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Design and Implementation of Haptic Prosthetic Hand for Realization of Intuitive Operation

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Abstract: This project presents the design and implementation of a microcontroller-based voice activated wireless automation and hand movement system replicating using flex sensor system. As speech is the preferred mode of communication for human beings, this project intends to make the voice-oriented command for controlling the hand movements. The voice command is user independent. The system comprises of transmitting section and receiving section. Initially, the voice command is stored in the data base with the help of the function keys. Later the input voice commands are transmitted to through wireless device. The voice received is processed in the voice recognition system where the feature of the voice command is extracted and matched with the existing sample in the database. The module recognizes the voice and sends control messages to the microcontroller. This project also focuses on replicating the movements of the human hand using a plastic 3D printed hand simulation (hand frame). The flex sensors and servo motors work in co-ordination with ARDUINO to achieve this. The sensor sends the value to the ARDUINO, the ARDUINO processes the data and sends it to the servo motors. Based on the values provided the motor moves and thus the movement of the prosthetic hand is observed-replicating the motion of the hand.The functionality of the proposed project is based on myo-electric arm
***Keywords*: Prosthesis hand, myo-electric arm, servo motor, Arduino**.

I. INTRODUCTION

India, there are about 5 million disabled people (in movement/motor functions). The disabled people affected with neuromuscular disorders such as multiple sclerosis (MS) or amyotrophic lateral sclerosis (ALS), brain or spinal cord injury, Myasthenia gravis, brainstem stroke, cerebral palsy etc., In order to express themselves one must provide them with augmentative and alternative communication. A robotic arm is a type of mechanical arm usually programmable, with similar functions to a human arm. The arm has links connected by joints, allowing either rotational motion or translatory displacement. The result is a system analogous to the functioning of a human arm. Here in our project, the robotic arm has been built on a primitive basis, however much complex and sophisticated one can be built. The robot works on simple components like a steel frame for simulating fingers, sensors for detection of motion and is driven by the ARDUINO board. The arm includes a glove which will be worn and thesensors based on the movement of the fingers will cause the exact same replication in the 3D printed arm simulation (the robotic arm).

A. Why Robotic Arm?

There are many situations where humans just can't just get their hands onto something. There are numerous situations when humans can’t directly involve themselves. Situations like working in canyons, caves, mining, works involving minute details like manufacture of watches, automobile parts, etc. The robotic arm has its applications not just in fields where things get smaller but also elsewhere. The Robotic Arm has huge applications in industries, where a lot of manpower is needed. The robotic arm has great use when it comes to precision and the research of robotic hand has grown significantly especially in the development of robotic prosthetic hand ranging from research hand to commercial hand. The available prosthetic hand in the market is very expensive and hence accessible to only certain people. The purpose of this project is to develop a low cost prosthetic hand using widely used mechatronics components. The hand must be easy to manufacture and easy to maintain with the available components in the market. The prosthetic hand also must be able to perform activities of daily living (ADLs) such as take, grasp and hold an object. Some researches about prosthetic hand significantly increased in the size, weight, and anthropomorphism. The prosthetic hand is used to replace the lost hand especially in transradial amputation. In order that the prosthetic hand can move using command from the remaining muscle of the amputee, the hand must read the muscle activities by using sensor. The most widely used sensor for reading the muscle activities is electromyography (EMG) sensor. In some research, hands use pattern recognition method of the EMG signal to understand the hand movement or gesture.

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One of common pattern recognition method in the EMG signal recognition is neural network [1, 2]. This method is difficult to implement in the prosthetic hand control system due to the limitation of hardware memory in the microcontroller. The simple control algorithm is developed in this project using the flex sensors & servo motors to drive several grip pattern of prosthetic hand.
Some open source hands are available today with reduces cost and to increase manufacturability. Open source prosthetic hand based on 3D print are widely used Ada Hand from Open Bionics and Dextrus from Open Hand
Project. The state of the art prosthetic hands commercially available are Vincent Hand , Michelangelo, Bebionic , and iLimb . They have great performance in ADLs especially for object grasping manipulation but they are still very expensive.

Fig.: 3D printed hand design

In this project the goal is to develop an affordable five degree of freedom (DOF) robotic prosthetic hand and two joints in each finger, for performing the activities of daily living (ADLs), The hand is designed with seven grip patterns, using widely used low cost servo motor incorporating tendon-spring mechanism. The proposed work of the prosthetic hand is to grasp various objects and perform activities of daily living (ADLs). Based on the refrence, the most widely used grasping pattern is power grip followed by precision grip. The prosthetic hand is designed with seven grip pattern to perform object grasping manipulation.
The prosthetic hand is being used in various countries of the world. The most widespread use of the prosthetic hand is in major countries like the United States of America, China, Russia etc , The use of the prosthetic hand is limited to developed and prosperous countries as, the prosthetic hand is usually very expensive since it is sophisticated. Technology has advanced so much that they are brain controlled hands which use brain waves. Others use voice and text inputs.

B. Objectives

1) Design and Implementation of a microcontroller based myoelectric arm which can replicate human hand movements.
2) Design a simple prototype prosthetic hand with the help of D.C. motor which can perform simple pickup and drop operation
3) Interface of microcontroller based embedded system to the voice commands

C. The Merits Of The Project

1) It helps the people who have lost one of their hands or if it is paralysed..
2) Very easily portable. Its is easy to carry the hand around.
3) Light weight 3D printed modules/parts, makes it very easy for the amputees to carry it around with them .
4) Low cost. The whole work can completed under 5000 rupees, which makes the robotic hand very affordable in comparisons to its present contemporary robotic hand proposal.

D. Wireless and Controlled by ARDUINO.

The Prosthetic hand has a lot of scope for modification. Its working can be made completely automatic and wireless. It can be controlled through cloud or wi-fi.

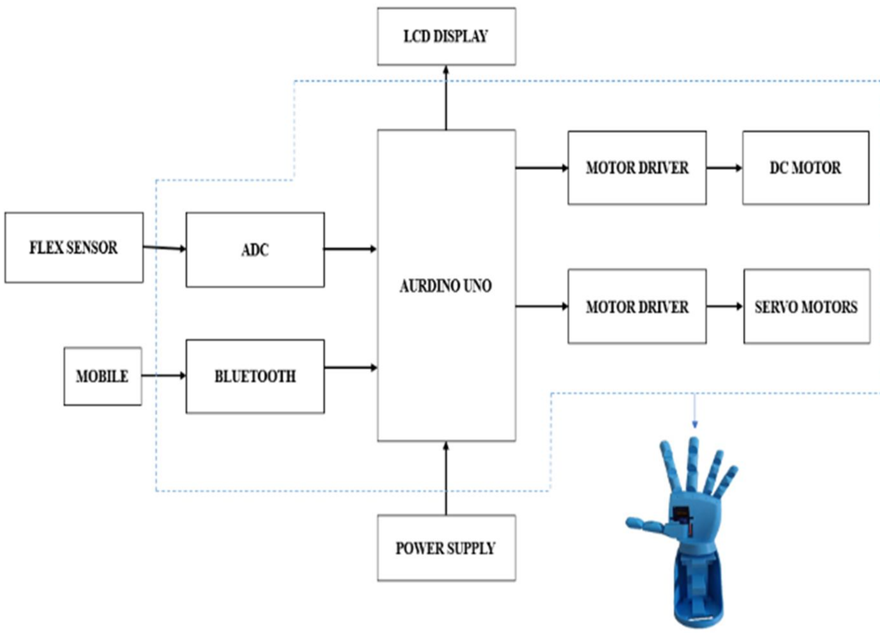
II. METHODOLOGY

A. *Block Diagram Of Prosthetic Hand*

The project proposes a wearable glove controller, to control the movements in the prosthetic arm. The prototype consists of two main parts the glove and the prosthetic arm. Two wireless Bluetooth modules are used to establish wireless communication link between the glove controller and the prosthetic arm.

The interconnection between hardware and software components used of the proposed prosthetic hand is as shown in Fig 1

Fig1.: Block Diagram of Prosthetic Hand Components.



B. *Robotic Arm*

This is the physical motorized robotic arm which will contain the exoskeleton and the actuators required to move the various parts of the arm to emulate real arm movements. Actuators may include various servo motors for precise movement. A microcontroller is used to control all the motors in the arm.

C. *Bluetooth Module*

The Bluetooth technology manages the communication channel of the wireless part. The Bluetooth modules can transmit and receives the data wirelessly by using two devices. The Bluetooth module can receive and transmits the data from a host system with the help of the host controller interface (HCI).

D. *Flex Sensor*

The flex sensor is a type of sensor that changes its resistance when it is bent or flexed. When placed in a prosthetic hand, the flex sensor can detect the movement of the fingers as they bend and flex. The flex sensor is usually attached to the surface of the prosthetic hand where it will be in contact with the user's skin. As the user flexes their fingers, the flex sensor will detect the movement and send a signal to the microcontroller or processor that controls the prosthetic hand.

E. *DC Motor*

DC motors are commonly used in prosthetic hands to provide the necessary power and control for movement. DC motors are able to convert electrical energy into mechanical motion, making them ideal for use in prosthetic devices. In a prosthetic hand, DC motors are typically used to control the movement of the hand.

F. Servo Motor

In a prosthetic hand, servo motors are typically used to control the movement of each finger individually. The servo motors are connected to the fingers using a series of cables or linkages, and when activated, they can move the fingers to a specific position and hold them there.

III. IMPLEMENTTION

A. Working Of Prosthetic Hand

The Flex sensor controller is a form of wearable Human machine Interface, where the machine (prosthetic arm) follows the control signals from human via the glove controller. The glove controller has five flex sensors embedded to each finger to gather the information of the finger positions respectively. Flex sensors used gives the change in the resistance over bending or deflection action which is read in terms of voltage in voltage divider. A gyroscope module is located at the wrist to measure the angular variations and mimic the same in the prosthetic arm. An Arduino UNO microcontroller is used in the glove controller, which processes the input data from the flex sensors by the Analog to digital converter (ADC) pin present and sends the digital output to the Arduino Nano with The digital data from the Arduino UNO is converted into corresponding Pulse width Modulation (PWM) signal. These signals in-turn serve as the guide for controlling the rotation of the servomotors accordingly.

There are five servo motors, five for fingers and one DC motor for the elbow motion. The elbow motion is restricted to 90 degree on both sides .The strings were used to connect the fingers to the servos to act as artificial tendons, present in the fingers. Synchronous movement of each finger is obtained with the given input data and the servo pulleys. The Arduino board is the microcontroller used for processing in the prosthetic arm.

B. Flow Chart Using Flex Sensor

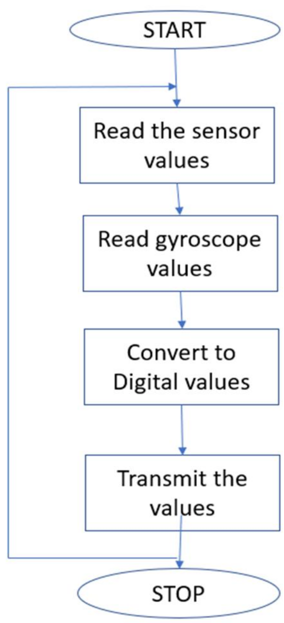


Fig 2: Transmitter Flow chart

As shown in Figure shows the Work flow or the flow chart of the transmitter or in other words of the glove controller, as to how the input signals from the glove is transmitted to the receiver that is the prosthetic arm. These input signals from the glove controller control the movements of the prosthetic arm.

As seen in figure 7, as soon as the Arduino is powered up, the variable flex sensors ouput according to the action or movement in the glove is sensed and the output obtained is converted into corresponding voltage values with the voltage divider circuit setup.

These outputs from the five flex sensors along with the gyroscopes output i.e., x, y & z axis alignments are converted into digital values. These digital values are then transmitted using the Bluetooth transceiver module.

The output from the sensors is transmitted continuously and uninterruptedly. The output changes with the change in gloves action, which changes flex sensors and gyroscopes output in-turn. The process stops with the loss of power.

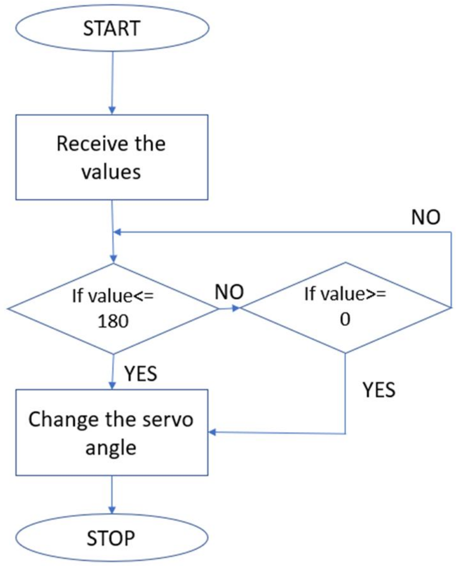


Fig 3. Receiver Flow Chart

As show in above Figure 4.2.2 depicts the Work flow or the flow chart of the receiver or in other words of the prosthetic hand, as to how the output signals are received from the transmitter or the glove controller and is processed to obtain the required actions accordingly.

The Arduino is first powered up for the entire process to happen. The digital output obtained is in the form of PWM waves. Based on the digital values of the flex sensors at two extremities two Threshold values, Threshold 1 and Threshold 2 was set accordingly.

When the digital values varies between the Threshold 1 and the Threshold 2 values the servo motors are aligned accordingly, as seen in the flow chart. The gyroscopes output determines the wrist motion of the prosthetic hand, the angle of rotation of the wrist is restricted to 45 degrees.

The prosthetic arm remains in one position until the output values obtained is changed. In the actions where the grasping of certain objects is required, the prosthetic hand developed as the ability to align then according to the shape of the object due to their flexible movements.

C. Flow Chart Using Bluetooth Module

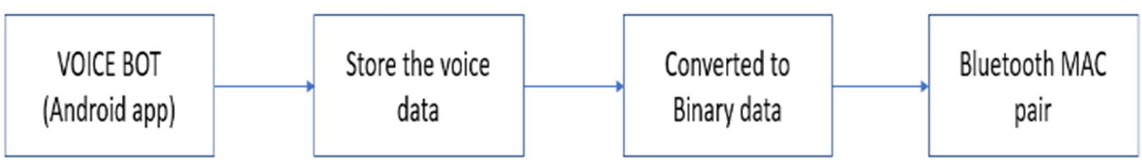


Fig 4 : Transmitter Flow Chart

A Bluetooth transmitter can be used in a prosthetic hand to enable wireless communication between the hand and external devices such as smartphones or computers. The Bluetooth transmitter essentially acts as a wireless communication module, allowing the prosthetic hand to send and receive data over a Bluetooth connection.

In a prosthetic hand, the Bluetooth transmitter is typically connected to the microcontroller or processor that controls the hand. When the user wants to send data to an external device, such as a command to open or close the hand, the microcontroller sends the data to the Bluetooth transmitter. The transmitter then uses Bluetooth technology to send the data wirelessly to the external device.

Similarly, when the external device sends data back to the prosthetic hand, such as data from sensors on the external device that can be used to control the prosthetic hand, the Bluetooth transmitter receives the data wirelessly and sends it to the microcontroller or processor in the prosthetic hand.

Overall, the use of a Bluetooth transmitter in a prosthetic hand allows for wireless communication between the hand and external devices, enabling greater flexibility and ease of use for the user. It also allows for greater customization and control over the prosthetic hand, as external devices can be used to send commands or data to the hand, allowing the user to tailor its movements and capabilities to their specific needs.

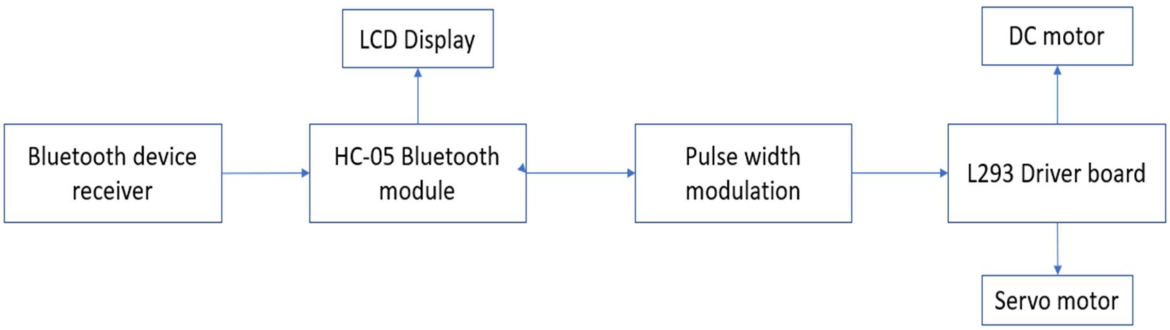


Fig 5 . Receiver Flow Chart

A Bluetooth receiver can be used in a prosthetic hand to receive wireless signals from an external device such as a smartphone or computer. The Bluetooth receiver essentially acts as a wireless communication module, allowing the prosthetic hand to receive data over a Bluetooth connection

In a prosthetic hand, the Bluetooth receiver is typically connected to the microcontroller or processor that controls the hand. When an external device sends data to the prosthetic hand, such as data from sensors on the external device that can be used to control the prosthetic hand, the data is transmitted wirelessly using Bluetooth technology. The Bluetooth receiver in the prosthetic hand receives the data and sends it to the microcontroller or processor for processing.

Similarly, when the user wants to send data from the prosthetic hand to an external device, such as sending data about the position of the hand or the movement of the fingers, the microcontroller or processor in the prosthetic hand sends the data to the Bluetooth transmitter, which sends it wirelessly to the external device

Overall, the use of a Bluetooth receiver in a prosthetic hand allows for wireless communication between the hand and external devices, enabling greater flexibility and ease of use for the user. It also allows for greater customization and control over the prosthetic hand, as external devices can be used to send commands or data to the hand, allowing the user to tailor its movements and capabilities to their specific needs

IV. RESULT

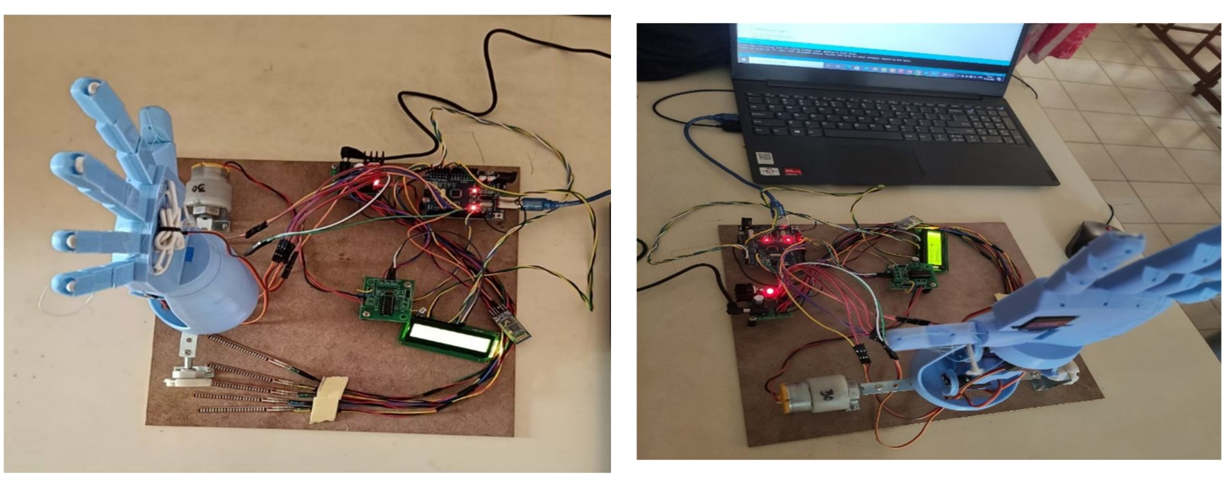


Fig 6&7.Complete setup of prosthetic hand architecture

The prosthetic arm connection with the Arduino UNO, Bluetooth module and LCD display is as shown in the above figures.

V. CONCLUSION

The project proposes a mechanical completely active and multifunctional 3-D printed prosthetic arm imitating a normal human hand structurally and functionally. The aim of being able to perform general actions and activities as the normal human hand was met. A functional glove controller with prosthetic arm was successfully built. The glove controller was able to control the actions of the prosthetic arm in most appropriate way, not only the flexing action but the wrist motion was an added advantage for the gripping action of the object. The prototype built is a cost-effective model which can aid prosthesis is most efficient way. Thus, an anthropomorphic 3-D printed prosthetic arm was designed and developed meeting the aim of the project.

VI. FUTURE SCOPE

With 3D printing advancing and becoming more affordable, the possibility of anyone being able to easily design and print a prosthetic arm or limb could soon become a reality. New 3D scanning and body modelling technology could also enable people to 3D scan their arm or limbs and have prosthetics modelled after them, making for more natural fitting and appearance. New state-of-the-art prosthetics that take in data on how the wearers walk or move their hand and build algorithms to anticipate their intentions are being built. These developments are intended to help those using prosthetic devices to move in the most natural manner possible. Even more impressive, researchers are developing versions of bionic arm and limbs, controlled by thought. They attach to an implant inserted directly into the bone, and nerve reassignment surgery then allows brain signals to directly control movement.

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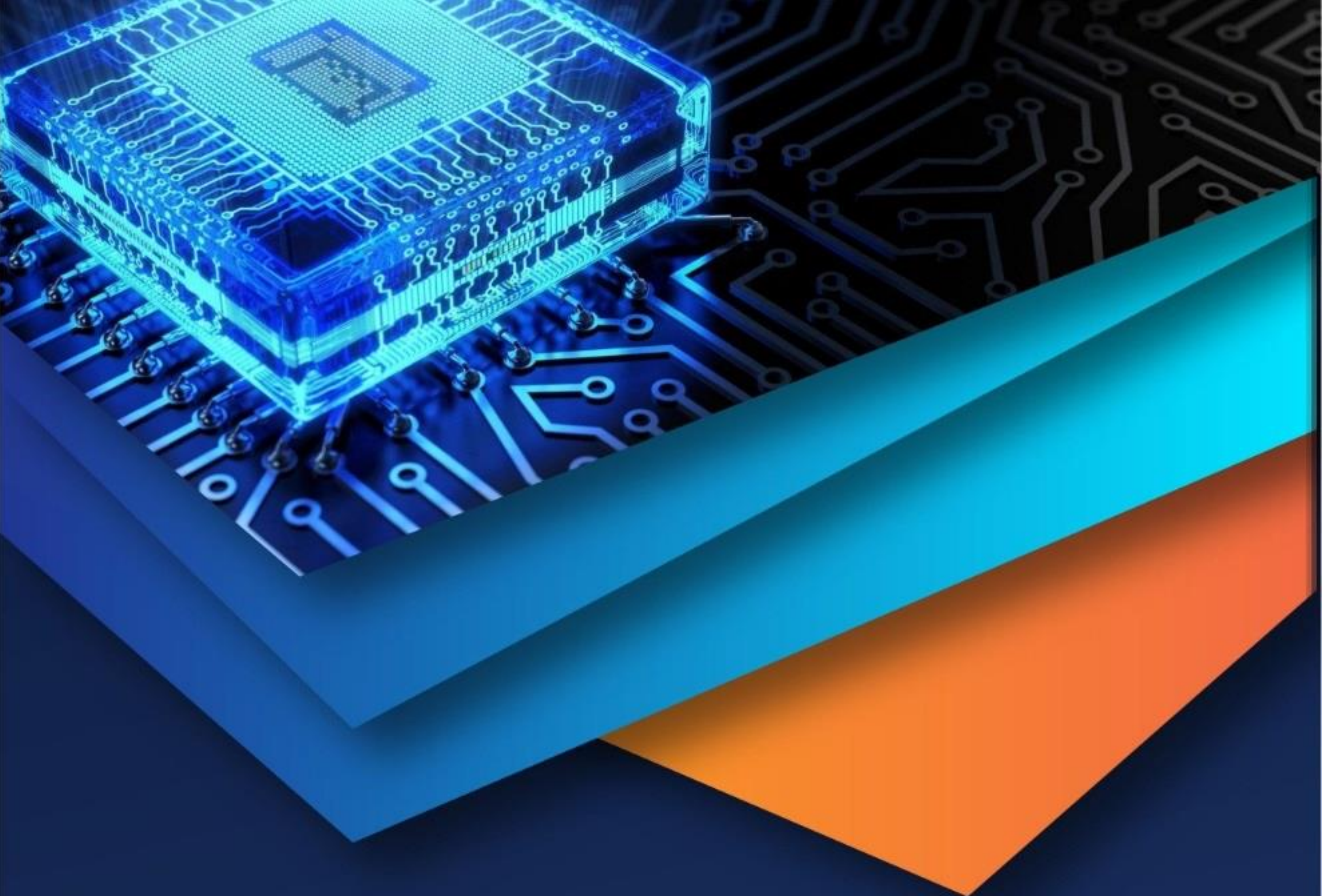

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