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# Design and Quantization of FIR and IIR Filter for OFDM Signal

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***Abstract: In Digital Signal Processing (DSP) applications, digital filter coefficients are an essential part. The principle goal is to design the FIR Filter using different windowing strategies such as Hamming, Hanning, Blackman and Rectangular Window and IIR Filter using Bilinear and Impulse Invariant Transformation based on the input OFDM Signal. Then the quantization of input signal and filter coefficients are performed. Finally comparisons were made based on Signal to Quantization Ratio (SQNR).***
***Keywords: OFDM, FIR Filter, IIR Filter, Quantization***

## I. INTRODUCTION

Digital filters play a vital role in digital signal processing applications. When digital filters are implemented on a computer or with extraordinary reason equipment, each filter coefficient has to be represented by a finite number of bits. The principle operation in digital filters is multiplication and addition. When these operations are performed in a digital system, the input data as well as the product and sum have to be represented in finite word length which depends on the span of the register used to store the data. In digital computation, the input and output data are quantized by to convert them to a finite word size. This creates a blunder in the output or creates the limit cycles in the output. These effects due to the finite precision representation of numbers in a digital system are called finite word length effects. Digital filters are implemented using finite word length effects for the OFDM Signal. Digital filters are classified either as Finite duration impulse response (FIR) filters or Infinite duration impulse response (IIR) filters, depending on the form of impulse response of the system. In the FIR system, the impulse response sequence is of finite duration. In the IIR system, the impulse response is of infinite duration. OFDM Signal is an input signal which is used in this project. In this paper, FIR filters are designed using windowing method. A window function is a mathematical function that is zero-valued outside of some chosen interval.

## II. LITERATURE SURVEY

Cantin.M. A, Savaria.Y, Prodanos.D, and Lavoie.P (2001) used the programmed word length assurance of equipment information ways which requires a few blunder models, client details and equipment costs. The technique utilizes a C/C++ fixed point simulation apparatus to demonstrate the effect of finite word lengths on general precision. Dusan M. Kodek (2005) proposed the derivation of a lower bound on channel corruption. The significance of this bound is not just hypothetical. It’s down to earth viability is appeared in the calculation for ideal finite word length FIR channel outline where it fundamentally diminishes the measure of calculation.Govinda Mutyala Rao T, Bibhudendra Acharya and Sarat Kumar Patra (2008) paper breaks down the impacts of Fast Fourier Transform (FFT) calculation in Orthogonal Frequency Division Multiplexing (OFDM) for Wireless Local Area Network (WLAN) application. Abhijit Mitra (2008) built up the limited word length for block floating point arithmetic and the hypothetical mistakes connected with the floating point quantization procedure were figured with the assistance of blunder appropriation capacity. Eitan Sayag, Amir Leshem, Nicholas D. Sidiropoulos and Fellow (2009) examined the execution of linear zero forcing precoders within the sight of limited word length blunders. This technique utilizes a configuration device for DSL linear crosstalk precoders. DSL frameworks were utilized to convey high information rate. Armein Z. R. Langi (2011) built up the finite word length consequences for two distinctive VLSI models of number Discrete Wavelet Transform (DWT) such as basis correlation and pyramidal algorithm and it assessed the signal to noise ratio for different estimations of whole number word length. Angita Solanki, Devendra Singh Mandloi (2012) composed the low pass channel with adjusting procedure in view of Remez exchange algorithm. The configuration depends on the remez exchange (RE) for the outline of high pass channels. Ankita Mahajan and Rajesh Mehra (2013) proposed the Digital channels utilizing finite word length for information yield coefficients in the outline

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of Interpolator.

## III. METHODOLOGY

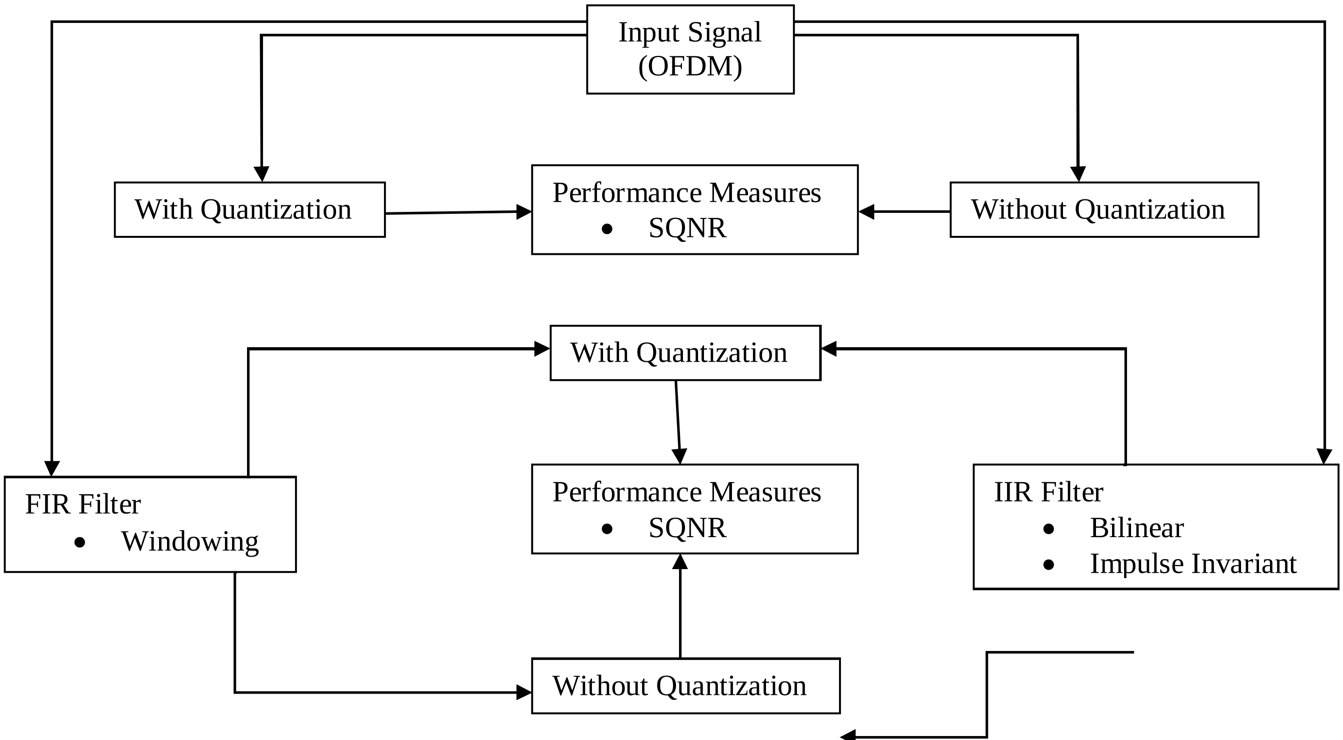


Fig.1 Block Diagram of Quantization of filter coefficients for OFDM Signal

Fig.1 shows the block diagram of the Quantization of filter coefficients for OFDM Signal. OFDM is a input Signal. FIR filter and IIR Filter were designed based on the OFDM SIGNAL. An OFDM is based on the concept of frequency-division multiplexing (FDD), the method of transmitting multiple data streams over a common broadband medium. Each data stream is modulated onto multiple adjacent carriers within the bandwidth of the medium, and all are transmitted simultaneously. A Basic OFDM system has an input data symbols are supplied into a channel encoder that data are mapped onto BPSK/QPSK/QAM constellation. The data symbols are converted from serial to parallel and using Inverse Fast Fourier Transform (IFFT) to achieve the time domain OFDM symbols.

For an OFDM system with N subcarriers, OFDM signal in baseband notation can be expressed by,

$$x(k) = \frac{1}{\sqrt{N}} \sum_{k=1}^{N-1} X_K e^{i2\pi\Delta f t}$$

### A. *FIR Filter*

FIR Filter is designed using Windowing Techniques .The basic design principles of window function are to calculate $h$(n) by the Fourier transform based on the ideal demanded filter frequency response $H_d(e^{jw})$.

1) *Hamming Window:* The hamming window is, like the Hanning window, also a raised cosine window. The hamming window exhibits similar characteristics to the Hanning window but further suppress the first side lobe.

$$w(n) = \begin{cases} 0.54 - 0.46cos\left(\frac{2n\pi}{N-1}\right); 0 \le n \le n-1 \\ 0; otherwise \end{cases}$$

2) *Hanning Window:* The Hanning window is a raised cosine window and can be used to reduce the side lobes while preserving a good frequency resolution.

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$$w(n) = \begin{cases} 0.5 - 0.5cos\left(\frac{2n\pi}{N-1}\right); 0 \le n \le n-1 \\ 0; otherwise \end{cases}$$

3) *Blackman Window:* The Blackman window is similar to Hanning and Hamming windows. An advantage with Blackman window over other windows is that it has better stop band attenuation and with less pass band ripple.

$$w(n) = \begin{cases} 0.42 - 0.5cos\left(\frac{2n\pi}{N-1}\right) + 0.08cos\left(\frac{4n\pi}{N-1}\right); 0 \le n \le n-1 \\ 0; otherwise \end{cases}$$

4) *Rectangular Window:* The rectangular window is the simplest window, taking a chunk of information without any modification. It is also called as Boxcar or Dirchlet window.

$$w(n) = \begin{cases} 1; 0 \le n \le N-1 \\ 0; otherwise \end{cases}$$

*B. IIR Filter*

Digital filters with infinite Impulse Response referred to as IIR Filter. The commonly used filters are Butterworth filter that have no ripples and Chebyshev filters that have ripples in stop band or pass band. The magnitude function of the Butterworth filter is given by,

$$|H(j\Omega)| = \frac{1}{\left[1 + \left(\frac{\Omega}{\Omega_c}\right)^{2N}\right]^{\frac{1}{2}}}$$

The magnitude square function of the Butterworth filter is given by,

$$\left|H(j\Omega)\right| = \frac{1}{1 + \varepsilon^2 {C_N}^2\left(\frac{\Omega}{\Omega_p}\right)}$$

There are two techniques to design the IIR Filters namely Bilinear and Impulse Invariant Transformation. The bilinear transform is used to convert a transfer function of a linear, time-invariant (LTI) filter in the continuous time domain to a transfer function of a linear, shift-invariant filter in the discrete-time domain. Impulse Invariance is a technique in which the impulse response of the continuous-time system is sampled to produce the impulse response of the discrete-time system.

*C. Quantization*

Quantization is the process of converting Discrete Time Continuous Amplitude into Discrete Time Discrete Amplitude signal. The quantization is calculated by,

Quantized Signal = round(input signal*2^(b-1)) / 2^(b-1)

Where b is the number of bits.

## IV. RESULTS AND DISCUSSION

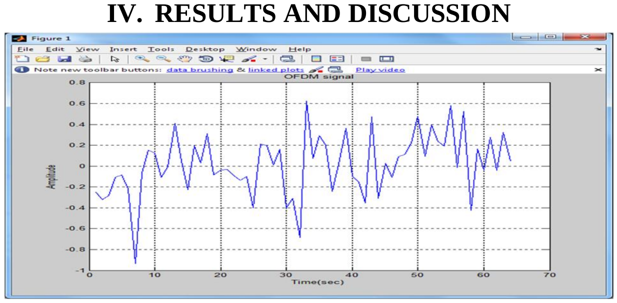


Fig.2 OFDM Signal

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The above figure shows the OFDM Signal which is modulated using QAM with subcarrier of 64 and signal constellation of 16. The sampling frequency used is 31.25 KHz and the symbol duration is 4Ωsec.

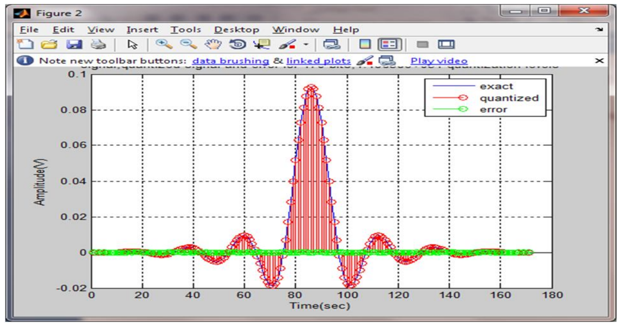


Fig.3 Original, Quantized and Quantization error for the Hamming Window

The above figure shows the original, quantized and Quantization error of the Hamming Window Low pass Filter.

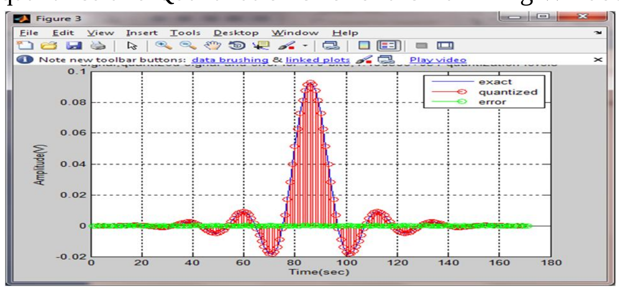


Fig.4 Original, Quantized and Quantization error for the Hanning Window

The above figure shows the original, quantized and quantization error of the Hanning Window Low pass Filter.

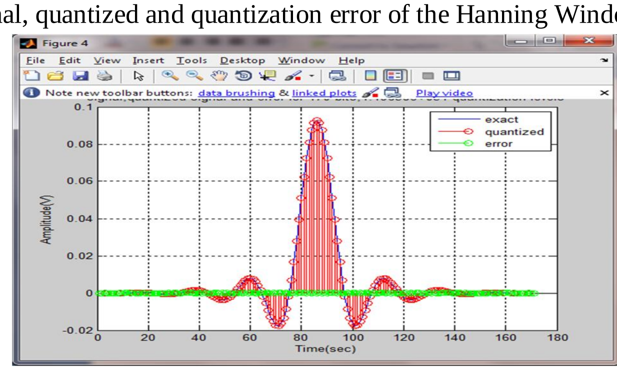


Fig.5 Original, Quantized and Quantization error for the Blackman Window

The above figure shows the original, quantized and quantization error of the Blackman Window Low pass Filter.

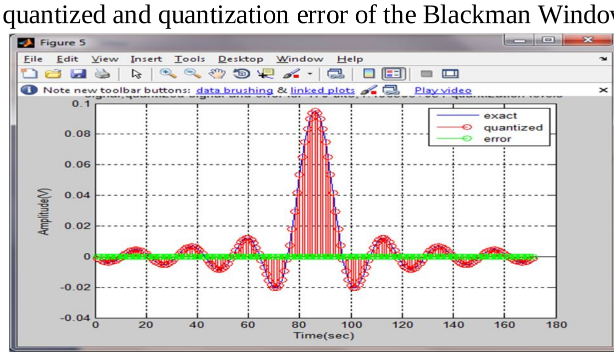


Fig.6 Original, Quantized and Quantization error for the Rectangular Window

The above figure shows the original, quantized and quantization error of the Rectangular Window low pass filter

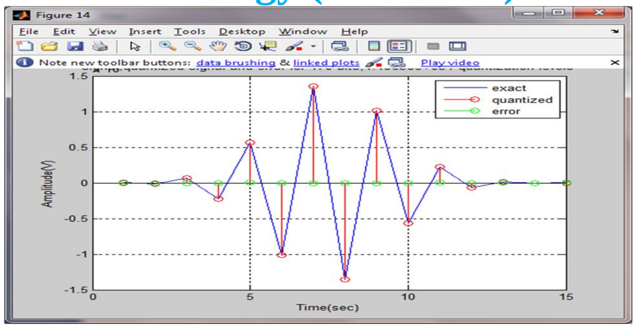


Fig.7 Original, Quantized and Quantization error for the Butterwoth LPF- Bilinear

The above figure shows the original, quantized and quantization error of the Butterworth low pass filter for Bilinear Tranformation

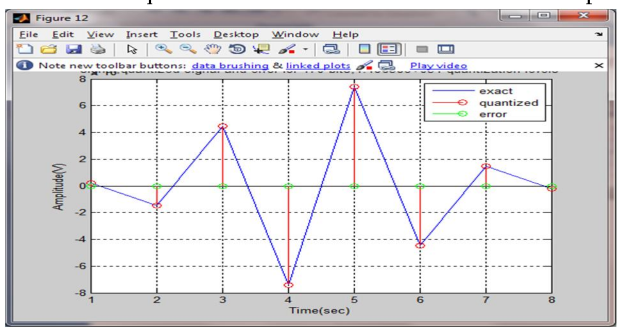


Fig.8 Original, Quantized and Quantization error for the Chebyshev LPF- Bilinear

The above figure shows the original, quantized and quantization error of the Chebyshev low pass filter for Bilinear Tranformation

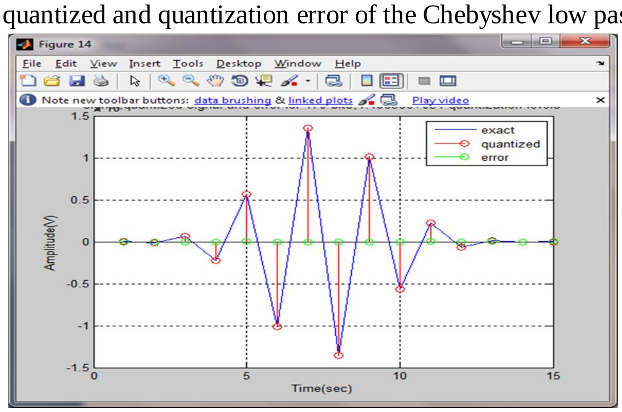


Fig.9 Original, Quantized and Quantization error for the Butterworth LPF- Impulse Invariant

The above figure shows the original, quantized and quantization error of the Butterworth low pass filter for Impulse Invariant Tranformation

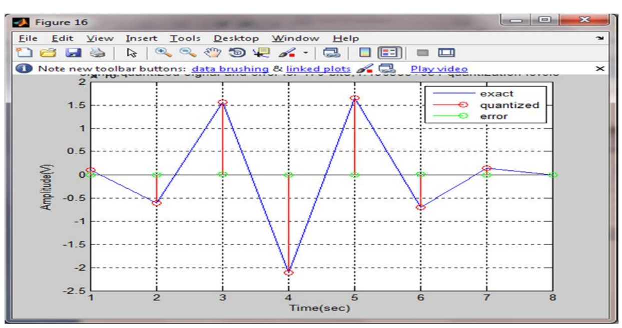


Fig.10 Original, Quantized and Quantization error for the Chebyshev LPF- Impulse Invariant

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The above figure shows the original, quantized and quantization error of the Chebyshev low pass filter for Impulse Invariant Tranformation

*A. Signal to Quantization Noise Ratio (SQNR)*

The SQNR provides the relationship between the maximum nominal signal strength and the quantization error.

$$SQNR = 10log10\left(\frac{Normalized\ Sinal\ power}{Quantized\ Signal\ power}\right)$$

Where,

Normalized Signal power= Σ(input signal^2)
Quantized Signal power= Step size/ Quantizer level

TABLE 1
Signal to Noise Quantization Ratio (db) for OFDM Signal

| OFDM Signal | Without Quantization | With Quantization |
|---|---|---|
| | 37.5112 | 51.2466 |

The above table 1 shows that the OFDM provides the maximum Signal to Quantization Noise Ratio for With Quantization a

TABLE 2 Comparisons of Signal to Noise Quantization Ratio (db) for Different Window

| Windowing Techniques for LPF | Without Quantization | With Quantization |
|---|---|---|
| Hamming Window | 43.3898 | 76.3009 |
| Hanning Window | 43.3884 | 76.3276 |
| Blackman Window | 43.3953 | 76.3960 |
| Rectangular Window | 43.4474 | 75.9919 |

The above table 2 shows that the Blackman Window provides the maximum Signal to Quantization Noise Ratio for With Quantization and Rectangular Window provides a maximum Signal to Quantization Noise Ratio for Without Quantization.

TABLE 3Comparisons of Signal to Noise Quantization Ratio (db) for IIR Filter

| IIR Filter | Without Quantization | With Quantization |
|---|---|---|
| Butterworth LPF- Bilinear | 34.7081 | 243.1358 |
| Chebyshev LPF- Bilinear | 33.3277 | 180.4667 |
| Butterworth LPF- Impulse Invariant | 34.3339 | 117.9980 |
| Chebyshev LPF- Impulse Invariant | 33.5756 | 272.3875 |

The above table 3 shows that the Butterworth low pass filter- Bilinear Transformation provides the maximum Signal to Quantization Noise Ratio for Without Quantization and Chebyshev low pass filter- Impulse Invariant Transformation provides a maximum Signal to Quantization Noise Ratio for With Quantization.

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## V. CONCLUSION

In this paper, FIR Filter and IIR Filter is designed based on the input OFDM Signal and the Filter coefficients are quantized. The Quantization error is calculated between the input signal and the quantized signal. Finally comparisons are made based on the signal to quantization noise ratio.

## VI. ACKNOWLEDGMENTS

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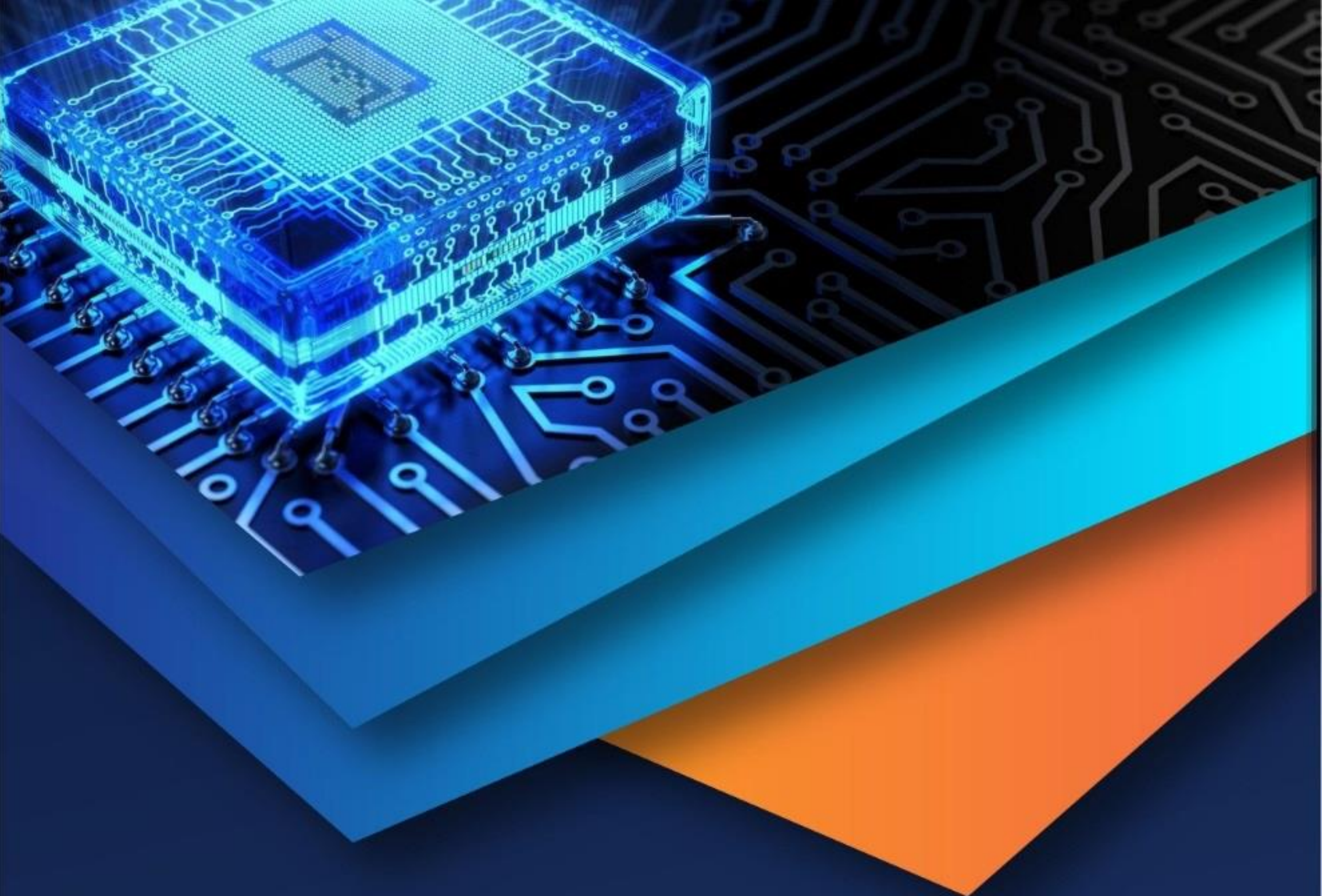


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