RESPIRATORY MEASUREMENTS 7

EXPERIMENT NO 7 RESPIRATORY MEASUREMENTS

7.0 PURPOSE

The purpose of the experiment is to help students understand respiratory measurements, including breath-holding ability, overventilation, and respiratory frequency. Students will also see how to measure temperature changes with a semiconductor-type thermal sensor.

7.1 PHYSIOLOGICAL PRINCIPLES

As a result of metabolic activities in the tissues, oxygen is consumed and carbon dioxide is produced. Oxygen is taken from the atmosphere and carbon dioxide is released into the atmosphere. Through respiration, gases enter and exit the lungs. After gas exchange in the lungs, the oxygen content in low-oxygen blood increases. The high-oxygen blood is sent to other tissues, where gas exchange also occurs. The tiny bronchioles in the lungs are responsible for transporting air to the alveoli. Gas exchange occurs across the thin surfaces of the alveoli.

During normal breathing, the diaphragm contracts regularly. When the diaphragm contracts, it moves downward, contracting the intercostal muscles. This movement increases internal thoracic volume and reduces thoracic pressure by 3-5 mmHg. Thus, air is forced out of the thorax. Figure 7.1 illustrates the changes in thoracic physiology during respiration. In addition, the sternomastoid muscles assist the thoracic muscles. During exhalation, the abdominal muscles move upward, pushing the diaphragm, thus assisting in exhalation.

There are two central control systems for breathing. The first is voluntary control, and the second is involuntary control, which regulates respiratory activity spontaneously. Involuntary breathing is controlled by the respiratory center in the medulla. The respiratory center regulates the rate of gas exchange according to the body's needs. When demand increases, both the frequency and volume of breathing increase, allowing more gaseous air to enter the lungs. An increase in the partial pressure of carbon dioxide causes the respiratory center to receive more oxygen-rich air.

In this experiment, changes in respiratory frequency will be measured. There is a temperature difference between body temperature (37°C) and ambient temperature (25°C). The temperature of the air leaving the body during exhalation is approximately the same as the temperature of the air entering the body during inhalation. Similarly, the temperature of the air entering the body during inhalation is approximately the same as the ambient temperature. Consequently, a temperature sensor can be placed at the entrance to the nose to measure temperature changes between inhalation and exhalation. This allows us to obtain respiratory rate.

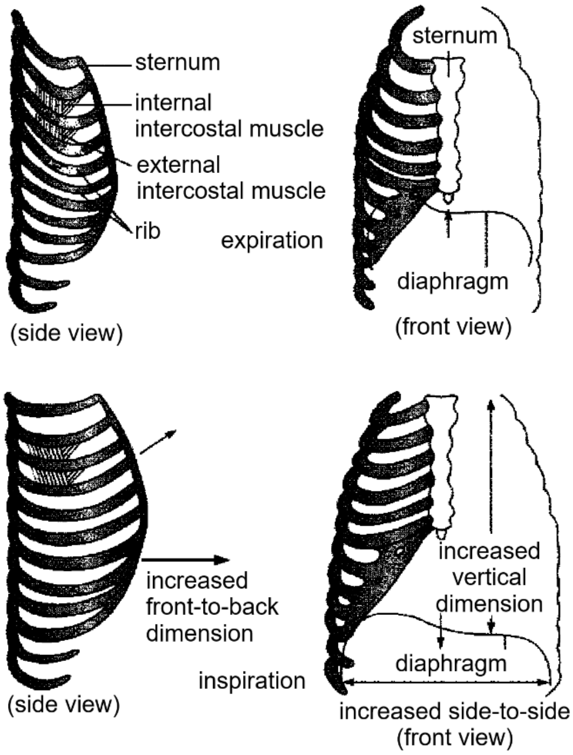


Figure 7.1 Conditions of the intercostal muscles and diaphragm during breathing

7.2 CIRCUIT DESCRIPTIONS

1. Respiratory Measurement Circuit Block Diagram

The ambient temperature sensor amplifier module is essentially a signal converter. The difference between ambient temperature and body temperature is measured by a differential amplifier. This allows for the measurement of respiratory frequency.

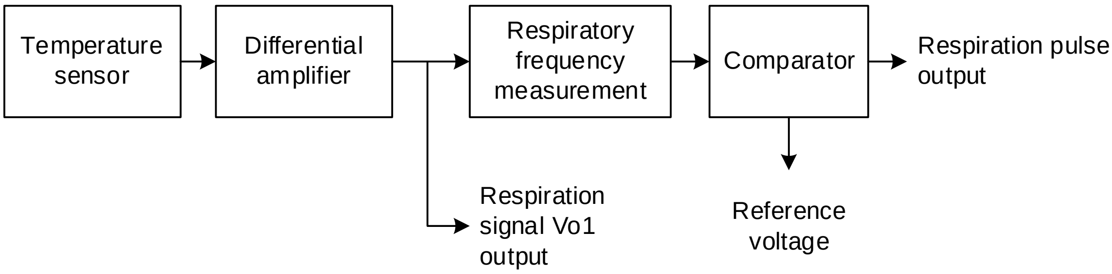


Figure 7.2 Respiratory measurement block diagram

Figure 7.2 shows the block diagram for respiratory frequency. A 1N4148 diode is used as temperature sensor. Using a Wheatstone bridge circuit, the voltage change can be amplified by 100 using a differential amplifier. For example, if the voltage drop across the diode for a 1°C temperature change is 2.2 mV, the output voltage must be 2.64 V if the ambient temperature is 25°C and the body temperature is 37°C (see Equation 7.1).

$$100 \cdot 2.2(mV/°C) \cdot (37 - 25) = 2.64V \tag{7.1}$$

In this way, a voltage of 2.64Vpp can be measured on Vo1.

A differentiator circuit is used to detect the respiratory frequency and amplify small changes in the signal. When the signal passes through the hysteresis comparator, a square wave is generated. This square wave is used for triggering a monostable multivibrator circuit to detect the respiratory frequency.

2. Differential Amplifier Circuit

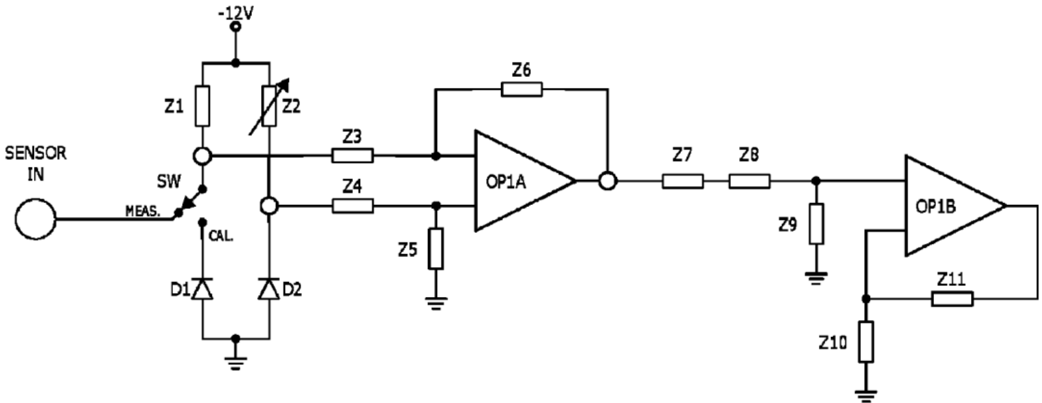


Figure 7.3 Differential amplifier circuit

In Figure 7.3, D1 (1N914) is used for calibration. To calibrate at room temperature, the circuit switch must be set to the CAL position. Z2 is adjusted so that the OP1A voltage output is zero. To measure respiratory activity, the switch must be in the MEAS position. The differential amplifier amplifies the voltage difference between 1N4148 and D2. When Z3 = Z4 and Z5 = Z6, the gain expression can be expressed as in Equation 7.2.

$$A_v = \frac{Z_6}{Z_3} \tag{7.2}$$

Z7, Z8, and Z9 are used to eliminate the drift voltage (DC voltage) containing very low frequencies. The signal will be amplified again as it passes through OP1B (non-inverting amplifier). By measuring Vo1, a waveform that varies with respiration is obtained.

3. Integrator Circuit

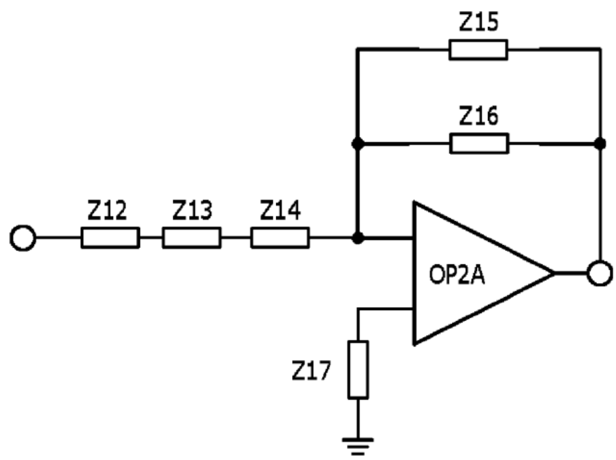


Figure 7.4 Integrator circuit

Figure 7.4 shows an integrator circuit consisting of OP2A, Z14, and Z16, used to detect the rate of change of the respiratory waveform. Resistors Z12 and Z13 are used for eliminating DC drift voltage from the amplifier, while resistors Z15 and Z16 are used for eliminating high-frequency noise. By ensuring that Z16 = Z17, the effect of voltage drift can be reduced and the circuit can be prevented from reaching the saturation region.

4. Hysteresis Comparator Circuit

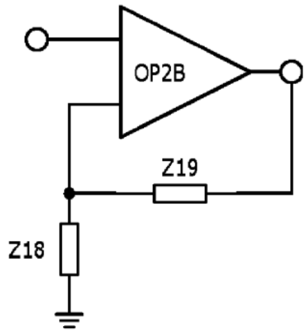


Figure 7.5 Comparator circuit with hysteresis

A hysteresis comparator circuit consisting of OP2B, Z18, and Z19 is shown in Figure 7.5. The hysteresis comparator output is between the negative and positive saturation regions. The reference voltage, V_{th}, depends on Z18 and Z19 as expressed in Equation 7.3.

$$V_{th} = \pm \frac{Z_{18}}{Z_{18}+Z_{19}} V_{ss} \qquad (7.3)$$

During exhalation, the signal voltage is less than the reference voltage because body temperature is higher than the ambient temperature. In this case, the OP2B output reaches the negative saturation voltage, $V_{ss(sat)}$. Similarly, during inhalation, the sensor detects room temperature, and because the signal voltage is greater than the reference voltage, the OP2B output reaches the positive saturation region, $V_{ss(sat)}$. Thus, a square wave is generated during inhalation and exhalation.

5. Monostable Multivibrator Circuit

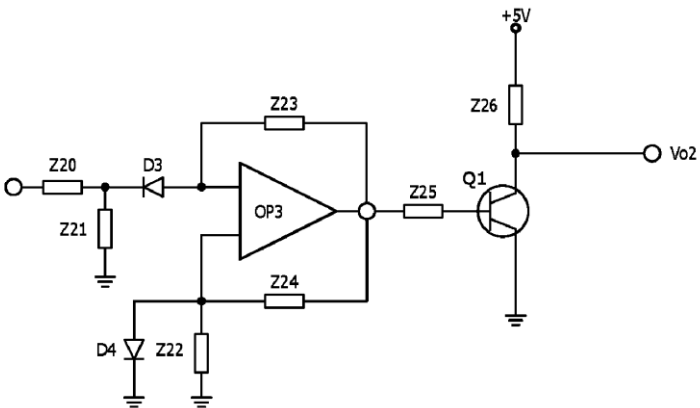


Figure 7.6 Monostable multivibrator circuit

A monostable multivibrator circuit implemented with D4, Z22, Z23, Z24, and OP3 is shown in Figure 7.6. In stable operation, the OP3 output is in positive saturation. The circuit charges through Z22 and Z24, resulting in a voltage of 0.6V at Z22. Z20 and Z21 are used to detect the square wave from the comparator. Because only negative signal can pass through D3, the OP3 positive input voltage remains 0.6V lower than the negative input voltage. This causes the OP3 output to enter negative saturation, triggering the circuit. Z22 then discharges until the Z22 voltage drops below the positive input voltage, and the stable potential is achieved again.

7.3 REQUIRED EQUIPMENTS

1. KL-71001 Main Controller
2. KL-73007 Experiment Module
3. Oxygen Mask with Respiratory Sensor (KL-73007A)
4. Digital Storage Oscilloscope (extra hardware)
5. 10mm Connectors
6. HUB
7. D-sub 9-9 Cable

7.4 EXPERIMENT PROCEDURE

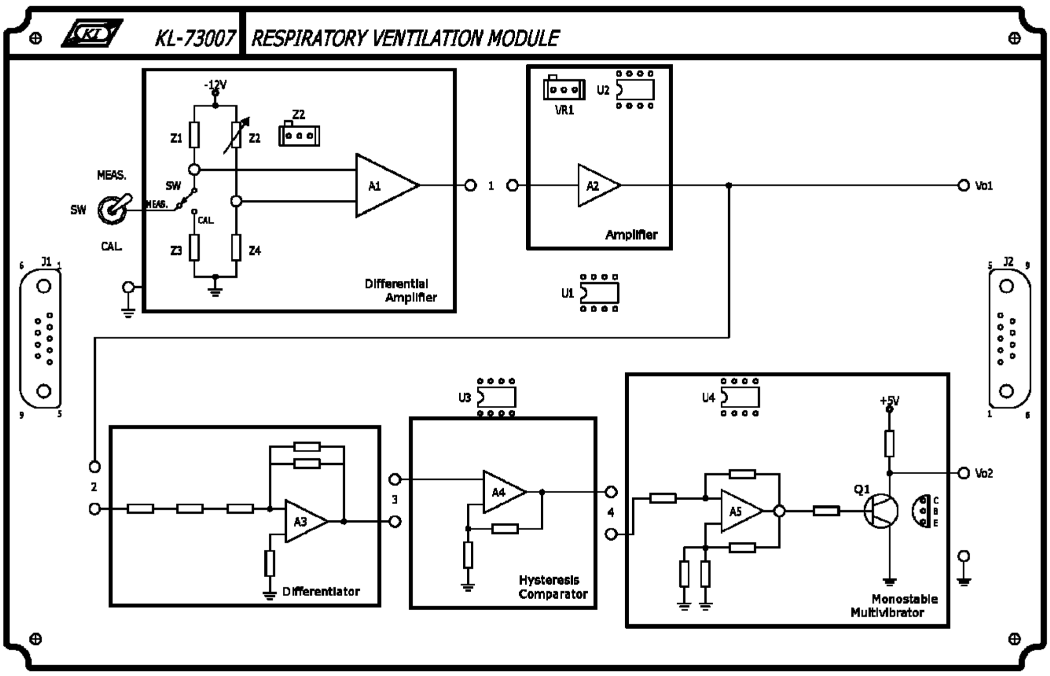


Figure 7.7 Respiratory measurements module

1. Differential Amplifier Circuit Calibration Experiment

(1) Connect the J2 connector of the KL-73007 to the MODULE OUTPUT terminal of the KL-71001. There is no need for a connector plug between any two circuit blocks.

(2) Set the SW switch to CAL. Measure the 'Differential Amplifier' output with a digital multimeter. Adjust the Z2 SVR value so that the output voltage is zero.

2. Amplifier Experiment

(1) Connect the J2 connector of the KL-73006 to the MODULE OUTPUT terminal of the KL-71001. There is no need for a connector plug between any two circuit blocks.

(2) Connect the function generator output of the KL-71001 to terminal 1 of the KL-73007, and the GND terminal of the KL-71001 to the ground terminal of the KL-73007. Connect the function generator output to the CH1 channel of the oscilloscope, and the "Amplifier" output terminal to the CH2 channel of the oscilloscope.

(3) Set the function generator sinusoidal frequency to 1kHz and the amplitude to 100mVpp. Record the amplifier output amplitude to Table 7.1 at Results section.

(4) If the amplifier output is at the saturation region, reduce the output amplitude of the function generator to avoid distortion.

(5) Adjust the frequency to various values and record the amplifier output amplitude in Table 7.1 at Results section.

3. Differentiator Circuit Experiment

(1) Connect the J2 connector of the KL-73007 to the MODULE OUTPUT terminal of the KL-71001. There is no need for a connector plug between any two circuit blocks.

(2) Connect the function generator output of the KL-71001 to terminal '2' of the KL-73007, and the GND terminal of the KL-71001 to the ground

terminal of the KL-73007. Connect the function generator output to the CH1 channel of the oscilloscope, and the ‘Differentiator’ output terminal to the CH2 channel of the oscilloscope.

(3) Set the function generator sinusoidal frequency to 1kHz and the amplitude to 1Vpp. Record the differentiator output amplitude to Table 7.2 at Results section.

(4) Adjust the frequency to various values and record the amplifier output amplitude in Table 7.2 at Results section.

4. Hysteresis Comparator Experiment

(1) Connect the J2 connector of the KL-73007 to the MODULE OUTPUT terminal of the KL-71001. There is no need for a connector plug between any two circuit blocks.

(2) Connect the function generator output of the KL-71001 to terminal '3' of the KL-73007, and the GND terminal of the KL-71001 to the ground terminal of the KL-73007. Connect the function generator output to the CH1 channel of the oscilloscope, and the ‘Hysteresis Comparator’ output terminal to the CH2 channel of the oscilloscope.

(3) Set the sinusoidal frequency of the function generator to 1kHz and its amplitude to 100mVpp. Adjust the GAIN 1 SVR value until you get an output from the comparator. Record the comparator output amplitude in Table 7.3 at Results section.

(4) Increase the input amplitude until the circuit output changes state. Record this input amplitude.

(5) Decrease the input amplitude until the circuit output changes state. Record this input amplitude.

(6) Determine the $+V_{th}$ and $-V_{th}$ amplitudes.

5. Monostable Multivibrator Experiment

(1) Connect the J2 connector of the KL-73007 to the MODULE OUTPUT terminal of the KL-71001. There is no need for a connector plug between any two circuit blocks.

(2) Connect the function generator output of the KL-71001 to terminal '4' of the KL-73007, and the GND terminal of the KL-71001 to the ground terminal of the KL-73007. Connect the function generator output to the CH1 channel of the oscilloscope, and the 'Monostable Multivibrator' output terminal to the CH2 channel of the oscilloscope.
(3) Set the sinusoidal frequency of the function generator to 100Hz and its amplitude to 1Vpp. Record the comparator output amplitude in Table 7.4 at Results section
(4) Set the frequency to various values and record the differentiator output amplitude to Table 7.4 at Results section.

6. Respiratory Frequency Measurement Experiment (Results should be stored using digital storage oscilloscope)

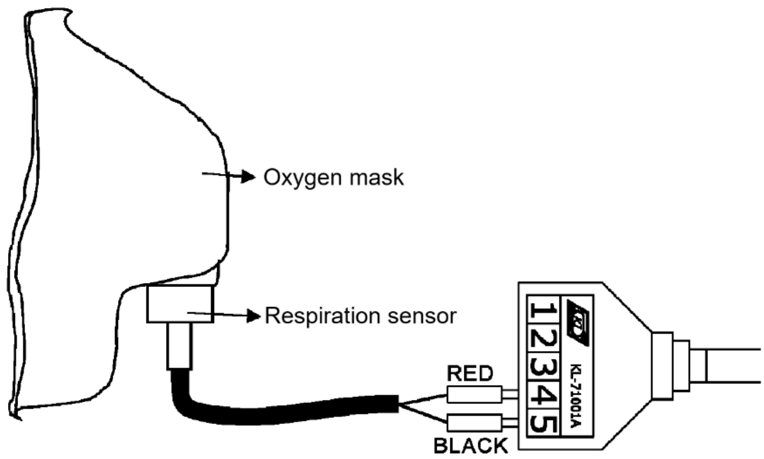


Figure 7.8 Oxygen mask ~ HUB connection

(1) Connect terminals J1 and J2 of the KL-73007 to the MODULE INPUT and MODULE OUTPUT terminals of the KL-71001, respectively. Use the connectors to connect terminals 1, 2, 3, 4. Connect the Vo1 output terminal to the CH1 channel of the oscilloscope, and the Vo2 output terminal to the CH2 channel of the oscilloscope.
(2) Select the KL-73007 module using the INPUT SELECT button on the KL-71001 (see LCD display). The IN4 and IN5 LEDs on the KL-71001 panel should light up. This indicates that the input signal should be connected to this input. Therefore, connect the respiration sensor KL-73007A to this input terminal. The red terminal should be connected to

IN4 and the black terminal to IN5 as shown in Figure 7.8.

(3) Set the oscilloscope input coupling setting for both channels to DC. Set the CH1 and the CH2 voltage scales to 5V/div. Set the time scale setting to 5S/div.

(4) Set the SW switch to CAL and adjust the Z2 SVR value so that the A1 output voltage is zero.

(5) Connect the oxygen mask to the respiratory sensor and turn the SW switch to MEAS. Start measuring respiratory activity.

(6) Keep the respiratory rate at a normal level and record the respiratory curve and trigger waveform on the oscilloscope in Table 7.5 in the Results section.

7. Respiratory Frequency Measurement Experiment (Results are recorded to the computer via the RS232 interface)

(1) Connect terminals J1 and J2 of the KL-73007 to the MODULE INPUT and MODULE OUTPUT terminals of the KL-71001, respectively. Use the connectors to connect terminals 1, 2, 3, 4. Connect the Vo1 output terminal to the CH1 channel of the oscilloscope, and the Vo2 output terminal to the CH2 channel of the oscilloscope.

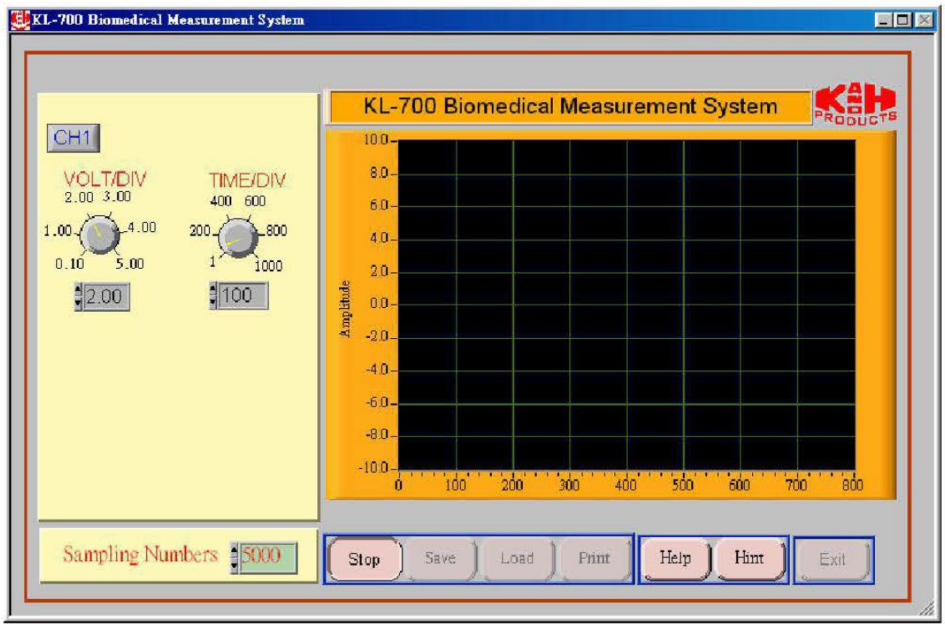
(2) Select the KL-73007 module using the INPUT SELECT button on the KL-71001 (see LCD display). The IN4 and IN5 LEDs on the KL-71001 panel should light up. This indicates that the input signal should be connected to this input. Therefore, connect the respiration sensor KL-73007A to this input terminal. The red terminal should be connected to IN4 and the black terminal to IN5 as shown in Figure 7.8.

(3) Set the SW switch to CAL and adjust the Z2 SVR value so that the A1 output voltage is zero.

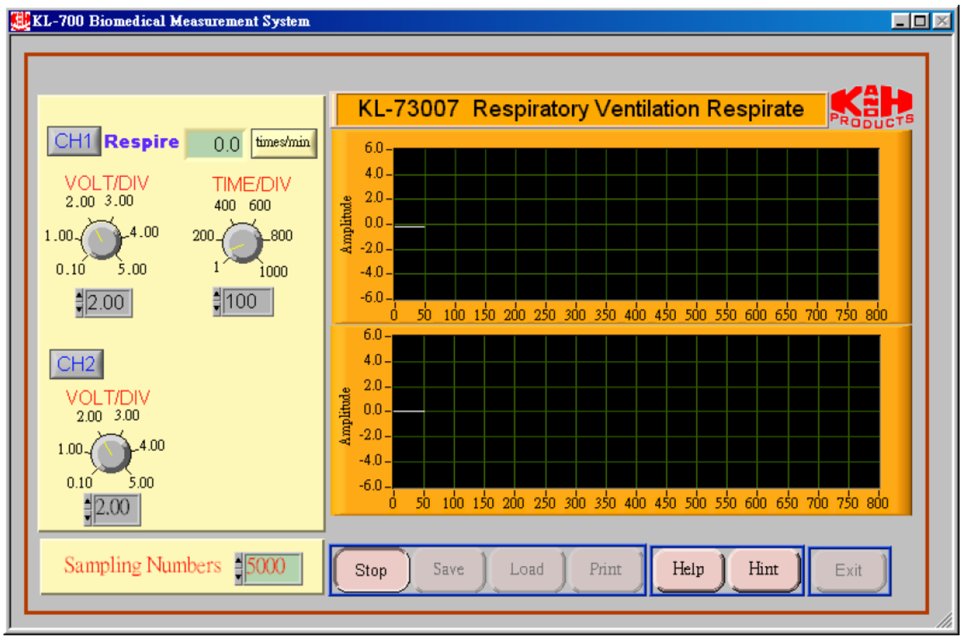
(4) Connect the 9-pin RS232 cable to COM Port on the computer.

(5) Run the KL-700 Biomedical Measurement System software. For instructions and installation information, see Chapter 0.

(6) When the system is loaded, the image below will appear on the screen.



(7) Press the 'Acqu' button to display the image below. The KL-73007 Respiratory Ventilation recording screen will appear.



(8) Adjust the VOLT/DIV and TIME/DIV settings so that the signal waveform appears in the center of the graph area.

(9) Connect the oxygen mask to the respiratory sensor and turn the SW switch to MEAS. Start measuring respiratory activity.

(10) Keep the respiratory rate at a normal level and record the respiratory curve and trigger waveform on computer.

7.5 RESULTS

Table 7.1 Amplifier Experiment

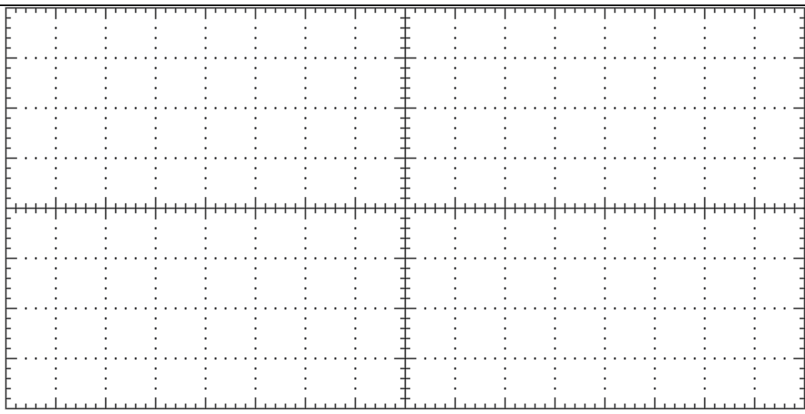
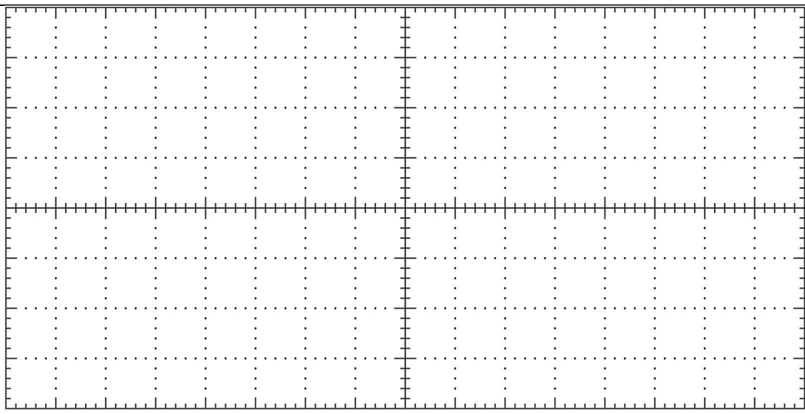
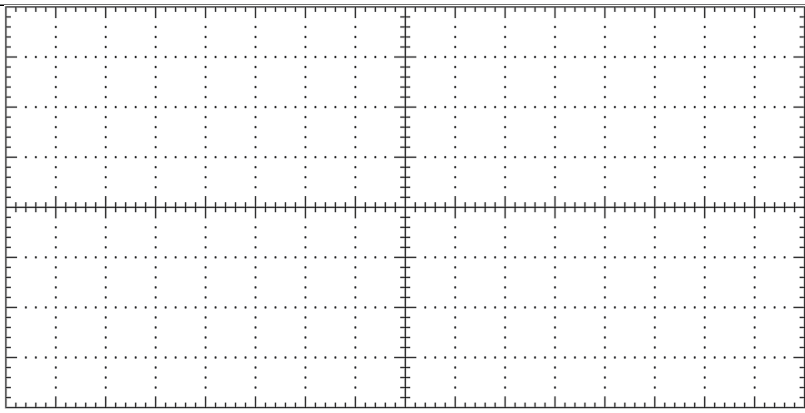
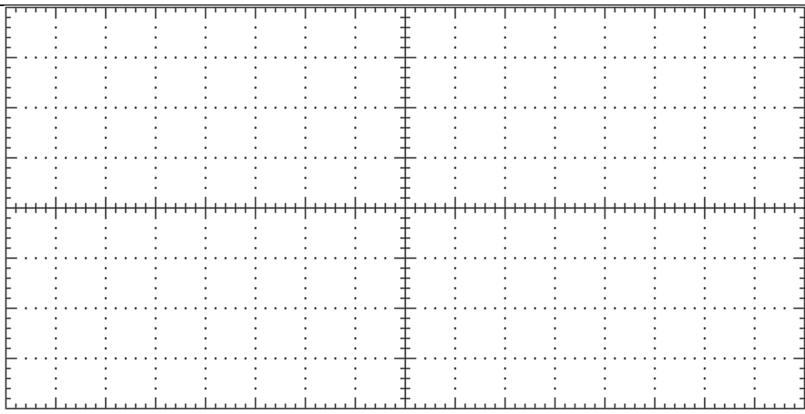
Input Frequency	Amplifier Output
10Hz	
100Hz	
500Hz	
1kHz	

Table 7.2 Differentiator Experiment

Input Frequency	Differentiator Output
10Hz	
100Hz	
500Hz	
1kHz	

Table 7.3 Hysteresis Comparator Experiment

	Input Amplitude	V_{th} (V_{ss})
Increase the input amplitude until the output changes state		
Decrease the input amplitude until the output changes state		

Table 7.4 Monostable Multivibrator Experiment

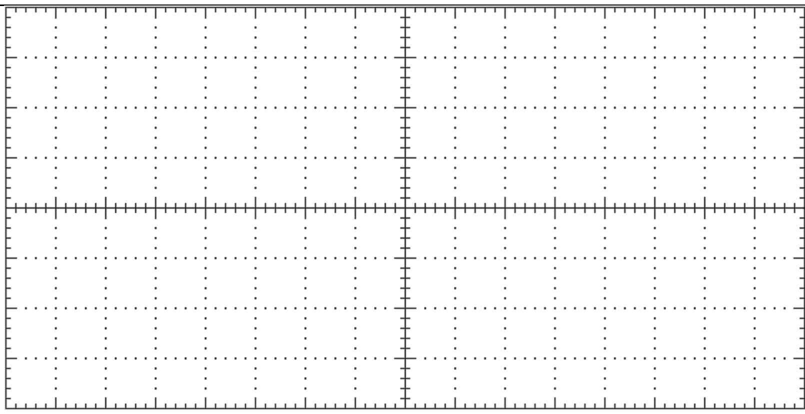
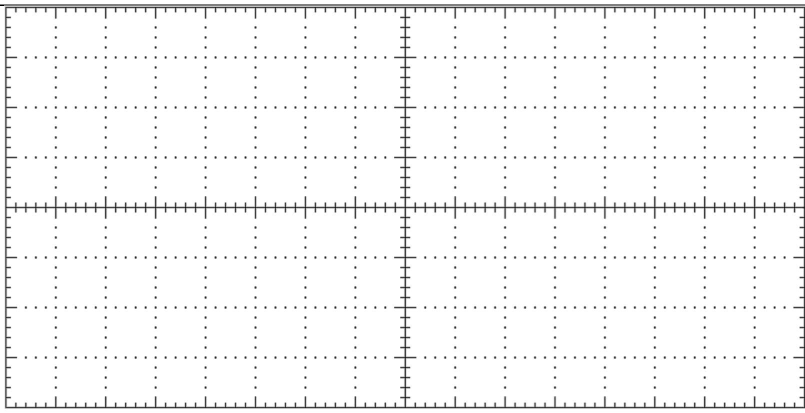
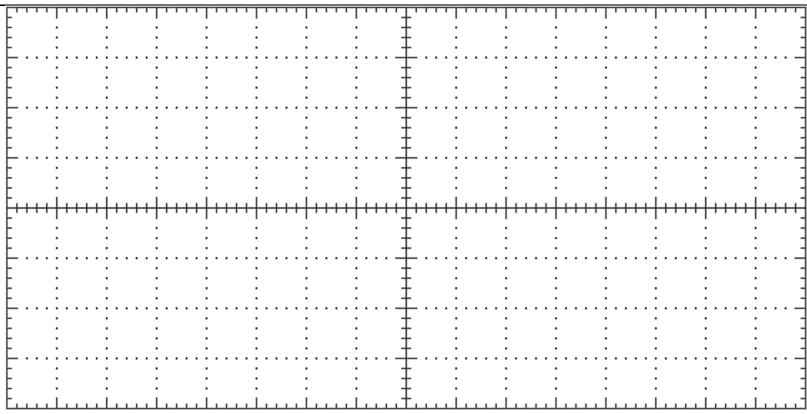
Frequency	Monostable Multivibrator Output
1Hz	
10Hz	

Table 7.5 Respiratory Frequency Measurement Experiment

Frequency	Vo1 (CH1) / Vo2 (CH2) Waveform
Normal respiratory frequency	

7.6 QUESTIONS

1. When the oxygen mask is not worn on the face, why is the A1 output not 0 at room temperature?
2. What happens if a bistable multivibrator is used in this experiment?
3. Why was a monostable multivibrator used in this experiment?