EXPERIMENT 9 BODY IMPEDANCE DETECTION

9.0 OBJECTIVE

The purpose of the experiment is to teach students how to measure body impedance correctly and be familiar with the principle of body impedance measurement. When the heart contracts and dilates, the students can observe the corresponding variations in body impedance due to the change in chamber volume of the ventricle and atrium. Furthermore, this experiment will provide the students with an insight into the understanding of practical application of body impedance measurement.

9.1 PHYSIOLOGICAL PRINCIPLE

** DO NOT allow patients with a pacemaker to do this experiment **

Impedance (Z) is the total resistance to the flow of alternating current through both resistive and reactive components in the measuring path. There are three components of impedance: the resistance (R), the inductive reactance (X_L) and the capacitive reactance (X_C). All conductive substances, including living tissue, possess the impedance that varies with seasons or with tissue fluids. In general, resistance is opposition to the flow of DC and AC caused by the material through which current is flowing. All materials possess resistance when temperature is above the absolute zero (-273.16°C). According to Equation (9.1), such resistance is inversely proportional to the cross-sectional area A of the material that the current passes through, and directly proportional to the length L of the current path and the material resistivity, ρ.

$$R = \rho \frac{L}{A} \tag{9.1}$$

The resistivity ρ varies with the different types of tissue. For example, the resistivity is about 150 Ω-cm for the blood, 300 Ω-cm for the urine, 300 - 1600 Ω-cm for the skeletal muscle, 1275 Ω-cm for the lung tissue and 2500 Ω-cm for the fatty tissue. The so-called inductive reactance is the impedance effect, $X_L = 2\pi f L$, caused by inductors (L, in henrys). For a circuit containing a single inductor that is excited by an AC sinusoidal wave, the inductor will impede the change in current. Thus, the conductive current (I) will lag 90 degrees behind the voltage (V). Figure 9.1 shows the relationship between the vector relationships. The so-called capacitive reactance is the impedance effect, $X_C = \dfrac{1}{2\pi f C}$, caused by capacitors (C, in farads). For a circuit containing a single capacitor that is excited by an AC sinusoidal wave, the capacitor will impede the change in voltage. Thus, the capacitive current (I) will lead the voltage V by 90 degrees. Figure 9.2 illustrates the relationships between those vectors. Conventionally, the relationship between the resistance and the two kinds of reactance is described using a Cartesian coordinate system. As shown in Figure 9.3, the +X axis represents the resistance (R) and is the reference point for all angle measurements. The +Y axis denotes the inductive reactance ($+X_L$) and the -Y axis denotes the capacitive reactance ($-X_C$). From the figure, because both kinds of reactance are along the vertical axis, they can be algebraically added to form a combination. But, when a circuit includes simultaneously the resistance (R), the inductive reactance ($+X_L$) and the capacitive reactance ($-X_C$), the resultant impedance can be determined by
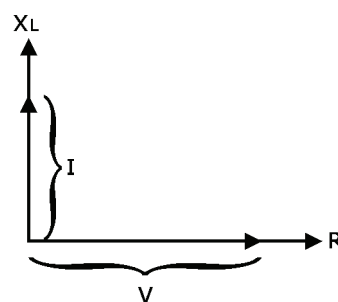
$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

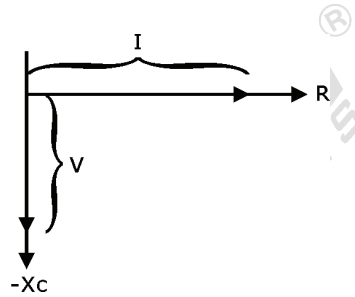Figure 9.1 Phase relationship between V and I in an AC RL circuit.

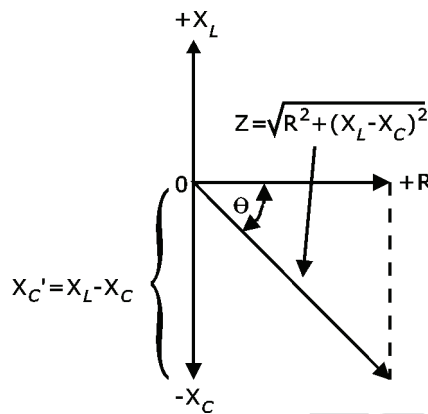Figure 9.2 Phase relationship between V and I in an AC RC circuit.

Figure 9.3 Phase relationship between the impedances in an AC RLC circuit.

Most impedance measurements of physiological experiments relate to the AC impedance. This is due to that the capacitive reactance effect dominates the resistance and inductive reactance effects in human body. Therefore, the human body has a tolerance to DC current, usually 1 mA minimal through skin conduction. The human tissue is the electrolyte- type intrinsically, but it is not a simple electrolyte. During the cellular activation, the potassium ion and sodium ion concentrations inside and outside the cell membrane will be changed. In addition, the AC current does not pass through the tissue evenly, and is affected by the frequency. This makes the measured impedance sensitive to the frequency of the input current. As a result, differing impedance are seen at different frequencies. For example, when common Ag-AgCl electrodes are applied, the impedance of skin is a function of frequency, as shown in Figure 9.4. About 50 Hz for measuring superficial layer of body impedance is sufficient, but it is too close to the frequency of the AC power lines. So, the measurement may be easily interfered with the power line frequency. When observing deeper organs, the investigator might want to adopt higher frequencies (> 20 Hz) to decrease the effect of skin impedance on

the final measurement. Another reason for choosing higher frequencies is that cells and other structures react to the current with a specific strength-duration characteristic. The strength-duration is defined as the duration of a stimulus having twice the intensity of a stimulus that would be just sufficient to cause stimulation if allowed to remain on for an infinite time. In other words, it is the stimulus duration at twice the threshold for a steady-state stimulus. The duration values from 0.2 ms for nerve tissues to 100 ms for smooth muscles. An important point of the duration value is that the period of the AC signal used to excite tissue in impedance measurements must be less than that for the tissue. From the relation $f = \dfrac{1}{T}$, the minimum frequency should be 5000 Hz for nerve tissue.
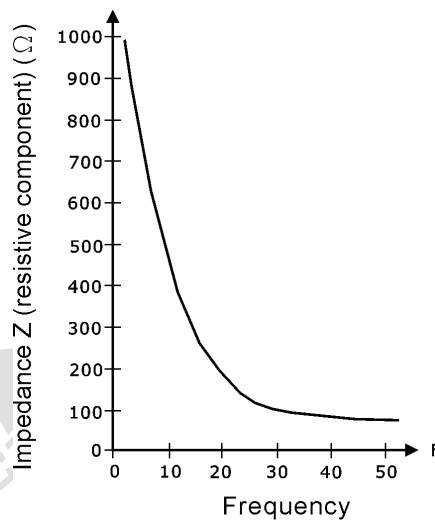

Figure 9.4 Frequency response of impedance.

9.2 PRINCIPLE OF CIRCUIT DESIGN

1. Block Diagram of Body Impedance Measurement Circuit

As described in the previous section, the human tissue is electrolyte-like and its main impedance effect is the capacitive reactance. Thus, an AC constant current source must be input to the body to obtain a potential signal proportional to the body impedance. In the experiment, the impedance of a current path through the heart will be measured. When the heart is in the

systole or diastole, there is an obvious change in the amount of blood inside the cardiac chambers. This also reflects on the change in the body impedance. Therefore, two current electrodes are placed on the upper arms proximal to the wrists, respectively, and two measurement electrodes are placed on the upper arms close to the elbow. Further, 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 impedance detection. Figure 9.5 shows the block diagram related to the body impedance measurement. In the figure, a 50 KHz sine wave is first provided by the Wien-bridge oscillator and passes through the constant current source, and is then sent to body by means of surface electrodes. Another pair of electrodes is used to measure the impedance signal. The preamplifier constructed by an instrumentation amplifier is used to extract a unipolar signal from vector signals. Its gain is designed to 5. The isolation circuit designed here is intended to isolate the signal and line power source, and can be implemented either by an optical or by voltage-transformed method. A demodulator constructed by a full-wave rectifier circuit can be used to separate the low-frequency impedance signal from the 50 KHz carrier signal. After passing through a band-pass filter with a bandwidth 0.1~10 Hz, the impedance signal associated with change in cardiac output will be obtained. Finally, we can directly watch the signal related to the body impedance change on the oscilloscope screen with an amplification of 500.
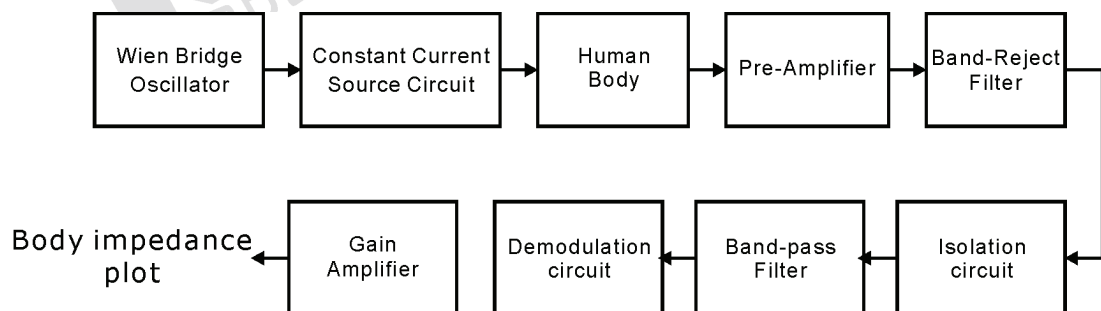
Figure 9.5 Block diagram of body impedance measurement.
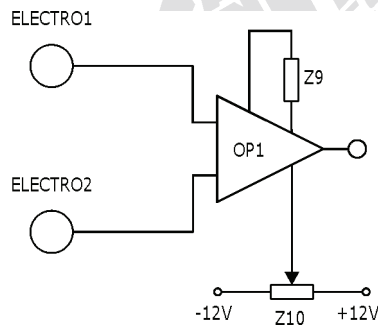
2. Preamplifier

Figure 9.6 Preamplifier circuit.

Figure 9.6 shows the preamplifier circuit that is composed of an instrumentation amplifier OP1 (AD620). Its gain can be determined with Equation (9.2), and the pin 5 is used as the reference terminal. We can adjust Z_{10} to eliminate the drift voltage appearing on the output terminal.

$$Av = \frac{49.4k\Omega}{Z_9} + 1 \tag{9.2}$$
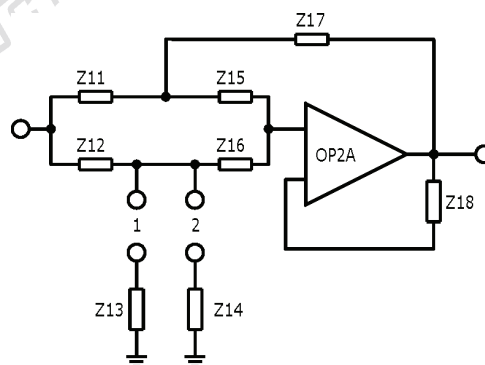
3. Band-Reject Filter

Figure 9.7 Band-reject filter circuit.

Figure 9.7 shows a twin-T band-reject filer composed by RC networks, including OP2A, Z_{11}, Z_{12}, Z_{13} (or Z_{14}), Z_{15}, Z_{16} and Z_{17}. If $Z_{11} = Z_{15}$, $Z_{12} = Z_{16}$, $Z_{13} = 0.5Z_{11}$ (or $Z_{14} = 0.5Z_{11}$) and $Z_{17} = 2Z_{12}$, the center frequency can be calculated by Equation (9.3).

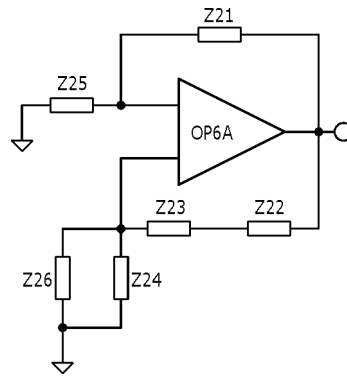$$f = \frac{1}{2\pi Z_{11} Z_{12}} \tag{9.3}$$

4. Wien Bridge Oscillator

Figure 9.8 Wien-bridge oscillator circuit.

Figure 9.8 shows the Wien-bridge oscillator circuit constructed by OP6A, Z_{21}, Z_{22}, Z_{23}, Z_{24}, Z_{25} and Z_{26}, which can provide a sinusoidal wave. The oscillator circuit is designed using a positive-feedback concept, and its frequency of oscillation can be calculated by Z_{22}, Z_{23}, Z_{24} and Z_{26}, as expressed in Equation (9.4).

$$f = \frac{1}{2\pi\sqrt{Z_{22}Z_{23}Z_{24}Z_{26}}} \tag{9.4}$$

The condition of oscillation is decided by Z_{21}, and must satisfy with Equation (9.5).

$$\frac{Z_{21}}{Z_{25}} \geq 2 \tag{9.5}$$
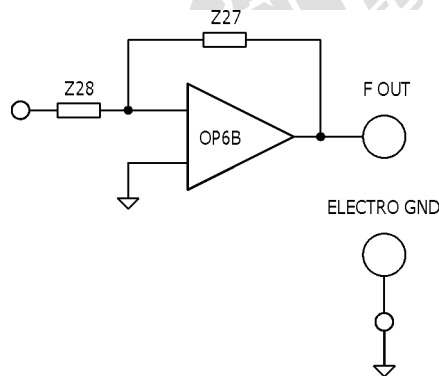
5. Constant Current Circuit

Figure 9.9 Constant current circuit.

Figure 9.9 illustrates the constant current circuit, in which OP6B possesses a negative feedback. There is a virtual short-circuit phenomenon between the input terminals, so the output current is independent of the load and merely depends on the input voltage, that is, $I_L = \dfrac{V_i}{Z_{28}}$. Thus, the combination of OP6B, Z_{27} and Z_{28} can be considered as a constant-current source.
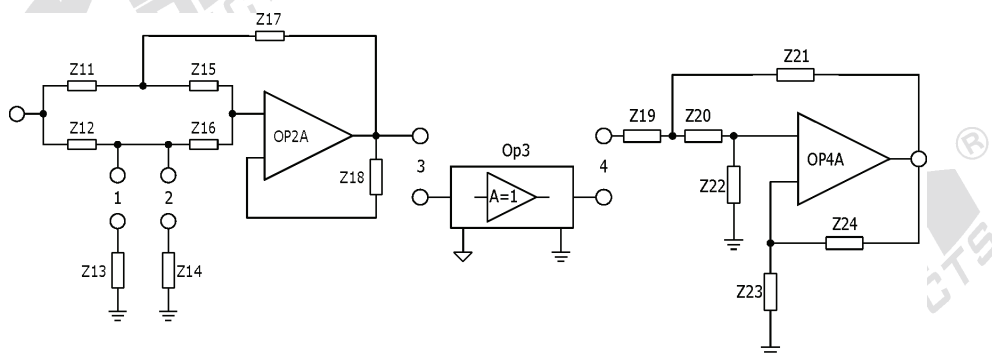
6. Isolation Circuit

Figure 9.10 Isolation circuit.

As shown in Figure 9.10, the isolation circuit is constructed by OP3. In the experiment, the signal isolation is performed with an optical approach.
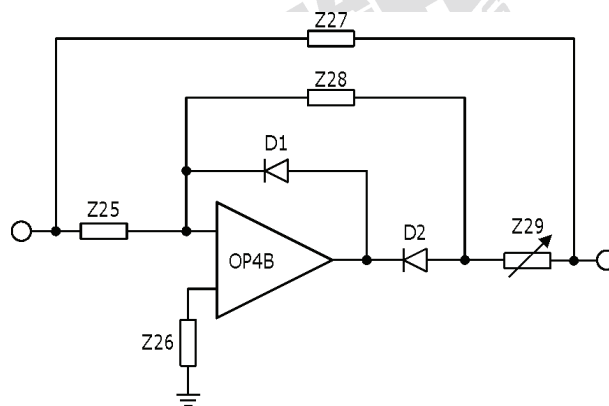
7. Demodulator Circuit

Figure 9.11 Demodulator circuit.

Figure 9.11 demonstrates the demodulator circuit, in which an inverting half-wave rectifier is constructed by OP4B, D_1, D_2, Z_{25} and Z_{28}. Also, the full-wave rectifying function is performed by the summation of the half-wave signal and the original signal through Z_{27} and Z_{29}.

8. Band-Pass Filter Circuit
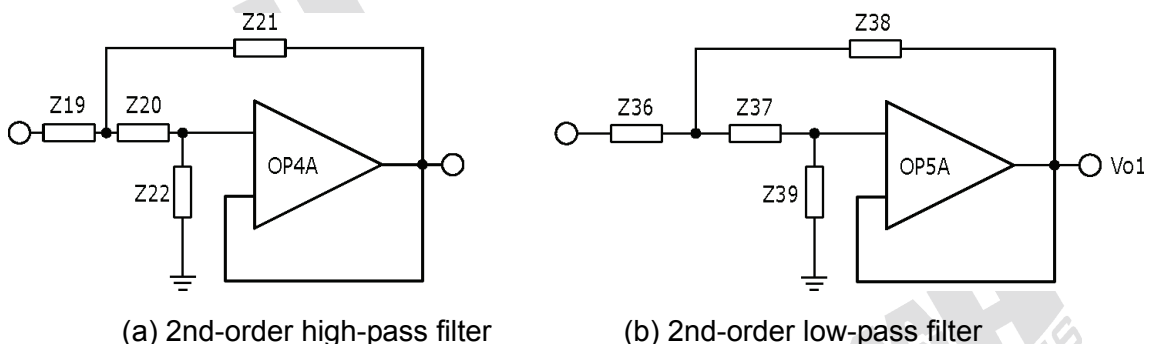
(a) 2nd-order high-pass filter   (b) 2nd-order low-pass filter

Figure 9.12 Band-pass filter circuits.

OP4A is used to construct an active 2nd-order high-pass filter that can reduce the voltage level deviation after isolation, as shown in Figure 9.12. The cutoff frequency (f_L) of the filter is set at 0.1 Hz, and can be calculated using Z_{19}, Z_{20}, Z_{21} and Z_{22}, as expressed in Equation (9.6),

$$f_L = \frac{1}{2\pi\sqrt{Z_{19}Z_{20}Z_{21}Z_{22}}} \tag{9.6}$$

OP5A is used to construct an active 2nd-order low-pass filter. Its cutoff frequency (f_H) is set at 10 Hz, and can be calculated using Z_{36}, Z_{37}, Z_{38} and Z_{39}, as expressed in Equation (9.7),

$$f_H = \frac{1}{2\pi\sqrt{Z_{36}Z_{37}Z_{38}Z_{39}}} \tag{9.7}$$

9. Gain Amplifier
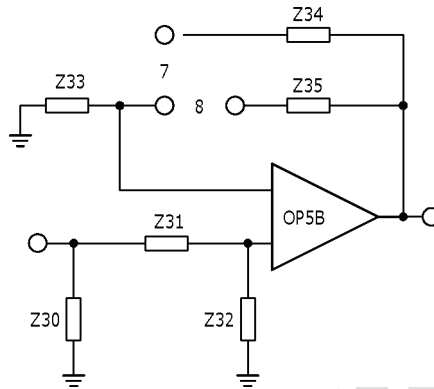
Figure 9.13 Gain amplifier circuit.

Figure 9.13 shows a non-inverting amplifier constructed by OP5B. In the amplifier, Z_{34} and Z_{35} are used for the gain adjustment, as expressed in Equation (9.10).

$$A_V = \frac{Z_{33} + Z_{34}}{Z_{33}} \quad \& \quad A_V = \frac{Z_{33} + Z_{35}}{Z_{33}} \tag{9.8}$$

9.3 EQUIPMENT REQUIRED

1. KL-72001 Main Unit
2. KL-75009 Impedance Module
3. Digital Storage Oscilloscope
4. Digital Voltmeter (DVM)
5. KL-79101 5-Conductor Electrode Cable
6. Body Surface Electrodes
7. Alcohol Prep Pads
8. Electrode Leads
9. DB9 Cable
10. BNC Cables
11. RS-232 Cable
12. Connecting Wires
13. 10-mm Bridging Plugs
14. Trimmer

9.4 PROCEDURE

※ **Caution! People with a cardiac pacemaker must avoid performing this experiment.**
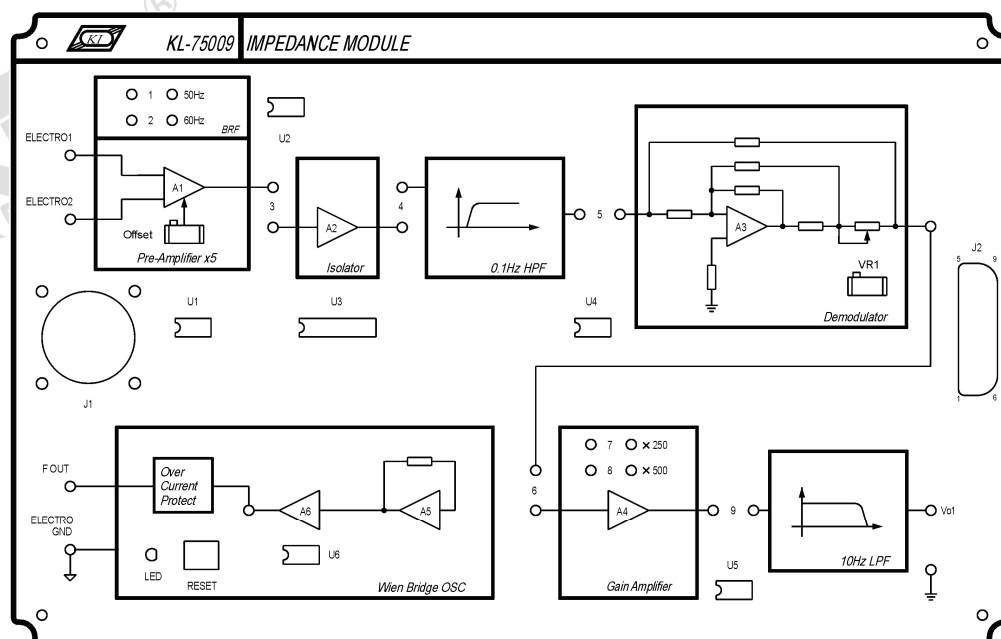
Figure 9.14 Front panel of KL-75009 Impedance Module.

A. Calibrating the Pre-Amplifier

1. Set KL-75009 Impedance Module on KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit				KL-75009 Impedance Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2

KL-75009 Impedance Module				
Block	Terminal	To	Block	Terminal
Pre-Amplifier x5	ELECTRO1	→	Pre-Amplifier x5	ELECTRO2
Pre-Amplifier x5	ELECTRO2	→	Wien Bridge OSC	ELECTRO GND

2. Turn power on.

3. Connect the positive probe of DVM to the output terminal of Pre-Amplifier and the negative probe to ELECTRO GND.

4. Adjust the Offset potentiometer to make the output DC voltage indicated by the DVM equal to 0 V.

5. Turn power off and disconnect circuit.

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

1. Set KL-75009 Impedance 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-75009 Impedance Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	–	OUTPUT	→	Pre-Amplifier x5	ELECTRO1
FUNCTION GENERATOR	–	GND	→	Pre-Amplifier x5	ELECTRO2
SCOPE ADAPTOR	--	CH2	→	Pre-Amplifier x5	Output

KL-75009 Impedance Module				
Block	Terminal	To	Block	Terminal
Pre-Amplifier x5	ELECTRO2	→	Wien Bridge OSC	ELECTRO GND

2. 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).
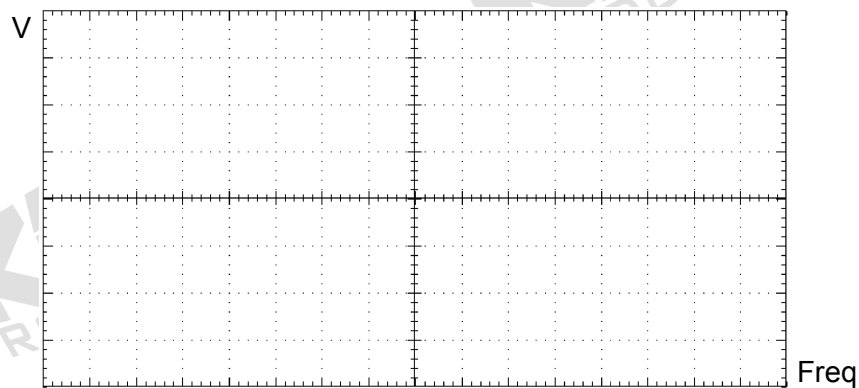
3. Turn power on.

4. Apply a 5 Hz, 1 Vpp sine signal to the ELECTRO1 input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR, and observe CH1 trace on the oscilloscope screen.

5. Observe BRF output signal displayed on CH2 trace, then record the amplitude in Table 9.1.

6. Without changing the amplitude of input sine signal, repeat Steps 4 and 5 for other frequency values listed in Table 9.1.

Table 9.1 Measured output amplitude of BRF.

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

7. According to the recorded data in Table 9.1, plot the characteristic curve of band-reject filter in Table 9.2.

Table 9.2 Characteristic curve of BRF.

8. Turn power off and disconnect circuit.

C. Measuring the Characteristics of Wien Bridge Oscillator

1. Set KL-75009 Impedance Module on KL-72001 Main Unit. Complete the following connections:
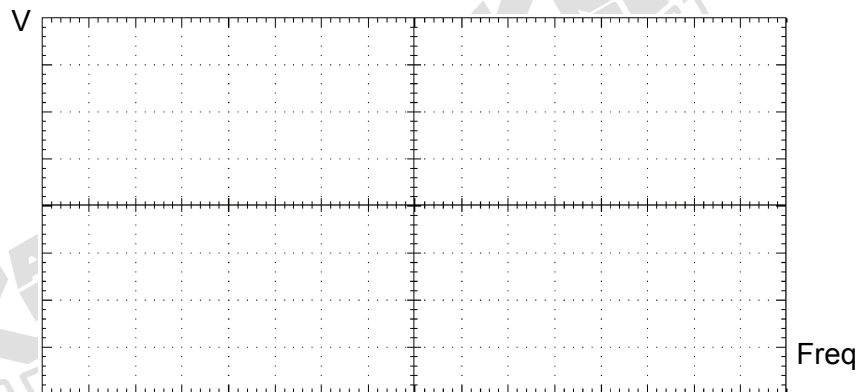
KL-72001 Main Unit				KL-72001 Main Unit		
Section	Area	Terminal	To	Section	Area	Terminal
SCOPE ADAPTOR	–	CH1 (BNC)	→	CH1 input of the oscilloscope		

KL-72001 Main Unit				KL-75009 Impedance Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
SCOPE ADAPTOR	--	CH1	→	Wien Bridge OSC	F OUT

KL-75009 Impedance Module				
Block	Terminal	To	Block	Terminal
Wien Bridge OSC	ELECTRO GND	→	--	GND

2. Turn power on.

3. Observe the output signal displayed on CH1 trace and record the waveform in Table 9.3.

Table 9.3 Measured output waveform of Wien Bridge OSC.

4. Turn power off and disconnect circuit.

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

1. Set KL-75009 Impedance Module on KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit			To	KL-72001 Main Unit		
Section	Area	Terminal		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		

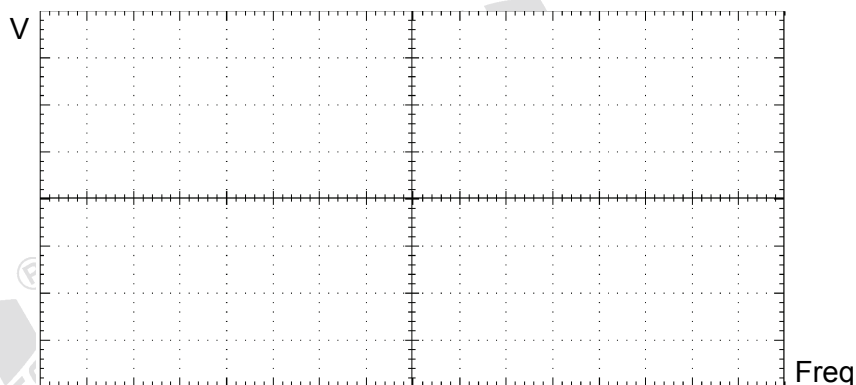| KL-72001 Main Unit			To	KL-75009 Impedance Module	
Section	Area	Terminal		Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	0.1Hz HPF	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	0.1Hz HPF	Output

2. Turn power on.

3. 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.

4. Observe HPF output signal displayed on CH2 trace and record the amplitude in Table 9.4.

5. Without changing the amplitude of input sine signal, repeat Steps 3 and 4 for different frequency values listed in Table 9.4.

Table 9.4 Measured output amplitude of HPF.

Input Freq	1KHz	10Hz	1Hz	0.6Hz	0.5Hz	0.4Hz	0.3Hz	0.2Hz	0.1Hz
HPF Output (Vpp)									

6. According to the recorded data in Table 9.4, plot the characteristic curve of HPF in Table 9.5.

Table 9.5 Characteristic curve of HPF.

V

Freq

7. Turn power off and disconnect circuit.
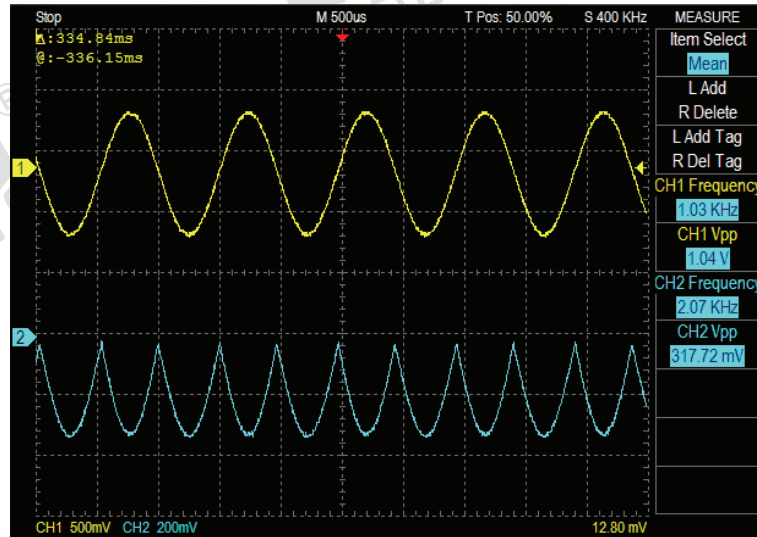
E. Measuring the Characteristics of Demodulator

1. Set KL-75009 Impedance Module on KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit			To	KL-72001 Main Unit		
Section	Area	Terminal		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		

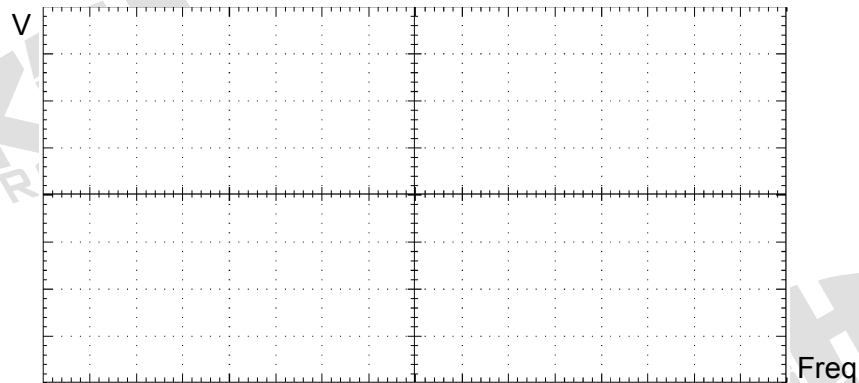| KL-72001 Main Unit			To	KL-75009 Impedance Module	
Section	Area	Terminal		Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	Demodulator	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	Demodulator	Output

2. Turn power on.

3. Apply a 1 KHz, 1 Vpp sine signal to the Demodulator input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR, and observe CH1 trace on the oscilloscope screen.

4. Observe the Demodulator output signal displayed on the CH2 trace. Adjust the VR1 potentiometer, so the output negative peaks are equal. See the figure below.

5. Record the input and output signals of Demodulator in Table 9.6.

Table 9.6 Measured input and output signals of Demodulator.

6. Turn power off and disconnect circuit.

F. Measuring the Characteristics of Gain Amplifier

1. Set KL-75009 Impedance Module on KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit			To	KL-72001 Main Unit		
Section	Area	Terminal		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			To	KL-75009 Impedance Module	
Section	Area	Terminal		Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	Gain Amplifier	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	Gain Amplifier	Output

2. On KL-75009 Impedance Module, insert the bridging plug in the position 7 (gain=250).
3. Turn power on.
4. Apply a 100 Hz, 30 mVpp sine signal to the Gain Amplifier input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR, and observe CH1 trace on the oscilloscope screen.
5. Observe the Gain Amplifier output signal displayed on CH2 trace and record the amplitude in Table 9.7.

Table 9.7 Measured output amplitude of Gain Amplifier.

Amplifier Gain Setting	Amplifier Output Voltage (Vpp)
250	
500	

6. Remove the bridging plug from position 7 to position 8 (gain = 500). Repeat Steps 4 and 5.

7. Turn power off and disconnect circuit.

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

1. Set KL-75009 Impedance Module on KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit			To	KL-72001 Main Unit		
Section	Area	Terminal		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			To	KL-75009 Impedance Module	
Section	Area	Terminal		Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	10Hz LPF	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	10Hz LPF	Output (Vo1)

2. Turn power on.

3. Apply a 0.1 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.

4. Observe LPF output signal displayed on CH2 trace and record the amplitude in Table 9.8.

5. Without changing the amplitude of input sine signal, repeat Steps 3 and 4 for other frequency values listed in Table 9.8.

Table 9.8 Measured output amplitude of LPF.

Input Freq	0.1Hz	1Hz	5Hz	8Hz	10Hz	15Hz	20Hz	50Hz	100Hz
LPF Output (Vpp)									

6. According to the recorded data in Table 9.8, plot the characteristic curve of LPF in Table 9.9.

Table 9.9 Characteristic curve of LPF.
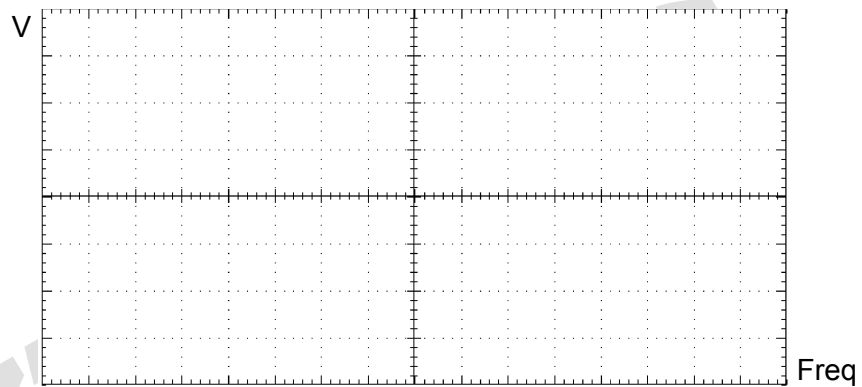
7. Turn power off and disconnect circuit.

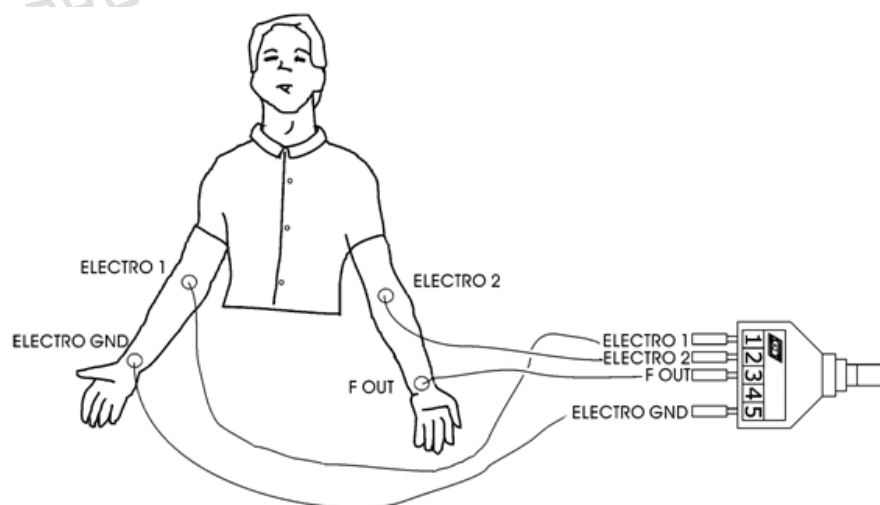## H. Body Impedance Measurement using Oscilloscope

Caution! People with a cardiac pacemaker must avoid performing this experiment.

1. Set KL-75009 Impedance Module on KL-72001 Main Unit. Complete the following connections:

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

KL-72001 Main Unit			To	KL-75009 Impedance Module	
Section	Area	Terminal		Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2

2. On KL-75009 Impedance Module, insert bridging plugs in positions 1 or 2 (according to local line frequency), 3, 4, 5, 6, 7 (gain=250), and 9.

3. Refer to the electrode placement shown below, clean the skin with alcohol prep pads and apply the electrodes on the subject arms.

4. As shown above, connect the electrodes to the lead side of KL-79101 5-Conductor Electrode Cable, and then connect the module side of the electrode cable to J1 connector on KL-75009 Impedance Module.

5. Turn power on. Select the MODULE:KL-75009 (IMP) item from the LCD display by pressing the SELECT button of KL-72001 Main Unit.

6. Make sure that the Pre-Amplifier and Demodulator circuits have been calibrated (refer to Procedure A and E).

7. Set the VOLT/DIV control of CH1 to 200 mV/div, the TIME/DIV control to 250 ms/div, and set Coupling mode to AC.

Notes:

a. During the experiment, the subject should keep hands loose and motionless.

b. If a large noise is present on the measured signal, it maybe caused by the high impedance existed between the skin and electrode. Use the alcohol prep pads to remove the oil on the skin before re-applying the electrodes.

c. When the indicator LED located in the Wien Bridge OSC block lights, it indicates that there is overloading and the output amplitude must be reduced to protect the subject from risk or discomfort. In such situation, disconnect all the bridging plugs and connecting wires from KL-75009 Impedance Module. To resume, press the RESET button just beside the LED, and then re-power KL-72001 Main Unit.

8. Observe the body impedance signal Vo1 displayed on the CH1 trace. Adjust the VR1 potentiometer to get the plethysmogram as shown below. Record the waveform in Table 9.10.

9. Remove the bridging plug from position 7 to 8 (gain = 500). Repeat Steps 7 and 8.

Table 9.10 Measured body impedance signal.

| Amplifier Gain	Vo1 Waveform
250	
500	

10. Turn power off and disconnect circuit.

I. Body Impedance Measurement using KL-720 Software

Caution! People with a cardiac pacemaker must avoid performing this experiment.

1. Set KL-75009 Impedance Module on KL-72001 Main Unit. Connect as follows:

KL-72001 Main Unit				KL-75009 Impedance Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2

2. On KL-75009 Impedance Module, insert bridging plugs in positions 1 or 2 (according to local line frequency), 3, 4, 5, 6, 7 (gain=250), and 9.

3. Refer to the electrode placement shown below, clean the skin with alcohol prep pads and apply the electrodes on the subject arms.
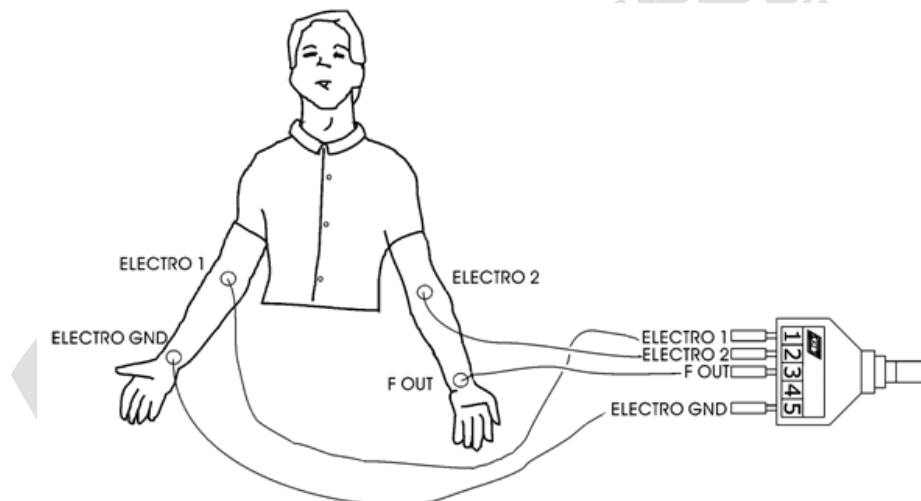

4. As shown above, connect the electrodes to the lead side of KL-79101 5-conductor electrode cable, and then connect the module side of the electrode cable to J1 connector on KL-75009 Impedance Module.

5. Connect RS-232 OUTPUT connector of KL-72001 Main Unit to RS-232 port on the computer using RS-232 cable.

6. Turn power on. Select the MODULE:KL-75009 (IMP) item from the LCD display by pressing the SELECT button of KL-72001 Main Unit.

7. Make sure that the Pre-Amplifier and Demodulator circuits have been calibrated (refer to Procedure A and E).

8. Boot the computer.

9. Execute KL-720 program. The window of KL-720 Biomedical Measurement System appears as shown below.
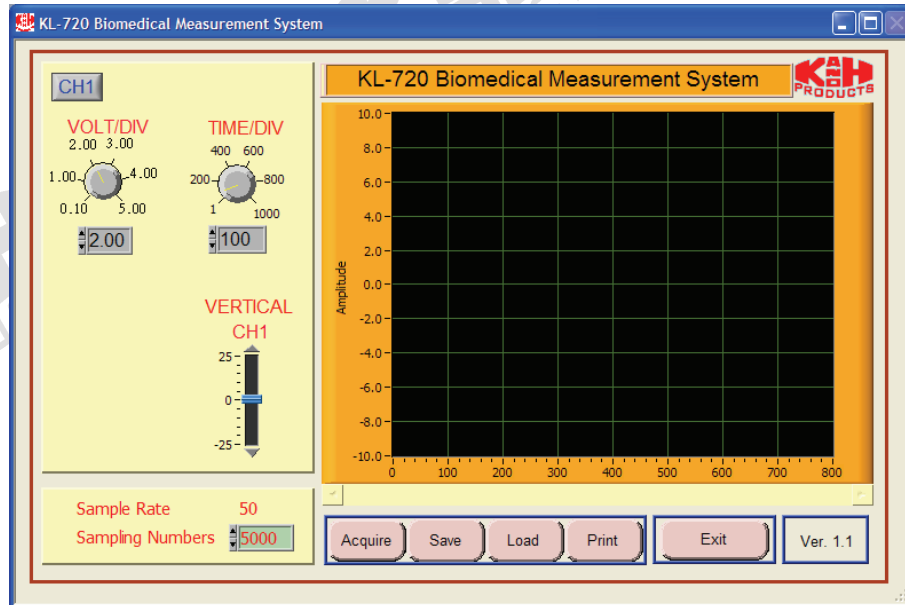
10. Click the Acquire button. The system begins to acquire the measured data via RS-232 port and shows the waveform in the window of KL-75009 Impedance to look like this:
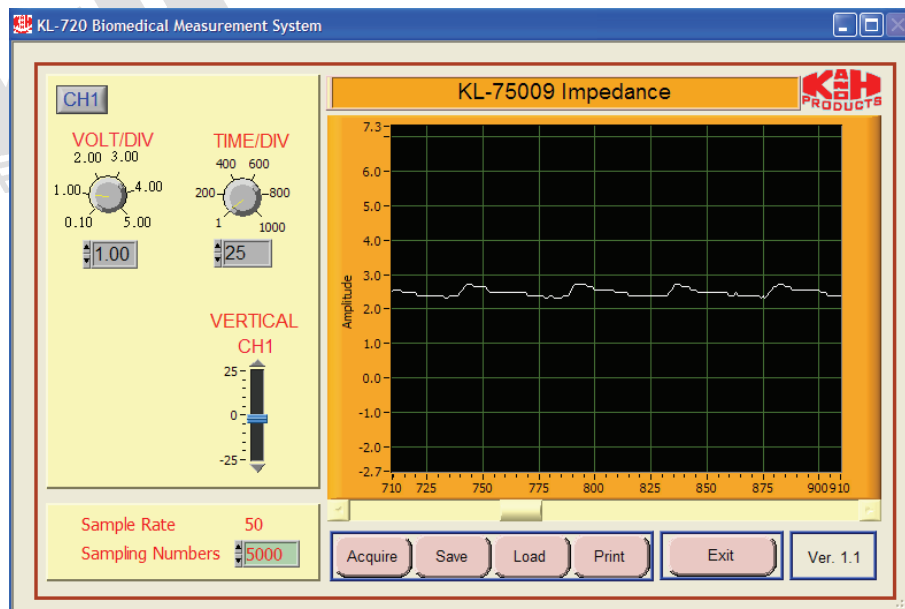

Note: If the message "time out, please check the COM port was connected the device" appears, check the connection and setup of RS-232 port.

11. Adjust VOLT/DIV and TIME/DIV knobs, so the signal can be read accurately.

Notes:

    a. During the experiment, the subject should keep hands loose and motionless.

    b. If a large noise is present on the measured signal, it maybe caused by the high impedance existed between the skin and electrode. Use the alcohol prep pads to remove the oil on the skin before re-applying the electrodes.

    c. When the indicator LED located in the Wien Bridge OSC block lights, it indicates that there is overloading and the output amplitude must be reduced to protect the subject from risk or discomfort. In such situation, disconnect all the bridging plugs and connecting wires from KL-75009 Impedance Module. To resume, press the RESET button just beside the LED, and then re-power KL-72001 Main Unit.

12. Observe the body impedance signal Vo1 displayed on the CH1 trace. Adjust the VR1 to get the plethysmogram as shown below.
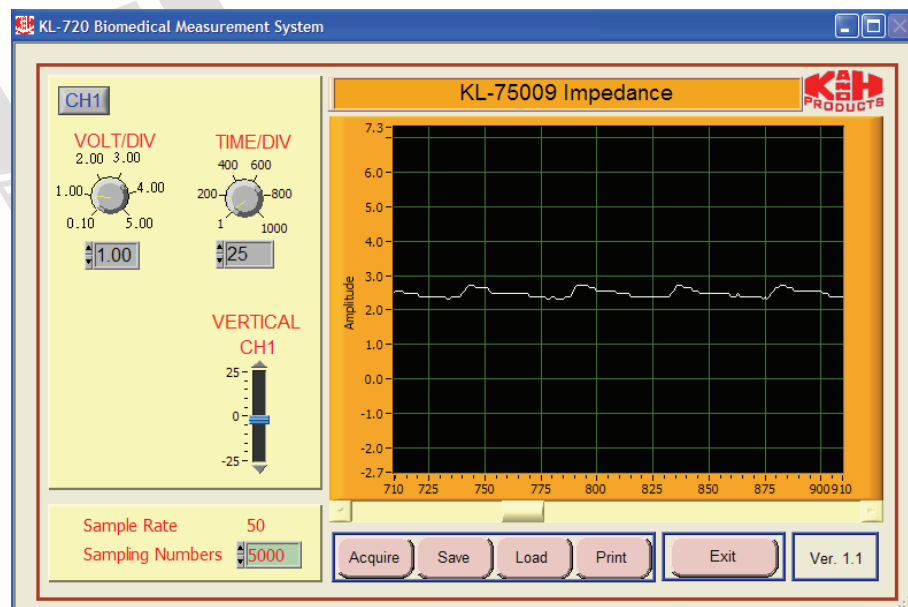
13. Save the waveform data on disk.
14. Exit KL-720 Biomedical Measurement System, turn power off and disconnect circuit.