ELECTROENCEPHALOGRAM (EEG) MEASUREMENT 4

EXPERIMENT 4: ELECTROENCEPHALOGRAM (EEG) MEASUREMENT

4.0 PURPOSE OF THE EXPERIMENT

The purpose of this experiment is to help students understand electrical activity in the human brain. Subjects' electroencephalogram (EEG) measurements will be taken, interface signals will be observed, and the effects of visual stimulation on the α-wave will be tested.

4.1 PHYSIOLOGICAL PRINCIPLES

The human cerebral cortex contains numerous neurons that excite in synchrony, creating specific rhythmic behaviors. Potential changes occurring in the cerebral cortex can be recorded with a pair of electrodes placed on the skull.

These potential changes consist of electrical rhythms and spontaneous discharges, and are called electroencephalograms (EEGs). EEG signals can be classified according to their measurement locations, frequency ranges, amplitudes, signal waveforms, periods, and the movements that cause the signal.

When externally stimulated, EEGs are synchronized. Meanwhile, EEGs are affected by varying degrees of arousal. Different periods of sleep lead to different EEG characteristics. In the clinic, EEGs are used as a diagnostic tool for epilepsy and to diagnose death.

Technical problems related to amplitude are often encountered in measuring EEG signals. When the EEG signal passes through the dura, cerebrospinal fluid, and skull into the scalp, its peak-to-peak amplitude is only around 1-100μV, and its frequency is in the range of 0.5-100Hz. Furthermore, the electrode material and degree of contact also affect the measurements. During experimental procedures, an unexpected amount of noise interferes with the EEG. In general, EEGs can be divided into four types of waveforms based on frequency range, as shown in Table 4.0 and Figure 4.1.

Table 4.0. EEG waveforms based on frequency range.

Delta	δ	0.5-4 Hz	It is observed in the 3rd and 4th phases of the Non-Rapid-Eye Movement period during deep sleep and is associated with serum, a conductive substance.
Theta	θ	4-8 Hz	It usually occurs in adults and children when they are angry.
Alpha	α	8-13 Hz	It is seen when people are attentive and close their eyes to rest.
Beta	β	13-22 Hz	It is seen when the human nervous system is active (in a thinking state).

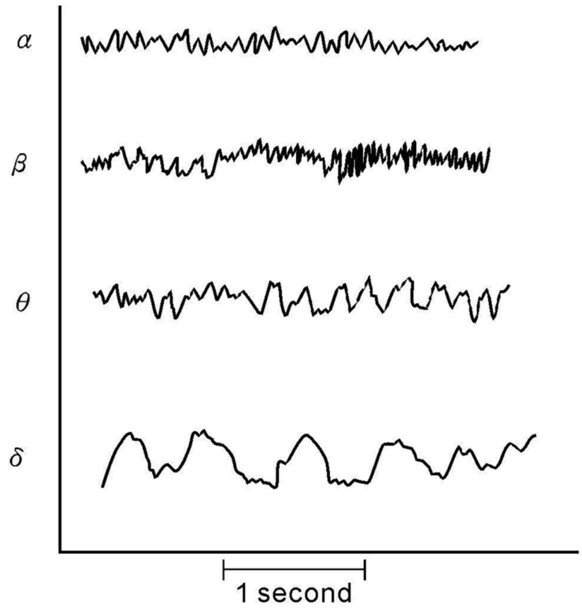


Figure 4.1. Typical EEG waveforms

In the clinic, the location of the electrodes directly affects the amplitude, phase, and frequency of the EEG. Suitable locations for electrode placement are the frontal, parietal, temporal, or occipital lobes. The most preferred placement scheme is the 10-20 EEG electrode placement system, recommended by the International Federation of EEG Societies (see Figure 4.2). In this system, the boundaries for electrode locations are the root of the nose, the nasal (top of the nose), and the inion bones of the occipital lobe (back of the neck). This divides the skull surface into left and right sections. The ears serve as boundaries that divide the skull surface into front and back sections. Three EEG signal measurement modes are available: unipolar, averaging, and bipolar modes; see Figure 4.3. For simplicity, only the bipolar mode will be used in this experiment. Figure 4.4 shows the electrode locations in the frontal and ear lobes. F_{p2} and A_1 are used for EEG signals, and F_{p1} is used for the reference potential.

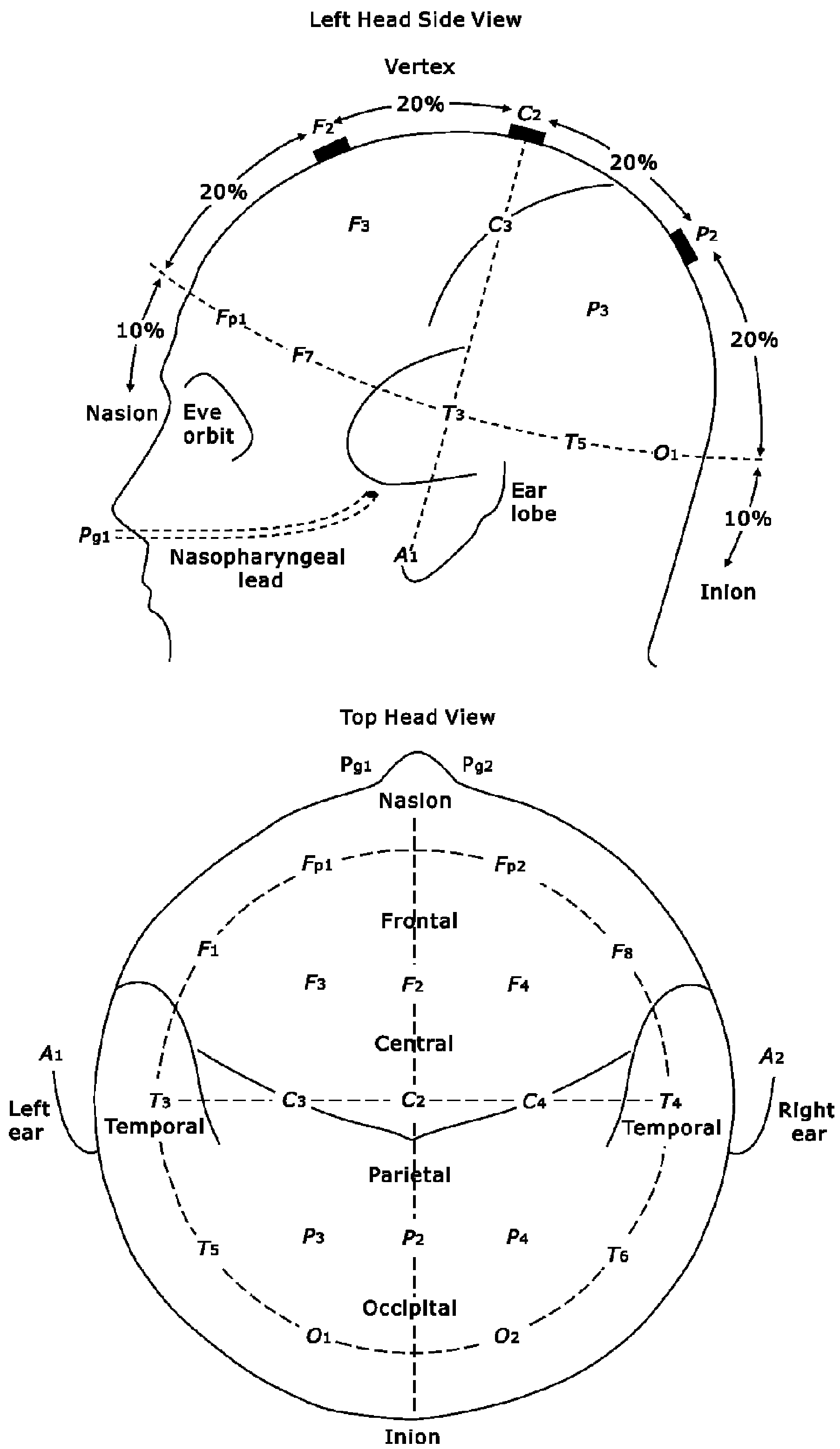


Figure 4.2 the 10-20 EEG electrode placement system

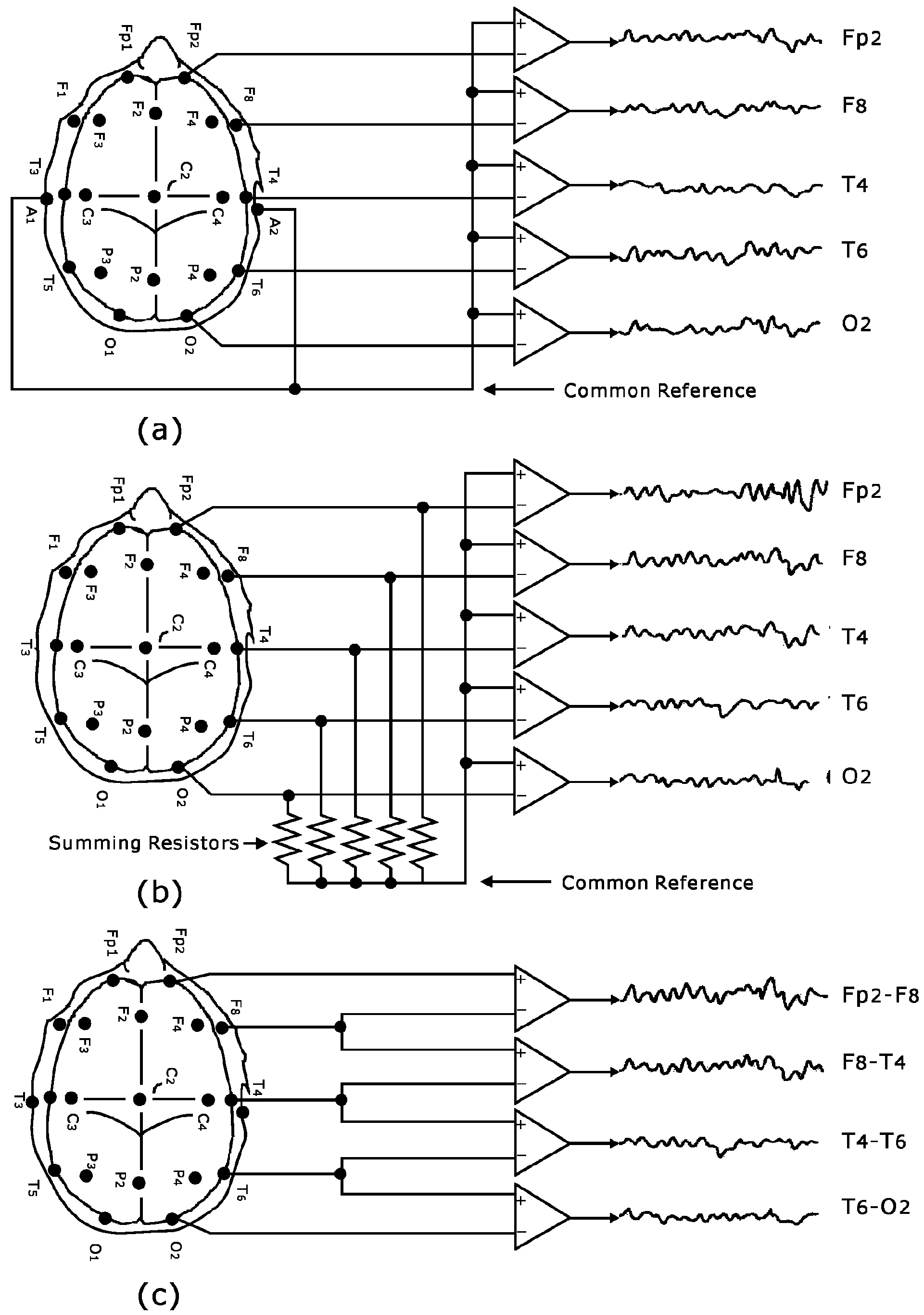


Figure 4.3 EEG Measurement Modes; (a) Unipolar, (b) Average, (c) Bipolar

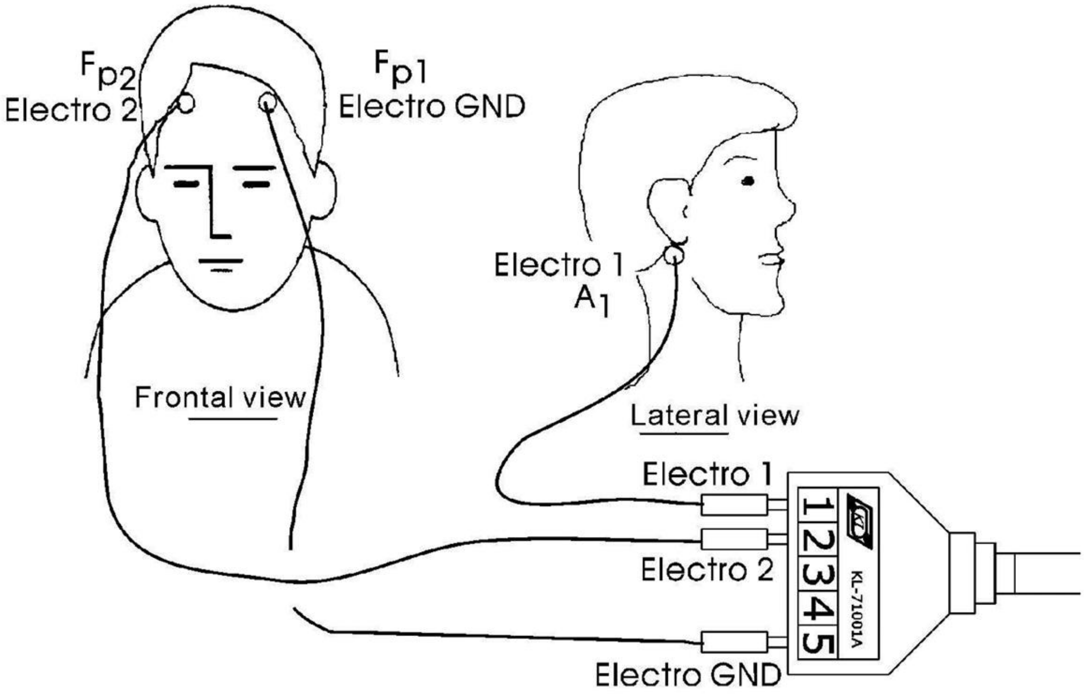


Figure 4.4 Electrode Locations

4.2 CIRCUIT DESCRIPTION

1. EEG Measurement Circuit Block Diagram

As explained in the previous section, EEGs are obtained from potential changes in the cerebral cortex and consist of electrical rhythms and spontaneous discharges. Different parts of the cortex control different physiological functions.

Therefore, the EEG recorded from one cortical region will not be the same as that obtained from a different cortical region. In the experiment, scalp hair makes it difficult to attach the electrodes to the appropriate locations, making EEG measurement difficult.

Therefore, electrodes should be placed at points F_{p1}, F_{p2}, and A_1 (Figure 4.4), with F_{p1} selected as the potential ground. Insulation should be considered in the design of the EEG measurement circuit to protect against electrical shocks caused by leaks in the power supply or measurement devices. Figure 4.5 shows the EEG measurement circuit block diagram.

Surface electrodes were used to measure the very weak alpha waves generated by light stimulation of the eye. An arrhythmic alpha wave occurs when the eyes are open or closed.

An instrumentation amplifier with a gain of 50 was used as a preamplifier to detect the unipolar component of the EEG signals.

A JFET operational amplifier was used to match the impedance between the electrode and the circuit. The function of the isolation circuit is to isolate the signal and the power supply line, which can be achieved by optical or voltage conversion methods. The band-pass filter has a bandwidth of 1-20 Hz.

The gain amplifier amplifies the weak signal from the filter by a factor of 1000. The amplified EEG signal can be sent directly to an oscilloscope for display.

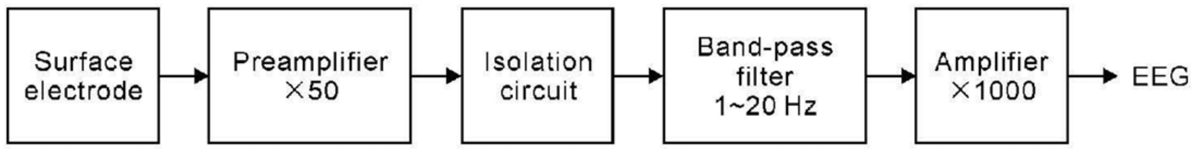


Figure 4.5 EEG Measurement Circuit Block Diagram

2. Pre-amplifier Circuit

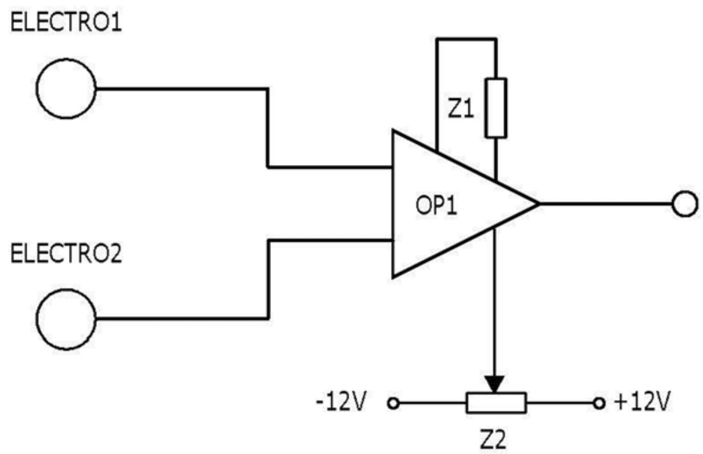


Figure 4.6 Preamplifier.

Figure 4.6 shows the preamplifier circuit consisting of OP1 instrumentation amplifiers (AN620). The preamplifier gain can be calculated using Equation 4.1. Pin 5 of the OP1 integrated circuit is the voltage reference input. The potential obtained from Z2 can be used to adjust the output voltage drift and set the output to zero.

$$Av = \frac{49.4k\Omega}{Z_1} \tag{4.1}$$

3. Isolation Circuit

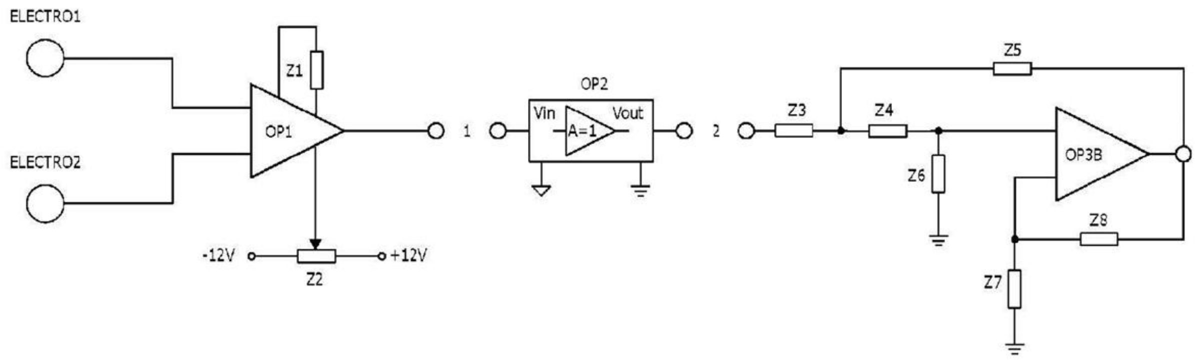


Figure 4.7 Isolation Circuit

Figure 4.7 shows the isolation circuit implemented with OP2. Here, isolation is achieved using the optical method.

4. Band-Pass Filter Circuit

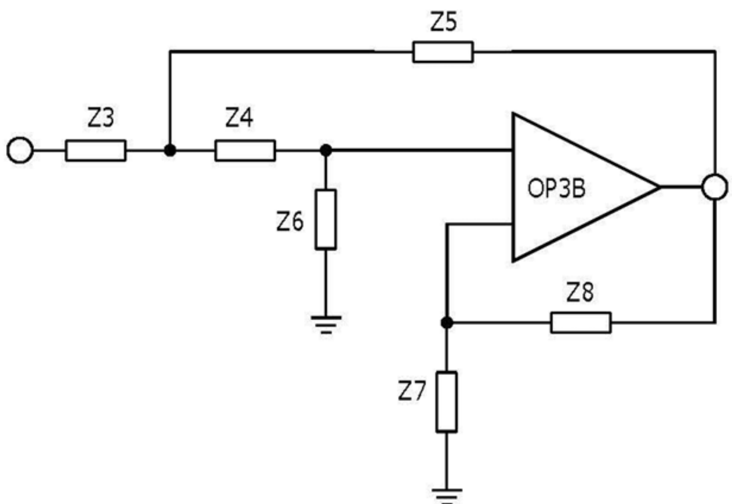


Figure 4.8 2-Order High Pass Filter

In the EOG measurement circuit design, OP3B was used to create an active 2-order high-pass filter, Figure 4.8. The corner frequency of the filter was set to 1 Hz, and the corner frequency (f_H) can be calculated using Z3, Z4, Z5, and Z6, as shown in Equation 4.2.

$$f_H = \frac{1}{2\pi\sqrt{Z_3 Z_4 Z_5 Z_6}} \quad (4.2)$$

Pole designs are explained in Equation 4.3.

$$\frac{(Z_7 + Z_8)}{Z_8} = 1.51 \quad (4.3)$$

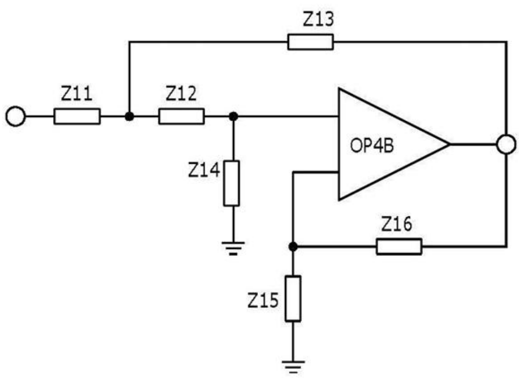


Figure 4.9 2-Order Low Pass Filter

In the EEG measurement circuit design, OP4B was used to create an active 2-order low-pass filter, Figure 4.9. The corner frequency of the filter was set to 20 Hz. The corner frequency (f_L) can be calculated using Z11, Z12, Z13, and Z14, as shown in Equation 4.4.

$$f_L = \frac{1}{2\pi\sqrt{Z_{11} Z_{12} Z_{13} Z_{14}}} \quad (4.4)$$

Pole designs are given in Equation 4.5.

$$\frac{(Z_{15} + Z_{16})}{Z_{15}} = 1.51 \quad (4.5)$$

5. Amplifier Circuit

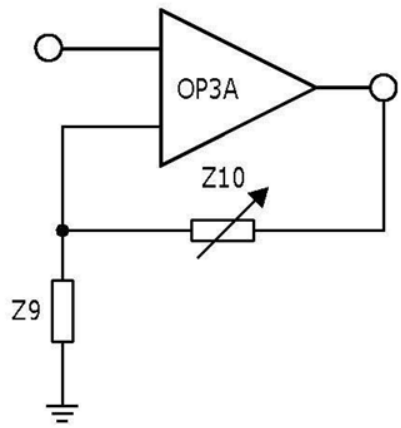


Figure 4.10. Gain Amplifier

Figure 4.10 shows a non-inverting amplifier implemented using OP3A. In the amplifier, Z10 is used for gain adjustment, as expressed in Equation 4.6.

$$Av = \frac{(Z_9 + Z_{10})}{Z_9} \quad (4.6)$$

4.3 REQUIRED EQUIPMENT

1. KL-71001 Main Controller
2. KL-73004 Experiment Module
3. Surface Electrodes
4. EEG Simulator (Additional Equipment)
5. Digital Memory Oscilloscope (Additional Equipment)
6. Cleaning Cloth (Swab)
7. 10 mm Connector Plugs
8. Electrode Cable
9. Hub
10. D-Sub 9-9 Cable

4.4 HOW TO CONDUCT THE EXPERIMENT

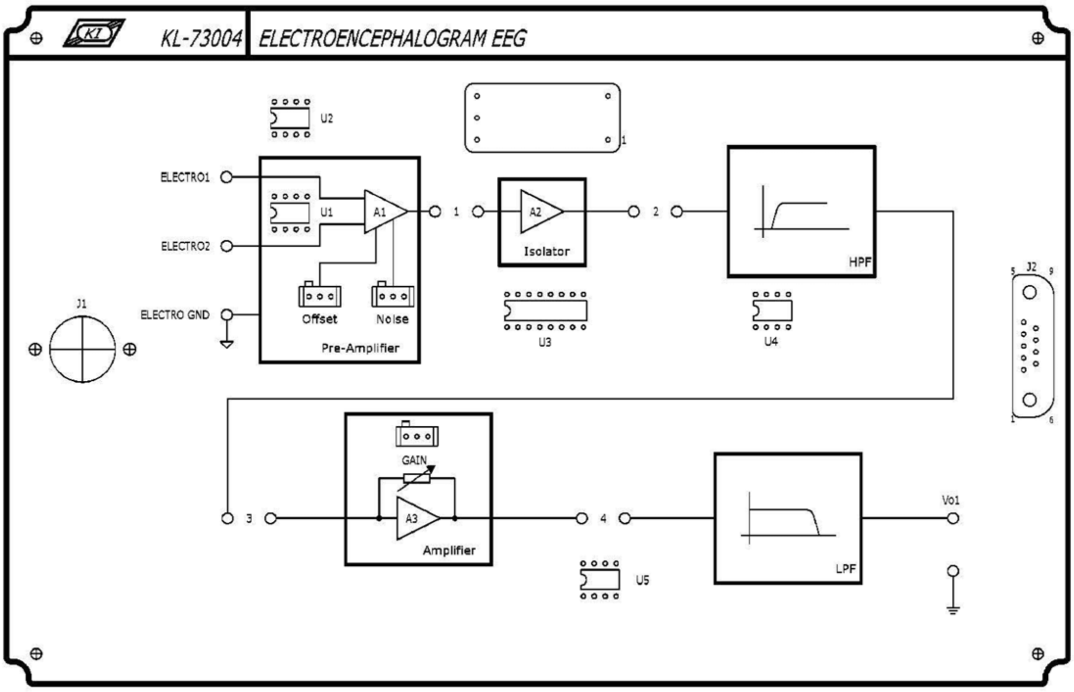


Figure 4.11 EEG Measurement Module

1. Preamplifier Calibration Experiment

(1) Connect the J2 connector of the KL-73004 to the MODULE OUTPUT terminal of the KL-71001. There is no need for a connector plug between any two circuit blocks.

(2) Using the connecting cables, connect the 'ELECTR01' and 'ELECTR02' terminals to the left ground terminal (ELECTRO GND terminal). Measure the 'Preamplifier' output terminal with a Digital Meter.

Set the output voltage to zero by changing the SVR value of the Offset. Connect the negative terminal of the Digital Meter to the 'ELECTRO GND' terminal.

(3) Disconnect the connecting cables.

2. High-Pass Filter Characteristics Experiment

(1) Connect the J2 connector of the KL-73004 to the MODULE OUTPUT terminal of the KL-71001. There is no need for a connector between any two circuit blocks.

(2) Connect the function generator output of the KL-71001 to terminal '2' of the KL-73004, and the GND terminal of the KL-71001 to the right ground terminal of the KL-73004. Set the sinusoidal frequency of the function generator to its maximum value and its amplitude to 1 Vpp. Connect the function generator output to the CH1 channel of the oscilloscope, and the HPF output terminal to the CH2 channel of the oscilloscope.

(3) Adjust the frequency to various values and record the output amplitude of the high-pass filter in the space shown in Table 4.1 in the Results section.

(4) Using the results in Table 4.1, plot the characteristic curve of the high-pass filter at the location shown in Table 4.2 in the Results section.

3. Amplifier Experiment

(1) Connect the J2 connector of the KL-73004 to the MODULE OUTPUT terminal of the KL-71001. There is no need for a connector between any two circuit blocks.

(2) Connect the function generator output of the KL-71001 to terminal '3' of the KL-73004, and the GND terminal of the KL-71001 to the right ground terminal of the KL-73004. Adjust the gain to its minimum value by turning the variable resistor counterclockwise. Connect the function generator output to the CH1 channel of the oscilloscope, and the "Amplifier" output terminal to the CH2 channel of the oscilloscope.

(3) Set the sinusoidal frequency of the function generator to 100Hz and its amplitude to 50mVpp. Record the amplifier output amplitude in the location shown in Table 3.4 in the Results section.

(4) Change the amplifier gain and record the amplifier output amplitude in the location shown in Table 4.3 in the Results section.

(5) If the amplifier output is in the saturation region, reduce the function generator output amplitude to prevent distortion.

4. Low-Pass Filter Characteristics Experiment

(1) Connect the J2 connector of the KL-73004 to the MODULE OUTPUT terminal of the KL-71001. There is no need for a connector between any two circuit blocks.

(2) Connect the function generator output of the KL-71001 to terminal '4' of the KL-73004, and the GND terminal of the KL-71001 to the right ground terminal of the KL-73004. Set the sinusoidal frequency of the function generator to its minimum value and its amplitude to 1 Vpp. Connect the function generator output to the CH1 channel of the oscilloscope, and the LPF output terminal to the CH2 channel of the oscilloscope.

(3) Adjust the frequency to various values and record the output amplitude of the low-pass filter in the location shown in Table 4.4 in the Results section.

(4) Referring to the results in Table 4.4, plot the characteristic curve of the low-pass filter in the location shown in Table 4.5 in the Results section.

5. Simulated EEG Experiment

**Refer to the EEG simulator output as the standard.

(1) Connect the J1 connector of the KL-73004 to the hub, and connect the J2 connector to the MODULE OUTPUT terminal of the KL-71001. Connect the terminals marked 1, 2, 3, and 4 with the connectors. Connect the Vo1 output terminal to the oscilloscope and set the oscilloscope input coupler to the AC coupler position.

(2) Use the INPUT SELECT button on the KL-71001 (see the LCD screen) to select the KL-73004 module. The IN1, IN2, and IN5 LEDs on the KL-71001 front panel will light. This indicates that the input signals should be connected to these input terminals.

(3) Connect the output of the EEG simulator to the hub. ELECTR01 →IN1, ELECTR02 →1N2, ELECTRO GND →IN5.

(4) Set the EEG simulator frequency to 10Hz. Record the Vo1 output in the location shown in Table 4.6 in the Results section.

(5) Set the EEG simulator frequency to various values and record the changes in the Vo1 output.

(6) Adjust the variable resistor to bring the amplifier gain to its midpoint.

6. Real EEG Experiment (EEG signals are recorded by a digital storage oscilloscope)

** EEG experiment on the human body

(1) Connect the J1 connector of the KL-73004 to the hub, and connect the J2 connector to the MODULE OUTPUT terminal of the KL-71001. Connect the terminals marked 1, 2, 3, and 4 with the connectors. Connect the Vo1 output terminal to the oscilloscope.

(2) Use the INPUT SELECT button on the KL-71001 to select the KL-73004 module (see the LCD screen). The IN1, IN2, and IN5 LEDs on the KL-71001 front panel will light up. This indicates that the input signals should be connected to these input terminals.

(3) Refer to Figure 4.12 and connect the electrodes to the Fp1, Fp2, and A1 regions.

(4) Ask the subject to sit comfortably, look forward, and remain calm.

(5) Measure the preamplifier output terminal with a digital meter. Adjust the SVR offset value so that the output is zero. If the noise is too high, reduce the noise amplitude by adjusting the resistors.

(6) Set the oscilloscope input coupling to AC. Set the voltage scale to 5V/div and the time scale to 500ms/div.

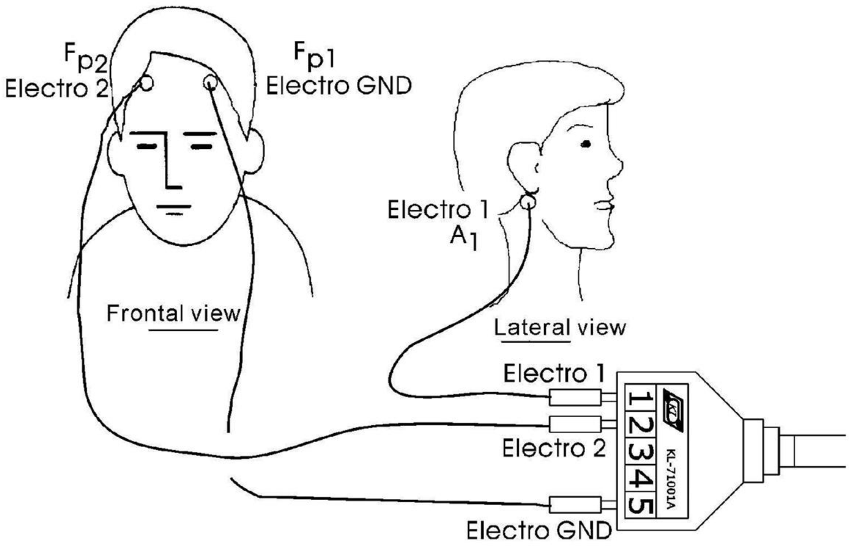


Figure 4.12 Electrode Locations

Note:

A. When recording EEG waveforms, there are three important factors that affect them:

(a) EMG caused by face or scalp movement

(b) Electrode movement, especially the front electrode, may not make sufficient contact with the frontal lobe due to head movement

(c) EOG caused by eye movement.

B. During the experiment, because EEG signals are very small, the electrode cables must be neat and clean, and the subject must be asked to remain calm. The device should also be operated by another student.

C. If the noise in the α-wave is very large, it may be due to high impedance between the skin and the electrodes. The electrodes should be repositioned. Wipe the skin with a cleaning cloth to remove oil from the skin or apply gel to the electrodes, which will lower the impedance.

D. If the output signal is very small, set the gain to x1000. To do this, simply unplug the connector from the point marked 4 and plug it into the point marked 5.

(7) Noise Test:

Ask the subject to open and close their eyes repeatedly and record a 5-10-second EEG recording with an oscilloscope. Record this waveform in the area shown in Table 4.7 in the Results section. If the noise is excessive, minimize it by adjusting the variable resistor.

(8) Ask the subject to move their eyes up and down, then left and right. Continue this movement for 5-10 seconds. Record the EEG waveform in Table 4.8 in the Results section. The head should remain still while the eyes move.

(9) Ask the subject to turn their head slightly and repeat this movement. Record the 5-10-second EEG waveform in Table 4.9 in the Results section.

(10) Observe the alpha wave in the EEG signals and examine the effect of eye opening on the EEG. Ask the subject to remain calm and close their eyes. Record the 10-second waveform with an oscilloscope, and record the waveform in Table 4.10 in the Results section.

(11) Ask the subject to remain calm and open their eyes. Record the 10-second waveform with an oscilloscope, and record the waveform in Table 4.11 in the Results section.

(12) Compare the results of steps (10) and (11). Is there a difference in amplitudes? If so, what is the reason?

7. Real EEG Experiment (EEG signals are recorded by a computer via RS232)

** EEG experiment on the human body

(1) Connect the J1 connector of the KL-73004 to the hub and the J2 connector to the MODULE OUTPUT terminal of the KL-71001. Connect the terminals marked 1, 2, 3, and 4 with the connectors. Connect the Vo1 output terminal to the oscilloscope.

(2) Use the INPUT SELECT button on the KL-71001 to select the KL-73004 module (see the LCD screen). The IN1, IN2, and IN5 LEDs on the KL-71001 front panel will light up. This indicates that input signals should be connected to these input terminals.

(3) Refer to Figure 4.12 and connect the electrodes to the Fp1, Fp2, and A1 regions.

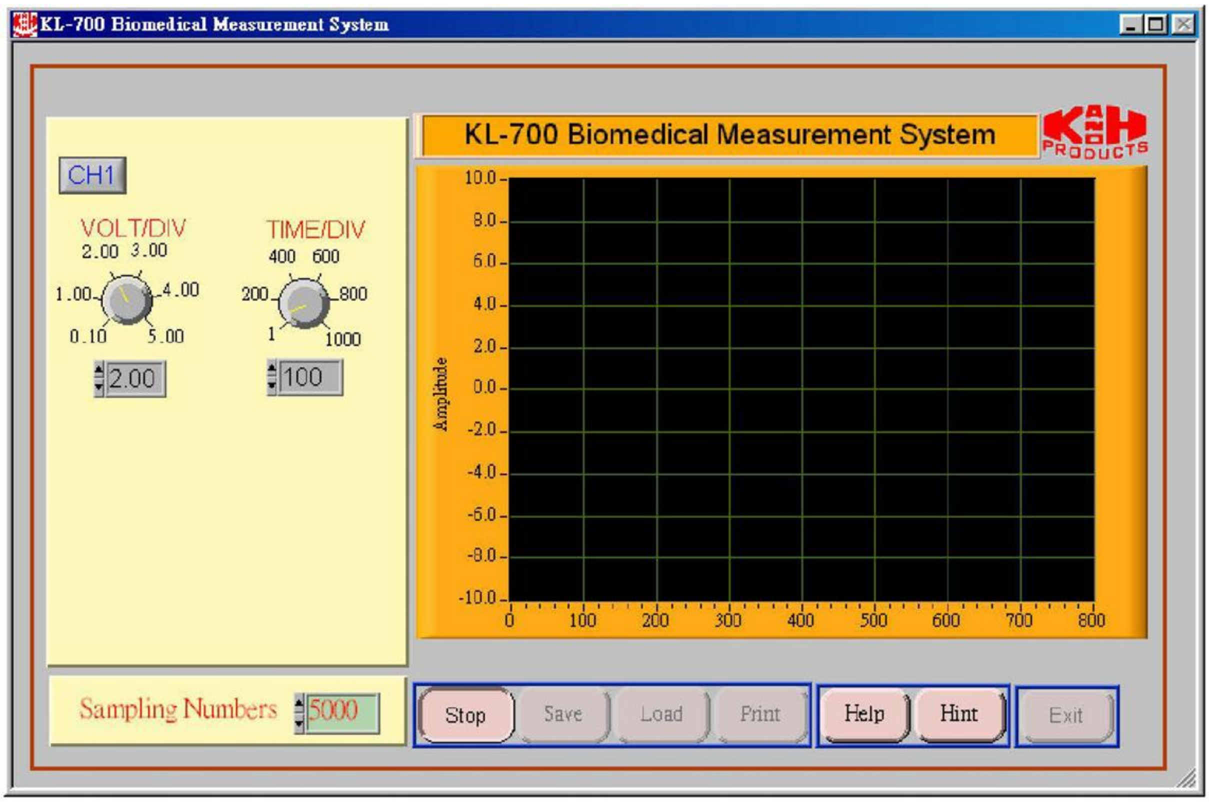
(4) Ask the subject to sit comfortably, look forward, and remain calm.

(5) Measure the preamplifier output terminal with a digital meter. Adjust the SVR value of the offset so that the output is zero. If the noise is too large, reduce the noise amplitude by adjusting the resistors.

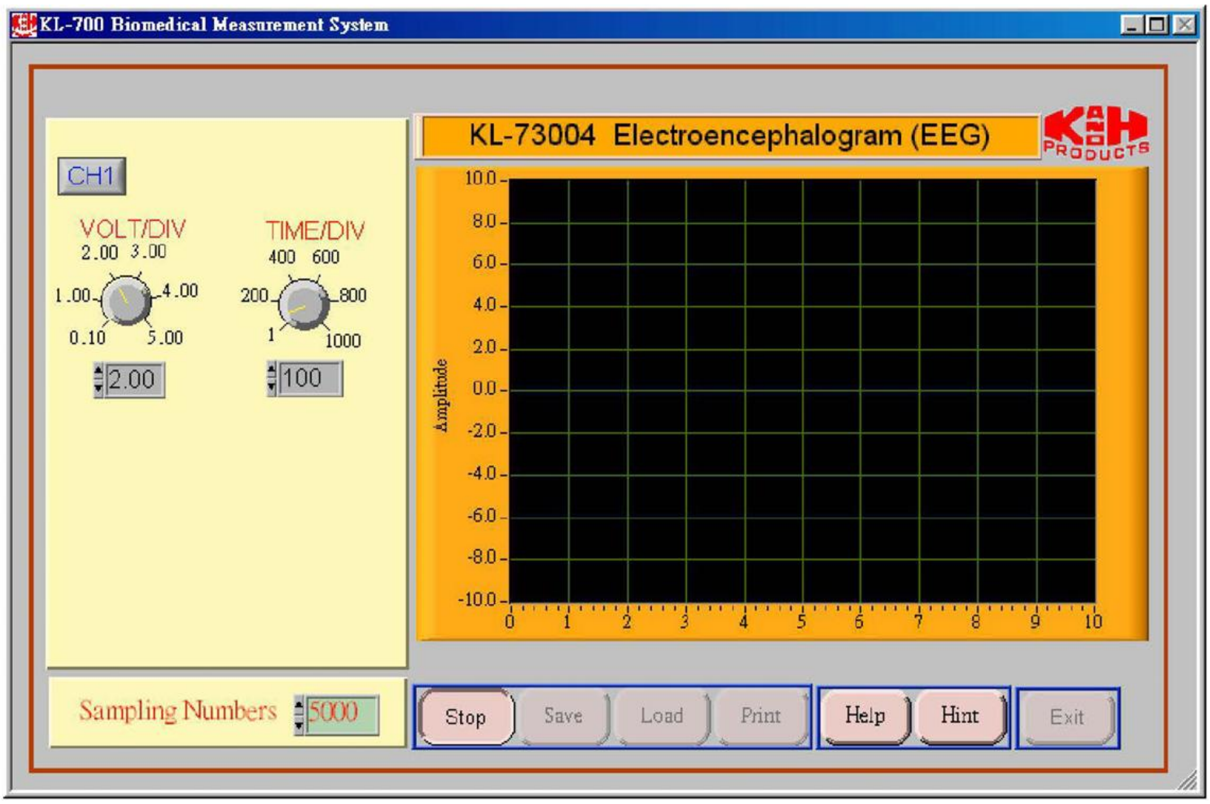
(6) Connect the 9-pin RS232 cable to your computer's communication port.

(7) Run the KL-700 Biomedical Measurement System program. See Section 0 for detailed installation information and explanations.

(8) After the system is loaded, the image below will appear.



(9) Press the 'Acqu' button to display the image below: KL 73004 EEG Recording Screen.



(10) Adjust the VOLT/DIV and TIME/DIV settings so that the signal waveforms are in the middle of the graphic area.

Note:

A. When recording EEG waveforms, there are three important factors that affect them:

(a) EMG caused by face or scalp movement

(b) Electrode movement, especially the front electrode, may not make sufficient contact with the frontal lobe due to head movement

(c) EOG caused by eye movement.

B. During the experiment, because EEG signals are very small, the electrode cables must be neat and clean, and the subject must be asked to remain calm. The device should also be operated by another student.

C. If the noise in the α-wave is very large, it may be due to high impedance between the skin and the electrodes. The electrodes should be repositioned. Wipe the skin with a cleaning cloth to remove oil from the skin or apply gel to the electrodes, which will lower the impedance.

D. If the output signal is very small, set the gain to x1000. To do this, simply unplug the connector from the point marked 4 and plug it into the point marked 5.

(11) Noise Test:

Ask the subject to open and close their eyes repeatedly and record a 5-10-second EEG waveform using an oscilloscope. Record this waveform on the computer. If the noise is excessive, minimize the noise by adjusting the variable resistor.

(12) Ask the subject to move their eyes up and down, then left and right. Continue this movement for 5-10 seconds. Record the EEG waveform on the computer. The head should remain still while the eyes move.

(13) Ask the subject to turn their head slightly and repeat this movement. Record the 5-10-second EEG waveform on the computer.

(14) Observe the α-wave in the EEG signals and examine the effect of eye opening on the EEG.

Ask the subject to remain calm and close their eyes. Record the 10-second waveform on the computer.

(11) Ask the subject to remain calm and open their eyes. Record the 10-second waveform on the computer.

4.5 RESULTS

Table 4.1 High Pass Filter Characteristics experiment

Frequency	1 KHz	500 Hz	100 Hz	10 Hz	5 Hz	4 Hz	3 Hz	2 Hz	1 Hz
HPF Output (Vpp)									

Table 4.2 High-Pass Filter Characteristic Curve

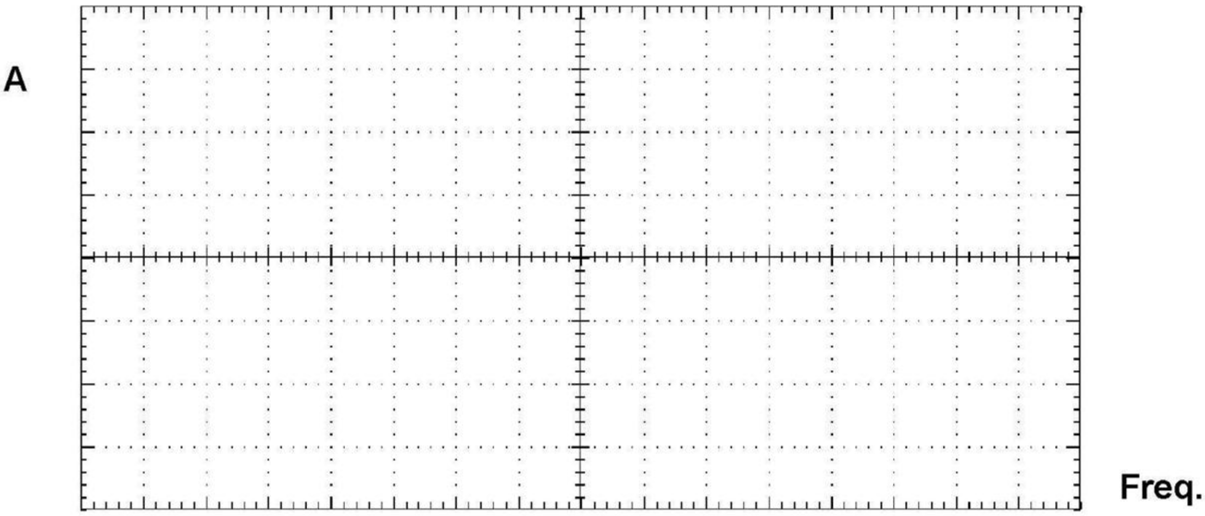


Table 4.3 Amplifier (1) Experiment

Gain of Amplifier	**Amplifier output**
GAIN 1 → Minimum	
GAIN 1 → Medium	
GAIN 1 → Maximum	

Table 4.4 Low-Pass Filter Characteristics experiment

Frequency	1 Hz	2 Hz	3 Hz	4 Hz	5 Hz	10 Hz	100 Hz	500 Hz	1 KHz
LPF Output (Vpp)									

Table 4.5 Low Pass Filter Characteristic Curve

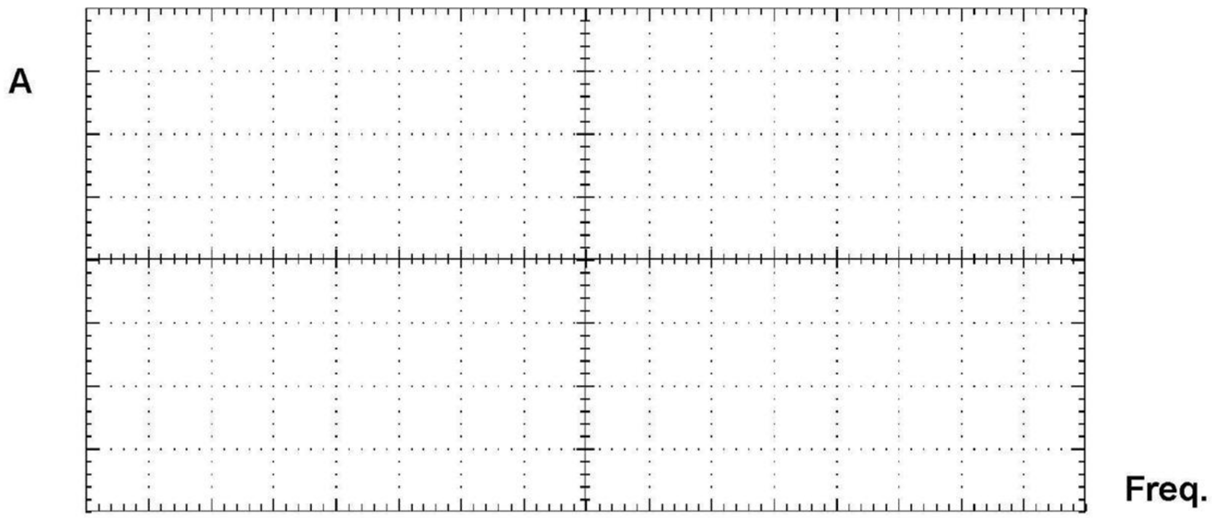


Table 4.6 Simulated EEG Experiment.

** Use the EEG simulator output as the standard reference (the EEG simulator must be purchased as it is additional hardware). Vo1 Output Waveform

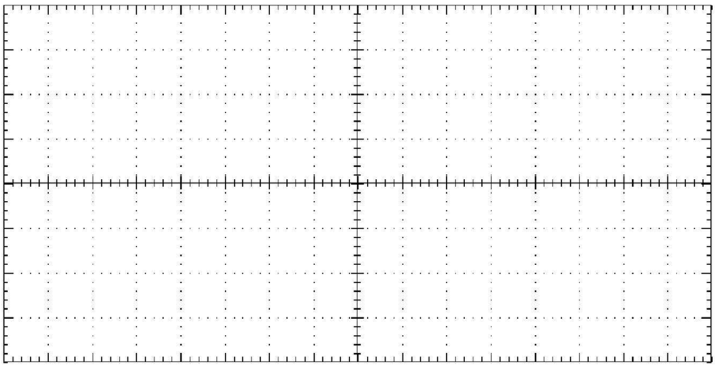
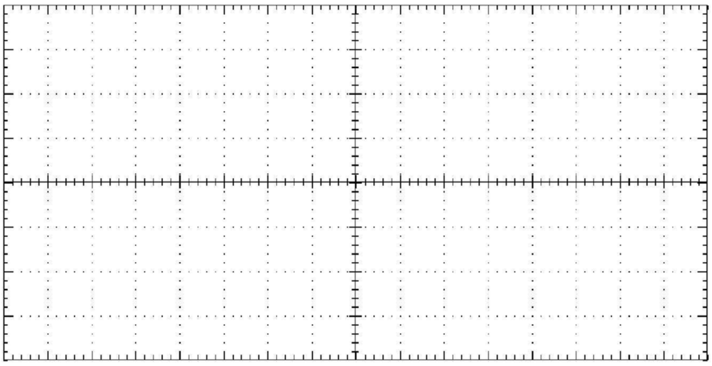
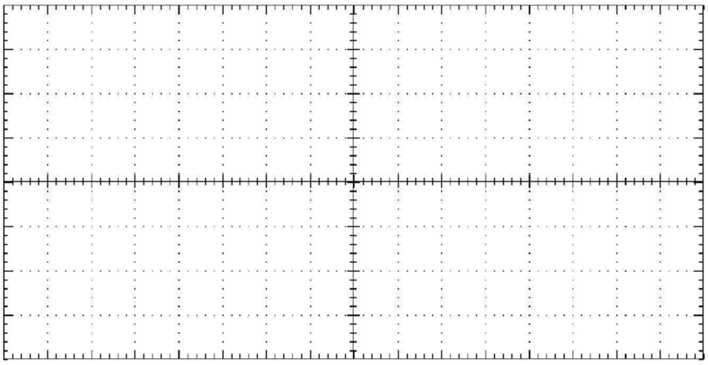
		Vo1 Output
3 Hz	Gain X1000	
10 Hz	Gain x1000	
13 Hz	Gain X1000	

Table 4.7 Real ECG Experiment

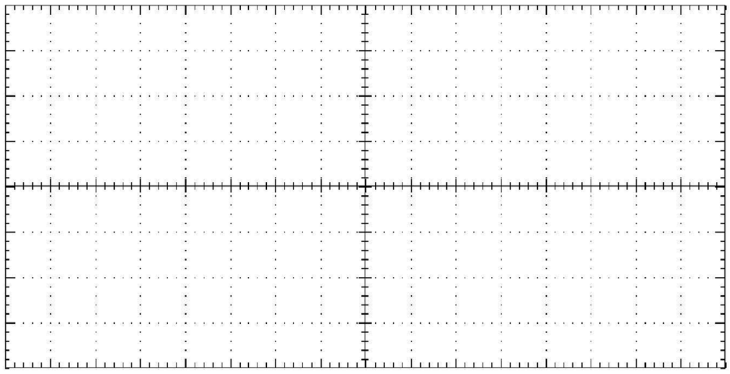
Condition	Output
Repeated blinking	

Table 4.8 Ask the subject to turn his eyes up and down, then left and right. Repeat the movement for 5-10 seconds. The head should remain still while the eyes move.

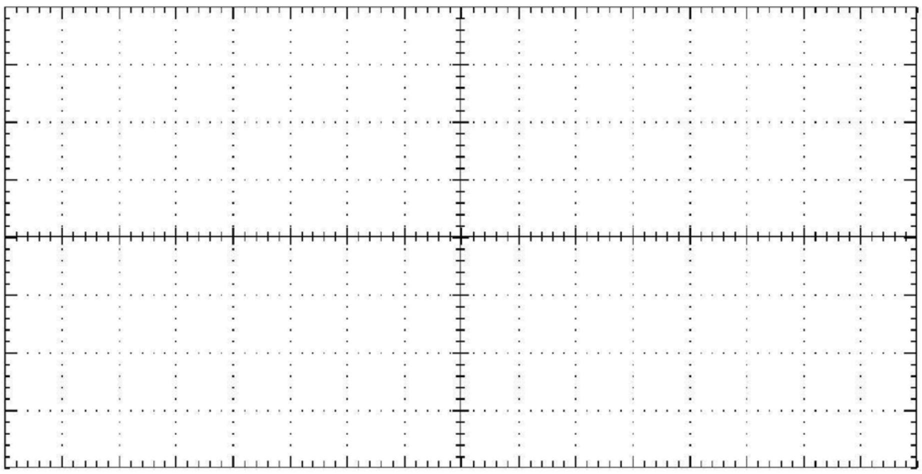
Condition	Output
The eyes are moved first up and down, then left and right, and the movement is repeated.	

Table 4.9 Ask the subject to move his/her head slightly and repeat this movement. Record the EEG waveform for 5-10 seconds.

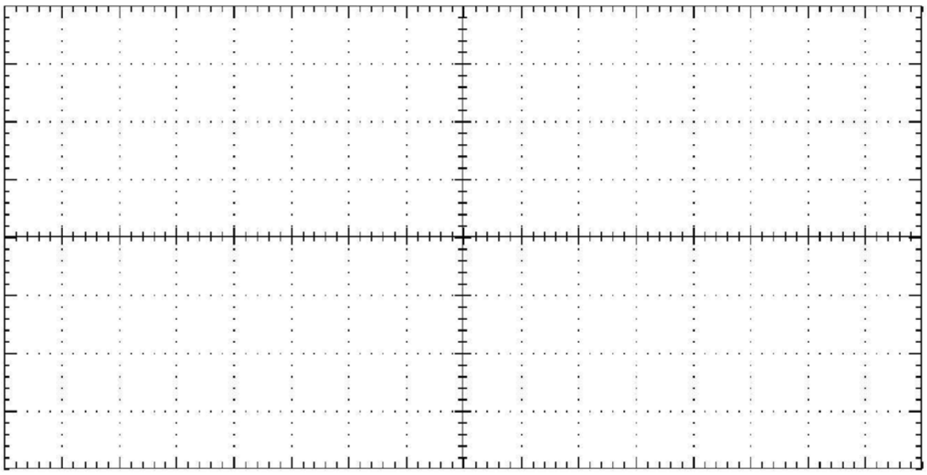
Condition	Output
The head is moved slightly, and the movement is repeated.	

Table 4.10 Observe the alpha wave in the EEG signals, and examine the effect of opening the eyes on the EEG.

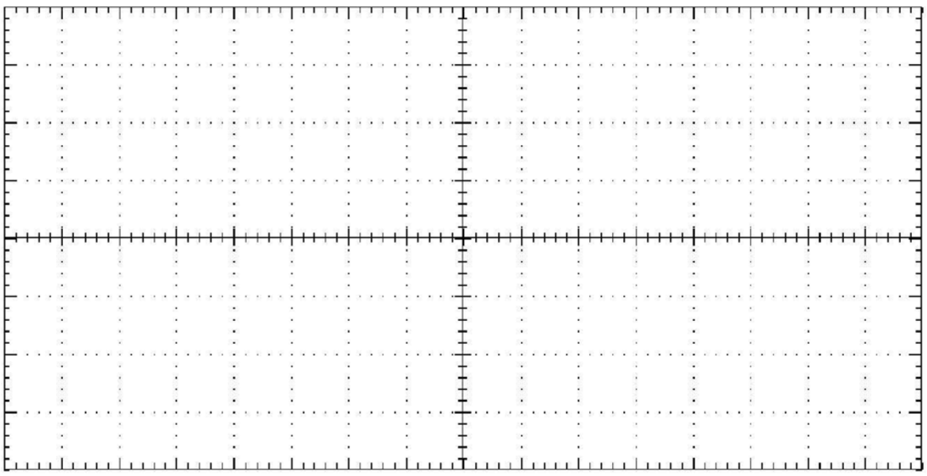
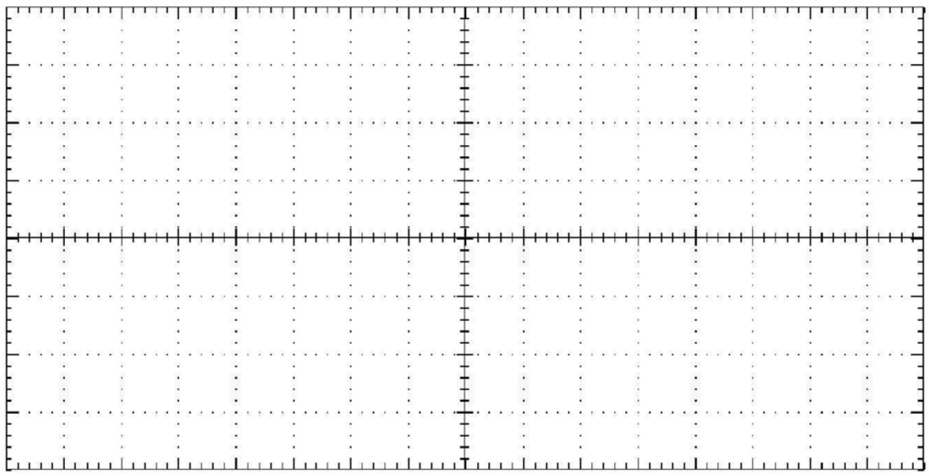
Condition	Output
Eyes closed	

Table 4.11 Ask the subject to remain calm and open his eyes. Record the EEG waveform with an oscilloscope.

Condition	Output
Eyes open	

4.6 QUESTIONS

1. Where is the -3dB frequency of the high-pass filter?

2. Where is the -3dB frequency of the low-pass filter?

3. What could be the reason for the absence of alpha waves?

4. How can you distinguish the alpha wave from the recorded EEG waveform?

5. What is the reason for the high noise in the measured EEG signal?

6. Explain why blinking or eye movements affect the EEG signal.