FIGARO

an ISO9001 company

Technical Information for Acetone Sensors

Figaro's 1800 series is a new hot wire semiconductor type gas sensor, with a miniature bead sensing element formed on the noble metal coil for achieving low power consumption and low driving voltage.
The TGS1820 features high sensitivity and high selectivity to acetone, making it ideal for the detection of gaseous acetone at low concentration.

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IMPORTANT NOTE: OPERATING CONDITIONS IN WHICH FIGARO SENSORS ARE USED WILL VARY WITH EACH CUSTOMER'S SPECIFIC APPLICATIONS. FIGARO STRONGLY RECOMMENDS CONSULTING OUR TECHNICAL STAFF BEFORE DEPLOYING FIGARO SENSORS IN YOUR APPLICATION AND, IN PARTICULAR, WHEN CUSTOMER'S TARGET GASES ARE NOT LISTED HEREIN. FIGARO CANNOT ASSUME ANY RESPONSIBILITY FOR ANY USE OF ITS SENSORS IN A PRODUCT OR APPLICATION FOR WHICH SENSOR HAS NOT BEEN SPECIFICALLY TESTED BY FIGARO.

1. Basic Information and Specifications

1-1 *Features*

* High sensitivity and selectivity to acetone
* Low interference from ethanol and hydrogen
* Quick response
* Compact
* Low power consumption

1-2 *Applications*

* Acetone detectors
* Breath acetone testers

1-3 *Structure*

Figure 1 shows the structure of TGS1820.
A heater coil made of platinum alloy is embedded in a small bead of metal oxide semiconductor (MOS) sensing material. The heater is connected to two nickel pins.
The sensor base is made of resin (FR-PET). The sensor cap is made of stainless steel (SUS305). The upper opening in the cap is covered with a stainless steel gauze.

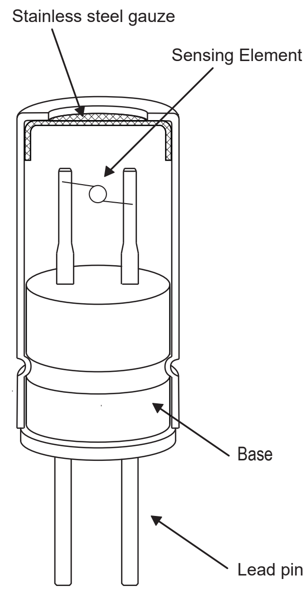


Fig. 1 - Sensor structure

1-4 *Basic measuring circuit*

Basic measuring circuit for TGS1820 is shown in Figure 2. The circuit voltage of 2.30±0.05VDC is applied to the four arms of Wheatstone bridge consisting of the sensor heater and the load resistor R_L for V_{RL} output, and two opposite side resistors for the reference voltage V_{REF}. The sensor output voltage is measured as the difference between V_{REF} and the divided voltage V_{RL}, as defined by the following formula:

$$Vb = V_{RL} - V_{REF}$$

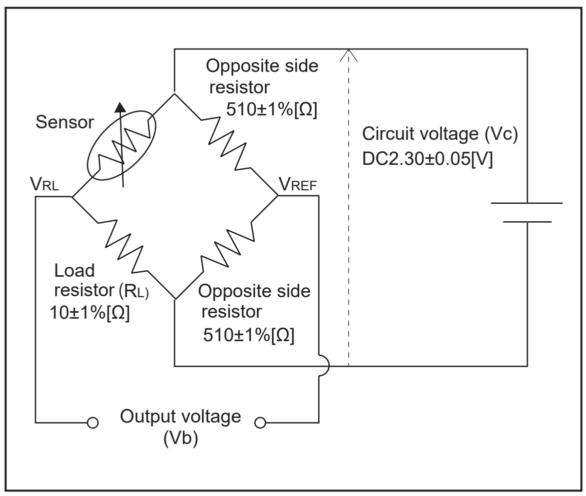


Fig. 2 - Basic measuring circuit

1-5 *Specifications*

Item		Specification	
Model number		TGS1820	
Sensing principle		Hot wire semiconductor type	
Standard package		Plastic base and metal can	
Target gases		Acetone	
Typical detection range		1 ~ 20ppm	
Operating temperature and humidity		0 ~ 40˚C, 10 ~ 80%RH	
Standard circuit conditions	Circuit voltage (Vc)	2.30±0.05V DC	
	Load resistance	10Ω ±1%	
	Opposite side resistance	510Ω ±1% (variable)	
Electrical characteristics under standard test conditions	Power consumption	125mW	
	Sensor current	≤ 85mA	
	Output voltage Vb (Air)	-370 ~ -290mV	
	Output voltage difference ΔV (1ppm Acetone) *	20 ~ 60mV	
	Sensitivity to Acetone (ratio of ΔV)	1.4 ~ 2.5	ΔV(3ppm Acetone) / ΔV(1ppm Acetone)
	Ethanol interference	≤ 1.0	ΔV(10ppm Ethanol) / ΔV(1ppm Acetone)
	Hydrogen interference	≤ 1.0	ΔV(10ppm H_2) / ΔV(1ppm Acetone)
Standard test conditions	Test gas conditions	20±5˚C, 60±5%RH	
	Circuit conditions	Circuit voltage: 2.30±0.05V DC Load resistance: 10Ω ±1% Opposite side resistance: 510Ω±1%	
	Preheating period before test	≥ 1 hour	
Life expectancy at 20˚C, 60%RH in normal air		> 2 years	

Table.1-Specifications

*ΔV = ΔV_{OUT} = Vb(Gas)-Vb(Air)
Vb(Gas) = output voltage in gas
Vb(Air) = output voltage in clean air

All sensor characteristics shown in this brochure represent typical characteristics. Actual characteristics vary from sensor to sensor and from production lot to production lot. The only characteristics warranted are those shown in the Specification table above.

1-6 *Dimensions*

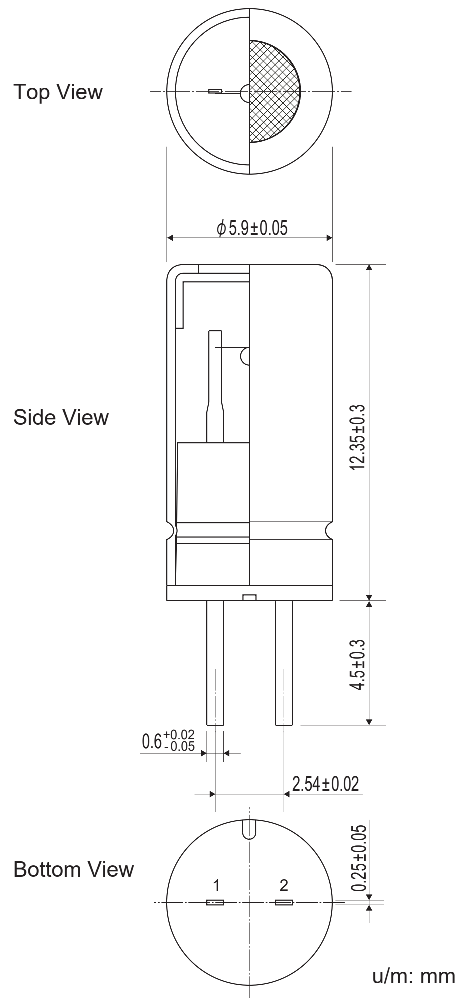


Fig. 3 - Sensor dimensions

NOTE: There is no polarity between two pins.

2. Typical Sensitivity Characteristics

2-1 *Sensitivity to various gases*

Figure 4 shows the typical sensitivity of TGS1820 to various gases at the standard test conditions described in Table 1.

The Y-axis represents the output voltage difference ΔV_{OUT} which is defined as follows:

$$\Delta V_{OUT} = Vb\ (Gas) - Vb\ (Air)$$

TGS1820 has excellent selectivity to acetone with low cross-sensitivity to hydrogen and ethanol.

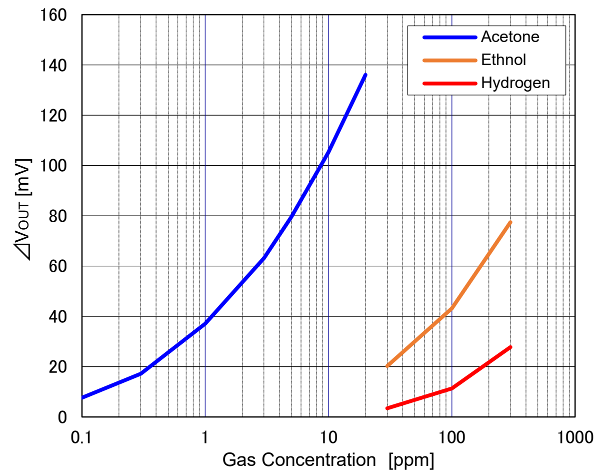


Fig. 4 - Sensitivity to acetone, ethanol and hydrogen (ΔV_{OUT})

2-2 *Temperature and humidity dependency*

Figures 5a and 5b show the temperature and humidity dependency of TGS1820 in clean air and in acetone, respectively.
The test sample was energized for 1 hour under each temperature and humidity conditions before the sensor output was measured.

The Y-axis of Figure 5a represents the output voltage in clean air Vb(Air).

The Y-axis of Figure 5b represents the output voltage difference ΔV_{OUT}, which is defined as follows:

$$\Delta V_{OUT} = Vb(1ppm\ acetone) - Vb(Air)$$

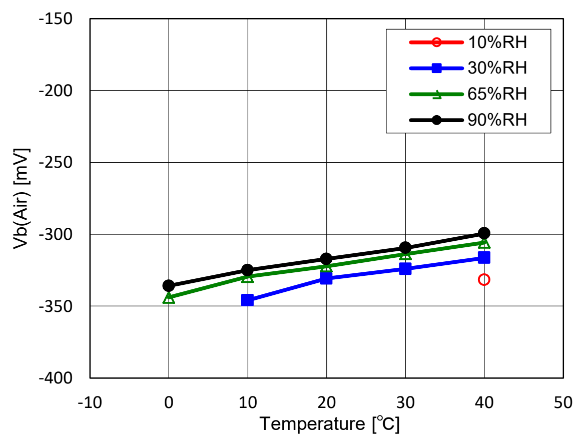


Fig. 5a - Temperature and humidity dependency in clean air (Vb)

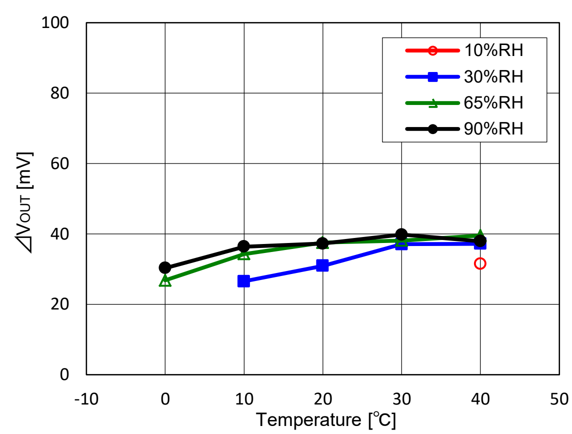


Fig. 5b - Temperature and humidity dependency of sensitivity to 1ppm Acetone

2-3 *Repeatability*

Figure 6 shows the response pattern of TGS1820 for 5 cycles of exposure to 1ppm Acetone. Each one test cycle is that the sensor was exposed to 1ppm Acetone for 90sec and then removed to clean Air for 120sec.

The Y-axis represents the output voltage difference ΔVOUT, which is the output voltage Vb normalized by the output voltage measured in clean air before the test.
The calculation formula is as follows:

ΔVOUT = Vb - Vb(in air before the test)

The output voltage difference ΔVOUT at the last point of each 90 second period in acetone shows good repeatability in every cycle.

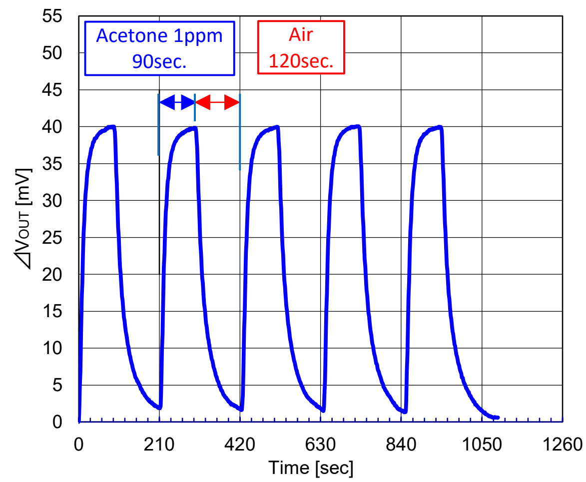


Fig. 6 - Repeatability of sensor output ΔVOUT (1ppm of Acetone)

2-4 *Circuit voltage dependency*

Figures 7a and 7b show the circuit voltage Vc dependency.
The circuit voltage Vc is the supplying voltage to the bridge circuit described in the basic measurement circuit shown in Figure 2.
The output voltage was measured at the circuit voltage of 1.8, 2.0, 2.3, 2.5 and 2.6VDC.

The Y-axis of Figure 7a represents the output voltage Vb in clean Air

The Y-axis of Figure 7b represents the output voltage difference ΔVOUT, which is defined as follows:

ΔVOUT = Vb(acetone) - Vb(air)

Note that the output voltage Vb and the sensitivity ΔVOUT may change depending on the circuit voltage. The standard condition of the circuit voltage, DC2.3V±0.05V, should be precisely controlled to ensure high accuracy.

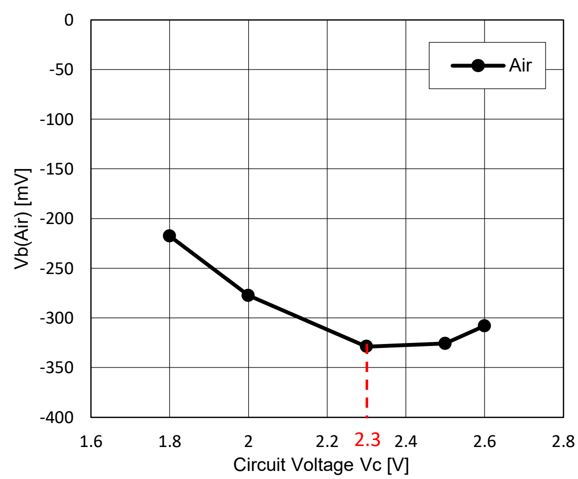


Fig. 7a - Circuit voltage dependency in Air Vb(Air)

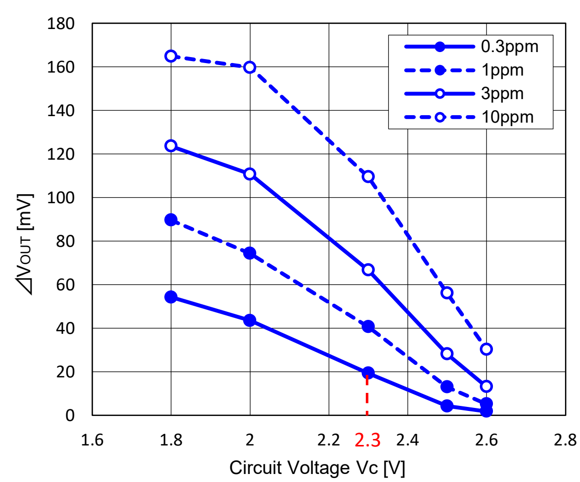


Fig. 7b - Circuit voltage dependency of sensitivity to Acetone ΔVOUT

2-5 *Gas Response*

Figure 8 shows the response pattern of the output voltage difference ΔVOUT when the sensor is placed into 0.3ppm, 1ppm, 3ppm and 10ppm of acetone. The sensor was energized for 1 hour before the test. At the point of zero second in Figure 8, the sensor was quickly placed into the atmosphere containing acetone.

The Y-axis represents the sensor output ΔVOUT normalized by the output voltage Vb measured at the point of 1 second before exposure to test gas, which is calculated by the following formula:

$$\Delta V_{OUT} = Vb - Vb(T = -1sec.)$$

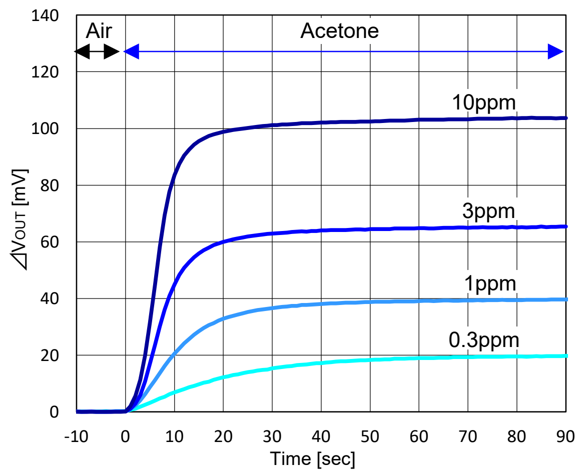


Fig. 8 - Response pattern of sensor output (ΔVOUT)

2-6 *Initial action*

Figure 9 shows the initial action of TGS1820 which has been stored unenergized in room air for one day, one week, one month, and three months, respectively, then energized in clean air.
The circuit voltage is applied from the point of 0 sec. in Figure 9.

The Y-axis represents the output voltage difference ΔVOUT which is defined as the output voltage Vb normalized by the output voltage Vb(1 hr) that was measured 1 hour after the starting point of energizing.

$$\Delta V_{OUT} = Vb - Vb\ (1\ hr)$$

The sensor output ΔVOUT rises sharply for the first few seconds after energizing and then reaches to a stable level.
Such behavior during the warm-up process is called "Initial Action".
The time to reach a fully stabilized state depends on the period of being unenergized. It takes more than 30 minutes to be stabilized if the sensor is kept unenergized for 3 months.

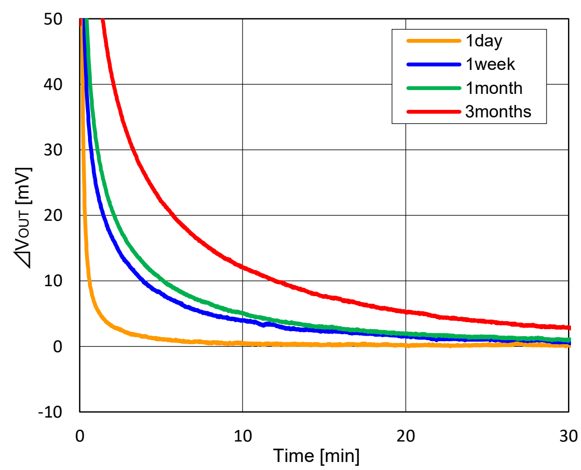


Fig. 9 - Initial action (ΔVOUT)

2-7 *Long term characteristics*

Figures 10a and 10b show the long term stability of TGS1820. The test sample was energized continuously in clean air at 20°C, 60%RH for 180 days.

The Y-axis of Figure 10a represents the output voltage in clean air Vb(Air).

The Y-axis of Figure 10b represents the output voltage difference ΔVOUT in acetone, ethanol, and hydrogen respectively.
The output voltage ΔVOUT is defined as follows:

ΔVOUT = Vb(Gas) – Vb(Air)

The output voltage difference in 1ppm acetone was stable over the test period of 180 days.

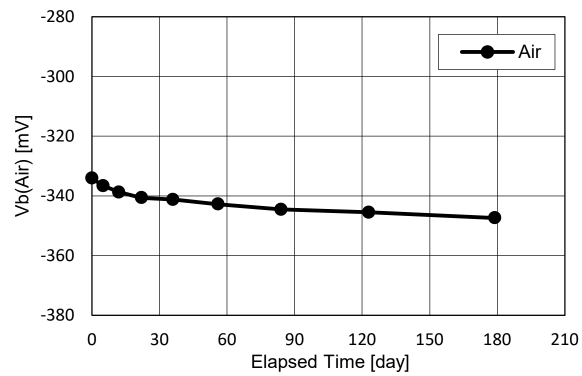


Fig. 10a - Long term stability of the sensor output in air (Vb(Air))

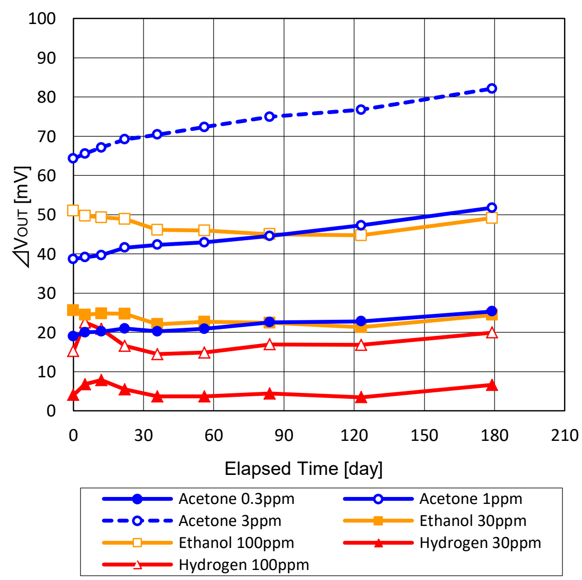


Fig. 10b - Long term stability of sensitivity to acetone, ethanol and hydrogen (ΔVOUT)

2-8 *Long term characteristics of unenergized sensor*

Figures 11a and 11b show the long term stability of TGS1820 which has been stored unenergized in clean air at 20°C, 60%RH for 210 days.

The Y-axis of Figure 11a represents the output voltage in air Vb(Air).

The Y-axis of Figure 11b represents the output voltage difference ΔVOUT at 0.3ppm, 1ppm and 3ppm acetone respectively.
The output voltage difference ΔVOUT is defined as follows:

$$\Delta V_{OUT} = Vb - Vb(Air)$$

The output voltage in air Vb(Air) and the output voltage difference ΔVOUT in acetone are very stable over the test period.

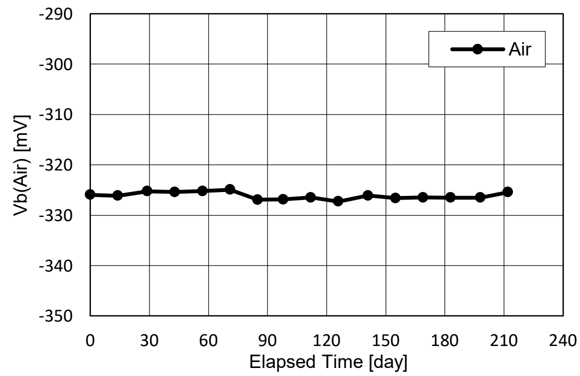


Fig. 11a - Long term stability of the sensor output in air (Vb(Air)) in unenergized condition

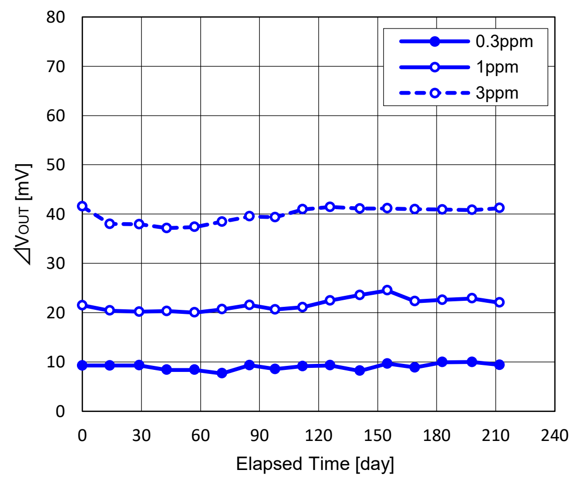


Fig. 11b - Long term stability of sensitivity to acetone (ΔVOUT) in unenergized condition

2-9 *Effect of air flow*

Figures 12a and 12b show the effects of air flow of TGS1820 in air and in 1ppm acetone, respectively. The test procedure involves situating the sensor in an air stream of 3 or 6 meters per second, with the air flow vertical to the stainless steel gauze of the sensor's housing for 300 seconds from the point of 300 seconds after starting the test.

The Y-axes of both Figures 12a and 12b represent the output voltage difference ΔVOUT normalized by the output voltage Vb(T=290sec.) that was measured at 290 seconds from the start of the test without air flow. The output voltage difference ΔVOUT is defined as follows:

ΔVOUT =Vb - Vb(T=290 sec.)

The output voltage measured in air was quite stable as shown in Figure 12a. In contrast, the increase of output voltage in 1ppm acetone was observed as shown in Figure 12b. As a result, direct air flow on the sensor should be avoided.

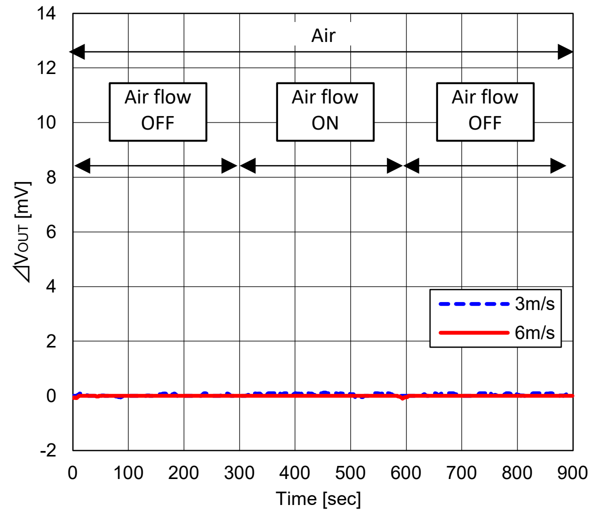


Fig. 12a - Effect of air flow in Air ΔVOUT

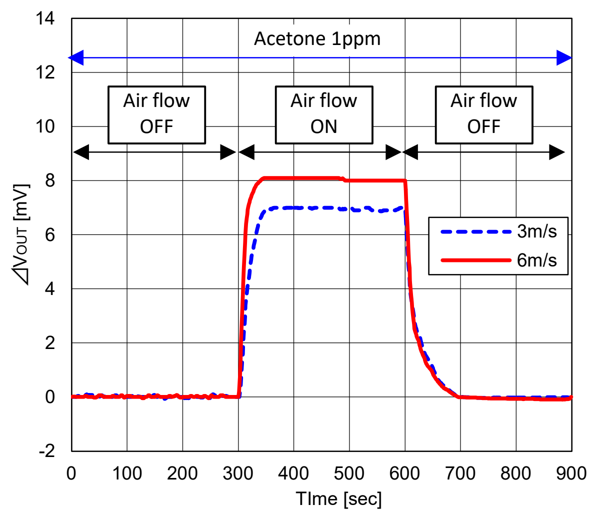


Fig. 12b - Effect of air flow in 1ppm acetone ΔVOUT

3. Reliability

3-1 *Exposure to High concentration acetone*

Figures 13a and 13b show the effect of exposure to high concentration acetone.
The initial points in Figure 13a and 13b show the output voltage values measured before the test. The sensor was exposed to 1000ppm acetone for 3 minutes.
The output voltage was measured at the point of 1 hour, 6 hours and 24 hours after the test.

The Y-axis of Figure 13a represents the output voltage in clean Air Vb(Air).

The Y-axis of Figure 13b represents the output voltage difference ΔV_{OUT} in 0.3ppm, 1ppm and 3ppm acetone respectively.
The calculation formula of the output voltage difference ΔV_{OUT} is as follows

$$\Delta V_{OUT} = Vb - Vb(Air)$$

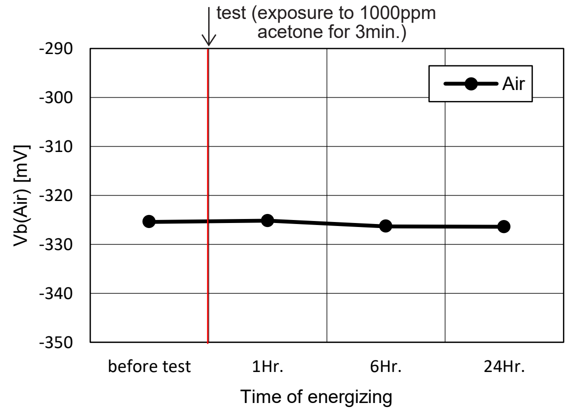


Fig.13a - Effect of exposure to high concentration acetone on sensor output in Air Vb(Air)

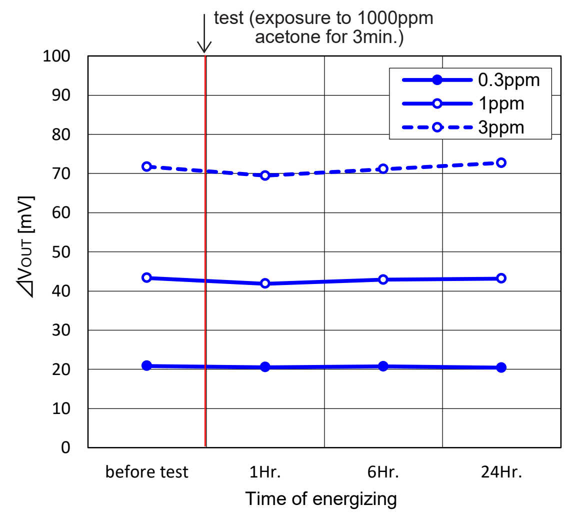


Fig.13b - Effect of exposure to high concentration acetone on sensitivity to acetone ΔV_{OUT}

3-2 *Durability to silicone vapor*

Figures 14a and 14b show the influence of silicone vapor on the sensor output in air Vb(Air) and the sensitivity to acetone, hydrogen and ethanol.
The initial points of the graphs in Figure 14a and 14b show the sensor output before exposure to silicone vapor.
After the initial measurements were taken, the sensor was exposed to 10ppm Octamethylcyclotetrasiloxane (OMCTS) vapor in unenergized condition.

The X-axes of Figures 14a and 14b represent the accumulated time of exposure to OMCTS.
Before each measurement of output voltage Vb, the sensors were energized in clean air for 1 hour.

The Y-axis of Figure14a represents the output voltage in air Vb(Air).

The Y-axis of Figure14b represents the output voltage difference ΔVOUT in acetone, hydrogen and ethanol.

As the accumulated time of exposure to silicone vapor elapsed, the output voltage in air Vb(Air) and the output voltage difference ΔVOUT were both gradually changed. To avoid such sensitivity change, exposure to silicone vapor should be avoided.

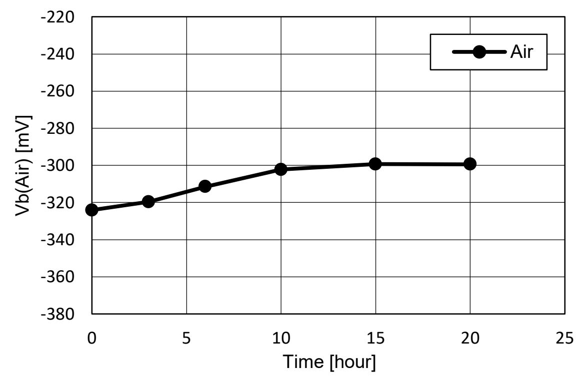


Fig.14a - Influence of OMCTS exposure on sensor output voltage Vb(air)

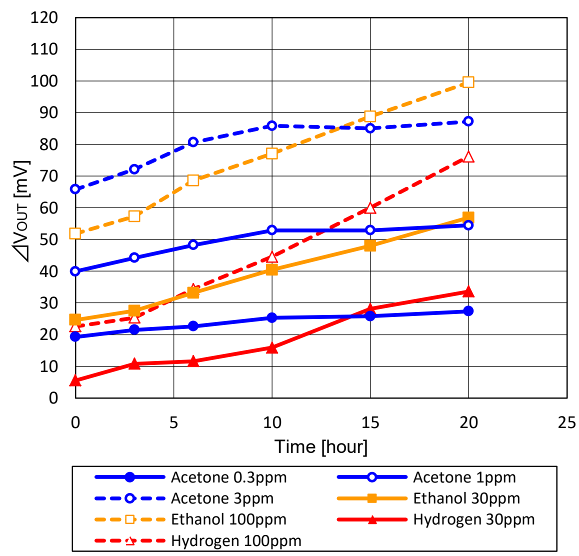


Fig.14b - Influence of OMCTS exposure on the output voltage difference ΔVOUT in acetone, ethanol and hydrogen.

3-3 *Storage conditions*

Figures 15a through 15d show the influence of storage conditions on the sensor packed in an aluminum bag for a month.
There are 2 sets of temperature and humidity conditions, i.e., 20°C, 65%RH for Figures 15a and 15b and 40°C, 85%RH for Figures 15c and 15d respectively.

The initial point of the graphs in Figures 15a through 15d show the sensor output before the storage test. After the initial measurement were taken, the sensors were kept in a sealed aluminum bag.
After the storage test, the sensor was energized, and then the sensor output was measured at the point of 1 hour, 6 hours, 1 day and 7 days from the start of energizing.

The Y-axes of Figures 15a and 15c show output voltage in clean air Vb(Air).

The Y-axes of Figures 15b and 15d show the output voltage difference ΔVOUT in 0.3ppm, 1ppm and 3ppm acetone.

The output voltage in air Vb(Air) and the output voltage differenceΔVOUT at low concentration acetone were very stable after the storage at 20°C, 65%RH.
On the other hand, it takes longer time of energizing to recover the original sensing characteristics after the storage in high temperature and high humidity conditions.

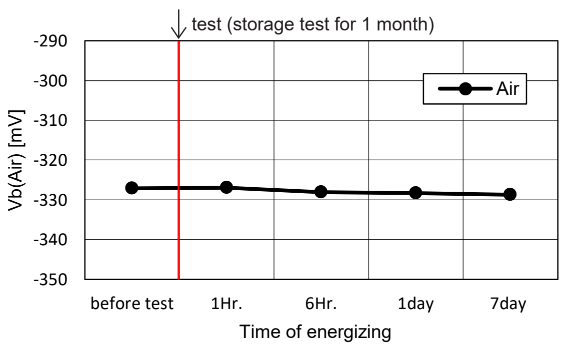


Fig.15a - Effect of storage at 20°C, 65%RH on the sensor output in air Vb(Air)

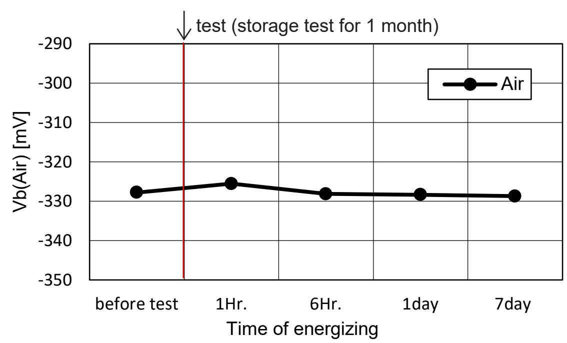


Fig.15c - Effect of storage at 40°C, 85%RH on the sensor output in air Vb(Air)

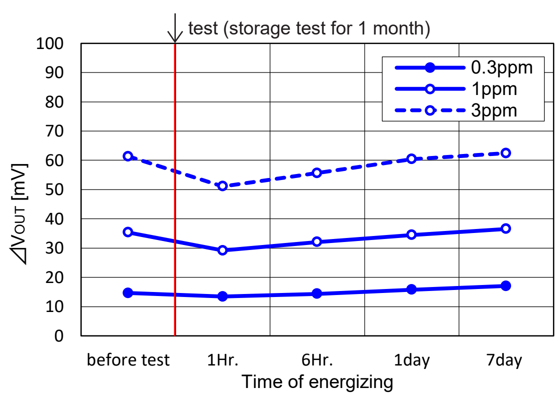


Fig.15b - Effect of storage at 20°C, 65%RH on the sensitivity to acetone ΔVOUT

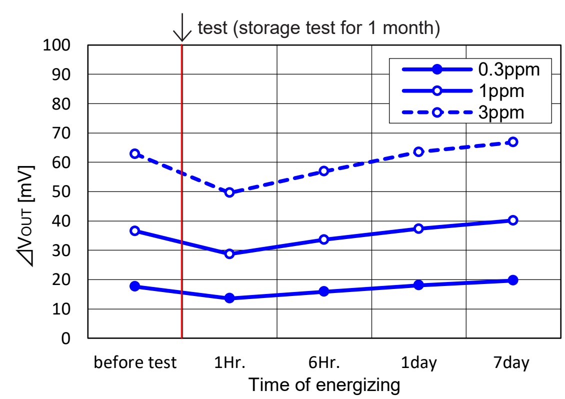


Fig.15d - Effect of storage at 40°C, 85%RH on the sensitivity to acetone ΔVOUT

NOTE:
All sensor characteristics in this technical brochure represent typical sensor characteristics.

4 Cautions

4-1 *Safety Precautions for Use of Figaro Gas Sensors*

1) Carefully read this document and other technical information provided by Figaro before using our products, and confirm specifications and operating conditions.
2) When designing an application circuit, please make sure that an accidental short circuit or open circuit of other electronic components would not cause the sensor to be subjected to excessive voltage, current, or temperatures exceeding the rated values.
3) When designing application products, please make sure that a gas sensor malfunction would not
   (1) cause adverse effects on other components,
   (2) directly or indirectly impair the safety of application products that use gas sensors (e.g., emit smoke, cause fire, or other unstable states of application products).
4) Consider adding safety measures for fail-safe where necessary, such as a protection circuit.

4-2 *Cautions for Use of Hot Wire Semiconductor type Gas Sensors*

[Conditions for use and storage]

1) Rated temperature and humidity conditions
   Using or storing the sensor in an environment outside the rated temperature and humidity range may cause physical damage and/or affect the sensor characteristics.

2) Storage conditions
   When storing for a long time, store the sensor in a sealed bag whose material does not emit odor or gas. Do not use dehumidifiers such as silica gel in the bag.

3) Condensation
   If water condenses inside the sensor housing, sensor characteristics may drift.

4) Freezing
   If water freezes on the sensing element surface, sensor characteristics may drift.

5) Oxygen concentration
   The sensor cannot properly operate in an environment with oxygen content other than normal ambient oxygen concentration.

6) High concentration of gases
   Sensor performance may be affected if exposed to a high concentration of gases for a long period of time during the operating or storage period.

7) Organic vapors
   If the sensor is exposed to organic vapors generated from alcohol, acetone, volatile oil etc., organic vapors will adsorb onto the sensing element surface, and sensor performance may be affected.

8) Dusts and oil mist
   Sensor performance may be affected if exposed where excessive dust, fine particles, or oil mist is present.

9) Silicone
   Sensor performance may be affected if exposed where silicone rubber/putty, or adhesives or hair grooming materials containing silicone are present. Avoid usage and storage of the sensor where such silicone-containing materials may be used.

10) Alkaline metals
   Sensor characteristics may be changed if the sensor is contaminated by alkaline metals. Avoid contamination by alkaline metals, especially salt water spray.

11) High concentration of corrosive gases
   Sensor performance may be affected if exposed to a high concentration of sulfur-based or chlorine-based corrosive gases for extended periods. Avoid usage and storage in highly corrosive environments.

[Handling]

1) Applied voltage
   If higher than the rated voltage is applied to the sensor circuit or the heater, the sensor may be damaged or sensor characteristics may be irreversibly impaired. Do not use the gas sensor if excessive voltage is applied.

2) Mechanical shock and vibration
   Avoid mechanical shock. Breakage of lead wires, short-circuit inside the sensor, or change in sensor characteristics may occur if the sensor is subjected to a strong shock or vibration. Do not use the sensor if subjected to a drop or other mechanical shock.

3) Electro static discharge
   ESD (Electro Static Discharge) may affect sensor characteristics. Exercise precaution against ESD during handling of sensors.

4) No soaking
   Avoid contact with water. Sensor characteristics may be affected due to soaking or splashing the sensor with water.

5) No disassembly or deformation
   Under no circumstances should the sensor be disassembled, nor should the sensor structure be deformed. Such action would void the sensor warranty.

6) Gas inlet
Do not block the gas inlet of sensor. The sensor would not work properly with a clogged inlet.

[Mounting process]

1) Soldering
Sensors should be soldered manually. High concentrations of flux or excessive soldering heat may affect sensor characteristics. When wave soldering is used, rosin flux with minimal chlorine should be used, and a trial assembly test should be conducted before production starts to see if there would be any influence to sensor characteristics.

The recommended materials and conditions for manual soldering are as following:

- Recommended Lead-free Soldering Material
  Senju M705
  Almit KR-19
- Recommended Conditions
  Temperature of soldering copper head: ≤ 390˚C
  Period: ≤ 4s/pin
  Number of Times: 3 times Max

2) Resin coating
When a resin coating is applied on a printed circuit board for improving its resistance to moisture, the chemical solvent contained in the coating material may affect sensor characteristics. Sample testing should be conducted to see if this process would adversely affect sensor characteristics.

3) Electro static discharge
Exercise necessary precaution against ESD during mounting of the sensors on finished instruments.

4) Resonance
Excessive vibration may cause damage of the sensor structure or breakage of the sensor components at the resonance frequency. Usage of compressed air drivers or ultrasonic welders on assembly lines may cause such vibration to the sensor. Before using such equipment, preliminary tests should be conducted to verify that there will be no influence on sensor characteristics.

[Application design]

1) Storage for a long time
When a sensor or a finished instrument incorporating the sensor is stored without powering for a long period, sensor characteristics may be affected according to the storage environment.

2) Preheating time
As unpowered storage becomes longer, a longer preheating period is required to stabilize the sensor before usage.

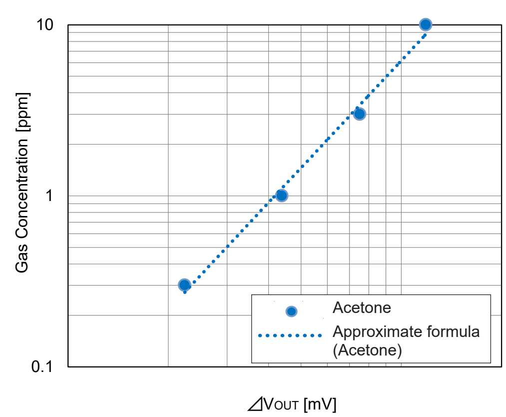
3) Heat generation
The gas sensor generates heat. A temperature sensor or a humidity sensor mounted close to the gas sensor may result in erroneous temperature or humidity measurement. Temperature and humidity sensors should be mounted at a sufficient distance from the gas sensor.

4) Explosion protection
The sensor does not fulfill technical requirements of industry standards for explosion protection. When the sensor will be used in explosive atmospheres, consider using an appropriate external explosion-proof enclosure according to the zone classification of where the sensor is intended to be used.

5) Foreign conductive objects
If foreign conductive objects get into the sensor, short-circuit may occur inside the sensor. When such conditions are expected to be encountered, installation of an external air filter is recommended.

6) Fitness for purpose
Before usage of the sensor, customers should verify and ensure that the sensor will work properly under the conditions where they intend to use it and that the sensor is fit for the purpose for which customers wish to use it.

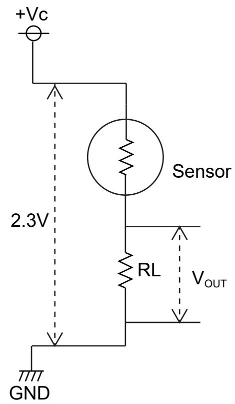
7) Calibration (For reference)
For example, measure sensor responses in 3 or more different gas concentrations. Plot the measured sensor output data on a logarithmic graph with the X-axis representing ΔV_{OUT}, and the Y-axis representing gas concentrations. Then, an approximate formula can be determined from exponential approximation.



Calibration (For reference)

8) Measuring circuit

For simple evaluation of the sensor, please use the simplified circuit as shown below.



Measure the voltage (VOUT) across the load resistor RL. ΔVOUT can be calculated by the following formula.

$$\Delta V_{OUT} = V_{OUT}(GAS) - V_{OUT}(Air)$$

The bridge output (Vb) can be calculated by the formula below.

$$Vb = V_{OUT} - (Vc/2)$$

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