iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** VIII **Month of publication:** August 2016

DOI:

www.ijraset.com

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Volume 4 Issue VIII, August 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Single Phase Variable Voltage Variable Frequency Pure Sine Wave Inverter

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Abstract— Energy is stored in form of Direct Current (DC) so inverter is required. An inverter device coverts DC into AC. Single phase inverter and three phase inverter are two types of inverters. Single phase inverter has again classified as half bridge and full bridge inverter. Square wave, modified sine wave and pure sine wave are single phase inverter techniques. Square wave and modified-sine wave inverter has strong power harmonics and low quality AC output. Pure sine wave inverter generates good-quality AC power and has less harmonic distortion. So the single phase pure sine wave inverter is design and implemented. Proposed approach of design a system is such that it generates sine wave as pure as possible. The Frequency and voltage of sine wave can be changed as per the requirement. Pulse Width Modulation (PWM) is utilized for sine wave generation and it is transformer less inverter. This system is specially designed for industrial applications for high sensitive electronic circuits which require extremely pure sine wave.

Keywords— harmonics; inverter techniques; pure sine wave; single phase inverters

I. INTRODUCTION

A device which converts DC (Direct Current) to AC (Alternating Current) is called as an inverter and this AC can be generated at any required frequency and voltage with the appropriate transformers, switching and control circuits. A large number of power applications use an inverter. On the design of the specific device or circuitry the frequency, input/output voltages and overall power handling is depends. Based on output waveforms there are three types of inverters as: square wave, modified-sine wave and pure sine wave.

A square wave is non sinusoidal waveform, mostly seen in electronics and signal processing. Square wave have two levels (positive and negative) and changes regularly between these two levels. The output of a modified sine wave inverter goes to 0V before it switching positive or negative. The square wave and modified sine wave inverter are generally used types of inverters but they produces a lower quality AC signal and has strong system harmonics. They have lower efficiency. A pure sine wave inverter generates good quality AC signal and has very little harmonic distortion. Most of the electronic devices work best with pure sine wave inverter. Pure sine wave inverter has merits as inductive loads run faster, reduces audible and electrical noise in equipments, avoid glitches in monitors, the fan or tube lights won't make any humming noise, mixer or grinder operates safely with sine wave inverters. So single phase pure sine wave inverter is design and implemented.

Ideally inverter should have sinusoidal waveform. However, practically inverters have non sinusoidal waveform and contain certain harmonics. With availability of high-speed power semiconductor devices, the harmonic contents present in the output voltage can be reduced significantly by means of switching techniques. BJTs, MOSFETs or IGBTs are ideal switches to use but IGBT is more popular as it combines the benefits of BJTs and MOSFETs. An IGBT has features like low on state conduction losses such as in BJTs and high input impedance as in MOSFETs. The IGBT is a minority-carrier device with large bipolar current carrying capability.

If the non-linear loads are introduced into the system, the non-sinusoidal voltage and current are drawn across network and therefore harmonics are generated. The existence of harmonics causes problems such as reduced power factor, failure of operation, reduced efficiency, shortens equipment life, overheating of lines etc.

II. LITERATURE SURVEY

In order to start the thesis, the first step is to study the previous work performed by researchers. For this purpose various papers have been studied.

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TABLE I
RELATED WORK

Sr. No.	Paper Title	Year	Work
1	A microcontroller based variable voltage variable frequency sinusoidal power source with a novel PWM generation strategy. [1]	2012	A sinusoidal power source is developed. The MOSFET H bridge inverter is used. The voltage and frequency is varying in an ac voltage range of 30–80Vrms and a frequency range of 40–70Hz. The SPWM is used in which constant amplitude pulses are generated but having different duty cycles for each pulse period.
2	Microcontroller based Design and Implementation of Single Phase Inverter Using IGBTs. [2]	2014	Single phase inverter is designed and implemented. IGBT is used as switch. Inverter has power section consists of IGBTs and control section consists of microcontroller. The PWM is used as switching technique. Sine wave is generated at the output and it has very small harmonic distortion.
3	Design and Implementation of a Pure Sine Wave Single Phase Inverter for Photovoltaic Applications. [3]	2014	Inverter control circuit is developed. The SPWM is used as switching method to get a pure sine wave. This method has a certain switching patterns. The convention method is replaced by PIC microcontroller.
4	Highly Efficient Pure Sine-Wave Inverter for Photovoltaic Applications with MPPT Technique. [4]	2014	A cost effective inverter is designed and implemented. They offer maximum efficiency and reduced THD. The MPPT technique is used.

III. BLOCK DIAGRAM OF PROPOSED SYSTEM

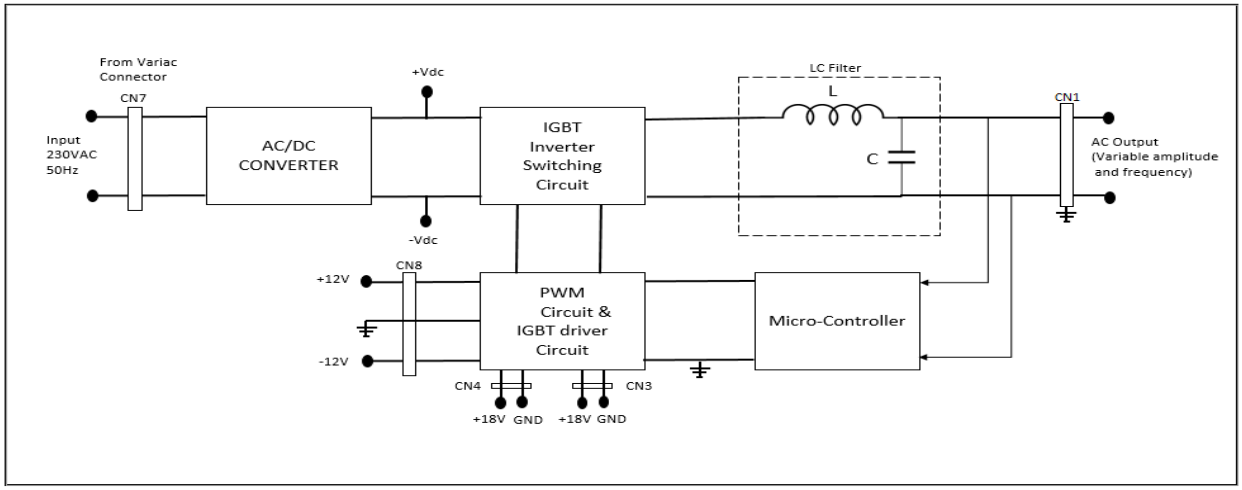

Fig-1: Block Diagram of Proposed System

The block diagram of proposed system i.e. pure sine wave inverter is as shown in above fig.1. This system is mainly having a power circuit and controller circuit. The power circuit consists of AC/DC converter, IGBT inverter switching circuit and LC filter. ARM7

LPC 2214 microcontroller is used as a controller circuit.

A. Power Circuit

The input AC signal is given to ac/dc converter from variac. This input signal voltage is varied between voltage ranges 0 to 230V AC. The MOV (Metal Oxide Varistor) is used at the input side of ac/dc converter to avoid voltage surges. The full wave bridge rectifier is used as ac/dc converter. The rectifier rectifies the input ac signal into dc. This dc signal is given as input signal to the IGBT inverter switching circuit. IGBT's are used instead of MOSFET's as it combines advantages of both BJT's and MOSFET's. The IGBT power module is used as inverter switching circuit. The PWM (Pulse Width Modulation) is used as switching technique. The PWM signal required for IGBT switching is generated by comparing triangular wave signal with sine wave reference signal. The triangular wave is produced by integrating square wave signal. This generated PWM signal is applied to the IGBT inverter switching circuit. According to PWM signal inverter generates AC signal at the output of it. As inverter converts DC voltage into AC waveform, at the output of IGBT inverter square wave is produced. The unwanted frequencies of the square wave signal are eliminated by LC filter. The pure sine wave is generated at the output of LC filter. The frequency and voltage of this generated sine wave can be varying as per the requirement.

B. Controller Circuit

The LPC 2214 microcontroller is used. This controller generates sine wave signal with the help of programming. The sine wave signal can be generated by two methods such as by using DAC and by using PWM. This generated sine wave signal is given to a PWM circuit as reference signal to produce PWM signal. To generate PWM, the triangular wave signal is compare with the reference sine wave signal by using the voltage comparator. The duty cycle of PWM signal is depends on frequency of triangular wave. Then this PWM circuit generate PWM signal and applied this signal to IGBT inverter switching circuit.

IV. SYSTEM OVERVIEW

A. ARM Microcontroller (LPC 2214)

It is based on ARM7TDMI-S™ CPU which is 32 bit with real-time emulation and having embedded trace support. The controller has 16kB on-chip Static RAM, 256kB Flash Program Memory and 10-bit A/D converter with 8 channels. There are 112 GPIO pins with 5V tolerant, Two 32-bit timers and PWM unit. The on-chip crystal oscillator is of 1 to 30 MHz range. It has features like In-System Programming & In-Application Programming. This controller has additional mode i. e. thumb mode which is used for critical code size applications. The thumb mode is 16 bit and it reduces code size more than 30%. These microcontrollers are suitable for applications such as medical systems, industrial control, access control etc.

B. DAC 8760

The DAC 8760 is used to generate reference sine wave. This sine wave signal can be generated by using two methods i. e. by using DAC or by using PMW. The microcontroller and DAC both together used to generate reference sine wave signal or PWM module of microcontroller is used to generate reference sine wave. Then this generated reference sine wave signal is given to PWM circuit for generation of PWM signal. This DAC having current output ranges as 4mA to 20mA, 0mA to 20mA, 0mA to 24mA and voltage output ranges as 0 V to 5 V, 0 V to 10 V, ±5 V, ±10 V.

C. IGBT

IGBT stands for "Insulated Gate Bipolar Transistor" which is the switching (or pulsing) component of the inverter. The IGBT provides high switching speeds (3000–16000 Hz) and less heat generation. This higher switching speed will increases the accuracy of AC wave emulation and reduced audible motor noise. As it reduces heat generation, the size of heat sinks also reduces and thus a smaller drive footprint.

IGBT Power Module is used as inverter switching circuit. This module is half-bridge and includes fast free-wheeling diodes. This power module is package with insulated metal base plate.

D. IGBT Driving Circuit

The IGBT driver IC is used to utilize full advantages of IGBT. They have standard series and high speed series. The photocoupler for high isolation and overcurrent protection circuit are built in. Single supply operation

Volume 4 Issue VIII, August 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

E. PWM circuit

The PWM technique is used as switching technique. The PWM signal is generated by comparing reference sine wave signal with triangular wave signal by using the voltage comparator LM 311.

F. LC Filter

Output of the inverter is chopped AC voltage with zero DC components. It contains harmonics. The low-pass LC filter is normally used at the inverter output to reduce the high frequency harmonics. The high purity sine wave output is required so proper filtering is must. At the filter output a pure sine wave is obtained.

V. IMPLEMENTATION AND RESULTS

This system is designed as explained in above section and ARM LPC 2214 kit is use as controller circuit to generate reference sine wave with the help of programming. Fig.2 shows experimental setup for DAC output and inverter output with power circuit consists of ac/dc converter, IGBT switching circuit, filter etc and controller circuit consisting of LPC 2214 controller.

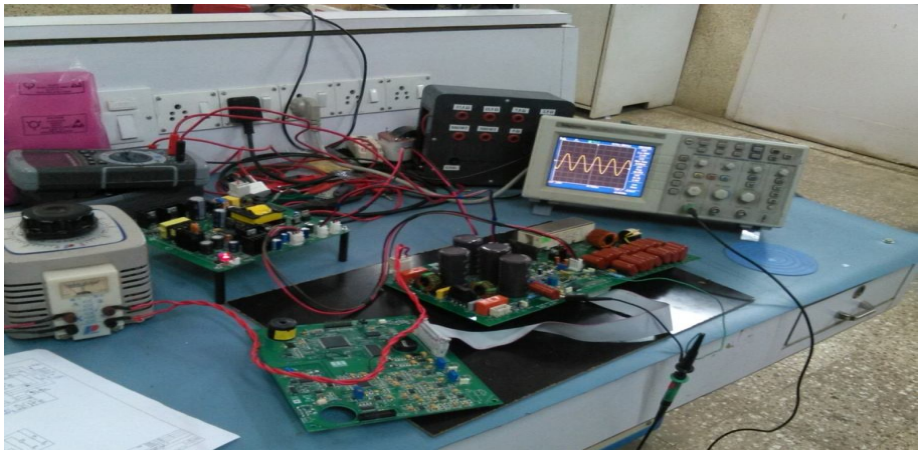

Fig. 2: Experimental Setup

The reference sine wave signal is generated by using DAC or by using PWM module of controller. The fig. 3 shows the sine wave generated by using DAC. The sine wave signal is given to PWM generation circuit.

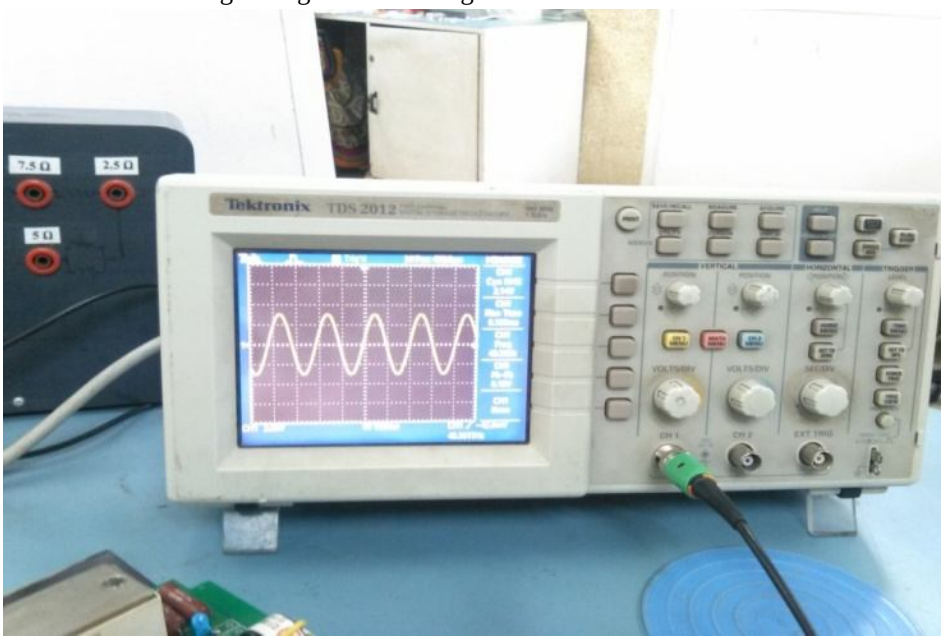

Fig. 3: DAC output

Volume 4 Issue VIII, August 2016
ISSN: 2321-9653
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The square wave inverter and modified sine wave inverter are having more harmonic contents and low quality AC output so true sine wave inverter is design and implemented. We try to design a system which produces a sine wave as pure as possible. Many industrial applications require a pure sine wave for their proper functioning. At the output we get pure sine wave as shown in fig. 4.

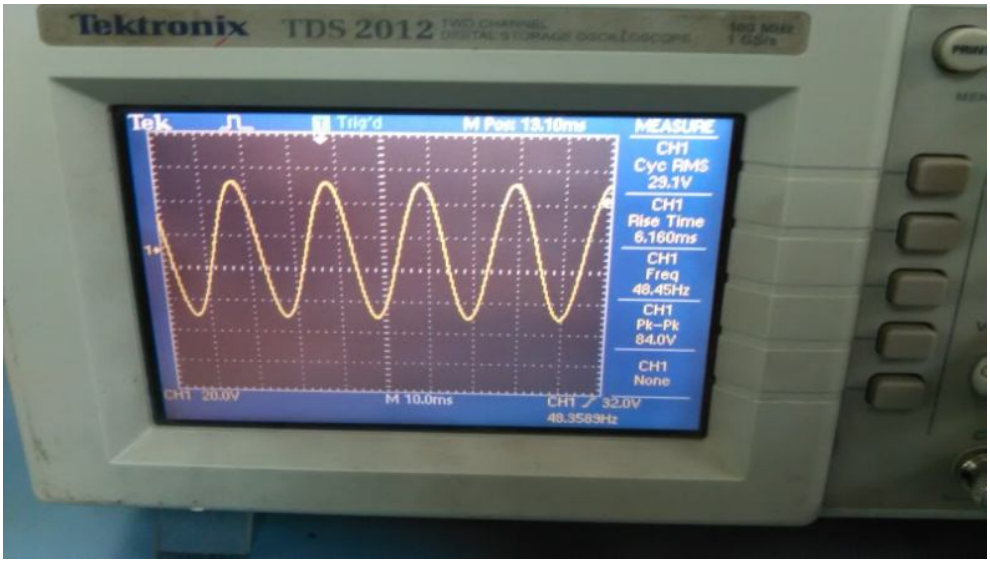

Fig. 4: inverter Output

Safety and life of appliances is higher with true sine wave inverter. It has higher battery life.

Key System Specifications:

The proposed system i.e. pure sine wave inverter has following specifications.

TABLE II
KEY SYSTEM SPECIFICATIONS

PARAMETER	VALUE
Input Voltage (Vin)	320V DC
Input Current (Iin)	1.7 Amps max
Output Voltage (Vout)	100Vrms or 200Vrms
Output Current (Iout)	max 5 Amps
VA Rating	max 600 VA
THDv: Voltage Total Harmonic Distortion	<5%
Efficiency	85%
Output Inductance	3mH
Output Capacitance	20uF
Switching Frequency	12kHz

VI. CONCLUSION

Square wave and modified sine inverter has strong power harmonics and low quality AC output. Pure sine wave inverter generates good-quality AC power and has less harmonic distortion. Many electronics devices work best with pure sine inverter. Pure sine wave has merits like inductive loads run faster & cooler, reduces audible and electrical noise in equipments, the fan or tube lights won't make any humming noise etc. So the single phase pure sine wave inverter is design and implemented which generates sine wave as pure as possible. The IGBT is used instead of MOSFET. The parameters of sine wave such as voltage and frequency can be varying as per the requirements. The proposed system is transformer less inverter. This system is specially designed for industrial applications for high sensitive electronic circuits which require extremely pure sine wave.

VII. ACKNOWLEDGMENT

I wish to express my sincere thanks and deep sense of gratitude to respected guide Prof. Devidas D. Dighe in Department of

Electronics and Telecommunication Engineering of Matoshri College of Engineering and Research Centre, Nashik for the technical advice, encouragement and constructive criticism which motivated to strive harder for excellence. I also wish acknowledgement to the people who gives support direct or indirectly to the paper writing.

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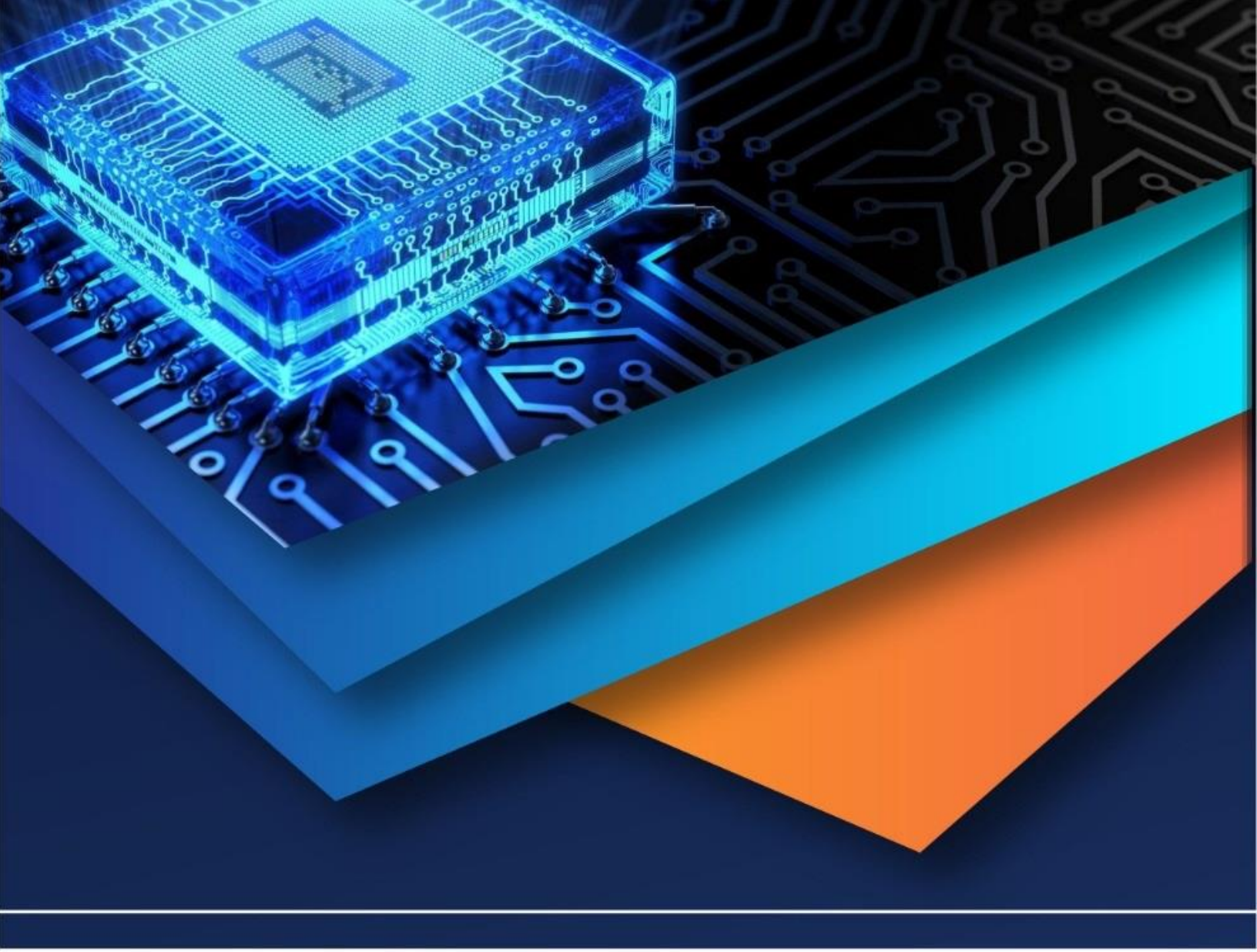

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