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Designing FIR Filter using Distributed Arithmetic

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Abstract: Distributed arithmetic technique is employed in this paper to develop the FIR filter. To eliminate undesired signal and noise, FIR filters are frequently employed as digital filters in digital signal processing. This method also calls for shift registers and an accumulator and stores the FIR filter coefficients in a look-up table (LUT).By using this method, shift and accumulate can take the place of the multipliers in the FIR filter. The size of the LUT can be reduced for larger filter coefficients by dividing it into any number of LUTs, which are made up of taps that are FIR filter coefficients. FIR filter is created in MATLAB using the DA technique, and manual computation yields the same result.
Keywords: MATLAB, FIR filter, Distributed arithmetic, filter coefficients, LUT

I. INTRODUCTION

Digital signal processing use FIR filters for a variety of purposes, including frequency selection, smoothing, and noise reduction. The complexity and power consumption of the FIR filter are increased by the necessity of a large number of multipliers to implement the necessary filter coefficients. By lowering the quantity of multipliers necessary for filter design, this problem can be resolved. The computation complexity of the multiplication operations employed in the filter design is reduced by the use of distributed arithmetic in the construction of FIR filters. This method substitutes another operation for multiplication. Page Layout

II. FILTER DESIGN

A. *FIR filter with Multiplier*

A finite number of input samples are used by the FIR filter to generate a finite number of output responses. It is chosen because it produces a linear phase response as a result of the symmetry of the filter coefficients. In a linear phase response, each component is delayed by the same amount of time and is also helpful in maintaining the phase of the signal, which is helpful in applications for image processing and audio. Each input sample is multiplied by a corresponding filter coefficient in order for the filter to work on the input signal. The results are then added together to create the filtered output sample.

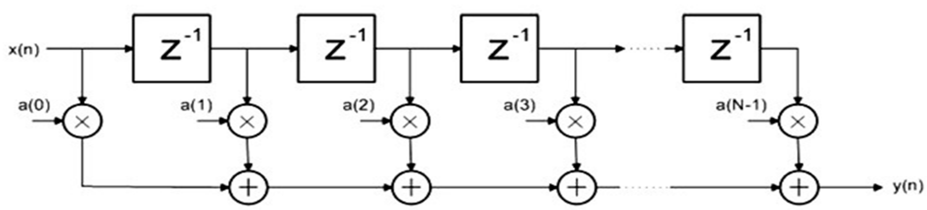

Fig: Conventional tapped delay line FIR filter

The FIR operation is described by the equation

$$y(n) = a_0x(n) + a_1x(n-1) + a_2x(n-2) + a_3x(n-3) + \dots\dots\dots\dots + a_Nx(n-N)$$
$$= \sum_{i=0}^{N} ai\ x(n\text{-}i)$$

where,

x(0) is input signal
y(n) is output signal
a_0 is taps or filter coefficients

Figure shows FIR filter with has N adder, N+1 filter coefficients (or taps) and N+1 multipliers If order of FIR filter is 4then equation is

$$Y(n)= \sum_{i=0}^{3} a(i\ )x(n\text{-}i)$$
$$y(n) = a(0)x(n) + a(1)x(n-1) + a(2)x(n-2) + a(3)x(n-3) + a(4)x(n-4)$$

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The filter coefficients can be used to calculate the frequency response of a filter, allowing for the design of a variety of filters, including high-pass, low-pass, band-pass, and band-stop filters.Windowing approach can be used to create the necessary filter taps or coefficients by multiplying the desired frequency response by the window function.Least Square and Parks McClellan are two additional implementation strategies that can be employed for filter design.Based on filter performance metrics including ripple, transition bandwidth, and attenuation, the FIR filter is chosen.FIR filters are preferred over IIR filters due to its advantages such as linear phase response, stability, and the possibility to construct same frequency responses.

B. FIR filter design using Distributed arithmetic

Digital signal processing uses the Distributed arithmetic technique to carry out computations quickly and effectively.This method replaces the standard addition and multiplication operations with algorithms that are implemented on hardware to save FPGA resources.This method lessens the number of arithmetic operations, which in turn lessens the complexity of the hardware. It is used to substitute a Look Up Table and a shifter-accumulator for all multiplications and additions. Multiplying c[n]x[n] results in a multiplication by a constant because DA depends on knowing the filter coefficients.

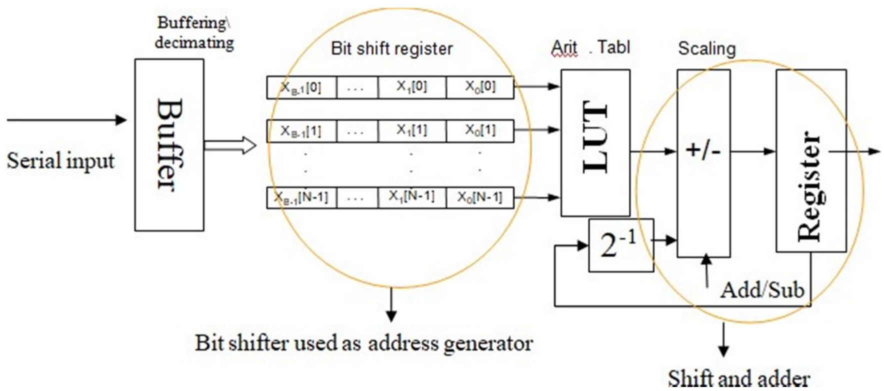

Fig: Block diagram of implementation of FIR filer using DA

The above image depicts the block design for the DA for FIR filter. When implementing DA, the number of inputs that must be stored must match the length of the coefficients in each buffer stage. Then, the LSB bits of each coefficient are used as the LUT's address.To accept an N-bit address, where N is the number of coefficients, a 2n word LUT is preprogrammed to do so.Each mapping is given the proper weight by the combined effect of two elements.A shift-adder is effectively used to implement the accumulation.For hardware implementation, shift the accumulator content itself in each direction by one bit to the right rather than shifting each intermediate value by power factor, which necessitates an expensive barrel shifter.

Below gives the explanation of distributed arithmetic technique:

1) Generation of coefficients for sampling frequency= $4KHz, Fpass = 60Hz, Fstop = 400Hz, Apass = 0.1dB, Astop = 60dB$ from MATLAB FDA tool and stored in a text file

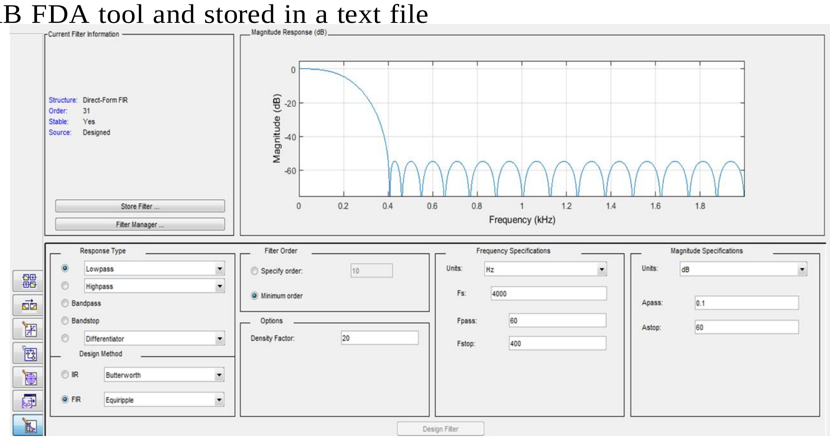

Fig: Coefficient generation in MATLAB FDA tool

2) MATLAB code is made to scale by power of 16 for the coefficients generated and to take take two's complement valueof all generated coefficients

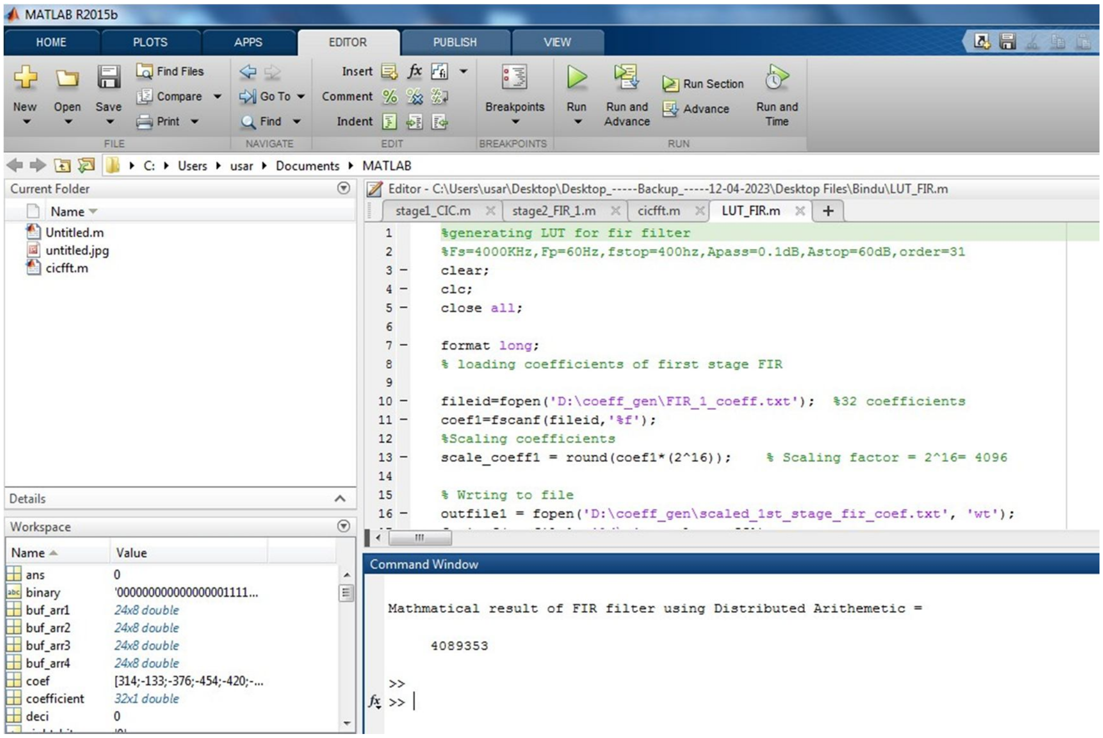

Fig: MATLAB code to generate FIR filter using DA

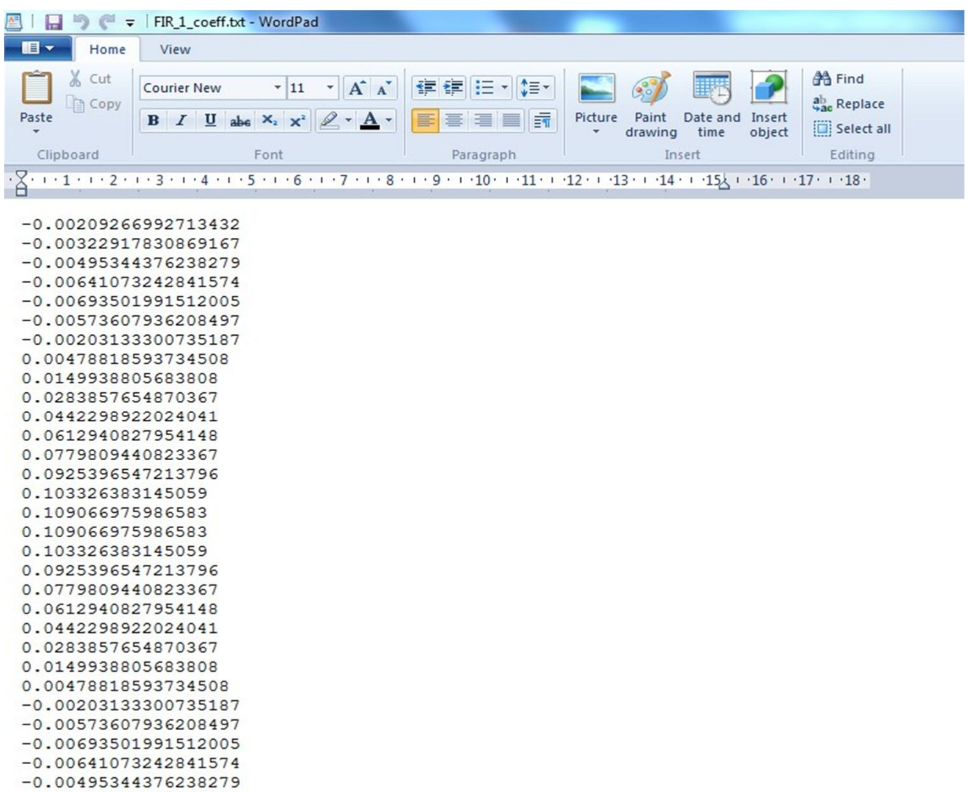

Fig: Coefficient generated from MATLAB FDA tool and loaded to text file

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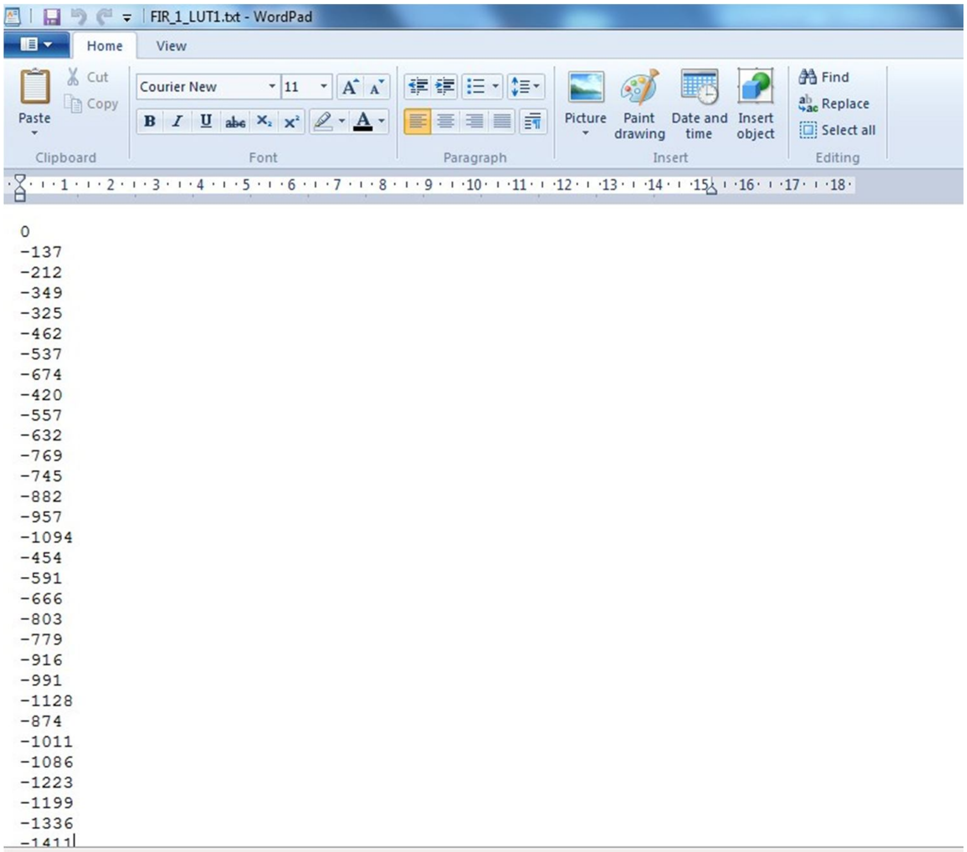

Fig: Coefficient scaled by factor 16

3) When more coefficients are considered the look up table is divided ,here four lookup table is considered hence the scaled two’s complement coefficients can be seen in four different text files this files are considered as the look up table for DA

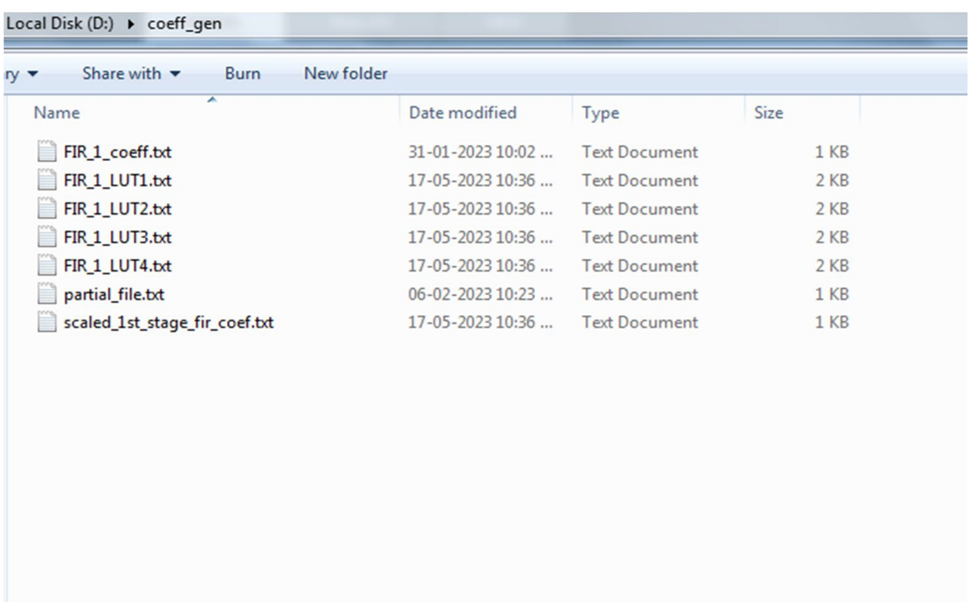

Fig: Files generated in different stages

SI.NO	32_coefficients
1	-137
2	-212
3	-325
4	-420
5	-454
6	-376
7	-133
8	314
9	983
10	1860
11	2899
12	4017
13	5111
14	6065
15	6772
16	7148
17	7148
18	6772
19	6065
20	5111
21	4017
22	2899
23	1860

	LUT_1	LUT_2	LUT_3	LUT_4
h7	-137	983	7148	314
h6	-212	1860	6772	-133
h5	-325	2899	6065	-376
h4	-420	4017	5111	-454
h3	-454	5111	4017	-420
h2	-376	6065	2899	-325
h1	-133	6772	1860	-212
h0	314	7148	983	-137

HAND_CALCULATIONS						
bit	pp0	pp1	pp2	pp3	sum	
0th	0	0	19952	-1199	18753	18753
1st	0	0	20935	-195	20740	41480
2nd	-694	19090	18714	-694	36416	145664
3rd	-564	20836	10111	-697	29686	237488
4th	-649	25096	5742	-360	29829	477264
5th	0	34855	0	-2057	32798	1049536
6th	0	0	34855	-1743	33112	2119168
						4089353

	256_partial products			
	LUT_1	LUT_2	LUT_3	LUT_4
0	0	0	0	0
1	-137	983	7148	314
2	-212	1860	6772	-133
3	-349	2843	13920	181
4	-325	2899	6065	-376
5	-462	3882	13213	-62
6	-537	4759	12837	-509
7	-674	5742	19985	-195
8	-420	4017	5111	-454
9	-557	5000	12259	-140
10	-632	5877	11883	-587
11	-769	6860	19031	-273
12	-745	6916	11176	-830
13	-882	7899	18324	-516
14	-957	8776	17948	-963
15	-1094	9759	25096	-649
16	-454	5111	4017	-420
17	-591	6094	11165	-106
18	-666	6971	10789	-553
19	-803	7954	17937	-239
20	-779	8010	10082	-796
21	-916	8993	17230	-482
22	-991	9870	16854	-929

Fig: Manual calculation of FIR filter in DA technique

	A	B	C	D
1				
2	SI.NO	Sine_data	coefficients	convolution
3				
4	1	0	-137	0
5	2	4	-212	-848
6	2	8	-325	-2600
7	2	12	-420	-5040
8	2	16	-454	-7264
9	2	20	-376	-7520
10	2	24	-133	-3192
11	2	28	314	8792
12	2	32	983	31456
13	2	36	1860	66960
14	2	40	2899	115960
15	2	44	4017	176748
16	2	48	5111	245328
17	2	52	6065	315380
18	2	56	6772	379232
19	2	60	7148	428880
20	2	64	7148	457472
21	2	68	6772	460496
22	2	71	6065	430615
23	2	75	5111	383325
24	2	79	4017	317343
25	2	83	2899	240617
26	2	87	1860	161820
27	2	90	983	88470
28	2	94	314	29516
29	2	98	-133	-13034
30	2	102	-376	-38352
31	2	105	-454	-47670
32	2	109	-420	-45780
33	2	113	-325	-36725
34	2	116	-212	-24592
35	2	120	-137	-16440
36				4089353

Fig: Manual calculation of FIR filter using FIR formula

The final value generated by MATLAB code using Distributed Arithmetic technique, manual calculation using DA and formula calculated value of FIR filter all results found to be same and examined.

III.CONCLUSIONS

Finite impulse response filters are frequently used in digital signal processing applications. The multiplier-less FIR filter is built using distributed arithmetic, which incorporates a look-up table and partitioning. Memory access takes longer than multiplication. LUT split reduces the need for memory. His approach reduces the amount of time, space, and power used. This architecture delivers an effective area-time power implementation with a great deal reduced latency and area-delay complexity when compared to other FIR Filter topologies.

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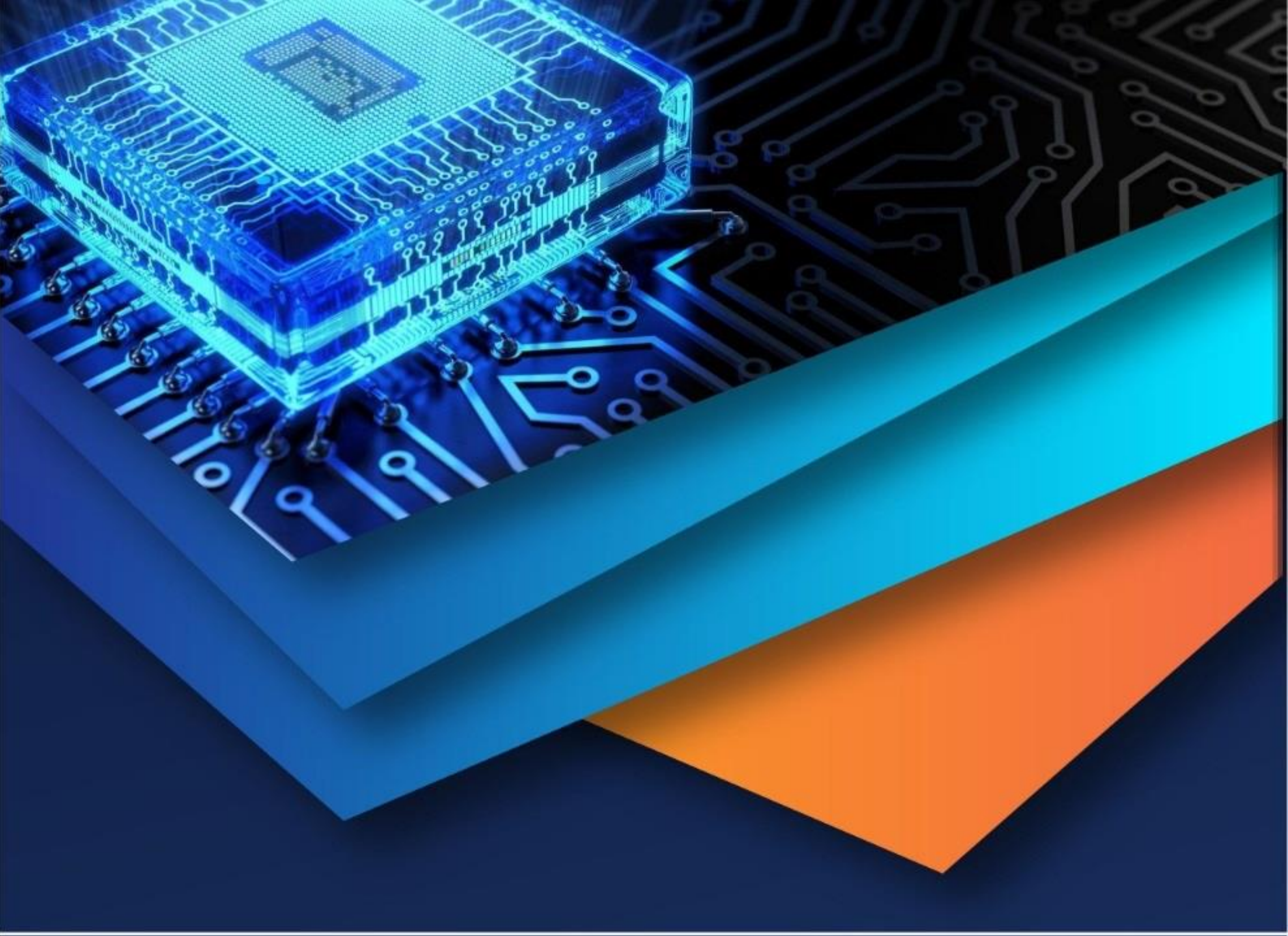

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