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Designing of a Low Cost GSR Acquisition System and Estimation of Stress Level from the Acquired Signal

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Abstract— Galvanic skin response provides us information about the electro-dermal activity i.e. the electrical characteristics of the skin. The electro-dermal activity or the skin conductance is an indication of psychological or physiological arousal which can give and indirect response of physiological stress. From Ohms law (V=IR) if we can keep the current constant and vary the resistance we can get a voltage output corresponding to the resistance ,hence a circuit was made so that the current can be made constant and the resistance was measured from the subject in respect to voltage output from the acquisition system. A best feed linear curve was made with some known resistance and hence a linear equation was developed for knowing unknown resistance of the skin and hence giving idea about the stress of the subject. Thus a system is designed for knowing the skin resistance and in terms giving an idea of the emotional stress of the subject who was taken into consideration.
Keywords— Electro-dermal response, Resistance ,Conductance ,Voltage –Resistance relation, Frequency to Voltage converter, Stress Level.

I. INTRODUCTION

The Galvanic Skin Response (GSR) is defined as a change in the electrical properties of the skin. The signal can be used for capturing the autonomic nerve responses as a parameter of the sweat gland function. The measurement is relatively simple, and has a good repeatability. Therefore the GSR measurement can be considered to be a simple and useful tool for examination of the autonomous nervous system function, and especially the peripheral sympathetic system.

Galvanic skin response (GSR), also known as electro-dermal response (EDR), psycho-galvanic reflex (PGR), or skin conductance response (SCR), is a method of measuring the electrical resistance of the skin.T he GSR is highly sensitive to emotions in some people. Fear, anger, startle response, orienting response and sexual feelings are all among the emotions which may produce similar GSR responses.

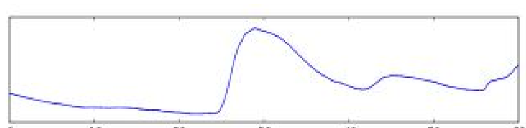

Fig 1: A sample GSR signal of 60 seconds.

A transient change in certain electrical properties of the skin, associated with the sweat gland activity and elicited by any stimulus that evokes an arousal or orienting response. Originally termed the psycho galvanic reflex, this phenomenon became known as the galvanic skin response. Electro-dermal response (EDR) has replaced galvanic skin response as the collective term.

The skin of a relaxed person has a low electrical conductance (high resistance), and the skin surface is some 40 mV negative with respect to interior tissues. Sweat gland activity changes these electrical properties by increasing skin conductance and by changing the balance of positive and negative ions in the secreted fluid.

Tonic skin conductance varies with psychological arousal, rising sharply when the subject awakens and rising further with activity, mental effort, or especially stress. Phasic skin conductance responses are wave like increases in skin conductance that begin 1–2 s after stimulus onset and peak within about 5 s. The amplitude of the skin conductance response varies with the subjective impact of the eliciting stimulus, which in turn varies with the intensity of the stimulus, its novelty or unexpectedness for the subject, and its meaning or signal value. Aroused subjects display spontaneous skin conductance responses, generated apparently by mental events or other internal stimuli; their frequency, like the tonic skin conductance level, increases with the level of arousal.

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Response of the skin to the passage of a small electric current. The ease with which the current flows between two points on the skin can be used to indicate stress. When a person is tense or emotional, the sweat glands become more active, increasing moisture on the skin; this allows the electric current to flow more readily. The response may also be used in relaxation training: information about the galvanic skin response is fed back aurally or visually to the subject who can, with practice, learn to increase or decrease sweating on the skin by learning to relax or tense muscles

II. PHYSIOLOGICAL BASIC AND DETECTION OF SKIN RESPONSE

The skin is a three-layered (epidermis, dermis, subdermis) adaptive organ which aids in the maintenance of the body's water balance and core temperature. These functions are carried out by blood vessels and eccrine sweat glands. The blood vessels constrict and dilate to deliver blood flow to the surface of the body for heat conservation or loss. The eccrine sweat glands function to cool the body by depositing moisture on the skin surface through ducts (in the dermis) and sweat pores (in the epidermis). The glands, which are located in the subdermis over most of the body, are about ten times denser on the palmar surface of the hands and soles of the feet.

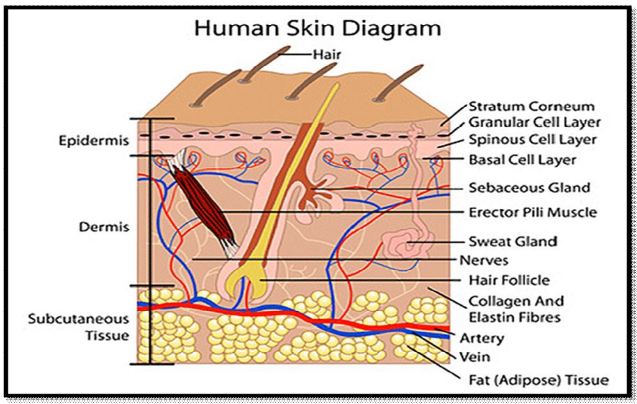

Fig 2: Human Skin

The most widely accepted model of skin conductance is the sweat circuit model proposed by Edelberg (1972). According to this model, phasic changes in skin conductance occur when the sweat ducts in the epidermis fill, and skin conductance recovers to tonic levels when the moisture is deposited on the skin or reabsorbed by the sweat glands. In Edelberg's model, the sweat ducts act as variable resistors; their resistance lowers (conductance increases) as they fill with sweat. The amplitude of the change in conductance depends on the amount of sweat delivered to the ducts and on the number of sweat glands which are activated. Sweat gland activation is a simple physiological survival mechanism, which is of interest in psychology because it is a neural response. This activation is controlled by the brain via the sympathetic division of the autonomic nervous system. Human sweat glands receive primarily signals from sympathetic cholinergic fibers that use the neurotransmitter, acetylcholine. This is an anomaly because most sympathetic fiber utilize nor-epinephrine.

The combined changes between electro-dermal resistance and electro-dermal potential make up electro-dermal activity. Galvanic skin resistance (GSR) was an older term that refers to the recorded electrical resistance between two electrodes when a very weak current is steadily passed between them. The electrodes are normally placed about an inch apart, and the resistance recorded varies according to the emotional state of the subject. Galvanic skin potential (GSP) refers to the voltage measured between two electrodes without any externally applied current. It is measured by connecting the electrodes to a voltage amplifier. Similarly, this voltage varies with the emotional state of the subject.

The Galvanic Skin Response (GSR) is one of several electro-dermal responses (EDRs). EDRs are changes in the electrical properties of a person's skin caused by an interaction between environmental events and the individual's psychological state. Human skin is a good conductor of electricity and when a weak electrical current is delivered to the skin, changes in the skin's conduction of that signal can be measured. The variable that is measured is either skin resistance or its reciprocal, skin conductance.

According to Ohm's Law, skin resistance (R) equals the voltage (V) applied between two electrodes on the skin divided by the current passed through the skin (I).

The law can be expressed as :**R=V/I**.

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III. CIRCUIT DESIGN AND METHODS

The circuit was developed part by part and tested individually to get the preferred result. The output of the individual part was measured by oscilloscope. Touch pads are used to make contact with the skin. It can be two small Aluminium sheets. When the touch pads are shorted with the middle and first fingers of the left hand (skin of left hand responds more to stress), current flows through it to the input of the signal amplifier. Touch pads can be of any type conducting plates such as Aluminium or copper plates having a dimension of 1x1cm

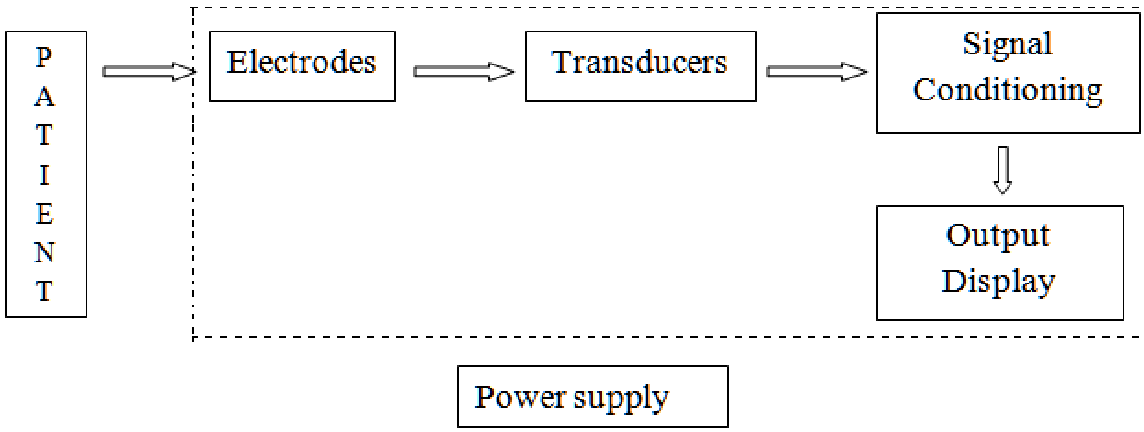

Fig 3: A Basic block diagram of acquisition system

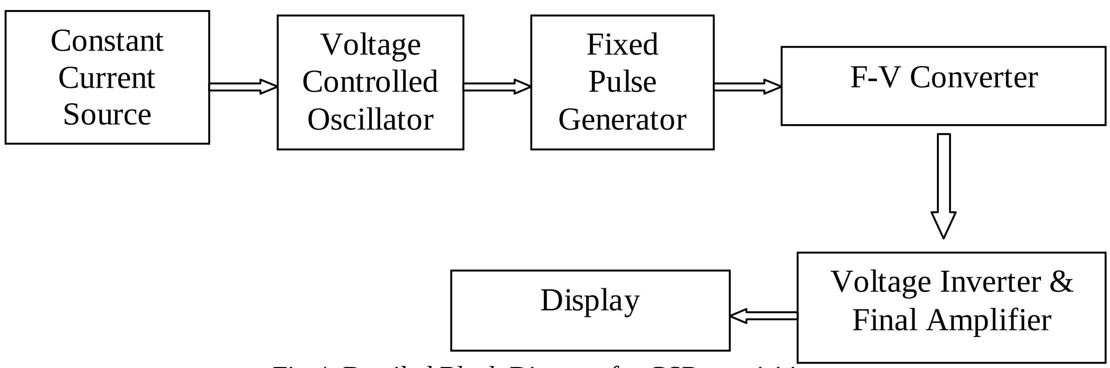

Fig 4: Detailed Block Diagram for GSR acquisition system

A. *Circuit design and methods*

1) *Electrodes:* Electrodes are used to pick up the input. In this project, Ag-AgCl non-invasive disc type two electrodes are used, one for Active and another one for Passive.
2) *Constant Current Source & Voltage Controlled Oscillator:* In order to convert the resistance into an equivalent voltage, a constant current source is required. Then this resulting voltage is again converted to frequency by using a Voltage Controlled Oscillator (VCO). A sinusoidal/triangular waveform is also to be generated as the output of the IC.
Integrated Circuit **XR-2206** is used for this purpose. The XR-2206 is a monolithic function generator integrated circuit capable of producing high quality **sine/triangle waveforms** of high-stability and accuracy. The output frequency of the VCO output is controlled by the external resistance and capacitance combinations. Here the capacitance is fixed and the resistance should be provided from the body. After the completion of this phase the output frequency (f) is inversely proportional to the body resistance(R),

$$R \propto 1/f$$

3) *Fixed Pulse Generator:* The VCO output provides sinusoidal/triangular waveform which is not suitable or further processing the signal, therefore, pulse wave form needs to be converted. The height and width of the pulse should be fixed for any frequency. Integrated circuit **NE555** is used for this purpose mentioned above. The NE555 timer acts as a monostable multivibrator.

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a) The VCO output is used as a trigger in this monostable multivibrator.
b) The output pulse width can be fixed by using the external the R and C combination.

4) *F-V Convertor:* Now this pulse output frequency is needed to convert into voltage, as the output is required in form of voltage. **LM331**was chosen to fulfil this specific requirement i.e proportional to voltage(V). As LM331 is from the family of voltage-to-frequency converters and is ideally suited for precision frequency-to-voltage conversion.

5) *Inverting & Final Amplifier:* As the resistance varies inversely to the frequency i.e

$$R \propto \frac{1}{f},$$

$$f \propto V.$$

Thus we can conclude that resistance(R) is inversely proportional to the voltage

$$R \propto \frac{1}{V}$$

So we need to make the resistance proportional to the voltage in order to get a linear reading So a inverting amplifier was used in order to get the desired output .Thus a LM741 Differential amplifier was used as non inverting amplifier so that the voltage gets inverted and the resistance varies as proportional to the voltage:

$$R \propto V$$

Emotional state of human beings is a physiological mechanism to prepare the body to face situations. Stress and other emotional states are controlled by the hypothalamus, a region in the brain and the hormones secreted by the Adrenal gland situated on the kidney. Sympathetic and Para sympathetic nervous systems are also involved. Adrenaline is the chief hormone from adrenal gland responsible for creating stress. It is called as 'emergency hormone' because it prepares the body to face emergency situations. Some emotional feelings like fear, anxiety etc stimulate hypothalamus which in turn increases adrenaline secretion. The effects of adrenaline includes, increase in heart beat, B.P, increase in breath rate, sweating and in more severe case fainting. All these are to prepare the body alert to face the situation. One important effect of adrenaline is increased blood flow to the skin. This is to remove excess heat from the body through sweating. Human skin has the property of electrical conductivity and offers resistance to current. That is why burning occurs in shocks. The resistance and conductivity are inversely proportional. That is when the resistance decreases, conductivity increases. Normal skin (in calm mood) has high resistance and low conductivity. When the blood flow to the skin increases in stress, blood vessels becomes leaky and water leaks out to form the sweat. This mechanism removes heat from the body through the evaporation of sweat. When this happens, the resistance of the skin decreases to remove water easily. The moist skin also increases electrical conductivity. This aspect is used in the circuit. That is, skin's resistance and conductivity are directly proportional to the emotional state.

IV. CIRCUIT DIAGRAM AND FABRICATION

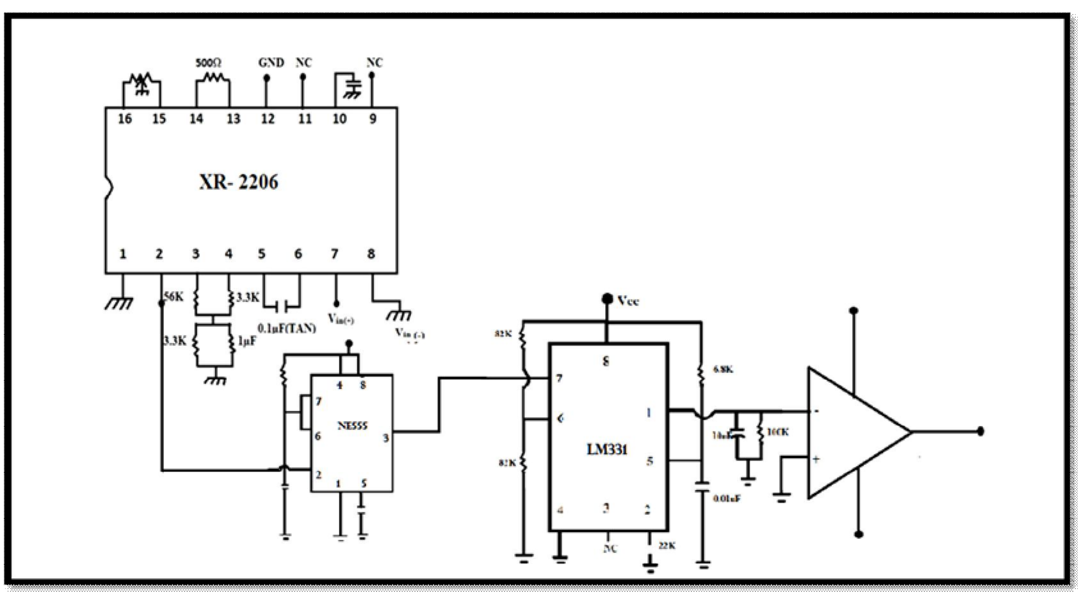

Fig 5:Circuit Diagram of GSR Acquisition System

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The circuit is based on the skin's electrical conductivity. The skin galvanic response depends on the resistance of the skin which varies depending on the stress level. In the fully relaxed state, skin offers around 2 Meg Ohm or more resistance which reduces to around 500 Kilo Ohms in the fully stressed condition. As a result of various physiological mechanisms during stress, blood flow to the skin increases and blood vessels becomes leakier. This increases sweating. As result, resistance of the skin reduces and it conducts more electricity. Thus the electrical conductivity is directly proportional to the stress level and skin resistance and electrical conductivity are inversely proportional.

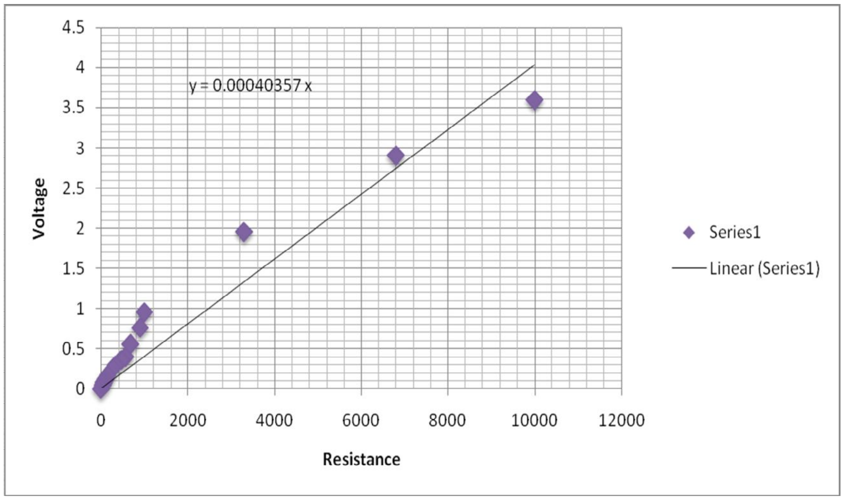
V. RESULTS AND DISCUSSION

The circuit fabricated and was tested . The voltage output was measure both from the inverting amplifier and from the F-V converter so as to derive a linear relationship between the voltage and the known resistance. Few resistance was taken into consideration and the corresponding voltage was measured keeping the capacitor fixed at 0.01µF

RESISTANCE ® (In Ω)	$F_{OUT} = 1/RC$ (THEORITICAL)	V_{OUT} (In V)	V_{OUT}(In V) (INVERTED)
47K	2127.66 Hz	1.726	0.0474
56K	1785.71 Hz	1.521	0.0609
68K	1470.59 Hz	1.290	0.081
75K	1333.33 Hz	1.180	0.092
100K	1000 Hz	0.938	0.1162
150K	666.67 Hz	0.655	0.1645
330K	303.03 Hz	0.598	0.2885
470K	212.76 Hz	0.517	0.3583
560K	178.57 Hz	0.447	0.3953
680K	147.06 Hz	0.434	0.5566
900K	111.11 Hz	0.371	0.7586
1M	100 Hz	0.355	0.9542
3.3M	30.30 Hz	0.277	1.95
6.8M	14.71 Hz	0.220	2.9
10M	10 Hz	0.193	3.59

Table 1: Corresponding voltage according to some known resistance

From the observed result a best feed graph was plotted taking resistance and the corresponding voltage and an equation of voltage in terms of resistance was calculated .



Graph 1: Résistance vs Voltage

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Hence a linear equation is derived from the observed result:

Voltage= 0.00040357 x Resistance

Thus if we can measure the voltage by placing the electrodes on the skin an estimation of resistance can be easily made ,as discussed earlier we can estimate a level of stress from the resistance .If the resistance is on the higher end then the subject under test is relaxed and if the resistance of the subject under test is low then the subject is under stress.

VI. CONCLUSION

The research provides an economic way of measuring the GSR of a subject/patient, and in terms estimating the stress level of the subject. With the increasing number of reported hypertension cases every year GSR test can provide a handy option to measure the stress level and hence going for a much quicker treatment. The circuit made is ran by a battery hence eliminating chances of shock hazard. The circuit for measuring the Galvanic Skin response actually measures electro-dermal responses which are measured in studies of emotion and stress, conditioning, habituation, and cognitive processing, that is, when it is desired to assess the differential or changing impact of a series of stimuli. It is a useful add on device in Lie detection, Polygraphy, Biofeedback monitoring etc.

VII. ACKNOWLEDGMENT

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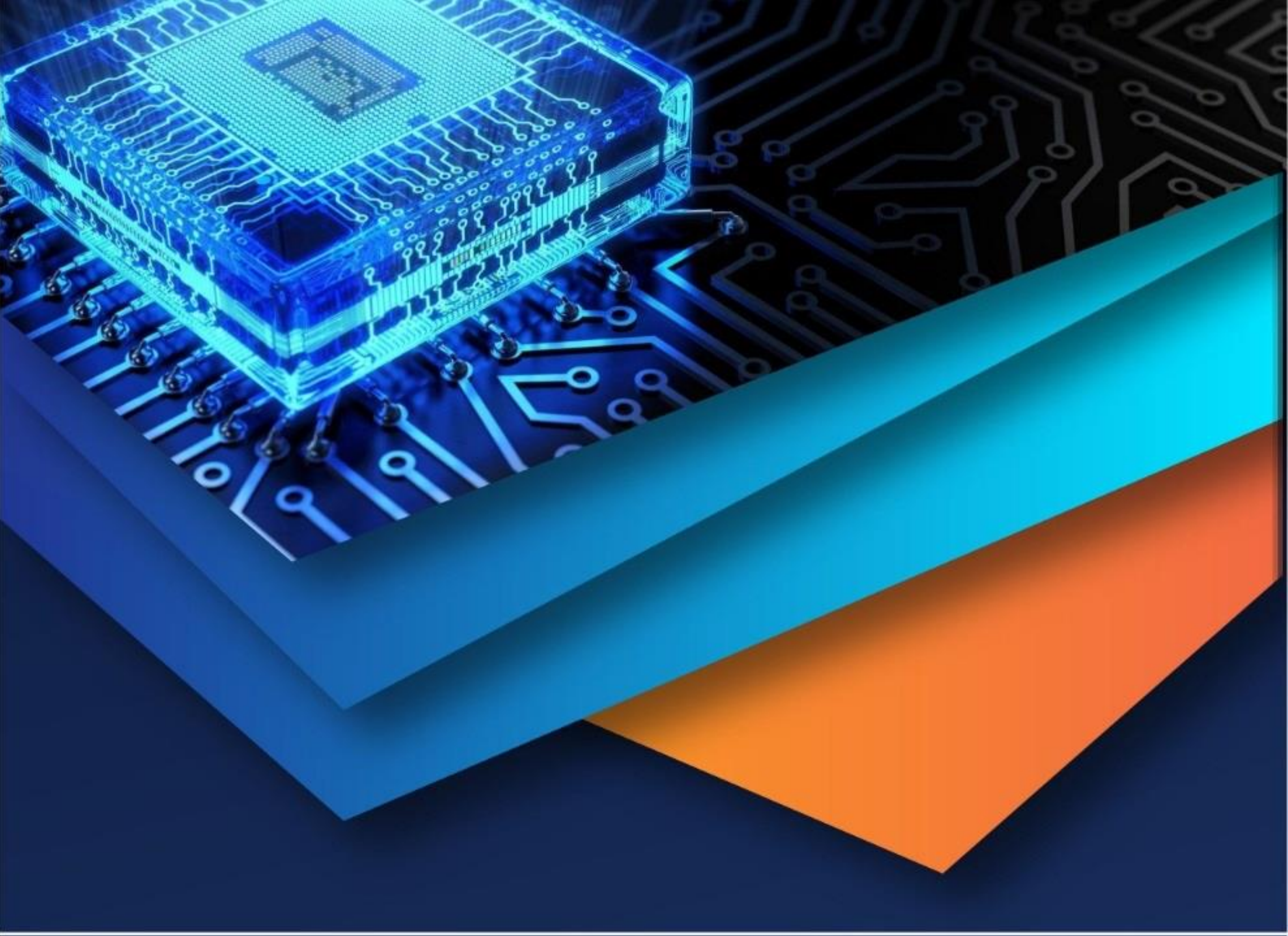

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