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Dynamic Wireless Charging of Electric Vehicles Using RFID Protection

Shiva Nandu Malkam[1], Vaishnavi Sanugommula[2], Pravallika Punumalli[3], Dr. T. Murali Krishna[4]
[1, 2, 3] *UG Scholar, Dept. of Electrical and Electronics Engineering, Chaitanya Bharati Institute of Technology,* Hyderabad, India
[4] *Assosiate Professor, Dept. of Electrical and Electronics Engineering, Chaitanya Bharati Institute of Technology, Hyderabad, India*

Abstract: Electric vehicle (EV) development in transportation is growing rapidly, offering clean and sustainable transportation. The key challenges in the EV are high cost, limited range, battery recycling, charging infrastructure, and many more. Among these challenges, charging presents a double difficulty: limited availability and slow charging times. To address these challenges, charging infrastructure needs to be expanded, develop wireless charging technologies and advancements in battery technologies. In wireless charging there is static, charging while the vehicle is at rest, and dynamic, charging when the vehicle is in motion. EVs can be charged dynamically while they are moving, maximizing energy efficiency and reducing downtime for charging. In this paper a small-scale prototype for dynamic wireless charging with Radio Frequency Identification (RFID), is discussed. RFID integration enables convenient and secure user access and prevents energy theft by unauthorized charging. RFID tag is positioned at the start of the charging path. The dynamic charging system with RFID protection is shown to be feasible and effective by the prototype. The prototype has to demonstrate its capacity to safely and effectively charge EVs in real time while reducing the possibility of unwanted access or energy theft.
Keywords: Wireless Power Transfer, Electric Vehicle, Radio Frequency Identification

I. INTRODUCTION

Over the past century, our dependence on vehicles, especially the Internal Combustion Engine (ICE) vehicles, has become essential in our daily lives. However, there are significant drawbacks, which majorly include an increment in oil prices and harmful air pollution, leading to health issues and climatic change [1]. Electric vehicles present a promising solution to these issues by significantly reducing emissions. If EVs are powered by clean, renewable energy sources (Ex: wind, solar), they have the potential to nearly eliminate pollution from their operation, addressing both local air quality concerns and the broader issue of global climate change [2].

EVs run on electric motors powered by rechargeable batteries. To compete with the performance of ICE vehicles, EVs need good performance, which means the battery capacity and charging options must meet market standards. In response to the challenges posed by traditional wired connections, there has been a surge in interest in wireless charging for EVs [3]. Wireless technology has two main methods: static and dynamic charging. With static charging, EVs need to come to a stop and align with a ground-based charging pad at a stationary charging station [4]. While this eliminates the need for physical plugs, it introduces charging delays as the vehicle remains stationary during the charging process. On the other hand, dynamic charging presents an innovative solution. This method enables vehicles to charge while on the move, eliminating downtime.

A. Wireless Power Transfer

Wireless charging has several advantages over wired charging methods. Its major appeal is the convenience and ease of use it offers, eliminating the need for complicated cables. With reduced wear and tear on charging equipment and devices, wireless charging ensures enhanced durability and longevity. Moreover, wireless charging is much safer because it minimizes the risk of electrical hazards and damage. Wireless charging enhances aesthetics and offers greater flexibility. Additionally, ongoing advancements in efficiency and charging speeds ensure that wireless charging remains a fool-proof solution for powering modern electronics.

The WPT technologies are classified into two types, they are Non-radiative (Near-field) and Radiative (Far-field). These are further classified as shown in fig.1 [5]. They are Inductive Power Transfer (IPT), Magnetic Resonant Coupling (MRC), Radio waves, Capacitive Power Transfer, Magnetic gear etc., among the mentioned technologies

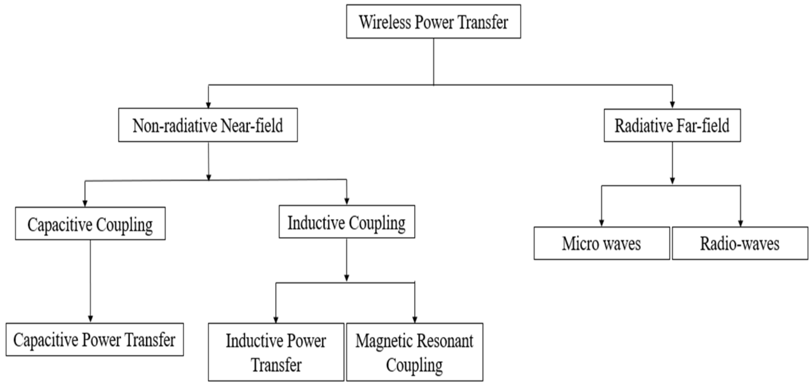

Fig.1 Types of WPT

IPT, MRC are very effective in charging these EVs. More importantly, they all transmit the power through an AC supply and then follow the rectification, AC to DC, for charging of batteries.

1) Mechanism

The wireless charging mechanism initiates with the power grid as the primary power source, where electricity undergoes conversion from alternating current (AC) to direct current (DC) via a power converter. The DC power is then supplied to the transmitter unit, comprising an inverter circuit and a copper coil, which generates an alternating electromagnetic field. This field propagates outward, carrying energy to the receiver unit located within its range. The receiver unit, equipped with a receiver coil and associated circuitry, captures the electromagnetic energy and converts it back into DC. This rectified and regulated power is then supplied to the battery for charging, with safety and control mechanisms in place to monitor and regulate parameters like temperature and voltage. Throughout this process, efficient energy transfer and careful management ensure optimal charging while maintaining safety and reliability.

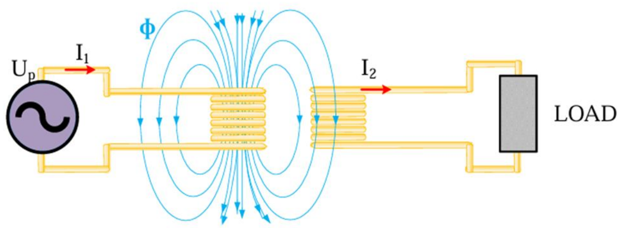

Fig. 2 Inductive Power Transfer [6].

In this paper, Inductive Power Transfer (IPT) is further discussed. Inductive Power Transfer relies on electromagnetic waves to transmit the power from the transmitter coils to the receiver coil, then the power is rectified to charge the battery. IPT has been widely accepted in the automobile industry as it possesses the potential to charge EVs efficiently. However, the inefficiency of IPT due to significant leakage inductance [7] can be mitigated using compensation networks and this approach may introduce compatibility challenges and higher costs. They have little range of power transmission as the Electromagnetic field strength decreases with an increase in the distance of EV to be charged. This can’t be a serious issue as the transmitter and receiver coils can be closely spaced with the former being placed on the road and the latter on the bottom of the EV. The level of power transmission and efficiency is high in the case of IPT and can be the best choice in WPT for EVs. Besides the technical aspects, these are straightforward in design and offer a high level of convenience in WPT.

B. Dynamic Wireless Charging

Dynamic charging is also known as in-motion charging. It presents a novel approach to address many challenges by enabling vehicles to charge while on the move without depleting the batteries [8]. Dynamic charging systems involve the transmission of electrical energy from a power source to a vehicle's battery pack without the need for physical cables or plugs.

This is typically achieved through electromagnetic induction or conductive coupling between infrastructure embedded in the road surface and receiving coils integrated into the vehicle. As an EV travels along a road equipped with dynamic charging infrastructure, it automatically receives electrical power, replenishing its battery and extending its driving range. The concept of dynamic charging holds significant potential to revolutionize the way we think about EVs and charging infrastructure. By enabling continuous charging while in motion, it can mitigate concerns related to range anxiety and reduce the need for large, expensive battery packs, thereby potentially lowering vehicle costs and improving energy efficiency.

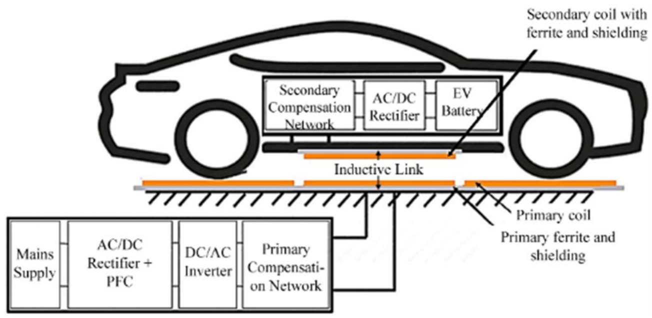

Fig.3 Block diagram of dynamic wireless power transfer in EV

As shown in fig.3, the inductive link consists of the primary and secondary coils, and their corresponding ferrite and shielding layers. The compensation networks are required to resonate the primary and secondary sides at the desired operating frequency, to maximize the efficiency of the power transfer from the primary side to the secondary one. A suitable compensation topology for dynamic charging systems is one in which the secondary side current is independent of the secondary voltage and only depends on the input AC voltage, i.e., constant current source operation.

C. Radio Frequency Identification (RFID)

Despite wireless power transfer for EVs being a highly advanced and promising concept, there remains a significant risk of energy theft. To mitigate this concern, RFID technology is integrated into the system.

RFID technology operates on the principle of wireless communication via radio waves between an RFID tag and a reader device. RFID systems typically consist of three main components: the RFID tag, the RFID reader, and the backend database. The RFID tag contains a unique identifier and may store additional data relevant to the EV, such as user authentication credentials or charging preferences. When the RFID tag comes into the range of an RFID reader, the reader emits radio waves that power the tag and retrieve its data, enabling seamless identification and communication.

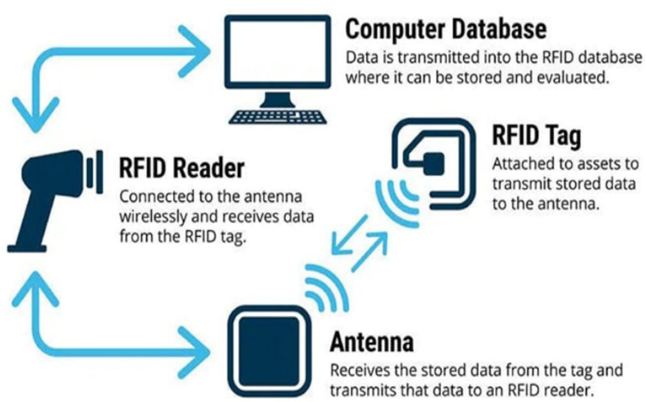

Fig.4 RFID mechanism

D. Components of RFID Systems

1) *RFID Tags:* RFID tags come in various forms, including passive, active, and semi-passive. Passive RFID tags do not have an internal power source and rely on energy transmitted from the RFID reader to function. Active RFID tags, on the other hand, contain their power source and can transmit data over longer distances. Semi-passive RFID tags combine elements of both passive and active tags.

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2) *RFID Readers:* RFID readers are devices equipped with antennas that emit radio waves to communicate with RFID tags. They can be fixed or handheld and are responsible for reading the data stored on RFID tags.
3) *Backend Database:* The backend database stores and manages the data collected from RFID tags, including information related to EV authentication, charging sessions, and billing.

In this paper, the development and implementation of a prototype model for the dynamic charging of electric vehicles (EVs) with integrated RFID technology is studied.

II. METHODOLOGY

The dynamic charging prototype presented in this project showcases a simplified yet effective demonstration of wireless charging technology for EVs, complemented by RFID integration for enhanced security and control. The prototype utilizes a modified prototype, where the original large battery pack is replaced with a smaller, controllable battery pack equipped with a PWM speed controller to adjust the car's speed for clear observation. The prototype is supplied with 12V DC via an adapter. Battery Eliminator Circuit (BEC) is connected to control the voltage supply to the circuit. The core of the prototype consists of a receiver coil mounted underneath the car and transmitter coils positioned on the floor along the charging path. As the car moves over the transmitter coils, the receiver coil receives power wirelessly through electromagnetic induction. To optimize energy transfer efficiency, each transmitter coil is equipped with an infrared (IR) sensor, detecting the presence of the vehicle and activating the corresponding transmitter coil accordingly.

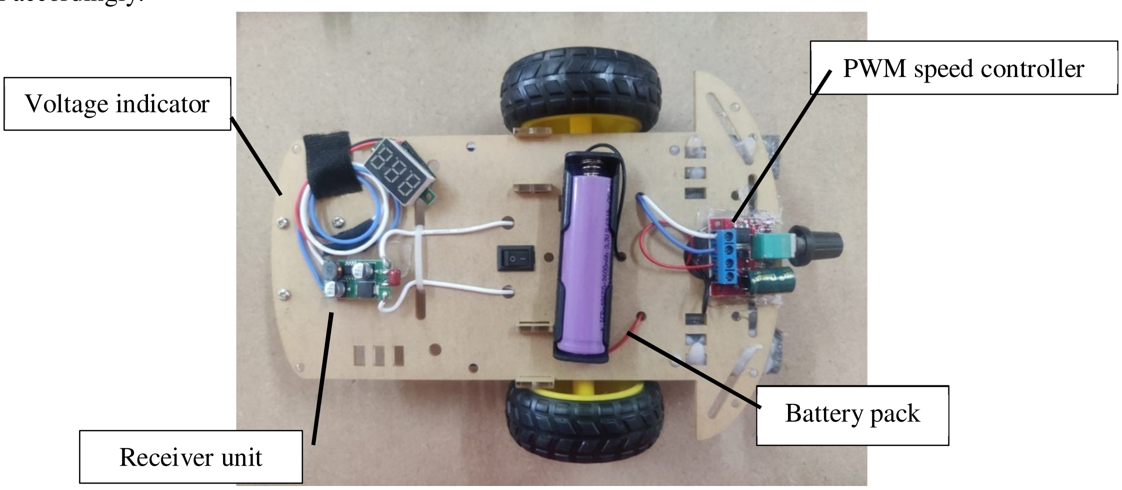


Fig.5 Prototype car

This switching mechanism is facilitated by relays, ensuring precise control over charging initiation and termination. To visualize the charging process, a voltage indicator is connected to the receiver coil, providing real-time feedback on the received power. The transmitter side is powered by an input voltage ranging from 9 to 12 volt, while the output side delivers a stable 5 volt at 2 amp, suitable for charging the battery pack of the prototype.

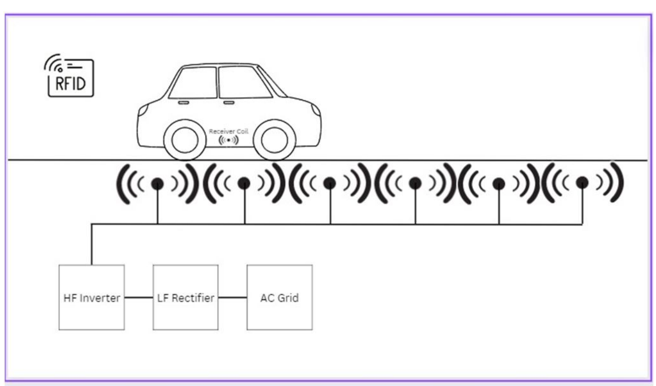


Fig.7 project model

The components of the prototype are meticulously selected to ensure optimal performance and compatibility. The launch coil, launch module, and receiving module are carefully designed to meet specific size and performance requirements. For instance, the launching coil boasts an outside diameter of 43mm and a thickness of 2.3mm, while the receiving coil offers a thickness of 1.2mm, ensuring efficient energy transfer within the optimal distance range of 3 to 6mm.

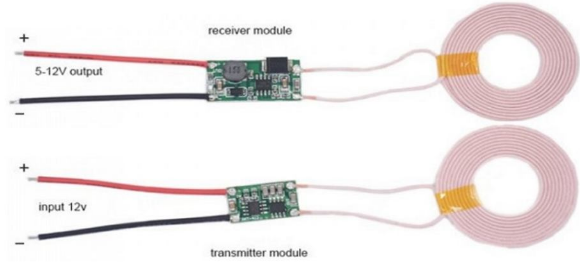


Fig. 8 XKT 412 Module

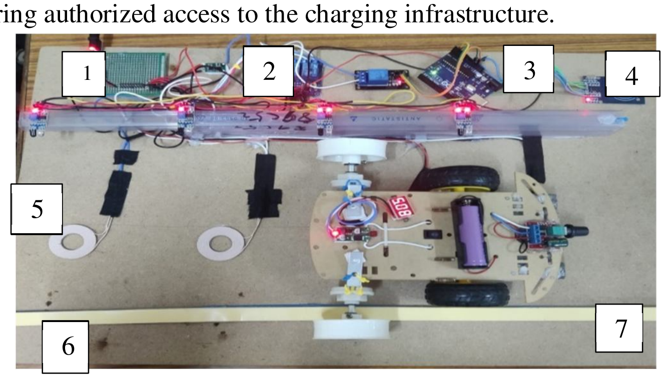
In addition to wireless charging functionality, RFID tags are seamlessly incorporated at the start and end of the charging path, enhancing security and authentication. These RFID tags play a crucial role in verifying the identity of the EV and authorizing charging sessions, contributing to the overall reliability and integrity of the dynamic charging system.

Model	XKT-412
Input Voltage	5-12VDC
Input Current	1.2-2 A
Output	5V/700 mA current
Normal Use Distance	2~10 mm
Tx/Rx Coil Dimensions	Diameter 43mm, Inner diameter 20mm
Coil Wire Thickness	2.3 mm
The transmitting module size	18mm*8.5mm*15mm
The receiving module size	10mm*25mm*3mm
Shipping Weight	0.035 kg
Shipping Dimensions	15*10*8 cm

TABLE I. Transmitter Reciever coils specifications

III. RESULT

During testing, it was observed that the voltage output of the receiver coil increased significantly when it came into proximity with the transmitter coil. This increase in voltage indicated successful wireless power transfer through electromagnetic induction. Furthermore, the infrared (IR) sensor accurately detected the presence of the vehicle, triggering the activation of the relay module to initiate the charging process. The incorporation of RFID tags at the start of the charging path provided an additional layer of security by authenticating the EV and ensuring authorized access to the charging infrastructure.



1) Battery Eliminator Circuit BEC serves the purpose of converting the 12V power supply to a stable 5V output. It employs a low dropout voltage regulator with a high current rating, offering superior performance compared to standard voltage regulators. This ensures efficient voltage conversion while supporting high current loads.
2) Relay module: The relay module functions as a controlled switch, positioned between the sensors and the transmitter coil. When the sensors detect any input, the relay module activates, causing the transmitter coil to power on and initiate transmission.
3) Arduino UNO & main relay: The Arduino Uno microcontroller unit is utilized to authenticate the user. Upon successful verification, the main relay is activated to initiate the operation of the entire system.
4) RFID tag reader: It is a passive RFID tag reader.
5) Infrared sensors: Used to detect the presence of the vehicle and send a signal to the corresponding relay.
6) Transmitter coil: High-frequency transmitter coils are used to transmit power wirelessly, a receiver coil is placed on the bottom of the vehicle to receive the power.
7) Prototype car: Four-wheel toy car with speed control shown in Fig 5

IV. CONCLUSION

The observed results validate the feasibility and effectiveness of the dynamic charging prototype with RFID integration. The successful wireless power transfer, coupled with precise control mechanisms facilitated by the IR sensor and relay module, underscores the potential of dynamic charging technology to revolutionize EV charging infrastructure. Furthermore, the incorporation of RFID authentication enhances the security and reliability of the system, paving the way for broader implementation in real-world settings. Overall, the prototype represents a significant advancement in dynamic charging technology, offering efficient and secure charging solutions for electric vehicles.

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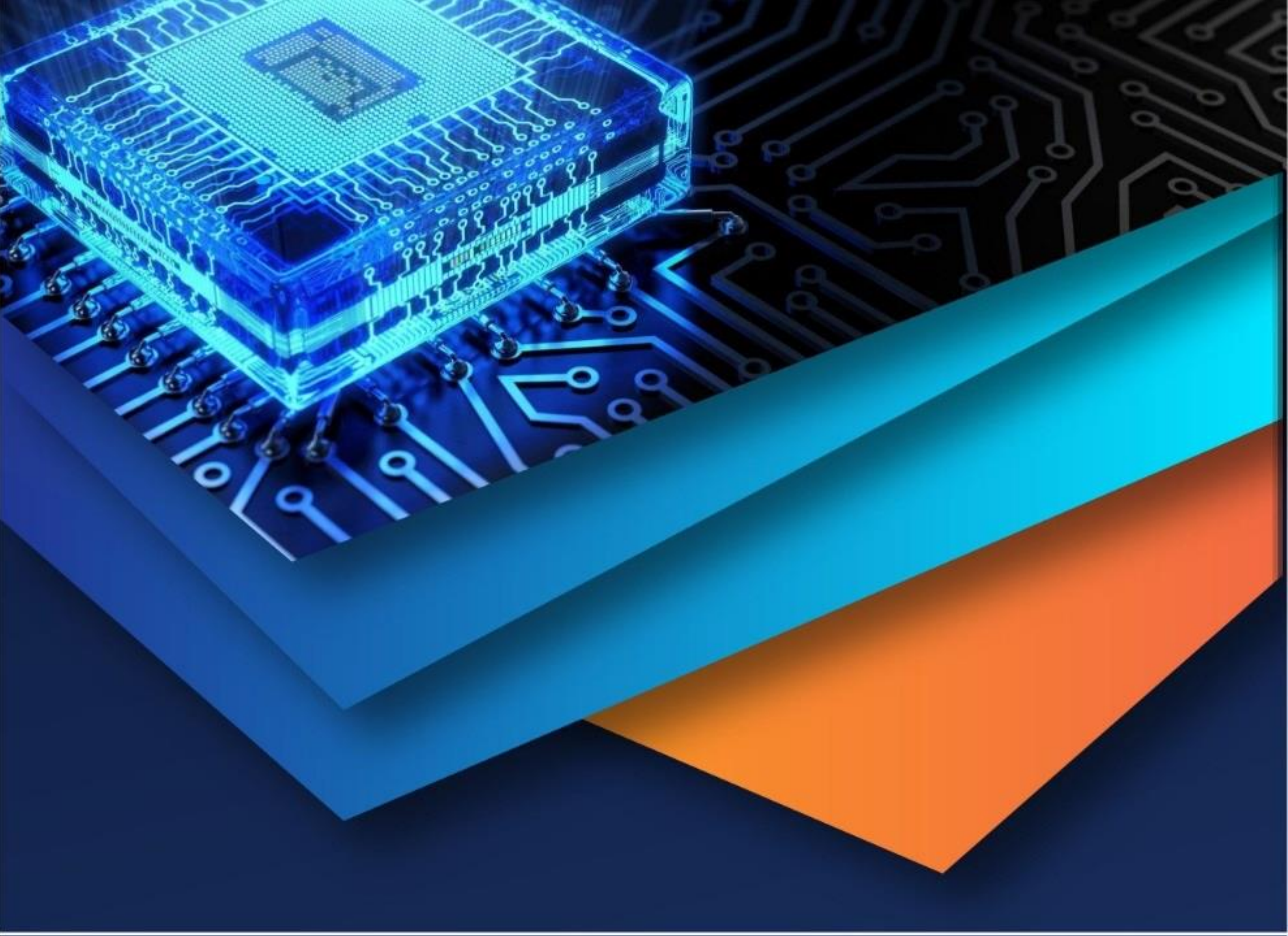

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