FC-CO-5000 Carbon Monoxide Sensor Technical Manual

Shenzhen PUSEN Sensing Technology Co., Ltd.

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1. Basic Information

1.1 Product Introduction

The FC-CO-5000 carbon monoxide sensor is renowned for its exceptional durability. It employs the reliable fuel cell principle for detection. When carbon monoxide gas is present in the environment, gas molecules rapidly reach the sensor's core detection unit through natural diffusion and concentration polarization. An oxidation reaction occurs at the working electrode,Oxygen in the environment undergoes a reduction reaction at the sensor's counter electrode, forming a closed-loop reaction. The resulting current is directly proportional to the concentration of carbon monoxide in the environment. By measuring the magnitude of this generated current, the carbon monoxide content in the environment can be accurately quantified.

The FC-CO-5000 is renowned for its exceptionally long service life, high interference resistance, and compact design, making it the preferred choice for size-sensitive applications such as portable CO detectors, residential CO alarms, and combination fire detectors. Calibration data is embedded and printed in a QR code on the sensor, eliminating the need for costly gas calibration procedures and ensuring traceability for each sensor.

The FC-CO-5000 offers an exceptionally long service life with no consumable components, eliminating the need for secondary calibration and providing a reliable, cost-effective CO detection solution.

1.2 Features

*Zero power consumption　*Rapid response　* Calibration-free　*Interference resistance

*Resistant to poisoning　*Wide temperature range　*Long service life　*Excellent repeatability and stability

*UL certification (EX28754), FTAM2 certification

*Complies with GB15322, UL2034, UL2075, EN50291, EN54-31, RoHS, and REACH requirements

1.3 Typical Applications

*Residential CO Alarms　*Industrial and commercial CO detectors

*Portable generator CO monitoring　*Energy storage system CO detection

1.4 Basic Circuit

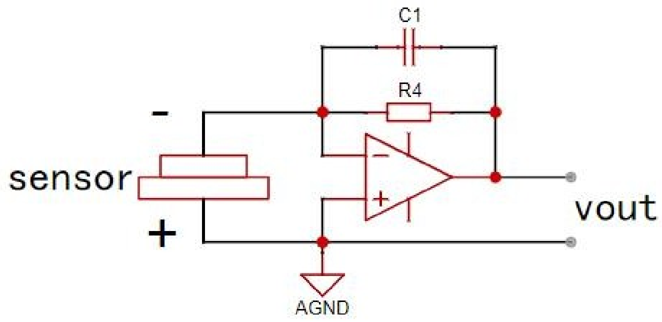


Figure 1 Basic Test Circuit Diagram

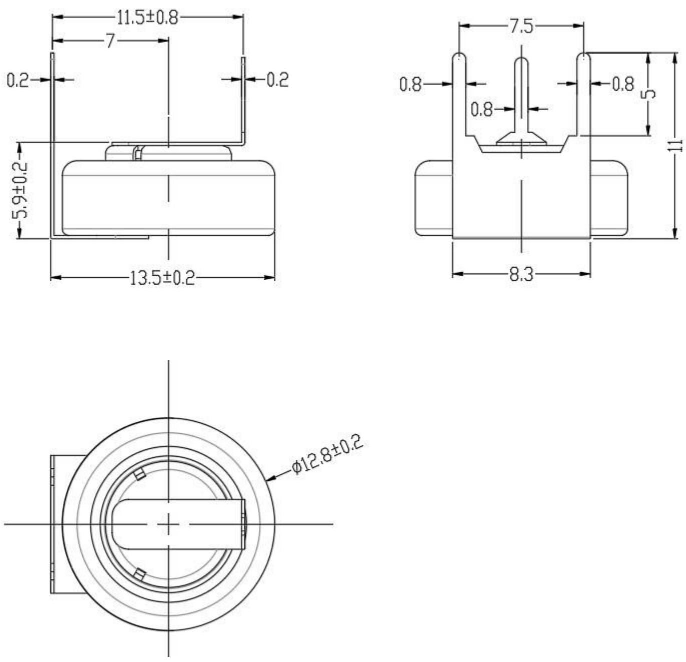
Figure 1 shows the basic test circuit for the FC-CO-5000 sensor. The microcurrent generated by the sensor is amplified by an operational amplifier and resistor (R4), converting it into the sensor output voltage (Vout). Vout increases as the carbon monoxide concentration rises. To ensure rapid stabilization after power cycling the sensor, it is recommended to add a depolarizing JFET to prevent sensor polarization when the circuit voltage is turned off.Pusheng recommends the following electronic components:

R4: 1Mohm

C1: 10uF

IC: TP5552 (or other op-amps with microvolt-level offset voltage)

1.5 Structural Dimensions



Note: 1 All dimensions are in mm

1.6 Technical Specifications

Item	Technical Parameters
Model	FC-CO-5000
Principle	Micro Fuel Cell
Range	0-5000 ppm
Maximum Overload	10000ppm
Sensitivity	1.5 ± 1 (nA/ppm)
Response Time	<60 seconds
Repeatability	3%
Output Linearity	Linear
Operating Temperature Range	-40°C to 70°C
Operating Pressure Range	Standard Atmospheric Pressure ±10%
Operating Humidity Range	10%–90% (non-condensing)
Service life	10 years (under normal use)
Warranty Period	12 months
Weight	3g
Silicone poisoning	No
1000ppm Alcohol Output	<10ppm

1.7 Mechanical Strength

Sensor samples underwent relevant testing under conditions specified by UL2034, with specific test parameters as follows: Vibration: Vertical amplitude 0.25mm, frequency 35Hz, directions x, y, z, duration 4 hours

Drop: Height 2.1 meters, repeated 5 times

Results indicate: The sensor possesses sufficient mechanical strength to meet UL2034 requirements for sensor mechanical strength.

1.8 Basic Performance Testing

1.8.1 Current Testing

Table 1: Fifteen sensor sets were placed in the test system to obtain the zero-point current value I_0in clean air. After introducing 500 ppm of standard carbon monoxide gas, the current value I_1under the current state was recorded. S represents the sensor sensitivity, and t90 represents the response time.

Table 1 Sensor Sensitivity Record

Sensor ID	I_0/nA	ΔI/nA	S (nA/ppm)	t_{90}/S
P1	-3	807	1.616	24
P2	0	888	1.775	24
P3	2	784	1.568	24
P4	-2	770	1.540	24
P5	-2	762	1.523	27
P6	1	831	1.661	27
P7	-3	720	1.440	24
P8	1	846	1.692	25
P9	-2	872	1.744	28
P10	0	812	1.624	24
P11	-1	572	1.524	24
P12	2	570	1.520	28
P13	2	591	1.578	27
P14	0	564	1.503	27
P15	1	534	1.422	28

1.8.2 Response-Recovery Time

Figure 2 shows the response time and recovery time of the sensor.During testing, the sensor was placed within the test system. Data was read for 5 minutes in clean air, followed by 5 minutes of exposure to 500 ppm standard carbon monoxide gas, then 5 minutes of replacement with clean air. This yielded the sensor's response time and recovery time curves. As shown in the figure, the sensor's response time is within 30 seconds and recovery time within 60 seconds, meeting the requirements of UL2034.

t90: Time required to reach **90%** of the saturated signal level

t10: Time required for the signal to return to **90%** of the baseline level

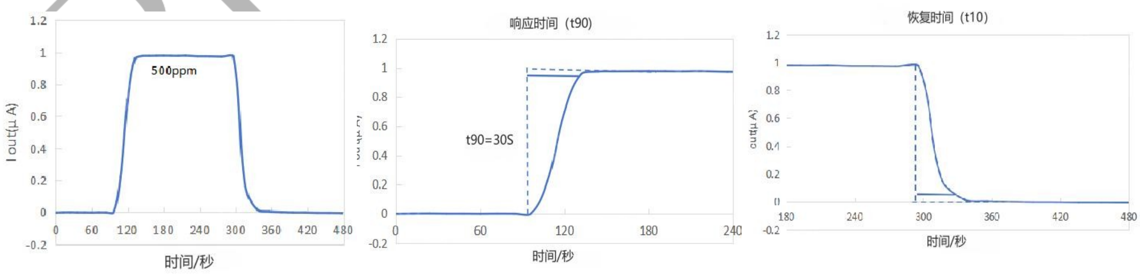


Figure 2 Response-Recovery Time

1.8.3 Linear

Figures 3-5 display the sensor's output values for different CO concentrations. The Y-axis shows output current (Iout/μA), which exhibits a linear relationship with CO concentration. Within the 0–5000 ppm range, deviation is less than ±5%. Precise data is provided in Table 2.

Table 2 Output Values at Different CO Concentrations

Concentration /ppm	Sensor ID									
	P21	P22	P23	P24	P25	P26	P27	P28	P29	P30
	I/μA	I/μA	I/μA	I/μA	I/μA	I/μA	I/μA	I/μA	I/μA	I/μA
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
200	0.336	0.3	0.291	0.297	0.324	0.354	0.3435	0.3495	0.351	0.36
400	0.6705	0.6045	0.5835	0.5985	0.648	0.708	0.69	0.7005	0.702	0.72
600	0.9855	0.8955	0.864	0.8865	0.9615	1.044	1.0185	1.032	1.0365	1.062
800	1.293	1.188	1.146	1.176	1.2735	1.365	1.3395	1.3485	1.365	1.401
1000	1.6125	1.4865	1.434	1.473	1.5825	1.6905	1.665	1.674	1.701	1.7445
3000	4.9635	4.866	4.5045	4.818	4.9575	4.9665	4.962	4.965	4.9065	5.0325
5000	8.2635	7.896	7.5045	7.818	8.2575	8.2665	8.262	8.265	8.172	8.3805

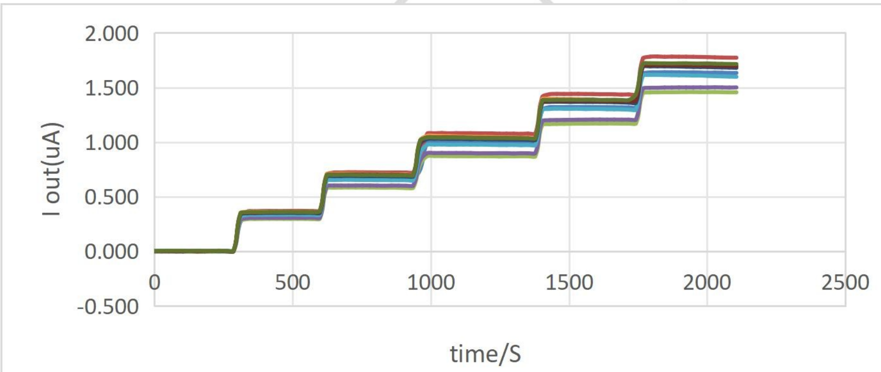


Figure 3 Response Plot

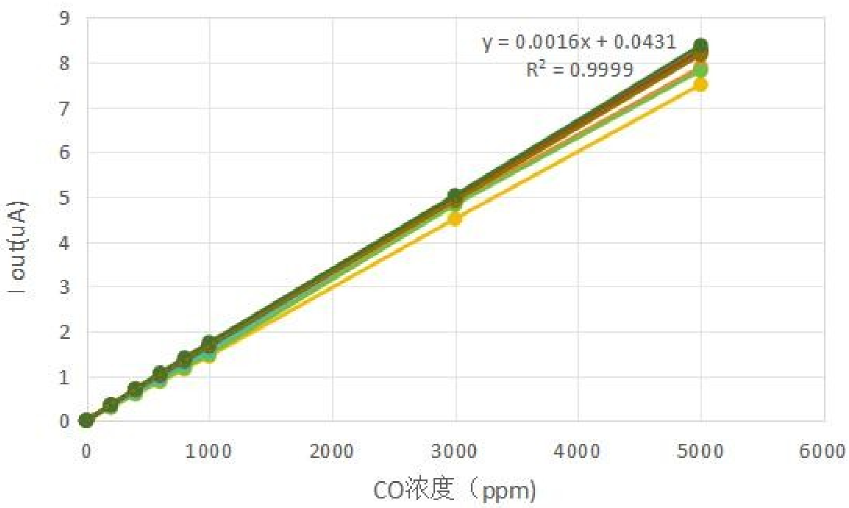


Figure 4 Linearity Chart

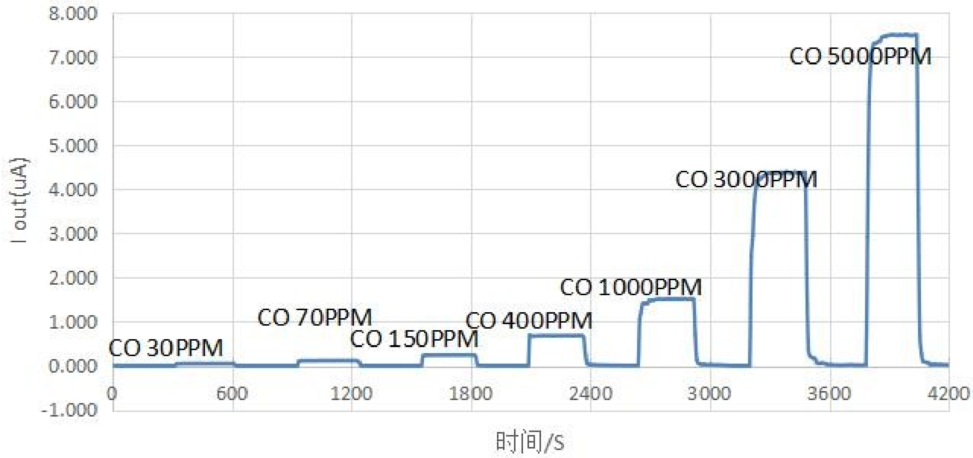


Figure 5 Response at Different CO Concentrations

1.8.4 Repeatability

Table 3 and Figure 6 show the response when the sensor was repeatedly placed in a 500 ppm carbon monoxide gas environment. During testing, the sensor was placed in clean air for 5 minutes to read data, then exposed to 500 ppm carbon monoxide standard gas for 5 minutes, followed by replacement with clean air for 5 minutes. This procedure was repeated four times. The test results indicate a standard deviation of less than ±5%, demonstrating good repeatability.

Table 3 Repeatability Test Data

	1#	2#	3#	4#
	△ I1/u A	△ I3/u A	△ I_4/u A	△ I5/u A
No.1	0.771	0.818	0.805	0.801
No.2	0.773	0.815	0.805	0.804
No.3	0.766	0.812	0.802	0.795
No.4	0.770	0.817	0.805	0.800
RSD	0.3%	0.3%	0.1%	0.4%

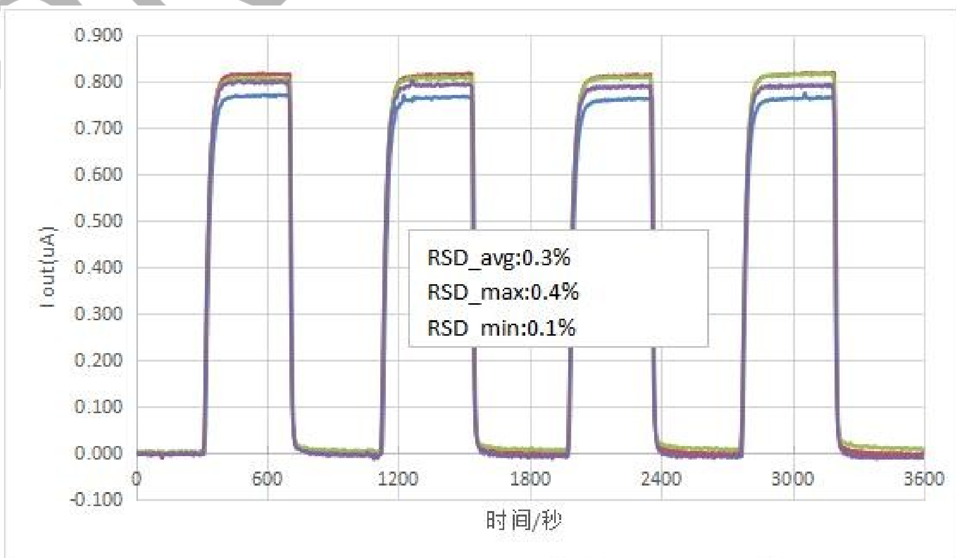


Figure 6 Sensor repeatability test for 500 ppm carbon monoxide

1.8.5 Sensitivity Test

Figure 7 shows the relevant experiment conducted according to the "Sensitivity Test" section of UL2034. The standard requires placing the sensor in a 20°C & 40%RH environment and exposing it to different concentrations of carbon monoxide gas for varying durations as per Table 4. Sensor sensitivity is tested before, during, and after exposure using the methods specified in UL2034.

Table 4: Sensor Exposure Concentrations and Corresponding Durations

No.	Concentration/ppm	Exposure Duration/min
1	30	900
2	70	240
3	150	90
4	400	30

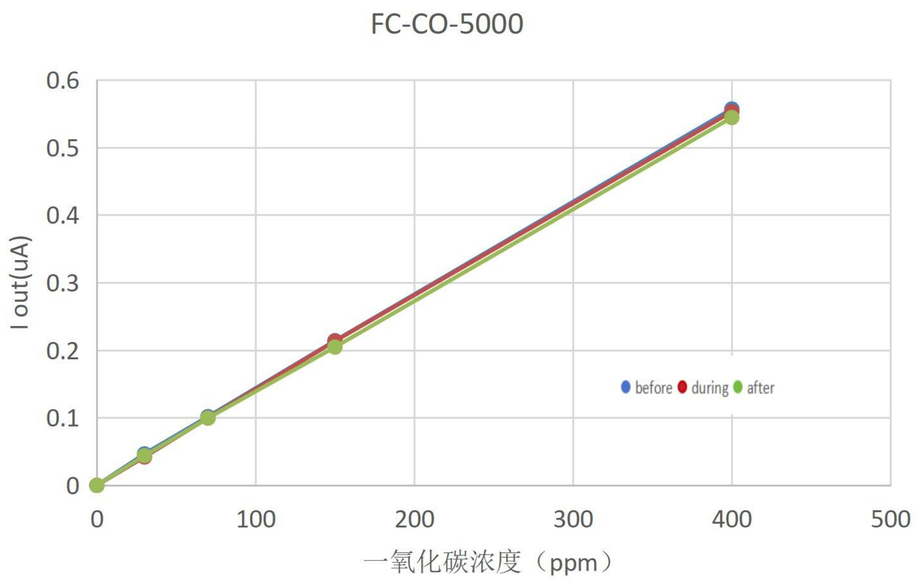


Figure 7 Tests Before, During, and After Sensitivity Testing

1.8.6 Effect of Storage Conditions

Sensors were stored in both short-circuit and open-circuit states for over three months. After storage, sensors were immediately connected to the test system to capture the initial output current in clean air, record the change process, and determine the time required to reach stable output, as shown in Figure 8.Results indicate that sensors stored in short-circuit condition rapidly achieved stable output current signals, whereas those stored in open-circuit condition exhibited slower current changes. Therefore, it is recommended that sensors stored in open-circuit condition be allowed to stabilize for at least 1 hour before mounting onto circuit boards equipped with anti-polarization circuits. If no anti-polarization circuit is present,

wait at least 2 hours after powering the circuit board.

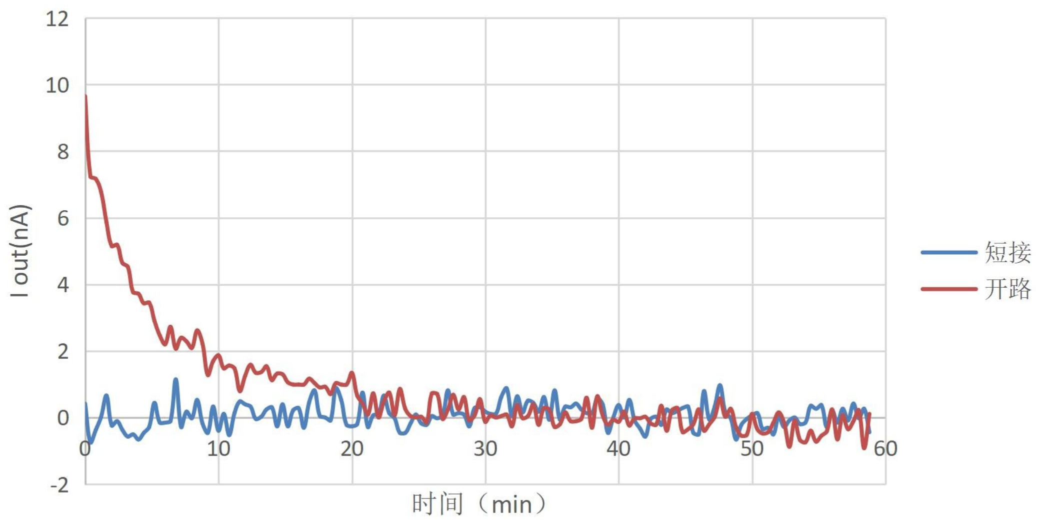


Figure 8 Effects of Short-Circuit and Open-Circuit Conditions During Storage

1.8.7 Normal Operation Test

Figure 9 shows tests conducted according to the "Normal Operation Test" in UL2034 standards. The standard requires exposing the sensor to 600ppm carbon monoxide at 20℃ and 40% RH for 12 hours, recording sensor response data before, during, and after the test. Results indicate the sensor is unaffected by high carbon monoxide concentrations.

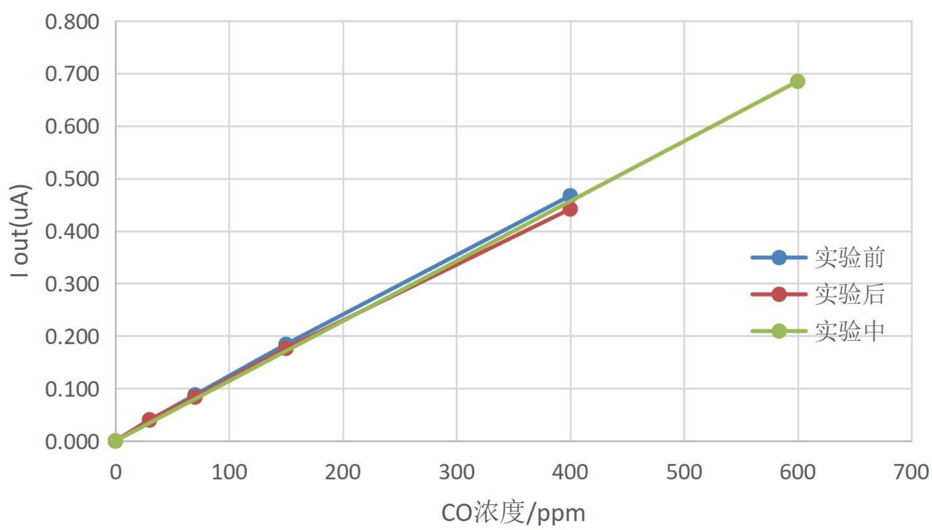


Figure 9 Normal Operation Test

1.9 Reliability Test

1.9.1 Interference Gas Test

1.9.1.1 Interference Gas Response Values

Table 5 shows the sensor's response to different interference gases at a specific concentration, with an exposure time of 5 minutes.

Table 5 Sensor Interference Data

Serial No.	Interference Gas	Interference Gas Concentration (ppm)	Equivalent concentration of carbon monoxide (ppm)
1	Hydrogen	1000	＜400
2	Methane	1000	＜10
3	Ethanol	1000	＜10
4	HMDS (Organosilicon Vapor)	1000	＜20
5	Toluene	1000	0
6	Isopropyl Alcohol	1000	＜10
7	Freon R22	1000	＜10
8	Acetone AD-1	1000	0
9	Trichloroethane	1000	0
10	Ammonia	200	0
11	Ethylene	200	＜30
12	Ethyl acetate	200	0
13	Acetylene	200	＜300
14	Formaldehyde	200	＜10

Note: The data in this table are typical values and should not be used as a reference for cross-calibration of interfering gases. The measured data represent the sensor's response after 5 minutes of exposure to the interfering gas. For certain gases, longer exposure times may result in different response values.

1.9.1.2 Interference Gas Durability Testing

Figure 10 illustrates the interference durability testing of the sensor against various interference gases, conducted in accordance with UL2034 specifications.The test procedure is as follows: The sensor is placed in each gas environment shown in Figure 10 for 2 hours, then removed to fresh air for 1 hour. The sensor is then placed in the next gas environment, repeating the above process. The test sequence, as shown in Figure 10, begins with 30ppm carbon monoxide and ends with 30ppm carbon monoxide.

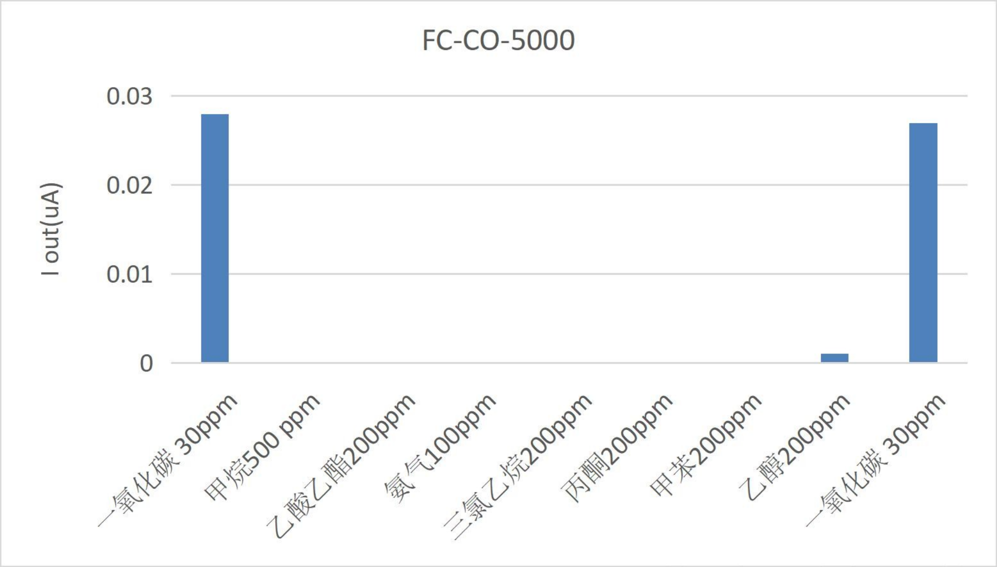


Figure 10 Interference Gas Test

Figure 11 shows the sensor's response performance for carbon monoxide before and after interference endurance testing conducted per the UL2034 protocol. The figure demonstrates excellent repeatability of the sensor's performance before and after testing. The sensor's detection capability was unaffected by the tested interference gases, confirming its compliance with UL2034 requirements for interference endurance.

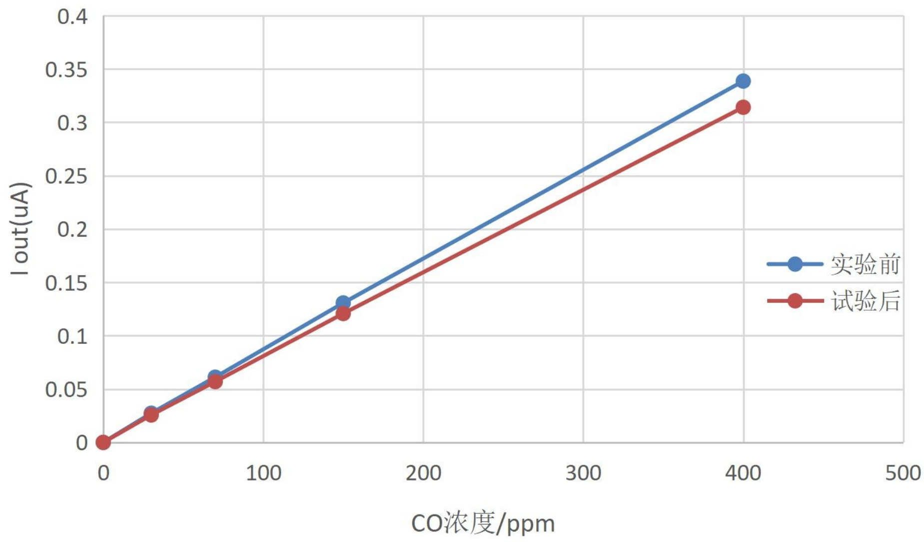


Figure 11: Test Variation Before and After Interference Gas Testing

1.9.2 Corrosion Resistance Test

Figure 12 shows the corrosion resistance test of the sensor. During testing, the sensor was sealed and stored in a 1ppm hydrogen sulfide environment for 4 weeks. The sensor's response before and after the test was recorded. Test results indicate that the sensor was unaffected by 1ppm hydrogen sulfide, and no signs of corrosion appeared on the sensor housing throughout the test, demonstrating excellent corrosion resistance durability.

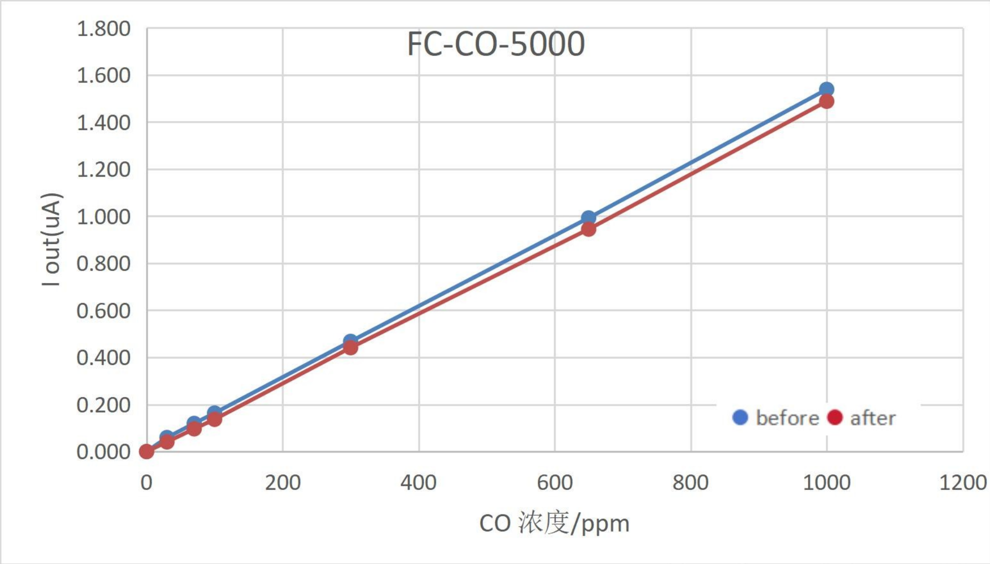
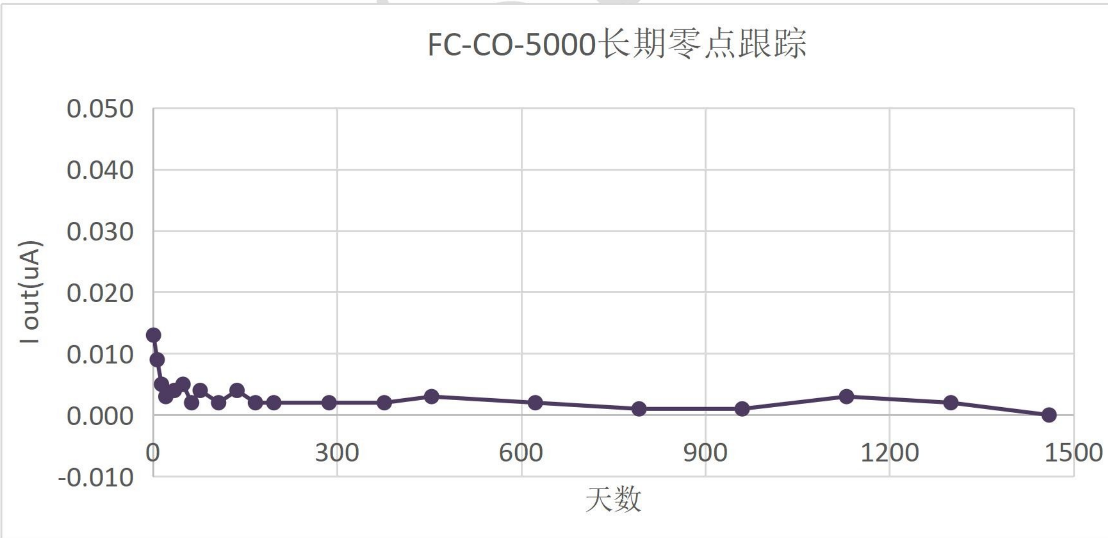


Figure 12 Changes Before and After Corrosion Resistance Testing

1.9.3 Long-Term Stability

Figures 13 and 14 present the sensor's long-term stability test.The tested sensor was stored in a kitchen environment in a shorted state. Its response to carbon monoxide was periodically measured. The Y-axis in Figure 13 represents the sensor's output current in normal air, while the Y-axis in Figure 14 represents the output current under 400 ppm CO. These graphs demonstrate that the sensor's performance remained highly stable over 1500 days.



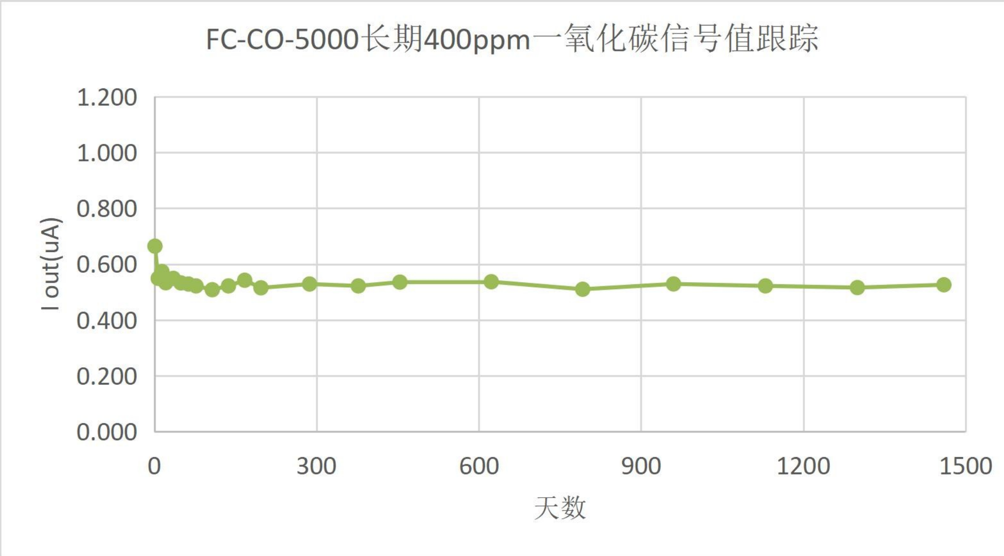
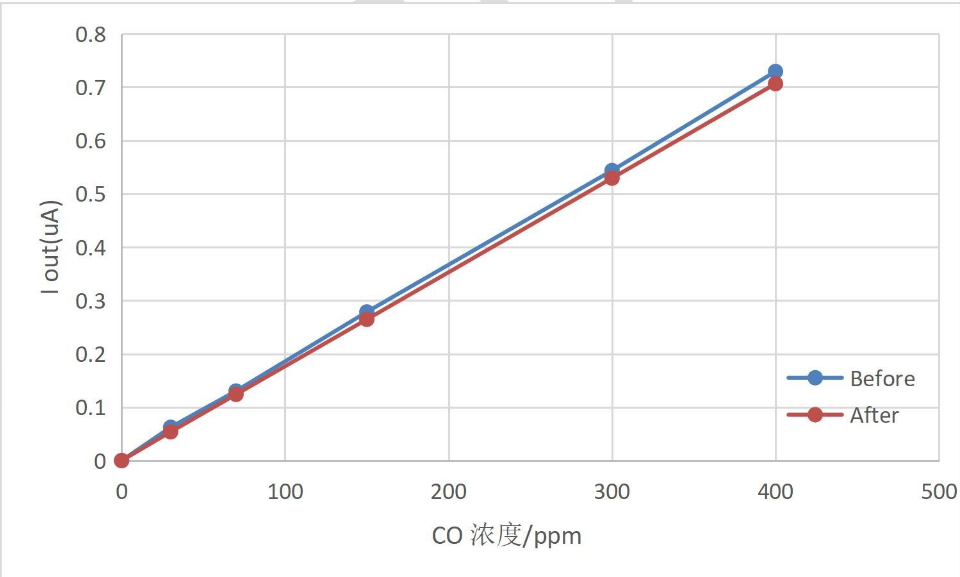


Figure 14 Long-Term Sensitivity Drift

1.9.4 False Alarm Testing

Figure 15 shows testing conducted according to the "Stability Test" in UL2034. The standard requires the sensor to be continuously exposed to 30 ppm of carbon monoxide for 30 days, testing the sensor's response to carbon monoxide before and after the test. The sensitivity shown in Figure 15 before and after testing indicates that the effect of long-term exposure to 30 ppm CO gas on sensitivity is negligible.



1.10 Environmental Testing

1.10.1 Temperature Effect

Figure 16 illustrates the temperature effect on the sensor in a 50%RH humidity environment. During testing, the sensor was placed within a test system maintained at 50%RH humidity. Data sets were collected at 5℃ intervals, with each temperature point equilibrated for 4 hours using 500ppm CO standard gas. Data analysis yielded the sensor's temperature compensation coefficient.

[illegible]

I: Sensor output current in 500ppm CO gas at 50%RH and various temperatures; I_0: Sensor output current in 500ppm CO gas at 25℃ & 50%RH;

Table 6 Sensor Temperature Compensation Coefficients

Temperature (℃)	-40	-35	-30	-25	-20	-15	-10	-5
I/IO	21%	28%	34%	38%	43%	51%	59%	65%
Temperature (℃)	0	5	10	15	20	25	30	35
I/IO	71%	78%	83%	88%	95%	100%	106%	111%
Temperature (℃)	40	45	50	55	60	65	70	
I/IO	114%	116%	119%	120%	120%	119%	116%	

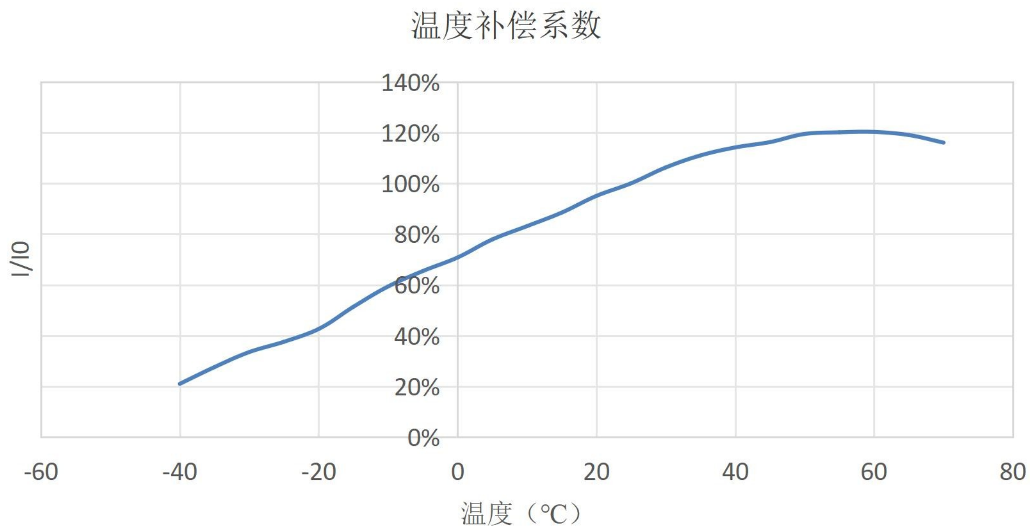


Figure 16 Sensor Temperature Compensation Coefficient Diagram

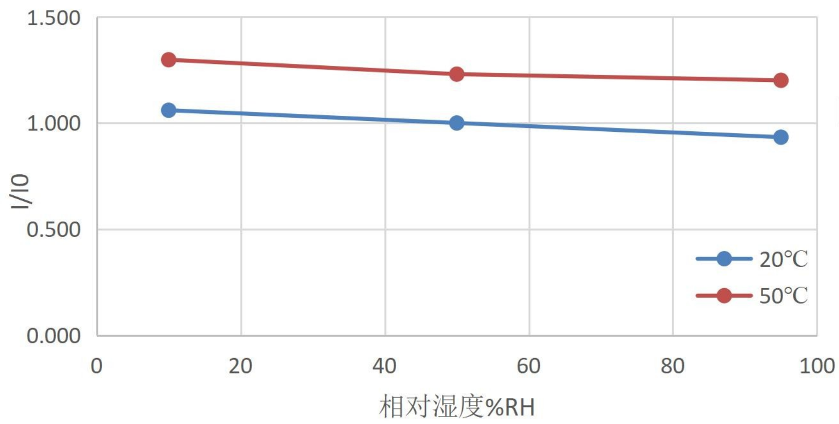
1.10.2 Humidity Effect

Figure 17 illustrates the humidity effect on the sensor, with tests conducted at two representative temperatures: 20℃ and 50℃.In this test, samples were placed in test systems maintained at 20℃ and 50℃, with temperature and humidity controlled to meet the requirements specified in Table 7. The output current values for 500 ppm carbon monoxide gas were recorded at different humidity levels. These data indicate that humidity dependence is negligible with respect to temperature variation.

Table 7 Experimental Conditions

Temperature/°C	Humidity	Temperature/°C	Humidity
20	10%RH	50	10%RH
	50%RH		50%RH
	95%RH		95%RH

I: Sensor output current in 500ppm carbon monoxide gas at various temperatures and humidity levels I_0: Sensor output current in 500ppm carbon monoxide environment at 20°C & 50%RH



1.10.3 Testing at Different Ambient Temperatures

This section describes tests conducted at different ambient temperatures to verify the sensor's tolerance to high and low temperatures, in accordance with the relevant sections of UL2034.

1.10.3.1 High and Low Temperature Operation Testing

After exposing the sensor to the environments specified in Table 8 for at least 3 hours, the sensor's output responses to 30, 70, 150, and 400 ppm CO concentrations were recorded as shown in Figure 18. This demonstrates that the sensor's performance remains unaffected by humidity.

Table 8: Sensor High and Low Temperature Operation Test Environment Control Table

Temperature/°C	Humidity %RH
-10	50
0	15
20	50
35	50
49	40

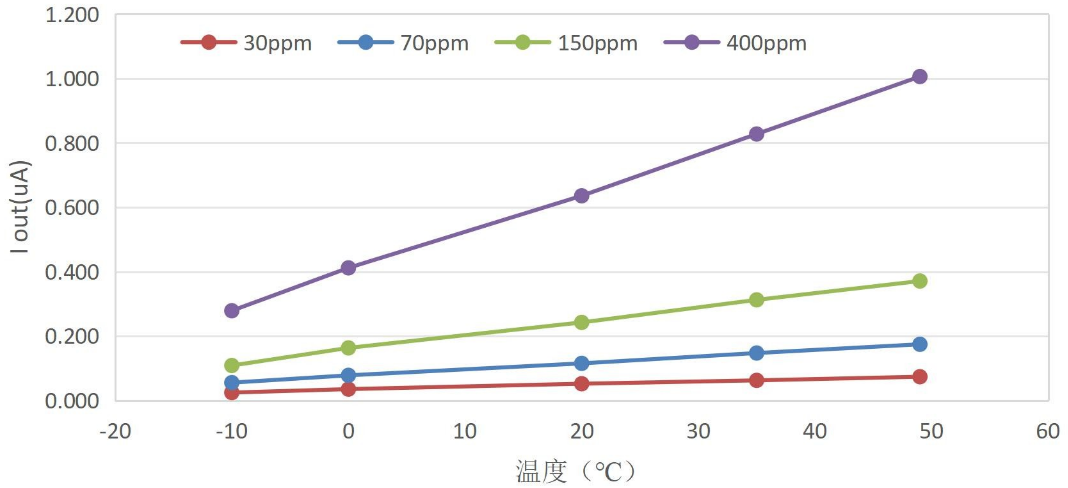


Figure 18 High and Low Temperature Operational Testing

1.10.3.2 Impact of Transportation and Storage

Figure 19 shows the transportation and storage test conducted in accordance with UL2034. The standard requires placing the sensor in a short-circuited state at 70°C for 24 hours, followed by cooling at room temperature for 1 hour, then exposure to -40°C for 3 hours, and finally removal and placement at room temperature for 3 hours. The gas response of the sensor was measured before and after the test, confirming that the sensor meets the requirements of UL2034.

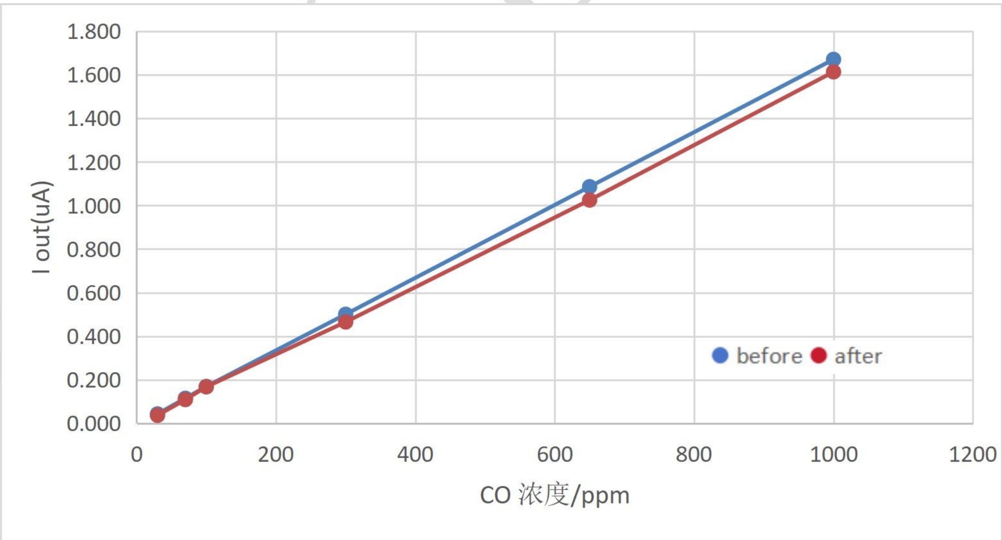


Figure 19: Changes Before and After Transportation and Storage Testing

1.10.3.3 Temperature Cycling Test

Figure 20 shows the sensor undergoing 10 cycles (each lasting >15 minutes and <1 hour) of exposure to environments of 0°C & 100% RH and 49°C & 40% RH, as specified in the "Stability Test" section of UL2034. Sensor response was measured before and after the test. Results indicate the sensor remains unaffected by the extreme temperature and humidity conditions encountered during testing.

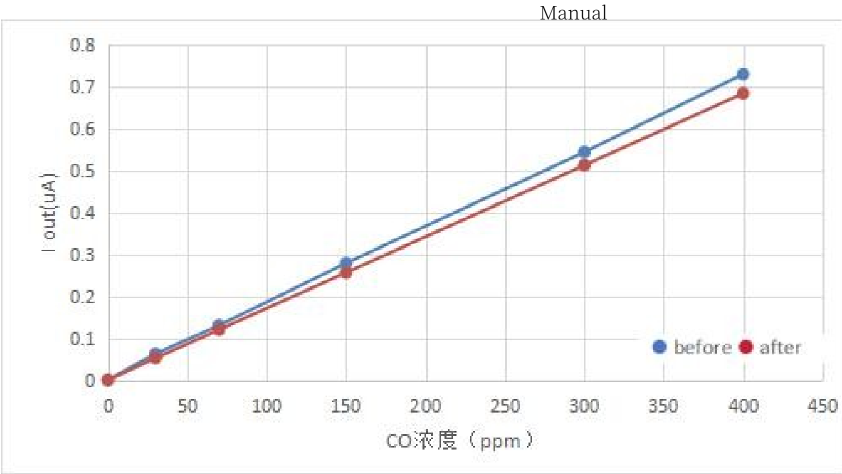


Figure 20 Changes Before and After Temperature Cycling Test

2. Circuit Design

2.1 Typical Application Circuit

The FC-CO-5000, based on proven fuel cell technology, generates a current signal proportional to CO concentration. For CO detection using the sensor, the output current is typically converted to a voltage for measurement.Figure 21 shows an example circuit. In this circuit, the output voltage (Vout) is measured to obtain an accurate CO concentration. If the circuit is powered by 3.3V, Vout should be 0.148V (Vref) when the sensor is disconnected. Vout increases as CO concentration rises. By measuring the increase in Vout, the CO concentration can be calculated.

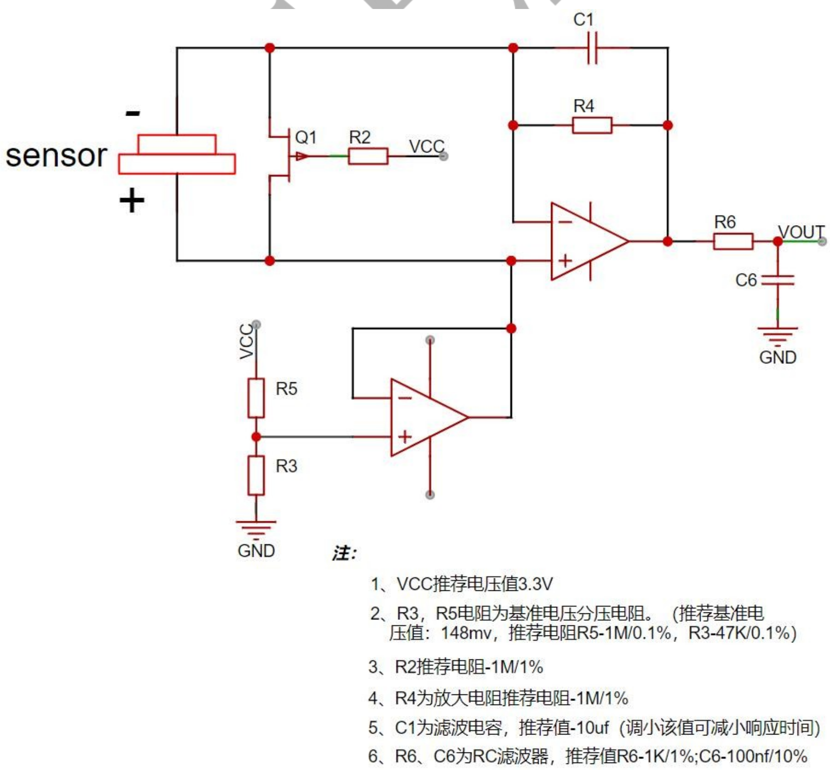


Figure 21 Typical Application Circuit

2.2 Setting the Reference Voltage Vref

Since fuel cell-type gas sensors exhibit a proportionally negative zero-current value in clean air, circuits detecting currents below zero become complex. Therefore, considering industry application characteristics and the sensor's zero-current limit, Vref is set to 0.148V. This maximizes circuit signal resolution while effectively masking any potential zero-current values below zero.

2.3 Anti-Polarization Circuit

For fuel cell-type sensors, charge accumulates on the working electrode when the sensor is open-circuited, causing polarization. When the positive and negative electrodes are reconnected, the accumulated charge on the working electrode requires a gradual release process known as depolarization.As shown in Figure 8 above, the longer the sensor remains open-circuited, the more time depolarization requires. Since sensors are stored and transported in an open-circuit state, they require prolonged power-on time for Vout to stabilize. An anti-polarization circuit is essential for rapid sensor stabilization. Therefore, the P-type JFET shown in Figure 21 is recommended to prevent polarization during open-circuit conditions, enabling the sensor to enter detection mode quickly after host power-up.

2.4 Current/Voltage Conversion Circuit

As shown in Figure 21, the sensor's output current is converted into voltage. Vout can be expressed by the following equation: Vout = $(S*C + I_0) / 1000000000*R + Vref$

Vout: Output voltage, unit: V

S: Sensor sensitivity, unit: nA/ppm C: Ambient carbon monoxide concentration, unit: ppm I0: Sensor zero-current value, unit: nA R: Amplifier resistance value, unit: ohms

Vref: Circuit reference voltage, unit: V. When powered by 3.3 V, it is 0.148 V.

When powered by other voltages, the circuit reference voltage is calculated using the following formula:

$$Vref = VCC^2 * (R3 / (R5 + R3))$$

2.5 Gain

Since the sensor's output current is a microcurrent in the nA range, it must be amplified to achieve effective resolution. The specific amplification factor (value of the amplification resistor) depends on the concentration range of the CO gas being measured, the sensor's sensitivity, the sensor's temperature coefficient, the selected MCU, the desired detection accuracy, and cost-performance requirements. The amplification resistor value can be calculated using the following formula:

$$R = (Vmax - Vref) / (Smax \times T \times Cmax)$$

Where: Vmax: Voltage value at Cmax, 3.3V when powered by 3.3V

Vref: Reference voltage value, 0.148V when powered by 3.3V

Smax : Maximum sensitivity value (nA/ppm) of the sensor ( ). For this sensor, it is 1.5

T: Temperature coefficient of the sensor, determined by the maximum possible ambient temperature. Refer to Table 7 for details. For example, at 60°C, this value is 1.31

Cmax: Upper limit of the carbon monoxide detection range (ppm). When the maximum detection range is 1000 ppm, the value of the amplification resistor is:

$$R = (3.3 - 0.148) / (1.5 / 1000000000 * 1.31 * 1000) = 1.6M$$

Thus, the maximum gain resistor value for this detection requirement is 1.6M

2.6 Operational Amplifier Selection

We recommend using an op-amp with a microvolt-level offset voltage, particularly the 3PEAK TP5552. If an op-amp with a millivolt-level offset voltage is used, noise in certain environments may be amplified synchronously. This can result in high baseline noise in the detection circuit, significantly reducing resolution. In extreme cases, even in clean air, baseline noise could reach the circuit's full-scale output, rendering the detection function inoperable.

2.7 Circuit Noise Filtering

Since the sensor generates microcurrent signals in the nA range, the circuit design employs high amplification to achieve effective detection. However, amplifying the useful current signal inevitably synchronously amplifies noise. Therefore, noise filtering measures are necessary to achieve a favorable signal-to-noise ratio. Methods include using a voltage follower circuit and increasing the value of capacitor C1 in Figure 21.The circuit in Figure 21 already employs voltage-follower technology. Increasing C1 effectively reduces noise at a fixed amplification level, but significantly slows response speed, thereby increasing response time. Therefore, when designing the circuit, the values of C1 and R4 must be selected based on specific detection accuracy requirements to ensure optimal detection performance.Additionally, noise filtering effectiveness and response time are also influenced by the chosen operational amplifier. Even with identical C1 and R4 values, response time and noise levels can vary significantly depending on the specific op-amp used. Select the appropriate components based on actual application requirements.When using the TP5552 operational amplifier, the impact on response time is negligible across a wide range of values for the gain resistor R4 (from 100K to 1M) and capacitor C1 (from 10nF to 10μF). A 10μF capacitor is recommended to achieve effective noise filtering.

2.8 Sensor Negative Pulse Phenomenon

Fuel cell-type gas sensors may experience negative drift when exposed to high-concentration gases for extended periods. This occurs when electrodes accumulate excessive target gas. After transferring the sensor to clean air, the trapped gas cannot be rapidly released due to structural limitations and must be consumed by the electrodes. Consequently, the sensor's output current may fall significantly below the zero-current level in clean air, a phenomenon termed negative drift.EN50291 specifies placing the sensor in a 5000ppm carbon monoxide environment for 15 minutes, followed by replacement into clean air for 1 hour to test basic alarm functionality. This test primarily addresses negative drift phenomena. If severe negative drift occurs, the sensor fails this test. Our sensors employ specialized electrode preparation technology to mitigate this issue.

This test primarily addresses the negative drift phenomenon. Sensors exhibiting severe negative drift will fail this test. Our sensors incorporate specialized anti-negative drift technology in electrode fabrication, effectively reducing negative drift after high-concentration exposure. Consequently, our sensors pass the EN50291 5000ppm test without requiring special circuit modifications.

2.9 Self-Diagnostic Circuit

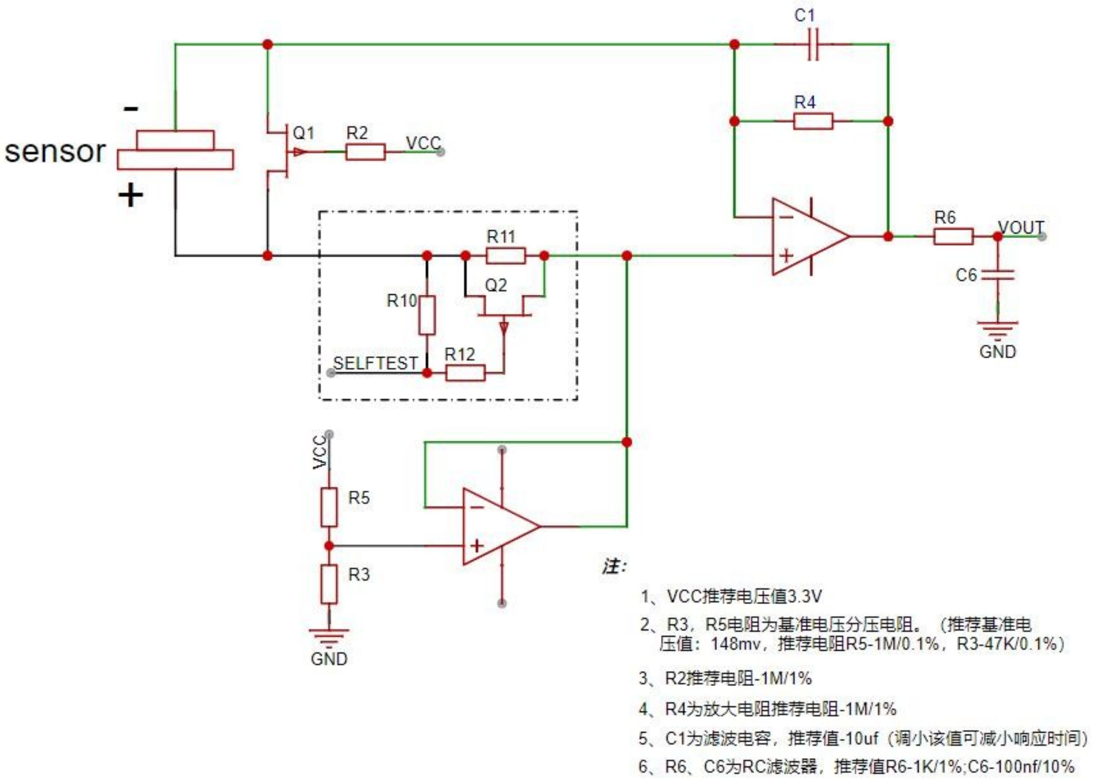


Figure 22 Schematic Diagram of Sensor Self-Diagnostic Circuit

UL2034 requires that sensor faults be promptly detected via the self-diagnostic circuit. Should the sensor disconnect from the amplifying resistor, this circuit will charge the sensor using an external power source. By analyzing the subsequent discharge pattern, sensor faults such as open circuits or short circuits can be detected. However, due to the absence of gas diffusion, this method cannot identify sensor sensitivity drift or sensitivity loss.

loss. The detection procedure is as follows:

1) Before self-diagnosis, the microcontroller sets the self-test port to GND;

2) Q1 activates the JFET, temporarily disconnecting the sensor from the circuit;

3) Set the self-test port to 3.3V and charge the sensor for a period (recommended 5 seconds);

4) At the end of step 3, set the self-test port to GND again to reconnect the sensor to the circuit and discharge accumulated charge;

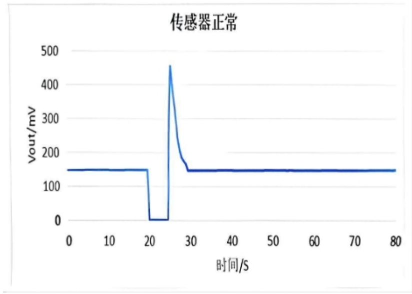
5) By recording the output data after reconnecting the sensor to the circuit, we can distinguish between faulty and functional sensors.

Self-Diagnostic Test Results (Example):

The example shows typical values at room temperature with an amplification resistor of 430K.

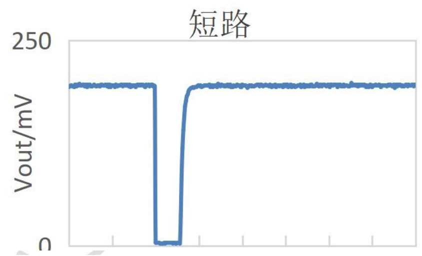
Sensor normal:

Vout first drops to near GND potential, then rises to near 1V, and finally discharges back to its initial value.

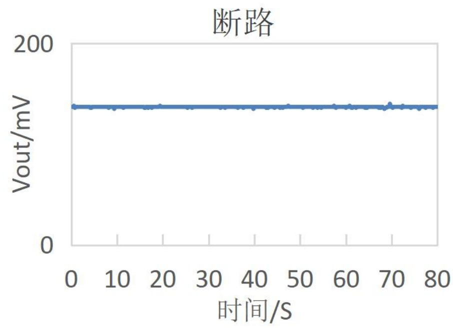


Sensor shorted:

Vout first drops to near GND potential, then recovers to its initial value in the sl



Sensor open circuit: Vout ≈ Vref



Note:

(1) Do not perform self-diagnosis in the presence of interfering gases;

(2) Self-diagnostic duration should not exceed 10 seconds; 5 seconds is recommended;

(3) Threshold determination depends on the resistance value of the amplification resistor and individual sensor variations. The threshold criteria must be set based on actual circuit test results;

(4) When setting the interval between self-diagnostic modes, consider the sensor's recovery time. Initiating self-diagnosis before the sensor returns to its initial level may damage the sensor.

2.10 Sensitivity Drift

Electrochemical sensors encounter complex gas compositions during operation. Certain macromolecular reaction gases, reaction intermediates, or environmental dust may partially cover the active sites of the catalyst, causing slow drift or attenuation of sensor sensitivity. It is recommended to compensate for sensor sensitivity at 3% annually.

3. Sensor Calibration

When using this sensor, it is strongly recommended to calibrate each sensor individually to achieve optimal detection accuracy. Calibration can be performed using either of the following methods:

3.1 Calibration with Carbon Monoxide Gas

1) Place the sensor in a suitable gas chamber

2) Record the sensor's output value I_0 in clean air. The duration depends on the sensor reaching a depolarized state. Once the output stabilizes, record the value in nA.

3) Introduce a specific concentration of carbon monoxide gas into the chamber

4) After the sensor output stabilizes (e.g., 3–4 minutes), measure the sensor output value I_1 in nA

5) Calculate the sensor sensitivity S

$S = (I_1 - I_0) / C$, in nA/ppm

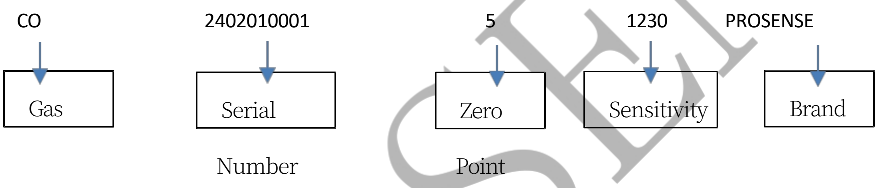
In the above equation, C represents the concentration of the calibration CO gas, measured in ppm.

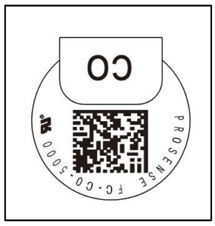
Since temperature affects sensor sensitivity, maintain stable ambient temperature during calibration.

3.2 Calibration Using Sensor QR Codes

Each sensor is calibrated at the ProSense factory prior to shipment, with the calibration data stored in a barcode on the sensor. This method significantly reduces costs and processes. It is strongly recommended to calibrate carbon monoxide alarms or detectors using carbon monoxide gas.

3.2.1 Sensor QR code encoding rules are as follows:





First Group: CO: Indicates sensor type; CO represents carbon monoxide sensor. Second Group: 2402010001: Ten-digit number; sensor serial number.

Third Group: 5: One sign digit (omitted if positive), followed by one or two digits representing zero-point current in nA. Divide by 10 to obtain the actual current value. For example, the zero-point current in the sample is 5/10 = 0.5nA

Fourth Group: 1230: Three to four digits, sensitivity in nA/ppm. Divide by 1000 to obtain the actual sensitivity value. Example sensitivity: (1230/1000 = 1.23 nA/ppm)

Fifth group: PROSENSE, indicating the brand

Example: CO2402010001 5 1230 PROSENSE

3.2.2 The sensor's factory calibration information can be written into the host's embedded software using the following methods:

1) Manually scan the QR code on the sensor to retrieve data;

2) Use a barcode scanner to read the QR code and input the data directly into the microprocessor.

3.3 Temperature Compensation

Temperature compensation is performed in the microprocessor using the compensation coefficients shown in Table 6 and Figure 16.

3.4 Calculation of Carbon Monoxide Concentration

During actual detection, the ambient carbon monoxide concentration can be calculated using the following formula: C = ((Vout - Vref) * 1000000000 / R - I0) / S_1

C: Carbon monoxide concentration value, unit: ppm Vout: Output value measured by the circuit, unit: V Vref: Reference voltage value of the circuit, unit: V R: Amplification resistance of the circuit, unit: ohms

S_1: Temperature-compensated sensitivity, unit: nA/ppm

I0: Sensor zero-current value, unit: nA

4. Storage

Before use, store the sensor in its original packaging provided by PUSEN and maintain it in an environment of 5~30°C / 30~80% RH. Avoid condensation.

5. PCB Soldering

When soldering the sensor to a printed circuit board, observe the following precautions:

1) Thoroughly dry the sensor before soldering it onto the PCBA to prevent any vapor contamination;
2) After soldering the sensor to the PCBA, allow sufficient time for polarization caused by open-circuit transportation to settle;
3) Ensure a clearance of over 1.5 mm between the sensor and the PCBA to allow target gas to freely reach the sensor. Refer to Figure 23 for details.

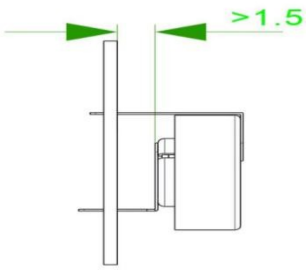


Figure 23 Sensor-to-PCB Soldering Schematic Diagram

4) Manual soldering is recommended under the following conditions:

Copper soldering tip temperature: 360°C Time: <5 seconds

6. Gas Testing

When conducting gas testing, use a mixed gas with air as the background gas. Avoid testing with gases using nitrogen as the background gas, as the sensor requires oxygen to function. Using a mixed gas with nitrogen as the background gas may cause sensor failure due to oxygen deprivation.

7. Precautions

- Sensors should avoid contact with high concentrations of organic solvents/vapors and corrosive gases.
- Avoid storage or use in environments with high concentrations of dust or oil vapors. Sufficient oxygen is essential for proper operation. Do not expose the sensor to environments containing high concentrations of alkaline substances.
- Avoid excessive impact or vibration to prevent internal damage.
- When using the sensor, adhere to the specified operating environment. Using the sensor beyond the permissible ranges stated in the datasheet may damage the sensor.
- Immersion or splashing of water onto the sensor may alter its performance.
- Prevent condensation and ice formation on the sensor's interior and exterior to ensure gas ingress.
- Manual soldering is recommended to avoid the effects of high-concentration flux on the sensor.
- During self-diagnosis, do not apply excessive voltage. The self-diagnosis duration should be less than 5 seconds to prevent sensor damage. Self-diagnosis should be conducted in an environment with 0 ppm CO.
- After self-diagnosis, wait 60 seconds before resuming normal operation to ensure the sensor has fully recovered.
- The sensor's QR code contains factory calibration data. For precise detection results, recalibration is recommended before use.
- Do not disassemble the sensor. Unauthorized disassembly will void the warranty.

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