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腦電圖（EEG）信號擷取系統設計

Electroencephalography (EEG) Signal Acquisition System Design

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Abstract in Chinese

(摘要)

為了解腦電活動 ，腦電（EEG）信號記錄了頭皮間所發出的微弱信號，也提供大腦動態活動表現的波形。本研究致力於電路設計和設備開發，用以實現所需之腦波電（EEG）信號擷取系統。採集信號需要一定強度的幅度， 通常以毫伏為單位表示 (millivolts)。一般而言， 數據擷取過程含了三個階段：1）原始 EEG 信號的擷取可以通過有源電極和具有較小增益的儀表放大器完成; 2）使用帶通濾波器和帶斥濾波器改善信號質量; 3）將 EEG 信號透過內嵌於微控制器的類比-數位轉換器（ADC）來轉換成數位碼。數位碼可再儲存於記憶體中， 並由藍牙模組進一步傳輸。實驗結果說明該系統可以有效地實現 EEG 信號的擷取和存儲。設計的印刷電路板（PCB）尺寸小於 5×5 cm^2。所提出之系統將有益於所有參與使用 EEG 進行臨床診斷和監測人員， 腦機介面開發。

關鍵詞：腦電圖（EEG）、腦計算機接口（BCI）、OPAMP、類比數位轉換器（ADC）、印刷電路板（PCB）、放大器和電極

Abstract in English

Electroencephalography (EEG) signals are recorded for knowing the electrical activity of brain from the scalp, and the recorded waveform provides acquits into the dynamic aspects of brain activity. This study incorporates the circuit design and device development to achieve the Electroencephalography (EEG) signal acquisition front-end circuit design for future Brain Computer Interface (BCI) applications. The amplitude of acquired signals should be strong enough and is usually expressed in unit of millivolts. The data acquisition procedure consists three stages: 1) The acquisition of original EEG signal can be done by the active electrode and an instrumentation amplifier with a smaller gain; 2) Improves the signal quality by using band-pass filter and band-stop filter; 3) Those EEG signals were converted into the digital code through the analog-to-digital converter (ADC) that was integrated to a micro-controller. The digital code is stored into an embedded memory, and is further transmitted via Bluetooth module. The experimental results show that the system could implement the acquisition and storage of the EEG signals efficiently. The size of printed circuit board (PCB) for the proposed deign is smaller than $5 \times 5\ cm^2$. This system would be benefit to all involve in the use of EEG for clinical diagnosis and monitoring, or even for brain computer interface.

Keywords: Electroencephalography (EEG), Brain Computer Interface (BCI), OPAMP, Analog-to-Digital Converter (ADC), Printed Circuit Board (PCB), Amplifier and Electrodes

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CHAPTER-01

INTRODUCTION
AND
BASIC DISCUSSION

1.1. Introduction:

The brain is a largest and noteworthy complex organ that controls all function of the body, interprets information from the inside and outside through embodies the mind and soul. Intelligence, creativity, emotion, memory and many more things are governed by the brain. The brain functions can be monitored through observing the electrical signal waves that generate in the neurons. Depending on the various location of the brain there are five major brain waves distinguished by their different frequency ranges. These frequency bands are categorized from low to high and can be recognized as Delta (δ) Theta (θ), Alpha (α), Beta (β), and Gamma (γ) respectively. The signals are called Electroencephalogram (non-invasive technology for recording continuous neurological data at natural environments) can be extracted by using electrodes and can be viewed using voltmeter, oscilloscope or on computer screen and recorded the phenomenon of electroencephalography. It is a relatively simple and completely harmless method for analyzing the brain activity. It detects pattern of brain motions and translates them into commands given as an input for the external device. These signals are roughly ranged from 0.1 Hz to more than 100 Hz and measured with electrodes placed on the scalp. In the traditional design, Driven Right Leg (DRL) circuit is operated to reject the common mode noise by injecting amplified noise to cancel the interference. In this study, the DRL circuit design constrains modularity and scalability for EEG channels due to interdependency of channels, as the number of channels of the system needs to be fixed at the design time for optimal operation. In fact, the circuit might increase differential mode noise if not properly matched. We achieved the independent channel design of EEG device with adding the DRL circuit to overcome this problem. The amplification subsystem is first discussed and this consists of a very high common mode rejection ratio (CMRR) instrumentation amplifier and a second gain stage. Next 60 Hz line noise is reduced by cascading a notch filter. After that, a band-pass filter is used for the desired frequency band for brain wave.

Since Hans Berger, German psychiatrist succeeded in recording the first human electroencephalogram and known as the inventor of electroencephalography (EEG) in 1924 [1], a lot of research work on it has been done by various researchers around the world. Increasing number of research activities and different types of studies in brain-computer interface systems (BCI) [2] and show the potential in this research area. Hereafter, an amplification module is required to amplify these small potentials to an acceptable level. In addition, due to the small amplitude, these signals are very susceptible to any interference introduced through body, amplifier, measurement tools and magnetically induction as described in it. To design a practical BCI product, the following topics need to be addressed: convenient and comfortable to use; stable system performance; low-cost hardware and should be sustainable. Most of the EEG signal acquisition equipment for the BCI are completed by the commercial EEG devices, the recording hardware with a large amount of channels is affordable. In this paper, we will introduce the EEG recording circuit design and simulation, signal characteristics and the overall framework of EEG read-out circuit. Then, we illustrate the details of the circuit design.

1.2. EEG Signal Characteristics:

An EEG signal generates from the currents flow between brain and cells in the cerebral cortex region of brain. When neurons are actives current flow between dendrites due to their synaptic excitation. The current generates a magnetic field and secondary electric field. The magnetic field is measurable by using electromyogram machines, and the electric field is measured by EEG system through scalp electrode. For obtaining basic brain patterns of individuals, subjects are instructed to close eyes and keep relaxation. Brainwave patterns form wave shapes that are commonly sinusoidal. Usually, they are measured from peak to peak and normally range from 5~200uV in amplitude.

In power spectrum contribution of sine waves with different frequencies are visible. Usually we can obtain the electrical activity above mentioned through electrodes placed on the scalp. Based on different frequency bands (0.1~100Hz), EEG signals can be categorized into 5 specific categories of brain activity as shown in Fig. 1.1, which have been commonly discussed in EEG literature: Delta, Theta, Alpha and Beta waves as shown in figure-1.1 below:

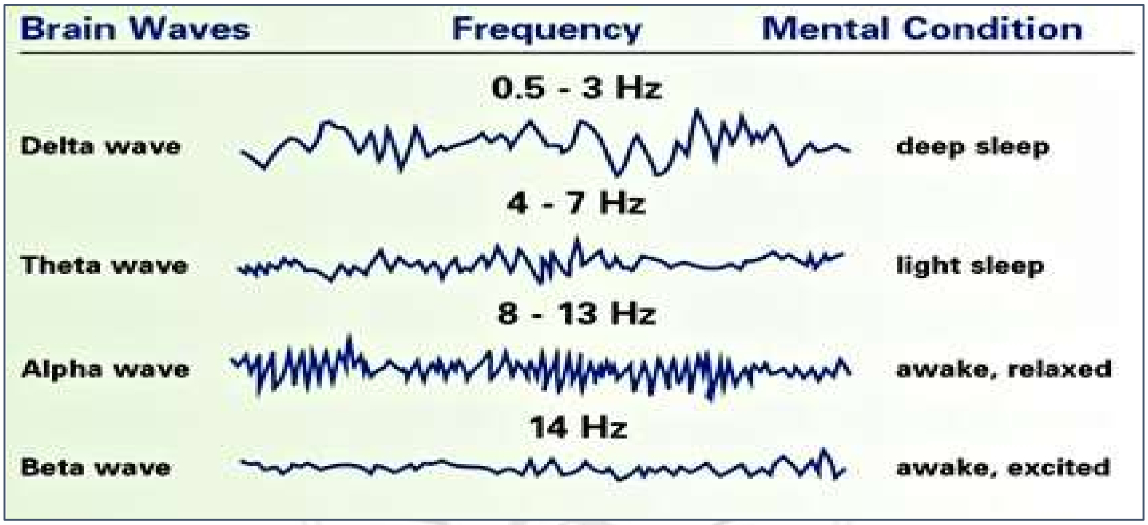


Figure-1.1: Classification of brain wave signals [3].

EEG is sensitive to a continuum of states ranging from stress state, alertness to resting state, hypnosis, and sleep. During normal state of wakefulness with open eyes beta waves are dominant. In relaxation or drowsiness alpha activity rises and if sleep appears power of lower frequency bands increase. Brain rhythms can be easily recognized by visual inspection of the EEG signal hence many neurological disorders can be easily identified. Various regions of the brain do not emit the same brain wave frequency simultaneously. An EEG signal between electrodes placed on the scalp consists of many waves with different characteristics. A large amount of data received from even one single EEG recording presents a difficulty for interpretation. The amplitude and frequency of these signals vary with human state, age, health etc.

1.3. Noise Cancellation Process:

The human head consists of various layers including the brain, skull, scalp and other thin layers in between. The level of attenuation due to skull is approximately hundred times greater than that of the soft tissues. While recording EEG signals internal and external noise can be increase while EEG signal recorded from scalp. Although, only a large number of active neurons can generate potential recordable signal. These signals have to be amplified for further processing. An EEG signal normally has a typical amplitude in range of 5~200uV. However, to reduced noise we will follow the steps of motion artifact and its equations.

1.3.1. Motion artifact

Motion artifact [4] is seen as the most common artifact in bio-signal measurement. It refers to the half-cell potential (electrode DC offset) difference which appears across the electrodes, whereas the half-cell potential is produced by a chemical reaction that occurs at the electrolyte-electrode interface. Thus, the root cause of the motion artifact is the electrolyte-electrode interface. However, the electrolyte electrode interface is inevitable, as long as we are using electrode to obtain EEG signal. So, only one way we can do is to choose an electrode with very low half-cell potential [5]. In this study, the applied electrodes are silver/silver chloride (Ag/AgCI) because of its very low half-cell potential of approximate 220mV.

1.3.2. Power Line Interface

Power line interference [6] is a significant source of noise. The power lights and the computer used to monitor the EEG can produce the power line interference. More specifically, this noise imposes serious impact on the raw EEG signal in magnetic and electric form. With respect to the power line noise arising from the magnetic field, we used the electrode line in twisted-pair form to reduce the loop surface area which is made of electrodes lead wires, human body and pre-amplifier.

1.4. Brain Computer Interface:

A Brain Computer Interface (BCI) as shown in Fig. 1-2 is a system that acquires and analyzes neural signals through some steps translates neuronal information into commands capable of controlling external software or hardware such as a computer to achieve the goal of creating a communication channel directly between the brain and the computer. Brain computer interface is a communication system that recognizes user's command only from his or her brainwaves and reacts according to them. Such a channel potentially has multiple uses. Therefore, Mr. Jonathan Wolpaw, doctors New York State Department of Health, proposed a brain-computer interface system consisting of three elements: measuring signal acquisition, extracting feature extraction, and converting into a translation algorithm. As shown in the system block diagram [7]. In some cases, it is possible to distinguish persons only according to their typical brain activity. For example, subjects who regard themselves as rational types or as holistic or intuitive types may demonstrate certain higher activity in their frontal left and frontal right hemisphere respectively.

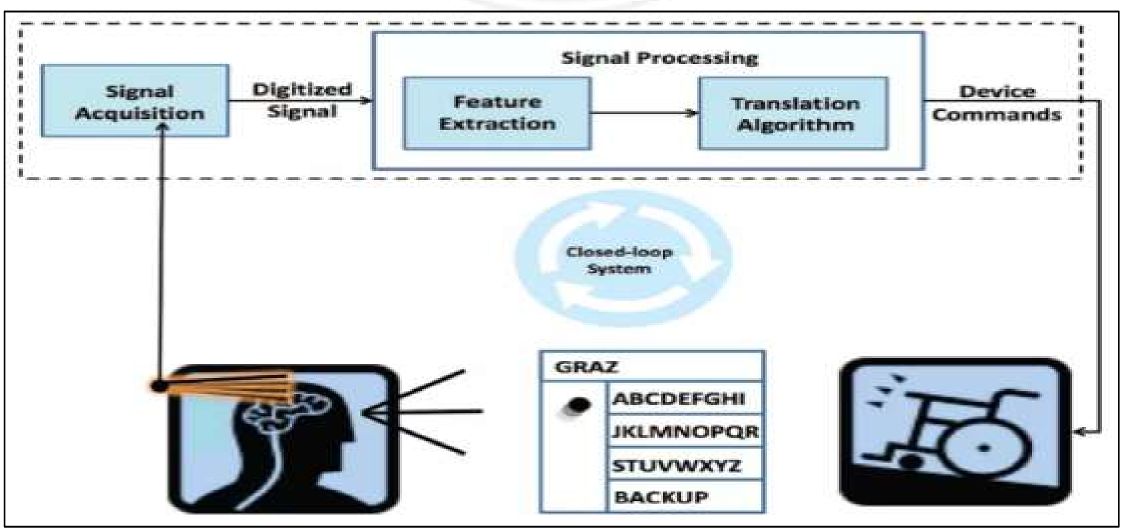


Figure-1.2: Block diagram for a BCI system

EEG signals are recorded in a short time, normally for 20-40 minutes. We get the recordings by placing the electrodes at various positions on the scalp. Figure1.3 shows the schematic view of the scalp and dots represent the placing of the multiple electrodes on the scalp. It is believed that the EEG signals not only represents the brain signal but also shows the status of the whole body. The head is divided into proportional distances from prominent skull landmarks (nasion, preauricular points, and inion) to provide adequate coverage of all regions of the brain. Label 10-20 designates proportional distance in percent between ears and nose where points for electrodes are chosen. Electrode placements are labelled according adjacent brain areas: F (frontal), C (central), T (temporal), P (posterior), and O (occipital). The letters are accompanied by odd numbers at the left side of the head and with even numbers on the right side (Fig. 1.3). As it is known from tomography, different brain areas may be related to different functions of the brain. Each scalp electrode is located near certain brain centers, F7 is located near centers for rational activities, Fz near intentional and motivational centers, F8 close to sources of emotional impulses. Cortex around C3, C4, and Cz locations deals with sensory and motor functions. Locations near P3, P4, and Pz contribute to activity of perception and differentiation. Near T3 and T4 emotional processors are located, while at T5, T6 certain memory functions stand. Primary visual areas can be found bellow points O1 and O2. However the scalp electrodes may not reflect the particular areas of cortex, as the exact location of the active sources is still open problem due to limitations caused by the non-homogeneous properties of the skull, different orientation of the cortex sources, coherences between the sources, etc.

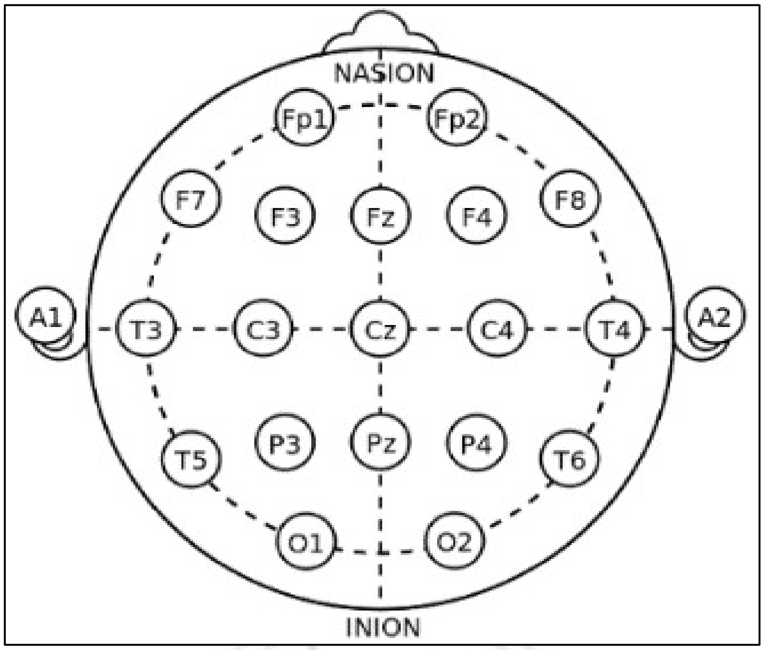


Figure-1.3: Standard placement of electrodes on scalp.

For quantization representation using 16 bits is mostly used. Figure 1.3 shows the conventional electrode arrangement recommended by the International Federation of Societies for Electroencephalography and Clinical Neurophysiology [8]. For the EEG data acquisition, electrodes are to be placed on the frontal region and the positions are Fp1, Fp2 in figure 1.3 on electrode position. For the single channel data acquisition process, positive electrode is placed on the Fp2 position, reference electrode is placed on the Fp1 position and negative electrode is placed on A1 (earlobe) position.

1.5. BCI Development History:

In this portion, we explain the development history of the brain-computer interface (I); the main steps are to introduce the three core steps of the BCI system: measuring the brain wave signal, (II), extracting the signal feature, (III), and converting it into machine instructions.

(I) **Long-term accumulation, rapid rise the history of the development of the brain computer interface:**

The human brain is a mystery in science. The earliest brain sciences can only be studied from anatomical brain injury patients. Since 1924, German doctor Hans Berger [9] first recorded the electromagnetic waves from the human scalp, and found that the oscillation signal of brain waves is related to brain diseases, opening a new way to explore the mysteries of the brain. In the 1970s, many scientists began to use brainwave signals as a conduit for communication with machines. One of the most successful to belong to the time UCLA BCI laboratory host Jacques Vidal's team, make use of visual stimuli to control the cursor maze of brain-computer interface[10]. The other main axis of the brain-computer interface is the intra cortical recordings. Neuroscientists have long used invasive electrodes to study the electrochemical behavior of nerve cells, but until the 1990s, Professor Richard Normann of the University of Utah developed a multi-electrode Utah array and showed that there are ways to use nearly one hundred electrode signals [11].

(II)**The roar of neurons - the principle and measurement of brain waves:**

The brain is made up of billions of nerve cells also known as neurons, each with an average of hundreds to thousands of links to other neurons. These cells transmit a signal action potential through the discharge, and release the nerve conduction material to stimulate the next nerve cell to continue to transmit this message. This complex neural network allows us to walk, remember, and think. So EEG signal is derived from the electrical activity of each neuron in the brain. According to the degree of intrusion of the electrode and the range of the measured signal, from the inside to the outside, from the small to the wide range, it can be roughly divided into three types: Intra cortical recordings, Electro cardio-graph (ECoG), and Electroencephalography (EEG).

(III)**Interpretation after the human brain Feature Extraction**

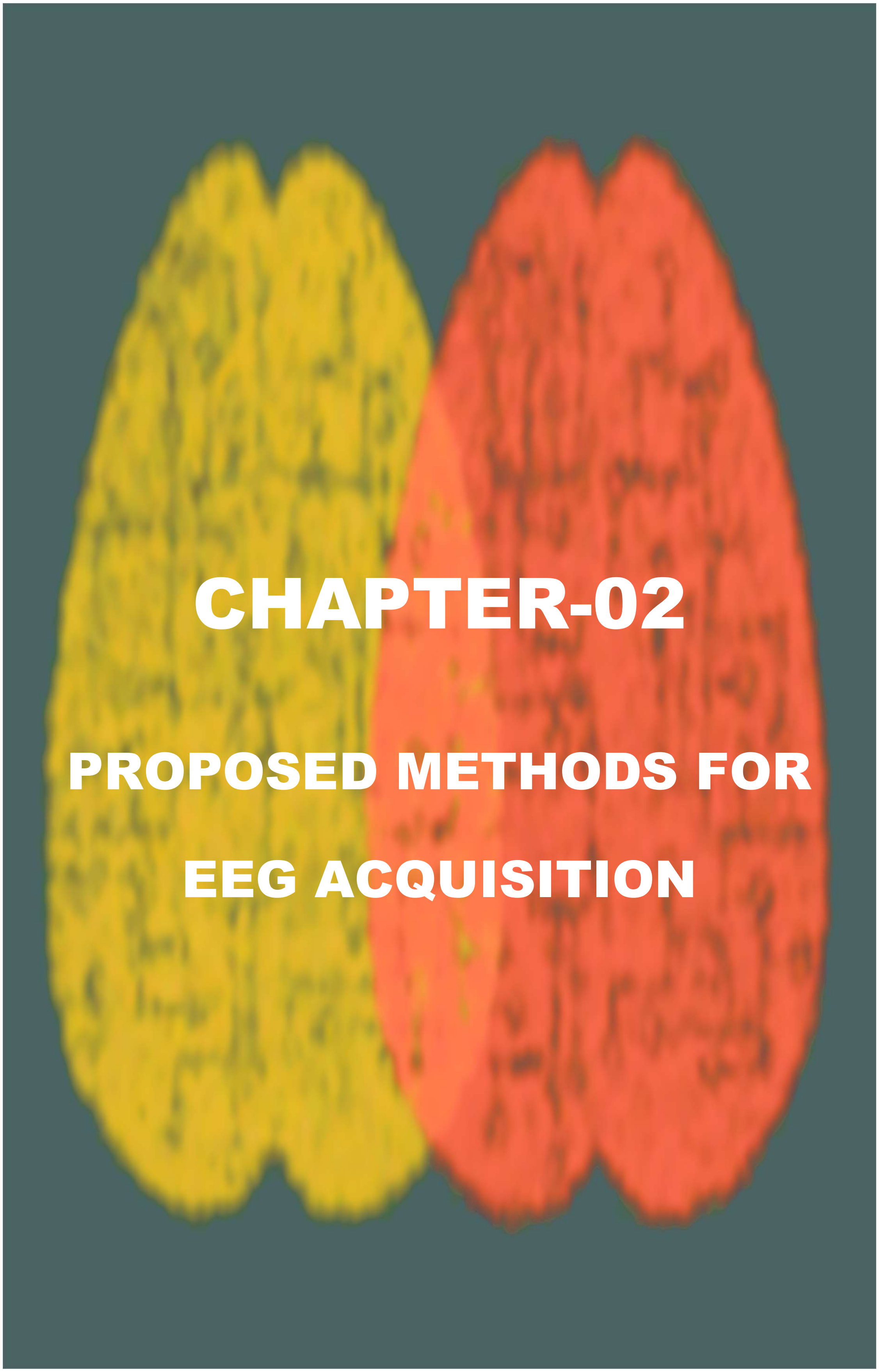
To get the pulse sequence or a brainwave signal, the next obvious question is: what information representing? How to extract useful information from a complex number of signals, Further reading the minds of people is the most challenging and important topic in the brain-computer interface. Due to limited space, this chapter only introduces the characteristics and analysis methods of brain waves (EEG).

The measure brain waves are the result of the hybrid of a large number of neuron signals and various noises, and it is possible to accurately decode the information. Therefore, the current method of brain wave analysis is still based on data-driven. Neuroscientists, signal processing experts, and statisticians try various analytical methods to find brainwave features in the brain that perform different tasks or are in different states. Although there is no way to analyze all the information in the brainwave, as long as we find some features that allow us to interpret the user's brain state or intention, we can allow users to communicate easily with the outside world through the brain computer interface. According to the way in which brain waves are generated, they can be divided into two types: endogenous and exogenous [12].

- ❖ Bioengineering applications: Assist devices for disabled people.
- ❖ Human subject monitoring: Sleep disorders, neurological diseases, attention monitoring, and/or overall mental illness.
- ❖ Real-time methods for correlating observable behavior signals recorded.
- ❖ Interface devices between human and computers, machines. The common structure of a Brain Machine Interface is the following:
- ❖ The EEG signals are obtained from the brain through invasive or non-invasive methods for example, electrodes. After, the signal is amplified and sampled.

- ❖ Signal pre-processing: once the signals are acquired, it is necessary to clean them.
- ❖ Signal classification: once the signals are cleaned, they will be processed and classified to find out which kind of mental task the subject is performing.
- ❖ Computer interaction: once the signals are classified, they will be used by an appropriate algorithm for the development of a certain application.

Then the amplified output is passed through a low pass band stop filter with cut off frequency 45 Hz. The EEG signals contain neuronal information below 100 Hz in many applications the information lies below 30 Hz. The important EEG wave groups (alpha, beta, theta, gamma, delta, and gamma) fall within 45 Hz range. Any frequency component above these frequencies can be simply removed without any loss of information. The isolator is used to totally isolate circuitry from mains electricity [13]. An isolator (or optical isolator, optical coupling device, optocoupler, photocoupler, or photoMOS) is a device that uses a short optical transmission path to transfer an electronic signal between elements of a circuit, typically a transmitter and a receiver.



CHAPTER-02

PROPOSED METHODS FOR EEG ACQUISITION

2.1. EEG Signal Processing:

The circuit analyzing unit has been designed to amplify the EEG signal for advance exemption. EEG signal gleaned by using electrodes have magnitude of around 5–200μV. The signals are confined in the frequency range 0.1 to more than 200 Hz, according to the EEG signals circuit diagram. The band pass filter and band stop filter have been designed in that cut off frequency range. A notch filter also has been considered while designed band stop filter for better performance, reduce noise and remove the power line interference. After design all filters and circuits, a post amplifier for further amplification of EEG signal and a voltage adder has been designed for signal keep in optimistic domain [14]. Figure 2.1, shows the block diagram of a general EEG signal acquisition system which is mainly collected alignment of scalp electrodes, instrumentation amplifier, band pass filter and band stop filter considering notch filter, post amplifier, voltage adder and the output display.

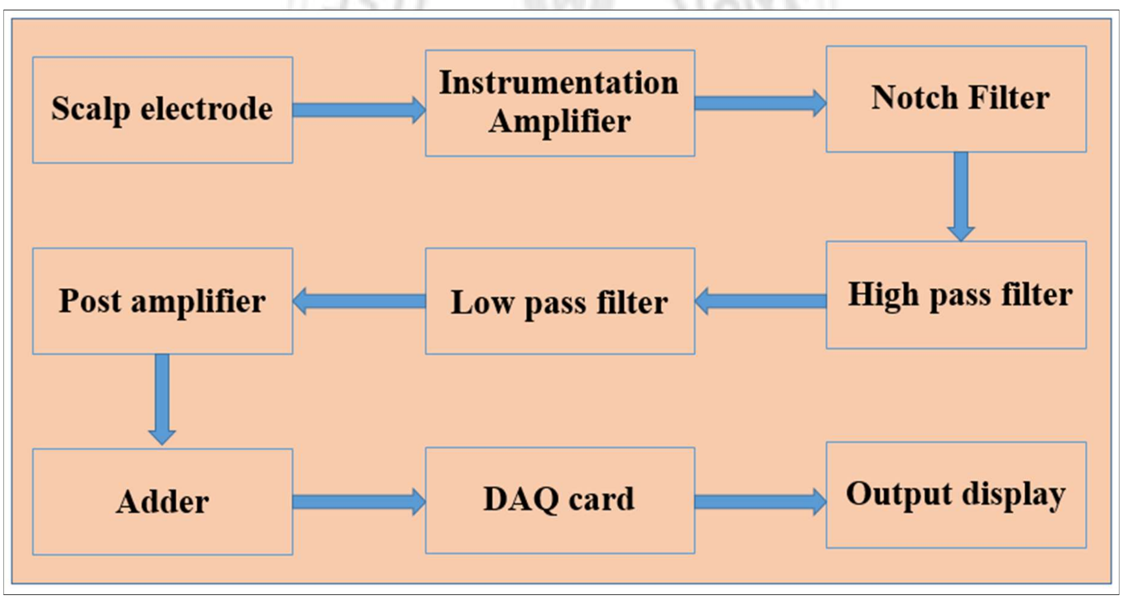


Figure-2.1: Block diagram of a general EEG acquisition system

In the filter position, band pass filter and band stop filter have been implemented through the designing an active high pass filter and active low pass filter circuit, respectively. The frequency response of the band pass filter estimate capacity is regularly introduced as maximally there is no ripples response on the grounds that the band pass filter is intended to have a frequency response which is as level as numerically conceivable from zero Hz to until the cut-off frequency.

2.2. Instrumentation Amplifier:

An Instrumentation amplifier is an integrated circuit (IC) used to amplify the signal, which is a type of differential amplifier because it amplifies between two input signals. In industries, physical quantities are converted into electrical signals using transducers and the signal is amplified for signal processing. The importance of an instrumentation amplifier is that it can reduce unwanted noise that is picked up by the circuit. The ability to reject noise or unwanted signals common to all IC pins is called the common-mode rejection ratio (CMRR). Always the input of an instrumentation amplifier is the output from the transducers and will have a small signal. Instrumentation amplifiers don't need input impedance that makes this amplifier suits for measurement purposes. Note that the DC power gain of an amplifier is equal to ten times the common log of the output to input ratio, whereas voltage and current gains are 20 times the common log of the ratio. A positive value of dB represents a Gain and a negative value of dB represents a loss within the amplifier. For example, an amplifier gain of +3dB indicates that the amplifiers output signal has "doubled", (x2) while an amplifier gain of -3dB indicates that the signal has "halved", (x0.5) or in other words a loss. The -3dB point of an amplifier is called the half-power point which is 3dB down from maximum, taking 0dB as the maximum output value [15].

The designed instrumentation amplifier is performed as the front cease of EEG signal acquisition system. To design the schematic layout of instrumentation amplifier the INA 333 (TINA IT) [16] has been used for EEG signal acquisition circuit. The INA333 measures small differential voltage with high common mode voltage developed between the non-inverting and inverting input. The high input impedance makes the INA333 suitable for a wide range of applications. The ability to set the reference pin to adjust the functionality of the output signal offers additional flexibility that is practical for multiple configurations. It is an excessive accuracy and low strength familiar cause amplifier. It has a number beneficial facets which made it by means of the INA 333 for the power-driven scientific applications, these are like low counterbalance voltage 50μV max, low drift 0.5μV/min, low enter bias current 5mA max, excessive CMRR (Common Mode Rejection Ratio) 120dB min, large furnish voltage range: -1.65 V to 3.3 V. The auto-calibration technique used by the INA333 device results in reduced low frequency noise, typically only 50 nV/√Hz, (G = 100). The spectral noise density can be seen in detail in Fig. 2.1 low frequency noise of the INA333 device is approximately 1μV_{PP} measured from 0.1 Hz to 10 Hz, (G = 100). The acquirer of the amplifier is managed with the aid of a POT (potentiometer) single exterior resistor [17]. A single external resistor sets any gain from 1 to 10,000. The INA333 is laser trimmed for very high common-mode rejection (100 dB at G ≥ 100. The DRL circuit was utilizing and adding the high CMRR instrument amplifier with differential inputs, and followed by a modified high Quality factor, active Twin-T notch filter ((fc Notch = 60 Hz, − 38 dB).

Another major factor is electronic noise which is important to reduce for the bio-signal measurements. Electronic noise can be caused by internal and external noise sources. The internal noise sources are thermal due to resistive components, shot down to semiconductor holes and diffusions, flicker caused by contact pins, and burst or popcorn, as a result of impurities in semiconductors noise and the most important external noise is caused by power-line interference. To extract bio-signals precisely from electronic noise requires efficient noise reduction methods that’s efficient analog and, or digital filtering are needed for this purpose. The amplifiers have the aim to increase the power of the signal, to a level useful for the following steps of conditioning. The different types of noise are superimposed on gainful components. The gainful components are carrying the necessary information for further visualization or control tasks. Moreover, the variation of the external electromagnetic field has its own contribution to the perturbation linked noise level. In all recordings and signal conditioning methods we considered the effect of the 50Hz or 60Hz noise of power suppliers. An important objective of this paper is to describe the improvements of the EEG signal acquisition systems using efficient signal conditioning proceedings. The times magnification of the circuit: (refer with: Eq. 2.1) and the term CMRR is a logarithmic expression of the Common-mode rejection ratio (CMRR).

The first step in developing a SPICE model for CMR is understanding an op amp's Common Mode Rejection Ratio (CMRR). The CMRR is a measure of how well the device rejects a common-mode signal.

$$CMRR= \frac{Ad}{Acm} \text{--} (2.1)$$

It's simply the ratio of the differential gain A_d over the common-mode gain A_{cm}. Differential Gain, $A_d = V_o / (v+ - v-)$, This is your basic open-loop gain of an op amp. Common-Mode Gain, $A_{cm} = Vo / V_{cm}$, Here's the gain with the inputs tied together at $V_{cm} = v+ = v-$. Putting the value of CMRR in the equation (2.2) we can get the value of CMR.

$$\text{That is, } CMR = 20 \log10 (CMRR) \text{ dB} \text{-------------------------------} (2.2)$$

The CMR behavior developed here is somewhat oversimplified in a number of ways. The actual error in a real op amp results from the imbalances in the transistors and resistors of the input stage.

2.2.1 Pin Configuration and Functions.

The INA333 device is available in both 8-pin VSSOP and WSON surface-mount packages and is specified over the TA = –40°C to +125°C temperature range. DGK Package 8-Pin VSSOP Top View.

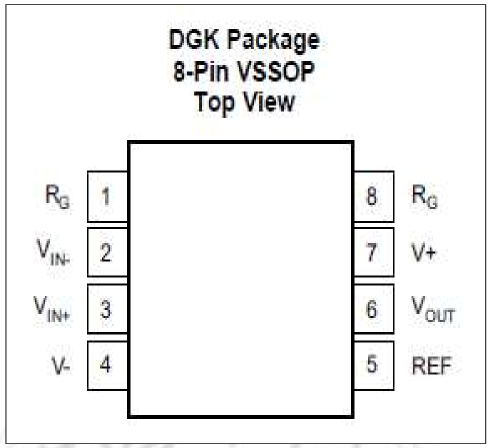


Figure-2.2: Pin Configuration of INA333 amplifier.

Features:

- Low Offset Voltage: 25 µV (Maximum), G ≥ 100
- Low Drift: 0.1 µV/°C, G ≥ 100
- Low Noise: 50 nV/√Hz, G ≥ 100
- High CMRR: 100 dB (Minimum), G ≥ 10
- Low Input Bias Current: 200 pA (Maximum)
- Supply Range: 1.8 V to 5.5 V
- Input Voltage: (V–) +0.1 V to (V+) –0.1 V
- Output Range: (V–) +0.05 V to (V+) –0.05 V
- Low Quiescent Current: 50 µA
- Operating Temperature: –40°C to +125°C
- RFI Filtered Inputs
- 8-Pin VSSOP and 8-Pin WSON Packages

The INA333 measures small differential voltage with high common-mode voltage developed between the non-inverting and inverting input. The high input impedance makes the INA333 suitable for a wide range of applications. The ability to set the reference pin to adjust the functionality of the output signal offers additional flexibility that is practical for multiple configurations. The pin configuration of instrumentation amplifier and its function, working principle presented by the table-01.

Table-01: Pin functions and description of INA333 amplifier.

Pin		Input / Output	DESCRIPTION
Name	Number		
R_{ref}	5	I	Reference input. This pin must be driven by low impedance or connected to ground.
R_G	1 & 8	--	Gain setting pins. For gains greater than 1, place a gain resistor between pins 1 and 8.
V^+	7	--	Positive supply
V^-	4	--	Negative supply
V_{in+}	3	I	Positive input
V_{in-}	2	I	Negative input
V_{out}	6	O	Output

2.2.2 INA 333 Instrumentation Amplifier:

The INA333 device is a low-power, precision instrumentation amplifier offering excellent accuracy. The versatile 3-operational amplifier design, small size, and low power make it ideal for a wide range of portable applications. A single external resistor sets any gain from 1 to 1000. The combination of the zero-drift amplifier core and the precision resistors allows this device to achieve outstanding DC precision and makes the INA333 ideal for many 1.8V and 5V industrial applications. The device can be configured to monitor the input differential voltage when the gain of the input signal is set by the external resistor R_G. The output signal references to the R_{ef} pin.

The gain of the amplifier is controlled by the single external resistor R_G. All the points are connected according to the pin configuration of INA 333 amplifier.

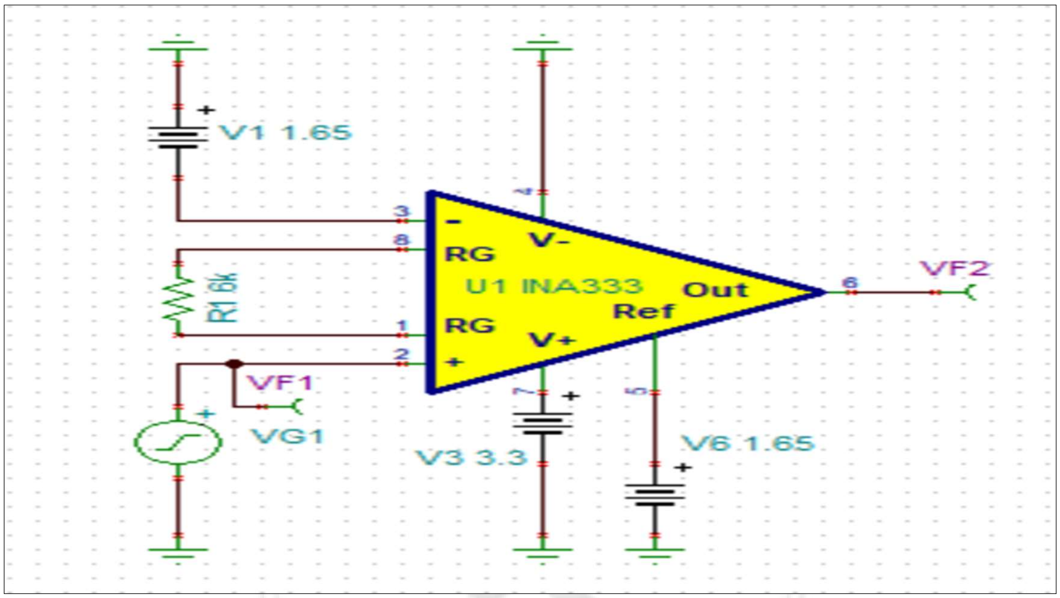


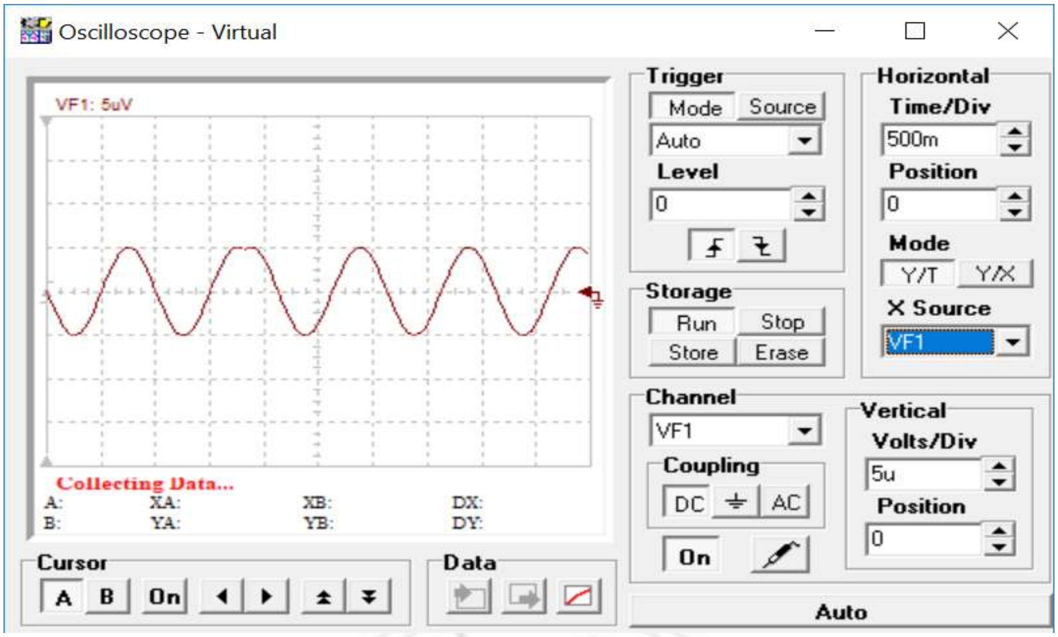
Figure-2.3: Functional block diagram of Instrumentation amplifier.

2.2.3. Voltage and Gain Calculation:

The gain of the particular instrumentation amplifier can be calculated by this industry standard Gain equation (2.3). Gain of the INA333 device is set by a single external resistor R_G, connected between pins 1 and 8. The value of R_G is selected according to equation (2.3).

$$G = 1 + (100k\Omega / R_G) \text{ --------------------------------------- } (2.3)$$

Where R_G is the external resistor. Here, we set $R_G = 6k\Omega$ to be an example. Hence, the gain of the amplifier is set G= 17.6



Fifure-2.4: Input signal of instrumentation amplifier

After getting the gain of instrumentation amplifier, the value of G is taken into the equation (2.4) and got the output of Instrumentation amplifier circuit.

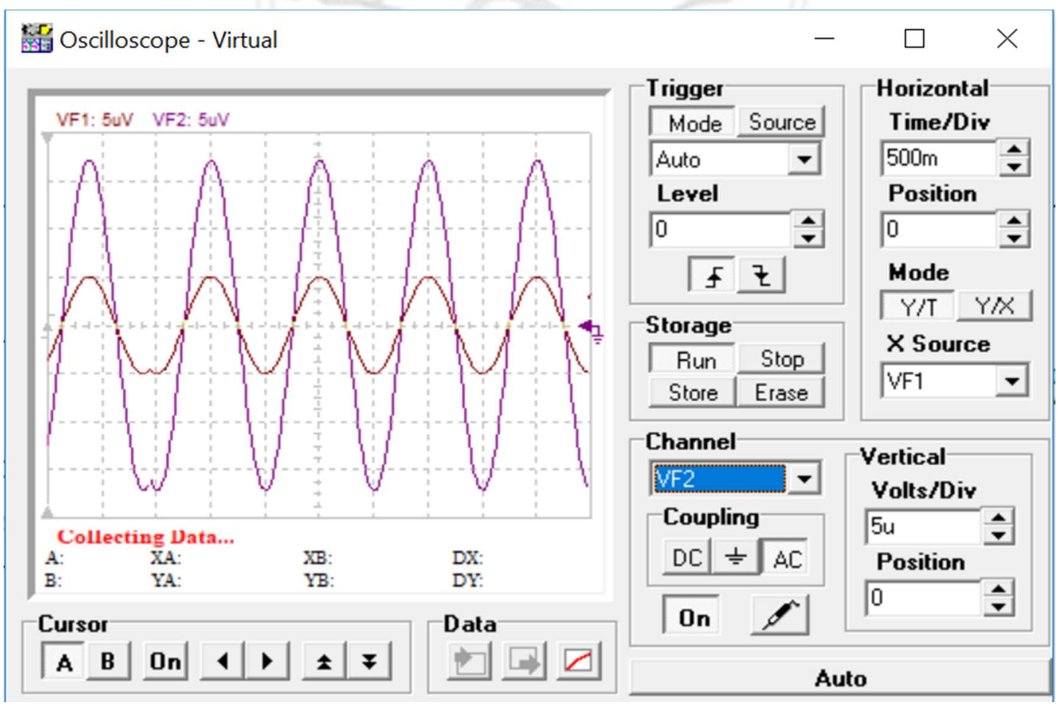


Figure-2.5: Output signal of instrumentation amplifier.

$$V = G^* (V_{in+} - V_{in-}) \text{ --- } (2.4)$$

Considering the figure-2.5, this is the input and out signal of instrumentation amplifier. Whereas, positive input value is 5uV and negative input value is 1.65V these value put in the equation (2.4) than we will get output voltage.

Where, gain G = 17.6, positive input voltage V_{in+} = 5uV negative input voltage V_{in-} = 1.65v O output voltage, V_{out} = 2917mV.

2.3. Notch Filter:

A Notch Filter is also known as a Band Stop filter or Band Reject Filter. These filters reject/attenuate signals in a specific frequency band called the stop band frequency range and pass the signals above and below this band. This notch filter is same as our narrow Band stop filter. This notch filter is applied to eliminate the single frequency. Since it consists of two 'T' shaped networks, it is mentioned as twin T network. The maximum elimination occurs at the notch frequency $f_C = 1/(4\pi RC)$. Any signal in this frequency range is attenuated by the Notch Filter. The level of attenuation is usually represented in dB. The general filter is low pass or high pass filters, which is to filter out high or filter out low frequencies. The Notch filter divides the signal into two parts, one part is considered low, the other part is filtered out, and the two are mixed together [18]. The frequency of the concave is the set by the frequency of notch filter.

The part of band pass filter is to cut off low frequency and high frequency and only let the middle frequency pass the result of the simultaneous application of both the low pass and high pass filters. If we adjust the cutoff frequency to a very small value when using a low-pass filter then no signal can pass, and the high-pass filter uses the same high cutoff frequency.

2.3.1 An Ideal Notch Filter.

In order to eliminate the specific value of the frequency in case of a notch filter, the capacitor chosen in the circuit design must be less than or equal to the 1 μF. By using the center frequency equation, we can calculate the value of the resistor. By using this notch circuit, we can eliminate single frequency at 50 or 60 Hz. The second order notch filter with active component op-amp is in non-inverting configuration. The reason the circuit is called twin T notch filter is that if you look at the circuit diagram, two 'T's are formed that are identical in shape, which is why they are called twins. This design modifies the classical twin-T notch filter to be Q-factor tunable as shown in figure-2.6 below:

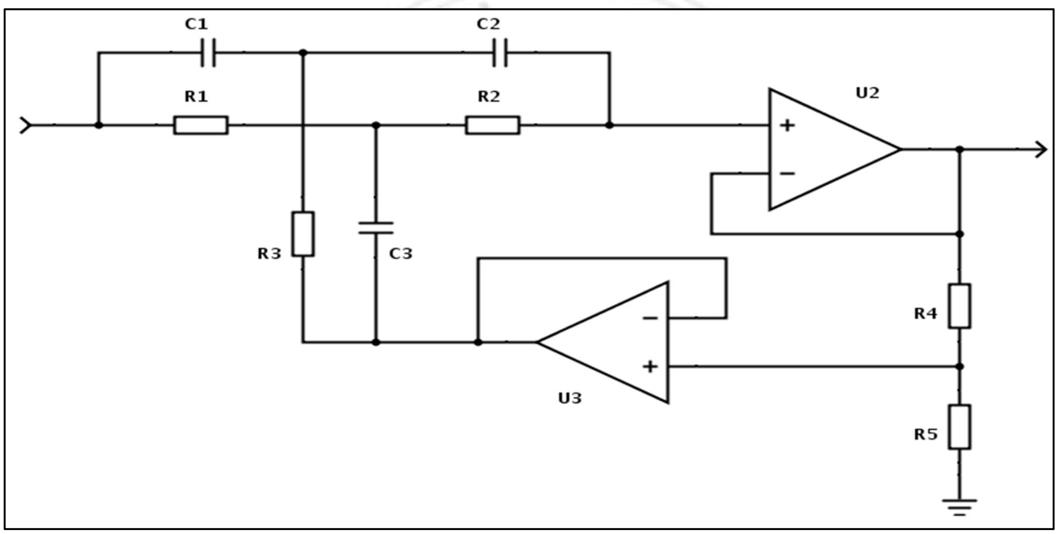


Figure-2.6: Notch filter block diagram

2.3.2 Notch Filter Parameters Calculation.

The twin T notch filter calculator calculates the values of the resistors and capacitors needed to obtain a notch frequency as entered in by the user. The notch frequency is the frequency that is most greatly attenuated by the circuit.

The twin-T network is used as band stop (notch) filter for a particular selection of component values[19]. Calculated the transfer function parameters by Sallen-Key:

Center Frequency	60	[Hz]
Feedback	16	[%], 1.0 < k < 99.0
Bandwidth	201.6	[Hz]
Q	0.298	
C1, C2	10	[nF]
C3	20	[nF]
R1, R2	265.3	[kΩ]
R3	132.6	[kΩ]
R4	84	[kΩ]
R5	16	[kΩ]

Figure-2.7: Parameters calculation for Notch filter

2.3.3. Ideal Response of The Notch Filter

Simple circuit connected by capacitor and resistor in series forms the band stop filter and the Band Stop filter with narrow band stop filter that features are called as a notch filter. It is used to eliminate single frequency value. It is formed by two resistors and two capacitors connected in two 'T' shaped networks. At the very high and very low frequencies the band stop filter circuit acts like an open circuit, whereas the mid frequencies the circuit acts as a short circuit. Hence, the circuit attenuates only mid frequencies and allows all other frequencies. The lower and higher cutoff frequencies of the filter depend on the filter strategy. The bandwidth of the filter is nothing but the stop band of the filter. If the quality factor is high and narrow the width of the notch response. These are widely preferred in communication circuits.

It is commonly used for attenuation of a single frequency such as 60 Hz power line frequency hum. The most widely used notch filter is the twin-T network illustrated. This is a passive filter composed of two T-shaped networks. One drawback of notch filter is that it has relatively low figure of merit quality factor. However, the quality factor of the network can be increased significantly if it is used with the voltage follower. Here the output of the voltage follower is supplied back to the junction of R/2 and 2 C. The standers diagram for Ideal response of the notch filter figure-2.8 given below:

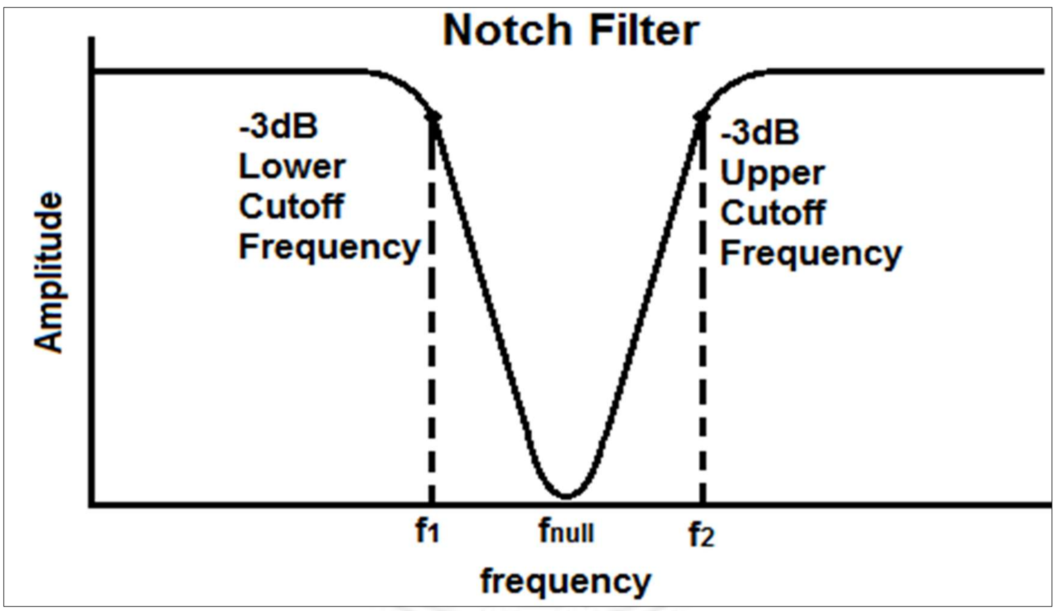


Figure-2.8: Standers diagram for Ideal response of the notch filter

Notice that two upper capacitors are C while the capacitor in the center of the network is 2 C. Similarly, the two lower resistors are R but the resistor in the center of the network is 1/2 R. This relationship must always be maintained [20].

2.4. Band Stop Filter:

The band stop filter has been designed by using the combination of low pass filter and high pass filter with the parallel connection as alternative cascading connection with it. The band stop filter also considered as a band reject filter that passes all frequencies with the exception of these inside a unique give up band which are significantly declined. This filter is stop a specific band of frequencies. Since it eliminates frequencies, it is moreover known as band elimination filter or band reject filter. It is aware of that in contrast to high pass and low pass filters, band pass and band stop filters have two cut-off frequencies. It will pass above and below a specific range of frequencies whose reduce off frequencies are predetermined relying upon the value of the components used in the circuit design. Any frequencies among these two cut-off frequencies are attenuated. It has two pass bands and one stop band. The band pass filter passes one set of frequencies whereas rejecting all others. The band stop filter does simply the opposite of band pass filter. It rejects a band of frequencies, while passing all others.

Likewise, band pass filters, band-stop filters may also additionally be categorized as wide-band and narrow band reject filters. A broad band-stop filter is used for a low-pass filter, a high-pass filter and a summing amplifier is shown in figure. For a perfect band reject response, the low cutoff frequency f_L of high-pass filter must larger than the excessive cut-off frequency f_H of the low pass filter. In addition, the band pass attain of both the high-pass and low pass sections ought to be equal. The filter cease is a second-order filter having two cutoff frequencies, acknowledged as the -3dB or half-power factors producing a widespread quit band bandwidth between these two -3dB points.

The appearances of a band stop filter are indeed opposite of the band pass filter characteristics. When the input signal is given, the low frequencies are passed through the low pass filter in the band stop circuit and the high frequencies are exceeded through the high pass filter in the circuit. In exercise, due to the capacitor switching mechanism in the excessive skip and low skip filter the output individualities are not equal as that of in the perfect filter. The pass band gain ought to be equal to low pass filter and high pass filter.

2.4.1. Band Stop Filter Circuit.

The frequency response of band stop filter is shown below and in experienced line indicates the sensible response in the below figure-2.9.

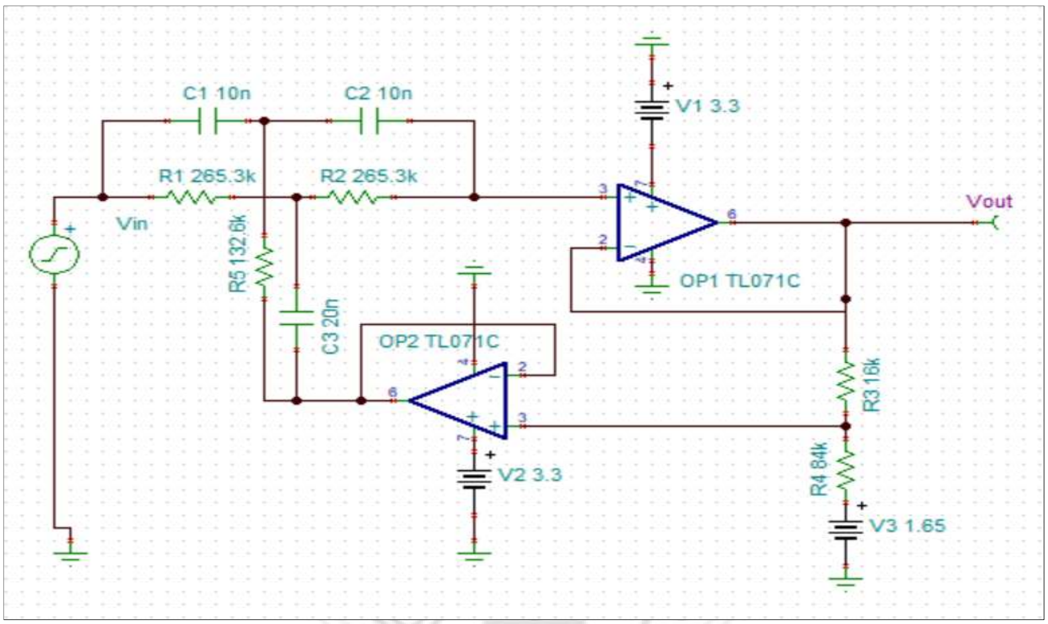


Figure-2.9: Band stop filter circuit diagram

If this band stop is very slight and highly attenuated over a few Hz, then the band stop filter is greater generally referred to as a notch filter, as its frequency response shows that of a deep notch with excessive selectivity instead than a flattened wider band. Then the feature of a band stop filter is too pass all these frequencies from zero Hz through DC up to its first lower cutoff frequency factor f_L, and pass all these frequencies above its second cutoff frequency f_H, however block or reject all these frequencies in between. Then the filters bandwidth is described as: $(f_H - f_L)$. So for the wide band and band stop filter, the filters proper stop band lies between its lower and higher -3dB factors as it attenuates, or rejects any frequency between these two cutoff frequencies.

2.4.2. Band Stop Signal Processing.

By way of this we can say that low and high frequencies the circuit acts like an open circuit due to the fact inductor and capacitor are linked in series. Band stop signal processing figure-2.10 given below:

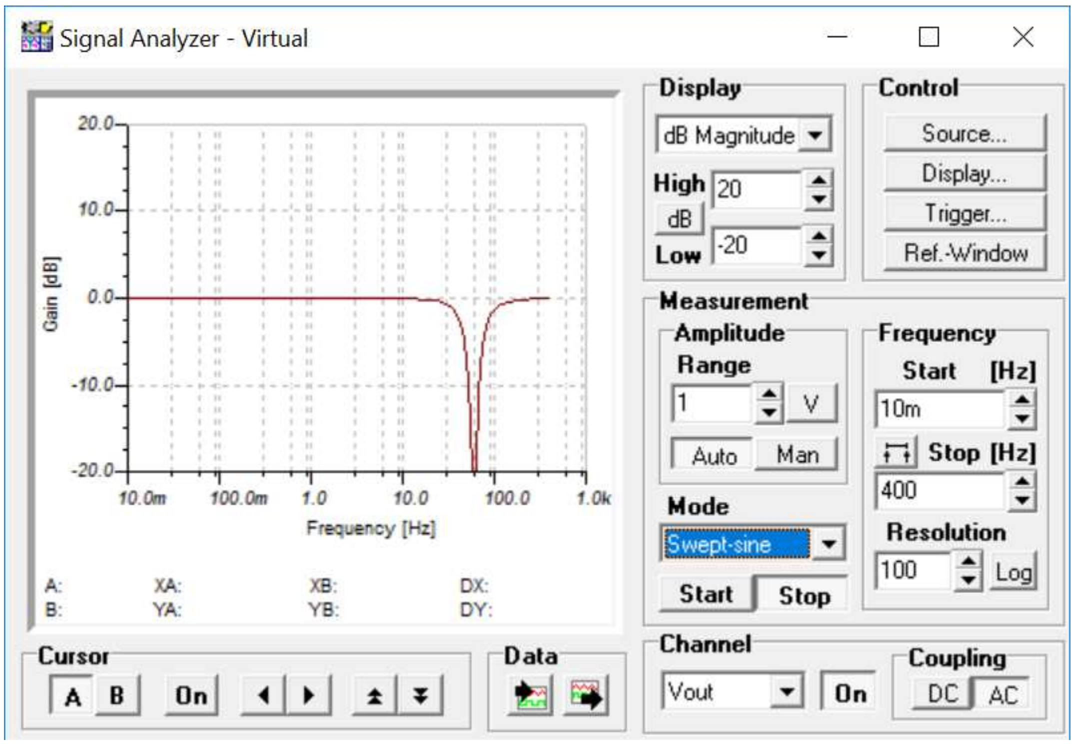


Figure-2.10: Band stop signal processing on analyzer.

Thus the mid frequencies are not allowed to skip through the circuit. The mid frequency range to which the filter acts as a short circuit relies upon on the values of lower and higher cutoff frequencies. This lower and upper cutoff frequency values depend on the factor values. These factor values are decided through the transfer functions for the circuit in accordance to the design. The transfer characteristic is nothing but the ratio of the output to the input.

2.4.3. Frequency Response of the Band Stop Filter

Taking the frequency and gain, the frequency response of the stop band is obtained as Band Pass filter Figure-2.11 given below.

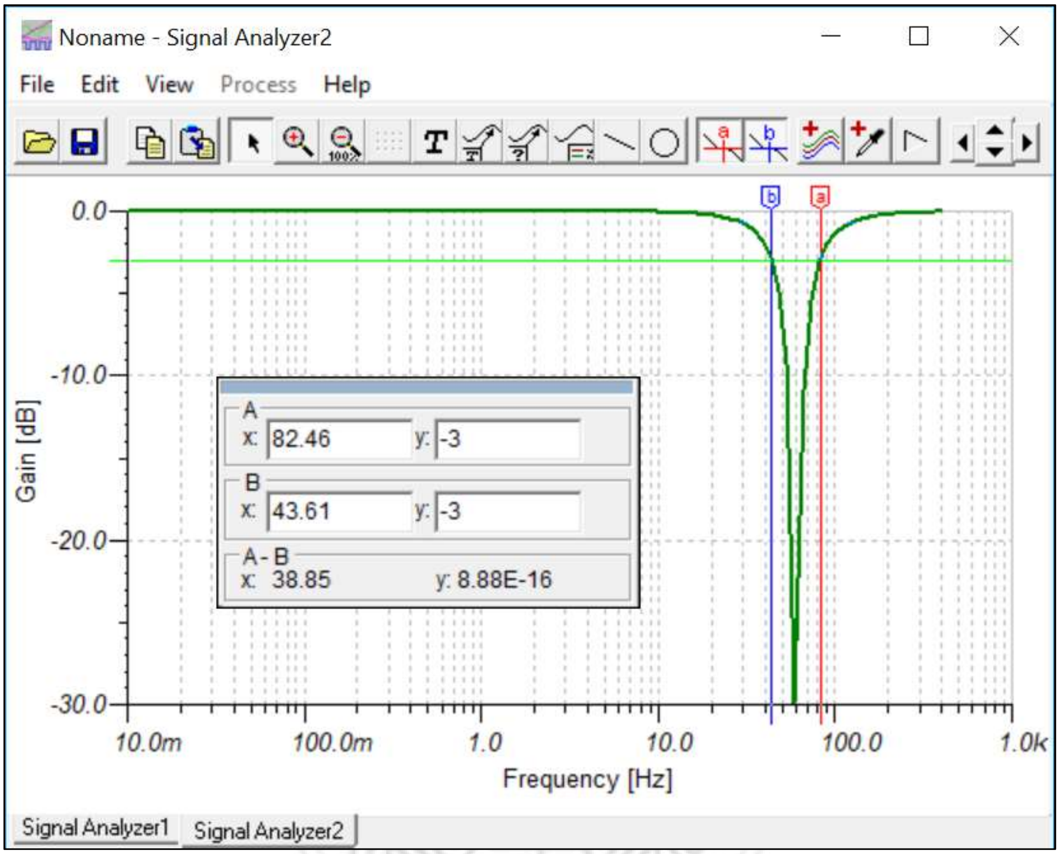


Figure-2.11: Band stop signal frequency response.

Where, the cut off frequency of the low pass filter indicates by f_L and the cut off frequency of the high pass filter is f_H. The center frequencies can calculate through this equation $fc = \sqrt{(f_L \times f_H)}$.

The bandwidth is taken throughout the lower and greater cutoff frequencies. According to ideal filter the pass band need to have to achieve and a stop band ought to have zero gain. In practice, there will be some transition region. We can measure the pass band ripple and end band ripples as follows.

Pass Band Ripple = – 20 log10 (1-δp) dB, Stop Band Ripple = – 20 log10 (δs) dB.

δp = Magnitude response of the pass band filter, δs= Magnitude response of the stop band filter.

Standard band stop signal diagram Figure 2.12: given bellow

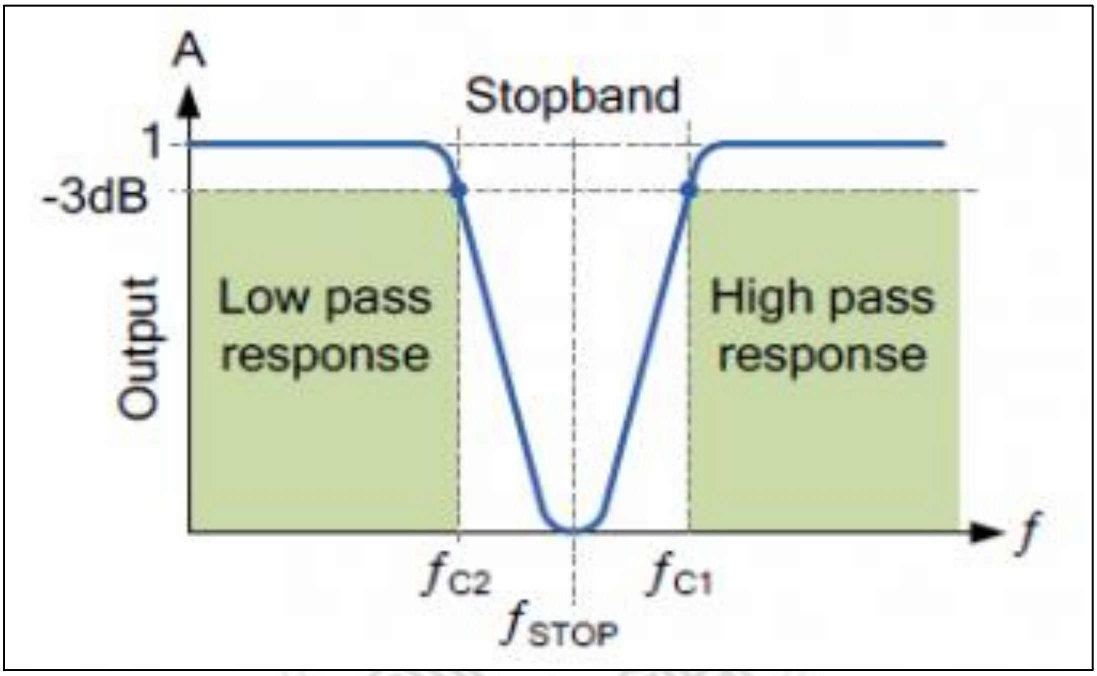


Figure 2.12: Standard band stop signal diagram

The typical stop bandwidth of the band stop filter is 1 to 2 decades. The highest frequency eliminated is 10 to 100 times the lowest frequencies eliminated.

2.5. Band Pass Filter:

A Band Pass Filter is a circuit which permits merely exceptional band of frequencies to pass through the signals. The main distinguishing feature of a band pass filter is its ability to pass frequencies relatively attenuated over a specified band or spread of frequencies. This Pass band cut-off frequencies range 0.1 to 200 Hz is between low pass frequency (f_L) and high pass frequency (f_H), where f_L is decrease cut-off frequency and f_H is increase cut-off frequency. The principle frequency is denoted via center frequency (f_C) and it's additionally known as resonant frequency. The low pass frequency value always have to be less than the value of high pass frequency. The Active Band Pass Filter is slightly different from a frequency selective filter circuit used in electronic systems to separate a signal at one particular frequency, or a range of signals that lie within a certain band of frequencies from signals of all other frequencies. This band or range of frequencies is set between two cut-off or corner frequency points' lower frequency (f_L) and higher frequency (f_H) while lessening any signals external of these two points. Through this band pass filter, any higher or lower than selected frequency will be blocked. This filter is more useful for removing unwanted noise by blocking everything that we don't be use anyway.

2.5.1 Band Pass Filter Circuit:

Combination of high and low pass filters to an amplifying op-amp circuit as shown Figure-2.13 below:

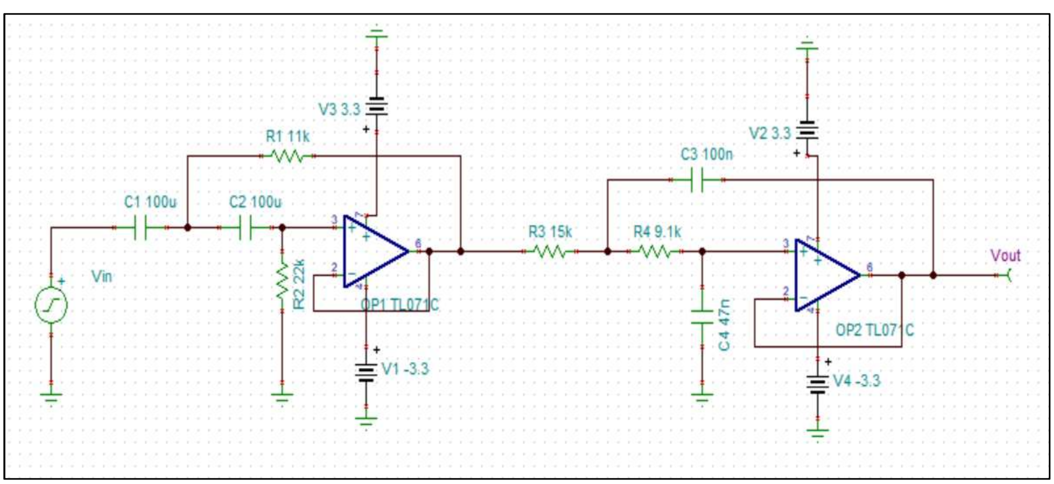


Figure-2.13: Band pass filter circuit diagram

The parameters of the first level of this filter: R1 =11kΩ, R2 =22kΩ, C1 =100uF, C2 =100uF. The cutoff frequency is f_{c1}. Parameters of the second level filter: R3 =15kΩ, R4 =10kΩ, C3 =100nF, C4 =47nF. We can calculate the cutoff frequency f_{c2}.

The raw EEG signal is overlapped with mixed frequency noises, to overcome from these noises a desirable high pass filter has to be designed. Here the energetic high ignore filter is designed with reduce the frequency. This is also assist in getting rid of the baseline drifting, which is created by using low frequency noise. This cascading together of the individual low and high pass passive filters produces a low type filter circuit which has a wide pass band. The first stage of the filter is high pass stage that uses the capacitor to block any DC biasing from the source. This design has the advantage of producing a relatively irregular pass band frequency response with one half representing the low pass response and the other half representing high pass response as shown. Combination of low pass by and high ignore responses gives us band pass by response as shown Figure-2.14 below:

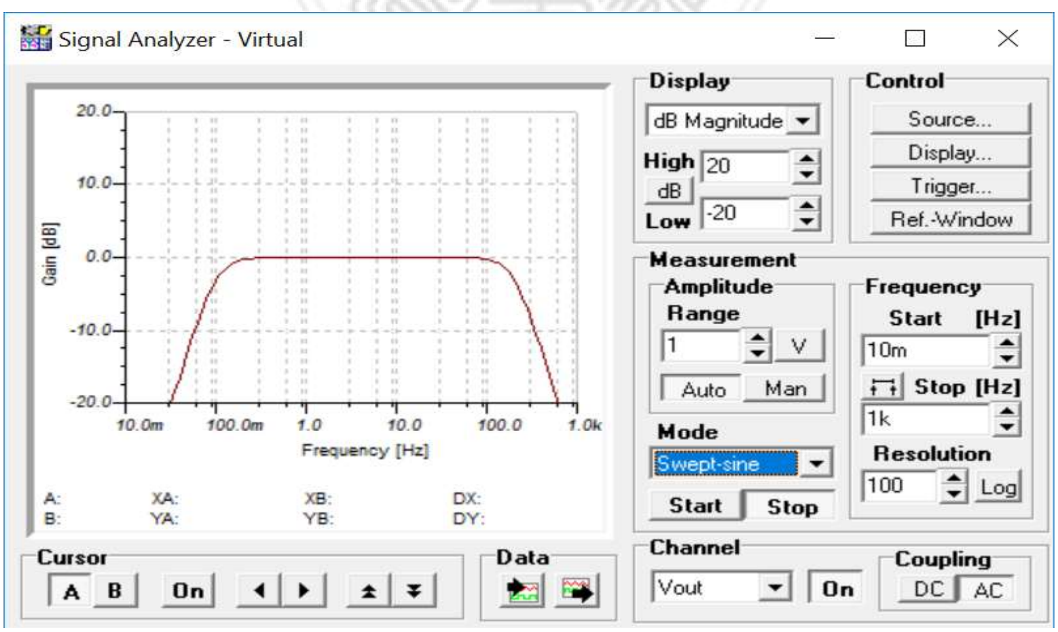


Figure-2.14: Band pass signal processing on analyzing

Depending on the quality factor the band pass filter is classified into wide band pass filter and Narrow band pass filter. The quality factor is also referred as figure of merit. By cascading high pass filter and low pass filter with an amplifying component we obtain band pass filter. The amplifier circuit between these high pass and low pass filter will provide isolation and gives over all voltage gain of the circuit. The values of the cut-off frequencies of both the filters must maintained with minimum difference. If this difference is very small, there may be a possibility of interacting of high pass and low pass stages. In order to have proper levels of these cut-off frequencies an amplifying circuit is necessary.

2.5.2. Frequency Response of the Band Pass Filter:

Band stop filter frequency response figure-2.15 given below:

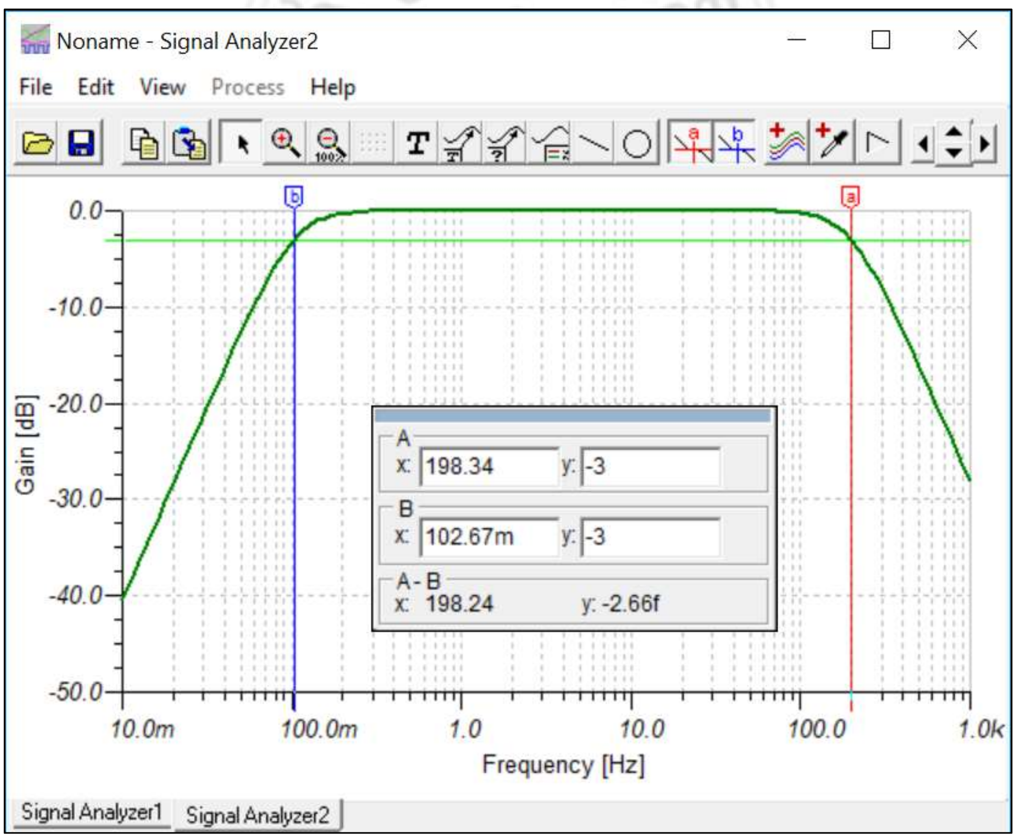


Figure-2.15: Band pass signal frequency response.

The acquired signal from figure-2.15 band pass filter is maximum at resonant or center frequency and this is referred as total pass band gain. For the low pass filter this band pass starts from zero Hz and continues to till it reaches the resonant frequency price at -3dB down from the most ignored band gain. Although the above passive tuned filter circuit will work as a band pass filter, the pass by bandwidth can be quite wide and this may also be a trouble if we want to isolate small band of frequencies.

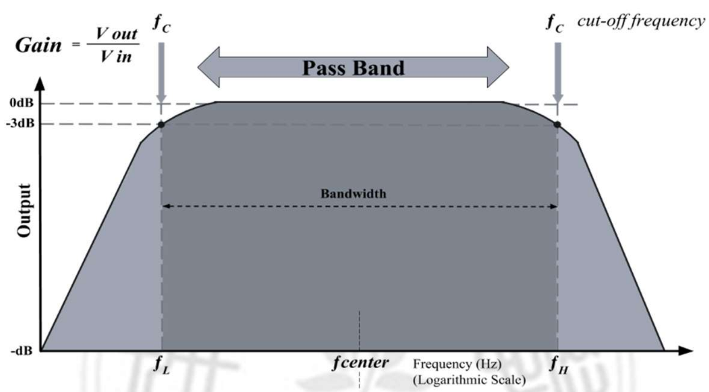


Figure 2.16: Standard band pass signal diagram

Through rearranging the positions of the resistors and capacitors inside the band pass filter we can produce a good deal better filter circuit as shown figure-2.16 [21].

2.6. The Gain Stage Amplification

To begin with, a multistage amplifier circuit, design of post-amplification circuit is a key link in the EEG signals data acquisition system. In respect to design a high quality of EEG signals amplifier, the post-amplifier must have high input impedance, high common mode rejection ratio, low noise, small non-linearity, strong anti-interference ability, the appropriate frequency and the range of dynamic, which makes the design of amplifier that is very difficult, but it is the most important to design circuit of acquisition the total system EEG signals. The design based on two paralleling TL071C instrumentation amplifier is improved by literature 2, the essence is two in-phase parallel structure of the preamplifier circuit cascade.

The purpose is to improve the zero drift and common mode rejection ratio of the system circuit. The circuit principle diagram is shown in figure 2.17 below.

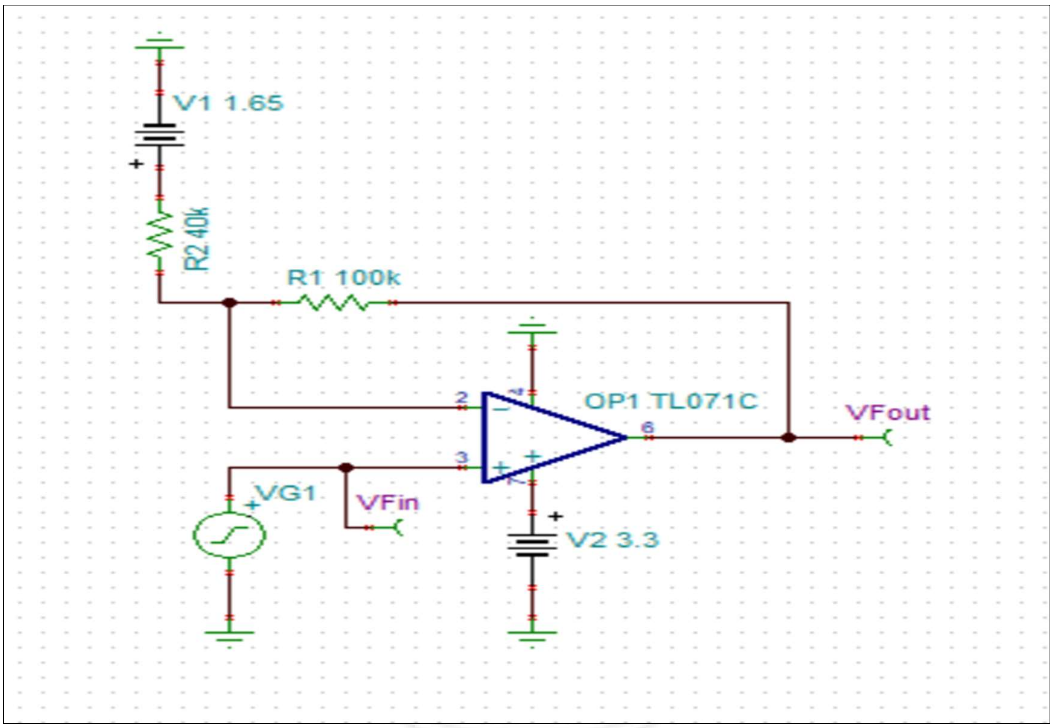


Figure 2.17: Gain stage post amplifier circuit

Using the formula (2.6) to calculate the output voltage of a potential divider network, we can calculate the closed-loop voltage gain of the Non-inverting Amplifier as follows:

Voltage gain, $G_{gain} = (1+\frac{R1}{R2})$ ------------------------------------ (2.6)

Where R1 is the feedback resistance and R2 ground resistance of gain stage amplifier circuit. Through the rearranging value of feedback resistance and ground resistance we can set value for our expected voltage gain. The input signal of gain stage amplifier and voltage output gain signal shows in the figure-2.18 below:

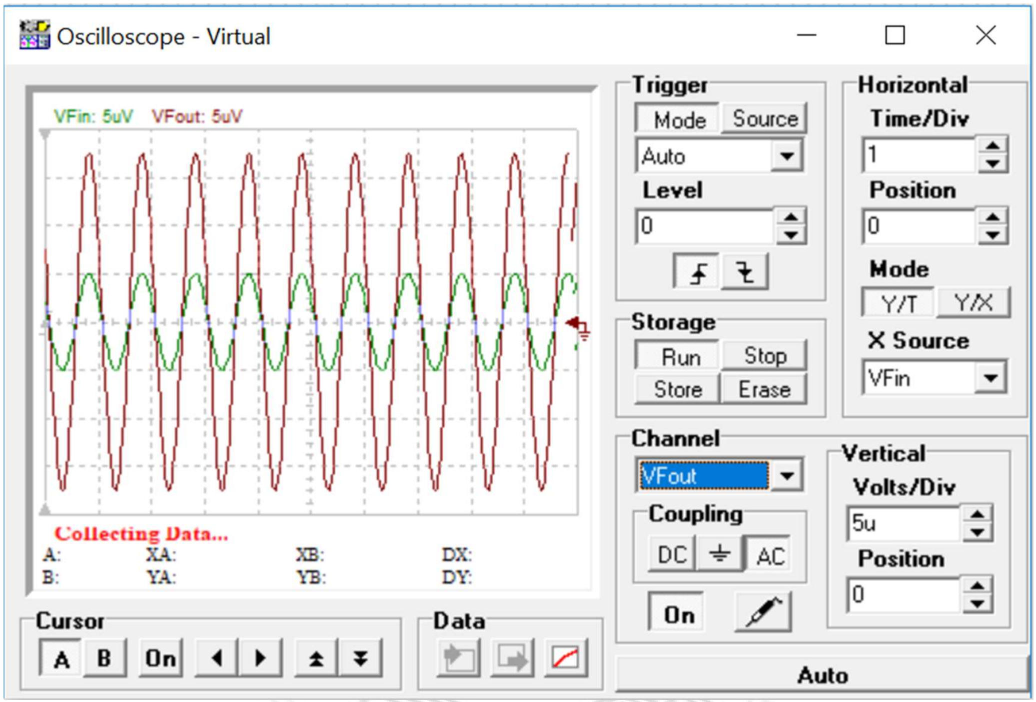
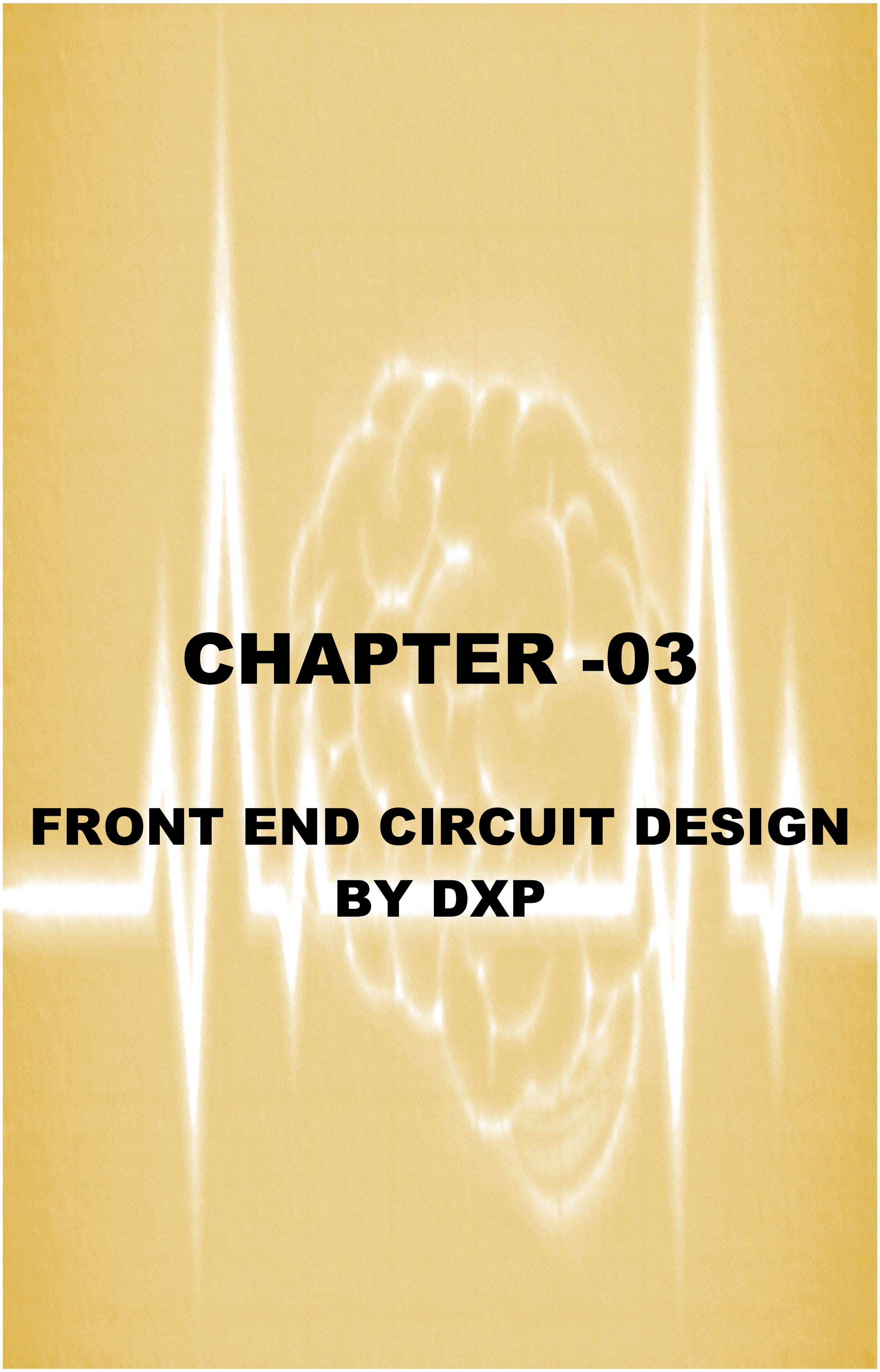


Figure 2.18: Gain stage amplifier output signal on oscilloscope.

EEG signals is very easily affected due to interference of the power frequency and the radio frequency, and these signals are easily into input through pins 4 and 5 the brain electrode in the pin configuration figure, which can be suppressed by improving the amplifier resistance. For INA 333, the voltage gain of resistance when access to pins 1 and 8 more than 100 dB, common mode rejection ratio is greater than 120dB, the circuit is up to 200dB, to meet the EEG of common mode rejection ratio of not less than the requirements of 120 dB.



CHAPTER -03

FRONT END CIRCUIT DESIGN BY DXP

3.1. PROPOSE METHOD FOR EEG SIGNAL ACQUISITION:

The signal acquisition circuit system has included signal amplifying as pre-amplifiers, filters design, gain amplifiers and so on. The acquired EEG signal is amplified using precision instrumentation amplifier INA 333 (TINA IT). An outstanding the conventional electrode has been used for this system. Three electrodes are sufficient to acquire EEG signal compared to 10-20 system. It is less complicated in terms of analysis and data processing. In our system, we will use disposable metal buckle electrodes. One electrode is placed at the center of the forehead as a reference electrode. Two electrodes are placed at the left and right of the forehead. The left electrode is connected to the inverting terminal (pin 1) and the right electrode is connected to the non-inverting terminal (pin 2) of the system. The electrodes will be connected to the device via buffer amplifiers or voltage followers.

3.2. Schematic Circuit Diagram:

The schematic diagram of EEG circuit system added the different part of Instrumentation amplifier, the INA333 is a low-power, zero-drift instrumentation amplifier offering excellent accuracy. The versatile three operational amplifier design and small size make the amplifiers ideal for a wide range of applications. Zero drift chopper circuitry provides excellent DC specifications. Driven right leg circuit, biological signal amplifiers to reduce Common-mode interference added with instrumentation amplifier. Biological signal amplifiers such as Electroencephalogram circuits measure very small electrical signals emitted by the body, often as small as several micro-volts (millionths of a volt). Unfortunately, the patient's body can also act as an antenna which picks up electromagnetic interference, especially 50/60 Hz noise from electrical power lines. This interference can obscure the biological signals, making them very hard to measure. Right Leg Driver circuitry is used to eliminate interference noise by actively cancelling the interference.

The schematic diagram of EEG signal processing circuit is showed below:

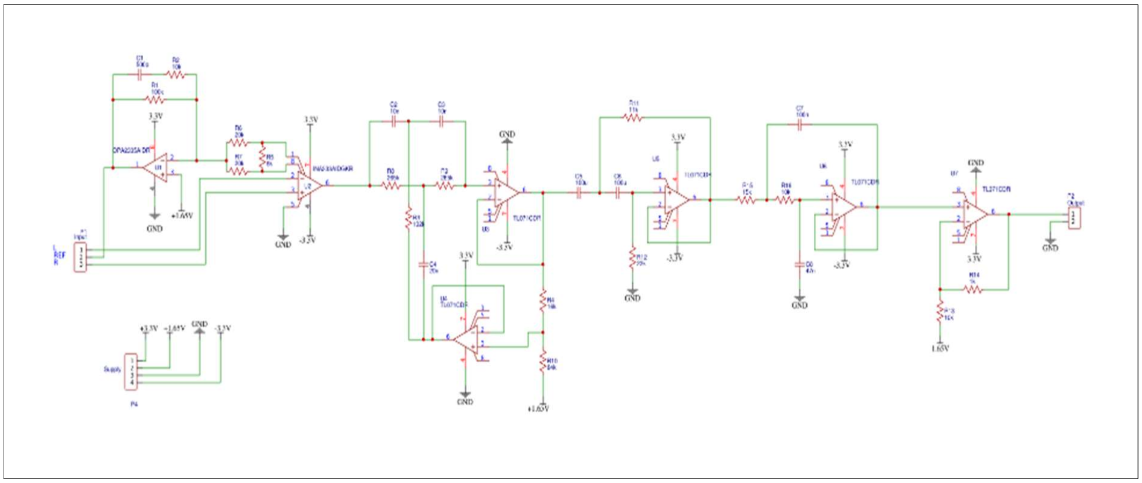


Figure-3.1: Schematic diagram of EEG signal acquisition system circuit

A band stop filter is connected with instrumentation amplifier that passes most frequencies unaltered, but attenuates those in a specific range to very low levels. Band pass filter is designed as like the T shape notch filter because this band-stop filter with a narrow stop band but it has high Q factor. The notch filter is used to pass very narrow bandwidth band stop filter, it has a gain which drops and then rises very steeply with increasing frequency and so the magnitude response has the shape of a notch. In addition, this filters are used to block a narrow range of wavelengths.

A band pass filter has been added along with band stop filter for signal processing and used to allow wanted frequency components from the signals and to remove unwanted ones. The background noise of the interfacing signal can be reduced by eliminating some frequencies, which is known as filtering. Filter circuits designed to combine the properties of the low pass filter and high pass filter into a single filter. The different types of filters include active or passive, time variant or time invariant, linearity-linear or non-linear, analog or digital, and so on. The main objective of this filter is transmitted to limit bandwidth.

3.3. Printed Circuit Board (PCB) Design:

There are some basic PCB concepts before start teaching on software. First of all, there must be an idea about circuit and PCB. PCB talks about the manufacturing process, not the circuit design. So even if a person don't know much about circuit design, just make sure you have a working circuit diagram, basically it can make a PCB board. If once maker, as long as once have mastered some Design Rule, he can also do their own board. However, you must first make sure there is a circuit diagram that can be "worked". First we need to verify the circuit with a whole plate or use a breadboard to insert a plug. When the Layout PCB arrives, the IC part can be selected for the SMD version, because the processing fee will be straightforward in mass production.

To complete a PCB board, it can basically be divided into three stages, in fact, it is also a workflow. The first phase of the circuit diagram is drawn, the second phase of the circuit layout, and the third phase is the establishment of the BOM table and the preparation of materials and hand soldering samples. However, the drawing of the circuit diagram in the first stage is rarely done by the PCB Layout by designer, but by the circuit design. The work of Layout was started after the circuit was converted to Net-list. At most, in this stage can get the circuit diagram only got the PDF file. If a person is the Maker by himself, his PCB needs to be laid out multi-layers or high-speed, RF, antenna such as high frequency. This is already a pro professional level. It is not easy to go without expert guidance. Didn’t have too many measuring instruments, and some are unlikely to do it by myself.

Printed circuit board (PCB) is the manufacturing process of device. Mechanically supported and electrically connected electronic components using conductive tracks, pads and other features etched from one or more sheet layers of copper laminated between sheet layers of a non-conductive substrate.

Components are generally soldered on to the printed circuit board (PCB) to both electrically connect and mechanically fasten them to it. Printed circuit boards are used in all but the simplest electronic products.

Before starting the PCB design we must check those following steps to complete work smoothly.

- ❖ PCB board design and planning.
- ❖ PCB sample test.
- ❖ PCB product certification operation.
- ❖ Familiar with surface adhesion technology.
- ❖ PCB sample follow-up test and test.
- ❖ Electronic parts product information collection.
- ❖ Daily inspection and preliminary investigation of abnormal conditions.
- ❖ Perform EMC/EMI safety test verification and reporting.
- ❖ Perform product reliability testing and problem analysis.

Printed circuit board layout for proposed EEG acquisition system circuit showed below:

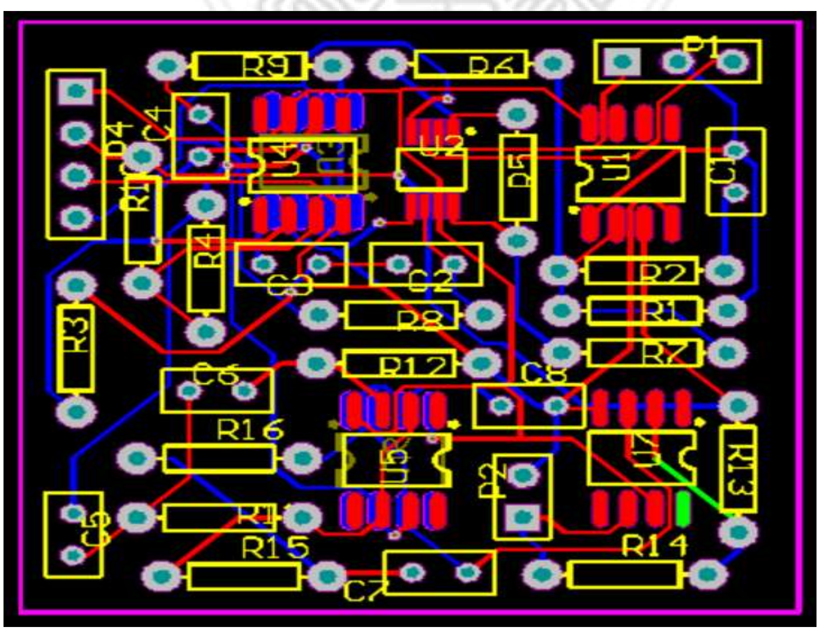


Figure-3.2: Printed circuit board layout for EEG signal acquisition circuit.

For experimental verification, a printed circuit board (PCB) has designed and assembled to provide off-chip bias voltages and currents, regulated supply voltage for individual blocks and logic control bits. A differential driver IC, with a gain is employed on the board to generate a differential input signal from the single-ended function generator and dynamic signal analyzer. Capacitors are connected between the output of the driver and the inputs of the IA in order to block DC voltages at the differential driver outputs. The pest pin of PCB layout is P1 that is set on the top right side of the PCB layout design.

While drawing PCB layout we need to consider some operational and safety issues:

- PCB Layout according to product designers.
- Designed products must comply with international safety certification standards such as electromagnetic interference.
- Generate a net list according to the schematic diagram of the electronic circuit, and cooperate with the product structure conditions and the PCB constraint specification document.
- Perform PCB layout and layout work and generate all the files needed for PCB production.
- Establish and maintain a package library of components, organize the review of PCB layout.
- Assist hardware engineers in PCB board debugging.

CHAPTER -04

RESULTS AND DISCUSSION

4. Results and Discussion

EEG signal acquisition system circuit design, spectrum analysis has been in this paper, and another part is device development to achieve the Electroencephalography (EEG) signal acquisition system for future Brain Computer Interface (BCI) applications. In this part we prepared schematic circuit design, spectrum analysis of signals. The FEC of each consists of an off-the-shelf instrumentation amplifier gain=17.6, and output voltage V_O= 2971mV an active notch filter f_c = 60Hz, 2nd order active Butterworth low-pass filter followed by a passive low pass filter f_c = 47.5 Hz, gain = 1.61 and a passive high pass filter f_c = 0.16 Hz.

Table-02: Data comparison table:

Experiment and Result Comparison	**Neuro-Monitor: A low-power, wireless, wearable EEG device with DRL-less AFE (Other paper)**	**Front-end circuit design for electroencephalography (EEG) signal (My Experiment)**
Driven Right Leg Circuit (DRL)	DRL circuit eliminated from instrumentation amplifier	DRL circuit added with instrumentation amplifier
T-win-T notch filter	Notch (fc) = 60 Hz, − 38 dB	Notch (fc) = 60 Hz, − 38.9 dB
Low-pass filter	Cut off frequency fc = 125 Hz	Cut off frequency fc= 122Hz
High pass filter	Cut off frequency fc= 0.5 Hz	Cut off frequency fc=0.16Hz
Overall gain	55.84 dB	48.50 dB
PCB Size	11.135 cm^2	Less than 5.5 cm^2
Gain	19.7	17.6

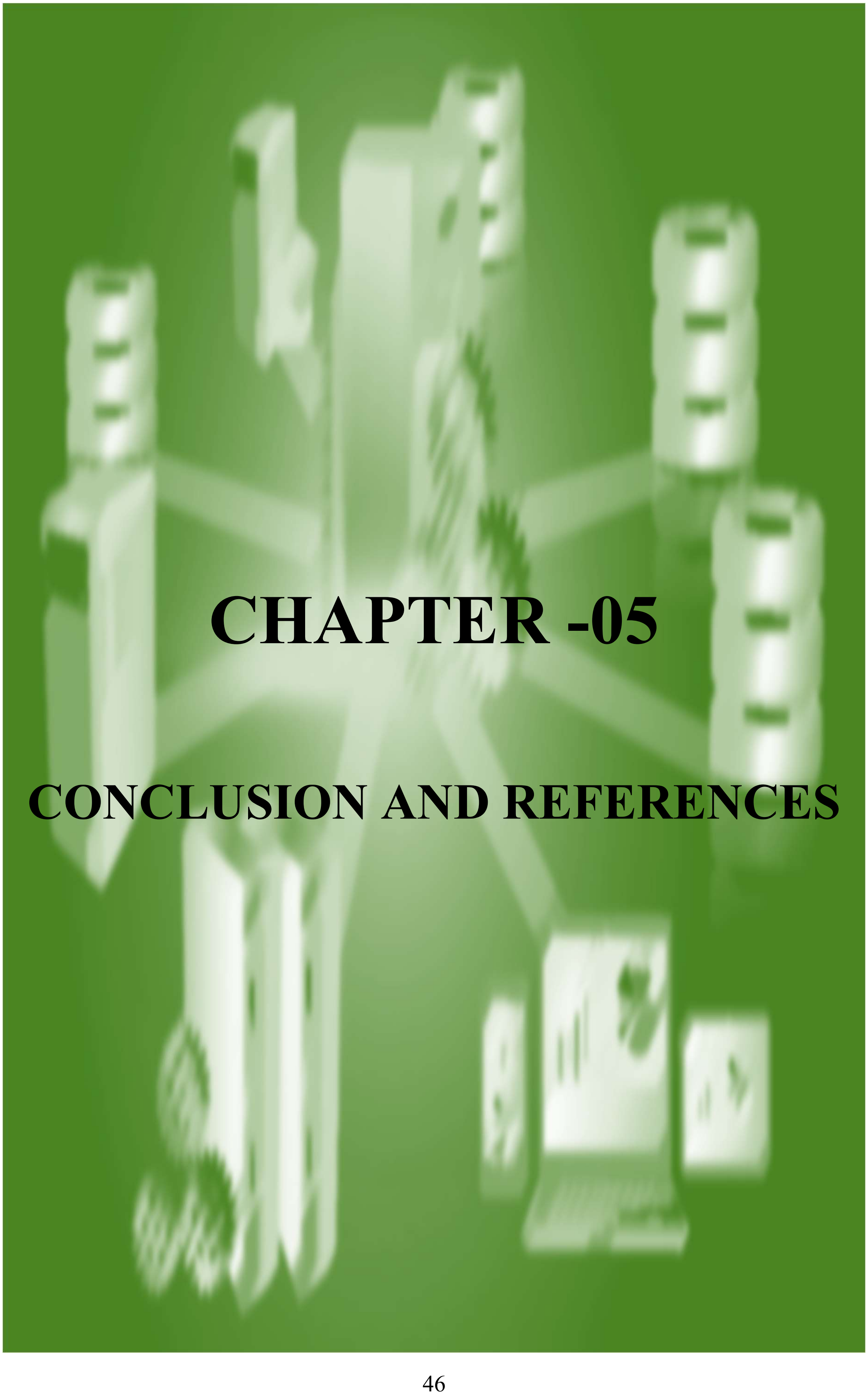
In this case, we used Instrumentation amplifier INA333 and DRL circuit that have high common moor rejection ratio. The gain of instrumentation amplifier gain is sillier with my work and others value of component also almost similar. But they didn't added DRL circuit with instrumentation amplifier. After completed the EEG signal acquisition system designing and implementation to PCB (printed circuit board) designing the next step is acquisition of the EEG signal. The acquisition system has been done by using the TINA TI and Altium designer will be used to design PCB layout.

Electrodes read the signal from the head surface, amplifiers bring the microvolt signals into the range where they can be digitalized accurately, converter changes signals from analog to digital form, and personal computer stores and displays obtained data. Scalp recordings of neuronal activity in the brain, identified as the EEG, allow measurement of potential changes over time in basic electric circuit conducting between signal electrode and reference electrode. Third electrode is called ground electrode, is needed for getting differential voltage by subtracting the same voltages showing at active and reference points. For the EEG data acquisition, electrodes are to be placed on the frontal region and the positions are Fp1, Fp2 in figure 1.3 on electrode position. For the single channel data acquisition process, positive electrode is placed on the Fp2 position, reference electrode is placed on the Fp1 position and negative electrode is placed on A1 (earlobe) position. The positions are determined according to the international 10-20 electrode system, shows the different position of electrodes on scalp according to the 10-20 electrode system. EEG electrodes are available as gold plated, tin plated, EEG cap, and disposable electrode.

The acquisition circuit has composed as pre-amplifiers, filters design, gain amplifiers and so on. Using this system, the non-successive brain activities such as epilepsy, sleeping disorder and abnormal behavior measured. In this paper, we firstly introduce the EEG characteristics and the overall framework of EEG signal recording circuit. Secondly, we illustrate the details about the experimental circuit. Furthermore, the experiment results showed in the oscilloscope. Finally, the advantages of EEG collection circuit are summarized, and the deficiencies and the future work are discussed. The new generation EEG machines are equipped with many signal processing tools, delicate and accurate measurement electrodes, and enough memory for very long-term recordings. EEG machines may be integrated with other neuroimaging systems such as functional magnetic resonance imaging for the advancement in the field of medical technology and will help in the clinical applications.

Selecting reference electrode point and adding Driven Right Leg (DRL) circuit was most challenging while design Front-end circuit simulation because the electroencephalogram (EEG) are recorded on the oscillations of brain electric potentials acquired from electrodes on the human scalp. Electric potentials are the direct consequence of the existence of electric dipoles created by the postsynaptic potentials generated at apical dendrites of pyramidal cells in the cortex. The poles of the electric dipole can be seen as the source and sink of ionic currents created by the excess and defect of captions at soma and apical dendrites, respectively.

Increasing the number of EEG electrodes used is not trivial, and the increase is not without drawbacks. For high-density EEG systems, data processing can take a significant amount of time, even on large computing clusters. In addition, more electrodes mean higher costs and more difficult experimental setups. Lastly, in experimental setups involving movement and in many real-world settings, wireless transmission of EEG signals is desirable.



CHAPTER -05

CONCLUSION AND REFERENCES

Conclusion

In this paper, we describes the method of constructing an Electroencephalography (EEG) signal acquisition system and circuit has been designed for the signal a question. The EEG signal acquisition system has been trying to improve and the signal quality by using band-pass filter and band-stop filter due to the further use in the brain computer interfacing (BCI) system. We use allow Driven Right Leg circuit, which allows independent channel design for EEG system as for the reference electrode. This was used to utilize a very low-noise, high CMRR instrument amplifier followed by a high-Q active notch filter to suppress the common mode noise. For the development of a real time BCI application, and the use of signal processing is always essential. From the experimental observation it can said that the designed system can be implement for the EEG signal acquisition and storage of data to a PC efficiently. This study included Front-end circuit design for electroencephalography (EEG) signal. First part is circuit simulation and advance study practical experiment. I have finished circuit simulation and got output signals from the schematic diagram. After that I have drown the PCB layout of the circuit.

The future work for this project can be divided into two parts. One part could be to expand the EEG three electrodes practical experiment. Several EEG circuits have constructed for that as each circuit takes in only two input electrodes and one ground electrode. All the circuits could be made on a single Printed Circuit Board (PCB) for as many EEG electrodes that one needs to use as that would reduce the noise in the signal. For further use of the system in case of BCI application, the different signal processing tools like feature extraction by using FFT (Fast Fourier Transform) or Wavelet Analysis and for training of the EEG data set Neural Network or SVM (Sample Vector Machine) would be benefit to involved the use of EEG for clinical diagnosis and monitoring, or even for Brain Computer Interface.

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