5. Experimental Contents

1) Understand the working principle of the gas pressure sensor and test its characteristics.
2) Use gas pressure sensor, amplifier and digital voltmeter to construct a digital pressure gauge and calibrate it with a standard pointer pressure gauge.
3) Understand the principle of measuring human heart rate and blood pressure, use pulse sensor to measure pulse waveform and heartbeat frequency, and use the constructed digital pressure gauge to measure human blood pressure.
4) Verify Boyle's law of the ideal gas. (Optional)
5) Use slow scanning long afterglow oscilloscope (need to be purchased separately) to observe the body pulse waveform and analyze the heart beat, estimate heart rate, blood pressure and other parameters. (Optional)

6. Experimental Procedure

A. Must do experiments: measurement of gas pressure sensor characteristics; assembly of digital pressure gauge and measurement of human heart rate and blood pressure

1) Preparation before the experiment

   Pre-warm the apparatus for 5 minutes till the instrument is stable before doing experiment. Note that it is strictly forbidden to pressurize more than 36 kPa during the experiment.

2) Characteristic measurement of the gas pressure sensor MPS3100
   a) Connect the power supply (+5 V) to the gas pressure sensor MPS3100 and connect its output to the digital voltmeter. Use the syringe to inject air into the pipeline of the sensor.
   b) Measure the output voltage of the gas pressure sensor (4-32 kPa) (Measure 8 points).
   c) Draw the relationship curve of the pressure P and the output voltage U of the gas pressure sensor, and calculate the sensitivity and correlation coefficient of the gas pressure sensor.
3) Construction and calibration of digital pressure gauge
   a) Connect the output of the gas pressure sensor MPS3100 to the input of the calibration amplifier (Cali Amp), and then connect the output of the amplifier to the digital voltmeter.
   b) Repeatedly adjust the "Zero" knob and "Gain" knob of the amplifier when the gas pressures are 4 kPa and 32 kPa, so that the amplifier output voltage is 40 mV when the gas pressure is 4 kPa, and 320 mV when the gas pressure is 32 kPa.
   c) After the previous operation, calibration is completed. Do not change "Zero" and "Gain". Press down the key switch to "kPa". The constructed digital pressure gauge can be used for human blood pressure or gas pressure measurement with digital display.
4) Measurement of heart rate

a) Place the piezoresistive pulse sensor on the arm where the pulse is strongest. Connect the pulse sensor to input socket of the apparatus. Connect the power supply (+ 5V), tie the blood pressure cuff, apply a little pressure (press the squeeze ball a few times).

If an oscilloscope is used to observe the output of the sensor, apply pressure till the clear pulse waveform is observed. If an oscilloscope is not applied, the location of the pulse sensor should be adjusted till the counting indicator lamp on the panel flashing accurately following the heartbeat frequency).

b) Press the Count/Save "Ct/Save" button, the instrument will automatically measure the number of pulses per minute within the specified one minute and display the measured number of pulses digitally.

5) Measurement of blood pressure

a) A typical Korotkoff sound method is used to measure blood pressure. Tie the blood pressure cuff to the pulse point of the upper arm, and place the medical stethoscope at the pulse point under the cuff.

b) Connect the blood pressure cuff with the apparatus air inlet with a tee. Pressurize the cuff with the squeeze ball to 20 kPa. Open the exhaust port to slowly exhaust, and at the same time listen to the pulse sound (Korotkoff sound) with a stethoscope. When a Korotkoff sound is heard, the reading of the pressure gauge is recorded as systolic pressure. Till the Korotkoff sound disappears, the reading of the pressure gauge corresponding to the last time of the Korotkoff sound is diastolic pressure.

c) If the diastolic pressure reading is not sure, you can inflate it again to above the diastolic pressure reading, and then slowly exhaust again to read the diastolic pressure.

B. Optional experiments: verification of the ideal gas law; observation of the pulse waveform

1) Verification of the ideal gas law

a) Suck air into the syringe to the 100 ml scale line. Connect the syringe outlet to the gas inlet of the apparatus with a tube. At this time, if the gas volume in the pipeline is *Vo*, then the total gas volume is $V_0 + V_1$ (100 ml). The pressure gauge shows that the pressure is zero (the actual pressure is about 760 mmHg or 101.08 kPa).

b) Press the syringe to compress the inside gas. At this time, the total gas volume will decrease and the pressure will increase. Measure the pressure in the pipeline every 5 ml volume reduction, at least 5 times. Then we get 5 sets of data: $(V_1 + V_0, P_1)$; $(V_2 + V_0, P_2)$; $(V_3 + V_0, P_3)$; $(V_4 + V_0, P_4)$; $(V_5 + V_0, P_5)$.

c) Make the straight line graph $\frac{1}{p_i + p_o} - V_i$, find the slope *K* and intercept K_{V0}, and then prove: $(V_2 + V_0)\ P_2 = (V_3 + V_0)P_3 = (V_4 + V_0)P_4 = (V_5 + V_0)P_5$. From the results to verify Boyle's law.

2) Observation of the pulse waveform and analysis of the systolic and diastolic blood pressure from the waveform

Send the pulse waveform signal to an oscilloscope (need to equip a slow-scan long afterglow oscilloscope) to observe and analyze the pulse waveform.

7. Examples of Data Recording and Processing

Note: the following data are for reference purposes only, not the criteria for apparatus performance.

Room temperature: 25 ℃ -30 ℃, power supply voltage 5.0 V

Table 1 Output characteristics of MPS3100 gas pressure sensor

Pressure (kPa)	4.0	8.0	12.0	16.0	20.0	24.0	28.0	32.0
Output Voltage (mV)	6.6	13.0	19.8	26.5	33.3	40.0	46.7	53.3

We got:

Gas pressure sensor sensitivity A = 1.664 mV / kPa; Correlation coefficient r = 0.99995