extensive investigation they reported the importance of WSN for various applications such as military target tacking [19, 20], natural disaster relief [21], biomedical and health monitoring [22, 23] etc. For investigation of underground water the WSN is developed [24], wherein the sensor network consists static as well as mobile sensor nodes. The nodes communicate via point to point link using high speed optical communication. They suggested to use TinyOS as a operating system. Health monitoring applications [25] using WSN can improve existing health care and patient monitoring. They developed WSN with five prototype design using T-node devices for sensing and dissemination of data. The Mica2, designed about AVR ATmega128L, is pioneering node, but it is costly and therefore, based on AVR ATmega8L microcontroller based embedded system design deploying Zigbee as a RF module, the Wireless Sensor Node is designed for measurement of light intensity of polyhouse environment.

II. DESIGNING OF WIRELESS SENSOR NODE

The objective of the present work is to design the sensor node for WSN to measure light intensity of polyhouse environment. The philosophy of sensor nodes and sensor nodes is almost identical. Differentiation is only the fact that, sensor nodes are contributing in communication of the data only and the sensor nodes designed to sense, process and communicate the data as well.

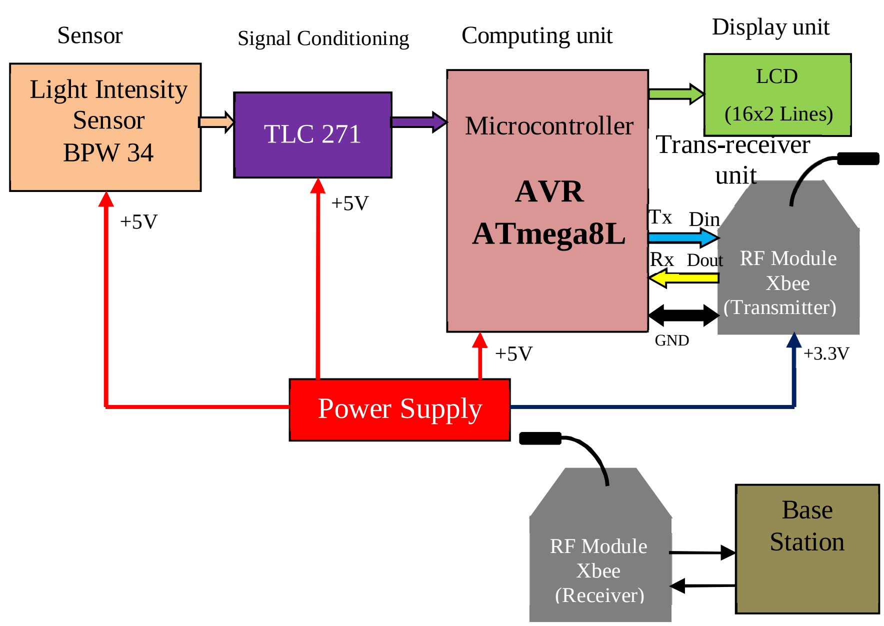

Figure 1. Block diagram Wireless Sensor node designed for Measurement of light intensity of polyhouse environment

Typically, wireless sensor node comprises a Sensor, Data acquisition system, Microcontroller, RF module and power supply unit. The node should be of good reliability and portability, battery operated and consume less power and caters the needs of WSN. Emphasizing this fact a node designed to measure light intensity of polyhouse environment. It is an embedded system developed about AVR ATmega 8L microcontroller. Therefore, it comprises both hardware and software. The details regarding designing of the hardware and the development of software are described though following article.

A. Hardware

The hardware of sensor node designed to monitor the light intensity of the polyhouse environment is depicted by block diagram [Fig 1].

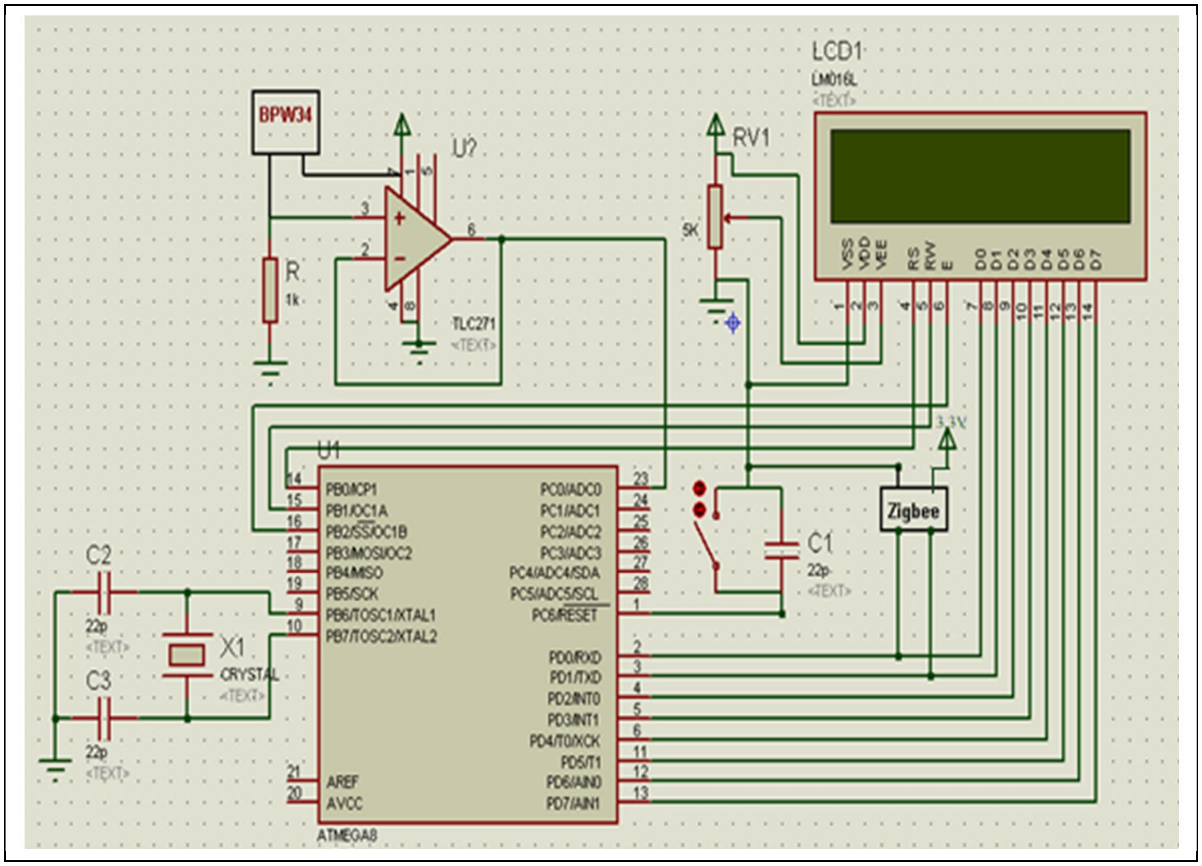

Figure 2. Circuit Schematic of Wireless Sensor node designed for Measurement of light intensity of polyhouse environment

Moreover, the circuit schematic is presented in figure 2.

Ensuring the facets of the embedded design, the sensor node is designed, wherein the following stages have been incorporated.

1) Light Intensity Sensor (BPW 34)
2) Operational Amplifier (TLC 271)
3) The microcontroller AVR ATmega8L
4) Trans-receiver section (RF Module, Zigbee)
5) Smart LCD
6) Power supply unit
7) In-system Programming Unit

a) Light Intensity Sensor (BPW 34): An objective of present work is to design wireless node for light intensity. Polyhouse agriculture is a best example of precision agriculture, wherein the crops are cultivated in controlled environmental conditions. The sun`s radiations are penetrating through the polyethane cover and used to stimulate the photosynthesis process. Therefore, intensity of light significantly affects the crop growth.

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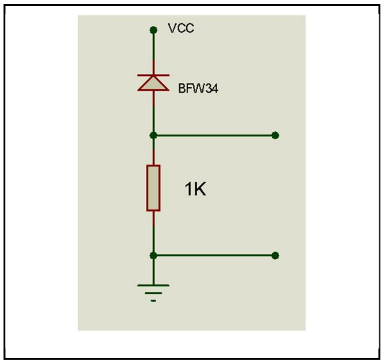

Figure 3. Circuit arrangement for Light intensity sensor BPW 34.

To detect light energy the sensor used is BPW34. It is a PIN photodiode with high speed and high radiant sensitivity. It is sensitive to visible and near infrared radiation as well. The sensor is wired in reverse biased mode and resulting current, A, is allowed to pass through a resistor of 1 killo Ohm [Fig.3]. The resulting emf is used for further analog design.

b) *Operational Amplifier (TLC 271):* The signal conditioning circuit is wired about operational amplifier TLC271. The operational amplifier TLC 271 is used to interface the analog signals. An important characteristic of this TLC 271 is that, it operates on single power supply and having very high input impedance (10^{12} Ω) is highly suitable for designing of the Wireless Sensor Node [5,98].

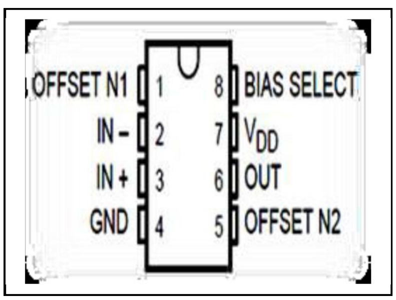

Figure 4: Pin description of TLC271

In addition, the TLC271 offers a bias-select mode that allows the user to select the best combination of power dissipation and ac performance for a particular application. The pin description of the TLC 271 is shown in figure 4. Output of the signal conditioning stage is given to the analog channel of the microcontroller. The AVR ATmega 8L has provision to deploy internal source of 2.56V as reference for on-chip ADC. Therefore, to ensure full range of operation, the gain of signal conditioning stage is limited to 1. It provides better solution for buffering of the signal. The microcontroller digitizes the signal with 10 bit resolution and processes the same for further action.

c) *The Microcontroller AVR Atmega8l:* In order to reduce hardware as well as software complexity and hence the cost, it is decided to employ AVR ATmega 8L microcontroller as a processing device for present wireless sensor node. As discussed earlier, the node has the capacity of processing, which is ensured by the use of promising on-chip resources of AVR ATmega 8L. As depicted in figure 2, the microcontroller is playing key role on operation of entire node. The deployment of on- chip resources of the AVR microcontroller such as ADC, IO Ports, memories etc helps to reduce complexity and hence cost and time to market. This microcontroller is having on-chip ADC of 10 bit resolution. Moreover, it is configured to a highly stable internal reference voltage of 2.5V in continuous conversion mode and also result is right justified. Therefore, it can significantly digitize the signal minimum of (2.56V/1024) 2.5mV. Thus the system under investigation is highly precise. The LCD (16 x 2 lines) from Toshiba make is interfaced to ensure digital read out of the parameters. To reduce power consumption, the interfacing of LCD is configured in sleep mode which can be switched on as per the need. In system programming facility is also provided on each node to embed the firmware. The firmware is developed to synchronize the entire operation of the node *d) Transreceiver Section (Zigbee, the RF Module):* Zigbee as shown in figure 5, is RF module [26, 27] defines the higher level communication protocol supporting IEEE 802.15.4 standards. It is low cost, low data rate module operating at 2.4 GHz of ISM band. In addition to that, the Digi corporation has vendored other Zigbee compliant modules employing which one can develop WSN for dedicated application. In addition, the Digi corporation has also provided the software (X-CTU) for configuration and testing of the Zigbee.

Figure 5: The ZigBee RF module

Zigbee is one of the global standards of communication protocol formulated by the relevant task force under the IEEE 802.15 working group. The fourth in the series, Zigbee is the newest and provides specifications for devices that have low data rates, consume very low power and are thus characterized by long battery life. Zigbee devices are actively limited to a data rate of 250Kbps, compared to Bluetooth's much larger pipeline of 1Mbps, operating on the 2.4 GHz ISM band, which is available throughout of the world. The target networks encompass a wide range of devices with low data rates in the Industrial, Scientific and Medical (ISM) radio bands. Therefore, is mostly suitable for wireless sensor network, wherein standard communication protocol can be implemented.

Security and data integrity are key benefits of the ZigBee technology. ZigBee leverages the security model of the IEEE 802.15.4 MAC sublayer, which specifies four security services such as access control, data encryption, frame integrity and sequential freshness [28]. To ensure serial communication, the serials lines, Tx and Rx, are interfaced to the microcontroller respectively at RxD and TxD pins. The data packets, when ported through serial buffer of microcontroller, are framed within the RF section of Zigbee and then transmitted towards another node and on hopping it reaches to the base station.

B. Embedded Firmware

The firmware required to fulfill the needs of embedded design is developed in code vision AVR the IDE. The source code of the firmware is described through the following modules.

1) Main Programme
2) Functions or subroutines
a) USART()
b) LCD()
c) LCD_INIT
d) LCD_CMD
e) LCD_data
f) ADC()
g) Calibration()
h) Dec_bcd_ASCII()
i) Msdelay()

The firmware realizes the sequential flow of execution. The USART ( ) is developed to establish serial communication. The LCD is interfaced in 4-bit mode and hence it is configured accordingly. The two subroutines LCD_CMD and LCD_data are designed to synchronize the digital display of the light intensity in relative units. The function ADC() handshakes the signal to initialize on-chip ADC and reads converted digital data (10 bit) in right justified format. This digital data is averaged over 1000 samples and then availed for further processing. The function Calibration ( ) plays significant role in data processing. The process of calibration is described in next section. Actually, the LCD needs the data in ASCII format. The function Dec_bcd-ASCII does this job. It is found that, both hardware and software are functioning to ensure synchronization in the operation. The IDE X-CTU is utilized to provide address of present node.

III. CALIBRATION

The wireless sensor mode under investigation is designed for monitoring of the light intensity of polyhouse environment. The amount of light entering a polyhouse is influenced by structure of polyhouse, the orientation of the structure, the materials used in construction and covers and the shape of the roof.

The part of radiation spectrum that the plants significantly use is called Photosynthetically Active Radiation (PAR) and it is in the range from 400 to 700 nanometer wavelength, which is almost the same as visible light spectrum (380 nm to 770nm) The currently preferred unit of measurement for light is □mol/m^2/s (Micromole per meter squared per second). This unit expresses an amount of photons of light incident on a unit area (m^2) per unit time (second). In order for a common light sensor to display a meaningful reading, a very large number of photons are needed to sufficiently activate the sensing element. Therefore, Avogadro's number (6.023 x10^{23}) of photons is defined as a 'mole' of light. A 'micromole' (□mol) is equals to 6.023 x 10^{17} photons. In order to measure the light intensity, normally, foot-candle (Ft-Cd) or Lux meters are employed. However, the foot-candle and Lux are human perspective and instantaneous units and therefore it provides constraints for quantification. Minimum light intensity required for the plants is 200 □mol/m^2/s. Intensity of Sun`s radiations is very low during morning time. It increases and peaks at about 12.00 noon and then declines. However, for the plants the integrated light intensity is considered. If the intensity is low then it is supplemented by deploying fluorescent source of light. Moreover, the sensor node under investigation is designed for monitoring the amount light inside the polyhouse environment, wherein agriculturists are working. The agriculturists rarely know about scientific units, specifically □mol/m^2/s. Therefore, with the view design the user`s friendly node for common agriculturists, instead of absolute units, the node is calibrated to the relative units, i.e. percentage of light with respect to the maximum sun light.

To sense the light energy, the precision photosensor, photodiode is employed. The current flowing through the photodiode is proportional the light intensity. Hence, the emf produced across the resistor Rp is proportional to the intensity of the light [Fig3]. It is proposed to calibrate the system in relative units. The relative unit is nothing but the percentage of light with respect to the sun`s radiation in open environment at 12 noon, at which intensity of radiations is assumed to be maximum.

For calibration of the system in relative units (%) following procedure is adopted. In the beginning, the sensor is exposed to the dark and resulting emf is compensated to zero. A care is taken to avoid the stray light also. Then, the system exposed to full sunlight, at 12.00 noon assuming that the sun rays are perpendicular to earth surface and it is bearing maximum light energy at this time. The observation is recorded. Let it be `Vm' in mV scale. It is found that the emf observed at this condition is Vm (= 2500 mV). Thus the calibration factor is obtained as (1/Vm) and the expression for light intensity (I) in percentage is

$$I (\%) = (V_{obs}/Vm) \times 100 \qquad \ldots(1)$$

Where, V_{obs} is instantaneous emf observed during implementation. This expression is employed in the software for processing and the data in percentage is communicated towards base station.

IV. RESULTS AND DISCUSSION

The wireless sensor node is designed and implemented to monitor the light intensity of the polyhouse environment. The computer is connected to the coordinator node; whereas the node under investigation is located in the Polyhouse plant located about 80 meter away from the base station. The light intensity data is collected by the sensor node under investigation and displayed at the base station. Light intensity for full day time is measured and the results are plotted against time. Figure 6 shows the graph of light intensity, in % , against hours of the day. The sensor node is calibrated to the maximum sunlight (100%).

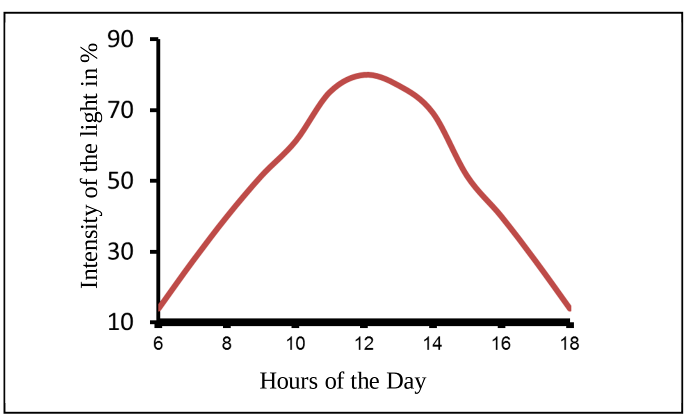

Fig. 6. Graph of observed Light intensity (%) of Polyhouse against time

The measurement of light intensity of polyhouse environment is carried out continuously for full day. It is found that the light intensity in the polyhouse environment varies with time. In the morning, it is about 20%. As sun rises, the light intensity increases and becomes maximum, up to 80%, during mid day and then decreases. The light intensity inside the polyhouse is less than that of open environment. This is due to cover of the polyhouse, which filters the sun`s radiation. Further, the design could be extended to control the light intensity to desired set point. For this, it is suggested to supplement the light through use of fluorescence light source. By controlling intensity of this source, the controlled light energy can be provided to help photosynthesis process.

V. CONCLUSION

The wireless sensor node under investigation is designed for monitoring of the light intensity of polyhouse environment. The precision light sensor employed in this project gives the signal with great reliability. The node is an embedded system developed about AVR ATmega8L microcontroller. It exhibit preciseness and reliability in the data. Deployment of promising feature of RF module, Zigbee wireless communication is established. It can be concluded that, the system works satisfactorily and helps to monitor light intensity of the environment very precisely.

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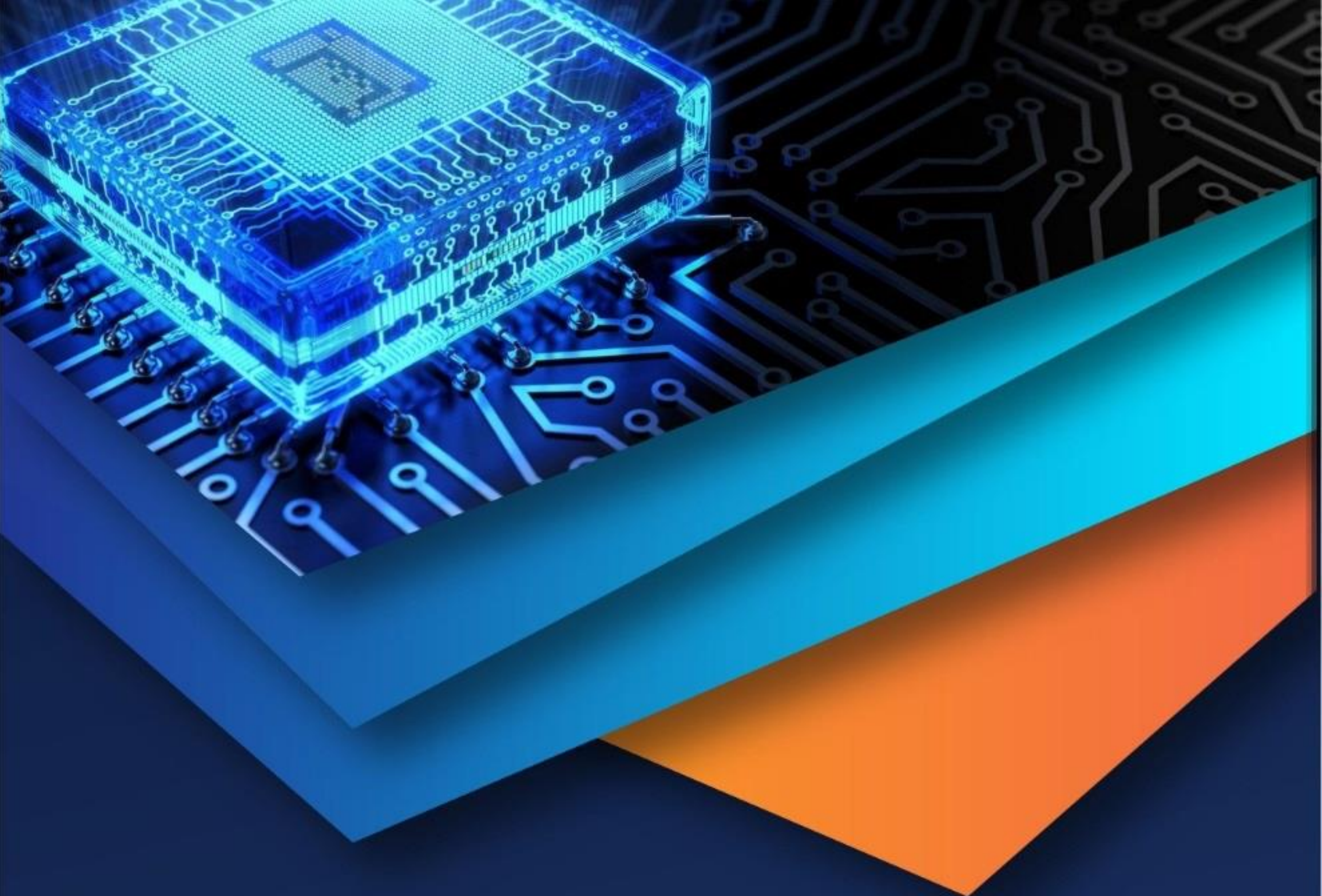

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