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Design and Development of a Compact Real Time ECG Device

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Abstract: Arrhythmia is the irregularity in normal heart rhythm which may lead to cardiovascular diseases like heart attack, blood pressure and stroke. Cardiac arrhythmia occurs in up to 86% of patients during anesthesia and surgery. So it is considerably important to detect these arrhythmia. In present work, Ventricular Tachycardia (VT), Atrial Fibrillation (AF), Left Bundle Branch Block (LBBB) and Right Bundle Branch Block (RBBB) have been displayed on CRO from the ECG device. The device is made compact by the use of surface mount device (SMD) technology. The developed device consists of hardware design with AD8232 for ECG extraction, with a gain of 100. Microcontroller to convert analog signal from AD8232 to digital form. Microcontroller is programmed using embedded C language in Atmel studio-7.0 version for ADC (Analog to Digital conversion) conversion, GPIO (General Purpose Input Output) and wireless Bluetooth transmission through UART communication. Bluetooth is used to transfer ECG data into the PC. The arrhythmia conditions were given from the ECG simulator to the developed device. The output was tapped from the developed ECG board and displayed on the CRO. The device has been tested for more than 20 arrhythmia conditions and it was able to display all the conditions on the CRO.
Keywords: Cardiac Arrhythmias, UART communication, Ventricular Tachycardia (VT), Atrial Fibrillation (AF), Bundle Branch Block.

I. INTRODUCTION

Arrhythmia is the irregular heart beat which may cause cardiovascular diseases like heart attack, blood pressure and stroke, these are the leading cause of death worldwide. According to 2015 survey from world health organization (WHO) 3.7 million deaths in south-east Asian region are due to these cardiovascular diseases and one third of these deaths are among people whose age is less than 70 years. Cardiovascular diseases is taking life of around 17.5 million people globally [1]. Cardiac arrhythmias during anesthesia and surgery occur in up to 86% of patients [4]. Many arrhythmia conditions are of clinical significance and therefore their detection is of considerable importance. Arrhythmia can be detected by Electrocardiogram (ECG) recordings. ECG has the bandwidth in the range of 0.05Hz to 150Hz. Cardiac Arrhythmias which are considering in this paper is Ventricular Tachycardia (VT), Atrial Fibrillation (AF), Left Bundle Branch Block (LBBB) and Right Bundle Branch Block (RBBB). Ventricular Tachycardia (VT) condition occurs when the beats/min is 100-250 which may establish heart disease or may occur prior to heart attack. Atrial Fibrillation (AF) is the rapid heart rate that can increase the risk of stroke and heart attack [3]. The bundle branch blocks have prolonged QRS duration (0.12sec or more) and are associated with hypertension, valvular heart disease, heart failure and cardiomyopathy. The early detection of these arrhythmia may reduce the risk of heart attack or stroke and save the life of the patient. The traditional way to detect arrhythmia is by take ECG recordings from 12 lead electrode system in which 6 are chest leads and the other 4 are limb leads, these are mainly used for bedside monitoring systems. 12 lead electrode systems have some limitations like skin preparation before connecting electrode and more number of wires which may lead to inconvenience to patients. The portable 12 lead data acquisition and monitoring devices which are made of SMD components are of size 12×16 cm in width and length respectively [6]. Data acquisition for 12 lead ECG was done by elastic belt on the chest region and by placing limb straps on the four limbs [2]. Later, it is reported 12 lead electrodes reduced to 4 lead electrodes, in which arrhythmia analysis was done by 4 lead electrodes using wavelet transform [5]. Long term ECG monitoring devices used zlink for wireless transmission of ECG data to monitoring center [7-8]. For ambulatory cardiac monitoring, clip on wireless microwave sensors was designed which measured motion of heart but not electrical activity of heart [9]. There is need for ambulatory monitoring. The applications for these technologies include elder care, patient monitoring, sports/fitness training, emergency response, and long-term monitoring of various chronic health conditions. Portability, low-power (for battery powered use), and relatively small size/weight are the basic system requirements for these applications [10]. In this paper arrhythmia detection is done by using single lead i.e., lead II position, and designed the device which is real time, portable and relatively small with dimensions of 35×35 mm length and width respectively. The device also consists of the Bluetooth module which helps in the wireless transmission of data to the PC.

System Specification

Sampling frequency	250Hz
ADC resolution	12 bit
Gain	100
Cutoff frequency	0.5Hz – 40Hz
Operating voltage	3.3V

II. DESIGN AND IMPLEMENTATION

The system design consists two parts, hardware and software design. The hardware design consists of AD8232 analog front end, microcontroller, Bluetooth module and power section. The hardware design block diagram is shown in the fig. 1.

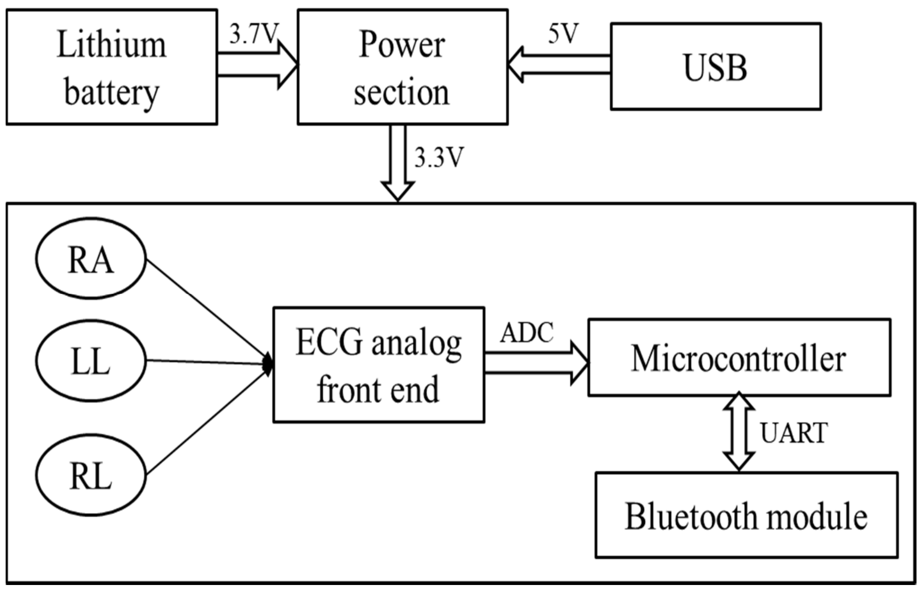

Fig 1: Block diagram of hardware design

The software design includes programing microcontroller for GPIO (General Purposes Input and Output) configuration and ADC (analog to digital conversion) conversion. Serial port UART communication is used for communication between microcontroller and Bluetooth module HC-05.

A. Hardware Design

The hardware design include ECG analog front end and microcontroller. The ECG analog front end consists of AD8232 IC, it is fully integrated with instrumentation amplifier, operational amplifier and the right leg drive amplifier. The AD8232 extracts, amplify and filter the small biopotential signal which is taken in the noisy conditions like motion artifacts and improper placement of electrodes. AD8232 is implemented with two pole high pass and low pass filter to remove motion artifacts and additional noise respectively. The cut off frequency is between 0.5Hz and 40Hz. In addition, it has the fast restore circuit and lead off detection. Bipolar lead II was chosen by electrodes connected to the right arm and left leg. Right leg is taken as the reference electrode. This is the most useful lead for detecting cardiac arrhythmias as it lies close to the cardiac axis (the overall direction of electrical movement). The ECG analog front end will extract the ECG signal from subject, amplify it and finally gives the filtered analog signal. The analog signal obtained has to be converted to digital signal so that the wireless transmission of data can be done through Bluetooth module for arrhythmia detection. The analog signal is converted to digital with a sampling rate of 250Hz by SAMD21 microcontroller which has 12 bit ADC resolution. Serial port UART communication is used for communication between microcontroller and Bluetooth module HC-05. The converted signal is transmitted through Bluetooth module and then displayed on PC for arrhythmia detection. The device consist of an audio jack connecting one end of leads and the other end it connected to the ECG simulator in lead II position (right arm, left leg and right leg). The ECG device is powered either by micro USB or by lithium batteries. 5V and 3.7V is received from micro USB and battery respectively. The whole device is powered by a single supply of 3.3V, so voltage regulator is used to convert the incoming voltage to 3.3V.

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B. Software Design

The software design includes programming microcontroller using Embedded C language in Atmel studio 7 for GPIO configuration and ADC conversion.

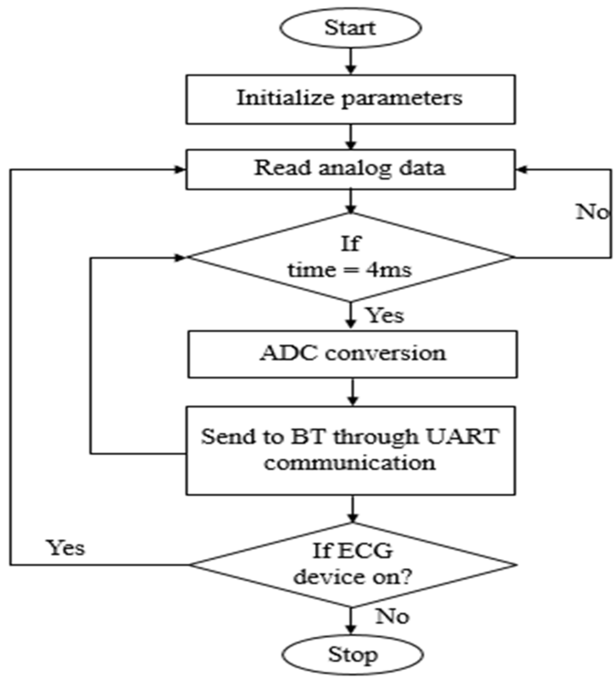

Fig 2: Flowchart for embedded software of ECG device

The AD8232 has the shutdown low pin for shutdown control input and hence programming was done for GPIO pin of microcontroller to make the shutdown pin high so that ECG can be recorded on CRO display. The microcontroller is programmed for ADC conversion and the converted data is transferred to PC through Bluetooth, the flowchart for this is shown in fig 2. First the baudrate is set then the transmitter (TX) and the receiver (RX) pins are configure for UART communication. Initialization of analog pin is done for signal ended conversion by configuring positive pin as analog pin of microcontroller and the negative pin as ground. The ADC is enabled and it starts converting the data at desired sampling frequency. HC-05 is the Bluetooth (BT) module used and it has a range of 9 meters.

III. RESULTS AND DISCUSSION

Designed real time ECG device is shown in fig. 3 is of dimension 35×35mm on length and width respectively. The ECG electrodes were connected to the ECG simulator in lead II position (right arm, left leg and right leg). Analog data from AD8232 is converted to digital by SAMD21 microcontroller. The converted signal is transmitted through Bluetooth module and then displayed on PC.

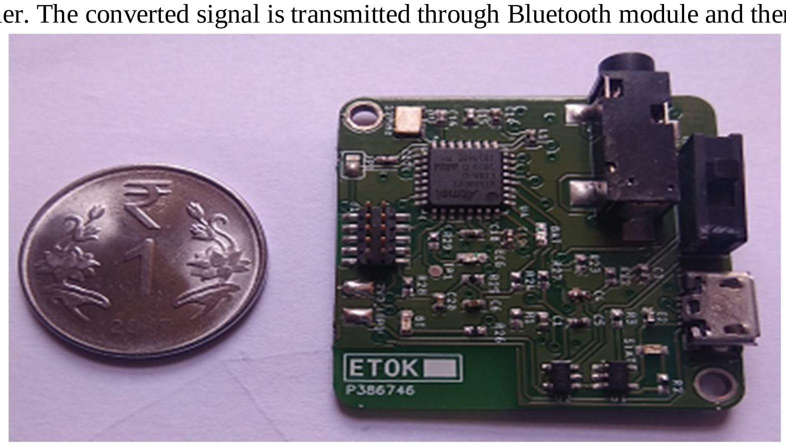

Fig 3: Real time ECG device

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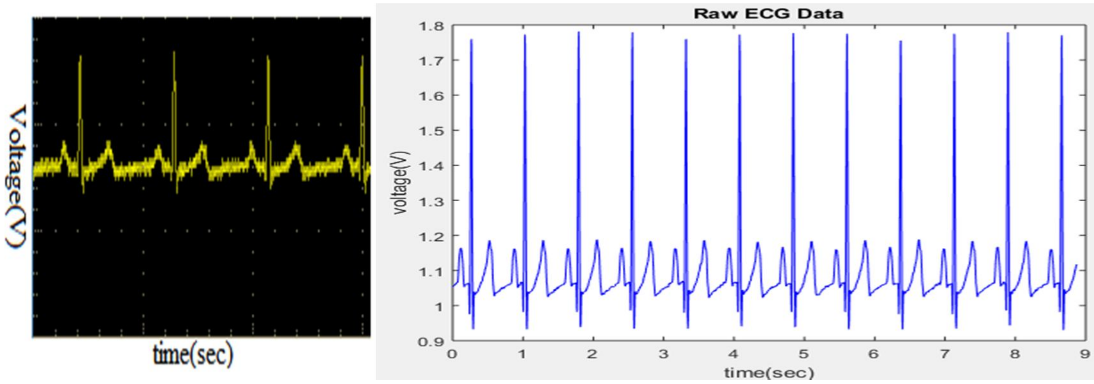
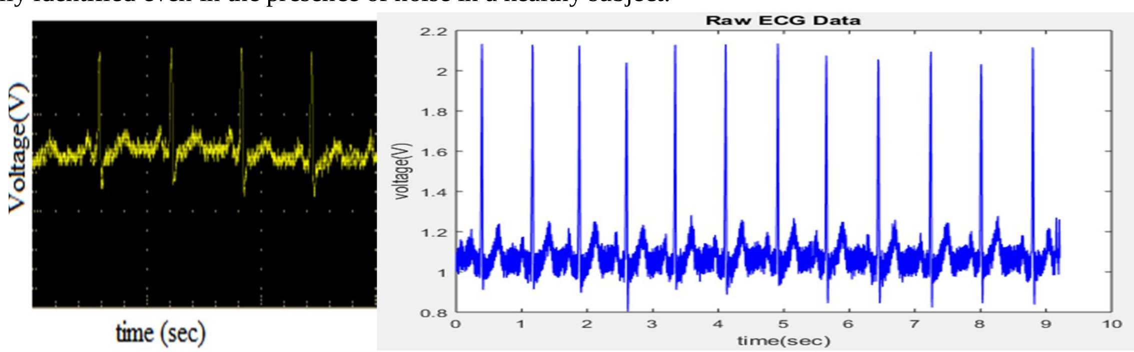
The data collected in PC is plotted using MATLAB. Each data was collected for around 10sec and the fig. 4(a) shows the 3sec data of normal ECG which was given from the ECG simulator and it is displayed on the CRO. Fig. 4(b) shows the 10sec data plotted using MATLAB in which all P, Q, R, S, & T wave is distinguishable.



(a) (b)

Fig 4: Normal ECG given from simulator

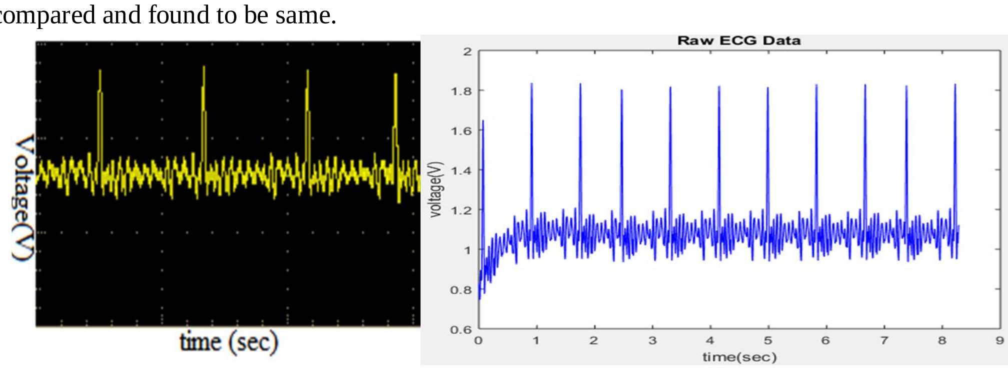
The waveform acquired from a healthy subject is shown in fig. 5(a) and the respective MATLAB plot is shown in fig. 5(b). P, Q, R, S & T is easily identified even in the presence of noise in a healthy subject.



(a) (b)

Fig 5: Normal ECG from healthy subject

The fig. 6(a)-9(a) shows four different arrhythmia conditions which were given through ECG simulator and screenshot of CRO display were taken. The fig. 6(b)-9(b) shows the image of arrhythmia conditions plotted in MATLAB. Other than these four arrhythmia conditions it is tested on more than 20 arrhythmia and the output was plotted on the CRO. The results from CRO display and MATLAB is compared and found to be same.



(a) (b)

Fig 6: Atrial fibrillation

Ventricular Tachycardia (VT) condition occurs when the beats/min is 100-250 which may establish heart disease or may occur prior to heart attack. For 8sec fig. 7(b) is showing 20 beats so it is 150 beats/min.

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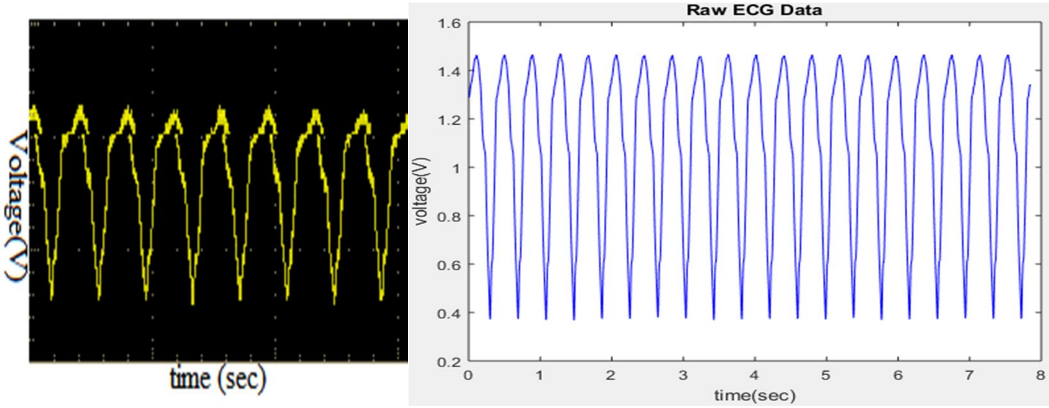
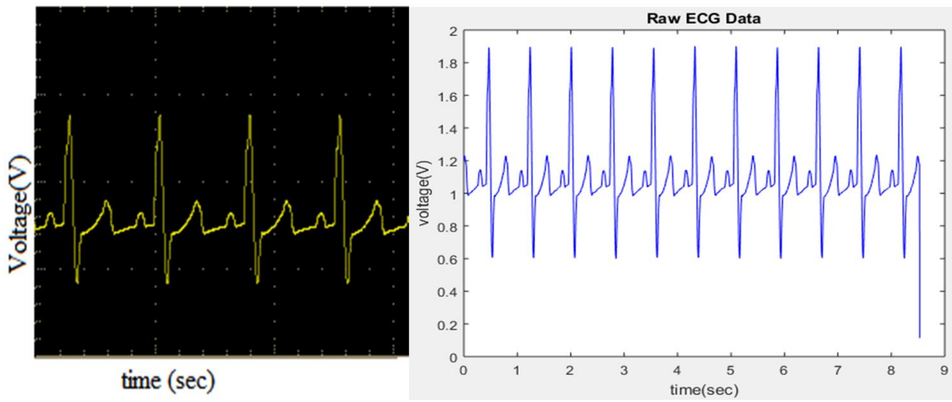


(a) (b)

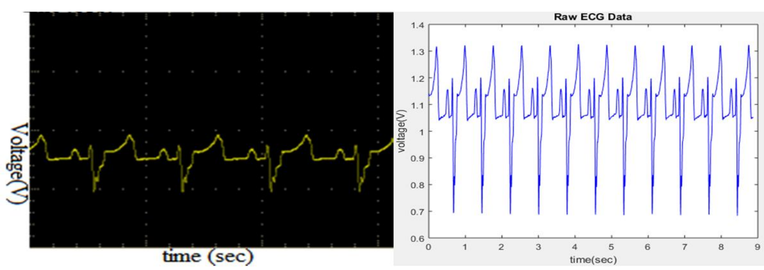
Fig 7: Ventricular Tachycardia

The bundle branch blocks have prolonged QRS duration (0.12sec or more) as observed in fig. 8 and 9 and are associated with hypertension, valvular heart disease, heart failure and cardiomyopathy.



(a) (b)

Fig 8: Left Bundle Branch Block



(a) (b)

Fig 9: Right Bundle Branch Block

IV. CONCLUSION AND FUTURE WORK

Four different type of arrhythmia is identified by using the real time ECG device. The AD8232 is used for ECG extraction, the extracted analog signal is converted to digital by SAMD21 microcontroller. The digital data is transmitted to PC by HC-05 Bluetooth module, and plotted using MATLAB. The main purpose of developing this device is to acquire ECG signal and to find out arrhythmia condition using single lead position. The results from CRO display and MATLAB is compared and found to be same. The ECG device is tested for 20 different arrhythmia conditions by using ECG simulator and results obtained is found to be same. Further this device can be made as wearable by adding the button electrode in the PCB design. It can be improved for real time arrhythmia detection and power consumption can be reduced by adding shutdown mode when device is not in use.

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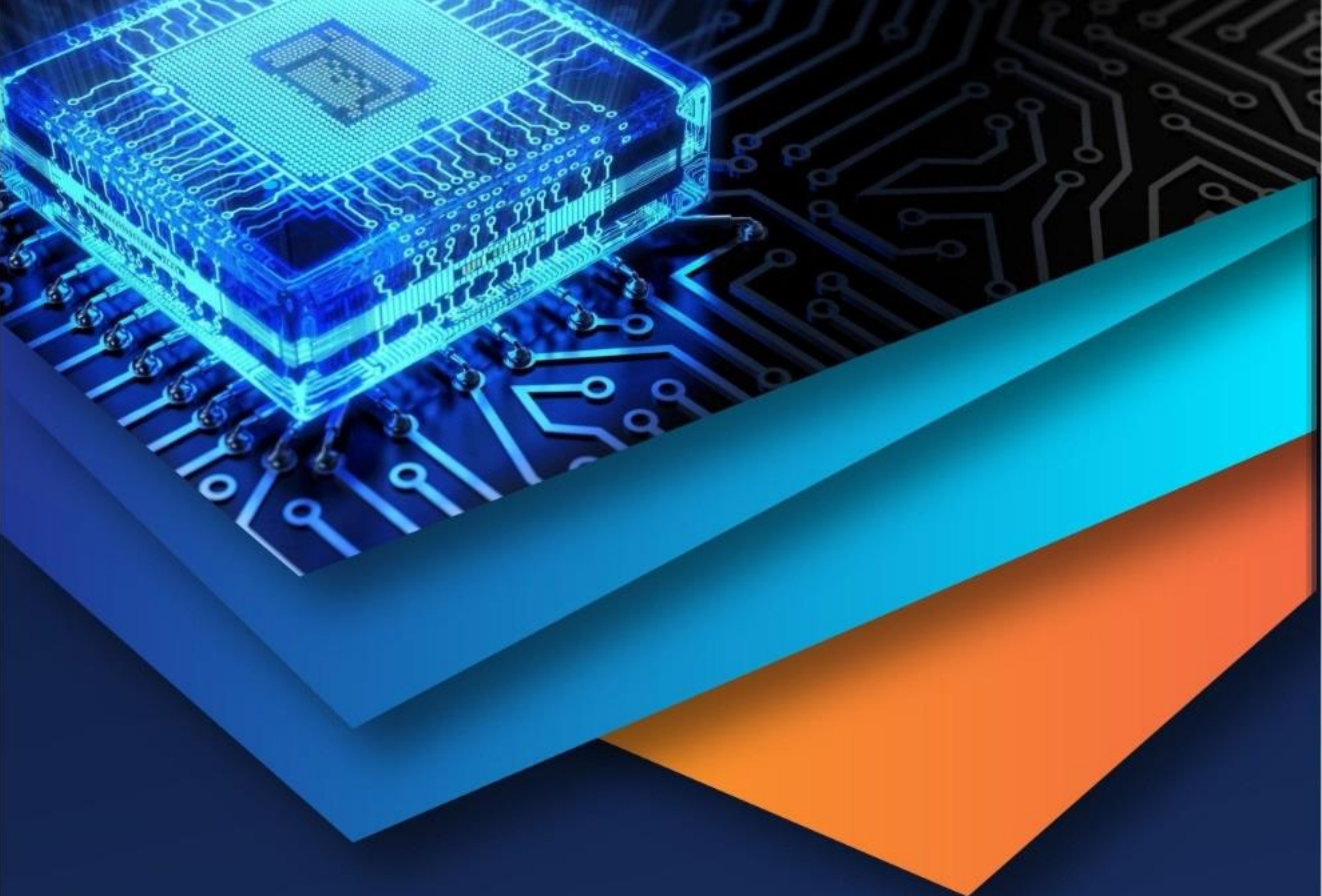

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