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The Continuous Acceptance Sampling of Truncated Frechet Distribution Based on CUSUM Schemes

N. Annapurna[1], Dr. P. Mohammed Akhtar[2], Dr. G.Venkatesulu[3], Dr. S. Dhanunjaya[4]
[1]*Research scholar, Dept. of Statistics, Sri Krishanadevaraya University, Anantapuramu-515003,AP, INDIA.*
[2]*Professor, Dept. of Statistics, Sri Krishanadevaraya University, Anantapuramu-515003,AP, INDIA.*
[3]*Leturer in statistics,Govt.College(A), Anantapuramu Dt., AP, INDIA.*
[4]*Assistant Professor, Department of Mathematics, Gitam University, Bengaluru.*

***Abstract:** Acceptance sampling plans were evaluated to draw valid conclusions regarding lots of finished products. Based on the assumption that the variable under consideration is distributed according to a Frechet distribution, CASP-CUSUM schemes are presented here for optimizing Type-C OC curves and ARLs. The Truncated Frechet distribution, its Type-C OC curve values, and ARL values at different shapes parameters were determined under this assumption. Finally, we determined an optimal CASP-CUSUM scheme that maximizes P_A.*
***Keywords:** CASP – CUSUM Schemes, Type-C OC curves, ARL Values, Truncated Frechet distribution.*

I. INTRODUCTION

In a global business market, the quality of products has become one of the most important factors that distinguish different commodities. The statistical process control and the statistical product control, or acceptance sampling, are two important techniques for ensuring quality.

Acceptance sampling is a quality control method used to accept or reject lots after testing a random sample of a product. Instead of estimating the quality of the entire batch, acceptance sampling is used to determine whether to accept or reject a lot of the product. Sample acceptance is a very useful technique when a lot is so large or when testing is destructive. It is too time-consuming and too expensive to inspect every single item in a large lot. Moreover, checking every single product does not guarantee that it will comply with the specification.

Vardeman.S, Diou Ray (9) introduced CUSUM control charts with the restriction that the values refer to quality and that they are exponentially distributed. Furthermore, the events under study are the rate of rare events and the inter-arrival time for a homogenous poison process that are identically distributed exponential random variables.

Lonnie. C. Vance (7) considers Average Run Length of Cumulative Sum Control Charts when controlling for normal means and determining CUSUM Chart parameters. To develop the parameters of CUSUM Chart, the acceptable and rejectable quality levels are considered as well as the desired respective ARL's.

The CASP-CUSUM optimization scheme was implemented by Sarma and Akhtar(1)by solving the integral equation using Gauss-Chebyshev integration using a computer program. Finally, the results of the analysis were compared at different values of the parameters.

Narayan Murthy(8) et. al examined CASP-CUSUM schemes on the basis of the truncated Rayleigh distribution to determine ARL values for CASP-CUSUM schemes. By evaluating integral equations using the Lobatto integration method, we obtained optimum continuous acceptance sampling plans cumulative sums. We compared the results obtained using different integration methods

According to Venkatesulu.G and Mohammed Akhtar.P.(2), they made Truncated Lomax Distributions and Optimised CASP-CUSUM Schemes by changing parameters and finally making critical comparisons based on the numerical results.

In the present paper, the CASP-CUSUM chart is determined when the variable under study follows Truncated Frechet Distribution. Therefore, it would be worthwhile to examine some interesting characteristics of this distribution.

A. Frechet Distribution

Extreme value theory plays a crucial role in statistical analysis. Generally, extreme data are described by generalized extreme value (GEV) distributions Gumbel, Weibull, and Fréchet distributions are all special cases of GEV distributions. According to mathematician Maurice René Fréchet, the Fréchet distribution was developed in the 1920s as a maximum value distribution (also known as the extreme value distribution of type II).

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These distributions were discussed in depth by Kotz and Nadarajah [3], D. Kundu and H. Howlader, Bayesian [5], Pedro L. Ramos, Francisco [6], including applications for accelerated life testing, natural calamities, horse racing, rainfall, supermarket queues, sea currents, wind speeds, track race records, etc.

Definition: A random variable with a non-negative Frechet distribution is said to have the P.D.F is given by

$$\mathbf{f(x;\alpha,\beta) = \alpha\beta x^{-(\alpha+1)} e^{-\alpha x-\beta}} \quad \text{Where } \alpha, \beta, \gamma,\ x > 0 \quad \text{...... (1.1)}$$

B. Truncated Frechet Distribution

Basically, it is the ratio of the probability density function of the Frechet distribution to the corresponding cumulative distribution function at B.

$$f_B(x) = \frac{\alpha\beta x^{-(\alpha+1)} e^{-\alpha x-\beta}}{(1-[1+e^{-\alpha B-\beta}])} \quad \alpha > 0,\ \beta > 0 \qquad \text{...... (1.2)}$$

Where' **B'** is the upper truncated point of the Frechet Distribution.

II. A DESCRIPTION OF THE PLAN AND THE CURVE OF TYPE-C

Beattie[4] proposed a method for the construction of continuous acceptance sampling plans. It consists of a chosen decision interval, "Return interval" with the length h', above which a decision line is taken. Sum $S_m = \sum (X_i - k_1) X_i' s (i = 1,2,3........)$ is distributed independently, and k_1 is the reference value, plotted on the chart. If the sum lies in the area of the normal chart, the product is accepted and if it lies in the of the return chart, the product is rejected, subject to the following assumptions.

1) When the recently plotted point on the chart touches the decision line, then the next point is to be plotted at maximum, i.e., h+h'.
2) Once the decision line is reached or crossed from above, the next point on the chart should be plotted from the baseline.

A network or a change of specification may be used instead of outright rejection when the CUSUM falls in the return chart.

The procedure is summarized below.

a) Begin plotting the CUSUM at Zero.
b) It is accepted when $S_m = \sum (X_i - k) < h;$ when $S_m < 0$, return cumulative to zero.
c) When h < S_m < h+h' the product is rejected: when S_m crosses h, i.e., when S_m>h+h' and continue rejecting product until S_m>h+h' return cumulative to . h+h'.

The Type - C, OC function is determined by incoming item quality and the sampling rate in acceptance and rejection regions is equal. Therefore, the probability of acceptance P_A can be calculated as follows:

$$P_A = \frac{L_0}{L_0 + L_0'} \qquad \text{...... (2.1)}$$

where, L_0 = Average Run Length in acceptance zone and
L_0' = Average Run Length in rejection zone.
Page E.S.[10] has introduced the formulae for L_0 and L_0' as

$$L_0 = \frac{N_0}{1-P_0} \qquad \text{...... (2.2)}$$

$$L_0' = \frac{N_0'}{1-P_0'} \qquad \text{....... (2.3)}$$

Where, P_0 = Probability for the test starting from zero on the normal chart,
N_0 = ASN for the test starting from zero on the normal chart,
P_0' = Probability for the test on the return chart and
N_0' = ASN for the test on the return chart

He further obtained integral equations for the quantities P_0, N_0, and N'_0, P'_0 as follows:

$$P_z = F(k_1-z)+\int_0^h P(y)\, f(y+k_1-z)dy, \qquad \ldots\ldots (2.4)$$

$$N_z = 1+ \int_0^h N(y)\, f(y+k_1-z)dy, \qquad \ldots\ldots (2.5)$$

$$P'_z = \int_{k1+z}^{B} f(y) + \int_0^h P'(y)\, f(-y+k_1+z)dy \qquad \ldots\ldots (2.6)$$

$$N'_z = 1+\int_0^h N'(y)\, f(-y+k_1+z)dy, \qquad \ldots\ldots (2.7)$$

$$F_x = 1+ \int_A^h f(x)dx$$

$$F(k_1-z) = 1+\int_A^{k1-z} f(y)dy$$

And z is the distance of the starting of the test in the normal chart from zero.

III. DETERMINATION OF ARLs AND P_A

We developed computer programs to solve equations (2.4), (2.5), (2.6) and (2.7) and we obtained the following results in Tables (3.1) to (3.28).

Table 3.1

α =1 β = 1 γ = 1 k = 4 , h=0.01, h' = 0.01			
B	L_0	L'_0	P_A
4.5	2.541672	1.065869	0.70454418
4.4	3.033483	1.073191	0.73867154
4.3	3.858639	1.081370	0.78109961
4.2	5.517222	1.090516	0.83496379
4.1	10.509679	1.100754	0.90519261

Table 3.2

α =1 β = 1 γ = 1 k = 4 , h=0.02, h' = 0.02			
B	L_0	L'_0	P_A
4.5	2.541856	1.138502	0.69065439
4.4	3.033730	1.154647	0.72432100
4.3	3.858997	1.172840	0.76691603
4.2	5.517822	1.193376	0.82218134
4.1	10.51114	1.216596	0.89626336

Table 3.3

α =1 β = 1 γ = 1 k = 4 , h=0.03, h' = 0.03			
B	L_0	L'_0	P_A
4.5	2.542042	1.217929	0.67608022
4.4	3.033982	1.244409	0.70914083
4.3	3.8593 61	1.274466	0.75175118
4.2	5.518432	1.308655	0.80831426
4.1	10.512637	1.347626	0.88637465

Table 3.4

α =1 β = 1 γ = 1 k = 4 , h=0.04, h' = 0.04			
B	L_0	L'_0	P_A
4.5	2.542232	1.304179	0.6609359
4.4	3.034237	1.342517	0.69326192
4.3	3.859733	1.386303	0.73574268
4.2	5.519056	1.436428	0.79348260
4.1	10.51416	1.493948	0.87558847

Table 3.5

α =1 β = 1 γ = 1 k = 4 , h=0.05, h' = 0.05			
B	L_0	L'_0	P_A
4.5	2.542424	1.397284	0.64533311
4.4	3.034497	1.449014	0.67681258
4.3	3.860113	1.508409	0.71902710
4.2	5.519692	1.576774	0.77780848
4.1	10.51572	1.655669	0.86397045

Table 3.6

α =1 β = 2 γ = 1 k = 4 , h=0.01, h' = 0.01			
B	L_0	L'_0	P_A
4.4	1.815961	0.843483	0.68283468
4.3	2.216361	0.820288	0.72987043
4.2	3.033228	0.797591	0.79179620
4.1	5.516596	0.778270	0.87636429
4.0	524286.1250	0.7672019	0.99999850

Table 3.7

$\alpha=1$ $\beta=2$ $\gamma=1$ $k=4$, $h=0.02$, $h'=0.02$			
B	L_0	L_0'	P_A
4.4	1.815958	0.771691	0.70177900
4.3	2.216356	0.766948	0.74291980
4.2	3.033220	0.783666	0.79468435
4.1	5.516580	0.837654	0.86817389
4.0	524284.2812	0.953647	0.99999815

Table 3.8

$\alpha=1$ $\beta=2$ $\gamma=1$ $k=4$, $h=0.03$, $h'=0.03$			
B	L_0	L_0'	P_A
4.4	1.815955	0.784557	0.69830662
4.3	2.216352	0.839861	0.72519546
4.2	3.033213	0.958011	0.75997054
4.1	5.516564	1.177764	0.82406538
4.0	524282.437500	1.558634	0.99999701

Table 3.9

$\alpha=1$ $\beta=2$ $\gamma=1$ $k=4$, $h=0.04$, $h'=0.04$			
B	L_0	L_0'	P_A
4.4	1.815952	0.882017	0.67308110
4.3	2.216348	1.038910	0.68085169
4.2	3.033206	1.320415	0.69670873
4.1	5.516548	1.798221	0.75416570
4.0	524280.656	2.581485	0.99999505

Table 3.10

$\alpha=1$ $\beta=2$ $\gamma=1$ $k=4$, $h=0.05$, $h'=0.05$			
B	L_0	L_0'	P_A
4.4	1.815949	1.064007	0.63054740
4.3	2.216344	1.363980	0.61903429
4.2	3.033199	1.870674	0.61853134
4.1	5.516533	2.698657	0.67150402
4.0	508391.656250	4.021540	0.99999207

Table 3.11

$\alpha=1$ $\beta=1$ $\gamma=2$ $k=4$, $h=0.01$, $h'=0.01$			
B	L_0	L_0'	P_A
4.5	2.541541	1.260030	0.66855013
4.4	3.033307	1.287440	0.70203286
4.3	3.858383	1.317748	0.74541836
4.2	5.516794	1.351260	0.80325424
4.1	10.508627	1.388318	0.88330459

Table 3.12

$\alpha=1$ $\beta=1$ $\gamma=2$ $k=4$, $h=0.02$, $h'=0.02$			
B	L_0	L_0'	P_A
4.5	2.541590	1.521093	0.62559401
4.4	3.033373	1.576147	0.65806698
4.3	3.858479	1.637048	0.70211267
4.2	5.516954	1.704424	0.76397514
4.1	10.50901	1.778974	0.85522657

Table 3.13

$\alpha=1$ $\beta=1$ $\gamma=2$ $k=4$, $h=0.03$, $h'=0.03$			
B	L_0	L_0'	P_A
4.5	2.541640	1.783212	0.58768260
4.4	3.033440	1.866151	0.61912107
4.3	3.858576	1.957944	0.66338217
4.2	5.517115	2.059553	0.72817170
4.1	10.509411	2.172049	0.82872247

Table 3.14

$\alpha=1$ $\beta=1$ $\gamma=2$ $k=4$, $h=0.04$, $h'=0.04$			
B	L_0	L_0'	P_A
4.5	2.541690	2.046411	0.55397427
4.4	3.033508	2.157486	0.58437889
4.3	3.858674	2.280481	0.62853497
4.2	5.517279	2.416707	0.69539809
4.1	10.50980	2.567626	0.80365979

Table 3.15

$\alpha=1$ $\beta=1$ $\gamma=2$ $k=4$, $h=0.05$, $h'=0.05$			
B	L_0	L_0'	P_A
4.5	2.541741	2.310717	0.52380484
4.4	3.033576	2.450187	0.55319237
4.3	3.858773	2.604706	0.59701174
4.2	5.517444	2.775949	0.66528183
4.1	0.510208	2.965792	0.77992045

Table 3.16

$\alpha=2$ $\beta=1$ $\gamma=1$ $k=4$, $h=0.01$, $h'=0.01$			
B	L_0	L_0'	P_A
4.5	4.531469	1.602746	0.73872029
4.4	5.531766	1.642751	0.77102971
4.3	7.203088	1.685779	0.81034934
4.2	10.555097	1.732090	0.85903280
4.1	20.661203	1.781969	0.92060083

Table 3.17

$\alpha=2$ $\beta=1$ $\gamma=1$ $k=4$, $h=0.02$, $h'=0.02$			
B	L_0	L'_0	P_A
4.5	4.544199	2.545325	0.64097380
4.4	5.549904	2.661849	0.67584890
4.3	7.231904	2.788398	0.72172510
4.2	10.611459	2.925940	0.78386247
4.1	20.850109	3.075539	0.87145429

Table 3.18

$\alpha=2$ $\beta=1$ $\gamma=1$ $k=4$, $h=0.03$, $h'=0.03$			
B	L_0	L'_0	P_A
4.5	4.560001	3.840910	0.54279839
4.4	5.57267	4.072864	0.57774621
4.3	7.268473	4.326282	0.62687593
4.2	10.683753	4.603369	0.69887280
4.1	21.095354	4.906580	0.81129944

Table 3.19

$\alpha=2$ $\beta=1$ $\gamma=1$ $k=4$, $h=0.04$, $h'=0.04$			
B	L_0	L'_0	P_A
4.5	4.580497	5.505215	0.45415702
4.4	5.602752	5.894555	0.48730996
4.3	7.317762	6.321855	0.53650790
4.2	10.783370	6.791235	0.61357676
4.1	21.443075	7.307314	0.74583601

Table 3.20

$\alpha=2$ $\beta=1$ $\gamma=1$ $k=4$, $h=0.05$, $h'=0.05$			
B	L_0	L'_0	P_A
4.5	4.608503	7.557050	0.37881577
4.4	5.644982	8.149601	0.40921729
4.3	7.389117	8.802523	0.45635384
4.2	10.932836	9.522729	0.53446757
4.1	21.990833	10.318037	0.68064385

Table 3.21

$\alpha=1$ $\beta=2$ $\gamma=1$ $k=4$, $h=0.01$, $h'=0.01$			
B	L_0	L'_0	P_A
4.4	1.815961	0.843483	0.68283468
4.3	2.216361	0.820288	0.72987043
4.2	3.033228	0.797591	0.79179620
4.1	5.516596	0.778270	0.87636429
4.0	524286.12500	0.767201	0.99999850

Table 3.22

$\alpha=1$ $\beta=2$ $\gamma=1$ $k=4$, $h=0.02$, $h'=0.02$			
B	L_0	L'_0	P_A
4.4	1.815958	0.771691	0.70177900
4.3	2.216356	0.766948	0.74291980
4.2	3.033220	0.783666	0.79468435
4.1	5.516580	0.837654	0.86817389
4.0	524284.281	0.9536476	0.99999815

Table 3.23

$\alpha=1$ $\beta=2$ $\gamma=1$ $k=4$, $h=0.03$, $h'=0.03$			
B	L_0	L'_0	P_A
4.4	1.815955	0.784557	0.69830662
4.3	2.216352	0.839861	0.72519546
4.2	3.033213	0.958011	0.75997054
4.1	5.51656	1.177764	0.82406538
4.0	524282.437	1.558634	0.99999701

Table 3.24

$\alpha=1$ $\beta=2$ $\gamma=1$ $k=4$, $h=0.04$, $h'=0.04$			
B	L_0	L'_0	P_A
4.4	1.815952	0.882017	0.67308110
4.3	2.216348	1.038910	0.68085169
4.2	3.033206	1.320415	0.69670873
4.1	5.516548	1.798221	0.75416570
4.0	524280.6562	2.581485	0.99999505

Table 3.25

$\alpha=1$ $\beta=2$ $\gamma=1$ $k=4$, $h=0.05$, $h'=0.05$			
B	L_0	L'_0	P_A
4.4	1.815949	1.064007	0.63054740
4.3	2.216344	1.363980	0.61903429
4.2	3.033199	1.870674	0.61853134
4.1	5.516533	2.698657	0.67150402
4.0	508391.6562	4.021540	0.99999207

Table 3.26

$\alpha=1$ $\beta=3$ $\gamma=1$ $k=4$, $h=0.01$, $h'=0.01$			
B	L_0	L'_0	P_A
4.4	1.431011	1.756738	0.44890955
4.3	1.685115	2.139418	0.44060680
4.2	2.216362	2.752937	0.44601106
4.1	3.858267	3.757776	0.50659734
4.0	349525.37500	5.436113	0.99998444

Table 3.27

α =1 β = 3 γ = 1 k = 4 , h=0.02, h' = 0.02			
B	L_0	L_0'	P_A
4.4	1.431011	3.012907	0.32201567
4.3	1.685115	4.188890	0.28687670
4.2	2.216363	6.164184	0.26446521
4.1	3.858267	9.537398	0.28802359
4.0	349525.4062	15.378903	0.99995601

Table 3.28

α =1 β = 3 γ = 1 k = 4 , h=0.03, h' = 0.03			
B	L_0	L_0'	P_A
4.4	1.431011	4.768560	0.23082429
4.3	1.685115	7.148550	0.19076062
4.2	2.216363	11.23406	0.16478008
4.1	3.858268	18.339675	0.17381195
4.0	349525.406250	30.830390	0.99991178

IV. RESULTS AND CONCLUSIONS

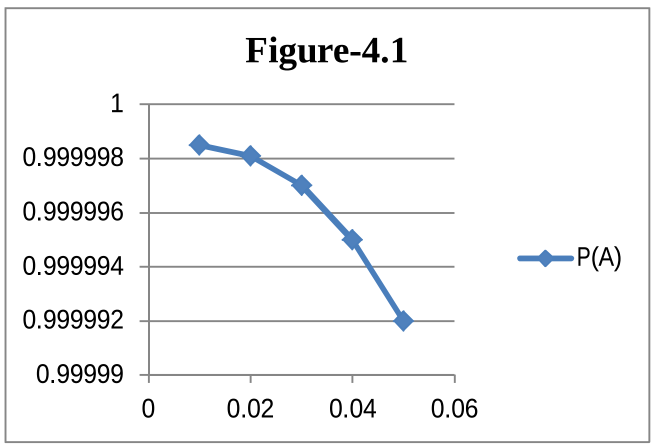
The hypothetical values of the parameters k, h, and h' are given at the top of each table, By determining optimum truncated point B, we can determine at which value P_A the probability of accepting an item is maximum, and by obtaining ARL's values, we can determine the acceptance zone and rejection zone. For random variable 'X', we have the values for the truncated point B, , and the values for the Type – C OC Curve, that is, P_A are given in columns I, II, III and IV respectively.

The following conclusions can be drawn from the above tables 3.1 to 3.28.

1) By observing the above tables, we see that h,h' increases and the related value of L_0 decreases. Therefore, the size of accepted and rejected zones is inversely related to L_0.
2) By observing the above tables, we notice that as h,h' increases, then related values of P_A decrease. P_A is inversely related to the sizes of accepted and rejected zones.
3) By observing the above table, we can see that as the value of parameter a of Frechet distribution changes, P_A changes along with it.
4) It is observed that the Table - 4.1 values of Maximum Probabilities increased as the decreased values of **h & h'**as shown below the Figure-4.1

TABLE 4.1

h& h'	**P_A**
0.01	0.9999985
0.02	0.9999981
0.03	0.999997
0.04	0.999995
0.05	0.999992



5) From the following Table No.4.2 we can observe the different relationships between the ARL's and Type-C OC Curves with the parameters of the CASP-CUSUM.

TABLE 4.2
CONSOLIDATED TABLE

B	α	β	γ	h	h'	P_A
4.1	1	1	1	0.01	0.01	0.90519261
4.1	1	1	1	0.02	0.02	0.89626336
4.1	1	1	1	0.03	0.03	0.88637465
4.1	1	1	1	0.04	0.04	0.87558847

4.1	1	1	1	0.05	0.05	0.86397045
4.0	*1*	*2*	*1*	*0.01*	*0.01*	*0.99999850*
4.0	1	2	1	0.02	0.02	0.99999815
4.0	1	2	1	0.03	0.03	0.99999701
4.0	1	2	1	0.04	0.04	0.99999505
4.0	1	2	1	0.05	0.05	0.99999207
4.1	1	1	2	0.01	0.01	0.88330459
4.1	1	1	2	0.02	0.02	0.85522657
4.1	1	1	2	0.03	0.03	0.82872247
4.1	1	1	2	0.04	0.04	0.80365979
4.1	1	1	2	0.05	0.05	0.77992045
4.1	2	1	1	0.01	0.01	0.92060083
4.1	2	1	1	0.02	0.02	0.87145429
4.1	2	1	1	0.03	0.03	0.81129944
4.1	2	1	1	0.04	0.04	0.74583601
4.1	2	1	1	0.05	0.05	0.68064385
4.0	1	2	1	0.02	0.02	0.99999815
4.0	1	2	1	0.03	0.03	0.99999701
4.0	1	2	1	0.04	0.04	0.99999505
4.0	1	2	1	0.05	0.05	0.99999207
4.0	1	3	1	0.01	0.01	0.99998444
4.0	1	3	1	0.02	0.02	0.99995601
4.0	1	3	1	0.03	0.03	0.99991178

$$\begin{bmatrix} B = 4.0 \\ \alpha = 1 \\ \beta = 2 \\ \gamma = 1 \\ h = 0.01 \\ h' = 0.01 \end{bmatrix}$$

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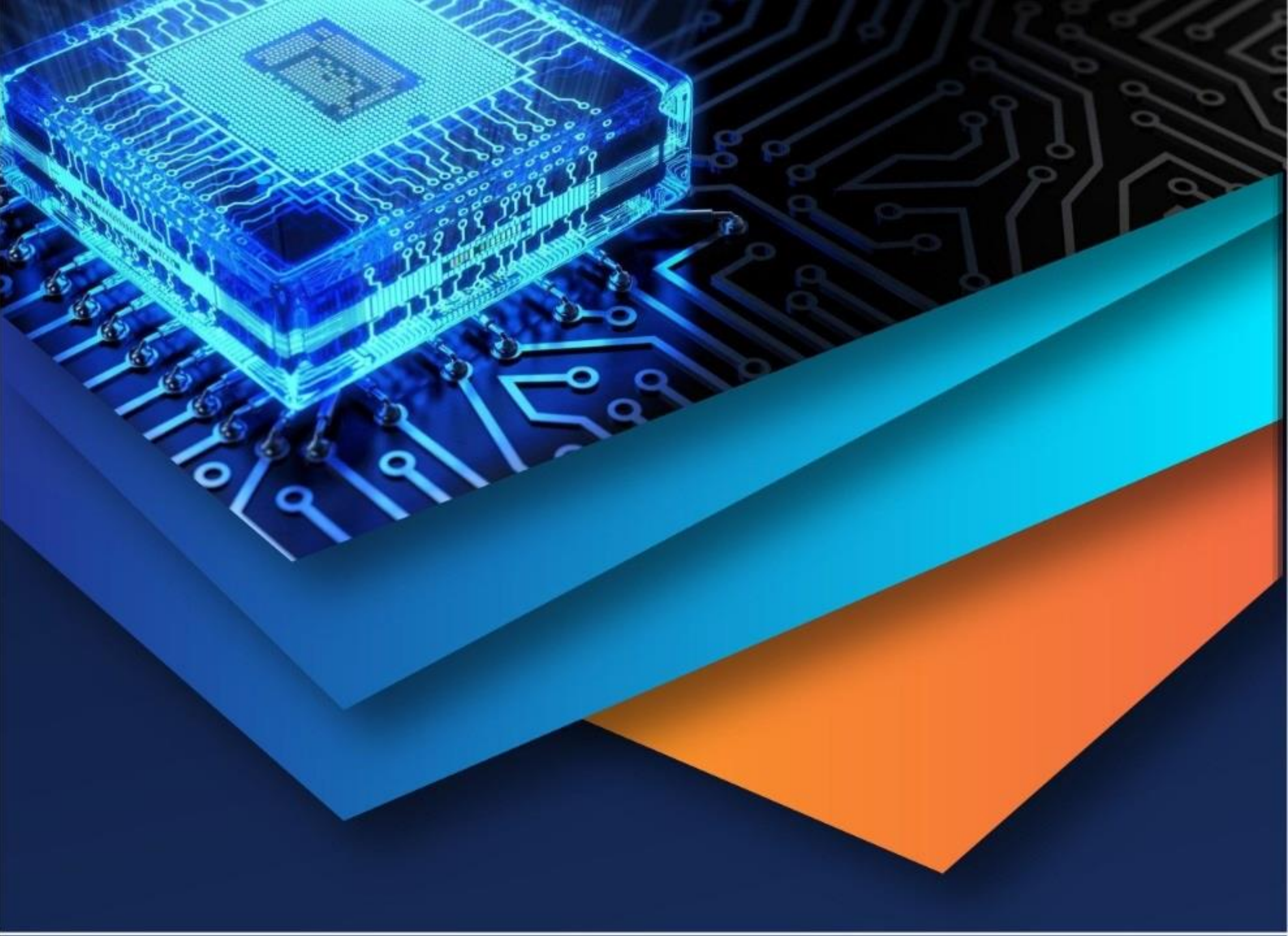

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