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Performance Analysis of PWM Based Full Wave Bridge Inverter

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Abstract: An obvious device for the utilization of renewable energy sources is inverter and Pulse Width Modulation technique is widely used method for voltage source inverters. This paper deals with the generation of PWM signals by analog circuit, where the comparison of sine wave and sawtooth wave for the operation of power circuit takes place. The above mentioned technique is studied and verified by Simulating the circuit. The prototype of PWM based, single phase, full bridge inverter is developed and the results are verified for the nominal voltage and frequency with the help of simulation and hardware is designed.
Keywords: Inverter, SPWM, VSI, Simulation, MATLAB

I. INTRODUCTION

Inverter is an essential device used for the conversion of DC into AC. As due to the growing demands of the energy, the utilization of renewable energy has become very important. And the output of renewable energy is found to be in the form of DC and the appliances being used require input in the form of AC, so Inverters are required for this purpose. Depending on the source available, Inverters are of two types, voltage source and current source inverters.

With the invention of power electronics devices in late 1950's, this area has grown extensively in different applications. The power electronics equipment converts the input power in any given state to an output power into a desired form. This power conversion is done using switching devices like Mosfets, IGBTs etc. Various types of the gating signal are available, most primitive of them is Pulse Width Modulation. SPWM is a type of PWM technique which is used to get pure sine wave with the help of high frequency pulses. THD is decreased by SPWM technique and it is characterized by having different duty cycles with constant amplitude pulses for each period. In this paper, SPWM technique is outlined by section II, SPWM signal is generated with analog circuit by the comparison of sinusoidal signal with a triangular waveform. Section III discusses the characterization of the proposed design that describes the intermediate stages. Section IV gives the result obtained from simulating the proposed circuit and hardware results obtained. At last, conclusion of the study with future scopes has been included.

II. SPWM TECHNIQUE

The output voltage of a voltage source inverter can be adjusted by various methods, either by external control of AC voltage at output side or DC voltage at input side or internal control within VSI. PWM control technique is the most efficient method used in various industrial applications. PWM is a technique for getting analog result with digital means. SPWM is the most commonly used technique in which sinusoidal reference voltage signal determines the amplitude and frequency of the PWM inverter's output voltage. SPWM is used in the power electronics for the digitization of the power to generate a sequence of voltage pulses by on and off of switches. It is basically used to control duty cycles (amount of time the signal is in high state) of the switches in such a way that a load sees a controllable output voltage and used to reduce THD. There are many advantages of SPWM, like lesser power dissipation, no degradation due to ageing or temperature, reduction of lower order harmonics etc.

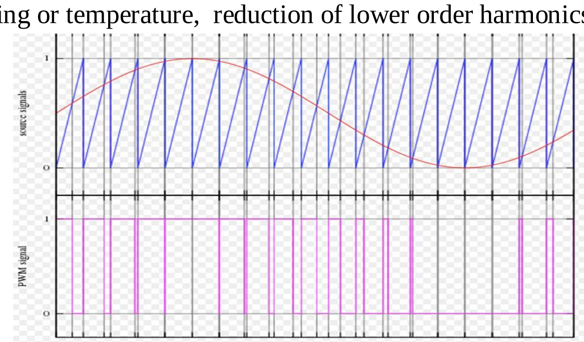

Fig. 1. **S**PWM generation

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PWM uses a rectangular pulse wave whose pulse width is modulated resulting in the variation of the average value of the waveform. It compares two different waves, i.e., sine wave as reference signal and triangular wave to generate the rectangular pulses. The frequency of sinusoidal wave is selected on the basis of required output frequency (50/60Hz). Triangular wave with higher frequency (in kHz) and amplitude is compared with sine wave, when sine is greater than triangular, the PWM signal is in high state, otherwise in low state.

Magnitude and frequency of triangular wave is greater than sine wave to produce different width of waves and their ratios must be an integer N. It's ratio is termed form factor. Form factor<1.

Amplitude Modulation, $M_f = \frac{A_s}{A_c}$ (1)

Frequency Modulation, $M_f = \frac{f_s}{f_c}$ (2)

Percentage of individual harmonics:

$$\% \left[\frac{rms(n)}{V_{DC}}\right] = 100[\frac{4}{n * \pi * 2^{\frac{1}{2}}}] \sum_{P=1}^{M_f} (-1)^{\iota+1} \, cosna_i$$

(3)

Where, n= n^{th} harmonics.

Percentage of total RMS of the output:

- M_f = even,

$$\%V_n = 100 * [\frac{2}{\pi} \sum_{p=1}^{\frac{M_f}{2}} (a_{2_p} - a_{2_{p-1}})]^{\frac{1}{2}} \quad (4)$$

- M_f = odd,

$$\%V_n = 100 * [\frac{2}{\pi} \sum_{p=1}^{M_f - \frac{1}{2}} (a_{2_p} - a_{2_{p-1}} + \frac{\pi}{2} - a_{M_f})]^{\frac{1}{2}}$$

(5)

$$THD(Total\ Harmonic\ Distortion) = \frac{V_h}{V_1} \quad (6)$$

Where,

$$V_h = [\sum_{n=1,2,3\ldots} V_n^2]^{\frac{1}{2}}$$ or

$$V_h = [V_{out}^2 - V_1^2]^{\frac{1}{2}}$$

And V_1 = fundamental component

III. CHARACTERIZATION OF PROPOSED DESIGN

Figure 2 shows the block diagram of proposed model. The desired voltage output of the inverter is 220V and frequency is 50Hz. The basic parts of the proposed model are:

1) Rectifier Stage
2) Control Circuit
3) Driver Circuit
4) Inverter Stage

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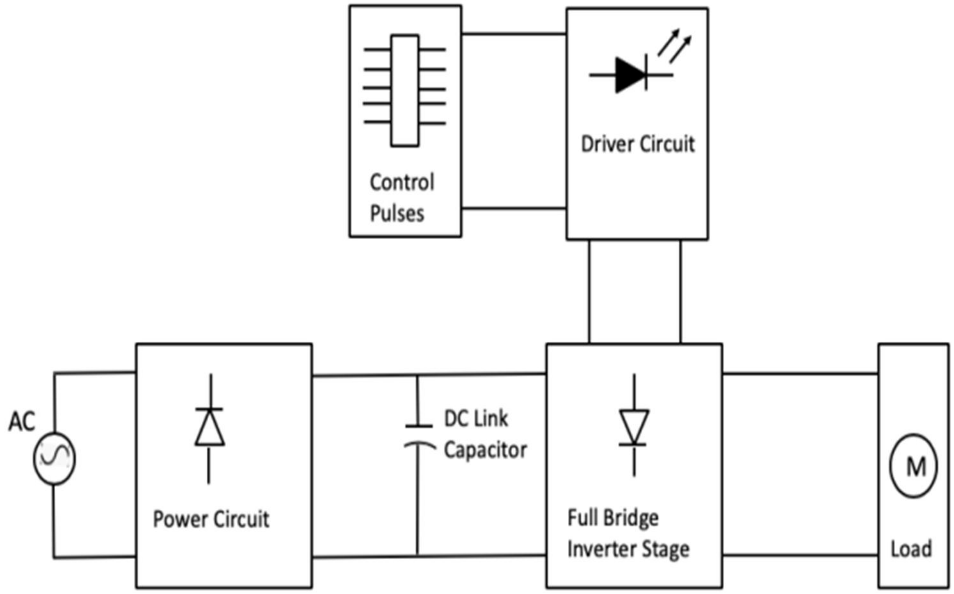

Fig. 2. Block Diagram of Proposed Model

At rectifier stage, input in the form of AC is converted into DC which is fed to next stage. Four diodes in the form of bridge are used at this stage fed by step down transformer.

Current Rating (of Transformer):	500mA
Safety Factor:	1.5
Input Current (at rectifier stage):	750mA
So, Diode:	6A4MIC

MOSFETs are used as switches at the inverter stage which converts DC in the form AC. IR2110 is used in the driver circuit which gives pulses to the inverter stage. The input to the driver circuit is given by control circuit. Analog circuit is being used as control circuit to generate SPWM pulses for the switching purpose.

A. Gate Driver Circuit

IR2110 is used as a gate driver for MOSFETs. MOSFET driver circuits are used to drive them in
high side or low side. They are voltage controlled device and to drive them, the gate capacitance should be charged to operating voltage between 9 to 10V. IR2110 can be used as high side and low side MOSFET driver. The input voltage required by MOSFETs are 12-13V and the output voltage given by IR2110 is greater than 10V. So, IR2110 is selected.

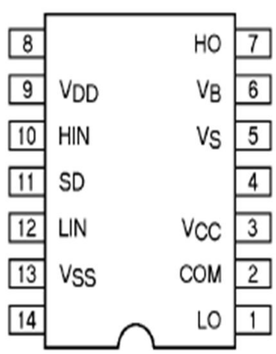

Fig. 3. Gate driver IR2110

The minimum value of Bootstrap capacitor is calculated by:

B. Control Circuit

In the proposed design, we have used analog circuit for the generation of PWM signal. Two signals, sinusoidal and triangular are generated which are compared using comparators. Output frequency of the inverter is determined on the basis of sinusoidal wave, so it is kept 50 Hz and the signal is generated by using comparators and integrators. The frequency of triangular wave is kept in kHz and it is generated by using two comparators. Figure 4 shows the generation of PWM signal, i.e., control circuit.

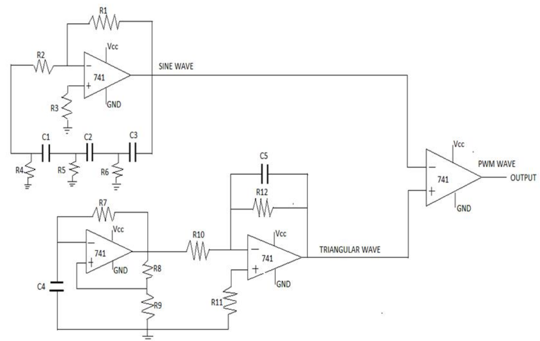

Fig.4. Control circuit

IV. RESULT AND DISCUSSION

This section presents the simulation and experimented results of the DC to AC conversion stage and performance analysis of the inverter. It covers the simulation results obtained for various parts of the project, and the hardware result for the experiment.

The hardware model designed for the inverter is given in the figure 5. It consists of rectifier stage, inverter stage, control circuit and driver circuit. We have also used voltage regulator 7805 to regulate voltage from 12V to 5V DC because driver circuit requires 5V for its operation. DC link capacitor reduces the ripples obtained from the rectifier with which bleeder resistor is connected through which this capacitor will discharge.

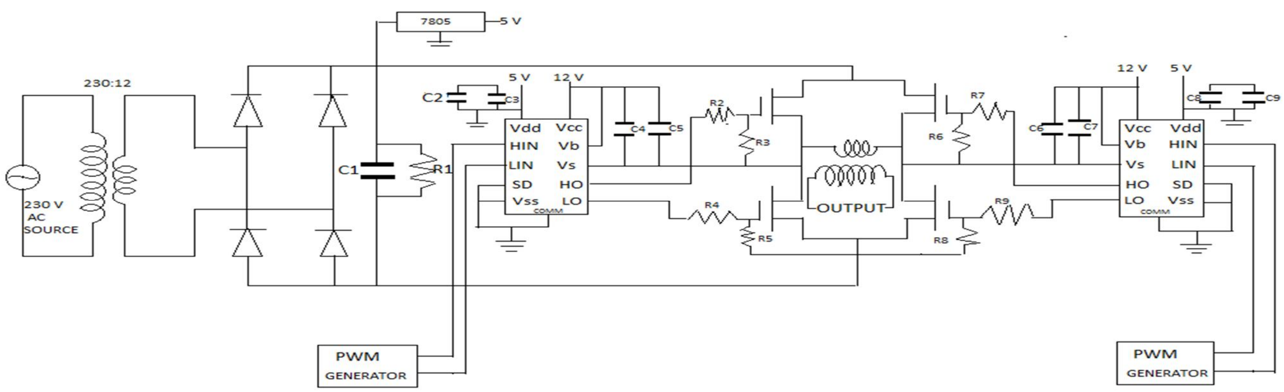

Fig. 5. Circuit Diagram of Proposed Model

A. Working of the Circuit

The hardware developed for the proposed model is given in the figure 6. The circuit is supplied via a step down transformer and the output waveforms are viewed on DSO.

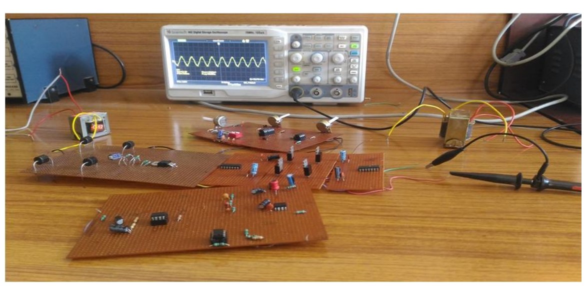

Fig. 6. Working Model

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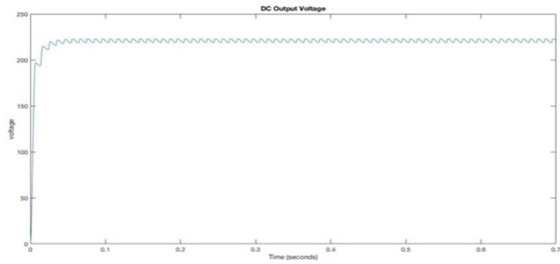
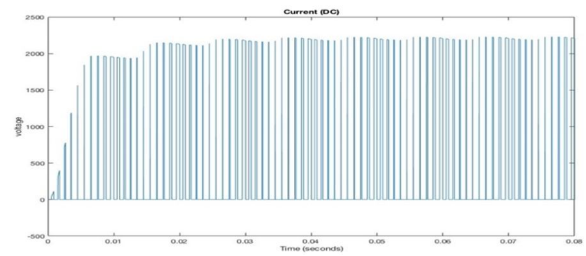
B. Performance of Rectifier Stage

The performance of this stage is demonstrated in the figure 7. The output is in the form of DC having some ripples.



(a)

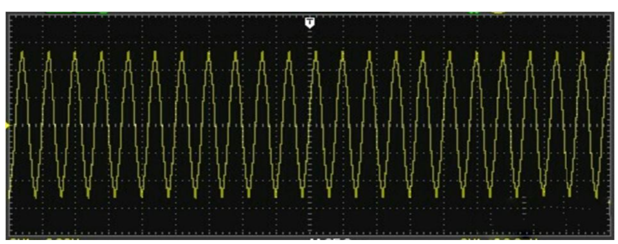


(b)

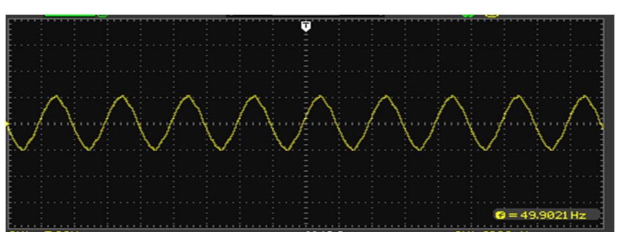
Fig. 7. Output of rectifier stage (a)Voltage (b)Current

C. Performance of Control Circuit

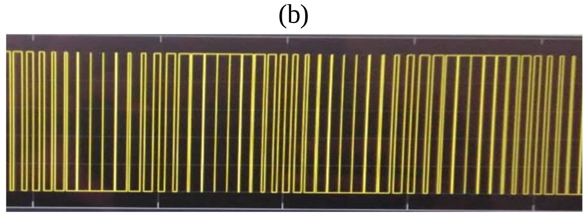
Control circuit designed to generate triangular and sinusoidal wave and afterwards, compared to generate SPWM with variable duty cycle.



(a)



(b)



(c)

Fig. 8. (a)Triangular Wave (b)Sinusoidal Wave (c)SPWM

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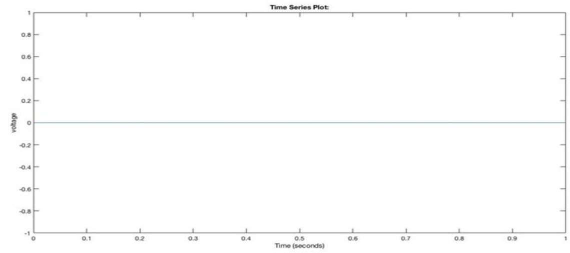
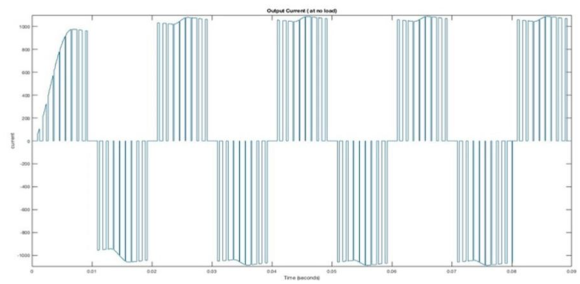
The output of the inverter is simulated at different load, i.e., at no load and R load.

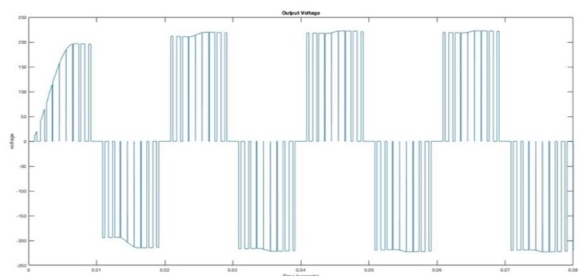


(a)

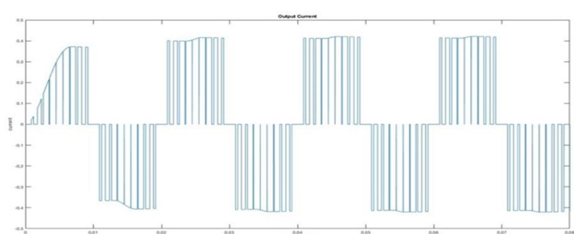


(b)

Fig. 9. Output waveform at no load (a)Voltage (b)Current



(a)



(b)

Fig. 10. Output Waveform at R load (a)Voltage (b)Current

Harmonic analysis of the circuit is done and the result is simulated.

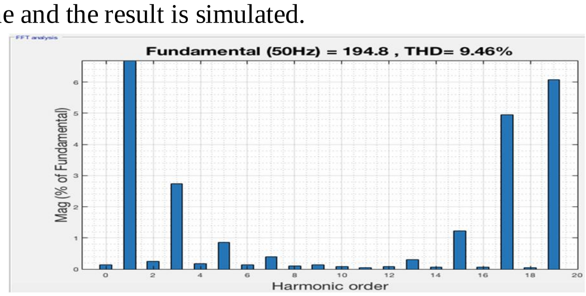


Fig. 11. THD

V. CONCLUSION

The inverter with SPWM technique is implemented. Through simulation and hardware results, its suitability is demonstrated. The SPWM technique is applied to achieve a good speed drive and reduce the total harmonic distortion (THD) in the inverter to get sinusoidal wave output irrespective of the load. The circuit is designed and its performance is analyzed through simulation at different load, i.e., no load, R load and RL load and simultaneously, hardware is also designed. Performance is simulated at two stages, rectifier and inverter. The result is simulated for both the stages. In future, it can be used to connect the output from renewable source to the grid, i.e., for grid connectivity.

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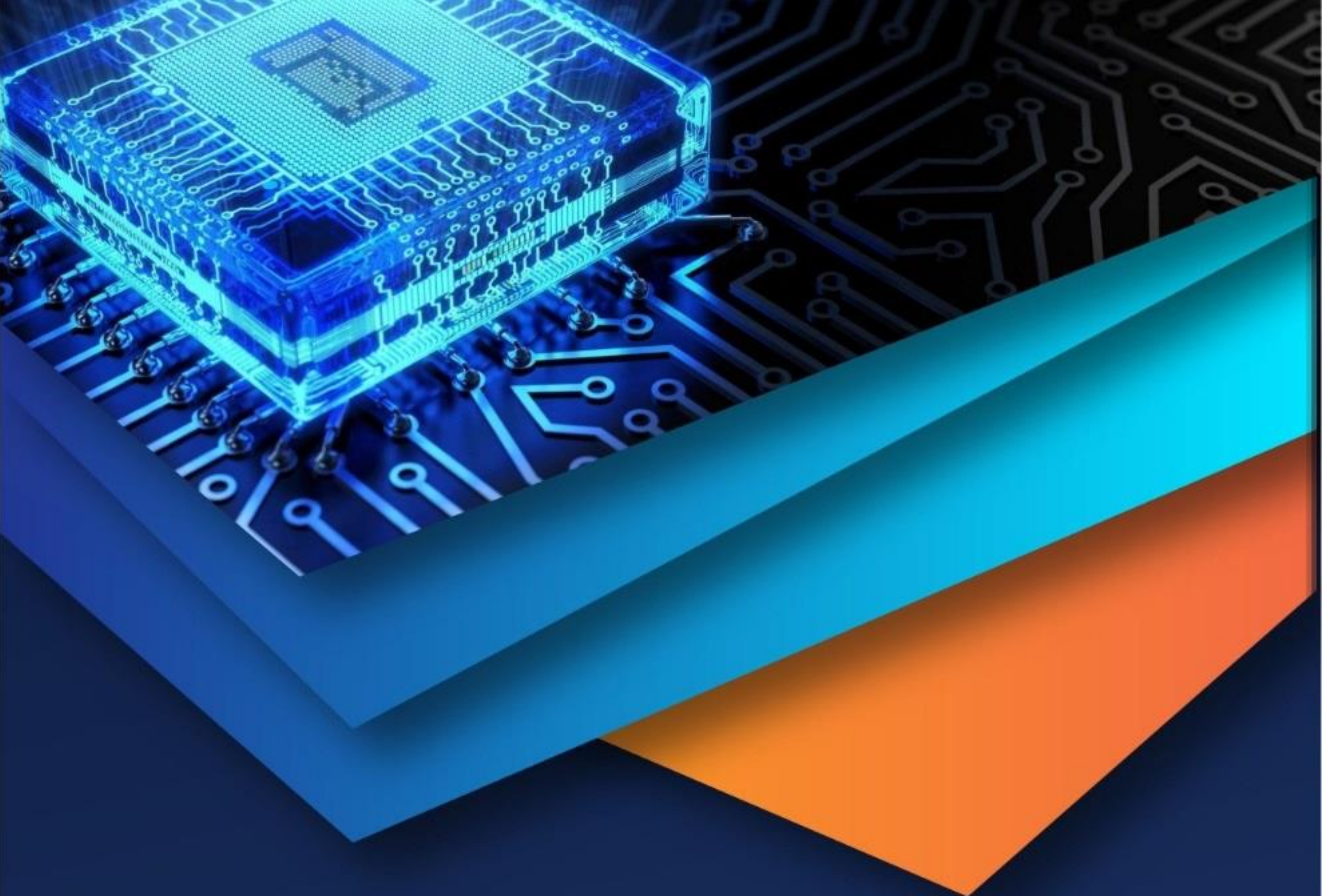

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