

# EXPERIMENT 4 ELECTROENCEPHALOGRAM (EEG) MEASUREMENT

## 4.0 OBJECTIVE

The purpose of this experiment is to help students be familiar with the electrical activity in human brain. The subjects' electroencephalogram (EEG) will be measured, the interference signals will be observed, and the effect of visual stimulation on the  $\alpha$  wave will be tested.

## 4.1 PHYSIOLOGICAL PRINCIPLE

A number of neurons exist in human brain cortex, which can be activated in somewhat 'synchronization,' resulting in certain rhythmic behavior. Potential alterations produced in brain cortex can be recorded with paired electrodes that are placed on the skull. These potential alterations occur due to the electrical rhythms and transient discharge, and are so-called the electroencephalogram, EEG. EEG signals can be classified with the measuring positions, frequency ranges, amplitudes, signal waveforms, periods, and the signal-induced actions. When stimulated externally, EEGs basically are of synchronization. Meanwhile, EEGs are affected due to different degree of alertness. Separate sleeping periods will result in EEGs with different characteristics. In clinic, EEG is used as a diagnostic tool specifically for epilepsy and for death recognition.

There are several technique problems in recording EEG signal, due mainly to its small amplitude. When EEG signal passes through the dura, cerebrospinal fluid, and skull to the scalp, its peak-to-peak amplitude is only about  $1 \sim 100 \mu\text{V}$ , and frequency range is  $0.5 \sim 100 \text{ Hz}$ . Furthermore, the electrode material and the contact tightness will also affect the recordings. During experimental operations, some unpredictable noise will still interfere with EEG detection. In general, EEGs can be divided into four types of waveform according to its frequency range, as summarized in Table 4.0 and as shown in Figure 4.1.

Table 4.0 Four types of EEG signals.

Delta	( $\delta$ )	0.5~4 Hz	It appears in the phases III and IV of the Non-Rapid-Eye-Movement period during deep sleeping, and is related to serum, one transmitter substance.
Theta	( $\theta$ )	4~8 Hz	Generally, it appears in children and adult when they are nervous.
Alpha	( $\alpha$ )	8~13 Hz	It appears when people are alert and close their eyes for taking a rest.
Beta	( $\beta$ )	13~22 Hz	It appears when peoples nervous system are active (in thinking state).

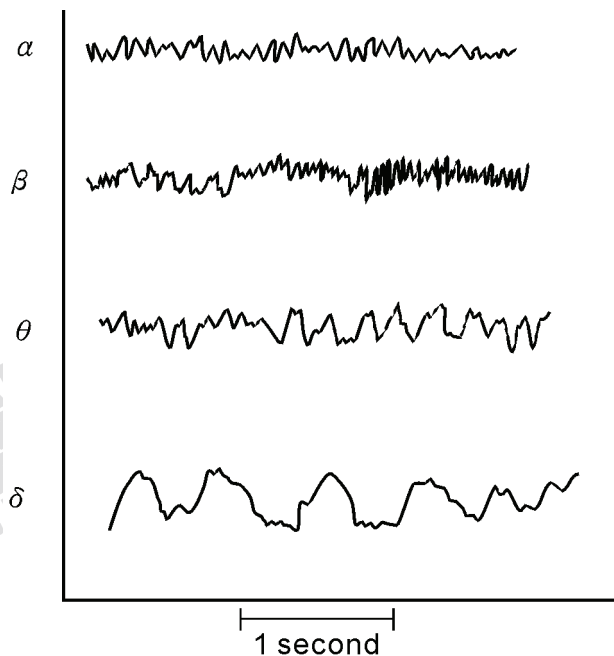


Figure 4.1 Four types of normal EEG wave

In clinic, the position of electrodes will directly affect the EEG's amplitude, phase, and frequency. Available locations for positioning electrodes are the frontal, parietal, temporal, and occipital lobes of the brain. The most favorite placement scheme is 10-20 EEG electrode position system, devised by the International Federation of EEG Societies, as shown in Figure 4.2. In the system, the boundary of the electrode positions is the root of the nose, nasion, and the inion ossification on the occipital lobe. This divides the surface of the skull into the right and left parts. Also, two ears are used as the boundary of the electrode positions, separating the

skull surface into the front and rear parts. There are three modes for recording EEG signals, including the unipolar, the average, and the bipolar modes, as shown in Figure 4.3. For simplicity, the present experiment will merely use a pair of electrodes in bipolar mode to record EEGs. Figure 4.4 shows the electrode positions on the frontal, occipital and the ear lobe for recording EEG signals from Frontal to Occipital, and the position  $A_1$  as the reference potential.

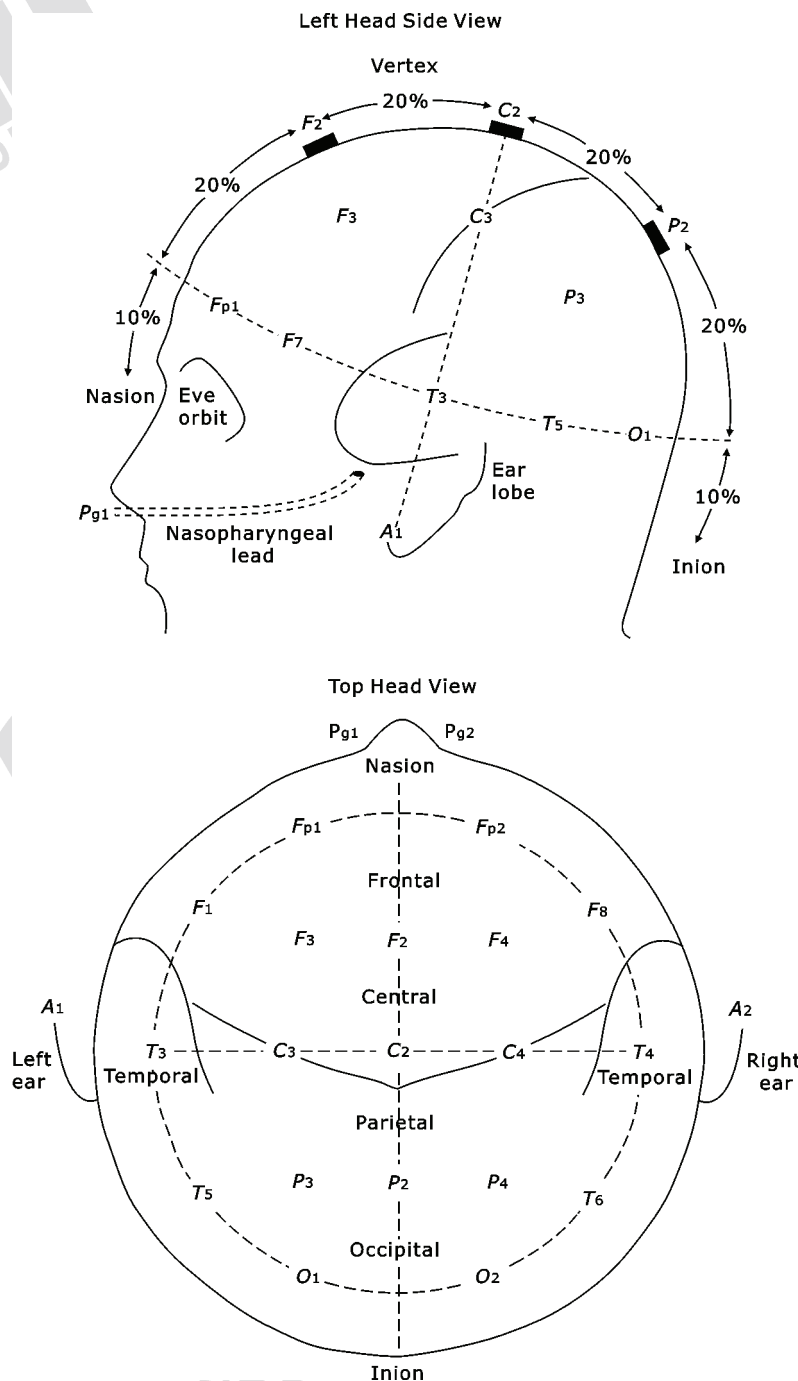


Figure 4.2 10-20 electrode position system of EEG.

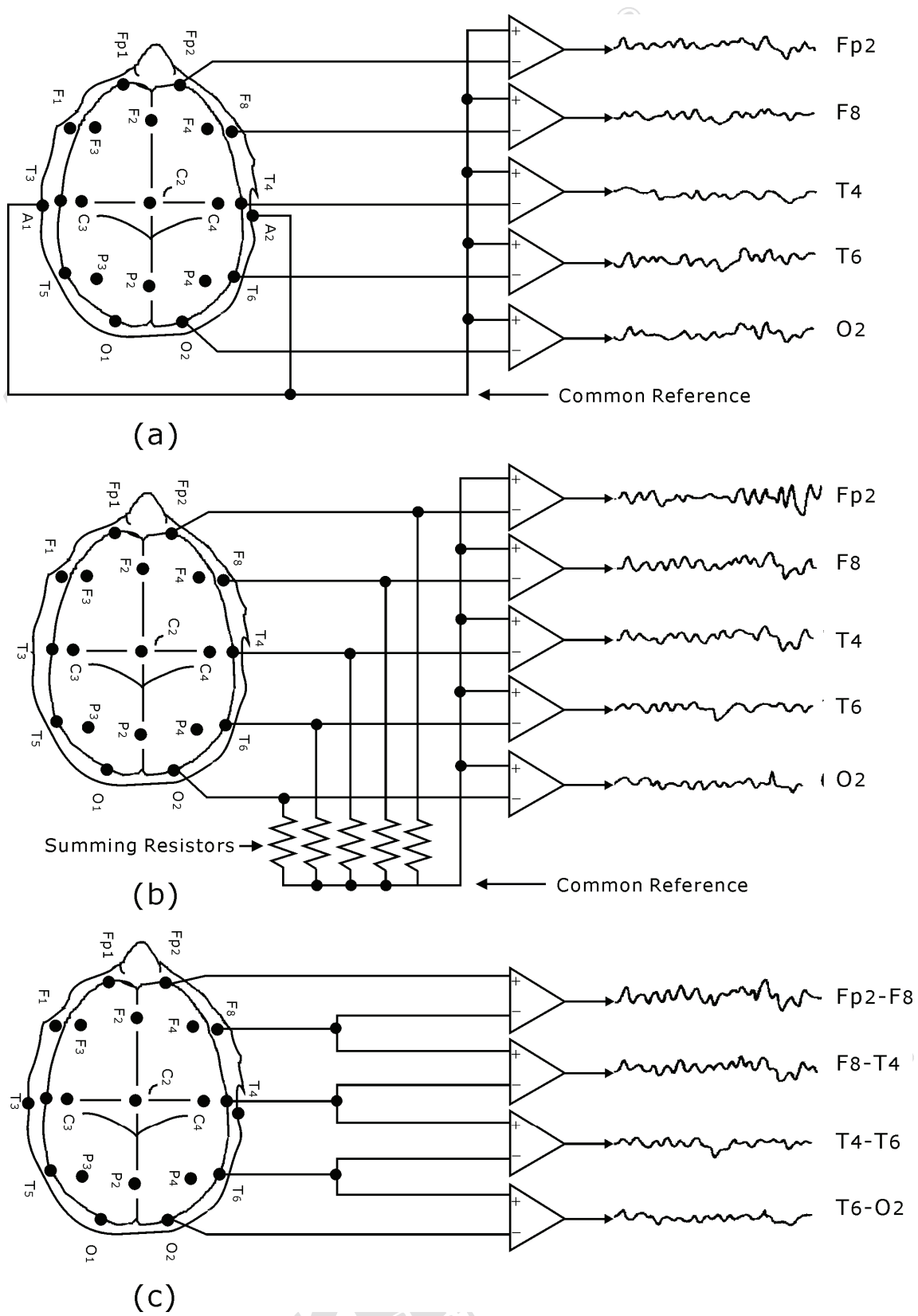


Figure 4.3 EEG recording modes, including the (a) unipolar, (b) average, and (c) bipolar.

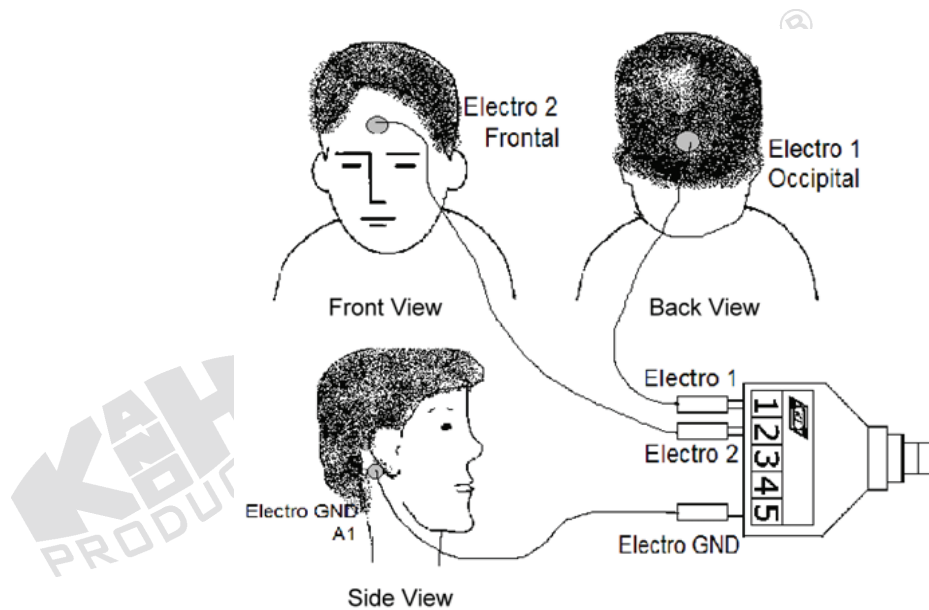


Figure 4.4 Position of electrodes.

## 4.2 PRINCIPLE OF CIRCUIT DESIGN

### 1. Block Diagram of EEG Measurement Circuit

As described in the previous section, EEGs are primarily from the potential alterations in the brain cortex, and consist of the electrical rhythms and the transient discharge. The different parts of the cortex control the different physiological functions. Thus, EEG recorded from one cortex region will be not the same as that from other cortex region. In the experiment, the hair on the scalp makes it difficult to place the electrodes on the proper regions, and it impedes EEG measurement. So, the students should place the electrodes on the positions of Frontal, Occipital and  $A_1$ , and choose  $A_1$  as the potential ground (Figure 4.4). To avoid the electrical shock caused by leakage from the power supply or measuring instrument, the isolation concept must be incorporated in designing a circuit for the EEG measurement.

Figure 4.5 shows the block diagram of EEG measurement circuit. The surface electrodes are used to measure the pretty weak  $\alpha$  wave that is induced by stimulating the eye with light. If the eyes open or close, an arrhythmic  $\alpha$  wave will show up. An instrumentation amplifier with a gain of 50 is used as the preamplifier for picking up the unipolar component of EEG signals. The function

of the isolation circuit is to isolate the signal and line power source, and can be implemented by using either an optical or voltage-transformed method. The bandwidth of the band-pass filter is from 1 to 20 Hz. and the amplifier with an amplification factor of 1000 (max) can magnify the weak signal that passes through the filter. Then, the amplified EEG signals can be directly sent to the oscilloscope for display.

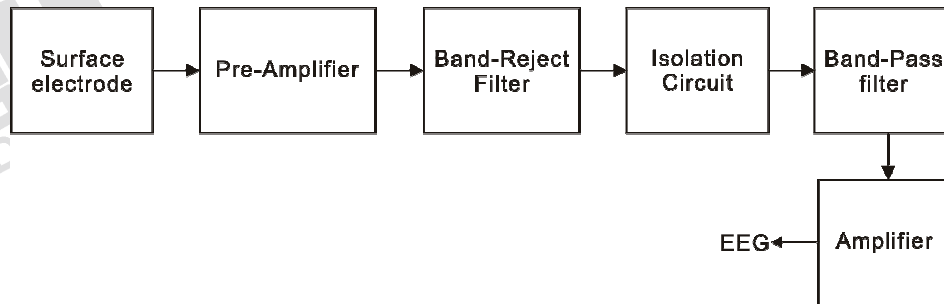


Figure 4.5 Block diagram of EEG measurement circuit.

## 2. Preamplifier

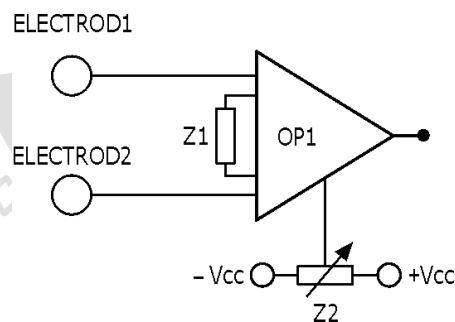


Figure 4.6 Preamplifier.

Figure 4.6 shows the preamplifier circuit that is composed of an instrumentation amplifier (AD620) OP1. The amplifying gain can be determined by Equation (4.1). The pin 5 of OP1 is the reference terminal. The compensated potential on  $Z_2$  can be used to adjust the drift level of the output voltage.

$$A_v = \frac{49.4k\Omega}{Z_1} + 1 \quad (4.1)$$

### 3. Band-Reject Filter

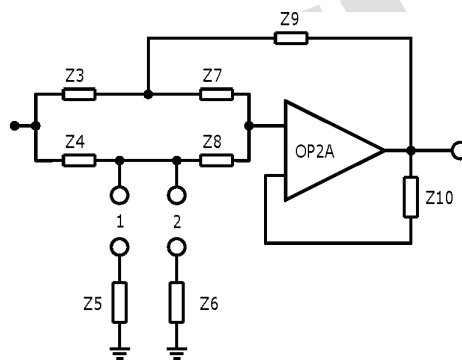


Figure 4.7 Band-reject filter.

Figure 4.7 shows a twin-T band-reject filter composed by RC networks, including OP2A,  $Z_3$ ,  $Z_4$ ,  $Z_5$  (or  $Z_6$ ),  $Z_7$ ,  $Z_8$  and  $Z_9$ . If  $Z_3 = Z_7$ ,  $Z_4 = Z_8$ ,  $Z_5 = 0.5Z_3$  (or  $Z_6 = 0.5Z_3$ ) and  $Z_9 = 2Z_4$ , the center frequency can be calculated by Equation (4.2).

$$f = \frac{1}{2\pi Z_3 Z_4} \quad (4.2)$$

### 4. Isolation Circuit

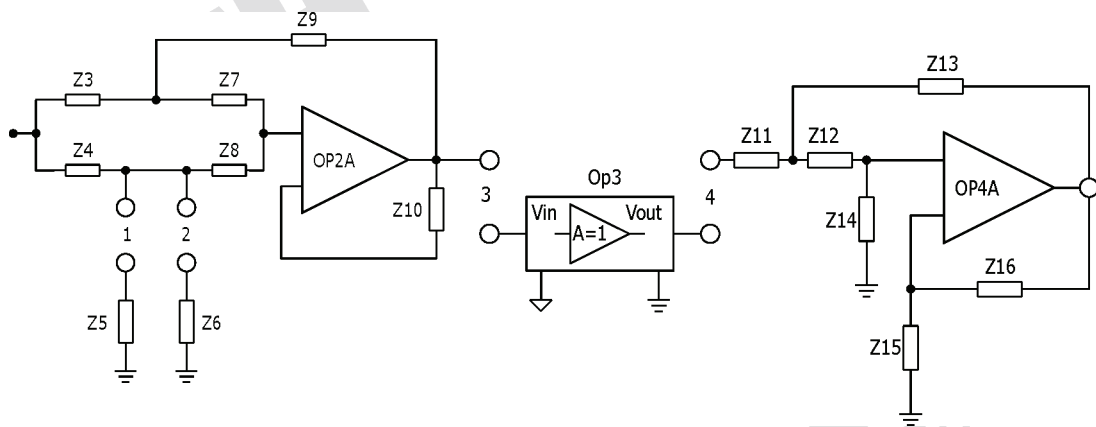


Figure 4.8 Isolation circuit.

Figure 4.8 shows the isolation circuit that is constructed by OP3. Here, the isolation of signal is carried out by means of an optical approach.

## 5. Band-Pass Filter Circuit

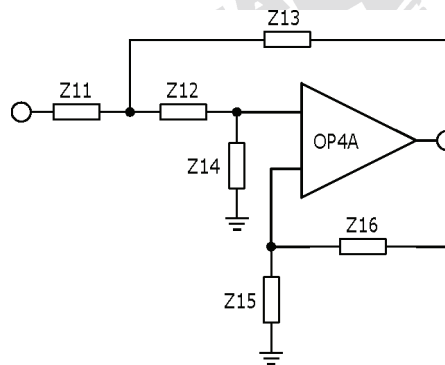


Figure 4.9 2nd-order high-pass filter.

In designing EEG measurement circuit, OP4A is used to construct an active 2nd-order high-pass filter, as shown in Figure 4.9. The cutoff frequency ( $f_L$ ) of the filter is set at 1 Hz, and can be calculated using  $Z_{11}$ ,  $Z_{12}$ ,  $Z_{13}$  and  $Z_{14}$ , as expressed in Equation (4.3),

$$f_L = \frac{1}{2\pi\sqrt{Z_{11}Z_{12}Z_{13}Z_{14}}} \quad (4.3)$$

And, its passband gain is explained in Equation (4.4).

$$\frac{Z_{15} + Z_{16}}{Z_{15}} = 1.56 \quad (4.4)$$

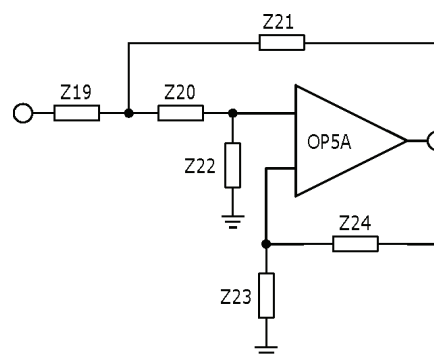


Figure 4.10 2nd-order low-pass filter.

OP5A is used to construct an active 2nd-order low-pass filter, as shown in Figure 4.10. The cutoff frequency ( $f_H$ ) of the filter is set at 20 Hz, and can be calculated using  $Z_{19}$ ,  $Z_{20}$ ,  $Z_{21}$  and  $Z_{22}$ , as expressed in Equation (4.5),



$$f_H = \frac{1}{2\pi\sqrt{Z_{19}Z_{20}Z_{21}Z_{22}}} \quad (4.5)$$

And, its passband gain is explained in Equation (4.6).

$$\frac{Z_{23} + Z_{24}}{Z_{23}} = 1.56 \quad (4.6)$$

## 6. Amplifier

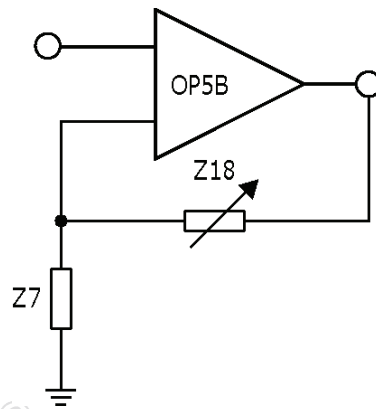


Figure 4.11 Amplifier circuit.

Figure 4.11 shows one non-inverting amplifier constructed by OP5B. In the amplifier,  $Z_{18}$  is used for the gain adjustment as expressed in Equation (4.7).

$$A_V = \frac{Z_{17} + Z_{18}}{Z_{17}} \quad (4.7)$$

### **4.3 EQUIPMENT REQUIRED**

1. KL-72001 Main Unit
2. KL-75004 Electroencephalogram EEG Module
3. Digital Storage Oscilloscope
4. Digital Voltmeter (DVM)
5. KL-79101 5-Conductor Electrode Cable
6. EEG Electrodes
7. Alcohol Prep Pads
8. Electrical Conductivity Jelly
9. Elastic Head Bandage
10. Medical Tape
11. DB9 Cable
12. BNC Cables
13. RS-232 Cable
14. Connecting Wires
15. 10-mm Bridging Plugs
16. Trimmer

## 4.4 PROCEDURE

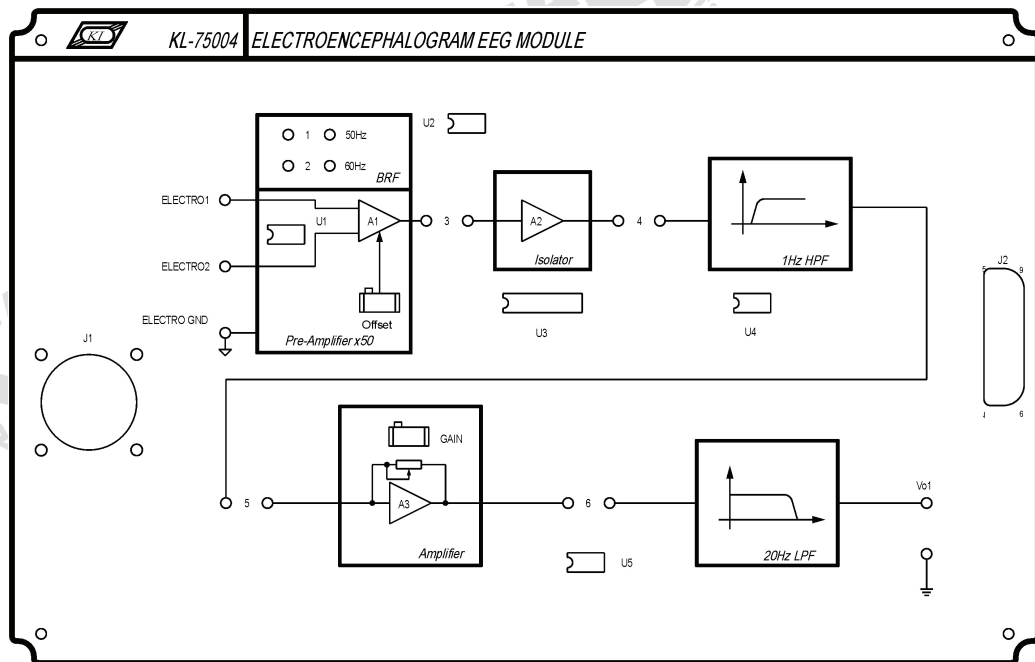


Figure 4.12 Front panel of KL-75004 EEG Module.

### A. Calibrating the Pre-Amplifier Circuit

1. Set KL-75004 EEG Module on KL-72001 Main Unit. Then, complete the following connections:

KL-72001 Main Unit			KL-75004 EEG Module		
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2

KL-75004 EEG Module					
Block	Terminal	To	Block	Terminal	
Pre-Amplifier x50	ELECTRO1	→	Pre-Amplifier x50	ELECTRO2	
Pre-Amplifier x50	ELECTRO2	→	Pre-Amplifier x50	ELECTRO GND	

2. Turn power on.
3. Connect the positive probe of DVM to the output of the Pre-Amplifier and connect the negative probe to ELECTRO GND terminal.
4. Adjust Offset potentiometer to make the output voltage indicated by DVM equal to 0 V.

- Turn power off and disconnect circuit.

## B. Measuring the Characteristics of Band-Reject Filter (BRF)

- Set KL-75004 EEG Module on the KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit				KL-72001 Main Unit			
Section	Area	Terminal	To	Section	Area	Terminal	
FUNCTION GENERATOR	--	OUTPUT	→	SCOPE ADAPTOR	--	CH1	
SCOPE ADAPTOR	--	CH1 (BNC)	→	CH1 input of the oscilloscope			
SCOPE ADAPTOR	--	CH2 (BNC)	→	CH2 input of the oscilloscope			

KL-72001 Main Unit				KL-75004 EEG Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	Pre-Amplifier x50	ELECTRO1
FUNCTION GENERATOR	--	GND	→	Pre-Amplifier x50	ELECTRO2
SCOPE ADAPTOR	--	CH2	→	Pre-Amplifier x50	Output

KL-75004 EEG Module					
Block	Terminal	To	Block	Terminal	
Pre-Amplifier x50	ELECTRO2	→	Pre-Amplifier x50	ELECTRO GND	

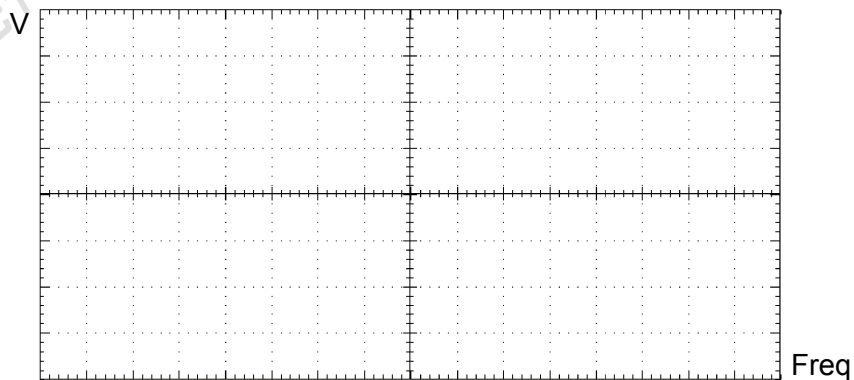
- Insert a bridging plug into position 1 or 2 to set the center frequency of BRF to 50 or 60 Hz (according to local line frequency).
- Turn power on.
- Apply a 5 Hz, 100 mVpp sine signal to the ELECTRO1 input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR, and observe CH1 trace on the oscilloscope screen.
- Observe the BRF output signal displayed on CH2 trace, then record the amplitude in Table 4.1.
- Without changing the amplitude of input sine signal, repeat Steps 4 and 5 for other frequency values listed in Table 4.1.

Table 4.1 Measured output amplitude of BRF.

Input Freq	5Hz	10Hz	20Hz	30Hz	50 or 60Hz	100Hz	200Hz	500Hz	1KHz
BRF Output (Vpp)									

8. According to the recorded data in Table 4.1, plot the characteristic curve of band-reject filter in Table 4.2.

Table 4.2 Characteristic curve of BRF.



9. Turn power off and disconnect circuit.

### C. Measuring the Characteristics of High-Pass Filter (HPF)

1. Set KL-75004 EEG Module on KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit				KL-72001 Main Unit			
Section	Area	Terminal	To	Section	Area	Terminal	
FUNCTION GENERATOR	–	OUTPUT	→	SCOPE ADAPTOR	–	CH1	
SCOPE ADAPTOR	–	CH1 (BNC)	→	CH1 input of the oscilloscope			
SCOPE ADAPTOR	–	CH2 (BNC)	→	CH2 input of the oscilloscope			

KL-72001 Main Unit				KL-75004 EEG Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	1Hz HPF	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	1Hz HPF	Output

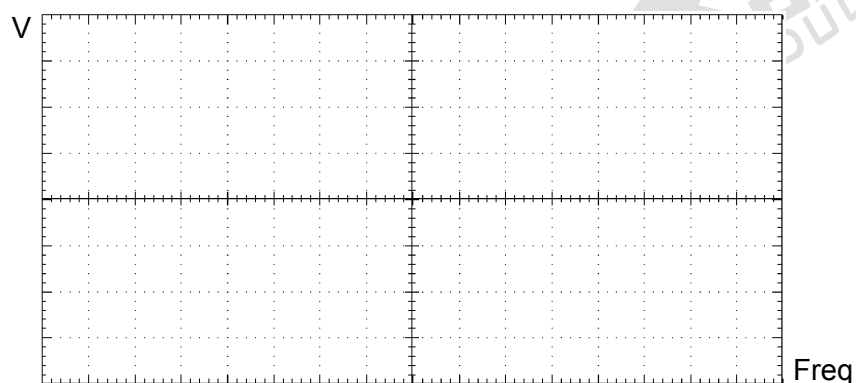
- Turn power on.
- Apply a 1 KHz, 1 Vpp sine signal to HPF input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR, and observe CH1 trace on the oscilloscope screen.
- Observe HPF output signal displayed on CH2 trace and record the amplitude in Table 4.3.
- Without changing the amplitude of input sine signal, repeat Steps 3 and 4 for different frequency values listed in Table 4.3.

Table 4.3 Measured output amplitude of HPF.

Input Freq	1KHz	10Hz	3Hz	2Hz	1Hz	0.9Hz	0.8Hz	0.5Hz	0.1Hz
HPF Output (Vpp)									

- According to the recorded data in Table 4.3, plot the characteristic curve of the high-pass filter in the space provided in Table 4.4.

Table 4.4 Characteristic curve of HPF.



7. Turn power off and disconnect circuit.

#### D. Measuring the Characteristics of Amplifier

1. Set KL-75004 EEG Module on KL-72001 Main Unit. Then, complete the following connections:

KL-72001 Main Unit				KL-72001 Main Unit		
Section	Area	Terminal	To	Section	Area	Terminal
FUNCTION GENERATOR	--	OUTPUT	→	SCOPE ADAPTOR	--	CH1
SCOPE ADAPTOR	--	CH1 (BNC)	→	CH1 input of the oscilloscope		
SCOPE ADAPTOR	--	CH2 (BNC)	→	CH2 input of the oscilloscope		

KL-72001 Main Unit				KL-75004 EEG Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	Amplifier	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	Amplifier	Output

2. Turn power on.
3. Apply a 100 Hz, 50 mVpp sine signal to the Amplifier input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR, and observe CH1 trace on the screen of scilloscope.
4. Adjust GAIN potentiometer to the minimum counterclockwise position (with clicks at the end). Record the minimum amplitude of the Amplifier output signal displayed on CH2 trace in Table 4.5.
5. Adjust the GAIN potentiometer clockwise to obtain maximum undistorted output signal. Record the output peak-to-peak voltage in Table 4.5.

Table 4.5 Measured output amplitude of Amplifier.

GAIN Position	Amplifier Output Voltage (Vpp)
Minimum counterclockwise	
Maximum undistorted output	

- Turn power off and disconnect circuit.

### E. Measuring the Characteristics of Low-Pass Filter (LPF)

- Set KL-75004 EEG Module on KL-72001 Main Unit. Then, complete the following connections:

KL-72001 Main Unit				KL-72001 Main Unit		
Section	Area	Terminal	To	Section	Area	Terminal
FUNCTION GENERATOR	--	OUTPUT	→	SCOPE ADAPTOR	--	CH1
SCOPE ADAPTOR	--	CH1 (BNC)	→	CH1 input of the oscilloscope		
SCOPE ADAPTOR	--	CH2 (BNC)	→	CH2 input of the oscilloscope		

KL-72001 Main Unit				KL-75004 EEG Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	20Hz LPF	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	20Hz LPF	Output (Vo1)

- Turn power on.
- Apply a 1 Hz, 1 Vpp sine signal to LPF input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR, and observe CH1 trace on the oscilloscope screen.
- Observe LPF output signal displayed on CH2 trace and record the amplitude in Table 4.6.
- Without changing the amplitude of input sine signal, repeat Steps 3 and 4 for different frequency values listed in Table 4.6.

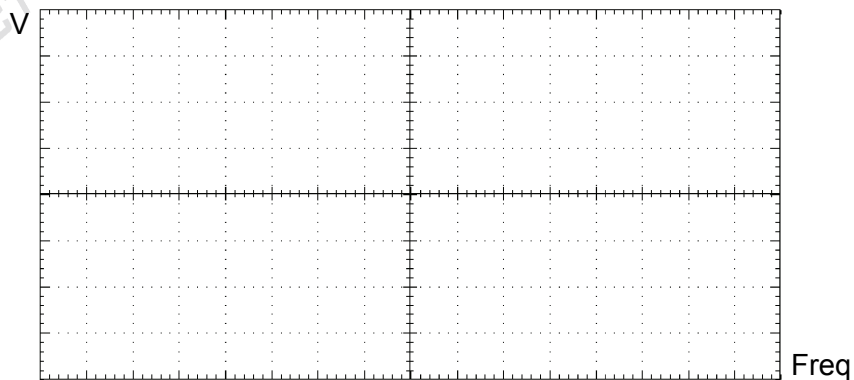


Table 4.6 Measured output amplitude of LPF.

Input Freq	1Hz	5Hz	10Hz	15Hz	20Hz	25Hz	30Hz	50Hz	100Hz
LPF Output (Vpp)									

6. According to the recorded data in Table 4.6, plot the characteristic curve of LPF in Table 4.7.

Table 4.7 Characteristic curve of LPF.



7. Turn power off and disconnect circuit.

## F. Human EEG Measurement using Oscilloscope

1. Set KL-75004 EEG Module on KL-72001 Main Unit. Then, complete the following connections:

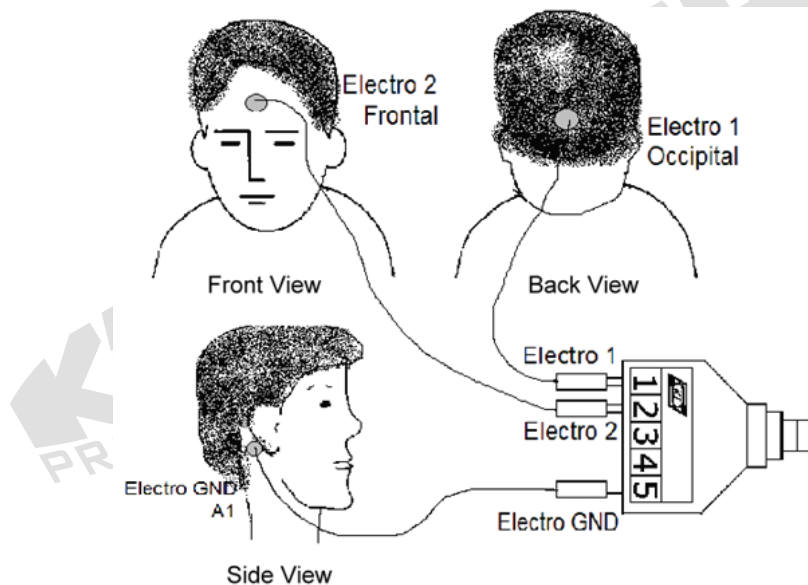
KL-72001 Main Unit				KL-72001 Main Unit		
Section	Area	Terminal	To	Section	Area	Terminal
SCOPE ADAPTOR	--	CH1	→	OUTPUT	ELECTROENC EPHALOGRAM	Vo1
SCOPE ADAPTOR	--	CH1 (BNC)	→	CH1 input of the oscilloscope		
SCOPE ADAPTOR	--	CH2 (BNC)	→	CH2 input of the oscilloscope		

KL-72001 Main Unit				KL-75004 EEG Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2

2. On KL-75004 EEG Module, insert bridging plugs in positions 1 or 2 (according to local line frequency), 3, 4, 5, and 6.
3. Apply an appropriate amount of electrical conductivity jelly to the valley of each EEG electrode.
4. Refer to the electrode placement shown below, clean the skin with alcohol prep pads and apply the electrodes on the subject frontal, occipital and the ear lobe A1.

**Notes:**

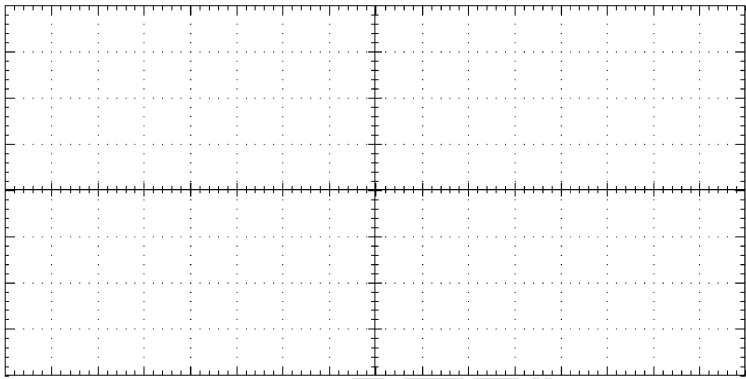
- a. Apply the electrodes on Frontal and ear lobe A1 and fix them with medical tape.
- b. Before applying the electrode on Occipital, the subject's hair must be separated first, and then fix it with an elastic head bandage.



5. Connect the electrodes to the lead side of KL-79101 5-Conductor Electrode Cable as follows: Occipital → 1, Frontal → 2, A1 → 5. Then, connect the module side of KL-79101 5-Conductor Electrode Cable to J1 connector on KL-75004 EEG Module.
6. Turn power on. Select MODULE:KL-75004 (EEG) item from LCD display by pressing SELECT button of KL-72001 Main Unit.
7. Ask the subject to sit down comfortably, to look forwards, and to keep quiet.
8. Make sure that the Pre-Amplifier and Amplifier have been calibrated. (Refer to Procedures A and D)

9. Set VOLT/DIV control of CH1 to 500 mV/div, and set TIME/DIV control to 250 ms/div.
10. Ask the subject to blink five times at intervals of one second. Observe and record the waveform of blinking test in Table 4.8.

Table 4.8 Measured human EEG waveform.

Condition	Vo1 Waveform
Blink 5 times	

11. Observe the  $\alpha$  wave in EEG signals:
  - 11-1. Ask the subject to open his/her eyes for 5 seconds. Observe and record the waveform of EEG  $\alpha$  wave in Table 4.9.
  - 11-2. Ask the subject to close his/her eyes for 5 seconds. Observe and record the waveform of EEG  $\alpha$  wave in Table 4.10.

Table 4.9 Measured human EEG waveform.

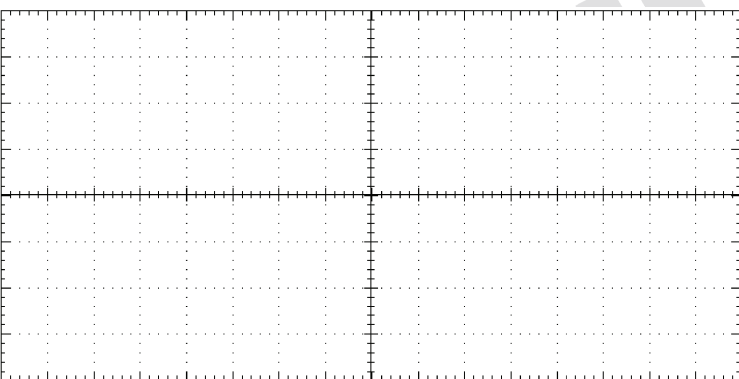
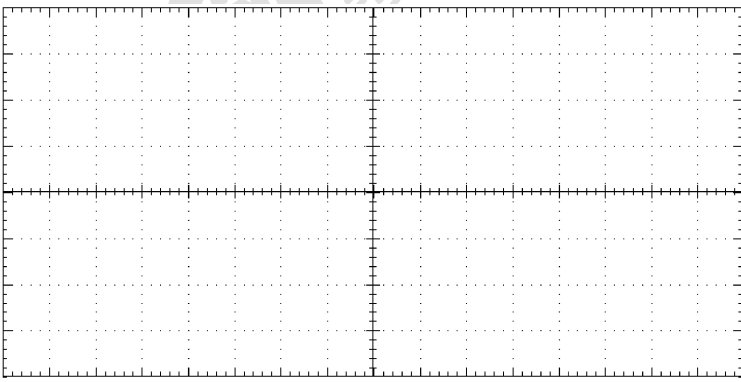
Condition	Vo1 Waveform
Open eyes for 5 seconds	

Table 4.10 Measured human EEG waveform.

Condition	Vo1 Waveform
Close eyes for 5 seconds	

12. Turn power off and disconnect circuit.

### G. Human EEG Measurement using KL-720 Software

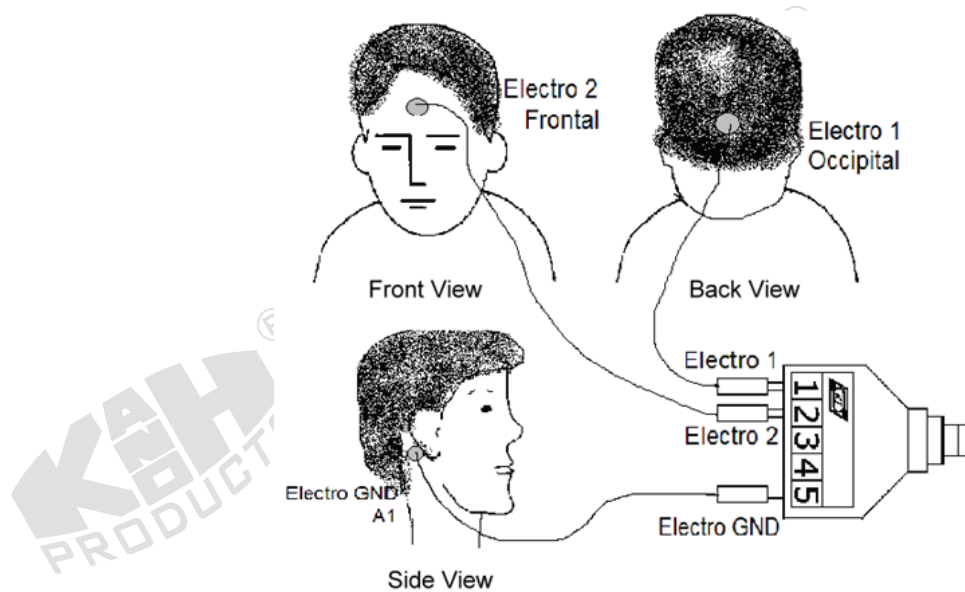
1. Set KL-75004 EEG Module on KL-72001 Main Unit. Then, make connection as follows:

KL-72001 Main Unit			KL-75004 EEG Module		
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	-	9-Pin	→	-	J2

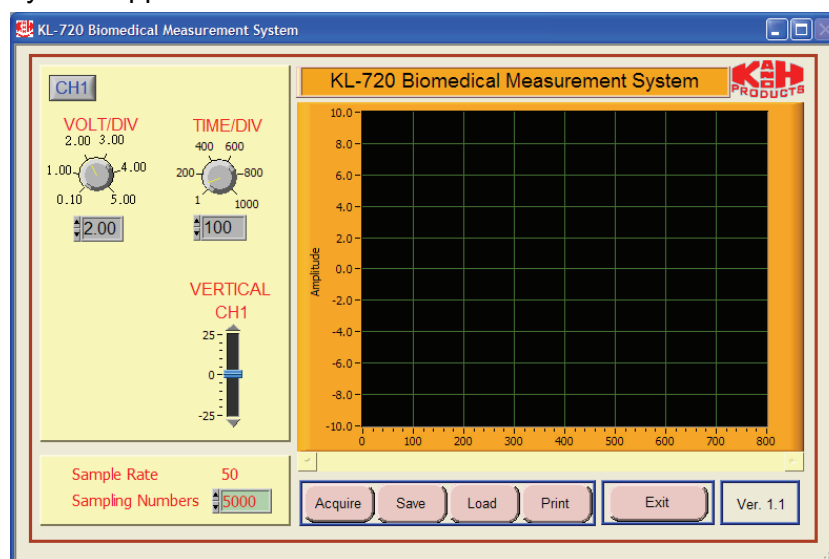
2. On KL-75004 EEG Module, insert bridging plugs in positions 1 or 2 (in accordance with local line frequency), 3, 4, 5, and 6.
3. Apply an appropriate amount of electrical conductivity jelly to the valley of each EEG electrode.
4. Refer to the electrode placement shown below, clean the skin with alcohol prep pads and apply the electrodes on the subject frontal, occipital and the ear lobe A1.

#### Notes:

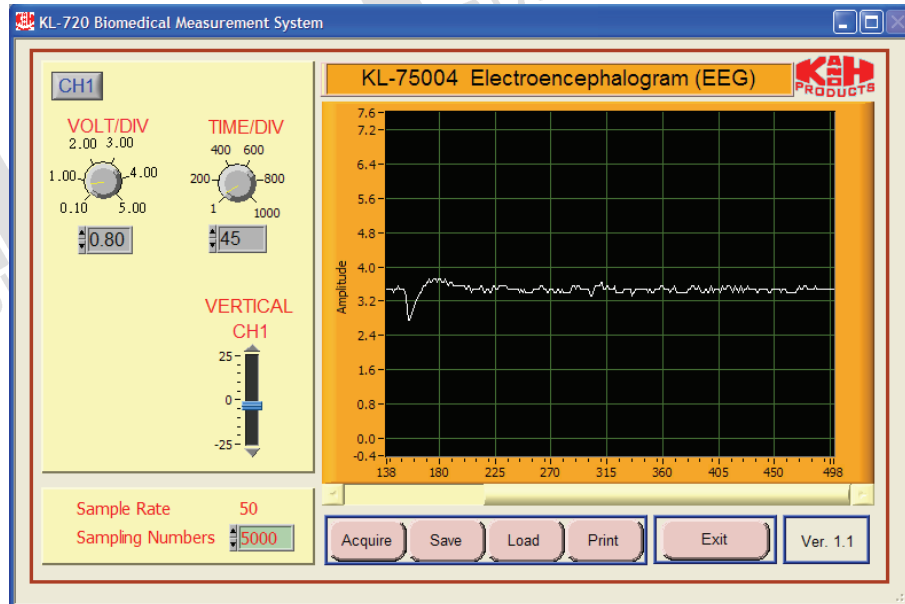
- a. Apply the electrodes on Frontal and ear lobe A1 and fix them with medical tape.
- b. Before applying the electrode on Occipital, the subject's hair must be separated first, and then fix it with an elastic head bandage.



5. Connect the electrodes to the lead side of KL-79101 electrode cable as follows: Occipital → 1, Frontal → 2, A1 → 5. Then, connect the module side of KL-79101 electrode cable to J1 connector on KL-75004 EEG Module.
6. Connect RS-232 OUTPUT connector of KL-72001 Main Unit to RS-232 port on the computer using RS-232 cable.
7. Turn power on. Select the MODULE:KL-75004 (EEG) item from LCD display by pressing SELECT button of KL-72001 Main Unit.
8. Make sure that the Pre-Amplifier and Amplifier have been calibrated. (Refer to Procedures A and D)
9. Boot the computer.
10. Execute KL-720 program. The window of KL-720 Biomedical Measurement System appears as shown below.



11. Click the Acquire button. The system begins to acquire the measured data via RS-232 port and displays the waveform in the waveform window of KL-75004 Electroencephalogram as shown below:



**Note:** If the message “time out, please check the COM port was connected the device” appears, check the connection and setup of RS-232 port.

12. Adjust VOLT/DIV and TIME/DIV knobs to make the signal be read accurately.
13. Ask the subject to blink five times at intervals of one second. Observe and record the waveforms of blinking test on disk.
14. Observe the  $\alpha$  wave in EEG signals:
  - 14-1. Ask the subject to open his/her eyes for 5 seconds. Record the waveform of EEG  $\alpha$  wave on disk.
  - 14-2. Ask the subject to close his/her eyes for 5 seconds. Record the waveform of EEG  $\alpha$  wave on disk.
15. Exit KL-720 Biomedical Measurement System, turn power off and disconnect circuit.