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Evolution of the Mechatronic systems and its Overview

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Abstract- Mechatronic systems have been one of the most advanced subjects in mechanical engineering and design in recent years, and finding numerous applications in a wide range of today's modern society. This article presents the brief overview and basic characteristics of the mechatronic system. Also, focuses on the most recent development in the mechatronic system that has been made in last several years. The architecture and key elements of the mechatronic system along with principles and methods of processing and controlling mechanism have been discussed and presented. This article also presents the overall existing and present scenario of the mechatronic system in an industry from origin to its present applications.

Keywords— Mechatronics, mechatronic systems, electrical engineering, electronics engineering, modern machines.

I. INTRODUCTION

In recent days there is a growing trend towards the use of advanced technology for the rapid development of the manufacturing machines. Mechatronics coined nearly 40 years ago, in 1969. The word, mechatronics was described by Ko Kikuchi [1], and mechatronics constitutes from two words, the mecha from mechanics and topics from electronics [2]. In other word, mechatronics is the branch of engineering which deals with the integration of the mechanical engineering, electronics engineering and control engineering. We found mechatronics everywhere around us, from medical instruments, robots, washing machines.

Modern machines have been designed by using mechatronic systems; in [3] Devdas Shetty et al. presents, the mechatronic system using the simulation of complex structures with amending empathize of the dynamic behavior and interactions of the components and also recent advancement in mechatronic systems with integrated design issues. For getting inexpensive prices, the automotive industries uses equipment for manufacturing, integrating and controlling in the production flow. Trends in the development of new equipment for the automotive applications in mechatronic systems described [4]. The necessity of the mechatronic system and benefits to include mechatronic systems into the traditional electrical and mechanical fields and importance towards future generation have been discussed [5], and the overview of the mechatronics degree program has also been discussed. A survey on the need for mechatronics education in Norway and Poland presented by Hirpa G. Lemu et al. [6]. In [7], the approach for synergistic integration in mechatronics and with the use of 3+1 Sys ML-view model approach, the challenges in synergistic integration, size and complexity, reuse, as well as requirements handling and traceability, support for decision making, and maintaining consistency are presented and discussed.

Medical mechatronics plays a vital role in the medical instruments by optimizing traditional instruments and also creates innovative and intelligent instruments [8], in medical mechatronics, electronic instruments and equipment are used for medical applications such as diagnosis, therapy, research, anesthesia control, cardiac control, and surgery. In [9], the research opportunities and challenges described and reviews on artificial intelligence and mechatronics design. Mechatronics as a new trend in machine control [10], The TPS-3920 system is accompanied with the SES-LATHE software. The overall aspect of mechatronic systems in an industry from its origin to its present applications described in [11].

II. EVOLUTION OF THE MECHATRONIC SYSTEMS

Consider the example of an automobile system. The radio was one of the substantial electronics in an automobile until the 1060s. Other functions were purely mechanical or electrical, for example battery charging system and starter motor. There were no any intelligent safety systems developed only augmenting the bumper and structural members to protect residents in case of accidents. Seat belts totally mechanical based were introduced in the early 1960s and developed for occupant safety [13]. All engine systems were controlled by the driver and mechanical control systems. Mechatronics system development from purely mechanical system is a logical and practical step in the development of science and technology. The electronics is the vital component that can't be separated from mechanical system. The evolution of the mechatronic systems shown in Fig. 1.

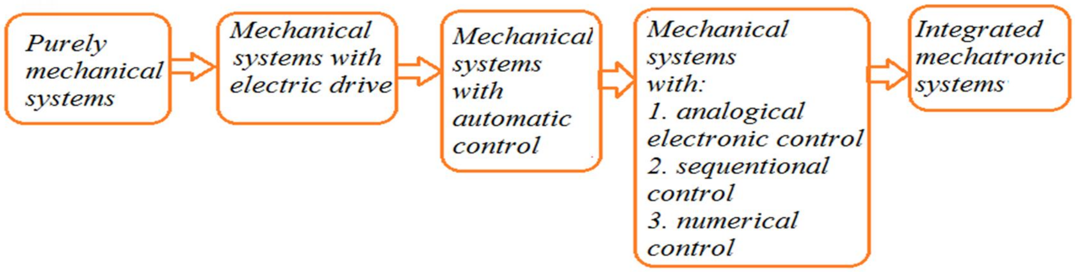


Fig. 1 Evolution of the mechatronic system

III. MECHATRONIC SYSTEMS OVERVIEW

The Yasakawa Electric Company defined mechatronics term as, the word, mechatronics, is composed of “mecha" from the mechanism and the "tronics” from electronics. In other words, technologies and developed products will be incorporating electronics more and more into mechanisms, intimately and organically, and making it impossible to tell where one ends and the other begins [2].

In another word, mechatronics defined as, the synergistic integration of mechanical engineering, with electronics and intelligent computer control in the design and manufacturing of industrial products and processes [12], as shown in Fig. 2. In [14], W. Bolton defined as a mechatronic system is not just a marriage of electrical and mechanical systems and is more than just a control system; it is a complete integration of all of them. It is noted that for researchers, the mechatronics is not just a commodious structure; it is the way of life in modern engineering technology. A conventional mechanical design approach and mechatronics design approach described in Fig. 3(a), 3(b). In a case of conventional design approach, there is no any integration with electronics engineering, control engineering and computer and IT engineering. On the other hand mechatronics, design approach includes integration of mechanical engineering, electronics, computer and IT engineering. The difference between these two systems summarized in Table I. It is seen that without mechatronics background, the mechanical engineer is assumed to be a mechanical engineer without the engineering drawing knowledge.

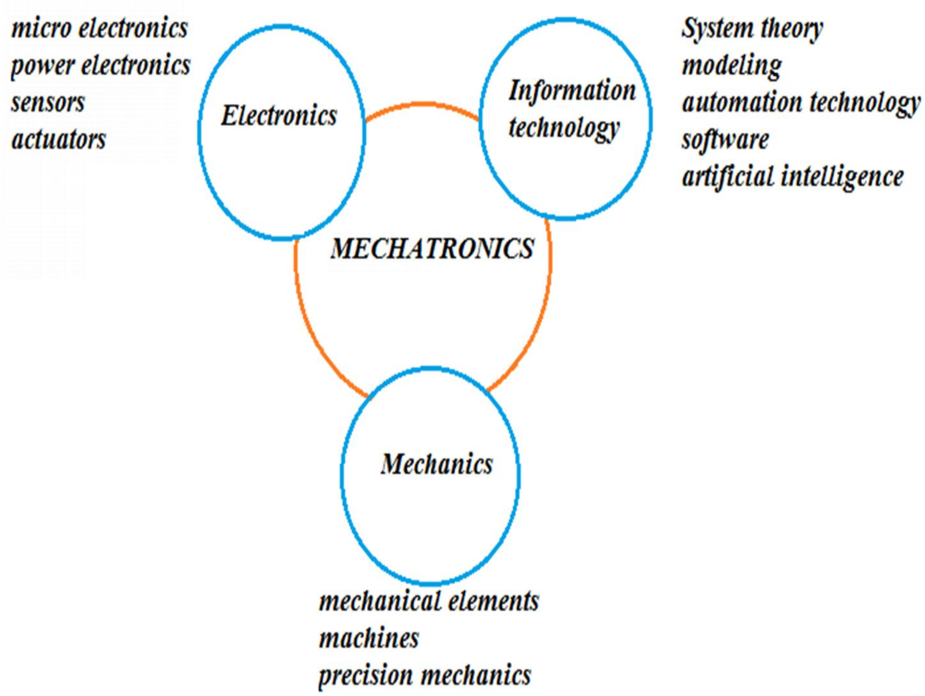


Fig. 2 synergetic integration of different fields

TABLE. I

COMPARISON OF THE MECHANICAL SYSTEMS

Conventional Systems	Mechatronics Systems
Centralized processing & control	Hybrid Control: Adaptive and/or Multi-architecture control (e.g., Centralized, Centralized processing & control Decentralized and Distributed)
Inspection stage toward the end of manufacturing processes	In-process automatic inspection
Bulky componentized systems	Compact integrated Systems

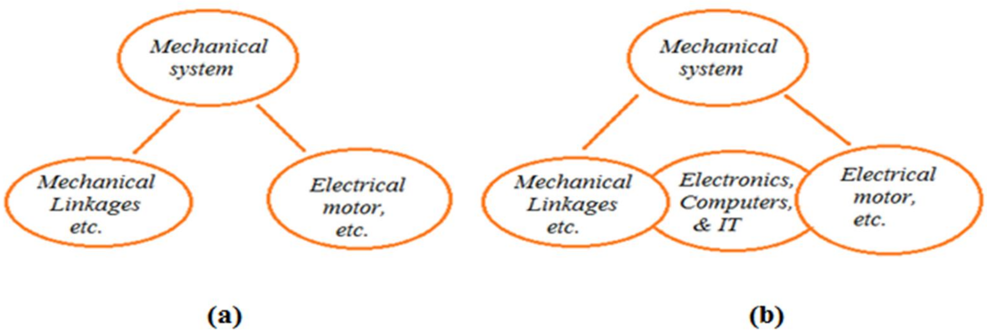


Fig. 3 (a) Conventional design approach and (b) Mechatronics design approach

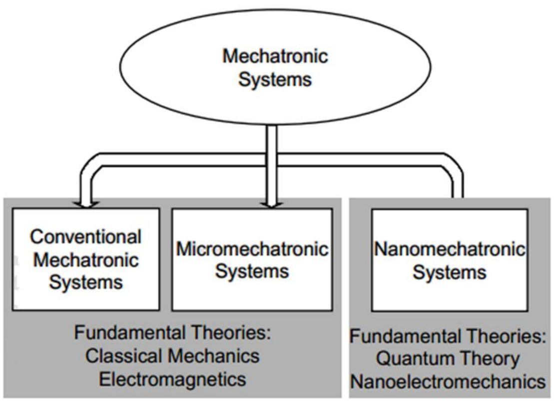


Fig.4 Mechatronic systems

The mechatronic systems are categorized shown in Fig. 4,

Conventional mechatronic systems,

Microelectromechanical-micromechatronic systems (MEMS),

Nanoelectromechanical nanomechatronic systems (NEMS).

For conventional mechatronic systems and MEMS, the operational principles and basic fundaments are same. In a peculiar, electromagnetics and classical mechanics apply the designer to study conventional mechatronic systems and MEMS. NEMS are constructed using Quantum theory and nanoelectromechanics.

In the late 1970s, the Japan Society for the Promotion of Machine Industry (JSPMI) classified mechatronics products into four categories [15]:

Class I: This includes mechanical products with electronics integrated to improve the practicality. The numerically controlled machine tools and variable speed drives in manufacturing machines are the examples.

Class II: This class includes the traditional mechanical systems with significantly updated internal devices incorporating electronics. The external user interfaces are unaltered. Examples include the modern sewing machine and automated manufacturing systems.

Class III: Systems that retain the functionality of the traditional mechanical system, but the internal mechanisms are replaced by electronics. An example is a digital watch.

Class IV: Products designed with mechanical and electronic technologies through synergistic integration. Examples include photocopiers, intelligent washers and dryers, rice cookers, and automatic ovens.

IV. KEY ELEMENTS OF MECHATRONICS

The key elements of mechatronic systems broadly classified into five categories and depicted in Fig. 5.

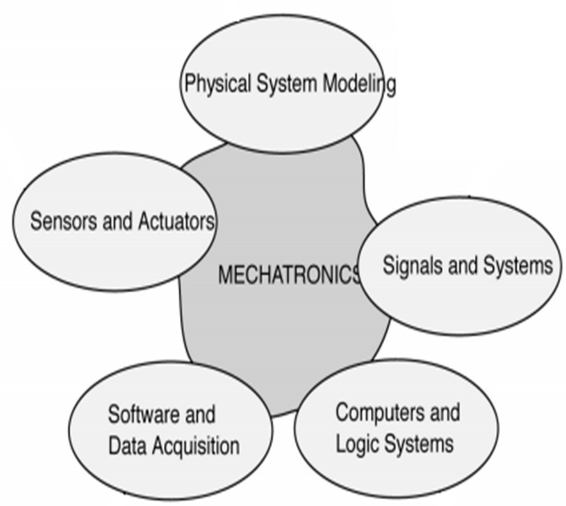


Fig. 5 Key elements of mechatronic systems

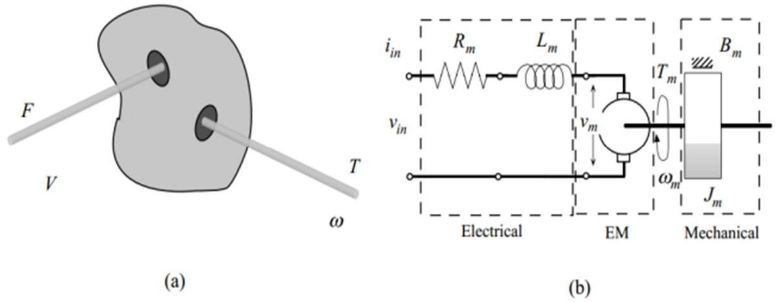
A. Physical Systems Modeling

It includes mechanics of solids, translational and rotational systems, fluid systems, electrical systems, thermal systems, micro, and nano-systems. Mechatronics applications are described by controlled motion of mechanical systems conjugated to sensors and actuators. The purpose of the physical systems modeling is to empathize how attributes and performance of mechanical components affect the overall mechatronic systems. Mechanical systems are rigid or elastic bodies these are moving relative to one another, the movement depends on upon how these bodies are completed by ingredients via joints, dampers, and other passive devices. One way to connect mechanical systems using power and energy variables shown in Fig. 6. In this Figure, at one port power flow is a product of force and velocity (F.V), and at other port, power is the product of torque and angular velocity ($\tau.\omega$).

B. Sensors and Actuators

A sensor is a device that receives a stimulus and responds with an electrical signal [13]. The sensor responds to an input physical quantity and converts it into an electrical signal. In other words, we can say senor converts non-electrical quantity into electrical quantity. For example, a chemical sensor initially converts the energy of a chemical reaction into heat (transducer) and then thermopile, converts heat into electrical signals. In this example a chemical sensor is a complex sensor; it is composed of transducer and sensor (heat). The direct sensors are those which convert physical properties into direct electrical signals shown in Fig. 7. Examples of modern sensors for mechatronic systems [13] are Disposable blood pressure sensors, Pressure sensors for automotive manifold air pressure, Accelerometers for airbag systems.

Actuators may work opposite to that of sensors [13]; it converts the electrical signal into non-electrical energy. For example, an electric motor (actuator) converts the electrical signal into mechanical energy. Modern actuators used in mechatronics applications are electro-mechanical actuators, motors: AC motors, DC motors, and stepper motors, pneumatic and hydraulic actuators.



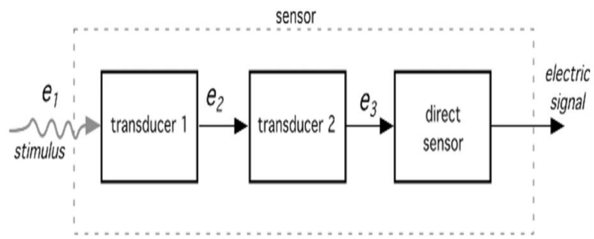


Fig. 6 Interconnection of systems using power variables [13]   Fig. 7 Sensor operation flow [13]

C. Signals and Systems

Signals and systems play a vital role in mechatronic systems. Anything that carries the information is the signal. Signals are important because by realizing them we can make sure that they can be transmitted faithfully and by interpreting the signal and their structure, we can determine more about an instrument that is generating them. Easily measured quantities, current and voltage are the form of electrical signals, thus sensors and transducers used to converts physical quantities into electrical signals. These signals must be processed by appropriate techniques if desirable results are to be obtained.

D. Computers and Logic Systems

In mechatronic systems, computers are used to model, analyze, and simulate mechatronic systems and useful for control design. As a part of measurement systems, computers are used in mechatronic systems to measure the performance of the mechatronic systems. Also, computers or microprocessors form central component in digital control systems for the design of mechatronic systems. As discussed earlier mechatronics is the synergistic combination of mechanical engineering, electronics, control systems, and computers and the key element in mechatronics is the integration of these areas through the design process. A successful design will be produced if computers and logic elements are used in mechatronic systems, only if this synergy is achieved.

E. Software and Data Acquisition

Data acquisition systems and software includes transducers and measurement systems, A/D and D/A converter, amplifiers and signal conditioning, data recording and software engineering [14]. A data acquisition system captures and analyzes some form of physical properties from the real world. Some physical properties like pressure, light, temperature that can interface to a data acquisition system. At the same time, data acquisition system produces electrical signals. These signals provide stimulus so that the data acquisition system can measure the response.

V. MECHATRONICS DESIGN FLOW

Mechatronics design flows shown in Fig. 8.

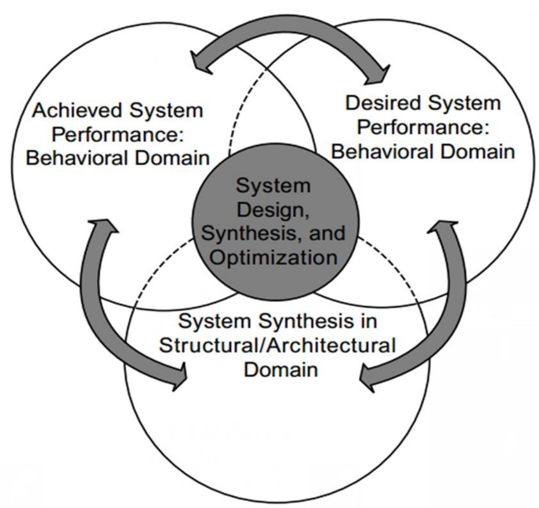


Fig. 8 Mechatronics design flow

VI. KEY ELEMENTS OF MECHATRONICS

A. The need
B. Analysis of problem
C. Preparation of Specification
D. Generation of possible solutions
E. Selection of a suitable solution
F. Production of a detailed design
G. Production of working drawings

The system architecture synthesis, system integration, optimization, selection of hardware and software of mechatronic systems design is one of the challenging problems. The design of mechatronic systems is a process that starts from the specification of requirements and progressively proceeds to perform a functional design and optimization that is gradually refined through a sequence of steps. Specification includes the performance requirements developed from systems functionality, operating envelope, affordability and other requirement.

VII. APPLICATIONS OF MECHATRONICS

Followings are the applications of mechatronics

A. Commercial applications automobiles, ships, appliances, sports.
B. Industrial applications robotics, machine control, vibration testing and instrumentation.
C. High-reliability applications military, space and aerospace, seismic monitoring, tilt, vibration and shock measurements.

VIII. CONCLUSION

The mechatronic system plays a vital role in the various fields of mechanical engineering. The conventional mechanical systems are not efficient to provide the precise solution. The mechatronics approach includes the synergistic combination of mechanical engineering, electronics, control systems, and computers and improves the performance of the mechanical design. In this article overview and basic characteristics of mechatronic systems has been presented with the most recent development in the mechatronic system that has been made in last several years. Also, the key elements of a mechatronic system along with principles and methods of processing and controlling mechanism have been presented.

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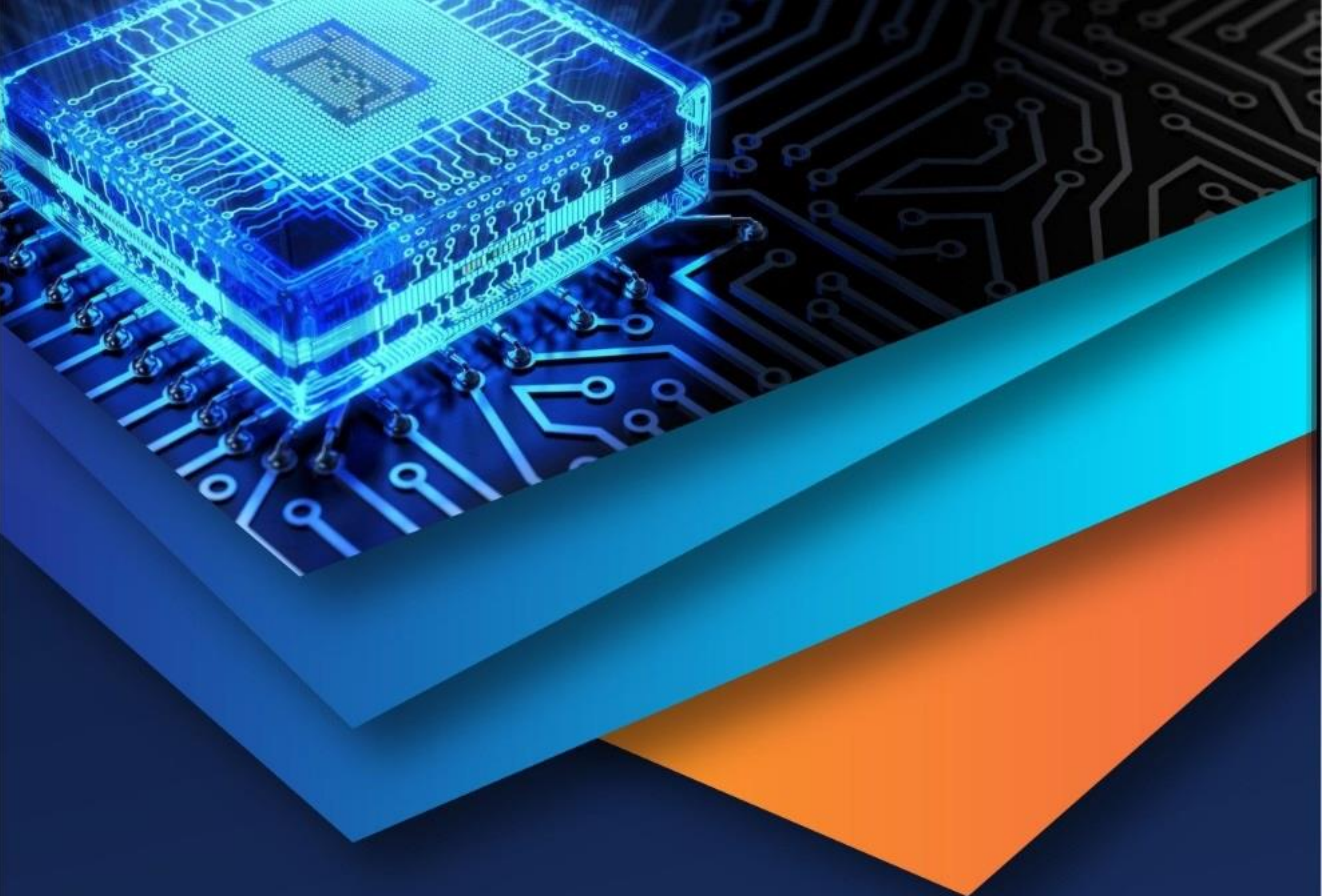

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