EXPERIMENT 8 PULSE METER

8.0 OBJECTIVE

The purpose of the experiment is to help students realize the alteration of pulse waveform in arteries under different external pressures. In addition, the students can learn how to estimate the arterial static compliance.

8.1 PHYSIOLOGICAL PRINCIPLE

From the oscillometric blood pressure measurement experiment, we know that the arterial properties can drastically affect the cuff pressure and its corresponding oscillation amplitude. Thus, it is possible to assess the arterial compliance by explication of above relationship. In general, the hemodynamic characteristics of an arterial vessel can be described by the relationship between the internal pressure (P) of the arterial lumen and its corresponding vessel volume (V). The vessel compliance (C) can then be determined by differentiating the pressure-volume relation with respect to the pressure, as expressed in Equation (8.1).

$$C = \frac{dV}{dP} \tag{8.1}$$

A mathematical model can be used to govern the vessel properties, as represented in Equation (8.2),

$$V = \begin{cases} V_o e^{\frac{C_{\max}}{V_o} P_t} & P_t \le 0 \\ V_{\max} - (V_{\max} - V_o) V_o e^{-\frac{C_{\max}}{V_o} P_t} & P_t > 0 \end{cases} \tag{8.2}$$

Where P_t is the transmural pressure, the difference between the external exerted pressure and the internal pressure of the artery. V is the apparent vessel volume at the specific transmural pressure. V_o is the vessel volume while the transmural pressure is zero. V_{max} is the vessel volume when the artery is fully dilated and C_{max} is the maximum of arterial compliance. From Equation (8.2), it is clear that the maximum compliance of the artery occurs when the transmural pressure is zero. Figure 8.1 shows the static arterial properties that are generated by using Equation (8.2). The relationship between the arterial pressure and its corresponding arterial volume, at different transmural pressures is shown in the figure. Obviously, when the slope of the curve increases, the corresponding compliance decreases due to a smaller change in volume.

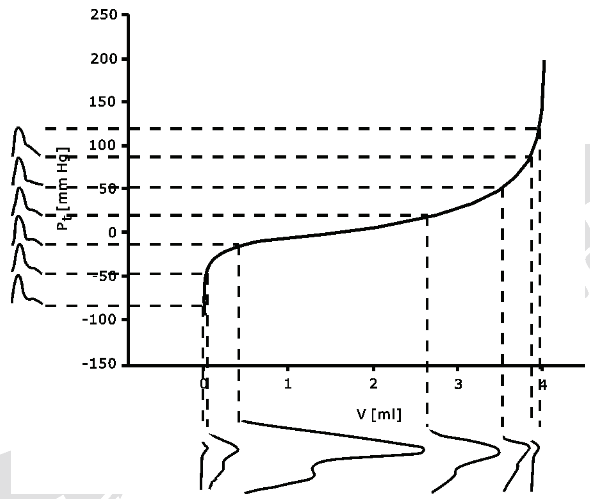


Figure 8.1 Static arterial properties (i.e., the relationship between the arterial pressure and the corresponding arterial volume at different transmural pressures.)

8.2 PRINCIPLE OF CIRCUIT DESIGN

1. Block Diagram of Pulse Measurement Circuit

From the previous section describing about the physiological principle related to the arteries, we know that the arterial compliance is not constant but nonlinearly varies with the arterial pressure. The response of the artery depends on the level of exerted force on it. It is similar to Chinese pulse diagnosis, in which we use fingers to sense the response of the radial artery to different force levels exerted on 'Chin,' 'Gwan,' and 'Schi' of the radial artery, respectively. In the experiment, a strain gauge is applied to detect the minute change in the arterial volume. Figure 8.2 shows a block diagram for the pulse measurement. In the beginning, the sensor is placed over the superficial radial artery at wrist. Then, a wrist - type cuff is wrapped around the strain gauge. The wrist - type cuff is inflated by a hand-operated air pump. The artery will respond to different transmural pressures and its wall properties may be assessed. The strain gauge is a strain-resistant component. Here, we thus use a Wheatstone bridge circuit to convert a change in the form of impedance to a change in the form of potential. Then, the differential amplifier will amplify the signal with varied voltage. After the amplified signal passes through the band-pass filer of 0.05~40 Hz, we can get a pulse signal. If we would like to obtain a synchronized pulse, we can use the hysteresis comparator to generate a square wave that triggers the monostable multivibrator circuit.

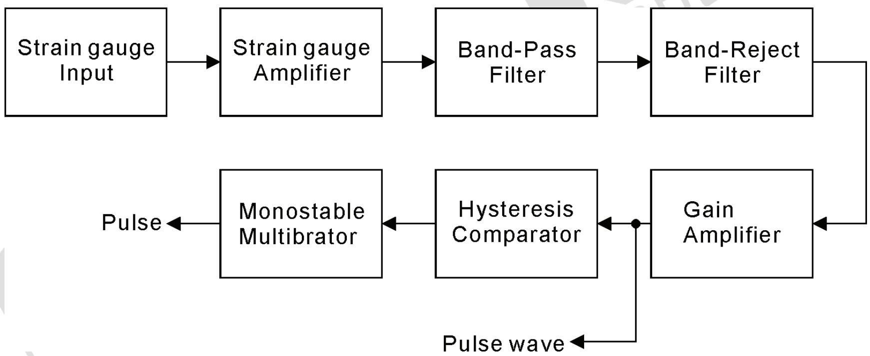


Figure 8.2 Block diagram of pulse measurement.

2. Strain Gauge

The strain gauge is a piezoelectric component made of metal wires, metal coils or semiconductors. It is used to measure the strain caused by an exerted force. Resistance (R) of a metal wire is defined as:

$$R = \frac{\rho L}{A} \tag{8.3}$$

where ρ is the resistivity, L is the length, and A is the cross section. When a cylindrical piezoelectric element is lengthened or compressed, its length and cross section will be correspondingly altered, leading to a change in its resistance, as expressed in Equation (8.4),

$$R = R_0 \pm \Delta R \propto \left(\frac{L_0 \pm \Delta L}{A_0 \mp \Delta A} \right) \tag{8.4}$$

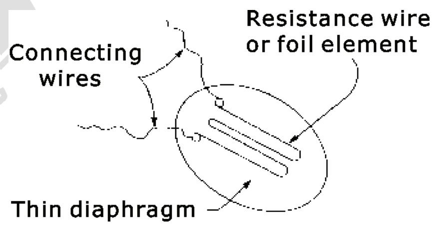
where R_0, L_0 and A_0 are the initial values before strain, and ΔR, ΔL and ΔA are the amounts of change. From Equation (8.4), when the lengthening or compression is due to a small physic amount of force, the change in resistance will almost be a linear function of the exerted force.

Usually, there are two kinds of strain gauges: bounded and unbounded, as shown in Figure 8.3. For a bounded strain gauge, a metal coil or semiconductor element is fixed with a thin but flexible vibration plate. The metal coil resistance will be changed when the vibration plate is bent due to an exerted force. For an unbounded strain gauge, a wire-resistant component is tightly pulled between two elastic supporters. The supporters are placed on a flexible film. When a force is exerted on the film, the length of the metal wire at the other end will correspondingly be altered, resulting in a change in its resistance. In the experiment, a bounded strain gauge is used, whose specification is summarized in Table 8.0. Sensitivity of the strain gauge is determined as the ratio of change in per unit length to change in per unit resistance, as expressed in Equation (8.5).

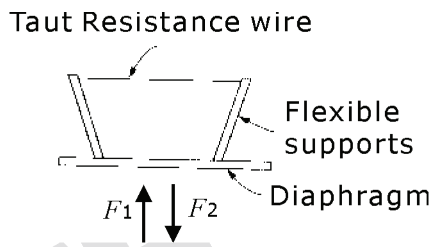
$$S = \left(\frac{\Delta R / R}{\Delta L / L} \right) \tag{8.5}$$

Table 8.0 Specification of strain gauge

Technical specification	
Gauge length	2 or 5 ㎜
Measurable strain	2 to 4% max.
Temperature range	-30℃ to + 180℃
Gauge resistance	120Ω ± 0.5%
Gauge factor	2.00(nominal)
Gauge factor temperature	
Coefficient	±0.05%/℃
Thermal	-30℃ to 20℃ not specified
Induced output	20℃ to 160℃ +2miro strain/℃*
	160℃ to 180℃ ±5 micro strain/℃*
Fatigue life	10 reversals at 1000 micro strain
Fait material	copper nickel alloy
Base material	Polyimide
Temperature compensation	
Material	*linear expansion factor*
Mild steel	$10.8 \times 10^{\ell}$/℃
Aluminium	$23.4 \times 10^{\ell}$/℃
*1 micro strain is equal to an extension of 0.0001%	
2mm gauges	



(a) Bonded strain gauge.



(b) Unbounded strain gauge.

Figure 8.3 Two types of strain gauge

3. Wheatstone Bridge Circuit

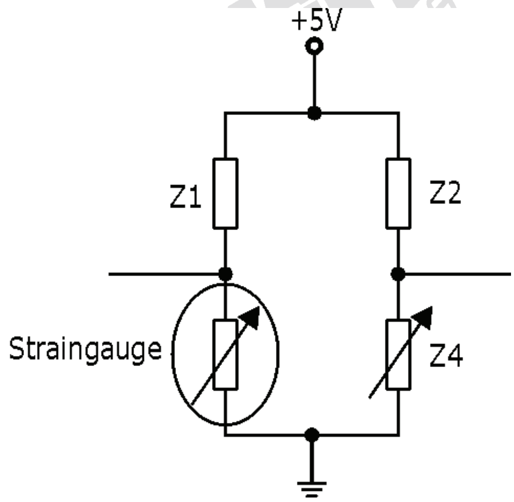


Figure 8.4 Wheatstone bridge circuit

Figure 8.4 shows a Wheatstone bridge circuit that consists of four elements and is often used in physiological measurement system. Here, the circuit contains four elements, Z_1, Z_2, Z_4 and SR (Strain gauge). SR represents the resistance of the strain gauge. If the excitation voltage is V, then the voltage difference between two terminals can be calculated by Equation (8.6).

$$V_d = V\left(\frac{SR}{SR+Z_1} - \frac{Z_4}{Z_2+Z_4}\right) \tag{8.6}$$

4. Strain Gauge Amplifier

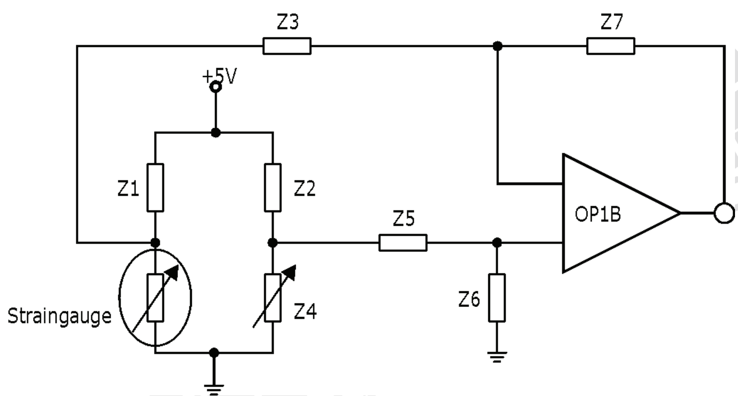


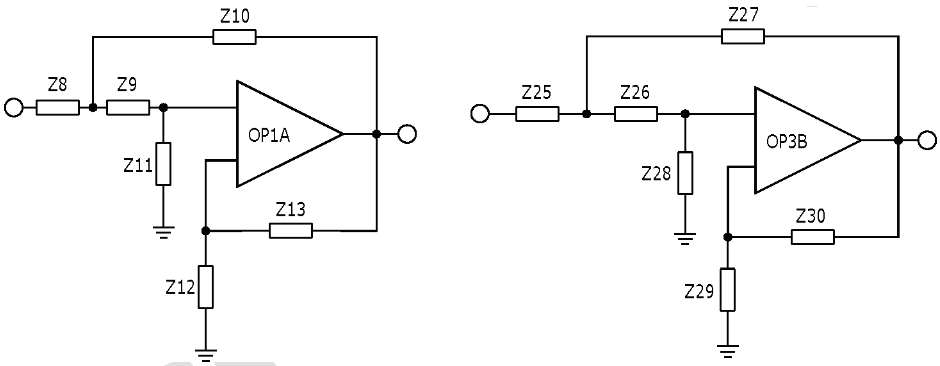
Figure 8.5 Strain gauge amplifier circuit

Figure 8.5 illustrates a differential amplifier that contains OP1B, Z_3, Z_5, Z_6, and Z_7. This differential amplifier can be used to magnify the voltage difference between the two terminals of Wheatstone bridge circuit. If $Z_3=Z_5$ and $Z_6=Z_7$, the gain of the differential amplifier is designed as Equation (8.7).

$$Av = \frac{Z_7}{Z_3} \tag{8.7}$$

When there is no force exerted on the strain gauge, we can adjust Z_4 to make the output of OP1B to be zero.

5. Band-Pass Filter Circuit



(a) 2nd-order high-pass filter (b) 2nd-order low-pass filter

Figure 8.6 Band-pass filter circuits

OP1A, an active 2nd-order high-pass filter, is used to reduce the DC level variation produced in the differential amplifier, as shown in Figure 8.6(a). The cutoff frequency (f_L) of the filter is set at 0.05 Hz, and can be calculated using Z_8, Z_9, Z_{10} and Z_{11}, as expressed in Equation (8.8).

$$f_L = \frac{1}{2\pi\sqrt{Z_8 Z_9 Z_{10} Z_{11}}} \tag{8.8}$$

And, its passband gain is explained in Equation (8.9),

$$\frac{Z_{12}+Z_{13}}{Z_{12}} = 1.56 \tag{8.9}$$

OP3B is an active 2nd-order low-pass filter, as shown in Figure 8.6(b). Its cutoff frequency (f_H) is set at 40 Hz, and can be calculated using Z_{25}, Z_{26}, Z_{27} and Z_{28}, as expressed in Equation (8.10).

$$f_H = \frac{1}{2\pi\sqrt{Z_{25}Z_{26}Z_{27}Z_{28}}} \tag{8.10}$$

And, its passband gain is explained in Equation (8.11)

$$\frac{Z_{29}+Z_{30}}{Z_{29}} = 1.56 \tag{8.11}$$

6. Band-Reject Filter

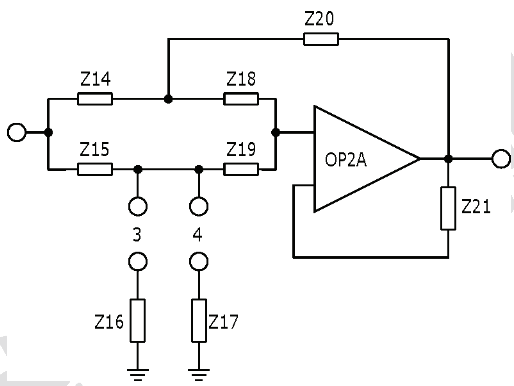


Figure 8.7 Band-reject filter circuit

Figure 8.7 shows a twin-T band-reject filer composed by RC networks, including OP2A, Z_{14}, Z_{15}, Z_{16} (or Z_{17}), Z_{18}, Z_{19} and Z_{20}. If $Z_{14} = Z_{18}$, $Z_{15} = Z_{19}$, $Z_{16} = 0.5Z_{14}$ (or $Z_{17} = 0.5Z_{14}$) and $Z_{20} = 2Z_{15}$, the center frequency can be calculated by Equation (8.12).

$$f = \frac{1}{2\pi Z_{14}Z_{15}} \tag{8.12}$$

7. Gain Amplifier

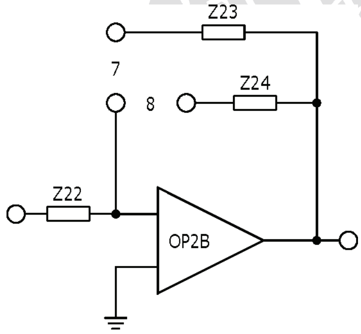


Figure 8.8 Gain amplifier

Figure 8.8 shows an inverting amplifier, OP2B. Here, Z_{23} and Z_{24} are used to select different gains, as expressed in Equation (8.12),

$$A_V = \frac{-Z_{23}}{Z_{22}} \quad \& \quad A_V = \frac{-Z_{24}}{Z_{22}} \tag{8.12}$$

8. Hysteresis Comparator Circuit

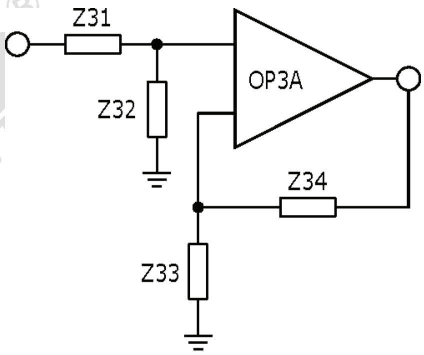


Figure 8.9 Hysteresis comparator circuit.

Figure 8.9 shows a hysteresis comparator consisting mainly of OP3A. The output of the hysteresis comparator is either negative or positive saturation voltage V_{CC}. The upper threshold voltage V_{UT} and the lower threshold voltage V_{LT} can be determined by Z_{33} and Z_{34}, as expressed in Equation (8.13):

$$V_{UT} = +\frac{Z_{33}}{Z_{33}+Z_{34}}V_{CC} \quad \& \quad V_{LT} = -\frac{Z_{33}}{Z_{33}+Z_{34}}V_{CC} \tag{8.13}$$

Both Z_{31} and Z_{32} construct a high-pass filter circuit which is capable of making the DC level of the pulse wave to be 0. Thus, when a pulse occurs, the comparator will send out a square wave.

9. Monostable Multivibrator Circuit

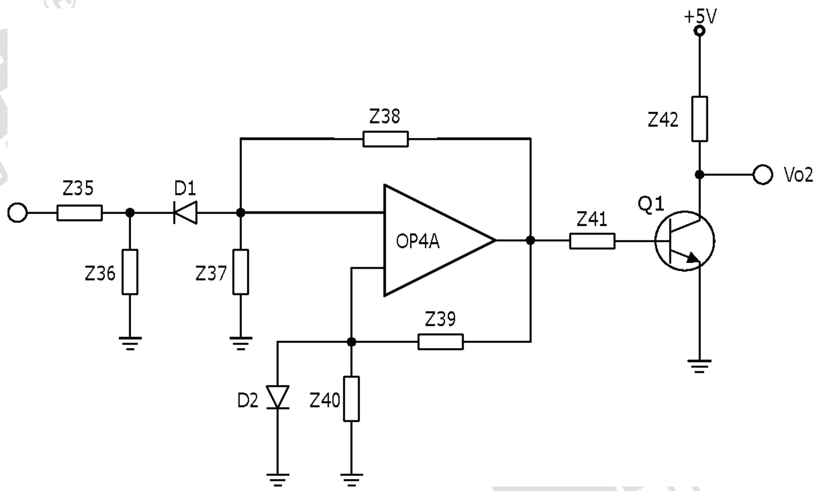


Figure 8.10 Monostable multivibrator circuit

Figure 8.10 shows the monostable multivibrator circuit that is composed of D_2, Z_{37}, Z_{38}, Z_{39}, Z_{40} and OP4A. In stable condition, the output of OP4A is positive saturation voltage. Z_{40} is charged through Z_{39}, and the voltage of Z_{40} remains to be 0.6V. Both Z_{35} and Z_{36} are used to differentiate the square wave from the comparator and to generate an impulse. Because only negative impulses can pass through D_1, this will cause a lower voltage on the positive terminal of OP4A than that (0.6V) on the negative terminal, and then trigger the occurrence of a transient. This makes the output of OP4A become negative saturation voltage. Then, Z_{40} will begin to discharge until its voltage is lower than the voltage on the positive input terminal, and finally the stable positive saturation voltage recovers.

8.3 EQUIPMENT REQUIRED

1. KL-72001 Main Unit
2. KL-75008 Pulse Meter Module
3. Digital Storage Oscilloscope
4. Digital Voltmeter (DVM)
5. Mechanical Sphygmomanometer
6. KL-79104 Strain Gauge Tie
7. Y Tube
8. Wrist - type Cuff
9. Hand-operated Pump
10. DB9 Cable
11. BNC Cables
12. RS-232 Cable
13. Connecting Wires
14. 10-mm Bridging Plugs
15. Trimmer

8.4 PROCEDURE

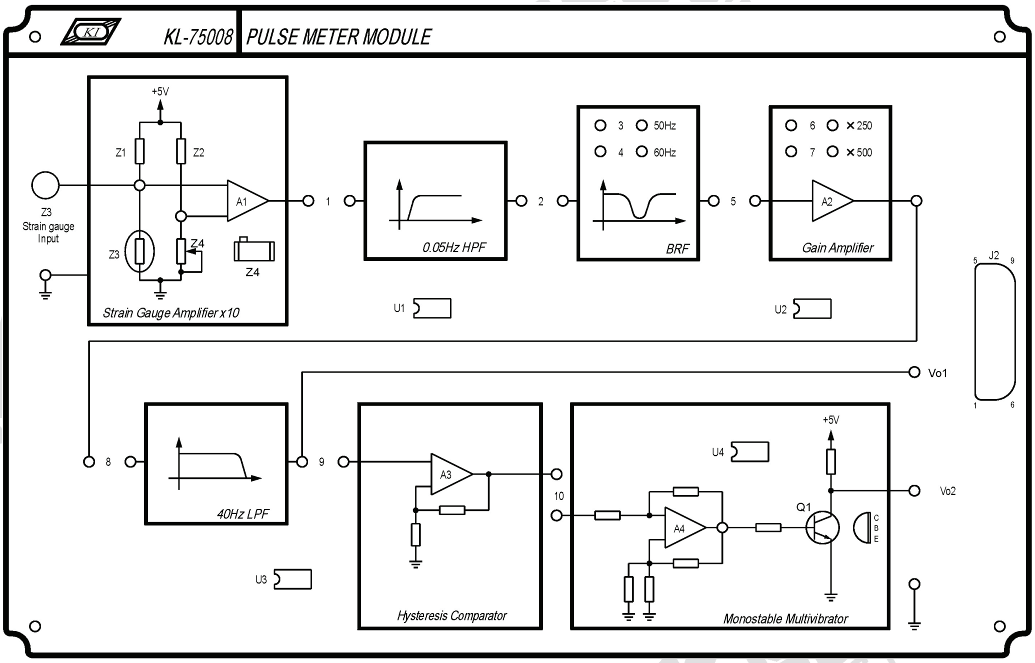


Figure 8.11 Front panel of KL-75008 Pulse Meter Module.

A. Calibrating the Strain Gauge Amplifier

1. Set KL-75008 Pulse Meter Module on KL-72001 Main Unit. Complete the following connection:

KL-72001 Main Unit				KL-75008 Pulse Meter Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2

2. Insert the output of KL-79104 Strain Gauge Tie into Strain gauge input jack Z3 on KL-75008 Pulse Meter Module.
3. Turn power on.
4. Connect the positive probe of DVM to the output terminal of the Strain Gauge Amplifier, and connect the negative probe to the ground terminal located at the bottom-right of KL-75008 Pulse Meter Module.
5. Put KL-79104 Strain Gauge Tie on the table horizontally. Adjust the Z4 potentiometer to make the output DC voltage indicated by DVM equal to 0 V.

6. Turn power off and disconnect circuit.

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

1. Set KL-75008 Pulse Meter 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-75008 Pulse Meter Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	0.05Hz HPF	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	0.05Hz HPF	Output

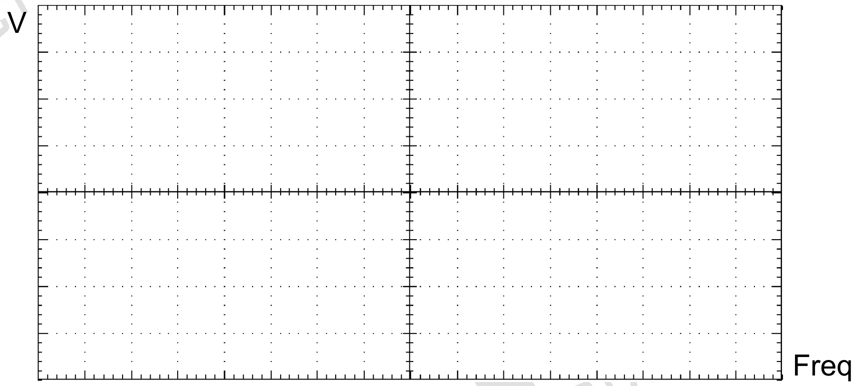
2. Turn power on.
3. Apply a 1 KHz, 1 Vpp sine signal to HPF input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR, and observe CH1 trace on the oscilloscope screen.
4. Observe HPF output signal displayed on CH2 trace and record the amplitude in Table 8.1.
5. Without changing the amplitude of input sine signal, repeat Steps 3 and 4 for different frequency values listed in Table 8.1.

Table 8.1 Measured output amplitude of HPF.

Input Freq	1KHz	100Hz	10Hz	1Hz	0.5Hz	0.4Hz	0.3Hz	0.2Hz	0.1Hz
HPF Output (Vpp)									

6. According to the recorded data in Table 8.1, plot the characteristic curve of HPF in Table 8.2.

Table 8.2 Characteristic curve of HPF.



7. Turn power off and disconnect circuit.

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

1. Set KL-75008 Pulse Meter 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-75008 Pulse Meter Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	—	9-Pin	→	—	J2
FUNCTION GENERATOR	—	OUTPUT	→	BRF	Input
FUNCTION GENERATOR	—	GND	→	—	Ground (in the bottom right corner)
SCOPE ADAPTOR	—	CH2	→	BRF	Output

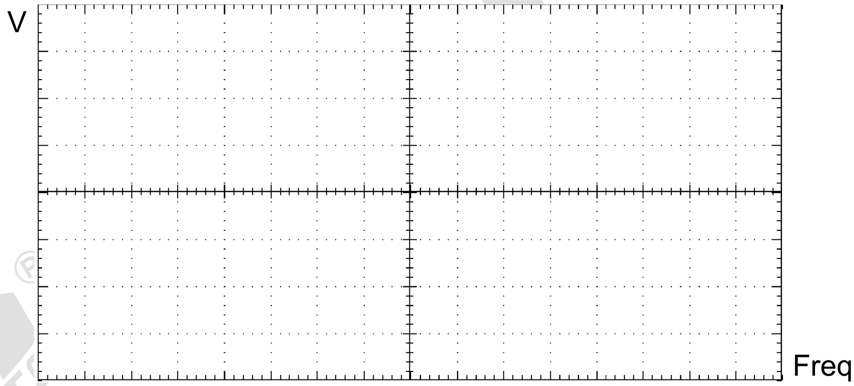
2. Insert a bridging plug into position 3 or 4 to set the center frequency of BRF to 50 or 60 Hz (according to local line frequency).
3. Turn power on.
4. Apply a 5 Hz, 1 Vpp sine signal to the ELECTRO1 input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR, and observe CH1 trace on the oscilloscope screen.
5. Observe BRF output signal displayed on CH2 trace, then record the amplitude in Table 8.3.
6. Without changing the amplitude of input sine signal, repeat Steps 4 and 5 for other frequency values listed in Table 8.3.

Table 8.3 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 8.3, plot the characteristic curve of band-reject filter in Table 8.4.

Table 8.4 Characteristic curve of BRF.



8. Turn power off and disconnect circuit.

D. Measuring the Characteristics of Gain Amplifier

1. Set KL-75008 Pulse Meter 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-75008 Pulse Meter Module	
Section	Area	Terminal	To	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-75008 Pulse Meter Module, insert the bridging plug in the position 6 (gain = 250).
3. Turn power on.

4. Apply a 1 KHz, 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 8.5.
6. Remove the bridging plug from position 6 to position 7 (gain = 500). Repeat Steps 4 and 5.

Table 8.5 Measured output amplitude of Gain Amplifier.

Amplifier Gain Setting	Amplifier Output Voltage (Vpp)
250	
500	

7. Turn power off and disconnect circuit.

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

1. Set KL-75008 Pulse Meter 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-75008 Pulse Meter Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	40Hz LPF	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	40Hz LPF	Output (Vo1)

2. Turn power on.
3. 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.
4. Observe the LPF output signal displayed on the CH2 trace and record the amplitude in Table 8.6.
5. Without changing the amplitude of input sine signal, repeat Steps 3 and 4 for different frequency values listed in Table 8.6.

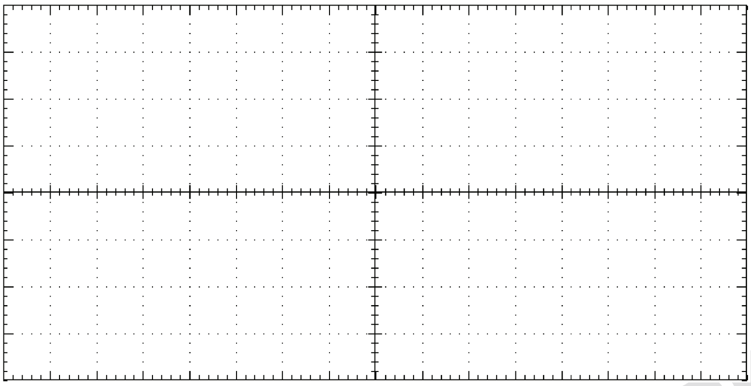
Table 8.6 Measured output amplitude of LPF.

Input Freq	1Hz	10Hz	20Hz	30Hz	35Hz	40Hz	45Hz	50Hz	100Hz
LPF Output (Vpp)									

6. According to the recorded data in Table 8.6, plot the characteristic curve of LPF in Table 8.7.

Table 8.7 Characteristic curve of LPF.

V



Freq

7. Turn power off and disconnect circuit.

F. Measuring the Characteristics of Hysteresis Comparator

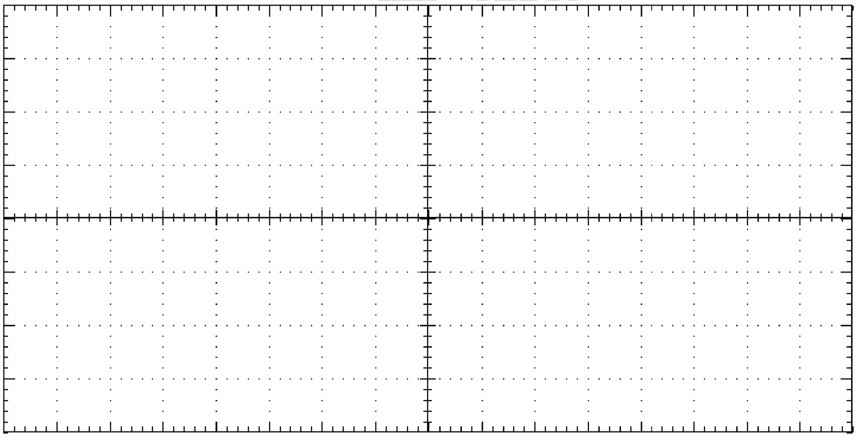
1. Set KL-75008 Pulse Meter Module on KL-72001 Main Unit. Complete the following connections:

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-75008 Pulse Meter Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	Hysteresis Comparator	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	Hysteresis Comparator	Output

2. Turn power on.
3. Apply a 1 KHz, 3 Vpp sine signal to the input of Hysteresis Comparator by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR, and observe CH1 trace on the oscilloscope screen.
4. Record the input and output waveforms of Hysteresis Comparator in Table 8.8.
5. Determine and record the upper threshold voltage V_{UT} and the lower threshold voltage V_{LT} of Hysteresis Comparator in Table 8.8.

Table 8.8 Measured input and output waveforms of Hysteresis Comparator.

CH1 (Input) / CH2 (Output)	Threshold Voltages
	V_{UT} = ____ V_{LT} = ____

6. Turn power off and disconnect circuit.

G. Measuring the Characteristics of Monostable Multivibrator

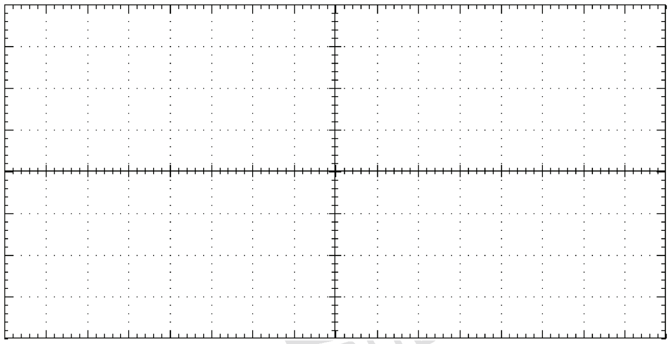
1. Set KL-75008 Pulse Meter Module on KL-72001 Main Unit. Complete the following connections:

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-75008 Pulse Meter Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	Monostable Multivibrator	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	Monostable Multivibrator	Output (Vo2)

2. Turn power on.
3. Apply a 1 Hz, 18 Vpp square signal to the input of Monostable Multivibrator by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR, and observe CH1 trace on the oscilloscope screen.
4. Observe the Monostable Multivibrator output signal displayed on CH2 trace and Record the waveform in Table 8.9.

Table 8.9 Measured input and output waveforms of Monostable Multivibrator.

Input Freq	Input and Output Waveforms
1Hz	

5. Turn power off and disconnect circuit.

H. Pulse Measurement using Oscilloscope

1. Set KL-75008 Pulse Meter Module on KL-72001 Main Unit. Complete the following connections:

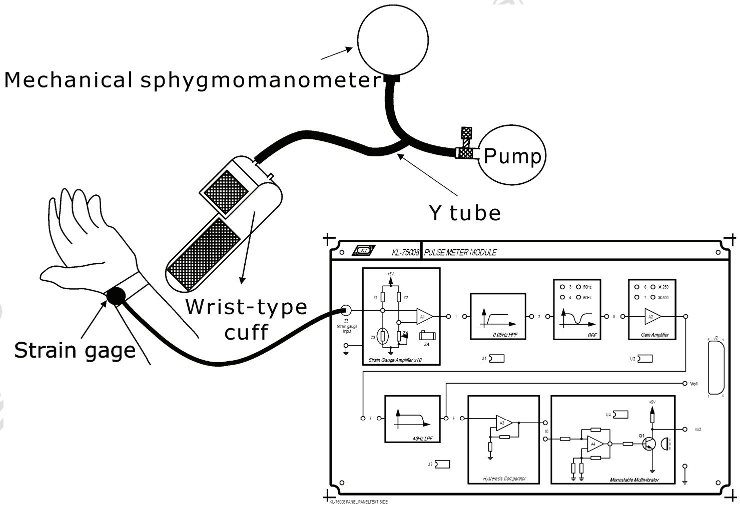
KL-72001 Main Unit				KL-72001 Main Unit		
Section	Area	Terminal	To	Section	Area	Terminal
SCOPE ADAPTOR	--	CH1	→	OUTPUT	PULSE METER	Vo1
SCOPE ADAPTOR	--	CH2	→	OUTPUT	PULSE METER	Vo2
SCOPE ADAPTOR	--	CH1 (BNC)	→	CH1 input of the oscilloscope		
SCOPE ADAPTOR	--	CH2 (BNC)	→	CH2 input of the oscilloscope		

KL-72001 Main Unit				KL-75008 Pulse Meter Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2

2. On KL-75008 Pulse Meter Module, insert bridging plugs in positions 1, 2, 3 or 4 (according to local line frequency), 5, 6 (gain = 250), 8, 9, 10.
3. Insert the output of KL-79104 Strain Gauge Tie into Strain gauge input jack Z3 on KL-75008 Pulse Meter Module.
4. Using Y tube and tube connector, connect mechanical sphygmomanometer, wrist - type cuff and hand-operated pump as shown below.
5. Turn power on. Select MODULE:KL-75008 (PM) item from the LCD display by pressing the SELECT button of KL-72001 Main Unit.
6. Make sure the Strain Gauge Amplifier has been calibrated. (Refer to Procedure A)
7. Ask the subject to put his/her left hand on the table and to place the palm up. Place KL-79104 Strain Gauge Tie on the superficial radial artery at wrist.
8. Tightly close (CW) the deflation valve of the pump.
9. Put the wrist - type cuff on KL-79104 Strain Gauge Tie.

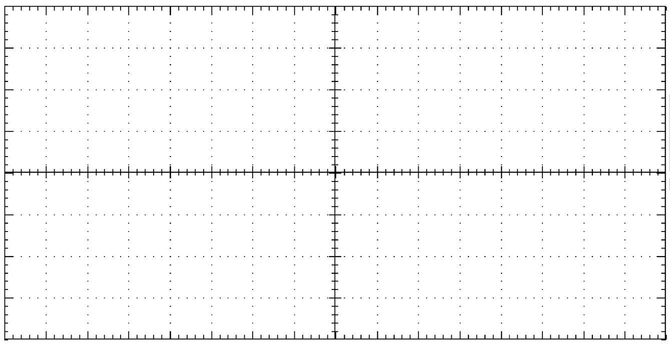
Notes:

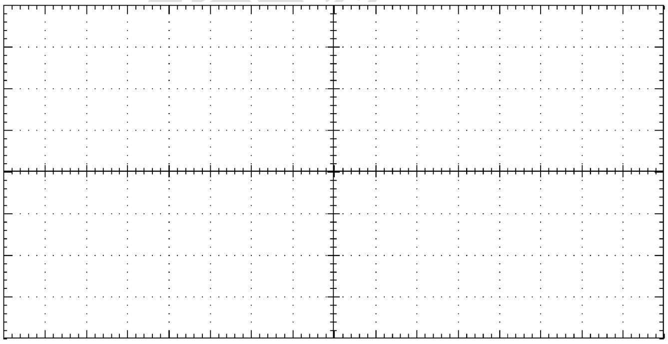
a. During the experiment, the subject should relax the hand and place the palm up. Do not make a handgrip.
b. Keep the cuff pressure less than 200 mmHg, in order not to make the subject feel uncomfortable.
c. After a pulse measurement is completed, take a rest for at least 3 minutes. Continuous measurement is not allowed.



10. Set VOLT/DIV controls of CH1 and CH2 to 5 V/div, and set the TIME/DIV control to 500 ms/div.
11. Observe the screen and inflate the cuff by pressing the hand-operated pump until a pulse wave appeared on the oscilloscope screen of CH2.
12. Record the measured Vo1 (CH1) and Vo2 (CH2) waveforms in Table 8.10.
13. Open deflation valve.
14. Remove the bridging plug from position 6 to position 7. This changes the Amplifier gain from 250 to 500. Repeat Steps 10 through 13.

Table 8.10 Measured waveforms of pulse measurement.

Amplifier Gain	Vo1 (CH1) / Vo2 (CH2)
250	

Amplifier Gain	Vo1 (CH1) / Vo2 (CH2)
500	

15. Turn power off and disconnect circuit.

I. Arterial Vessel Measurement using Oscilloscope

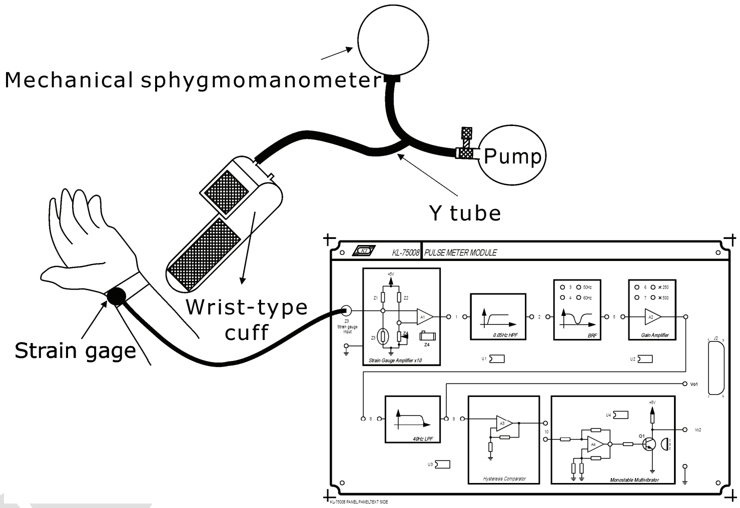
1. Set KL-75008 Pulse Meter Module on KL-72001 Main Unit. Complete the following connections:

KL-72001 Main Unit				KL-72001 Main Unit		
Section	Area	Terminal	To	Section	Area	Terminal
SCOPE ADAPTOR	--	CH1	→	OUTPUT	PULSE METER	Vo1
SCOPE ADAPTOR	--	CH2	→	OUTPUT	PULSE METER	Vo2
SCOPE ADAPTOR	--	CH1 (BNC)	→	CH1 input of the oscilloscope		
SCOPE ADAPTOR	--	CH2 (BNC)	→	CH2 input of the oscilloscope		

KL-72001 Main Unit				KL-75008 Pulse Meter Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2

2. On KL-75008 Pulse Meter Module, insert bridging plugs in positions 1, 2, 3 or 4 (according to local line frequency), 5, 6 (gain = 250), 8, 9 and 10.
3. Insert the output of KL-79104 Strain Gauge Tie into Strain gauge input jack Z3 on KL-75008 Pulse Meter Module.
4. Using Y tube, connect mechanical sphygmomanometer, wrist - type cuff and hand-operated pump as shown below.

5. Turn power on. Select MODULE:KL-75008 (PM) item from the LCD display by pressing the SELECT button of KL-72001 Main Unit.
6. Make sure the Strain Gauge Amplifier has been calibrated. (Refer to Procedure A)
7. Ask the subject to put his/her left hand on the table and to place the palm up. Wrap the left hand up in the KL-79104 Strain Gauge Tie and place the Strain Gauge just on the superficial radial artery at wrist.
8. Tightly close (CW) the deflation valve of the pump.
9. Wrap the Strain Gauge Tie up in the wrist - type cuff.



Notes:

a. During the experiment, the subject should relax the hand and place the palm up. Do not make a handgrip.
b. Keep the cuff pressure less than 200 mmHg, in order not to make the subject feel uncomfortable.
c. After a pulse measurement is completed, take a rest for at least 3 minutes. Continuous measurement is not allowed.

10. Set VOLT/DIV controls of CH1 and CH2 to 5 V/div, and set the TIME/DIV control to 500 ms/div.
11. Observe the pressure indication of mechanical sphygmomanometer and inflate the cuff by pressing the hand-operated pump.
12. At each of the cuff pressures 40, 60, 80, 100, 120, and 140 mmHg, observe and record the measured Vo1 (CH1) and Vo2 (CH2) waveforms as well as the peak voltage of Vo1 in Table 8.11.

Table 8.11 Measured waveforms of arterial vessel measurement.

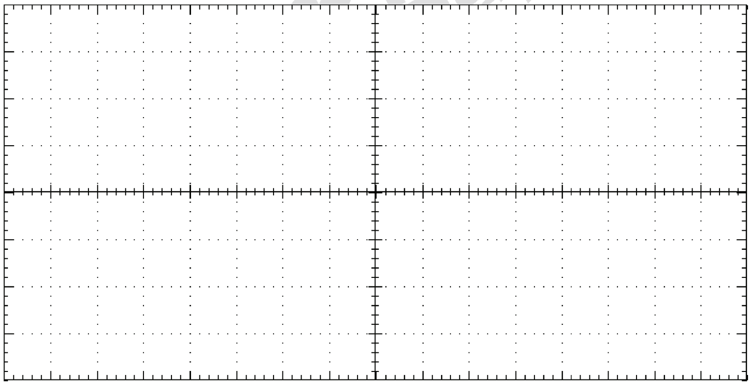
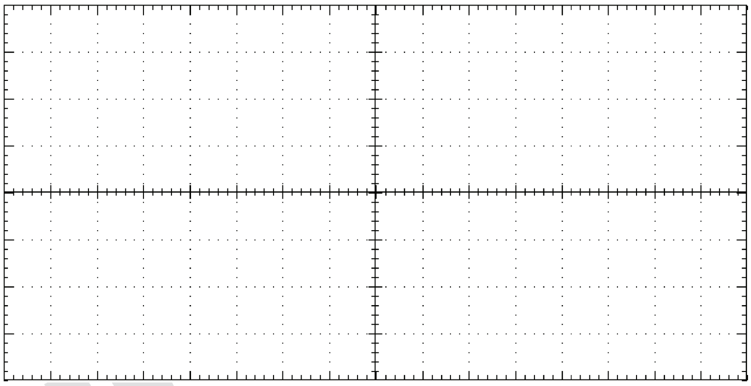
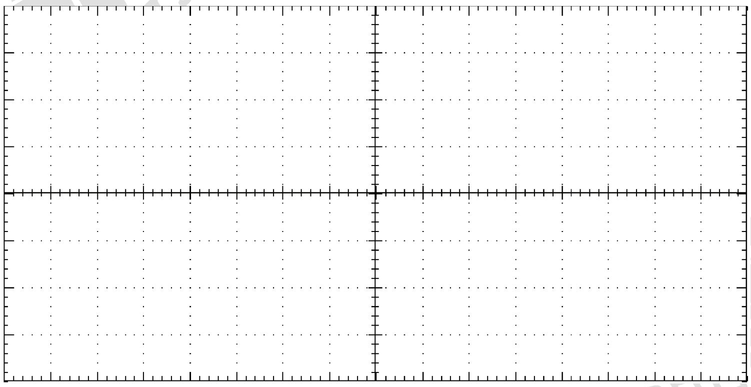
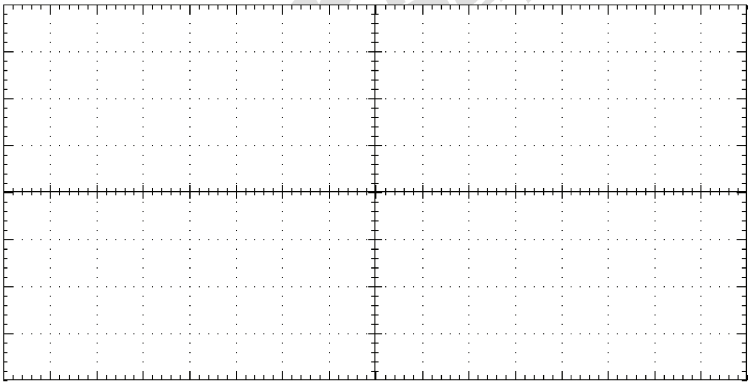
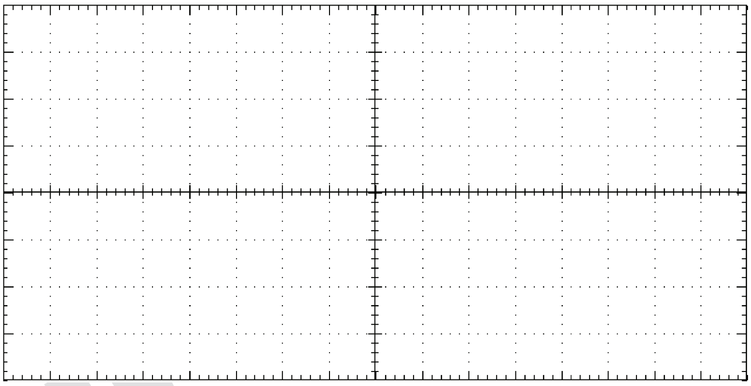
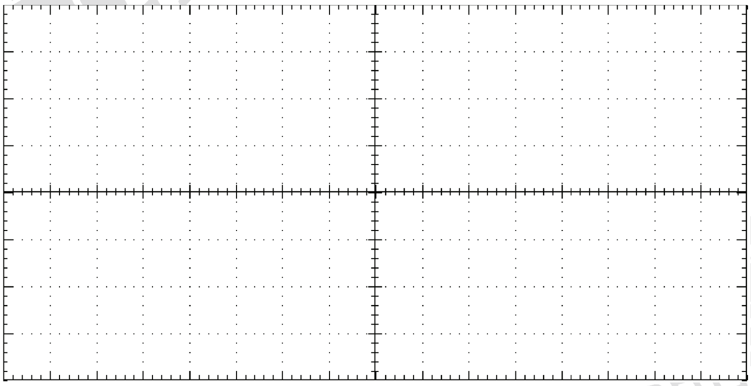
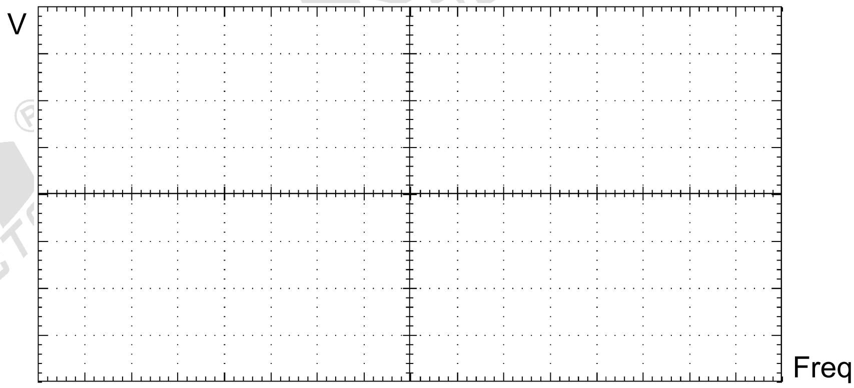
Pressure	Vo1 (CH1) / Vo2 (CH2)	Vo1 Peak Value
40 mmHg		
60 mmHg		
80 mmHg		

Table 8.11 (Continued)

Pressure	Vo1 (CH1) / Vo2 (CH2)	Vo1 Peak Value
100 mmHg		
120 mmHg		
140 mmHg		

13. According to the recorded data in Table 8.11, plot the characteristic curve of the cuff pressures in Table 8.12.

Table 8.12 Characteristic curve of cuff pressures.



14. Use the diastolic and systolic pressures measured in Procedure E of Experiment 5 to calculate the mean arterial pressure:

$$\text{Mean arterial pressure} = \text{Diastolic pressure} + \frac{\text{Systolic pressure} - \text{Diastolic pressure}}{3}$$

Inflate the wrist - type cuff up to the mean arterial pressure calculated, and see if the pulse amplitude is the maximum or not.

15. Open deflation valve, turn power off and disconnect circuit.

J. Pulse Measurement using KL-720 Software

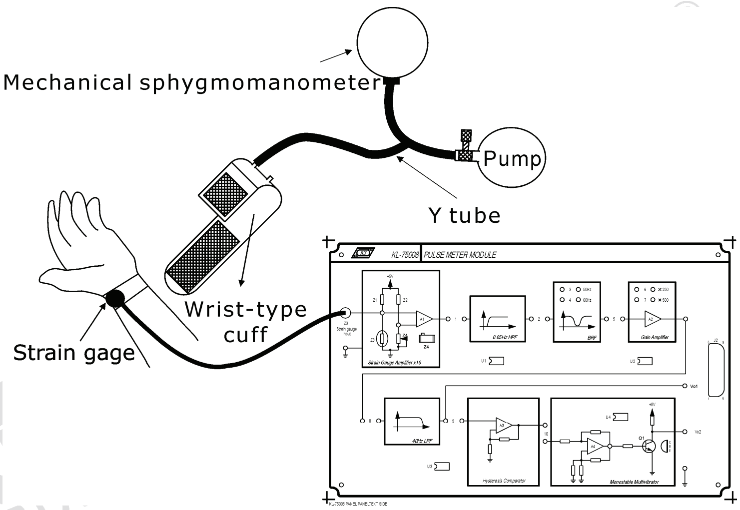
1. Set KL-75008 Pulse Meter Module on KL-72001 Main Unit. Complete the following connection:

KL-72001 Main Unit				KL-75008 Pulse Meter Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2

2. On KL-75008 Pulse Meter Module, insert bridging plugs in positions 1, 2, 3 or 4 (according to local line frequency), 5, 6 (gain = 250), 8, 9 and 10.

3. Insert the output of KL-79104 Strain Gauge Tie into Strain gauge input jack Z3 on KL-75008 Pulse Meter Module.

4. Using Y tube, connect mechanical sphygmomanometer, wrist - type cuff and hand-operated pump as shown below.
5. Turn power on. Select MODULE: KL-75008(PM) item from LCD display by pressing the SELECT button of KL-72001 Main Unit.
6. Make sure the Strain Gauge Amplifier has been calibrated (refer to Procedure A).
7. Ask the subject to put his/her left hand on the table and to place the palm up. Wrap the left hand up in the KL-79104 Strain Gauge Tie and place the Strain Gauge just on the superficial radial artery at wrist.
8. Tightly close (CW) the deflation valve of the pump.
9. Wrap the Strain Gauge Tie up in the wrist - type cuff.

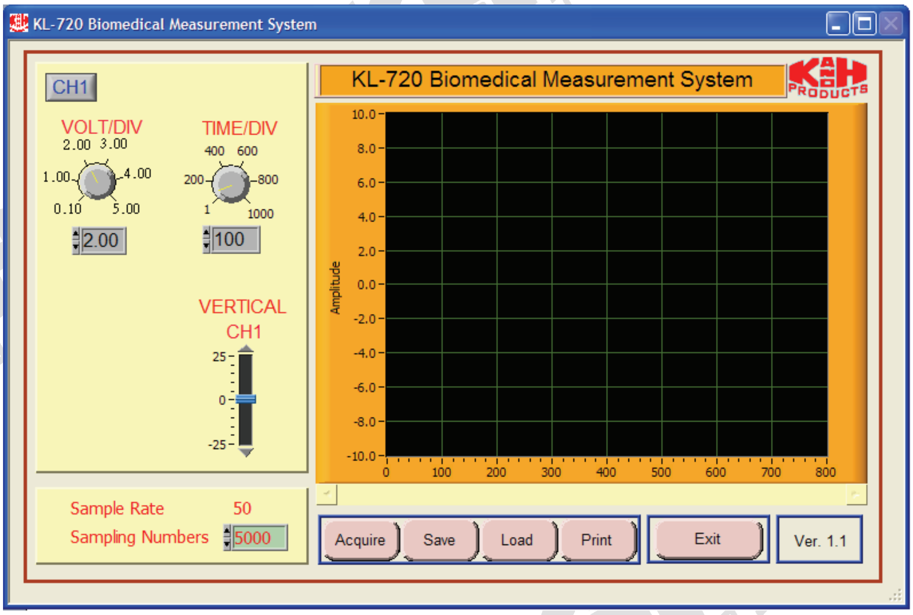


Notes:

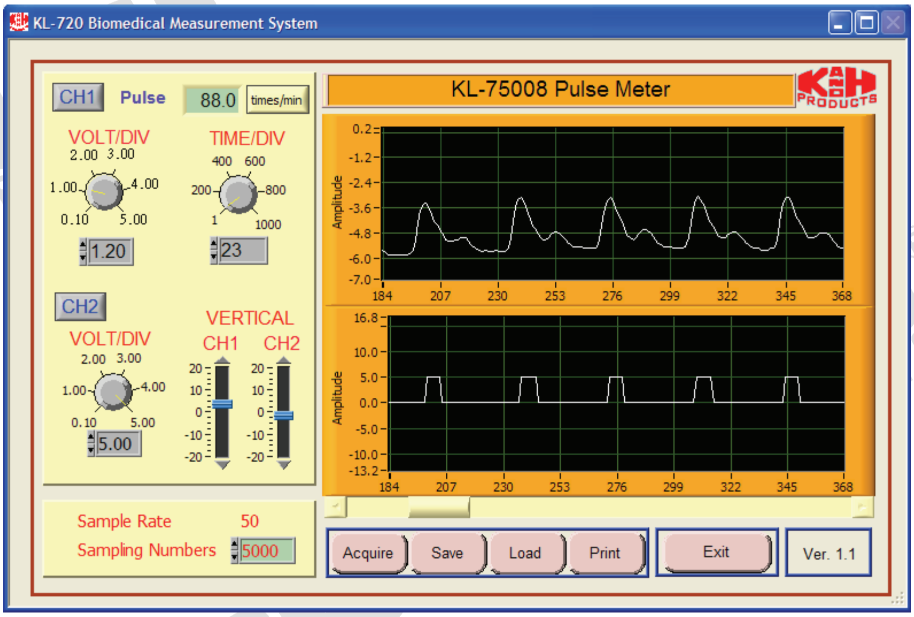
a. During the experiment, the subject should relax the hand and place the palm up. Do not make a handgrip.
b. Keep the cuff pressure less than 200 mmHg, in order not to make the subject feel uncomfortable.
c. After a pulse measurement is completed, take a rest for at least 3 minutes. Continuous measurement is not allowed.

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

12. Execute KL-720 program. The window of KL-720 Biomedical Measurement System appears as shown below.



13. Click the Acquire button. The system begins to acquire the measured data via RS-232 port and shows the waveforms in the waveform windows of KL-75008 Pulse Meter 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 the RS-232 port.

14. Adjust VOLT/DIV and TIME/DIV knobs, so the signals can be read accurately.
15. Inflate the cuff by pressing the hand-operated pump.
16. At each of the cuff pressures 40, 60, 80, 100, 120, and 140 mmHg, observe and save the measured Vo1 and Vo2 waveforms on disk.
17. Use the diastolic and systolic pressures measured in Procedure E of Experiment 5 to calculate the mean arterial pressure:

$$\text{Mean arterial pressure} = \text{Diastolic pressure} + \frac{\text{Systolic pressure} - \text{Diastolic pressure}}{3}$$

18. Inflate the wrist - type cuff up to the subject mean arterial pressure calculated, and see if the pulse amplitude is the maximum or not.
19. Open deflation valve and exit KL-720 Biomedical Measurement System.
20. Turn power off and disconnect circuit.