EXPERIMENT 7 RESPIRATORY VENTILATION DETECTION

7.0 OBJECTIVE

The objective of this experiment is to help students to understand the measurement of respiratory activities, including breath-holding ability, excessive ventilation and the frequency of respiratory. Meanwhile, the students will learn how to use a thermal sensor to detect temperature difference.

7.1 PHYSIOLOGICAL PRINCIPLE

Metabolic activities in living tissue will usually consume oxygen and produce carbon dioxide. Oxygen comes from atmosphere and carbon dioxide will be returned back to atmosphere. Through respiration, air is inhaled or exhaled from lungs. After the air exchange in lungs, the non-oxygenic blood will become oxygenic one and with the blood circulation, oxygen is transported to tissues for another air exchange. In lungs, a number of small bronchia are responsible for carrying air to alveoli. Then, the air exchange takes place on the pretty thin surface of alveoli.

In a normal respiratory, diaphragm contracts regularly and will be pulled down. At the same time, intercostal muscles contracts also, the volume of thoracic cavity increases and inner pressure drop about 3 ~ 5 mmHg. Thus, the air can easily enter to the thoracic cavity. Figure 7.1 shows the physiological change of thoracic cavity during respiration. Besides, the sternomastoid muscle of neck will help to lift thoracic ribs when inhaling with strength. When exhaling, abdominal muscle will move upward and push up the diaphragm. It makes an exhaling action with strength.

There are two central control systems related to respiration. One is the control by will and the other is unconscious control which regulates the respiratory activities spontaneously. Spontaneous respiration is controlled by the respiratory central control of medulla. The respiratory control center can adjust the air exchange according to the need of human body. If the need increases, the frequency and depth of breath will both be augmented in order to make more fresh air entering to lungs. When the percentage of carbon dioxide rises, the control center will be stimulated strongly. And when oxygen in blood decreases, control center will also be stimulated, but not less strongly than previous situation.

The present experiment is to measure the change of respiratory frequency by temperature difference between human body (37 °C) and ambient environment (25°C). The temperature of exhaled air is almost the same as that in human body, whereas the temperature of inhaled air is close to ambient temperature. So, we can put a temperature sensor to detect the change of temperature between exhaled and inhaled air and obtain the respiratory frequency by this way.

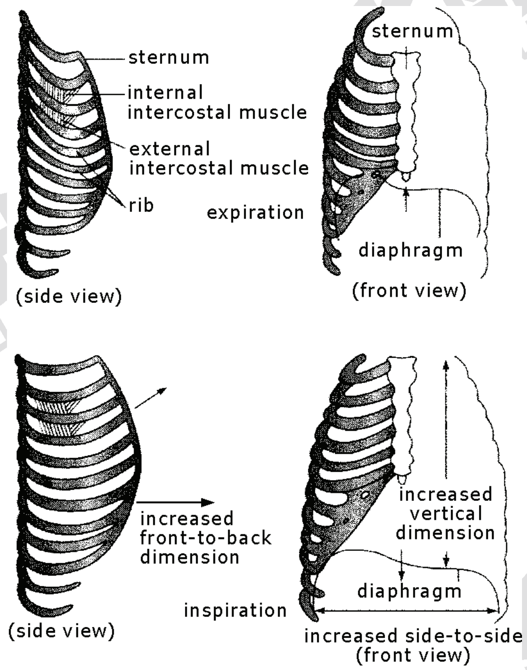


Figure 7.1 Placement of intercostal muscles and diaphragm during respiration.

7.2 PRINCIPLE OF CIRCUIT DESIGN

1. Block Diagram of Respiration Measurement Circuit

The module for the amplification of ambient temperature is a signal conditioner. With a differential amplifier, we can detect the difference between internal and ambient temperature, then complete the measurement of respiratory frequency by this solution.

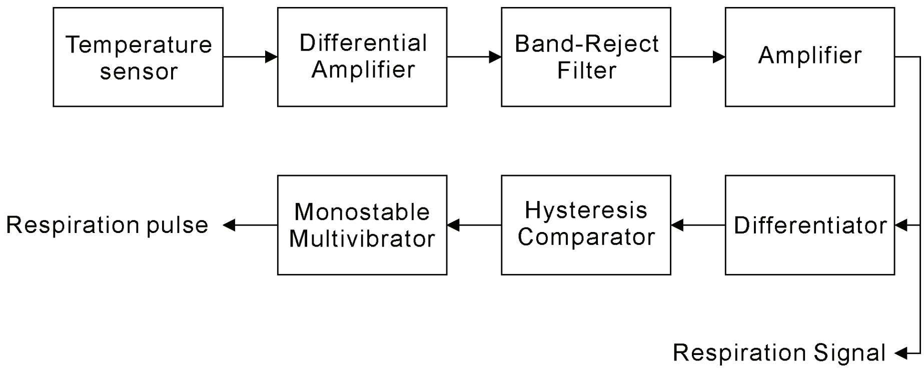


Figure 7.2 Block diagram of respiration measurement.

Figure 7.2 shows the block diagram of respiratory measurement. A thermistor with negative temperature coefficient is used as the temperature sensor. With a Wheatstone bridge circuit, the change in voltage is amplified 2 times by a differential amplifier.

For the measurement of respiratory frequency, we use a differentiator circuit to differentiate respiratory signal in order to emphasize his slight changes. Through a hysteresis comparator, a square wave is obtained. After, the square wave will trigger monostable multivibrator circuit and the measurement of respiratory frequency is done.

2. Differential Amplifier Circuit

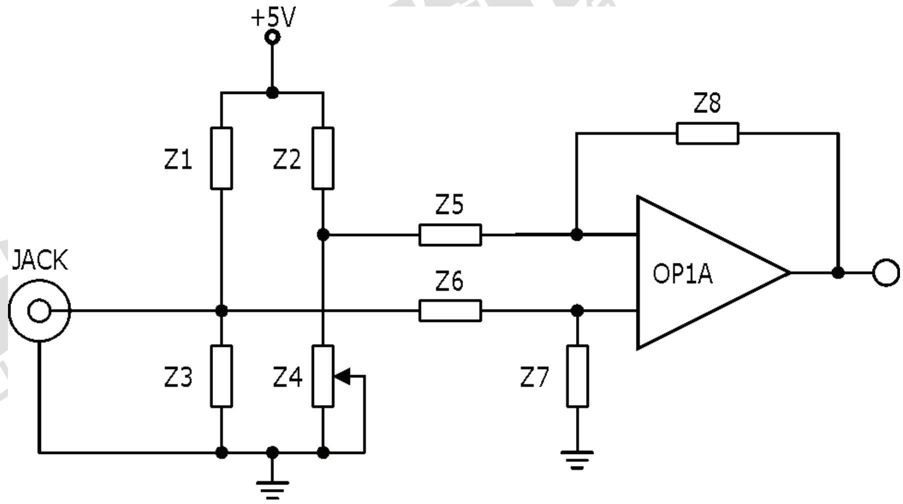


Figure 7.3 Differential amplifier circuit.

In Figure 7.3, Z_4 is used for calibration. When we make calibration under room temperature, Z_4 can be adjusted to make the output of OP1A zero. To measure the respiration, the differential amplifier will amplify the potential difference caused by the temperature difference. If Z_5=Z_6 and Z_7=Z_8, the gain is expressed by Equation (7.1).

$$Av = \frac{Z_8}{Z_5} \tag{7.1}$$

3. Band-Reject Filter

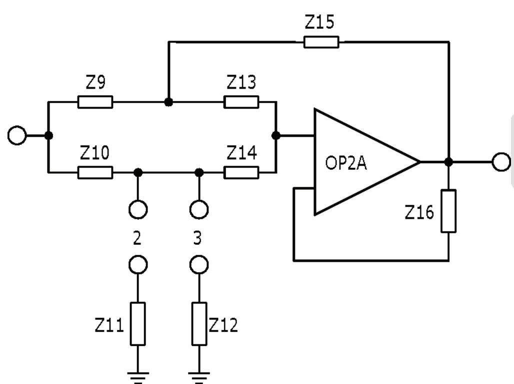


Figure 7.4 Band-reject filter circuit.

Figure 7.4 shows a twin-T band-reject filer composed by RC networks, including OP2A, Z_9, Z_{10}, Z_{11} (or Z_{12}), Z_{13}, Z_{14} and Z_{15}. If $Z_9 = Z_{13}$, $Z_{10} = Z_{14}$, $Z_{11} = 0.5Z_9$ (or $Z_{12} = 0.5Z_9$) and $Z_{15} = 2Z_{10}$, the center frequency can be calculated by Equation (7.2).

$$f = \frac{1}{2\pi Z_9 Z_{10}} \tag{7.2}$$

4. Amplifier

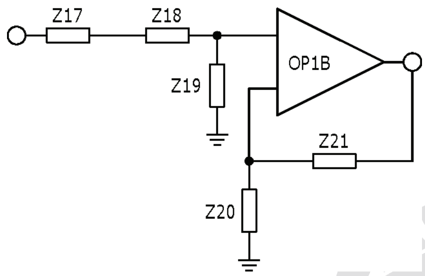


Figure 7.5 Non-inverting amplifier circuit.

Figure 7.5 shows a non-inverting amplifier constructed by OP1B, Z_{17}, Z_{18}, Z_{19}, Z_{20} and Z_{21}. Z_{17} and Z_{18} are used to block the dc voltage from the previous stage. The gain of the amplifier is determined by Z_{20} and Z_{21} and is expressed by

$$Av = \frac{Z_{21}}{Z_{20}} + 1 \tag{7.3}$$

5. Differentiator Circuit

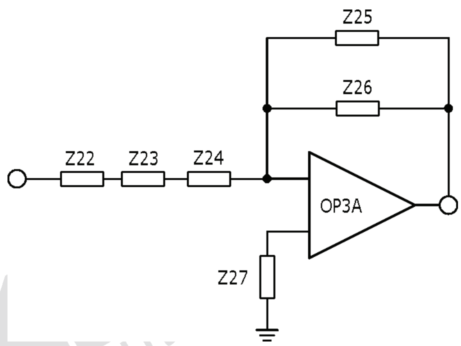


Figure 7.6 Differentiator circuit.

Figure 7.6 shows a differentiator circuit formed by OP3A, Z_{24}, Z_{25} and Z_{26}. This circuit is designed to indicate the change rate of respiratory waveform. Z_{22} and Z_{23} are used to avoid DC drift produced by the amplifier, and Z_{25} and Z_{26} for the elimination of high-frequency noise. When Z_{26}=Z_{27}, the effect of voltage shift can be reduced, preventing the circuit from saturation.

6. Hysteresis Comparator Circuit

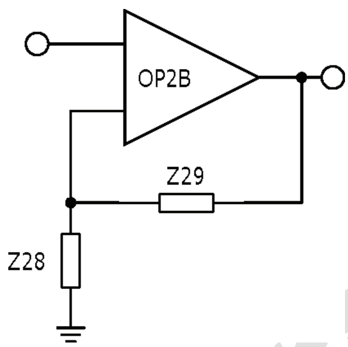


Figure 7.7 Hysteresis comparator circuit.

Figure 7.7 shows a hysteresis comparator consisting of OP2B, Z_{28} and Z_{29}. The output of 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_{28} and Z_{29}, as expressed in Equation (7.4),

$$V_{UT} = +\frac{Z_{28}}{Z_{28}+Z_{29}}V_{CC} \quad \& \quad V_{LT} = -\frac{Z_{28}}{Z_{28}+Z_{29}}V_{CC} \qquad (7.4)$$

When we exhale, the signal tested will be higher than the upper threshold voltage because the temperature inside human body is higher. And at this time the output of OP2B will be negative saturation voltage $-V_{CC(sat)}$. On the contrary, when we inhale, the tested signal will be lower than the lower threshold voltage since it's the room temperature which is measured. Therefore, the output of OP2B becomes positive saturation voltage, $+V_{CC(sat)}$. Finally, a square wave is generated.

7. Monostable Multivibrator Circuit

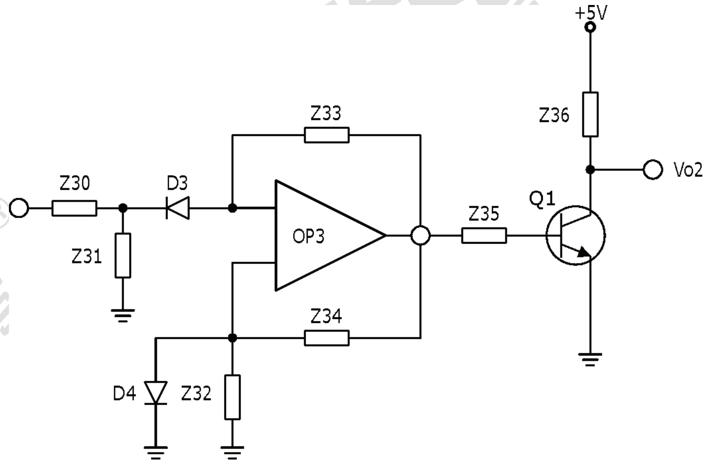


Figure 7.8 Monostable multivibrator circuit.

Figure 7.8 shows a monostable multivibrator circuit which is composed by D_4, Z_{32}, Z_{33}, Z_{34} and OP3. In stable condition, the output of OP3 is positive saturation voltage. Z_{32} is charged through Z_{34} and the voltage of Z_{32} remains 0.6V. Both Z_{30} and Z_{31} are used to differentiate the square wave which is generated from the comparator. After, the square wave becomes an impulse. Only negative impulses can pass through D_3, so the voltage on positive terminal of OP3 is lower than 0.6V on negative terminal of OP3. Then, it triggers a transient occurrence and makes the output of OP3 becoming negative saturation voltage. At this time, Z_{32} will begin to discharge until its voltage is lower than the voltage on positive terminal. Finally the stable potential is recovered.

7.3 EQUIPMENT REQUIRED

1. KL-72001 Main Unit
2. KL-75007 Respiratory Ventilation Module
3. Digital Storage Oscilloscope
4. Digital Voltmeter (DVM)
5. KL-79103 Temperature Sensor Mask
6. DB9 Cable
7. BNC Cables
8. RS-232 Cable
9. Connecting Wires
10. 10-mm Bridging Plugs
11. Trimmer

7.4 PROCEDURE

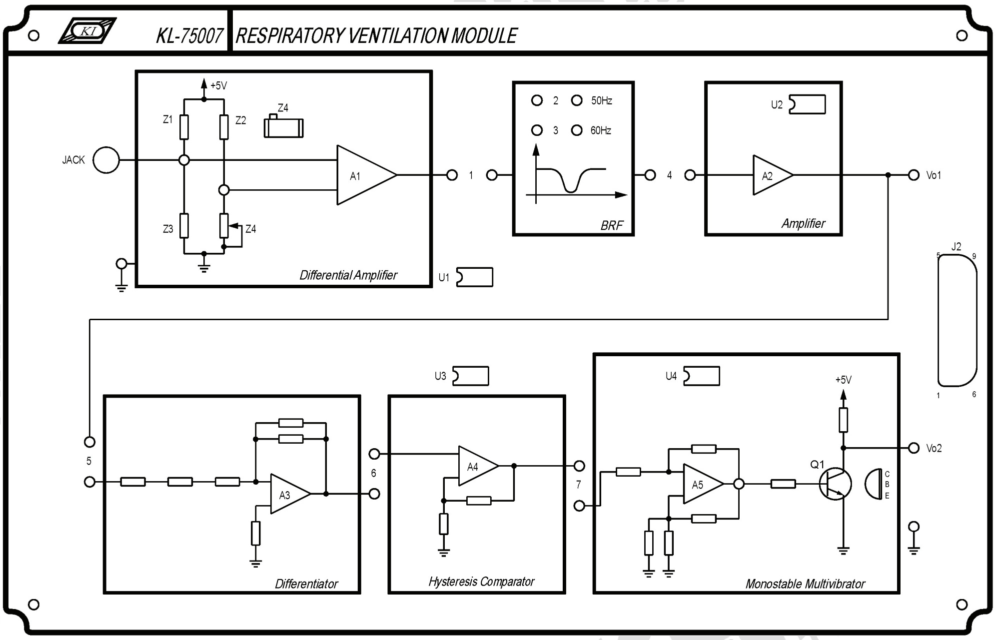


Figure 7.9 Front panel of KL-75007 Respiratory Ventilation Module.

A. Calibrating the Differential Amplifier

1. Set KL-75007 Respiratory Ventilation Module on KL-72001 Main Unit, complete the following connection.

KL-72001 Main Unit				KL-75007 Respiratory Ventilation Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	–	9-Pin	→	--	J2

2. Turn power on.
3. Insert the output of KL-79103 Temperature Sensor Mask into JACK input on KL-75007 Respiratory Ventilation Module.
4. Connect the positive probe of DVM to the output of Differential Amplifier and connect the negative probe to the ground terminal located at bottom-left of Differential Amplifier block.
5. Adjust Z4 potentiometer, so the output dc voltage indicated by DVM is equal to 0 V.
6. Turn power off and disconnect circuit.

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

1. Set KL-75007 Respiratory Ventilation Module on the 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-75007 Respiratory Ventilation 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

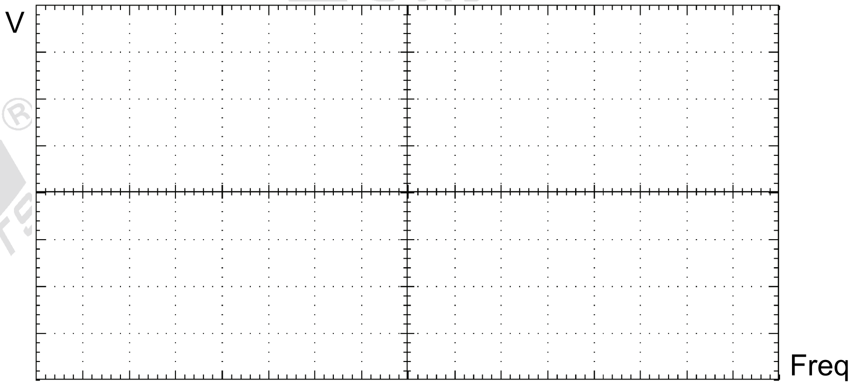
2. Insert a bridging plug into position 2 or 3 to set the center frequency of BRF to 50 or 60 Hz (according to local line frequency).
3. Turn power on.
4. Apply a 5 Hz, 1 Vpp sine signal to the ELECTRO1 input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR, and observe CH1 trace on the oscilloscope screen.
5. Observe BRF output signal displayed on CH2 trace, then record the amplitude in Table 7.1.
6. Without changing the amplitude of input sine signal, repeat Steps 4 and 5 for other frequency values listed in Table 7.1.

Table 7.1 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 7.1, plot the characteristic curve of band-reject filter in Table 7.2.

Table 7.2 Characteristic curve of BRF.



8. Turn power off and disconnect circuit.

C. Measuring the Characteristics of Amplifier

1. Set KL-75007 Respiratory Ventilation 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 oscilloscope		
SCOPE ADAPTOR	--	CH2 (BNC)	→	CH2 input of oscilloscope		

KL-72001 Main Unit				KL-75007 Respiratory Ventilation 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 (Vo1)

2. Turn power on.
3. Apply a 1 KHz, 100 mVpp sine signal to the Amplifier input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR and observe CH1 trace on the oscilloscope screen.
4. Observe the Amplifier output signal displayed on CH2 trace. The gain must be about 10.
5. Turn power off and disconnect circuit.

D. Measuring the Characteristics of Differentiator

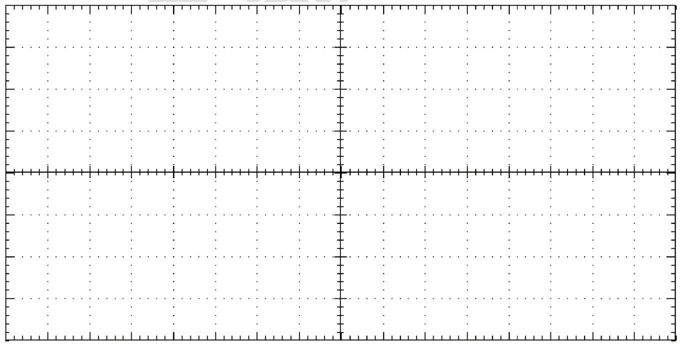
1. Set KL-75007 Respiratory Ventilation Module on KL-72001 Main Unit. Complete the following connections:

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 oscilloscope		
SCOPE ADAPTOR	--	CH2 (BNC)	→	CH2 input of oscilloscope		

KL-72001 Main Unit				KL-75007 Respiratory Ventilation Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2
FUNCTION GENERATOR	--	OUTPUT	→	Differentiator	Input
FUNCTION GENERATOR	--	GND	→	--	Ground (in the bottom right corner)
SCOPE ADAPTOR	--	CH2	→	Differentiator	Output

2. Turn power on.
3. Apply a 0.1 Hz, 1 Vpp square signal to the Differentiator input by adjusting FREQUENCY and AMPLITUDE knobs of FUNCTION GENERATOR and observe CH1 trace on the oscilloscope screen.
4. Observe the Differentiator output signal displayed on CH2 trace and record the input and output waveforms in Table 7.3.

Table 7.3 Measured input and output waveforms of Differentiator.

Input Freq	Input and Output Waveforms
0.1Hz	

5. Turn power off and disconnect circuit.

E. Measuring the Characteristics of Hysteresis Comparator

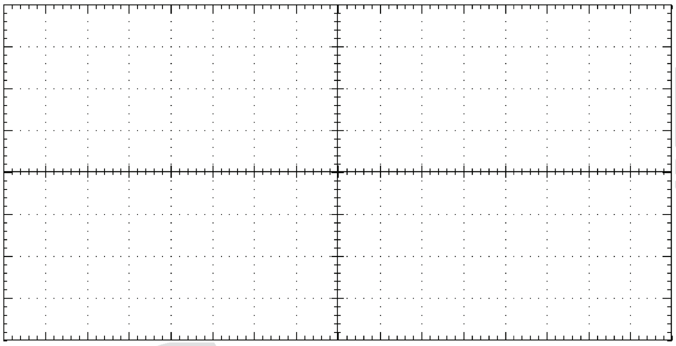
1. Set KL-75007 Respiratory Ventilation Module on KL-72001 Main Unit. Complete the following connections:

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-75007 Respiratory Ventilation 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 7.4.
5. Determine and record the upper threshold voltage V_{UT} and the lower threshold voltage V_{LT} of Hysteresis Comparator in Table 7.4.

Table 7.4 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.

F. Measuring the Characteristics of Monostable Multivibrator

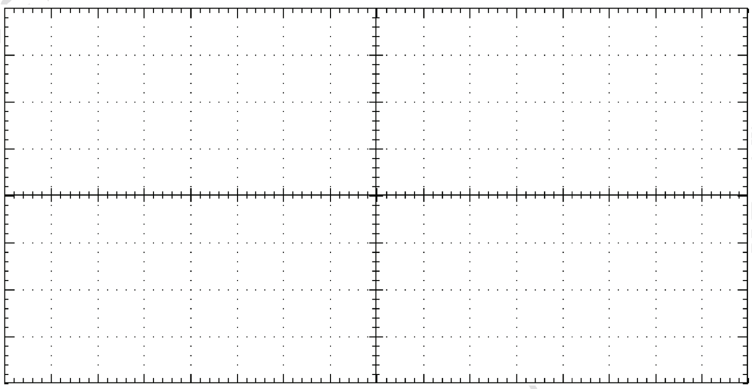
1. Set KL-75007 Respiratory Ventilation Module on KL-72001 Main Unit. Complete the following connections:

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-75007 Respiratory Ventilation 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 0.1 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 output waveform in Table 7.5.

Table 7.5 Measured output waveform of Monostable Multivibrator.

Input Freq.	Output Waveform
0.1Hz	

5. Turn power off and disconnect circuit.

G. Respiratory Frequency Measurement using Oscilloscope

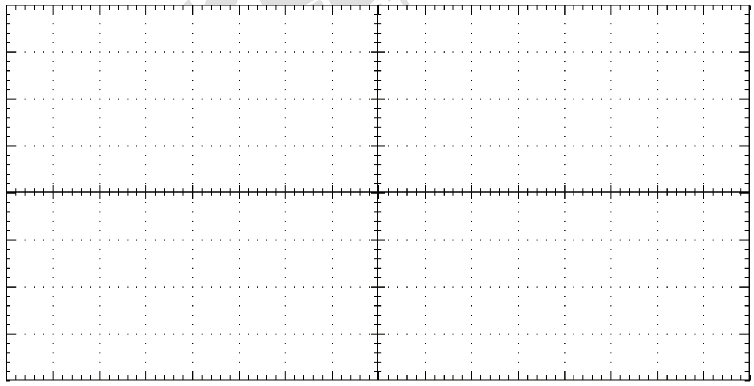
1. Set KL-75007 Respiratory Ventilation Module on KL-72001 Main Unit. Complete the following connections:

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

KL-72001 Main Unit				KL-75007 RESPIRATORY VENTILATION Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2

2. Insert the output of KL-79103 Temperature Sensor Mask into the JACK input on KL-75007 Respiratory Ventilation Module.
3. Insert bridging plugs in positions 1, 2 or 3 (according to local line frequency), 4, 5, 6 and 7.
4. Turn power on. Select MODULE:KL-75007 (RVR) from LCD display by pressing SELECT button of KL-72001 Main Unit.
5. Make sure that the Differential Amplifier has been calibrated (refer to Procedure A).
6. Ask the subject to put Temperature Sensor Mask on and breathe normally.
7. Set VOLT/DIV controls of CH1 to 1 V/div and CH2 to 5 V/div, and set the TIME/DIV control to 2.5 S/div.
8. Observe CH1 (Vo1) and CH2 (Vo2) traces and record them in Table 7.6.

Table 7.6 Measured waveforms of respiratory.

Condition	Vo1 (CH1) / Vo2 (CH2)
Breathe normally	

9. Turn power off and disconnect circuit.

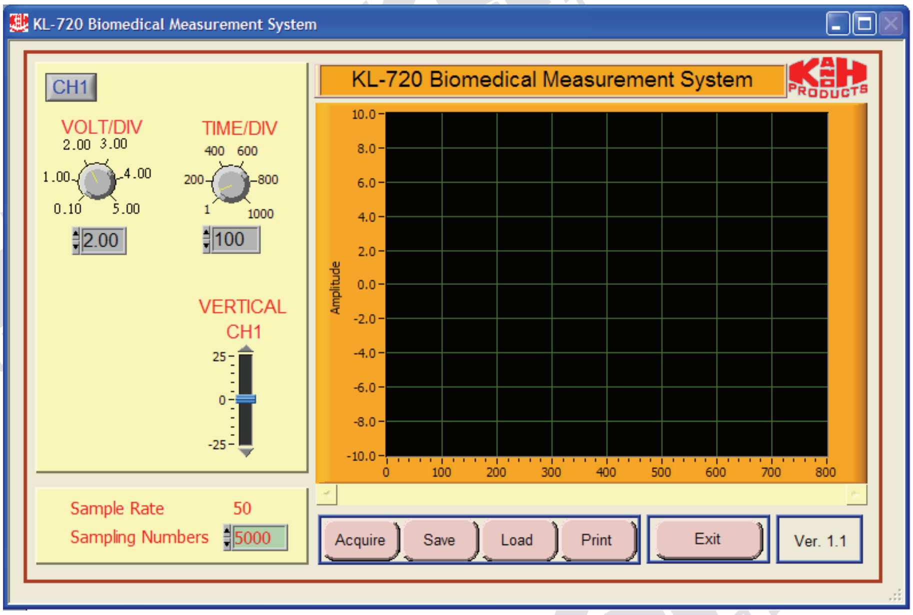
H. Respiratory Frequency Measurement using KL-720 Software

1. Set KL-75007 Respiratory Ventilation Module on KL-72001 Main Unit. Complete the following connections:

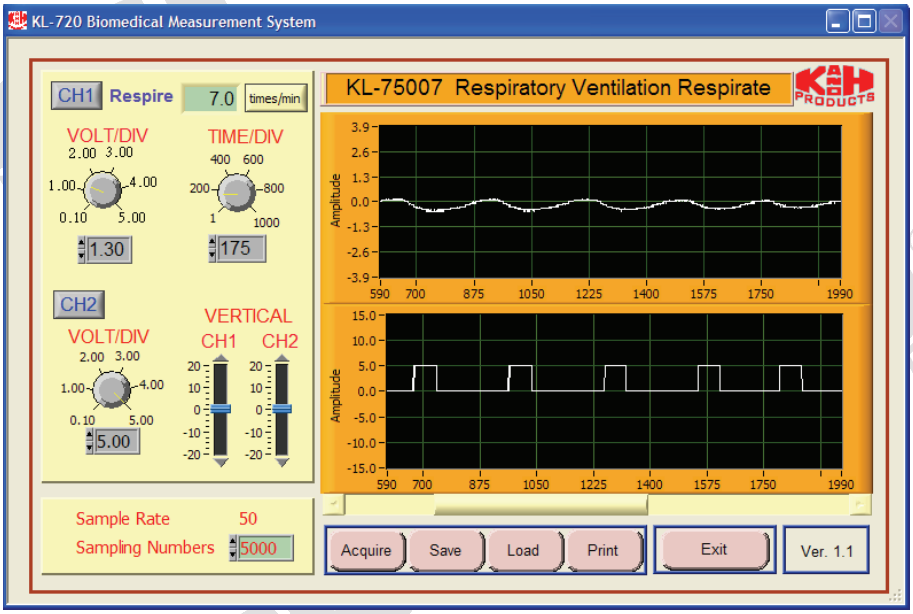
KL-72001 Main Unit				KL-75007 Respiratory Ventilation Module	
Section	Area	Terminal	To	Block	Terminal
MODULE OUTPUT	--	9-Pin	→	--	J2

2. Insert the output of KL-79103 Temperature Sensor Mask into JACK input on KL-75007 Respiratory Ventilation Module.
3. Insert bridging plugs in positions 1, 2 or 3 (according to local line frequency), 4, 5, 6 and 7.
4. Turn power on. Select MODULE:KL-75007 (RVR) from LCD display by pressing SELECT button of KL-72001 Main Unit.
5. Make sure that the Differential Amplifier has been calibrated (refer to Procedure A).
6. Ask the subject to put Temperature Sensor Mask on and breathe normally.
7. Connect the RS-232 OUTPUT connector on KL-72001 Main Unit to the RS-232 port on the computer using RS-232 cable.
8. Boot the computer.

9. Execute KL-720 program. The KL-720 Biomedical Measurement System window appears.



10. Click Acquire button. The system begins to acquire the measured data via RS-232 port and shows the waveforms in KL-75007 Respiratory Ventilation Respirate waveform windows to look like this:



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

11. Adjust VOLT/DIV and TIME/DIV knobs, so the signals can be read accurately.
12. Save the waveform data on disk.
13. Exit KL-720 Biomedical Measurement System, turn power off and disconnect circuit.