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Agrotech: Advanced Field Control

Samarth Asnani[1], Swarna Shenoy[2], Manali Mule[3], Utkarsh Pathak[4]
[1, 2, 3, 4]*Bachelor of Engineering in Instrumentation, University of Mumbai, India*

Abstract: Agriculture in most countries is largely dependent on the environmental conditions and climate. Real-time remote monitoring of field conditions allows for early detection of unfavorable conditions developing in the field that is generally a laborious task taken up by the farmers themselves. Additionally, with the rapid shift in climatic conditions and issues pertaining to global warming, the rainfall dependent agricultural yield is promptly affected. In this paper, we present a wireless system using nRF24L01 RF modules to monitor the farm environment conditions and operate the final control element aimed at implementing drip irrigation. The proposed system is designed to be economical and having a capacity for further expansion, allowing the widespread devices across the farm to be controlled. The soil sogginess level is measured by a self-made soil moisture sensor. A ball valve is actuated based on the levels of soil moisture, temperature and humidity checked against a set of predefined levels. The collected data is then pushed onto a cloud platform for future study or use.
Keywords: Wireless sensor network, real-time monitoring, nRF24L01 RF module, highly economical and efficient system

I. INTRODUCTION

Agriculture has played an important role in the development of human civilization across the globe. [1] Moreover, it is the foundation of Indian economy. 70 per cent of Indian population depends on farming, either directly or indirectly. Around 50 per cent of the total employment in the country is through agriculture. Also, the agricultural sector in our country contributes to about 17 per cent to the country's Gross Value Added (GVA). [2] However, in the recent times, its contribution to GDP is declining. Agriculture, the backbone of our country, has been facing numerous challenges with one of the biggest challenges being water scarcity. Water is a crucial factor in plant development. A major portion of the country's crop area is completely dependent on South-west monsoon as farmers are not equipped with proper methods of irrigation. Unpredictable and uncertain monsoon rainfall have led to improper irrigation affecting the economy in a negative way. That is why irrigation requires a thoughtful approach, as it should be neither excessive nor insufficient. Soil moisture sensors are extremely useful in determining water levels, considerably facilitating farmers' efforts and reducing costs. A remote soil moisture sensor, along with the real-time farm conditions empowers agriculturalists to estimate the water levels and schedule irrigation events more efficiently by either increasing or decreasing their frequency, without the need to be physically present in the field.

The next biggest challenge is to educate farmers in the use of modern technology and innovative approaches to increase productivity and raise profitability. Technological innovations have greatly shaped agriculture throughout time. From the creation of the plow to the global positioning system (GPS) driven precision farming equipment, humans have developed new ways to make farming more efficient and grow more food. New-age technologies focus on robotics, precision agriculture, artificial intelligence and more. The advent and advancements in embedded systems and wireless technologies also have great potential to boost this sector. These technological trends are key to feeding the ever-expanding global population with the decreasing freshwater supply.

Agrotech, refers to the use of technological innovations in agriculture to increase yield, quality, efficiency, and profitability. The present work proposes an approach to implement smart farming by harnessing and tracking information about the weather, humidity, and current condition of soil using remote sensors, which otherwise consumes a lot of farmers' time. The collected data is then utilized to implement automated irrigation.

II. SYSTEM BLOCK DIAGRAM

Architecture of the system is subdivided into 3 subsystems:

A. Power Supply Subsystem

It consists of a 9V solar panel connected to a Li-ion battery charger whose output voltage is amplified to the Arduino's working voltage level by a boost convertor.

B. Sensor Subsystem

It mainly consists of the hardware which includes different sensors like temperature, humidity and soil moisture. The sensors are integrated into a sensor network by using the RF module nRF24L01. These are long range RF nodes that require low energy for their operation. The RF nodes transmit the data to the IoT gateway which is further transmitted to the computer clients using Wi-Fi module. [3]

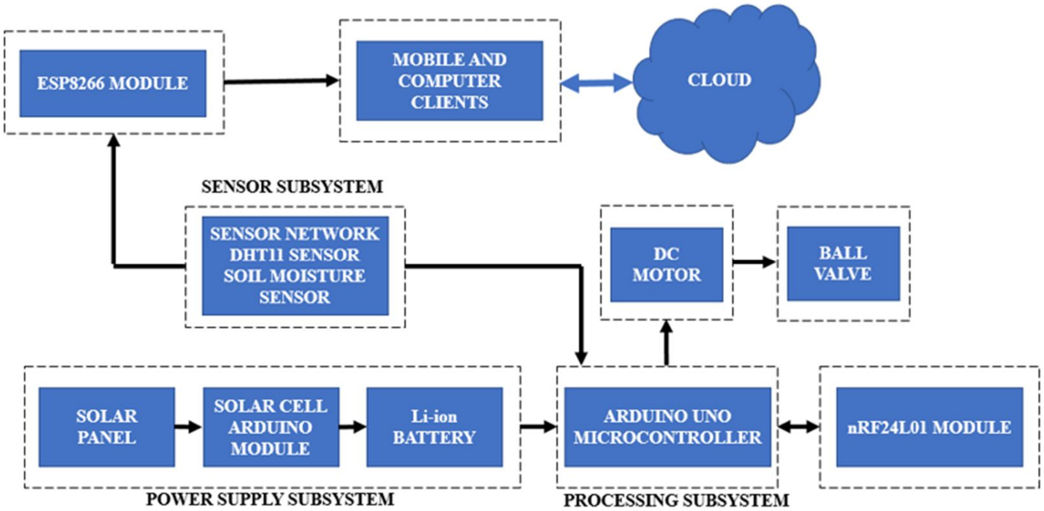

Fig.1 Block diagram of the system

C. Processing Subsystem

It consists of the Atmega328P microcontroller or the Arduino Uno microcontroller. Microcontroller controls all the activities taking place on board. Based on the control algorithm, a control action is initiated i.e. the motor is either turned ON or OFF which further actuates the valve to OPEN or CLOSE. The motor direction control is accomplished using the motor driver IC.

III. SYSTEM IMPLEMENTATION

A. Power Supply Implementation

Solar cells are connected to the input of the lithium battery charger (TP4056), whose output is connected to the 18560-lithium battery. A 5V step-up voltage booster is also connected to the battery and is used to convert from 3.7V DC to 5V DC. Arduino works satisfactorily until the battery is depleted. It is automatically put to charge when there is enough sunlight. A diode is used to limit the voltage and protect the charger circuit since its input is limited between 4.5 and 5.5V. [4]

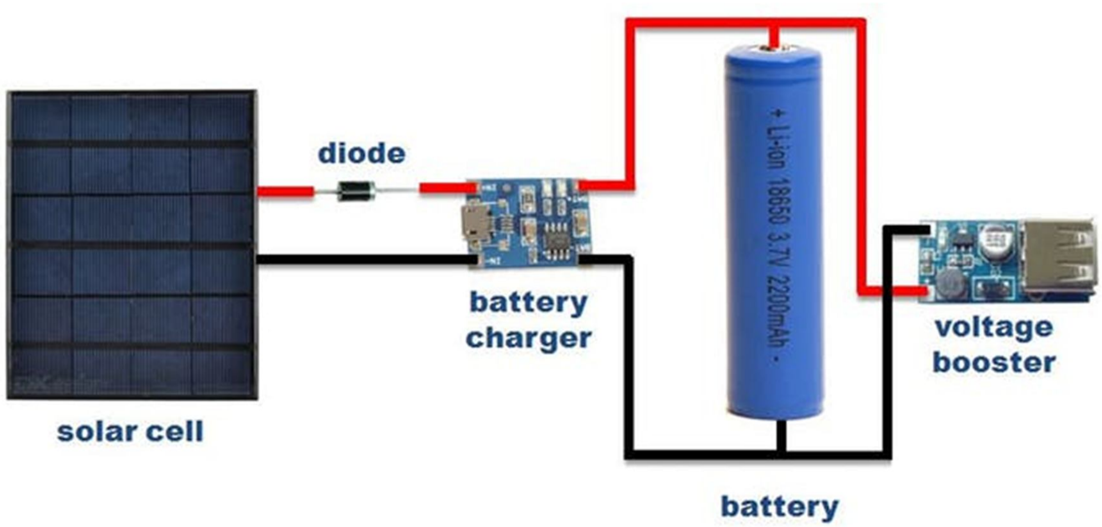

Fig.2 Assembly of solar powered battery charger

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B. Sensor Subsystem Implementation

The proposed sensor subsystem includes 2 sensors – soil moisture sensor and DHT 11 Humidity and Temperature sensor.

The commercial resistive soil moisture sensor is substituted with an economical alternative, i.e. a self-made soil moisture sensor. The sensor built is low tech, low-priced and easy to build using reclaimed materials in much of its construction. Stainless steel rods are used as sensor probes in comparison to the commercially available metallic probes as they are prone to corrosion and electrolysis when buried in soil with DC current flowing through it. The probes are set apart using a wooden block as an insulating medium. [5]

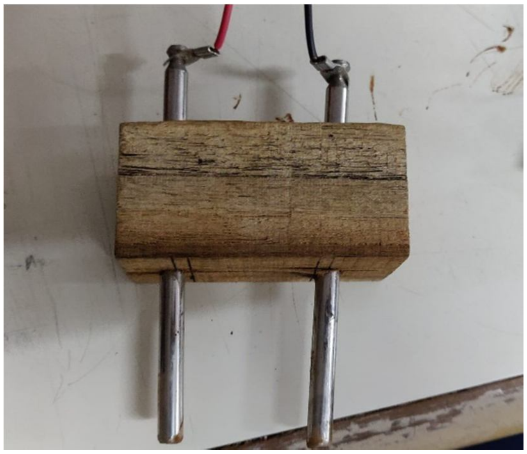

Fig.3 Soil moisture sensor

C. Wireless Transceiver Sensor Network

The nRF24L01 network is network layer for the RF radios running on the Arduino compatible hardware. The layer forms the background of a capable and scalable Wireless Sensor Network system, at the same time, it makes communication between two nodes very simple. The sensors are interfaced to the microcontroller. Together they give 3 data elements which are grouped into an array. Nodes are configured in star topology designed to operate under Master-Slave communication. Real-time values, collected from the sensors at the slave nodes, can be viewed at the Master node's terminal. These values are averaged and compared alongside a set of threshold values.

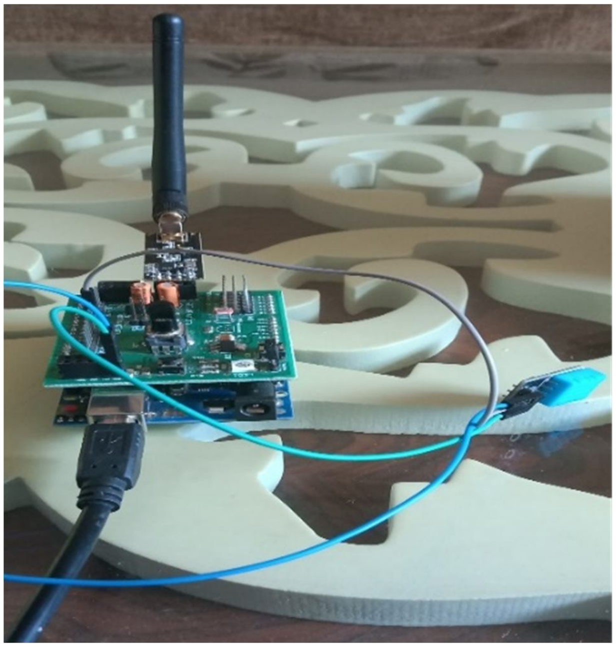

Fig.4 Slave node in system

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D. Automated Valve Actuator Implementation

Fig.5 depicts the proposed design of the automated valve. The DC motor is fixed at one end and the ball valve at the other end. Based on the slider-crank mechanism and concept of locomotive motion, first, the DC motor shaft is coupled to the crank using metal wheel hub. The crank is then connected to an additional link or connecting link. The motion of this link is constrained to a horizontal path. It then connects to the valve handle. The operation of this system is such that as the motor shaft rotates, the crank translates the rotary motion into linear motion of the connecting linkage which further produces the rotation of slider (valve handle). [6]

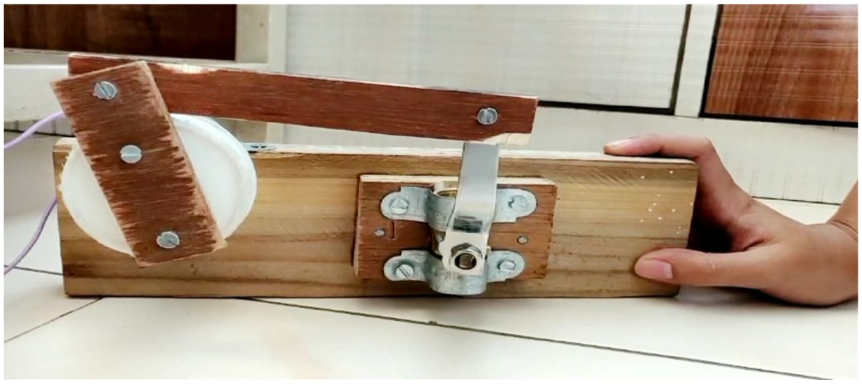

Fig.5 Design of ball valve actuator

IV. RESULTS AND DISCUSSION

The experimentation was restricted to sample soil conditions collected from the local nursery and limited to the environmental conditions of the institute. Hence, the findings are specific to the context of the conditions prevailing and cannot be generalized for wider geographical areas.

The sensor panel, which is the main powering source, was selected so as to be able to provide current for powering the microcontroller as well as current to charge the battery pack during the day. The solar charging circuit charged the batteries during the broad daylight and powered the Arduino modules at night time. Since the readings were to be taken at most for few minutes in a day, the probes were left unpowered for major part of the day, thereby reducing the power consumption.

Secondly, the proposed sensor subsystem was replicated in 4 pots with varying soil conditions i.e. from dry soil to moist soil having different degrees of water content, over a period of 7 days. The readout from the probes was not linear with the water content, but quite close to the values when determined with the use of commercial sensors. Fig. 6 and Fig. 7 illustrate the readout from the probe obtained on the cloud platform for wet and dry soil respectively.

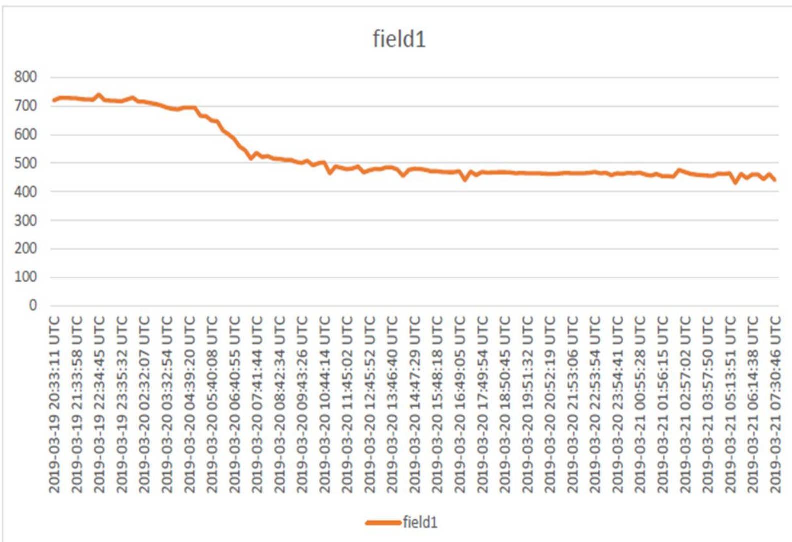

Fig. 6 Soil moisture sensor data graph for moist/wet soil

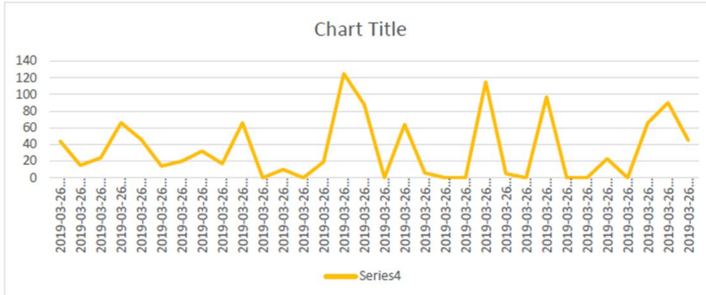

Fig. 7 Soil moisture sensor data graph for dry soil

Eventually, each sensor's data was collected using the measurement technique described and displayed on the respective serial monitors of the sensor subsystem. The sensor network, enabled using the Master Salve communication, worked appropriately in zonal area of radius 10m. The collected data from each pot was also observable on the serial monitor of Master node. The control action was initiated desirably based on the data gathered and algorithm fed into the microcontroller. The actuation of the ball valve took effect based on the control command. The geared DC motor was turned ON and OFF which further actuated the valve to OPEN or CLOSE. The motor direction control was also visibly accomplished using the motor driver IC.

Fig.8 and Fig. 9 depict the serial monitor display of the Master and Slave nodes. These values were averaged and compared alongside a set of threshold values. The data received and control action initiated can be clearly observed and understood from the same.

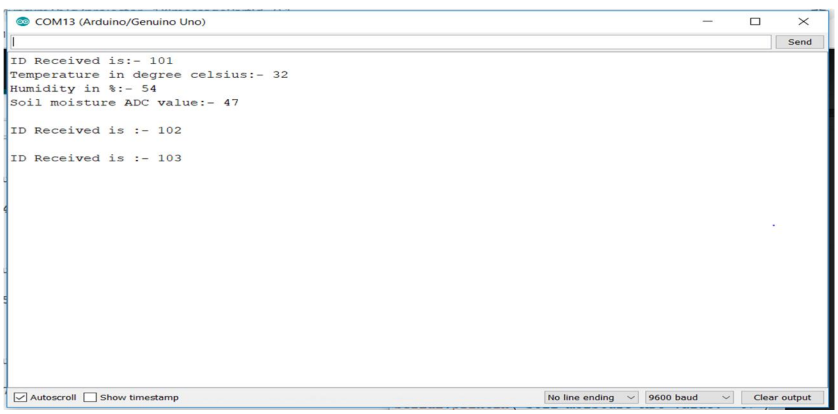

Fig.8 Slave 1 node output at serial terminal

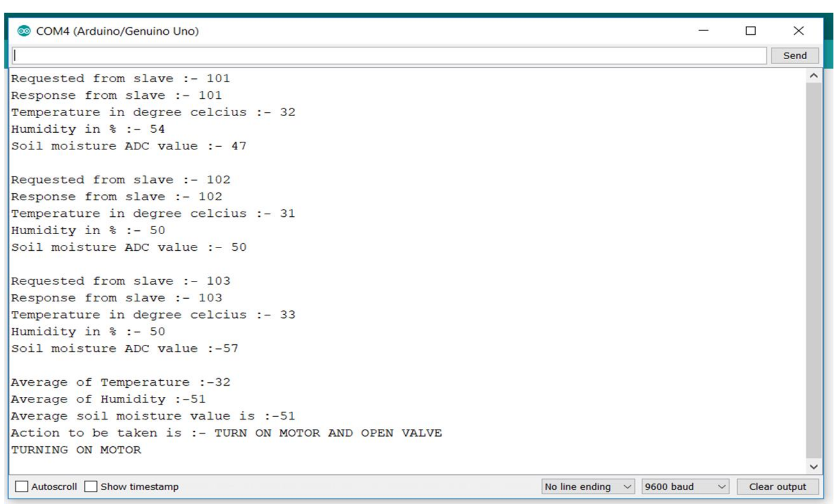

Fig.9 Master node output at serial terminal

V. CONCLUSION

In the present scope of work, we have attempted to design a low cost, low power Wireless Sensor Network developed using nRF2L01 modules and self-made soil moisture sensors making it a useful system for the farmer to incorporate and use in agricultural farm. It facilitates long distance transmission of sensor data and remote control of irrigation units. The development of a system for smart agriculture can greatly benefit from the knowledge of the soil and water dynamics. The efficacy of the soil moisture sensors can be enhanced with profound study of the soil types and careful calibration of the sensors for long term stability and operation. Besides soil moisture monitoring, to assess the plant water needs for its proper and healthy development, it is also important to assess the maximum optimization of natural resources' usage. Various measures like replacing the Atmega328P microcontroller with PIC microcontroller can result in subsequent reduction in power consumption, including a Maximum Power Point Tracker in the power subsystem can increase its efficiency by providing greater power gains.

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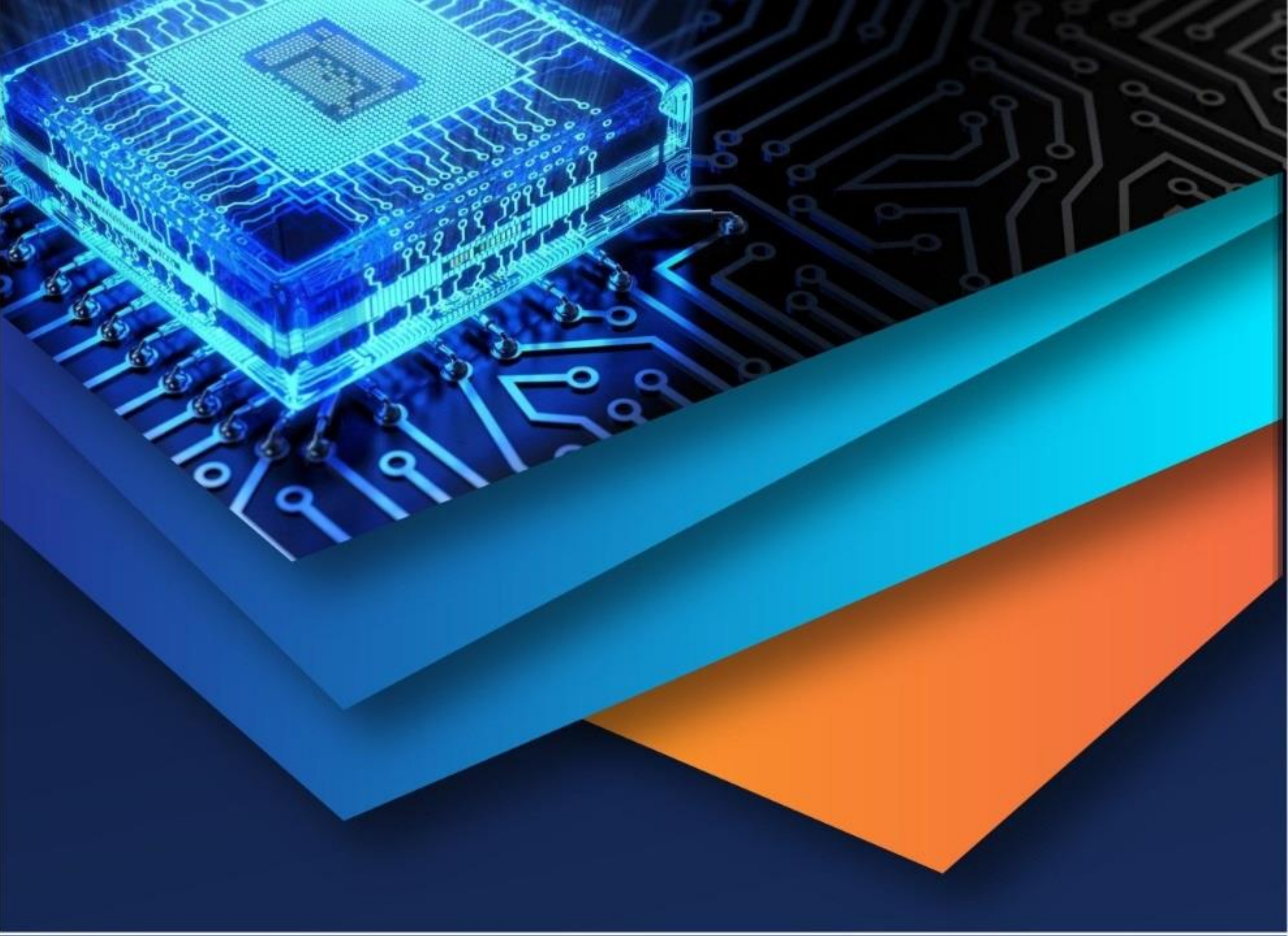

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