AM5023- PHYSIOLOGICAL MEASUREMENTS AND INSTRUMENTATION LABORATORY

BIOMEDICAL SIGNAL PROCESSING - LABORATORY REPORT

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ELECTROCARDIOGRAM MEASUREMENT

AIM:

To understand Electrocardiography (ECG) measurement techniques, principles, and the interpretation of ECG waveforms using limb leads.

OBJECTIVES:

- To understand the anatomy and physiology of the heart and the generation of electrical signals in the cardiac cycle.
- To record and interpret normal and abnormal ECG waveforms using limb leads.
- To understand the clinical significance of ECG measurements.

APPARATUS REQUIRED:

- ECG Machine
- ECG Electrodes (limb electrodes)
- Electrode gel or paste
- ECG paper

THEORY:

Heart:

The human heart is an electrical organ that generates electrical impulses, causing it to contract rhythmically. These electrical impulses can be recorded using an electrocardiogram (ECG). In Einthoven's triangle, the focus is on recording ECG signals using limb leads. Limb leads I, II, and III create a triangle on the body's surface, capturing electrical activity from different angles.

Principles:

- Electrical activity originates in the sinoatrial (SA) node and travels through the heart.
- Limb electrodes placed on the wrists and ankles capture electrical signals, creating Einthoven's triangle.
- Different limb leads provide a comprehensive view of the heart's electrical activity.

- The ECG waveform consists of P, QRS, and T waves, corresponding to atrial depolarization, ventricular depolarization, and ventricular repolarization.

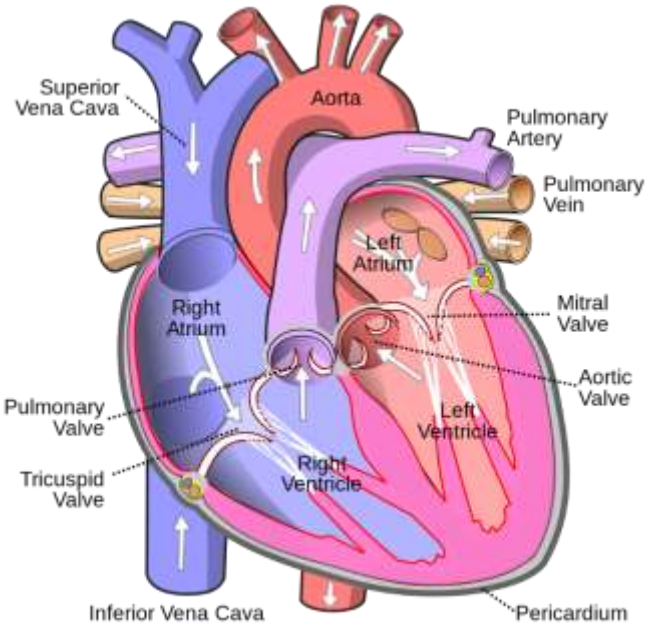


Fig 1. Anatomy of the Heart

METHODS:

1. Preparation:

a) Ensure the ECG machine is functioning correctly and connected to a power source.
b) Check and calibrate the ECG machine if necessary.
c) Clean the skin at the electrode placement sites on the wrists and ankles with alcohol swabs to remove oils and debris.
d) Apply electrode gel or paste to the electrode sites to ensure good electrical contact.
e) Attach limb electrodes to the wrists and ankles as per standard placement.

2. Creating Einthoven's Triangle:

Limb Lead I: Attach one electrode to the right wrist and another to the left wrist.

Limb Lead II: Attach one electrode to the right wrist and another to the left ankle.

Limb Lead III: Attach one electrode to the left wrist and another to the left ankle.

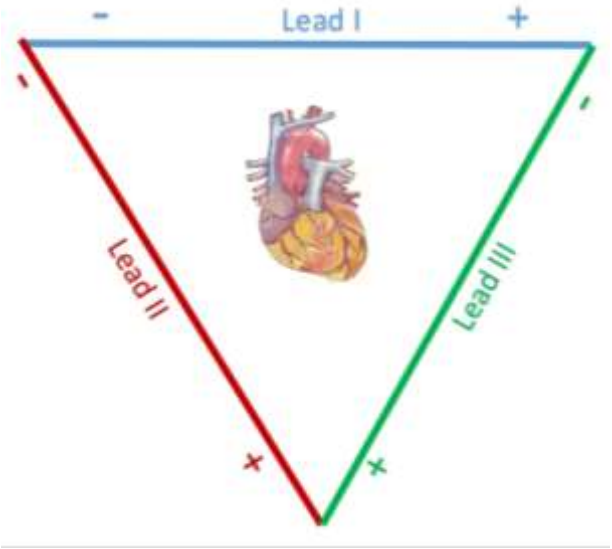


Fig 2. Einthoven's Triangle

3. ECG Recording:

a) Set the ECG machine to standard parameters (paper speed, voltage, lead configuration) if it's not set default.
b) Start the recording and allow the ECG to run for a sufficient duration to capture a representative cardiac cycle.

4. Analysis and Interpretation:

a) Examine the ECG waveform for P waves, QRS complexes, and T waves.
b) Measure the duration and amplitude of these waves.
c) Identify any abnormalities, such as arrhythmias or bundle branch blocks.
d) Interpret the findings based on clinical knowledge and reference materials.

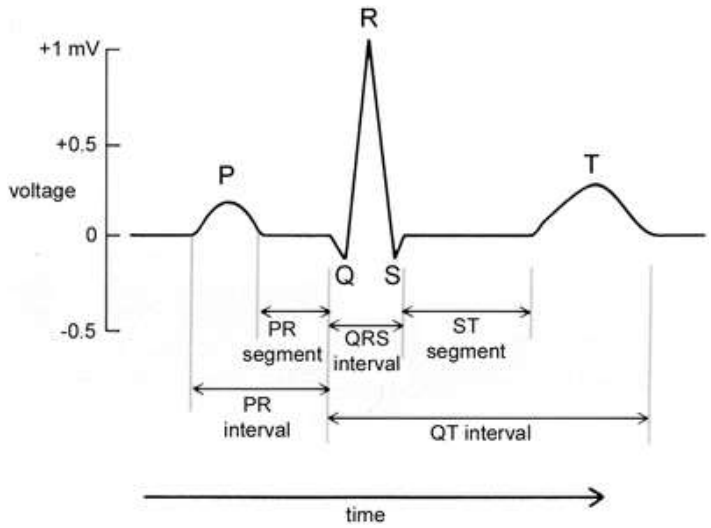


Fig 3. ECG Waveform

Remove electrodes and clean the subject's skin.

Turn off the ECG machine and disconnect all electrodes and leads.

OBSERVATION:

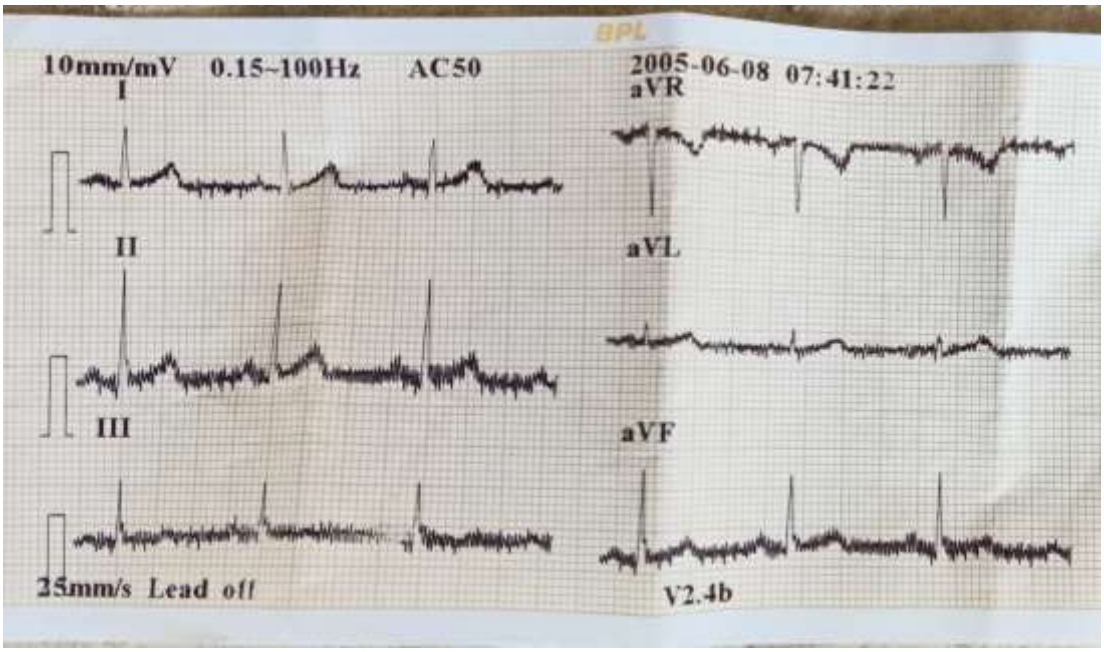


Fig 4. ECG Recording of the subject

Fig 5. Results Obtained

Calculations:

5 major boxes of electrocardiograph = 1 s

1 major box of electrocardiograph = 0.2 s

R-R interval = number of small boxes between the two R peaks x 0.2 s

= 4 x 0.2 = 0.8 s

Heart Rate = 60/ R-R interval

60/0.8 = 75 bpm

CONCLUSION:

Through ECG measurements with limb leads and the application of Einthoven's triangle, we obtained valuable data. Our analysis of the ECG waveforms enabled us to calculate the R-R interval, thus allowing for the accurate determination of the heart rate.

PURE TONE AUDIOMETRY MEASUREMENT

AIM

In this study, we assess an individual's auditory capacity using an audiometer, specifically evaluating their hearing through two methods:

- Bone conduction
- Air conduction.

OBJECTIVE

To gain insight into the proper utilization of an audiometer for evaluating air and bone conduction in an individual with typical hearing.

APPARATUS REQUIRED

- An audiometer (Sau Maico-MA 42) equipped with a pure tone generator
- A bone conduction oscillator designed for cochlear function assessment
- An attenuator for adjusting sound intensity
- A microphone for conducting speech tests
- Headphones for evaluating air conduction

THEORY

The ear, a sophisticated organ responsible for hearing and balance, comprises three main sections: the outer, middle, and inner ear. Its essential components include:

Outer Ear: This section encompasses the visible pinna and the ear canal, which collects sound waves and guides them into the ear canal. Scientifically known as the external acoustic meatus, the ear canal extends from the pinna to the eardrum and features unique skin and tiny hairs that act as filters for dust and dirt.

Middle Ear: Housing the eardrum, ossicles (small bones), and the Eustachian tube connecting to the throat, the middle ear plays a vital role in equalizing air pressure. The eardrum is a thin, cone-shaped membrane that separates the middle ear from the outer ear. When sound waves reach it, it starts to vibrate. Within the middle ear, three tiny bones, namely the hammer (Malleus), anvil (Incus), and stirrup (Stapes), work together to amplify and transmit these vibrations. The hammer is connected to the eardrum, the anvil connects the

hammer to the stirrup, and the stapes, the smallest bone in the human body, connects to the oval window.

Inner Ear: This is a delicate sensory organ containing the cochlea (responsible for hearing), semicircular canals (critical for balance), and the vestibule (responsible for orientation and sensing gravity). The cochlea, resembling a spiral seashell, is filled with fluid and lined with specialized cells that detect sound waves and convert them into electrical signals. This intricate process not only translates sound into neural impulses but also contributes to our overall sense of balance.

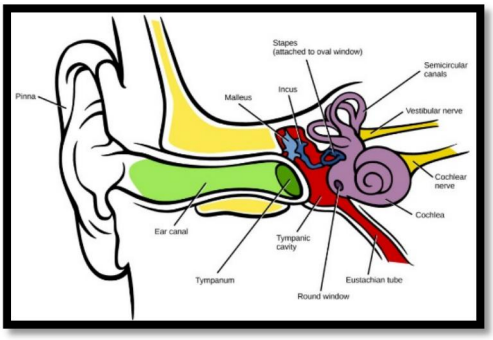


Figure 1. The anatomy of the ear.

TRANSMISSION OF SOUND IN THE COCHLEA

The transmission of sound in the cochlea involves these key steps:

1. Sound Entry: Sound waves enter through the oval window in the cochlea, initially collected by the middle ear's ossicles (hammer, anvil, and stirrup).
2. Cochlear Fluid Movement: Sound waves cause the fluids (perilymph and endolymph) inside the cochlea to move, generating pressure waves along the cochlear duct.
3. Basilar Membrane Vibration: The cochlea's coiled structure includes the basilar membrane, which vibrates in response to fluid waves, with specific regions vibrating to different sound frequencies.
4. Hair Cell Activation: Above the basilar membrane lies the organ of Corti, housing thousands of sensory hair cells. These cells bend when the basilar membrane vibrates, leading to electrical signals.
5. Neural Transmission: Bending hair cells open ion channels, allowing ions to enter and create electrical signals. These signals activate auditory nerve fibers connected to the hair cells.

6. Auditory Pathways: Auditory nerve fibers form the auditory nerve, transmitting impulses to the brainstem and onward to auditory processing centers, such as the auditory cortex, where sound is perceived.

STRUCTURE OF BASILAR MEMBRANE (DIFFERENT FREQUENCIES)

The basilar membrane isn't consistent but varies in stiffness and width, enabling the detection of different frequencies. The basal section near the oval window is sensitive to high-pitched sounds due to its rigidity, while the apical end, farther away, is responsive to low-pitched sounds because it's more flexible. This organization along the basilar membrane influences how we perceive pitch. Auditory nerve fibers transmit these distinctions to the brain, allowing us to recognize and differentiate various pitches and frequencies.

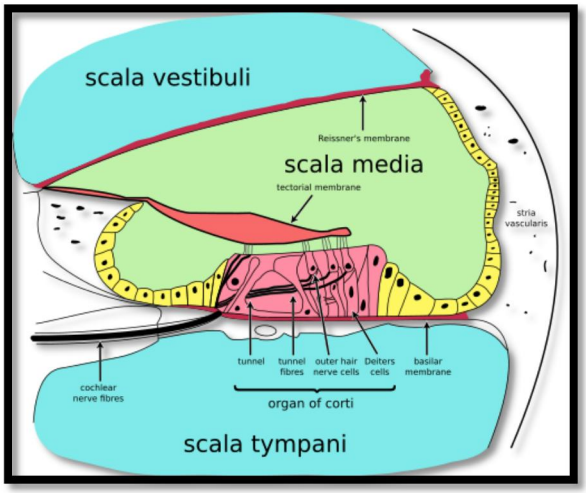


Figure 2. Basilar membrane

AIR CONDUCTION AND BONE CONDUCTION

Air conduction and bone conduction are two different ways that sound travels to the inner ear. With air conduction, sound goes through the ear canal and makes the eardrum vibrate. The middle ear's ossicles then amplify and send these vibrations to the cochlea, where hair cells convert them into signals for the brain. On the other hand, bone conduction doesn't use the outer or middle ear. Instead, it sends vibrations directly to the skull bones, which then stimulate the cochlea. This method is helpful in cases of conductive hearing

loss or issues with the outer or middle ear, letting people hear sounds without the usual air-conducted route.

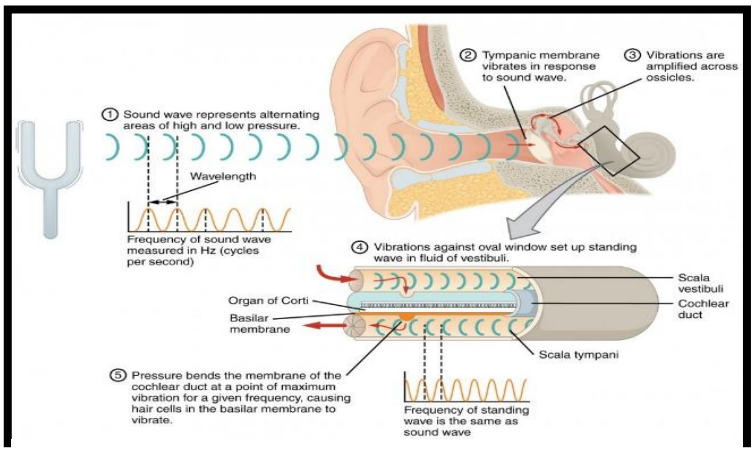


Figure 3. Air and bone conduction

AUDIOMETRY

The electric audiometer, a 1930s innovation, is vital for precise hearing assessment, measuring thresholds across a frequency range of 125 to 8,000 Hz. It includes an oscillator, amplifier, and attenuator. The audiogram, with "zero dB" marking normal hearing, is the international standard since 1964. Pure-tone audiometry involves separate ear tests in a quiet room, with subjects signaling when they hear a tone 50% of the time. Thresholds, like a 40-dB level for 4,000 Hz, help shape an audiogram, crucial for hearing issue diagnosis. The audiogram highlights hearing levels by frequency, vital for diagnosis in cases of hearing difficulties. It also incorporates bone conduction for assessing middle ear transmission issues and explores recruitment.

Figure 4. Audiometer

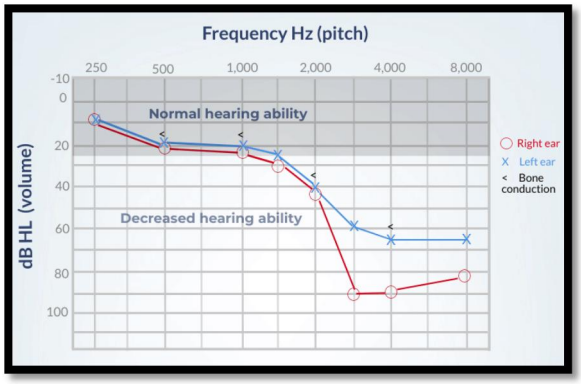


Figure 5. Frequency heard by right and left ear respectively.

METHODOLOGY

1. **Seating Position:** The individual should be comfortably seated at a minimum distance of 1 meter (about 3.3 feet) from the audiometer device. This distance is maintained to prevent any proximity-related influence on the individual's responses during the hearing test.
2. **Ear Clarity:** Prior to the test, it is essential to ensure that there are no obstructions interfering with the proper placement of the earphones over the patient's ears. Any items like hats or eyeglasses that might impede the correct fit of the headphones should be removed.
3. **Proper Headphone Placement:** Verify that the headphones are correctly positioned over the person's ears to guarantee an accurate test. For the bone conduction, it should be on the mastoid bone.
4. **Earphone Color Coding:** Employ a color-coded system to differentiate the right ear from the left ear. Typically, the red earphone is placed over the right ear, and the blue earphone is placed over the left ear, ensuring consistency and accuracy in the testing process.
5. **Headband Adjustment:** Adjust the headband of the headphones to ensure that the receivers (the speakers within the earphones) are positioned at the correct height, ensuring a secure and comfortable fit for the patient.

Reading:

Patient Response Switch: Advise the individual to activate the patient response switch or button when they detect a tone, even if it's faint. This is necessary to ensure accurate recording of the patient's responses by the audiologist.

RESULTS

CONCLUSION

Air Conduction

A typical hearing sensitivity pattern is evident, with lower frequencies requiring higher sound intensities (in dB) for audibility, while higher frequencies are heard at lower intensities.
Remarkably good hearing sensitivity at 8000 Hz is observed, with an incredibly low minimal audible level of 0 dB.

BONE CONDUCTION

Sensitivity to bone conduction varies across frequencies, with some frequencies showing better sensitivity (lower minimal audible levels) and others indicating poorer sensitivity (higher minimal audible levels).
An unusual occurrence at 4000 Hz in the right ear shows negative minimal audible levels, potentially suggesting a testing artifact or issue.

These findings provide valuable insights into the individual's hearing thresholds at different frequencies. However, the variations in bone conduction results may warrant further examination or reevaluation to ensure data accuracy. A comprehensive interpretation and clinical assessment are necessary to determine the implications of these results for the individual's overall hearing health.

DESIGN OF INSTRUMENTATION AMPLIFIER

AIM

To design an instrumentation amplifier and assess its amplification ability for biomedical signals.

OBJECTIVE

- Design the instrumentation amplifier meeting the specifications of voltage gain, input impedance, output impedance, CMRR and bandwidth suitable for amplifying the biomedical signals.

APPARATUS REQUIRED

- LM 324
- Resistors
- Function Generator and Oscilloscope
- Breadboard and connecting wires

THEORY

An instrumentation amplifier is a kind of differential amplifier that can be built with three operational amplifiers, as shown in Fig1. It is used to amplify very low-level signals, rejecting noise and interference signals. The essential characteristics of a good instrumentation amplifier are as follows:

1. Inputs to the instrumentation amplifiers will have low signal energy. Therefore,
2. it should have high and accurate gain
3. The gains should be easily adjustable using a single control.
4. It must have high input impedance and low output impedance to prevent
5. loading.
6. It should have high CMRR since the transducer output will usually contain
7. common mode signals, such as noise when transmitted over long wires.
8. It must also have a high slew rate to handle sharp rise times of events and
9. provide maximum undistorted output voltage swing

PROCEDURE

- Design instrumentation amplifier for suitable gain:

Gain= R3/R2[1+(2R1/Rgain)]

- Rig up the circuit as per Fig.1, using IC741's and the designed R1, R2, R3 and Rgain resistors.
- Use a Function generator to feed input voltages and an oscilloscope to measure the output voltage of the instrumentation amplifier.
- Find the differential mode voltage gain Ad=VoutV1-V2 by using the output voltage Vout obtained due to the unequal voltages V1 and V2 at the input of the instrumentation amplifier.

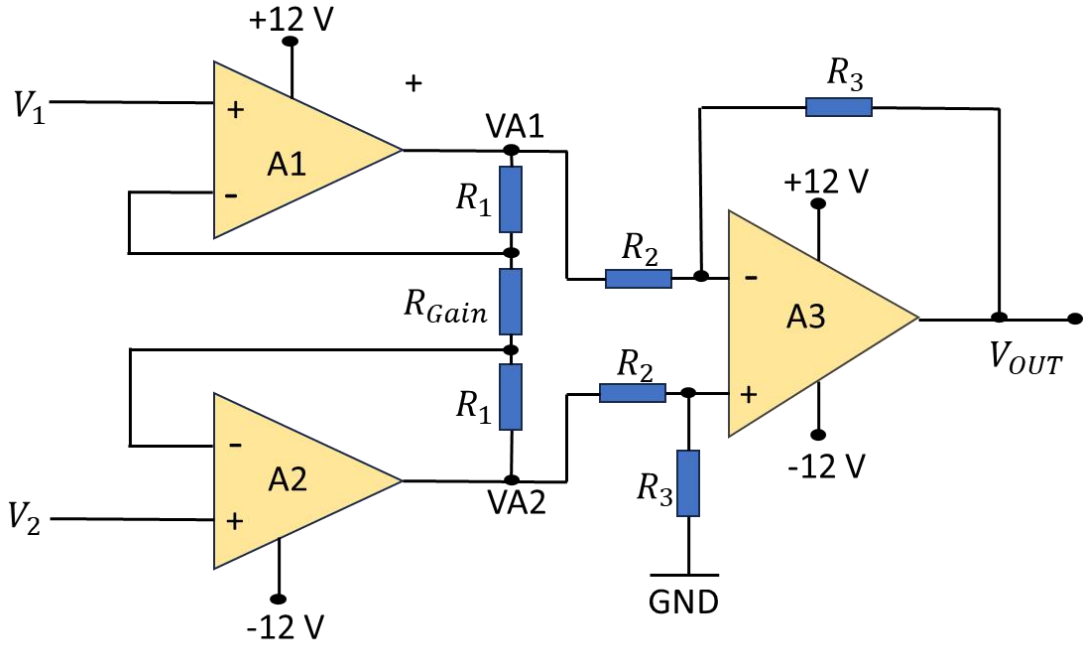


Figure 1. Instrumentation Amplifier

- Find the common mode gain voltage Ac= Vout/V, by feeding a common voltage to the V1 and V2 terminals of Fig.1.
- Compute the common mode rejection ratio CMRR = Ad/Ac

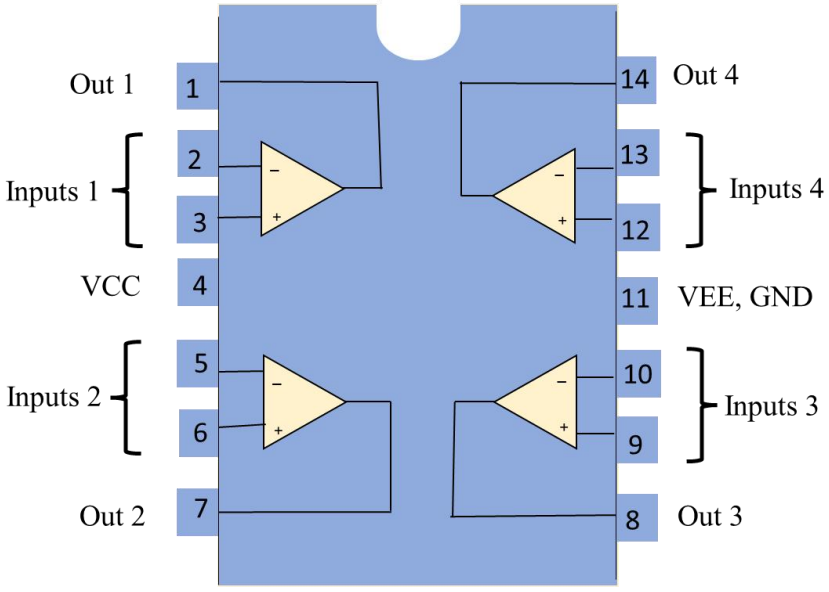


Figure 2. Pin Diagram of LM324

- Measure input impedance of the instrumentation amplifier by connecting the additional resistor, Rtest at the non-inverting terminal of one of the input op-amp by giving the non-inverting terminal of other input op-amp as shown in Fig.3.

Input Impedance = Rtest (V2/(V1-V2))

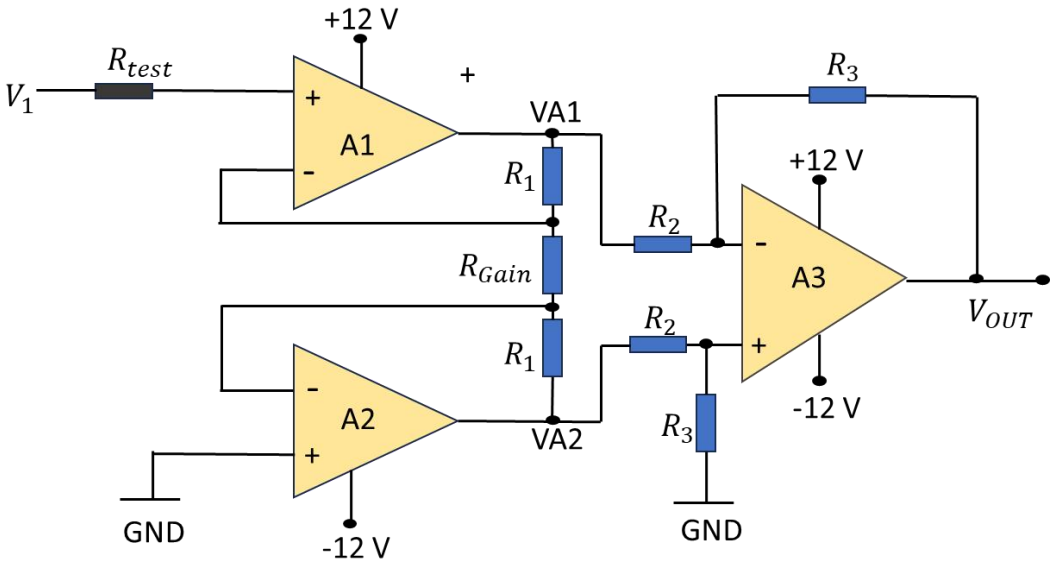


Figure 3. Measuring the input impedance of Instrumentation Amplifier

- Measure the output impedance of instrumentation amplifier by connecting a load resistor Rload at the output terminal Out, as shown in Fig.4.

Output Impedance = Rload ((Vopen/Vload)-1)

Where Vopen is the open circuit output voltage measured at terminal Out when Rloadis not connected, and Vload is the voltage measured at terminal Out when Rload is connected.

- Plot the frequency response characteristics by measuring the gain of the amplifier at frequencies range from 100Hz to 10KHz and calculate the bandwidth value.

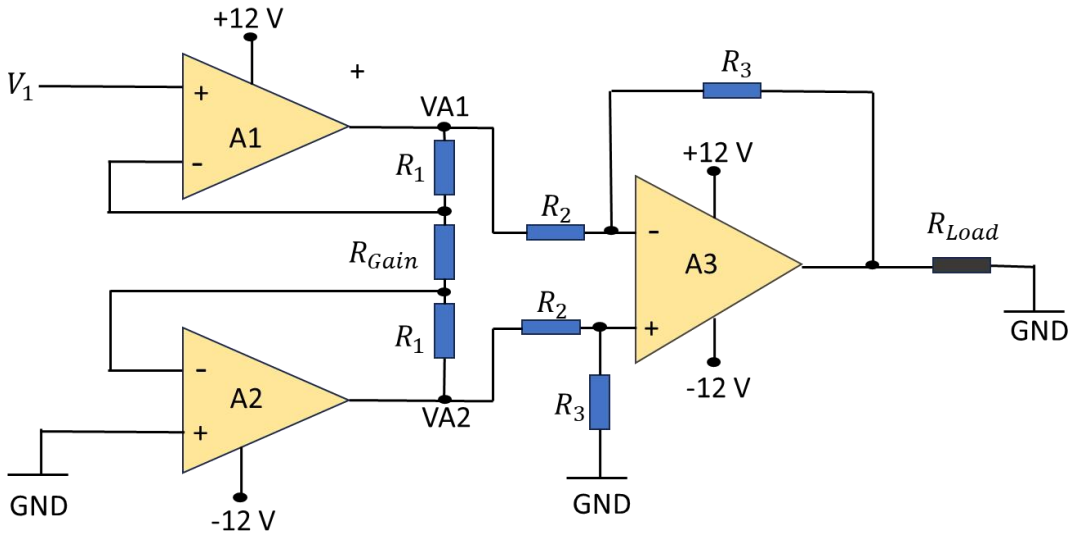


Figure 4. Measuring the output impedance of Instrumentation Amplifier

RESULTS & OBSERVATION

i. For gain =100, the resistors R1= 100kΩ, R2 = 100kΩ, R3 = 100kΩ and Rgain= 2kΩ
ii. Differential mode voltage gain Ad = 93.3
iii. Common mode voltage gain Ac = 0.06.
iv. CMRR = Ad/Ac= 93.3/0.06= 1555
v. Input Impedance = 13.65 kΩ & Output Impedance = 500Ω.
vi. Frequency Response for Vin = 30 mV

Table 1: Frequency Response

Frequency	Output voltage
200Hz	2.8 V
500 Hz	2.8 V
1 kHz	2.8 V
2 kHz	2.8 V
5 kHz	2.6 V
10 kHz	2.2 V

20 kHz	1.6 V
50 kHz	0.8 V
100 kHz	0.5 V
200 kHz	0.4 V
300 kHz	0.4 V
500 kHz	0.3 V
1 MHz	0.3 V

Upper cut-off frequency fH= 13.6 kHz, Lower cut-off frequency is fL is 0 Hz and -3dB bandwidth = fH-fl = 0 to 13.6 kHz.

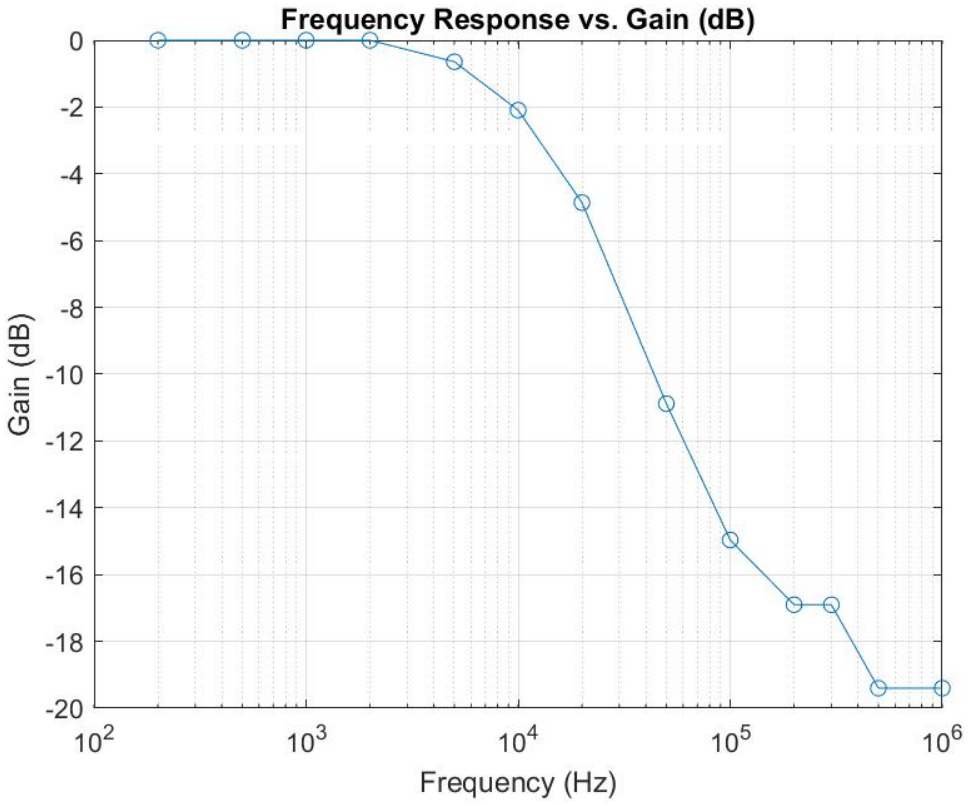


Figure 5. Frequency response of the instrumentation amplifier.

MATLAB CODE

```
frequency = [200, 500, 1000, 2000, 5000, 10000, 20000, 50000, 100000,
200000, 300000, 500000, 1000000];
voltage = [2.8, 2.8, 2.8, 2.8, 2.6, 2.2, 1.6, 0.8, 0.5, 0.4, 0.4, 0.3, 0.3];

reference_voltage = 2.8;
gain_dB = 20 * log10(voltage ./ reference_voltage);
semilogx(frequency, gain_dB, 'o-');
xlabel('Frequency (Hz)');
ylabel('Gain (dB)');
title('Frequency Response vs. Gain (dB)');
grid on;
```

CONCLUSION

The preamplifier meets the requirements necessary for acquiring bio signals is designed.

SSVEP ANALYSIS OF EEG

AIM

To understand the steady state visually evoked potentials (SSVEPs) from EEG during visual stimulation

OBJECTIVE

To obtain the frequencies in the EEG signal using MATLAB

APPARATUS REQUIRED

- EEG
- System with visual stimulation
- Electrode gel
- Laptop
- MATLAB software

THEORY

SSVEPs, or steady-state visually evoked potentials, refer to brain signals that align with the frequency of a visual stimulus, typically one that flickers consistently. This rhythmic stimulus has the ability to synchronize neural activity in the occipital lobe, which is closely linked to the visual cortex. Properly executed, the correlation between the frequency of the neural activity and the flickering stimulus allows for real-time determination of which stimulus a participant is observing. This is achievable by presenting a selection of stimuli flickering at distinct rates, with each SSVEP uniquely corresponding to the observed stimulus. In neuroscience, clinical neurology, and psychology, SSVEPs serve as an objective biomarker, particularly in studies related to the visual system. Additionally, SSVEPs are widely utilized in the realm of Brain-Computer Interface (BCI) research due to their reliability, accuracy, high information transfer rate, straightforward setup, and minimal training requirements.

PRINCIPLE OF EEG

EEG, or electroencephalogram, is a non-invasive neuroimaging technique that records electrical activity in the brain. The principle behind EEG is based on the detection and measurement of electrical potentials generated by the synchronized activity of large groups of neurons. Electrodes are placed on the scalp to capture the collective electrical signals produced by neural firing.

As neurons communicate with each other, they generate electrical impulses. These electrical signals produce voltage fluctuations that can be detected on the scalp. EEG measures these voltage changes over time, providing a dynamic representation of brain activity.

TYPES OF EEG WAVES

EEG recordings reveal different types of brain waves, each associated with specific mental states, activities, or conditions. These waves are categorized based on their frequency and amplitude. The main types of EEG waves include:

1. **Delta Waves (0.5-4 Hz):**
    - Delta waves are slow, high-amplitude waves.
    - They are typically associated with deep sleep and certain pathological states.
2. **Theta Waves (4-8 Hz):**
    - Theta waves are slower than alpha waves and are associated with drowsiness, relaxation, and the early stages of sleep.
3. **Alpha Waves (8-13 Hz):**
    - Alpha waves are present during relaxed wakefulness and are dominant in the posterior regions of the brain.
    - They are often associated with a state of calmness and alert relaxation.
4. **Beta Waves (13-30 Hz):**
    - Beta waves are associated with active, alert, and focused states of consciousness.
    - They are prominent during tasks requiring attention and mental effort.
5. **Gamma Waves (30-40 Hz and above):**
    - Gamma waves are associated with higher cognitive functions, including perception, learning, and problem-solving.
    - They are involved in integrating information across different brain regions.

Understanding the patterns and variations of these EEG waves provides valuable insights into brain function, cognitive states, and neurological disorders.

10-20 ELECTRODE PLACEMENT

The 10-20 system is a standardized method for electrode placement in electroencephalography (EEG). This system is widely used to ensure consistency in electrode positioning across different individuals. The name "10-20" refers to the fact that electrodes are placed at intervals of either 10% or 20% of the total front-back or right-left distance on the scalp. The distances are measured based on the individual's head circumference.

Electrodes are labeled with letters to denote their specific locations, such as F (frontal), C (central), P (parietal), O (occipital), and T (temporal). Common electrode sites in the 10-20 system include Fp1, Fp2, F7, F8, F3, F4, C3, C4, P3, P4, O1, O2, T3, T4, T5, and T6, among others. This standardized system facilitates consistency in EEG data collection and analysis across different research studies and clinical settings. It ensures that electrodes are placed in similar locations on the scalp for different individuals, allowing for meaningful comparisons and interpretations of EEG recordings.

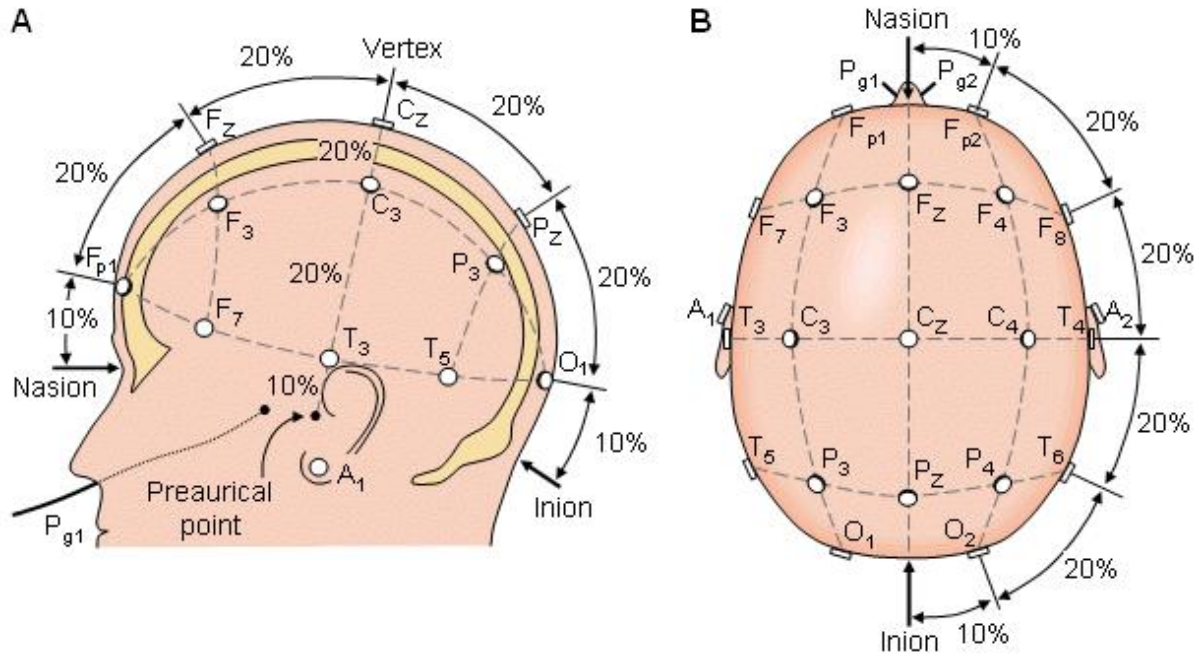


Figure 1: 10-20 electrode placement

METHOD

- The EEG electrode is placed at the occipital lobe, using the 10-20 electrode placement principle.
- The subject is allowed to rest and sit still with no disturbances
- The subject is asked to sit in front of an screen which shows flickering cubes at different rates.

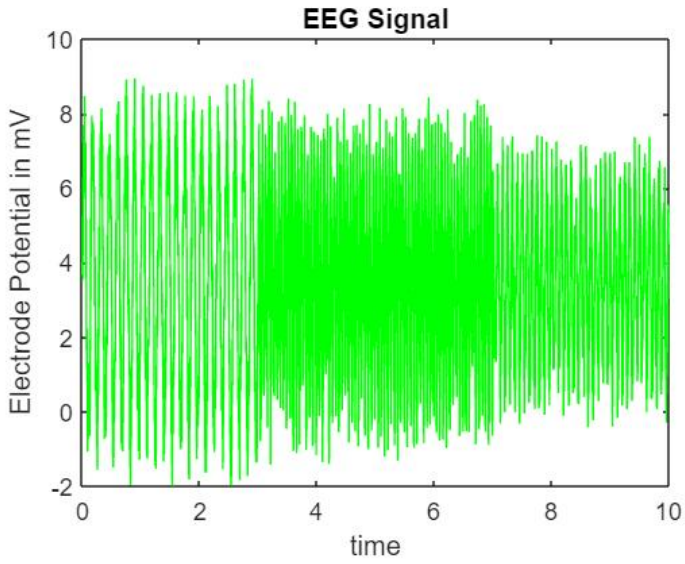
- The subject is asked to focus at one of the cubes and then is asked to change his focus to another square without informing.
- The EEG signal is recorded at a sampling rate of 250 Hz.

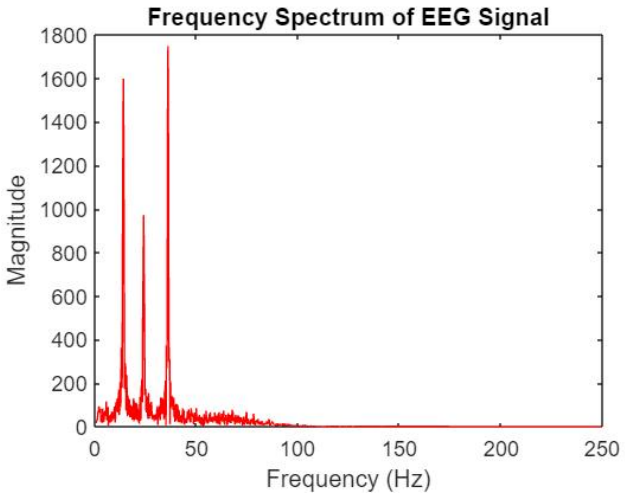
MATLAB CODE

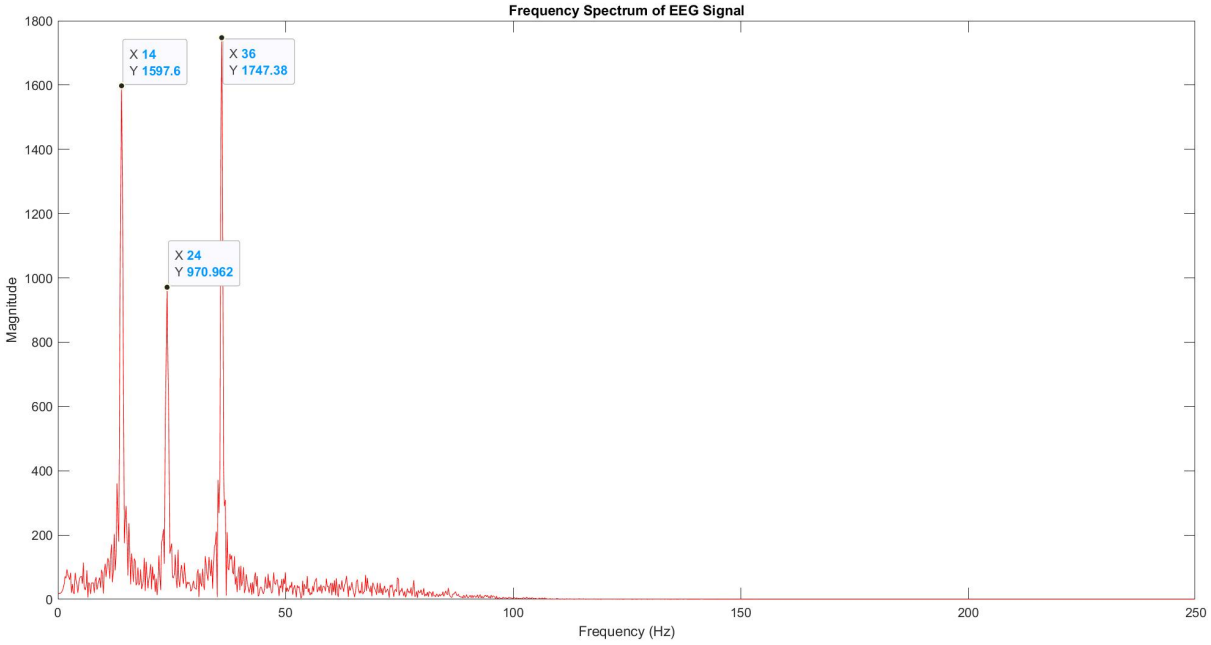
```
clear all;
close all;
clc;
% Load EEG data from .mat file
data=load("F:\IITM\Physiological measurements lab\EEGRAW.mat");
my_data=data.AM23M025;
time=(1:length(my_data))/250;
% Example: Bandpass filter between 1-30 Hz
figure();
plot(time,my_data);
title('EEG Signal');
ylabel('Electrode Potential in mV');
xlabel('time');

%sampling rate is 250 Hz
low_freq = 1;   % Set your desired low cutoff frequency in Hz
high_freq = 40;  % Set your desired high cutoff frequency in Hz
sampling_rate=250;
% Design a bandpass filter
[b, a] = butter(4, [low_freq, high_freq]/(sampling_rate/2), 'bandpass');

% Apply the bandpass filter
eeg_data_filtered = filtfilt(b, a, my_data);
% Example: Calculate FFT for each epoch
fft_data = fft(eeg_data_filtered);
% Example: Find peaks in the FFT
fft_result = fft_data(1:length(fft_data)/2); % Keep only the positive frequencies
% Calculate the frequency axis
% Calculate corresponding frequencies
frequencies = (0:length(fft_result)-1)*(sampling_rate/length(fft_result));

% Plot the spectrum
figure;
plot(frequencies, abs(fft_result));
xlabel('Frequency (Hz)');
ylabel('Magnitude');
```

```
title('Frequency Spectrum of EEG Signal');
% Identify SSVEP frequencies
% You may need to set a threshold or use peak detection to identify SSVEP
frequencies

% Example: Assume SSVEPs occur between 5 and 20 Hz
ssvep_min_freq = 5;
ssvep_max_freq = 20;
ssvep_indices = find(frequencies >= ssvep_min_freq & frequencies <=
ssvep_max_freq);
ssvep_magnitudes = abs(fft_result(ssvep_indices));

% Identify the dominant SSVEP frequency
[max_magnitude, max_index] = max(ssvep_magnitudes);
dominant_ssvep_frequency = frequencies(ssvep_indices(max_index));

fprintf('Dominant SSVEP Frequency: %.2f Hz\n', dominant_ssvep_frequency);
```

RESULTS







RESULT

Dominant SSVEP Frequency: 14.00 Hz and 36.00 Hz.

From the frequency spectrum, we can find three major peaks at **14Hz, 24 Hz and 36 Hz.**

CONCLUSION

In this experiment, we used EEG to obtain the steady-state visually evoked potentials and then used MATLAB to obtain the dominant frequency in the spectrum of the EEG signal. This can be used in brain computer systems to execute tasks.