

FIGARO

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18th July, 2019

Announcement of New Specifications for TGS2611-E00

Dear Figaro Distributors,

Let us inform you that we are now ready to implement the new specification of our methane sensor TGS2611-E00.

Since our announcement in August 2017, we have been working to switch to the new specification. For more information on the announcement, please refer to the attached file.

Please refer to the attached Product Information, Technical Information, and Application Notes of the new version.

The new specification will be implemented with all the shipments subsequent to manufacturing lot number 941T.

Should you have any questions, please do not hesitate to contact us.

FIGARO ENGINEERING INC.

FIGARO

an ISO9001 company

Application Notes for Methane Gas Detectors using TGS2611-E00

The TGS2611-E00 methane gas sensor has been presorted into groupings which will allow users to simplify the manufacturing process for methane gas detectors. This brochure offers example application circuits and important technical advice for designing and manufacturing gas detectors which use classified TGS2611-E00 sensors.



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See also Technical Brochure 'Technical Information on Usage of TGS Sensors for Toxic and Explosive Gas Leak Detectors'.

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.



TGS2611-E00 is a UL recognized component in accordance with the requirements of UL2075. Please note that component recognition testing has confirmed long term stability in 60ppm of methane; other characteristics shown in this brochure have not been confirmed by UL as part of component recognition.

To facilitate ease in manufacturing gas detectors, TGS2611-E00 methane gas sensors are individually marked with an ID number (see Figure 1) indicating a factory presorted classification which corresponds to narrow ranges of sensor resistance in methane. When the sensor's ID number is properly used, the calibration process can be greatly simplified, eliminating long preconditioning time and the complicated handling of calibration gas.

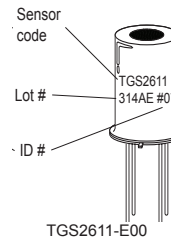


Fig. 1 - Sensor markings

1. Detector Circuit Design

1-1 Basic circuit with temperature compensation

Figure 2 shows an example of a basic circuit for gas detection, including temperature compensation for variations caused by ambient temperature fluctuations. Typical values for the circuit components are as follows:

- R_L : refer to Table 1
- R_{TH} : $4.7k\Omega (\pm 3\%)$, $B=3977 (\pm 5\%)$
- R_A : $11.5k\Omega (\pm 1\%)$
- R_B : $4.32k\Omega (\pm 1\%)$
- R_C : $8.25k\Omega (\pm 1\%)$

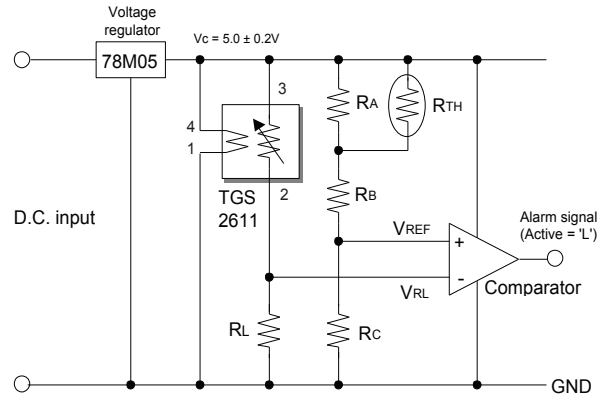


Fig. 2 - Basic circuit with temperature compensation

The values for components related to temperature compensation should be chosen so that V_{ref} is one-half of the V_c value at standard temperature (20°C). The V_{ref} curve should approximate the temperature dependency curve of the V_{RL} when compensation is properly done.

1-2 Selecting a load resistor (R_L)

To optimize resolution of the output signal at the desired alarming concentration, it is necessary to adjust the resistance of the load resistor (R_L). It is recommended that R_L be selected at a value which is equal to the sensor's resistance (R_s) at the alarming concentration (i.e. $R_s/R_L = 1.0$). Please refer to the brochure "General Information for TGS Sensors" for more details.

Since the ID number corresponding to sensor resistance in methane gas is indicated on the sensor cap, the load resistor value can be selected according to Table 1. For example, for an alarm setting at 10% LEL, when using a sensor having an ID number of 7, the R_L value should be set at $1.27k\Omega$. By using the recommended R_L , the V_{RL} value at the alarming point typically will be $2.5V$, which is equal to half of the circuit voltage (V_c).

Sensor ID#	RL with $\pm 1\%$ tolerance			
	5% LEL	10% LEL	15% LEL	20% LEL
03	1.21	0.866	0.715	0.619
04	1.33	0.953	0.787	0.682
05	1.47	1.05	0.866	0.750
06	1.62	1.16	0.953	0.826
07	1.78	1.27	1.05	0.909
08	1.96	1.40	1.15	1.00
09	2.15	1.54	1.27	1.10
10	2.37	1.70	1.40	1.21
11	2.61	1.87	1.54	1.33
12	2.87	2.05	1.70	1.47
13	3.16	2.26	1.87	1.62
14	3.48	2.49	2.05	1.78
15	3.83	2.74	2.26	1.96
16	4.22	3.02	2.49	2.16
17	4.64	3.32	2.74	2.37
18	5.11	3.65	3.01	2.61
19	5.62	4.02	3.32	2.88
20	6.19	4.43	3.65	3.16
21	6.81	4.87	4.02	3.48
22	7.50	5.36	4.42	3.83
23	8.25	5.90	4.87	4.22
24	9.09	6.50	5.36	4.65
25	10.0	7.15	5.90	5.11
26	11.0	7.87	6.49	5.63

Table 1 - Recommended R_L by sensor ID

Note: Lower explosion limit (LEL) of methane = 50,000ppm

1-3 Compensation for internally generated heat

Depending on the design of the case and the PCB, there is often a difference between the temperature near the thermistor's placement in the detector and the ambient temperature. Therefore it is recommended to measure the actual temperature difference between the inside and the outside of the detector and select the value of R_C according to Table 2. When R_C is selected in this manner and used in the basic circuit (Figure 2), the result would be that $V_{ref} = 1/2 V_c$.

ΔT (°C)	R_C (k Ω)
0	8.25
5	7.68
10	7.15
15	6.65
20	6.34

$\Delta T = (\text{temp near thermistor}) - (\text{temp outside detector})$

Table 2 - Effect on selection of R_C by temperature differential inside and outside of detector

1-4 Heater breakage detection circuit

Figure 3 shows an example of how breakage of the sensor's heater wire and/or heater element can be detected. By adding R_E (3.57 $\Omega \pm 1\%$) into the circuit and monitoring V_{RE} , a malfunction can be considered to have occurred when V_{RE} (0.2V typ.) drops to near 0V. Please note that a circuit voltage (V_c) of 5.2V should be applied to a circuit which incorporates a heater malfunction detection circuit.

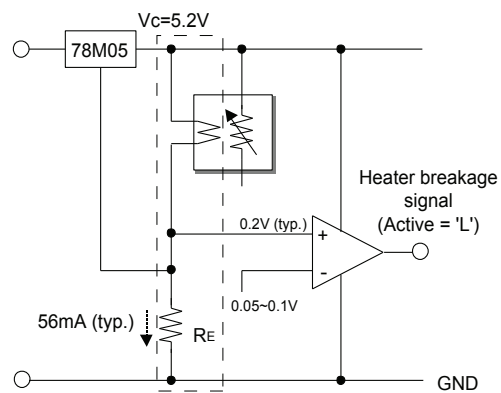


Figure 3 - Heater breakage detection circuit ($R_E = 3.57\Omega \pm 1\%$)

1-5 Sensor malfunction detection circuit

Breakage of lead wires to the sensor's electrodes and/or sensor element can be detected by using a circuit such as that shown in Figure 4. This involves replacing R_C with R_{C1} and R_{C2} , selecting their values so that $R_{C1}/R_{C2} \approx 35$. Since V_{RL} is normally greater than 70mV in any atmospheric conditions, by comparing V_{RL} to a reference voltage of 70mV, breakage of the lead wires and/or sensor element can be considered to have occurred if V_{RL} drops below 70mV.

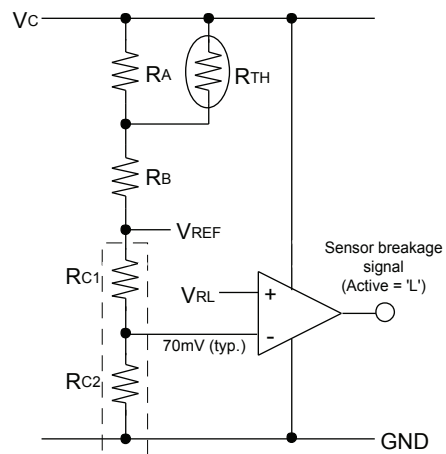


Figure 4 - Sensor malfunction detection circuit ($R_{C1}/R_{C2} \approx 35$)

1-6 Prevention of intermittent alarming

When gas concentration fluctuates right at the alarming threshold, dropping just below and rising just above, the detector would intermittently alarm in short bursts. In order to prevent the nuisance of intermittent alarming, a circuit such as that shown in Figure 5 can be used. By adding R_D to the original circuit, a Schmidt trigger circuit which includes a comparator can be created (the value of R_D should be set at 20-30 times that of R_C). As a result, a range for the alarming threshold is created. An alarm is then generated when the upper range of the threshold is breached and the alarm signal would cease after the signal drops below the lower end of the threshold range, thus eliminating frequent intermittent alarming.

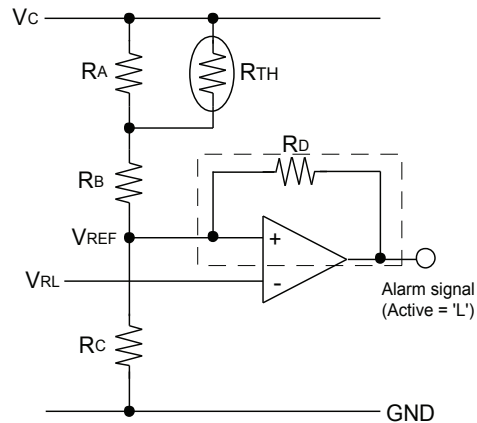


Figure 5 - Circuit for prevention of intermittent alarming ($R_D/R_C = 20\sim30$)

1-7 Alarm prevention during warm-up

As described in Sec. 2-5 of "Technical Information for TGS2611-E00", when energizing the sensor after an unpowered period, the sensor's resistance (R_s) drops sharply for the first few seconds after energizing, regardless of the presence of gases, before recovering to a stable level. This 'initial action' may cause activation of an alarm during the first few moments of energizing since V_{RL} would exceed V_{ref} . To prevent this from happening, a circuit modification such as that shown in Figure 6 may be used. After powering the detector, sensor output (V_{RL}) should be set to zero for a pre-determined period (2.5 minutes is recommended--the timer function should be created by selecting the proper combination of C_3 and R_{11}). In order to restrict current to the sensor during this period, the recommended value of R_F should exceed $5k\Omega$.

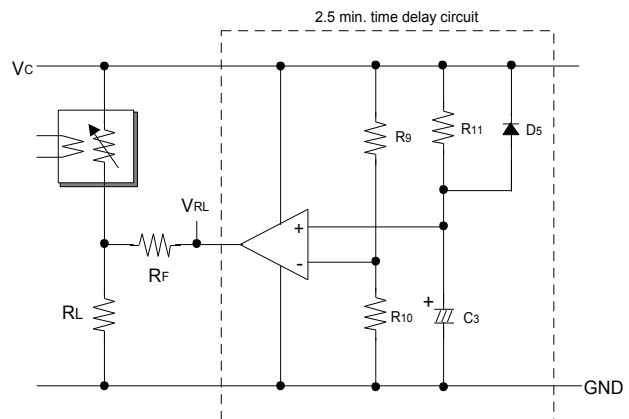


Figure 6 - Circuit for alarm prevention during warmup ($R_F > 5k\Omega$)

1-8 Alarm delay circuit

To prevent false alarms caused by transient interference gases such as alcohol in cooking vapors, a delay circuit modification such as that shown in Figure 7 can be used. The alarm signal generated by this circuit should be connected to the comparator in the basic circuit (see Figure 1). The recommended timer period for alarm delay is 15 seconds--the timer function should be created by selecting the proper combination of C4 and R15.

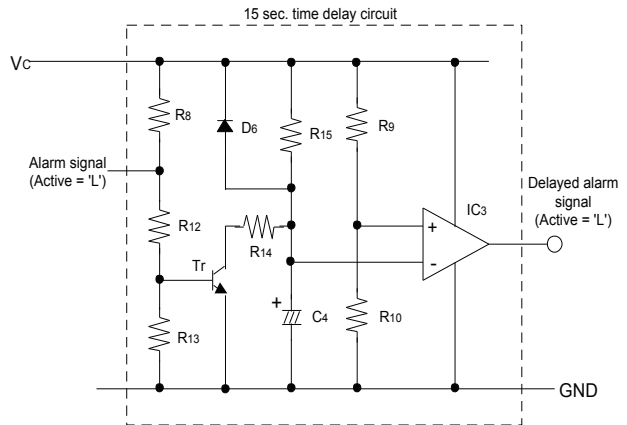


Figure 7 - Alarm delay circuit

1-9 Application circuit

An application circuit which incorporates all of the advice included in Secs. 1-1 through 1-8 can be seen in Appendix 1.

2. Manufacturing Process (see Fig. 8)

2-1 Handling and storage of sensors

Prior to usage, sensors should be stored at room temperature in a sealed bag containing normal clean air. During manufacturing, sensors should be handled in a clean air environment and at room temperature. Clean air refers to air free of contaminants, excessive dust, solvent vapors, etc. Room temperature should be 20~25°C.

2-2 RL selection

Choose the proper resistor for RL by referring to the ID number of the sensor and Table 1.

2-3 PCB assembly

Flux should be sufficiently dried before sensors are assembled onto the PCB to avoid any contamination of the sensor by flux vapors.

2-4 Sensor assembly

Manual soldering of the sensor to the PCB is strongly advised. Solders composed of Sn63:Pb37 or Sn60:Pb40 with non-chloric resin flux (MIL: RMA Grade; for example, Almit KR-19) are recommended for usage.

2-5 Final assembly

Avoid any shock or vibration which may be caused by air driven tools. This may cause breakage of the sensor's lead wires or other physical damage to the sensor.

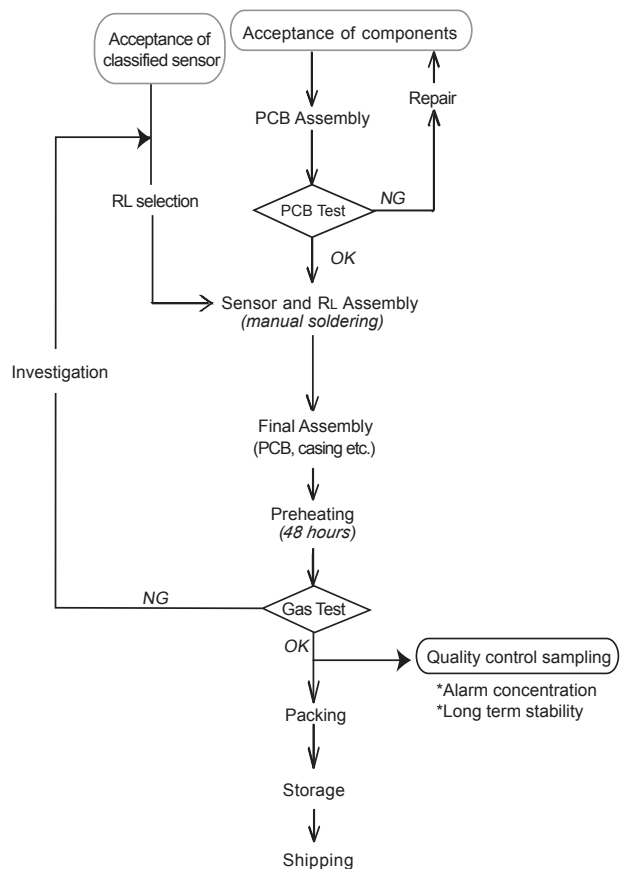


Figure 8 - Manufacturing process flowchart

2-6 Preheating of final assembly

To stabilize the detector assembly before gas testing, the minimum period for preheating final assemblies should be 48 hours at room temperature (20~25°C). Be certain to maintain clean atmospheric conditions for preheating.

2-7 Gas test

Test all finished products in the target gas under normal operating conditions. Keep the atmospheric conditions in the chamber stable, utilizing a user-defined standard test condition which is based on applicable performance standards and on anticipated usage for detectors. Remove any traces of smoke, adhesives, gases, or solvents from the chamber. **NOTE: Without testing after final assembly, detectors have no guarantee of accuracy or reliability.**

2-8 Storage of finished products

Detectors should be stored in a clean air environment at room temperature. Avoid storage in dirty or contaminated environments. Cautions listed in Sec. 6-1.3 of “General Information for TGS Sensors” should also be observed.

3. Anticipated Performance at 10%LEL of Methane

When using the classified TGS2611 with Figaro’s recommended RL for 10%LEL (Table 1) and temperature compensated circuit design (Figure 2), typical alarm tolerances for 10%LEL of methane such as those shown in Figure 9 are expected. Each RL classification contains a range of tolerance as exemplified by the alarming range labelled as ‘standard conditions’ (i.e. these conditions are well-controlled). When factoring in the additional effects of environmental extremes and the allowable variation in circuit conditions, the resulting alarming range would be typified by the range labelled as ‘operating conditions’. However, in actual usage, alarm thresholds may vary since the threshold is also affected by factors such as the tolerances of the thermistor and/or other components, load resistor value, test conditions, and heat generation inside the detector enclosure. As a result, Figaro neither expressly nor impliedly

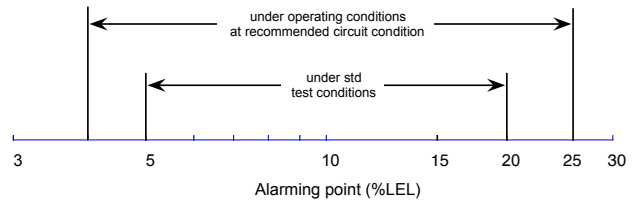


Figure 9 - Expected performance of methane detectors with classified TGS2611 & recommended RL for 10% LEL (refer to Table 3 for test conditions)

Temperature and humidity	Standard conditions	20±2°C, 65±5%RH
	Operating conditions	-10~40°C, 30~95%RH
Circuit conditions	Standard conditions	V _c =5.0±0.01V DC V _H =5.0±0.05V DC
	Operating conditions	V _c =5.0±0.2V DC V _H =5.0±0.2V DC
Conditioning prior to test		≥48 hours

Table 3 - Test conditions for measuring performance of methane detectors as shown in Figure 9

warrants the performance shown in Figure 9. If a large difference between the expected and actual performance of detectors is noticed, please consult with Figaro.

Pre-calibrated sensor module

Figaro has available a pre-calibrated methane sensor module NGM2611-E13 (see Fig. 10). This module includes the classified TGS2611-E00 sensor, a matched load resistor, and a factory preset temperature compensation circuit, all on a small PC board. The NGM2611-E13 module is calibrated for a typical set point at 10% LEL, achieving performance as indicated in Figure 9 by simply plugging it into a main PC board. Please refer to the brochure "Product Information for NGM2611-E13" for detailed information.

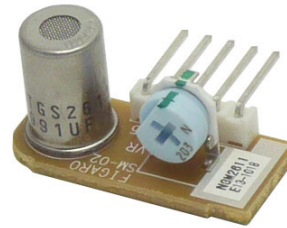


Figure 10 - Pre-calibrated sensor module NGM2611-E13

Important Reminder

Without testing alarm threshold after final assembly, detectors have no accuracy or reliability guarantee.

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Figaro's products are not authorized for use as critical components in life support applications wherein a failure or malfunction of the products may result in injury or threat to life.

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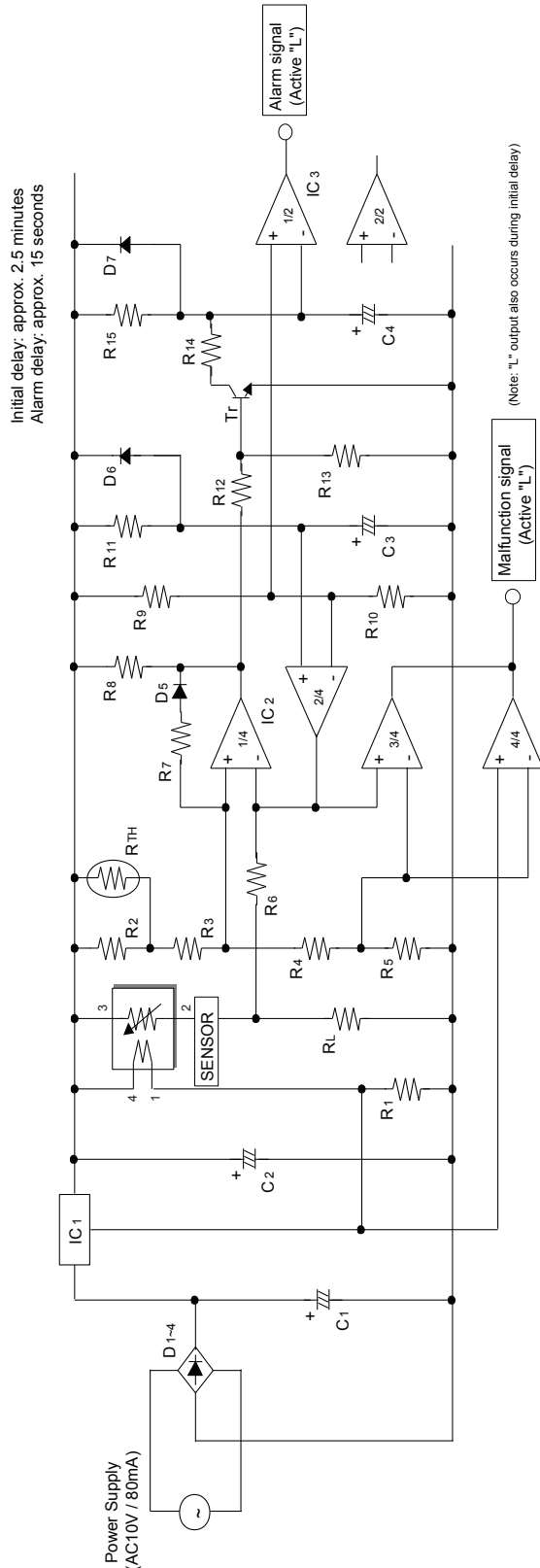
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Appendix 1 - Example application circuit for gas detector using classified TGS2611



Part No.	Part name	Model No./ Specification	Maker	Part No.	Part name	Model No./ Specification	Maker	Part No.	Part name	Model No./ Specification	Maker
Sensor	Gas sensor	TGS2610	Figaro	R9	Resistor	10kΩ, 5%, 1/8W		D1	Rectification diode	SS566G	Toshiba
RTH	NTC thermistor	4.7Ω, B=3977	Philips	R10	Resistor	10kΩ, 5%, 1/8W		D2	Rectification diode	SS566G	Toshiba
RL	Resistor	(See Table 1), 1%, 1/8W		R11	Resistor	470kΩ, 5%, 1/8W		D3	Rectification diode	SS566G	Toshiba
R1	Resistor	3.57Ω, 1%, 1/2W		R12	Resistor	10kΩ, 5%, 1/8W		D4	Rectification diode	SS566G	Toshiba
R2	Resistor	11.5kΩ, 1%, 1/8W		R13	Resistor	10kΩ, 5%, 1/8W		D5	Small signal diode	1S1588	Toshiba
R3	Resistor	4.32kΩ, 1%, 1/8W		R14	Resistor	1kΩ, 5%, 1/8W		D6	Small signal diode	1S1588	Toshiba
R4	Resistor	7.87kΩ, 1%, 1/8W		R15	Resistor	470kΩ, 5%, 1/8W		D7	Small signal diode	1S1588	Toshiba
R5	Resistor	226Ω, 1%, 1/8W		C1	Electrolytic capacitor	470μF/25V	Mitsubishi	Tr	NPN transistor	2SC2603	Mitsubishi
R6	Resistor	10kΩ, 5%, 1/8W		C2	Electrolytic capacitor	10μF/10V	Motorola	IC1	Voltage regulator	MC78M05CT	Motorola
R7	Resistor	200kΩ, 5%, 1/8W		C3	Electrolytic capacitor	470μF/10V, 10%	Motorola	IC2	Comparator	LM339	Motorola
R8	Resistor	10kΩ, 5%, 1/8W		C4	Electrolytic capacitor	470μF/10V, 10%	Motorola	IC3	Comparator	LM393	Motorola

TGS 2611-E00 - for the detection of Methane

Features:

- * High selectivity to methane
- * Low power consumption
- * Long life and low cost
- * Uses simple electrical circuit

Applications:

- * Domestic gas alarms
- * Portable gas detectors
- * Gas leak detector for gas appliances

TGS2611-E00 is a semiconductor type gas sensor which combines very high sensitivity to methane gas with low power consumption and long life. Due to miniaturization of its sensing chip, TGS2611-E00 requires a heater current of only 56mA and the device is housed in a standard TO-5 package.

TGS2611-E00 uses filter material in its housing which eliminates the influence of interference gases such as alcohol, resulting in highly selective response to methane gas. This feature makes the sensor ideal for residential gas leakage detectors which require durability and resistance against interference gas.

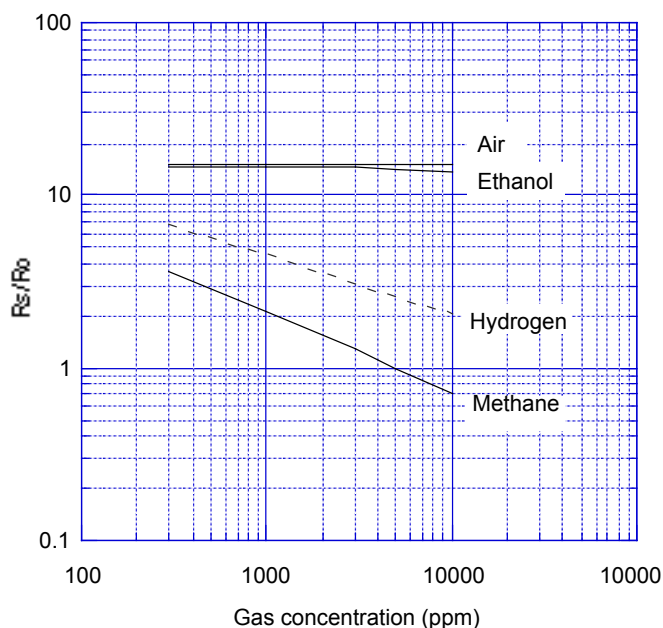
The TGS2611-E00 is able to satisfy the requirements of performance standards such as UL1484 and EN50194.



The figure below represents typical sensitivity characteristics, all data having been gathered at standard test conditions (see reverse side of this sheet). The Y-axis is indicated as sensor resistance ratio (R_s/R_o) which is defined as follows:

- R_s = Sensor resistance at various concentrations
- R_o = Sensor resistance in 5000ppm of methane

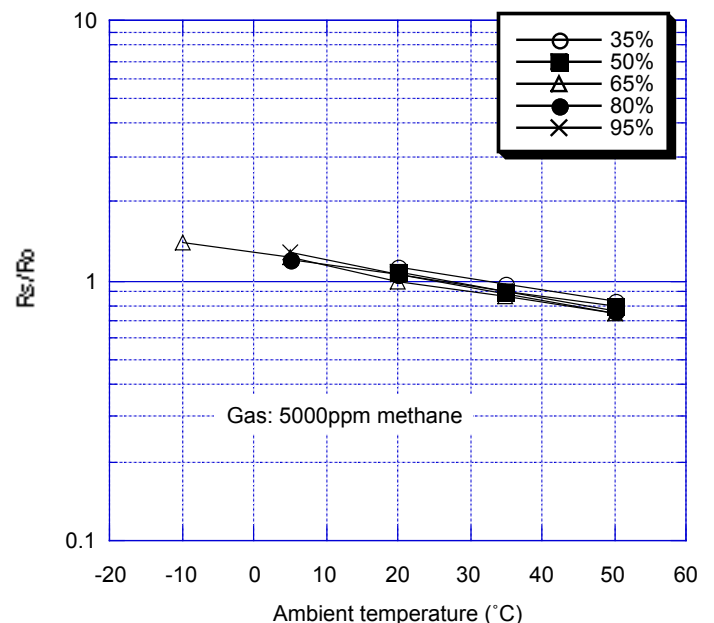
Sensitivity Characteristics:



The figure below represents typical temperature and humidity dependency characteristics. The Y-axis is indicated as sensor resistance ratio (R_s/R_o), defined as follows:

- R_s = Sensor resistance in 5000ppm of methane at various temp/humidities
- R_o = Sensor resistance in 5000ppm of methane at 20°C/65%RH

Temperature and Humidity Dependency:

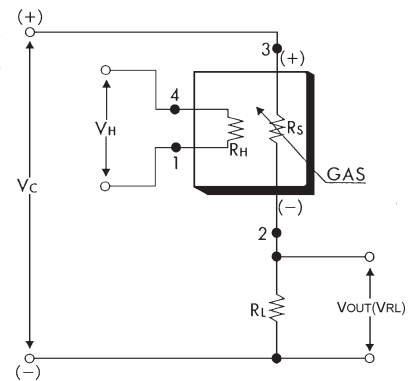


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Basic Measuring Circuit:

The sensor requires two voltage inputs: heater voltage (V_H) and circuit voltage (V_C). The heater voltage (V_H) is applied to the integrated heater in order to maintain the sensing element at a specific temperature which is optimal for sensing. Circuit voltage (V_C) is applied to allow measurement of voltage $V_{OUT}(V_{RL})$ across a load resistor (R_L) which is connected in series with the sensor.

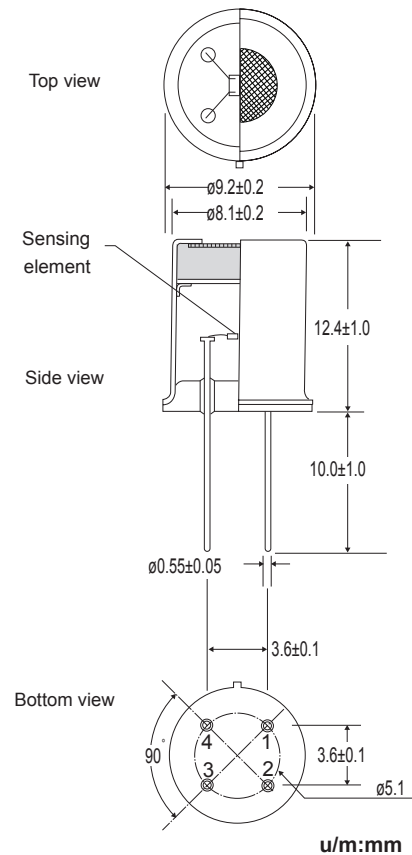
A common power supply circuit can be used for both V_C and V_H to fulfill the sensor's electrical requirements. The value of the load resistor (R_L) should be chosen to optimize the alarm threshold value, keeping power dissipation (P_S) of the semiconductor below a limit of 15mW. Power dissipation (P_S) will be highest when the value of R_S is equal to R_L on exposure to gas.



Specifications:

Model number		TGS2611-E00	
Sensing principle		MOS type	
Standard package		TO-5 metal can	
Target gases		Methane, Natural Gas	
Typical detection range		1~25% LEL	
Standard circuit conditions	Heater voltage	V_H	5.0±0.2V AC/DC
	Circuit voltage	V_C	5.0±0.2V DC $P_S \leq 15mW$
	Load resistance	R_L	variable 0.45kΩ min.
Electrical characteristics under standard test conditions	Heater resistance	R_H	approx 59Ω at room temp.
	Heater current	I_H	56±5mA
	Heater power consumption	P_H	280mW±25mW
	Sensor resistance	R_S	0.83~8.30kΩ in 5000ppm methane
	Sensitivity (change ratio of R_S)		0.52~0.65 in methane $R_S(9000ppm)$ $R_S(3000ppm)$
Standard test conditions	Test gas conditions	Methane in air at 20±2°C, 65±5%RH	
	Circuit conditions	$V_C = 5.0 \pm 0.01V$ DC $V_H = 5.0 \pm 0.05V$ DC	
	Conditioning period before test	7 days	

Structure and Dimensions:



Pin connection:

- 1: Heater
- 2: Sensor electrode (-)
- 3: Sensor electrode (+)
- 4: Heater

The value of power dissipation (P_S) can be calculated by utilizing the following formula:

$$P_S = \frac{(V_C - V_{RL})^2}{R_S}$$

Sensor resistance (R_S) is calculated with a measured value of $V_{OUT}(V_{RL})$ by using the following formula:

$$R_S = \left(\frac{V_C}{V_{RL}} - 1 \right) \times R_L$$

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

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FIGARO

an ISO9001 company

Technical Information for Methane Gas Sensors

The Figaro 2600 series is a thick film metal oxide semiconductor, screen printed gas sensor which offers miniaturization and lower power consumption. The TGS2611 displays high selectivity and sensitivity to methane.



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See also Technical Brochure ‘Technical Information on Usage of TGS Sensors for Toxic and Explosive Gas Leak Detectors’.

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1. Basic Information and Specifications

1-1 Features

- * High selectivity to methane
- * Low power consumption
- * Small size
- * Long life and low cost
- * Uses simple electrical circuit

1-2 Applications

- * Residential gas alarms
- * Portable gas detectors
- * Gas leak detectors for gas appliances

1-3 Structure

Figure 1 shows the structure of TGS2611. Using thick film techniques, the sensing material (SnO₂) is printed on electrodes (noble metal) which have been printed onto an alumina substrate. One electrode is connected to pin No.2 and the other is connected to pin No.3. The sensor element is heated by RuO₂ material printed onto the reverse side of the substrate and connected to pins No.1 and No.4.

Lead wires are Pt-W alloy and are connected to sensor pins which are made of Ni-plated Ni-Fe 50%.

The sensor base is made of Ni-plated steel. The cap is stainless steel. The upper opening in the cap is covered with a double layer of 100 mesh stainless steel gauze (SUS316). The TGS2611-E utilizes a charcoal filter inside the cap for reducing the influence of interference gases.

1-4 Basic measuring circuit

Figure 2 shows the basic measuring circuit. Circuit voltage (V_c) is applied across the sensor element which has a resistance (R_s) between the sensor's two electrodes and the load resistor (R_L) connected in series. When DC is used for V_c, the polarity shown in Figure 2 **must** be maintained. The V_c may be applied intermittently. The sensor signal V_{OUT} (V_{RL}) is measured indirectly as a change in voltage across the R_L. The R_s is obtained from the formula shown at the right.

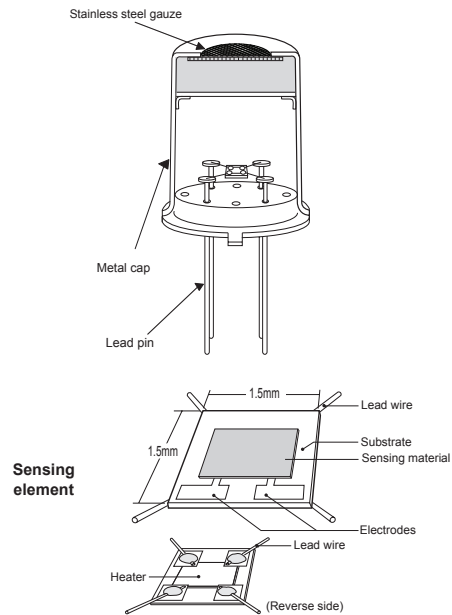


Fig. 1 - Sensor structure

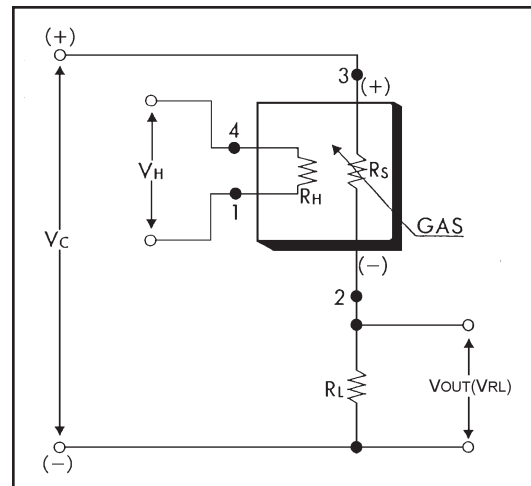


Fig. 2 - Basic measuring circuit

NOTE: In the case of V_H, there is no polarity, so pins 1 and 4 can be considered interchangeable. However, in the case of V_C, when used with DC power, pins 2 and 3 **must** be used as shown in the Figure above.

$$R_s = \left(\frac{V_c}{V_{RL}} - 1 \right) \times R_L$$

Formula to determine R_s

1-5 Circuit & operating conditions

The ratings shown below should be maintained at all times to insure stable sensor performance:

Item	Specification
Circuit voltage (V _c)	5.0V ± 0.2V AC/DC
Heater voltage (V _H)	5.0V ± 0.2V AC/DC
Inrush heater current (V _H =5.0V)	100mA max.
Heater resistance (room temp)	approx 59Ω
Load resistance (R _L)	variable (0.45kΩ min.)
Sensor power dissipation (P _s)	≤15mW
Operating & storage temperature	-40°C ~ +70°C
Typical detection range	1~25% LEL

1-6 Specifications ^{NOTE 1}

Item	Specification
Sensor resistance (5000ppm methane)	0.83kΩ ~ 8.3kΩ
Sensor resistance ratio (β)	0.52 ~ 0.65
$\beta = R_s(9000\text{ppm methane})/R_s(3000\text{ppm methane})$	
Heater current (R _H)	56 ± 5mA
Heater power consumption (P _H)	280m±25W

NOTE 1: Sensitivity characteristics are obtained under the following standard test conditions:

(Standard test conditions)

Temperature and humidity: 20 ± 2°C, 65 ± 5% RH

Circuit conditions: V_c = 5.0±0.01V DC

V_H = 5.0±0.05V DC

R_L = 10.0kΩ ± 1%

Preheating period: 7 days or more under standard circuit conditions.

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.

1-7 Dimensions

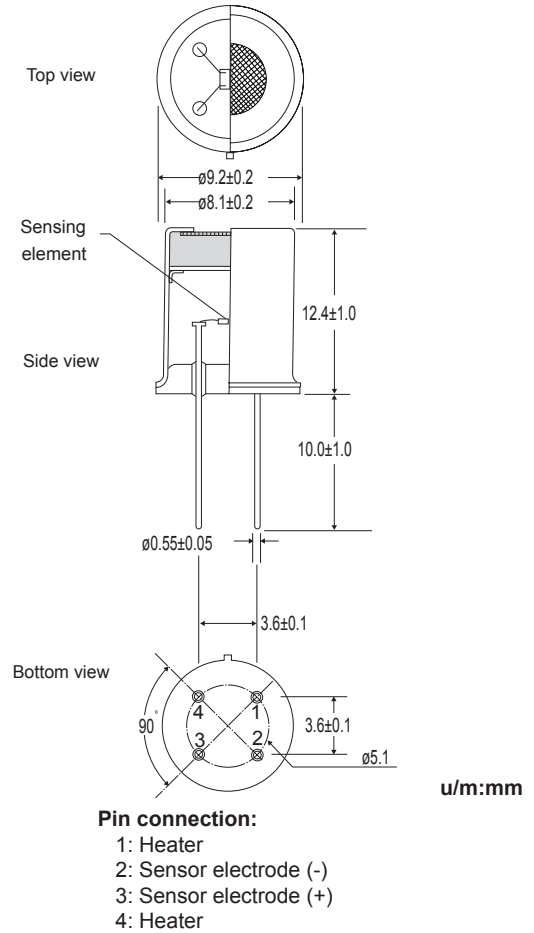


Fig. 3 - Sensor dimensions

Mechanical Strength:

The sensor shall have no abnormal findings in its structure and shall satisfy the above electrical specifications after the following performance tests:

Withdrawal Force - withstand force of 5kg in each direction (pin from base)

Vibration - frequency-1000cycles/min., total amplitude-4mm, duration-one hour, direction-vertical

Shock - acceleration-100G, repeated 5 times

2. Typical Sensitivity Characteristics

2-1 Sensitivity to various gases

Figure 4 shows the relative sensitivity of TGS2611 to various gases. The Y-axis shows the ratio of the sensor resistance in various gases (R_s) to the sensor resistance in 5000ppm of methane (R_o).

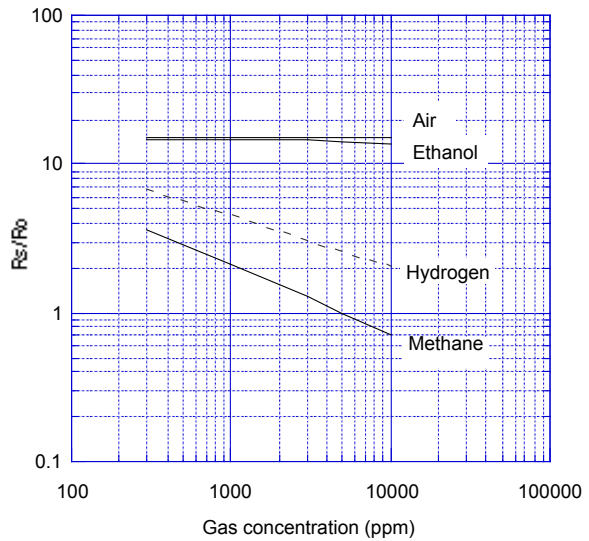


Fig. 4 - Sensitivity to various gases (R_s/R_o)

Using the basic measuring circuit illustrated in Fig. 2, and with a matched RL value equivalent to the R_s value in 5000ppm of methane will provide sensor output voltage (V_{RL}) change as shown in Figure 5.

NOTE:

All sensor characteristics in this technical brochure represent typical sensor characteristics. Since the R_s or output voltage curve varies from sensor to sensor, calibration is required for each sensor (*for additional information on calibration, please refer to the Technical Advisory 'Technical Information on Usage of TGS Sensors for Toxic and Explosive Gas Leak Detectors'*).

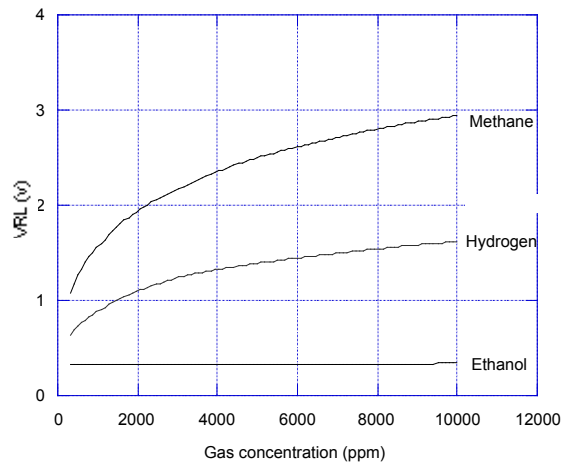


Fig. 5 - Sensitivity to various gases (V_{RL})

2-2 Temperature and humidity dependency

Figure 6 shows the temperature and humidity dependency of TGS2611. The Y-axis shows the ratio of sensor resistance in 5000ppm of methane under various atmospheric conditions (R_s) to the sensor resistance in 5000ppm of methane at 20°C/65%RH (R_o).

(°C) \ RH	35%RH	50%RH	65%RH	80%RH	95%RH
-10			1.40		
5			1.24	1.20	1.27
20	1.13	1.09	1.00	1.05	1.06
35	0.96	0.90	0.87	0.90	0.88
50	0.84	0.80	0.74	0.76	0.74
40	0.92	0.82	0.76	0.69	

Table 1 - Temperature and humidity dependency (typical values of R_s/R_o for Fig. 6)

Table 1 shows a table of values of the sensor's resistance ratio (R_s/R_o) under the same conditions as those used to generate Figure 6.

Figure 7 shows the sensitivity curve for TGS2611 to methane under several ambient conditions. While temperature may have a large influence on absolute R_s values, this chart illustrates the fact that effect on the slope of sensor resistance ratio (R_s/R_o) is not significant. As a result, the effects of temperature on the sensor can easily be compensated.

For economical circuit design, a thermistor can be incorporated to compensate for temperature (for additional information on temperature compensation in circuit designs, please refer to the Technical Advisory 'Technical Information on Usage of TGS Sensors for Toxic and Explosive Gas Leak Detectors').

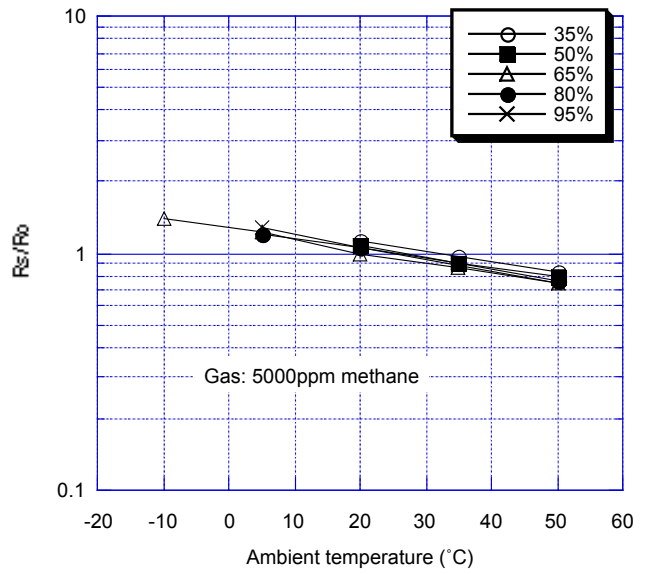


Fig. 6 - Temperature and humidity dependency (R_s/R_o)

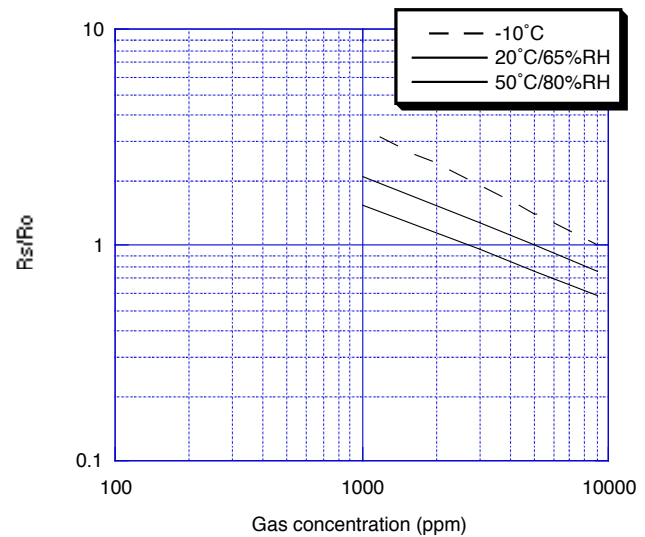


Fig. 7 - Resistance change ratio under various ambient conditions

2-3 Heater voltage dependency

Figure 8 shows the change in the sensor resistance ratio according to variations in heater voltage (VH).

Note that 5.0V as a heater voltage must be maintained because variance in applied heater voltage will cause the sensor's characteristics to be changed from the typical characteristics shown in this brochure.

2-4 Gas response

Figure 9 shows the change pattern of sensor resistance (Rs) for TGS2611 when the sensor is inserted into and later removed from 5000ppm of methane.

As these charts display, the sensor's response speed to the presence of gas is extremely quick, and when removed from gas, the sensor will recover back to its original value in a short period of time.

Figure 10 demonstrates the sensor's repeatability by showing multiple exposures to a 5000ppm concentration of methane. Unlike the test done for Fig. 9, here the sensor is located in a single environment which is exchanged periodically. As a result, though the process of gas diffusion reduces sensor response speed, good repeatability can be seen.

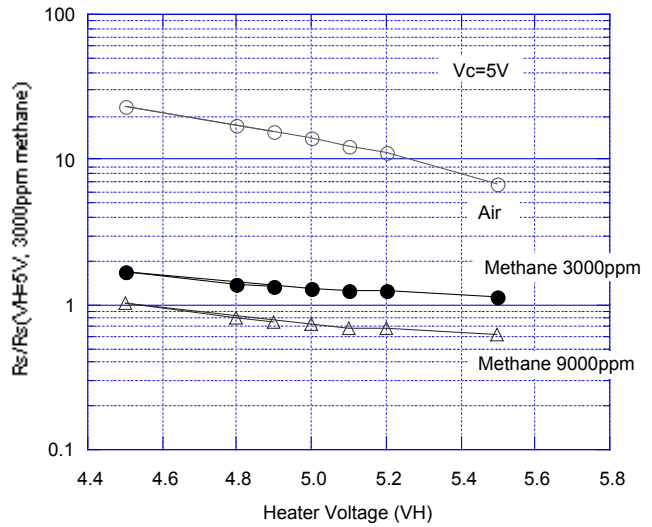


Fig. 8 - Heater voltage dependency (Vc=5.0)

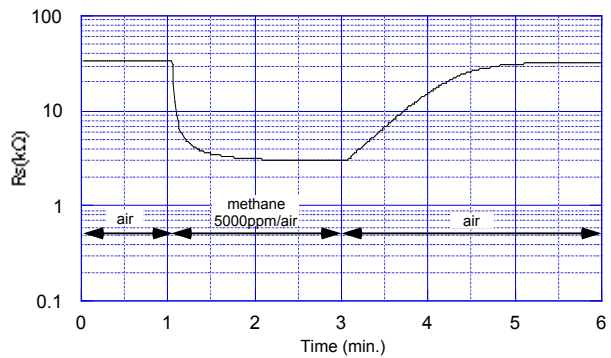


Fig. 9 - Gas response to methane

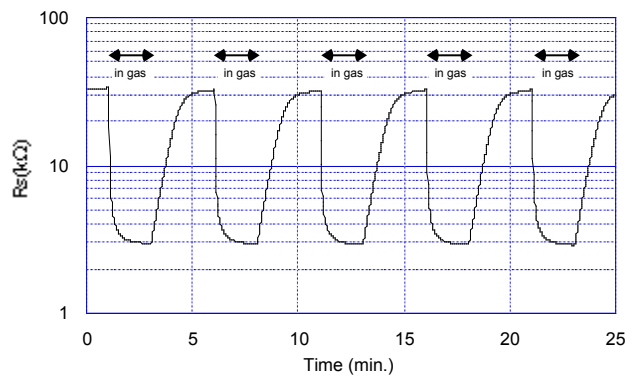


Fig. 10 - Repeatability

2-5 Initial action

Figure 11 shows the initial action of the sensor resistance (R_s) for a sensor which is stored unenergized in normal air for 90 days and later energized in clean air.

The R_s drops sharply for the first seconds after energizing, regardless of the presence of gases, and then reaches a stable level according to the ambient atmosphere. Such behavior during the warm-up process is called "Initial Action".

Since this 'initial action' may cause a detector to alarm unnecessarily during the initial moments after powering on, it is recommended that an initial delay circuit be incorporated into the detector's design (refer to *Technical Advisory 'Technical Information on Usage of TGS Sensors for Toxic and Explosive Gas Leak Detectors'*). This is especially recommended for intermittent-operating devices such as portable gas detectors.

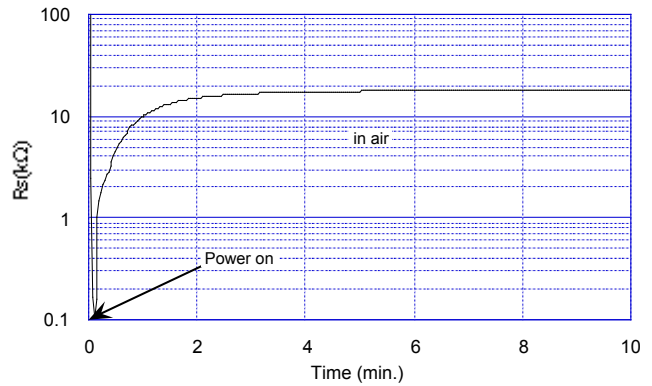


Fig. 11 - Initial action

2-6 Long-term characteristics

Figure 12 shows long-term stability of TGS2611 as measured for more than 1900 days. The sensor is usually energized in normal air. Measurement for confirming sensor characteristics is conducted under standard test conditions. The initial value of R_s was measured after preheating for at least three days in normal air at the rated voltage. The Y-axis represents the sensor resistance in air, 5000ppm of methane, 3000ppm of hydrogen, and 3000ppm of ethanol.

The R_s in methane is very stable over the test period.

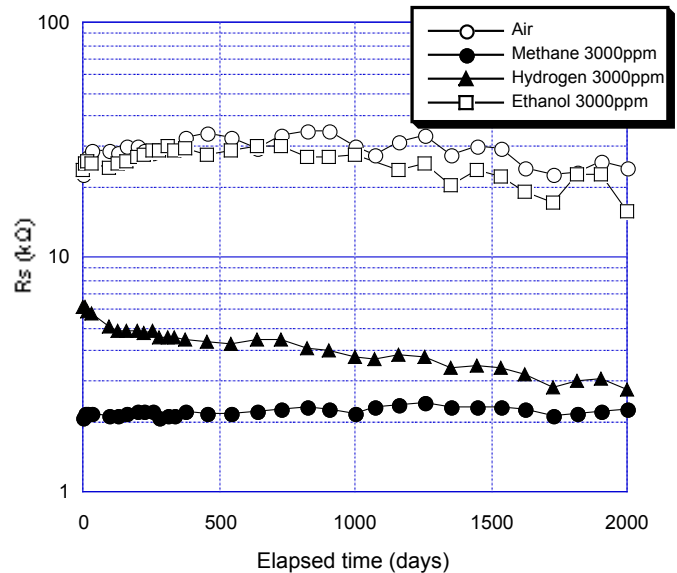


Fig. 12 - Long-term stability (continuous energizing)

3. Reliability

3-1 Ignition test (*)

TGS2611 has been successfully tested against the ignition test requirements of the UL1484 standard. The sensor did not initiate ignition of a propane concentration of 5.25% by volume.

3-2 HMDS test

Figure 13 shows the effect on TGS2611 of silicone vapor. Sensor resistance prior to HMDS (Hexamethyl disiloxane) gas exposure was measured (R_0). Energized sensors were placed into an environment of 20°C/50%RH. In this environment, the sensors were exposed to HMDS at 10 ppm for 40 minutes, 30 ppm for 40 minutes and 100 ppm for 40 minutes (test conditions specified in Item 5.3.13 of the ES (*European standard*) EN50194: 10ppm for 40 min.). After exposure, the sensor was returned to normal air. Sensor resistance (R_s) in both air and 5000ppm of methane were measured at 1 hour, 1 day, and 1 week after being removed from HMDS.

As this data would suggest, sensor characteristics remain largely unaffected by exposure to HMDS gas concentrations.

(*) The UL 1484 referenced tests have not been reviewed or accepted by Underwriters Laboratory as part of the component recognition.

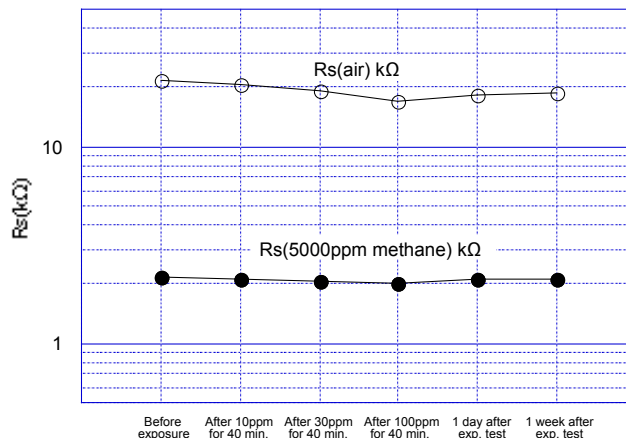


Fig. 13 - Durability to HMDS exposure

4 Cautions

4-1 Situations which must be avoided

1) Exposure to silicone vapors

If silicone vapors adsorb onto the sensor's surface, the sensing material will be coated, irreversibly inhibiting sensitivity. Avoid exposure where silicone adhesives, hair grooming materials, or silicone rubber/putty may be present.

2) Highly corrosive environment

High density exposure to corrosive materials such as H₂S, SO_x, Cl₂, HCl, etc. for extended periods may cause corrosion or breakage of the lead wires or heater material.

3) Contamination by alkaline metals

Sensor drift may occur when the sensor is contaminated by alkaline metals, especially salt water spray.

4) Contact with water

Sensor drift may occur due to soaking or splashing the sensor with water.

5) Freezing

If water freezes on the sensing surface, the sensing material would crack, altering characteristics.

6) Application of excessive voltage

If higher than specified voltage is applied to the sensor or the heater, lead wires and/or the heater may be damaged or sensor characteristics may drift, even if no physical damage or breakage occurs.

7) Operation in zero/low oxygen environment

TGS sensors require the presence of around 21% (ambient) oxygen in their operating environment in order to function properly and to exhibit characteristics described in Figaro's product literature. TGS sensors cannot properly operate in a zero or low oxygen content atmosphere.

8) Excessive exposure to alcohol

IF TGS2611-E00 is exposed to high concentrations of alcohol (such as 10,000ppm or more) for a long period of time, the filter may become saturated. In this case, the sensor would show a lower resistance in alcohol than that indicated in Figure 4.

9) Polarization

These sensors have polarity. Incorrect V_c connection

may cause significant deterioration of long term stability. Please connect V_c according to specifications.

10) Lighter gas exposure test

Consumers often check if detectors are actually sensing gas by exposing them to lighter gas (main component is iso-butane). Because the filter will block iso-butane from reaching the sensing element, this test **cannot** be used with TGS2611-E00.

4-2 Situations to be avoided whenever possible

1) Water condensation

Light condensation under conditions of indoor usage should not pose a problem for sensor performance. However, if water condenses on the sensor's surface and remains for an extended period, sensor characteristics may drift.

2) Usage in high density of gas

Sensor performance may be affected if exposed to a high density of gas for a long period of time, regardless of the powering condition.

3) Storage for extended periods

When stored without powering for a long period, the sensor may show a reversible drift in resistance according to the environment in which it was stored. The sensor should be stored in a sealed bag containing clean air; do not use silica gel. *Note that as unpowered storage becomes longer, a longer preheating period is required to stabilize the sensor before usage.*

4) Long term exposure in adverse environment

Regardless of powering condition, if the sensor is exposed in extreme conditions such as very high humidity, extreme temperatures, or high contamination levels for a long period of time, sensor performance will be adversely affected.

5) Vibration

Excessive vibration may cause the sensor or lead wires to resonate and break. Usage of compressed air drivers/ultrasonic welders on assembly lines may generate such vibration, so please check this matter.

6) Shock

Breakage of lead wires may occur if the sensor is subjected to a strong shock.

7) Soldering

Ideally, sensors should be soldered manually. However, wave soldering can be done under the

following conditions:

- a) Suggested flux: rosin flux with minimal chlorine
- b) Speed: 1-2 meters/min.
- c) Preheating temperature: 100±20°C
- d) Solder temperature: 250±10°C
- e) Up to two passes through wave soldering machine allowed

Results of wave soldering cannot be guaranteed if conducted outside the above guidelines since some flux vapors may cause drift in sensor performance similar to the effects of silicone vapors.

NOTE: To achieve the optimal level of accuracy in gas detectors, each TGS2611 sensor should be individually calibrated by matching it with a load resistor (RL) in an environment containing the target gas concentration for alarming (refer to Fig. 2).

For the convenience of users, TGS2611 is classified into 24 groups according to the each sensor's Rs in methane. ID numbers marked on the sensor's body indicate the sensor's grouping. Individual sensor calibration can be eliminated by matching the sensor with the recommended RL for each sensor ID. However, because group calibration is used instead of individual calibration, an average of 10% less accuracy would result for detectors using group calibration. Please refer to "Application Notes for TGS2611-E00" for more information.

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