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Intelligent Contactor Coil Drive Design For Soft Switching Of Load With Power Saving

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Abstract: Optimized contactor coil drive design and its intelligent realization with AC 110-240VAC input voltage is introduced in this project, the hardware and software design are emphasized especially around the commonly used 8 bit PIC microcontroller & IDE MPLAB. The use of power electronic switching device like MOSFET to control and adjust the voltage on the contactor's coil with PWM (Pulse Width Modulation) phenomenon, such that contactor works reliable and stable with a wide range AC (AC110~240V). This way contactor can be used in all the voltage class which solves the problem of voltage variation & exceed voltage case with less power consumed for the coil operation & increased reliability. The hardware design consists of a microcontroller PIC18F2520 with following module:

1. ***Power supply and Voltage measuring circuit with coil.***
2. ***PWM control circuit***
3. ***Freewheeling energy circuit***

This design ensure contactor to save coil power consumption, silent operation, less arc or no arc break, communication (Optional). The test results indicates more accurate and effective with less coil power & increased reliability operations in industrial application like Steel plant, Arc Furnace, Ball Mill, Cement Plant like areas as easy & more power saving option.
Keywords—PIC18F2520; Contactor; MOSFET; PWM; Surge test;AD; PUV; DOV

I. INTRODUCTION

AC contactor is one of the most important electric equipments in power and industrial control system. With the rapid development of computer, communication, control technique and the proposal of intelligent power grid, universality, intelligence, and high performance has become the main direction of the low voltage AC contactor development. At present, the conventional AC contactors can work under a certain AC voltage (PUV/DOV) as their input voltage of the coil is designed only in one class. Thereby it is inconvenient for some special power equipments and probably unable to work normally and effectively while the voltage of power system exceeds the certain value. Furthermore, the traditional AC contactor couldn't realize the intelligent functions of optimization and control in the whole process, setting online, parameter display, communication and so on. Therefore, the intelligent control design and realization proposal of a new-type AC contactor with wide-range input is researched in this paper. This kind of new AC contactor is designed based on the general AC contactor. By using PWM control and auto-adapted adjustment on the coil voltage, the contactor is able to be operated reliably and stably at the coil input AC voltages of 24 to 380 volts or DC voltages of 24 to 220 volts. Thus the contactor can be used in all the voltage class and solve the problem that the contactor could not work when the voltage of power system exceeds the certain value. Moreover, after having the general AC contactor controlled intelligently, the contactor has more functions of energy saving, silent operation, less arc or no arc break, setting, display, communication, remote operation etc. Accordingly, the performance and characteristic of the contactor will be enhanced considerably and the types of product will be reduced greatly as well. It is foreseeable that this kind of AC contactor will meet the urgent need of the market and has the broad application prospect

II. NECESSITY

As contactors are used for high-current load applications they are designed to control and reduce the arc produced when the heavy motor currents are interrupted. Other than the low current contacts, they are also setup with Normally Open contacts. These are devices which handle more than 20 Amperes current and over 100 Kilo Watts power. The contactor has an AC/DC supply driven coil input. This will depend on the requirement. This coil will mostly be controlled by a lower voltage PLC. They can also be controlled by the motor voltage. The motor may have series of coils connected to either control the acceleration or even the resistance. When current is passed through the contactor, the electromagnet starts to build up, producing a magnetic field. Thus the core of the contactor starts to wind up. This process helps in energizing the moving contact. Thus the moving and fixed contacts make a short circuit. Thus the current is passed through them to the next circuit. The armature coil brings in high current in the initial position. This reduces as soon as the metal core enters the coil. When the current is stopped, the coil gets de-energized and thus the contacts get open circuited. Ratings of a contactor are given according to the pole of the contactor. It also depends on factors like fault withstand current, coil voltage and so on. According to their rating, contactors are classified into the following.

A. AC1 – Non-inductive rows
B. AC2 – Contactors for starting of slip-ring motors
C. AC3 – Starting of squirrel-cage motors and switching off only after the motor is up to speed.
D. AC4 – Starting of squirrel-cage motors with inching and plugging duty.
E. AC11 – Auxiliary control circuits

Thus for higher rating contactor your coil wattage should be consumed low in order to save power. However in certain critical & typical areas where the arcing coming out of the breaking and making of power contacts leads to arcing in the contactor which requires soft switching of the contacts of power sources, which keeps the dangers away from the main power control system. Thus there is necessity to design such a control circuitry where the soft switching along with power saving cannot be compromised and industrial safety can be improve further to higher level. Looking at these requirements only the design of this intelligent contactor has initiated and successfully been implemented in wire range of power ratings. The basic study has been given here with for the overview of final project on contactor deign.

III. LITERATURE REVIEW

In order to map the functional parameters of the contactor operations & then working to optimise the bottleneck parameters through which the final aim of safe & power saving design for high rating contactor has initiated. For which the detailed study has done on the basic design which includes:

A. Contact spring
B. Fixed & Moving Magnet system of contactor
C. Coil design

The contact part of the contactor includes the power contacts as well as the auxiliary contacts. The power contacts gains the power for the contactor and the auxiliary contacts is used to bring a loop with the rest of the rest of the devices it is attached to. These contacts are connected to the contact springs. The contacts are controlled by the electromagnet. These electromagnets give the initial force to the contacts and make them closed. Both these contacts and electromagnet are enclosed in a frame which is usually made of insulating materials. The usually used insulating materials are Nylon 6, thermosetting plastics and so on. They are useful, as they completely insulate the contacts and help in preventing the touch of contacts. For high-end contactors, an open-frame contactor is commonly used. This will provide a greater protection from oil, dust, weather and also from explosion. The type of frame housing used may also differ according to the voltage rating used. The ones given above are restricted up to a certain voltage. If the contactors are used to manage volts higher than 1000 volts, inert gases and also vacuum is used as frame housing. Contactors are also used in DC circuits. For their use in DC circuits, magnetic blowouts are also used. The use of blowout coils help in stretching and moving the electric arc. The electric arcs can be AC or DC. An AC arc will have can be easily extinguished as they have low current characteristics. DC arcs of the same current characteristics need more stretching need more current to be blown out. They ratings differ from about 500 Amperes to about 1500 Amperes. In order to save power in a contactor when it is closed, an economizer circuit is also introduced. This circuit helps in reducing the coil current. There is difference in the amount of power that is required to close the contactor and that from keeping it closed. Greater power is required to close it. This circuit will also help it to stay cooler.

IV. SYSTEM DEVELOPMENT

A. Principle of Operation

In order to realize the function that the contactor can work with wide range input voltage, a power electronic device MOSFET is used to control the coil supply voltage in PWM mode. The parameters of PWM such as frequency and duty cycle can be adjusted auto-adaptively and dynamically according to the different voltage type and voltage value. Fig.1 shows the principle of system. The rated coil voltage of the general AC contactor which system selected is 24 VDC. The input AC or DC voltage is changed into DC voltage via a diode bridge, and then the voltage is transformed into unchanged output voltage via the electronic switching component MOSFET which is controlled by the PWM signal generated by microcontroller, finally the output voltage adds on to the

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two terminals of coil. The PWM duty cycle is decided by the value of input voltage measured by the input voltage measure module. The supply voltage keeps unchanged as the PWM duty cycle can be adjusted auto-adaptively via the coil voltage measure feedback module. When the supply voltage of coil is greater or less than the certain value 24 volts, the value of PWM duty cycle will be reduced or increased appropriately. In addition, after the contactor acted, the microcontroller will reduce the duty cycle to obtain lower output voltage to keep contactor holding, and the energy of system will be saved greatly

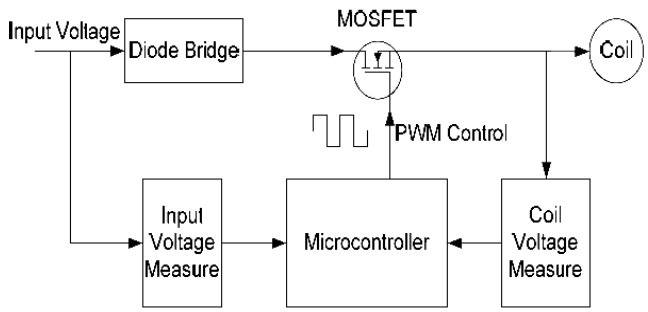

Figure 1: Principle diagram of system

B. Hardware design of system:

The hardware system is constructed mainly by following sections: microcontroller unit PIC16F873, PWM control circuit, input voltage type and value detecting unit, coil voltage value detecting circuit, main loop’s zero current detecting circuit, RS232/RS485 communication interface circuit, keyboard and LCD display, power supply, etc., as shown in Fig.2. The main part of the hardware system will be described in detail as follows.

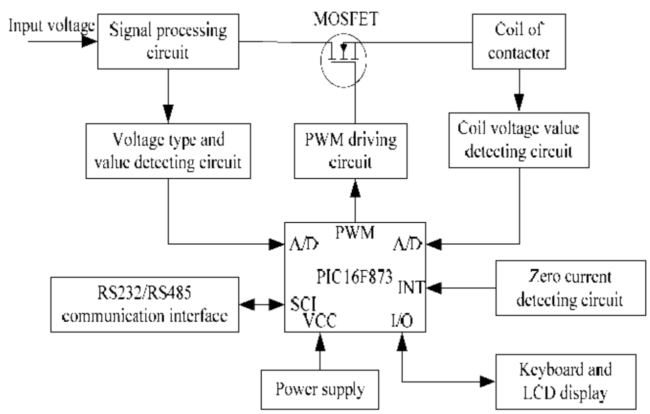

Figure 2: Block diagram of hardware system

1) *Microcontroller circuit :* The core of the central controlling unit is PIC18F2520 microcontroller, which integrated a lot peripheral such as 5-channels 10-bit A/D converter, USART/SCI interface, PWM modules, timers, and so on. These features are easy and convenient to provide a complete solution for the application in this article. PWM module generates a series pulse of different frequency and duty cycle to make the MOSFET switch on or off, A/D converter measures the voltage of power supply and coil, USART/SCI interface expands a typical communication port such as RS232 or RS485, external interrupt module detects zero-crossing current of the main loop circuit, and general purpose input/output ports are typical man-machine interface for keyboard and LCD display.
2) *PWM control circuit:* The schematic of PWM control circuit is shown in Fig.3. The circuit is mainly based on N-channel MOSFET Q1, high speed optical coupler U1, resistors R13/R14/R15/R16, capacitors C10/C11, diodes D6/D7, diode bridge and the contactor coil. The PWM control signal that comes from the pin RC0 of PIC16F873 is connected the MOSFET gate via the high speed optical coupler. In this way, the PWM signal will trigger the switch on or off to control supply voltage of the coil. By adjusting the pulse width of PWM signal, the contactor can work normally under the different input voltages. In addition, if the frequency of PWM is not high enough, the contactor will make noise. Therefore, PWM frequency value is set at 15 kHz to eliminate the noise in the system.

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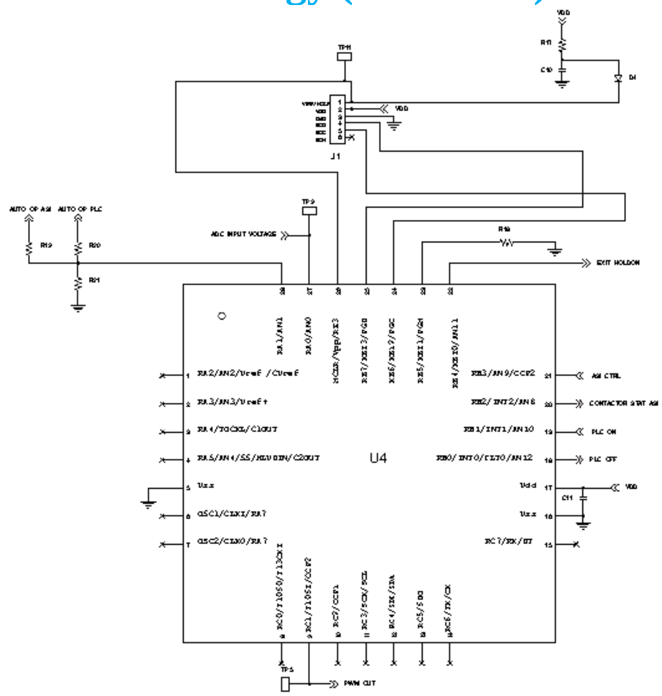

Figure 3: PWM control circuit

3) *AC Voltage detecting Circuit:* The input voltage type and value detecting is necessary in the design. The input voltage type detecting circuit transforms the voltage type into digital signal which is connected to the trigger pin of IC, as shown in Fig.4. The DC input voltage will be isolated by the capacitors C11/C12 and cause output to be low “0” via the amplifier U1A and the optocoupler IC2. However, the AC input voltage would not be isolated and the output will be high “1”. The schematic is shown in Fig.5. According to the test result, the relationship between output voltage and input AC voltage or DC voltage is shown in equation (1) or (2) respectively. In eq. (1) and (2), the X is input voltage and the Y is output voltage. Additionally, the coil voltage detecting circuit operates in the same manner as well and the detail about the circuit is no longer described here

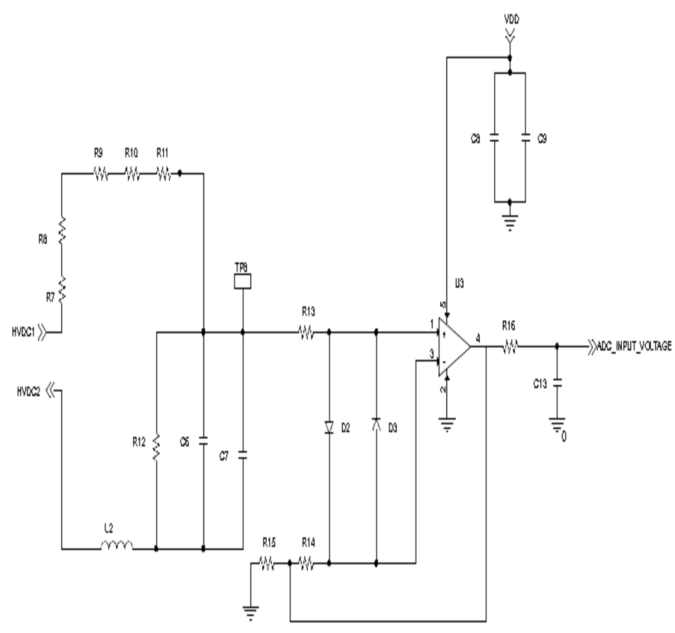

Figure 4: Voltage Detection Circuit.

V. SOFTWARE ARCHITECTURE

Figure 3: Software process floe & IED installation guide

As shown in the flow graph above the firmware installation tools required are –
PC with latest RAM & HD configuration ICD 3 for programming of cards with MPLAB source code

VI. PERFORMANCE ANAYSIS

A. Process Flow

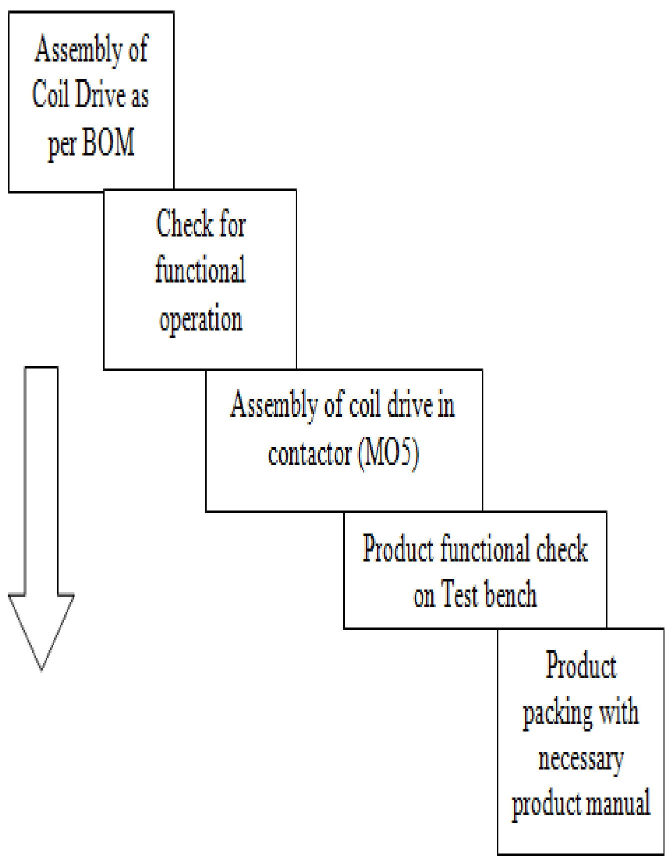

Figure 4: Process flow for MO5 contactor

B. Test Results

The general AC contactor MO 4 with 240VAC rated voltage of coil is chosen in this system and two tests of contactor were done in this paper.

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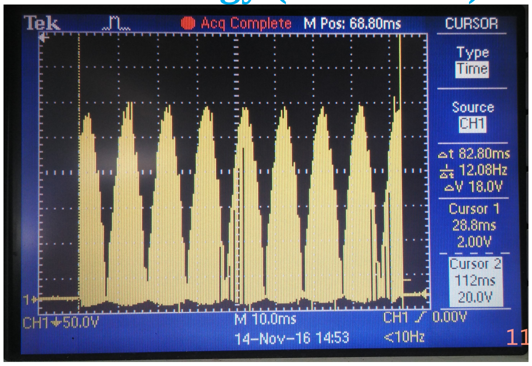

Image 1: PWM of contactor on 240VAC application

Testing, the results are shown in Image 1. Shows the relationships between PWM duty cycle and AC input voltage while the contactor is switching on and holding respectively. From the figures it is clear to find that the relationships are piecewise linear approximately. So long as the system satisfies this kind of piecewise linear relationship and uses the closed loop auto-adapted adjustment, the contactor can be ensured to work reliably and stably under the different input voltage It is the most important to find the relationship between duty cycle of PWM and value of input voltage to ensure the contactor work reliably

VII. CONCLUSION

The intelligent control design and realization proposal of a kind of AC contactor with wide-range input voltage is presented in this article. The design is mainly based on the technologies in microcontroller, power electronics and PWM control. By controlling the contactor intelligently and using PWM signal to adjust the coil supply voltage, this kind of contactor can be operated reliably and stably with rather wide range input voltage (AC80~140V). Moreover, the contactor has advantages of versatility, communication, energy saving, silent operation.

However the power consumption can further be improved with less arc or no arc break, setting, display, remote operation and so on. Therefore, it’s not difficult to foresee that it would find a broad application prospect in market. Meanwhile, the economic efficiency and the social efficiency would be pretty high.

The project is under execution for the Surge test results as the mandatory guidelines for the international sales is the conforms the Surge test as per the IEC 60947 4 1 standard.

Some hurdles are there regarding the components values and their availability being odd to the requirement to solve the problems in cards

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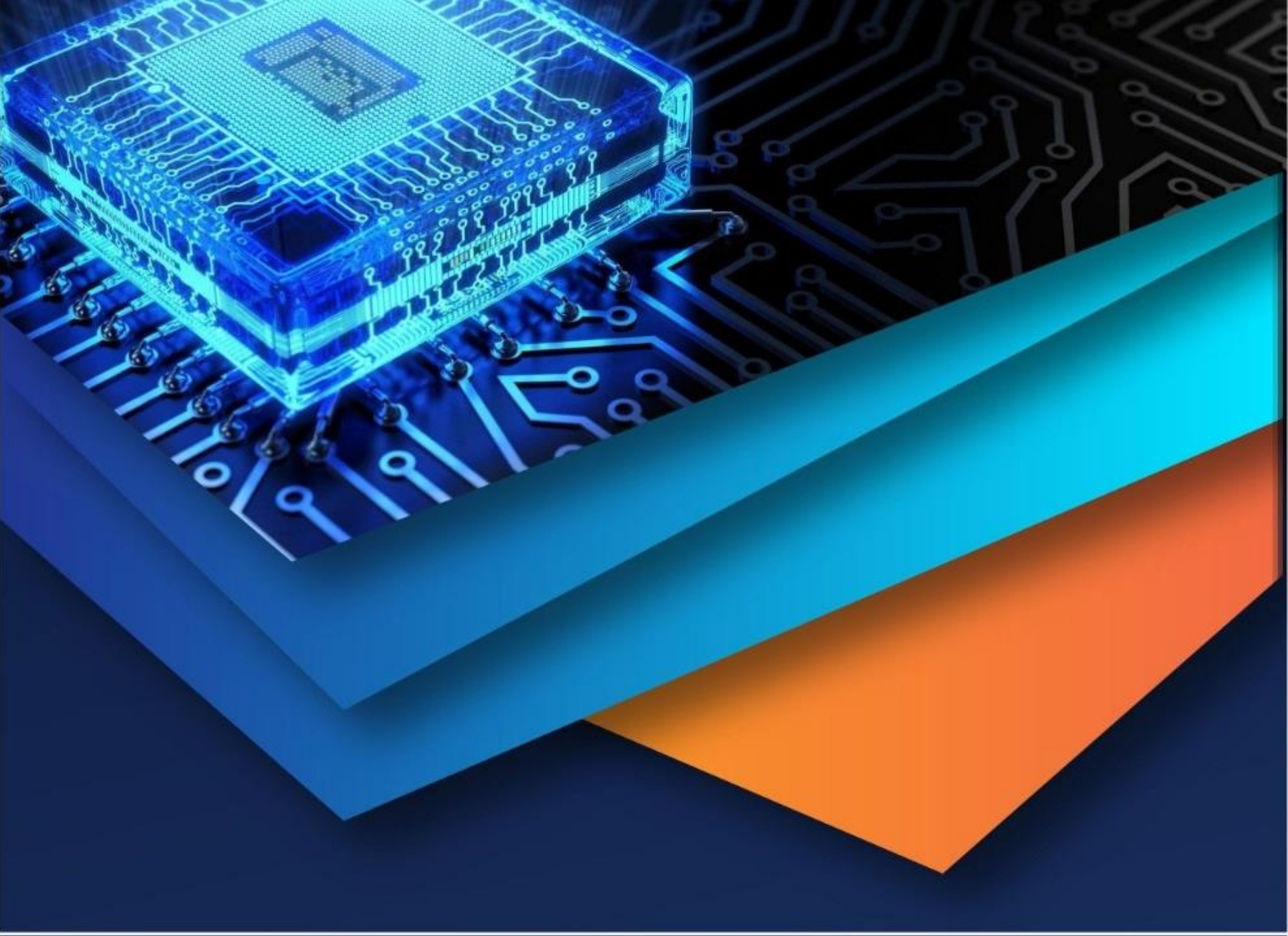

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