TGS 2610-D00 - for the detection of LP Gas

Features:

* High selectivity to LP and its component gases (e.g. propane and butane)
* Low power consumption
* Long life and low cost
* Uses simple electrical circuit

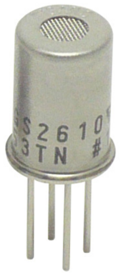
Applications:

* Residential LP gas detectors and alarms
* Portable LP gas detectors
* LP gas and vapor detection

TGS2610-D00 is a semiconductor type gas sensor which combines very high sensitivity to LP gas with low power consumption and long life. Due to miniaturization of its sensing chip, TGS2610-D00 requires a heater current of only 56mA and the device is housed in a standard TO-5 package.

TGS2610-D00 uses filter material in its housing which eliminates the influence of interference gases such as alcohol, resulting in highly selective response to LP gas. This feature makes the sensor ideal for residential gas leakage detectors which require durability and resistance against interference gas.

The TGS2610-D00 is able to satisfy the requirements of performance standards such as UL1484 and EN50194.



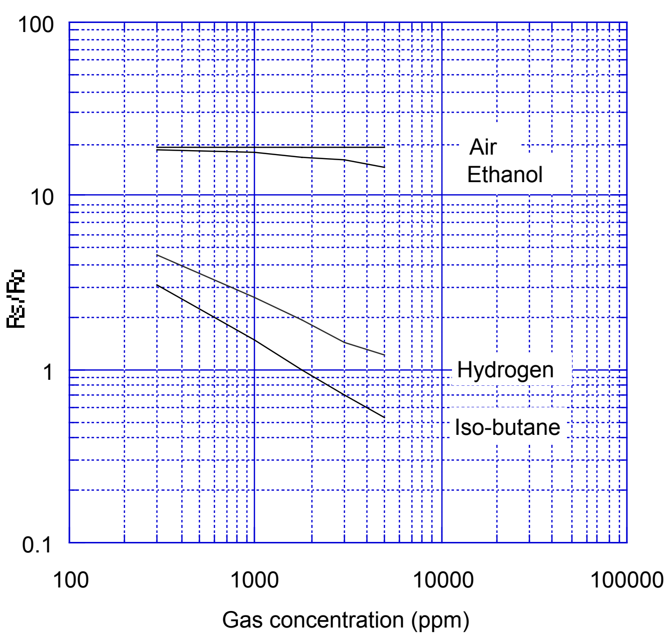
The figure below represents typical sensitivity characteristics, all data having been gathered at standard test conditions (see reverse side of this sheet). The Y-axis is indicated as sensor resistance ratio (Rs/Ro) which is defined as follows:

Rs = Sensor resistance at various concentrations
Ro = Sensor resistance in 1800ppm of iso-butane

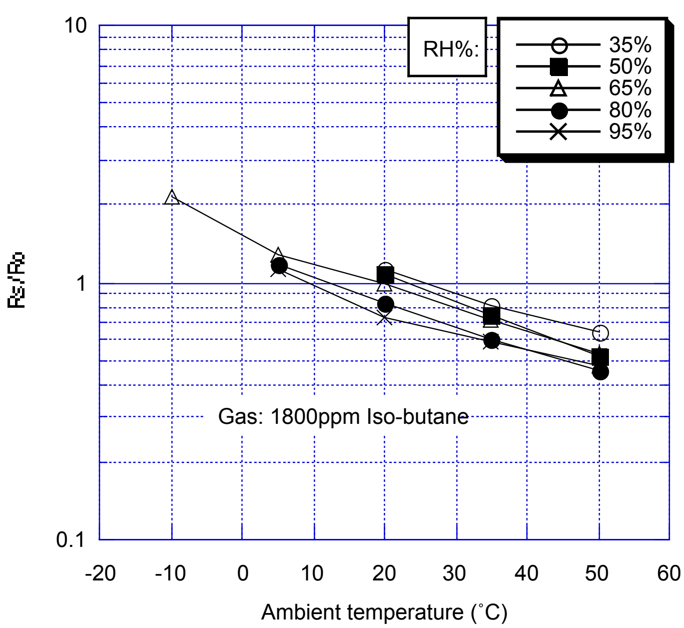
The figure below represents typical temperature and humidity dependency characteristics. The Y-axis is indicated as sensor resistence ratio (Rs/Ro), defined as follows:

Rs = Sensor resistance in 1800ppm of iso-butane at various temp/humidities
Ro = Sensor resistance in 1800ppm of iso-butane at 20˚C/65%RH

Sensitivity Characteristics:



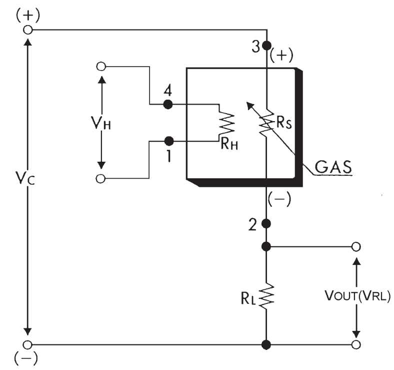
Temperature and Humidity Dependency:



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}) across a load resistor (R_L) which is connected in series with the sensor.

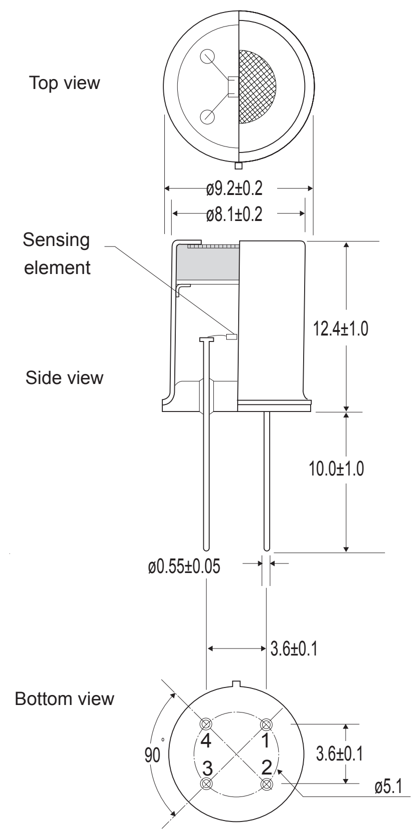
A common power supply circuit can be used for both V_C and V_H to fulfill the sensor's electrical requirements. The value of the load resistor (R_L) should be chosen to optimize the alarm threshold value, keeping power dissipation (P_S) of the semiconductor below a limit of 15mW. Power dissipation (P_S)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



Specifications:

Model number			TGS2610-D00	
Sensing principle			MOS type	
Standard package			TO-5 metal can	
Target gases			Butane, LP 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≤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	V_H=5.0V DC
	Sensor resistance	R_S	1.2~12.0kΩ in 1800ppm iso-butane	
	Sensitivity (change ratio of Rs)		0.37~0.60 in iso-butane	$\frac{Rs\ (3000ppm)}{Rs\ (1000ppm)}$
Standard test conditions	Test gas conditions		iso-butane in air at 20±2°C, 65±5%RH	
	Circuit conditions		Vc = 5.0±0.01V DC V_H = 5.0±0.05V DC	
	Conditioning period before test		7 days	

Structure and Dimensions:



u/m:mm

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 (Rs) 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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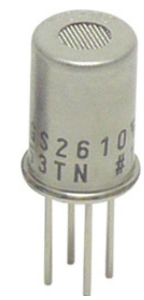
Technical Information for LP Gas Sensors

The Figaro 2600 series is a thick film metal oxide semiconductor, screen printed gas sensor which offers mini-aturization and lower power consumption. The TGS2610 displays high selectivity and sensitivity to LP gas and its components (e.g. propane and butane).



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

TGS2610-D 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 propane; other characteristics shown in this brochure have not been confirmed by UL as part of component recognition.*

1. Basic Information and Specifications

1-1 *Features*

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

1-2 *Applications*

* Residential LP gas leak detectors
* Recreational vehicle LP gas leak detectors

1-3 *Structure*

Figure 1 shows the structure of TGS2610. Using thick film techniques, the sensing material (SnO_2) 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 RuO_2 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 TGS2610-D utilizes a zeolite 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 (Vc) is applied across the sensor element which has a resistance (Rs) between the sensor's two electrodes and the load resistor (R_L) connected in series. When DC is used for Vc, the polarity shown in Figure 2 **must** be maintained. The Vc may be applied intermittently. The sensor signal V_{OUT} (V_{RL}) is measured indirectly as a change in voltage across the R_L. The Rs is obtained from the formula shown at the right.

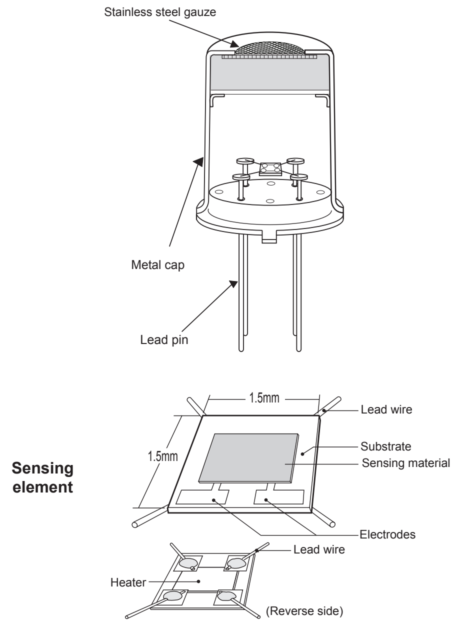


Fig. 1 - Sensor structure

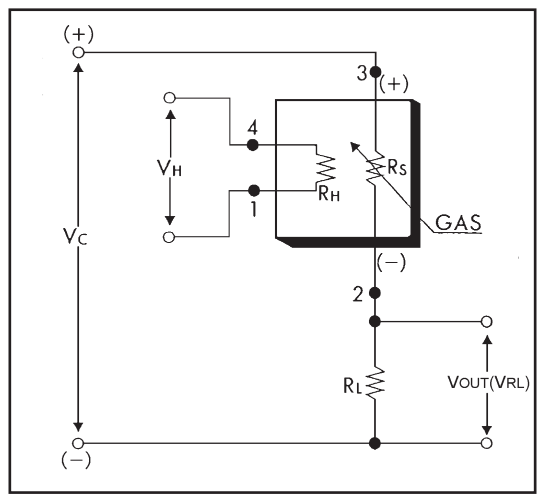


Fig. 2 - Basic measuring circuit

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

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

Formula to determine Rs

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

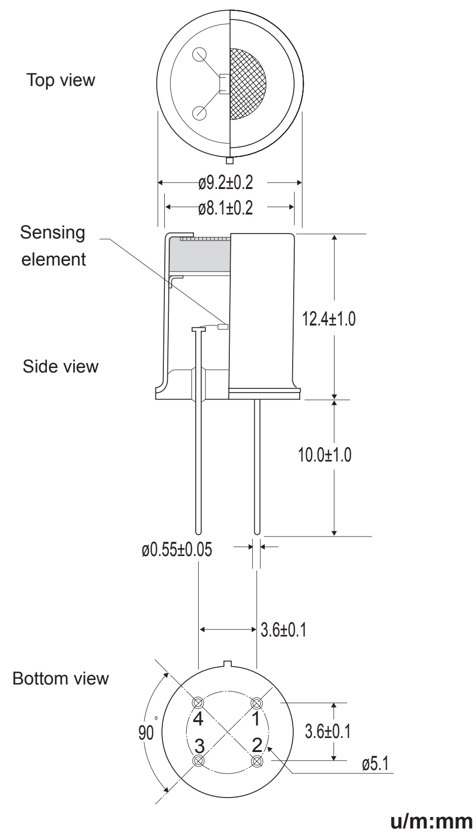
Item	Specification
Sensor resistance (1800ppm iso-butane)	1.2kΩ ~ 12.0kΩ
Sensor resistance ratio (ß)	0.37 ~ 0.60
ß = Rs(3000ppm iso-butane)/Rs(1000ppm iso-butane)	
Heater current (R_H)	56 ± 5mA
Heater power consumption (P_H)	approx. 280mW

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*



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

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 (pin from base) - withstand force of 5kg in each direction
Vibration - frequency-1000c/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 TGS2610-D00 to various gases. The Y-axis shows the ratio of the sensor resistance in various gases (Rs) to the sensor resistance in 1800ppm of iso-butane (Ro).

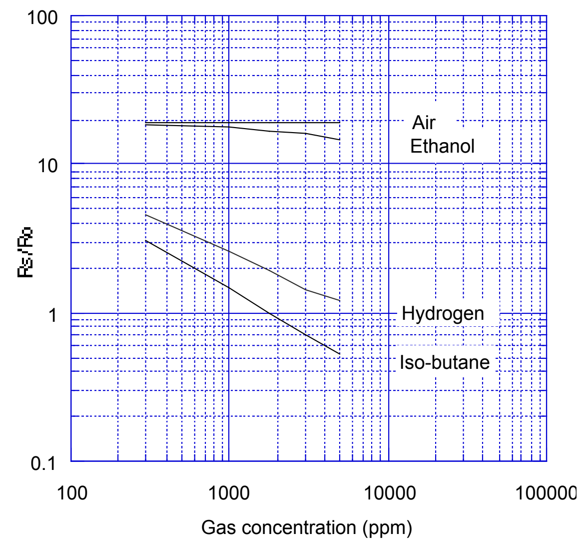


Fig. 4 - Sensitivity to various gases (Rs/Ro)

Using the basic measuring circuit illustrated in Fig. 2, and with a matched RL value equivalent to the Rs value in 1800ppm of iso-butane, will provide the sensor output voltage (VRL) change as shown in Figure 5.

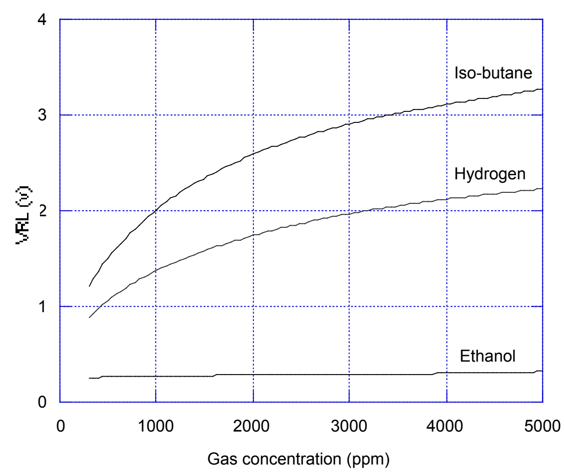


Fig. 5 - Sensitivity to various gases (VRL)

<u>NOTE</u>:
All sensor characteristics in this technical brochure represent typical sensor characteristics. Since the Rs 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'*).

2-2 *Temperature and humidity dependency*

Figure 6 shows the temperature and humidity dependency of TGS2610. The Y-axis shows the ratio of sensor resistance in 1800ppm of iso-butane under various atmospheric conditions (Rs) to the sensor resistance in 1800ppm of iso-butane at 20˚C/65%RH (Ro).

RH / (˚C)	35%RH	50%RH	65%RH	80%RH	95%RH
-10			2.14		
5			1.28	1.19	1.13
20	1.12	1.09	1.00	0.83	0.73
35	0.81	0.75	0.72	0.60	0.59
50	0.64	0.52	0.53	0.45	0.47

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

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

Figure 7 shows the sensitivity curve for TGS2610 to iso-butane under several ambient conditions. While temperature may have a large influence on absolute Rs values, this chart illustrates the fact that effect on the slope of sensor resistance ratio (Rs/Ro) 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'*).

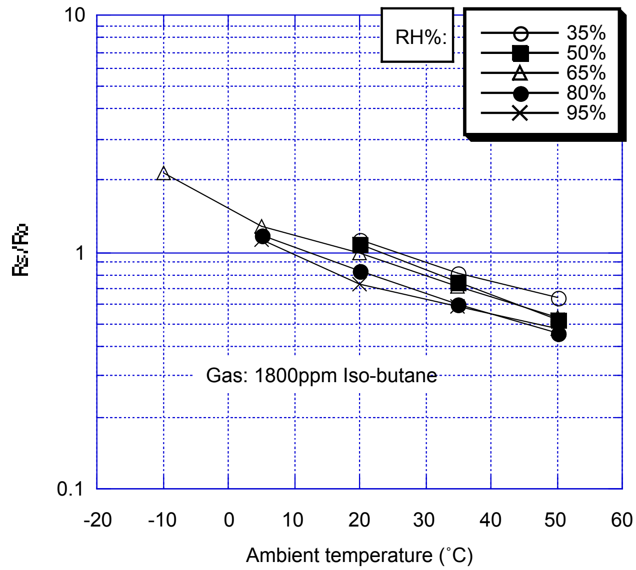


Fig. 6 - Temperature and humidity dependency (Rs/Ro)

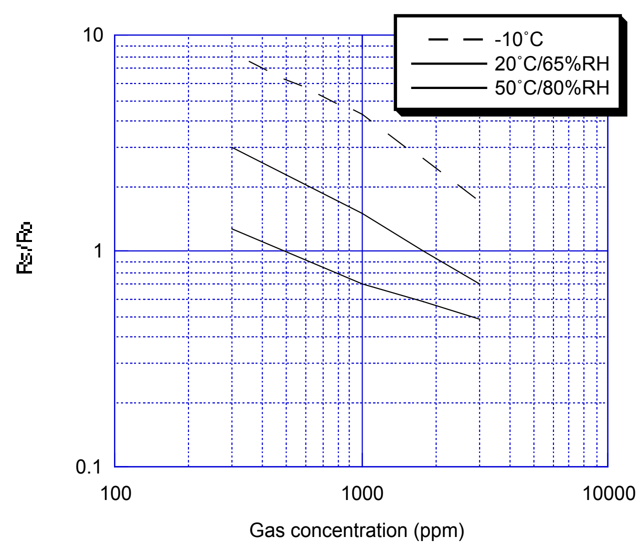


Fig. 7 - Sensor resistance
under various ambient conditions

2-3 *Heater voltage dependency*

Figure 8 shows the change in the sensor resistance ratio according to variations in the 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.

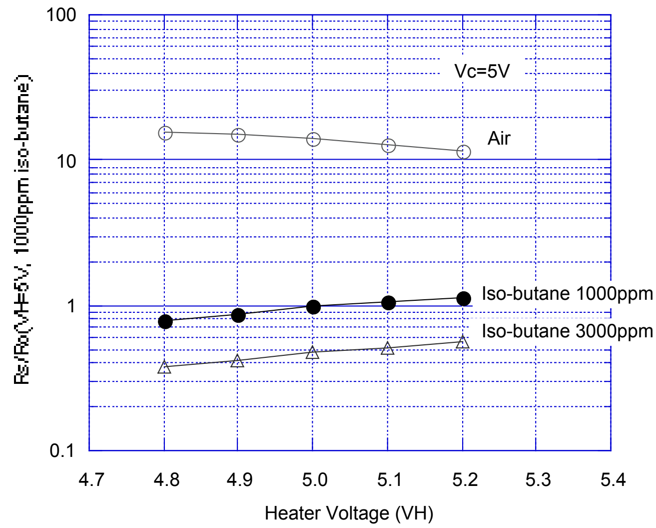


Fig. 8 - Heater voltage dependency (Vc=5.0)

2-4 *Gas response*

Figure 9 shows the change pattern of sensor resistance (Rs) when the sensor is inserted into and later removed from 1800ppm of iso-butane.

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.

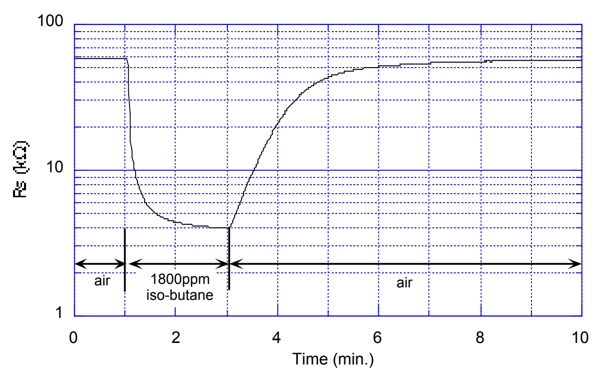


Fig. 9 - Gas response to iso-butane of TGS2610-D

Figure 10 demonstrates the sensor's repeatability by showing multiple exposures to a 1800ppm concentration of iso-butane. 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.

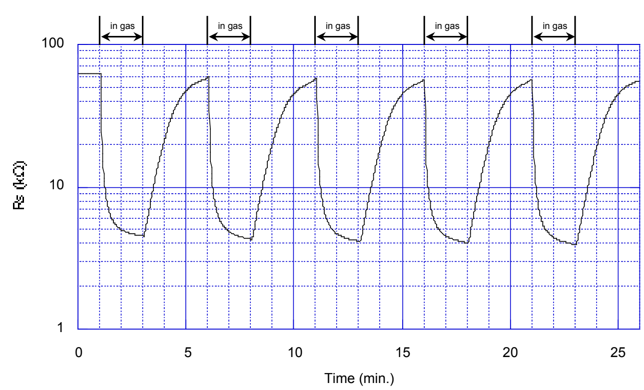


Fig. 10 - Repeatability

2-5 *Initial action*

Figure 11 shows the initial action of the sensor resistance (Rs) for a sensor which is stored unenergized in normal air for 30 days and later energized in clean air.

The Rs 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.

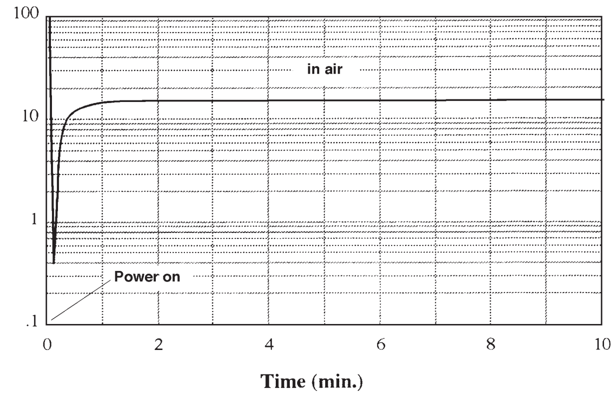


Fig. 11 - Initial action

2-6 *Long-term characteristics*

Figure 12 shows long-term stability of TGS2610-D00 as measured for more than 1800 days. The sensor is first energized in normal air. Measurement for confirming sensor characteristics is conducted under standard test conditions. The initial value of Rs was measured after two days energizing in normal air at the rated voltage. The Y-axis represents the sensor resistance in air, 1800ppm of iso-butane, 2200ppm of propane, and 1000ppm of hydrogen.

The Rs in iso-butane is very stable over the test period.

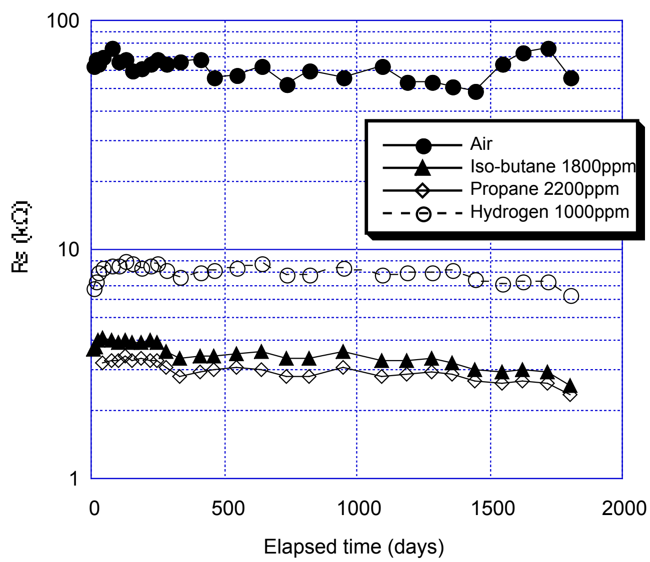


Fig. 12 - Long-term stability (continuous energizing) of TGS2610-D

3. Reliability

3-1 *Ignition test (*)*

TGS2610 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 effects of silicone vapor on TGS2610. Prior to exposure to HMDS (hexamethyl disiloxane), the sensor resistance in normal air (Ro) was measured. Next, energized sensors were placed into an environment of 20°C/65%RH and then exposed to 10ppm of HMDS for 2 hours. This condition is 36 times longer than that specified in Item 5.3.13 of the European standard (EN50194). After exposure, the sensor was returned to normal air. Sensor resistance (Rs) was then measured in air, and 1000 and 3000ppm of iso-butane. These measurements were taken one hour and 10 days after being removed from HMDS.

As this data would suggest, sensor characteristics remain largely unaffected by exposure to HMDS gas concentrations specified by performance standards. Higher HMDS gas concentrations may affect sensor characteristics. Silicone vapor (which is of a low molecular weight) can easily be thermally decomposed to silicone dioxide (SiO2) at the sensor's working temperature. Decomposed SiO2 would cause deactivation of the catalyst in the sensing material and therefore decrease the sensor's resistance in air, altering its sensitivity to gas.

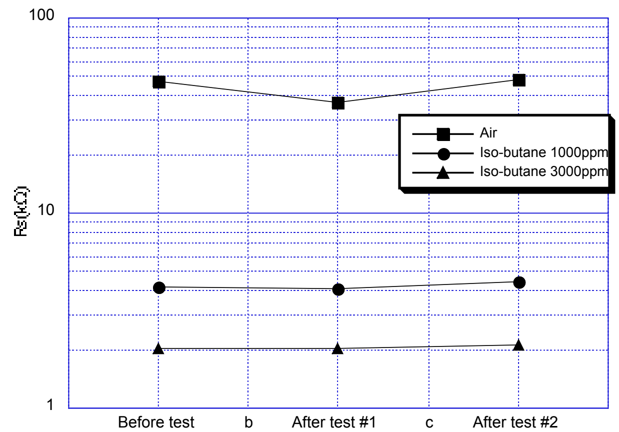


Fig. 13 - HMDS test

3-3 *Effect of air flow*

Figure 15 shows how the sensor signal (VRL) is affected by air flow. The test procedure involves situating the sensor in an air stream of 3.1 meters per second, with the air flow vertical/horizontal to the flameproof stainless steel double gauze of the sensor's housing.

The decrease in sensor signal shown in Figure 15 resulted from the decrease in sensor element temperature caused by the air flow. As a result, direct air flow on the sensor should be avoided.

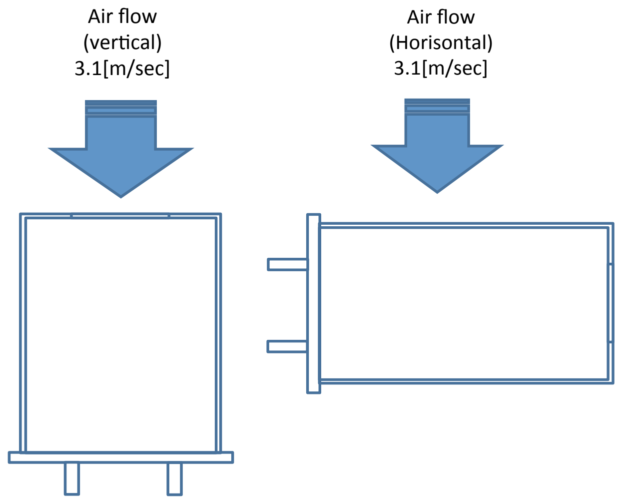


Fig. 14 - Direction of air flow test

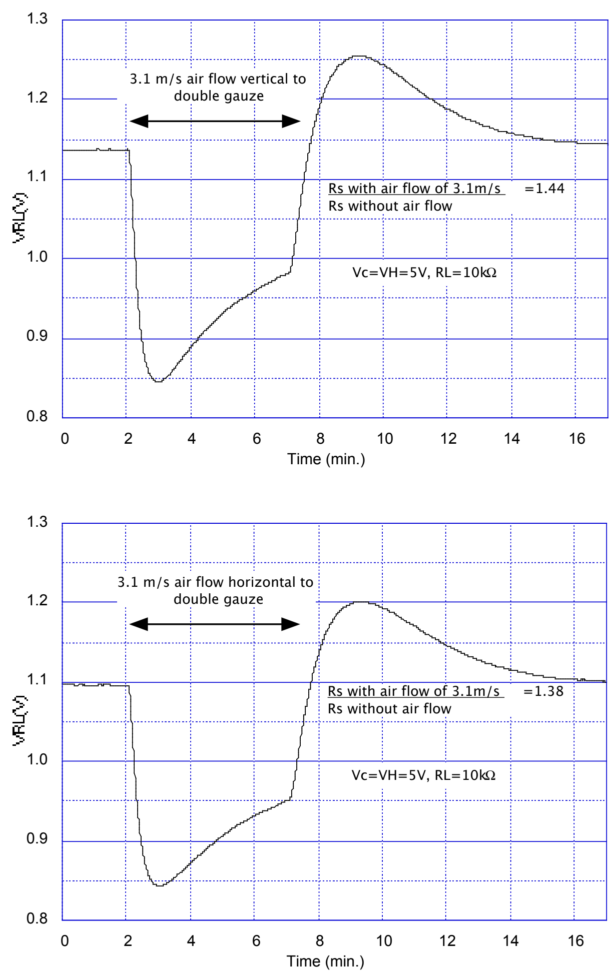


Fig. 15 - Effect of air flow

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

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 H_2S, SO_x, Cl_2, 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) Polarization
These sensors have polarity. Incorrect Vc connection may cause significant deterioration of long term stability. Please connect Vc according to specifications.

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 TGS2610 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, TGS2610 is classified into 24 groups according to the each sensor's Rs in isobutane. 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 TGS2610-D00*" for more information.

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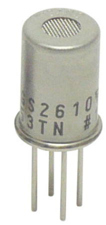
an ISO9001 company

Application Notes for LP Gas Detectors using TGS2610-D00

The TGS2610-D00 LP gas sensor has been presorted into groupings which will allow users to simplify the manufacturing process for LP gas detectors. This brochure offers example application circuits and important technical advice for designing and manufacturing gas detectors which use classified TGS2610-D00 sensors.



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.

TGS2610-D00 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 propane; other characteristics shown in this brochure have not been confirmed by UL as part of component recognition.*

To facilitate ease in manufacturing gas detectors, TGS2610-D00 LP 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 isobutane. 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.

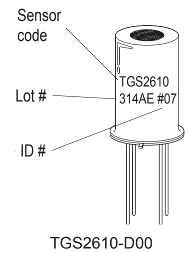


Fig. 1 - Sensor markings

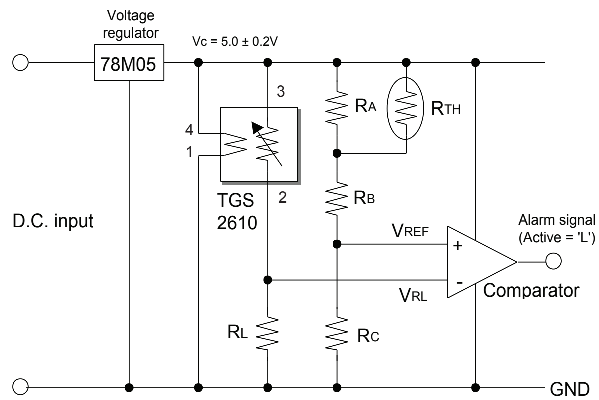


Fig. 2 - Basic circuit with temperature compensation

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 compen-sation for variations caused by ambient temperature fluctuations. Typical values for the circuit components are as follows:

R_L : refer to Table 1
R_{TH} : 5.0kΩ (±3%), B=4100 (±5%)
R_A : 7.50kΩ (±1%)
R_B : 1.00kΩ (±1%)
R_C : 4.42kΩ (±1%)

The values for components related to temperature compensation should be chosen so that Vref is one-half of the Vc value at standard temperature (20˚C). The Vref 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 (Rs) at the alarming concentration (i.e. $Rs/R_L = 1.0$). Please refer to the brochure "*General Information for TGS Sensors*" for more details.

Since the ID number corresponding to sensor resistance in isobutane 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 1.27kΩ. 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 (Vc).

Sensor ID#	RL with ±1% tolerance			
	5% LEL	10% LEL	15% LEL	20% LEL
07	2.00	1.27	0.976	0.787
08	2.21	1.40	1.07	0.887
09	2.49	1.54	1.18	0.976
10	2.74	1.69	1.30	1.07
11	3.01	1.87	1.43	1.18
12	3.24	2.05	1.58	1.30
13	3.57	2.26	1.74	1.43
14	3.92	2.49	1.91	1.58
15	4.32	2.74	2.10	1.74
16	4.75	3.01	2.32	1.87
17	5.23	3.32	2.55	2.10
18	5.76	3.65	2.80	2.32
19	6.34	4.02	3.09	2.55
20	6.98	4.42	3.40	2.80
21	7.68	4.87	3.74	3.09
22	8.45	5.36	4.12	3.40
23	9.31	5.90	4.53	3.74
24	10.5	6.49	4.99	4.12
25	11.3	7.15	5.49	4.53
26	12.4	7.87	6.04	4.99
27	13.7	8.66	6.65	5.49
28	15.0	9.53	7.32	6.04
29	16.9	10.5	8.06	6.65
30	18.2	11.5	8.87	7.32

Table 1 - Recommended R_L by sensor ID

Note: *Lower explosion limit (LEL) of isobutane = 18,000ppm*

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 Vref=1/2 Vc.

ΔT (˚C)	Rc (kΩ)
0	4.42
5	4.02
10	3.57
15	3.24
20	2.94

ΔT= (temp near themistor)-(temp outside detector)

Table 2 - Effect on selection of Rc 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 (3.57Ω±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 (Vc) of 5.2V should be applied to a circuit which incorporates a heater malfunction detection circuit.

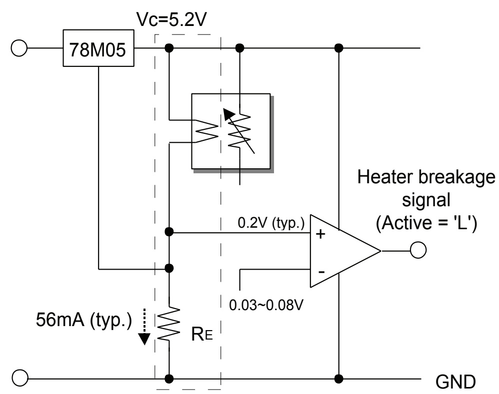


Figure 3 - Heater breakage detection circuit
(R_E = 3.57Ω±1%)

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 $R_{C1}/R_{C2}\approx 50$. Since V_{RL} is normally greater than 50mV in any atmospheric conditions, by comparing V_{RL} to a reference voltage of 50mV, breakage of the lead wires and/or sensor element can be considered to have occurred if V_{RL} drops below 50mV.

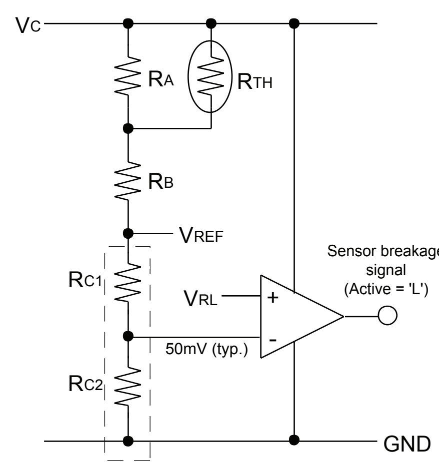


Figure 4 - Sensor malfunction detection circuit
($R_{C1}/R_{C2}\approx 50$)

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 Rc). 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.

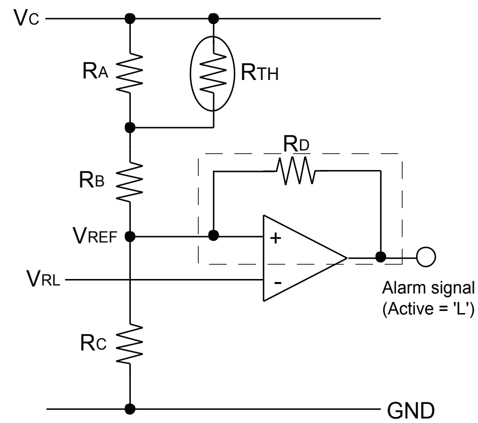


Figure 5 - Circuit for prevention of intermittent alarming
(R_D/R_C = 20~30)

1-7 *Alarm prevention during warm-up*

As described in Sec. 2-5 of "*Technical Information for TGS2610-D00*", when energizing the sensor after an unpowered period, the sensor's resistance (Rs) 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 Vref. 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 5kΩ.

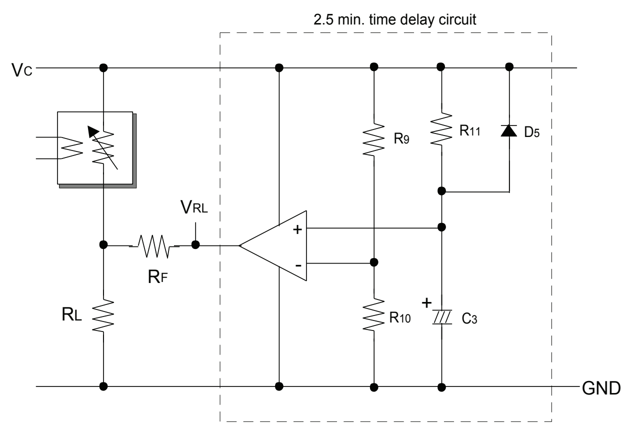


Figure 6 - Circuit for alarm prevention during warmup
(R_F > 5kΩ)

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 C_4 and R_{15}.

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.

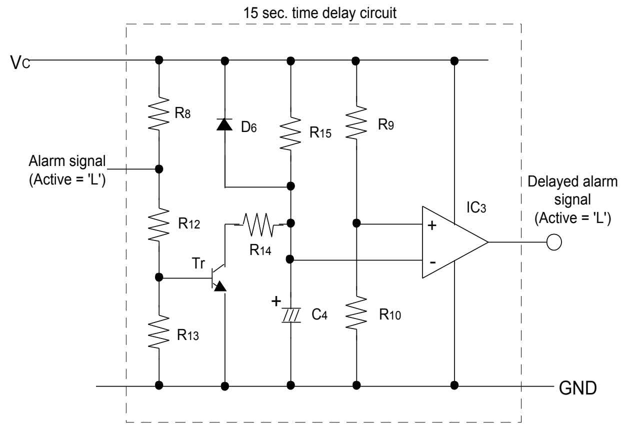


Figure 7 - Alarm delay circuit

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 *R_L selection*
Choose the proper resistor for R_L 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.

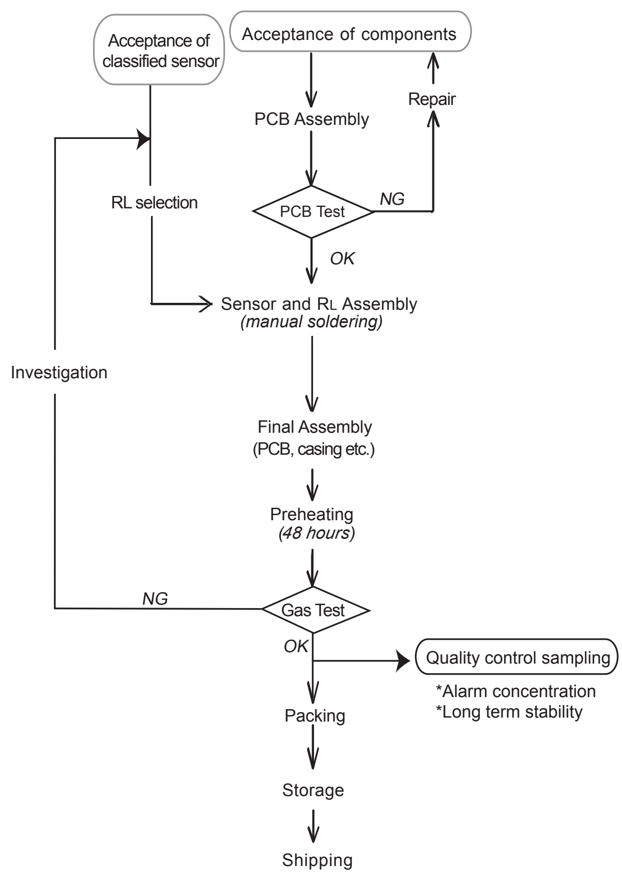


Figure 8 - Manufacturing process flowchart

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 Isobutane

When using the classified TGS2610 with Figaro's recommended R_L for 10%LEL (Table 1) and temperature compensated circuit design (Figure 2), typical alarm tolerances for 10%LEL of isobutane such as those shown in Figure 9 are expected. Each R_L 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 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

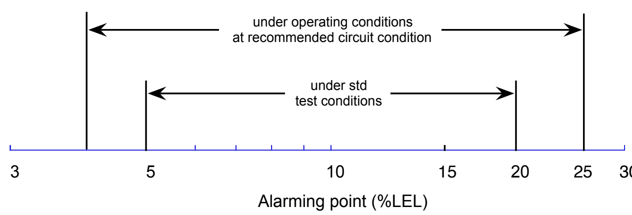


Figure 9 - Expected performance of isobutane detectors with classified TGS2610 & recommended R_L for 10% LEL (*refer to Table 3 for test conditions*)

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 isobutane 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 isobutane sensor module LPM2610-D09 (*see Fig. 10*). This module includes the classified TGS2610-D00 sensor, a matched load resistor, and a factory preset temperature compensation circuit, all on a small PC board. The LPM2610-D09 module is calibrated for a typical set point at 10% LEL, insuring performance as indicated in Table 3 by simply plugging it into a main PC board. Please refer to the brochure "*Product Information for LPM2610-D09*" for detailed information.

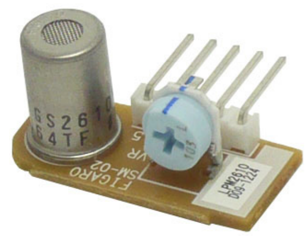


Figure 10 - Pre-calibrated sensor module LPM2610-D09

<u>Important Reminder</u>
Without testing alarm threshold after final assembly, detectors have no accuracy or reliability guarantee.

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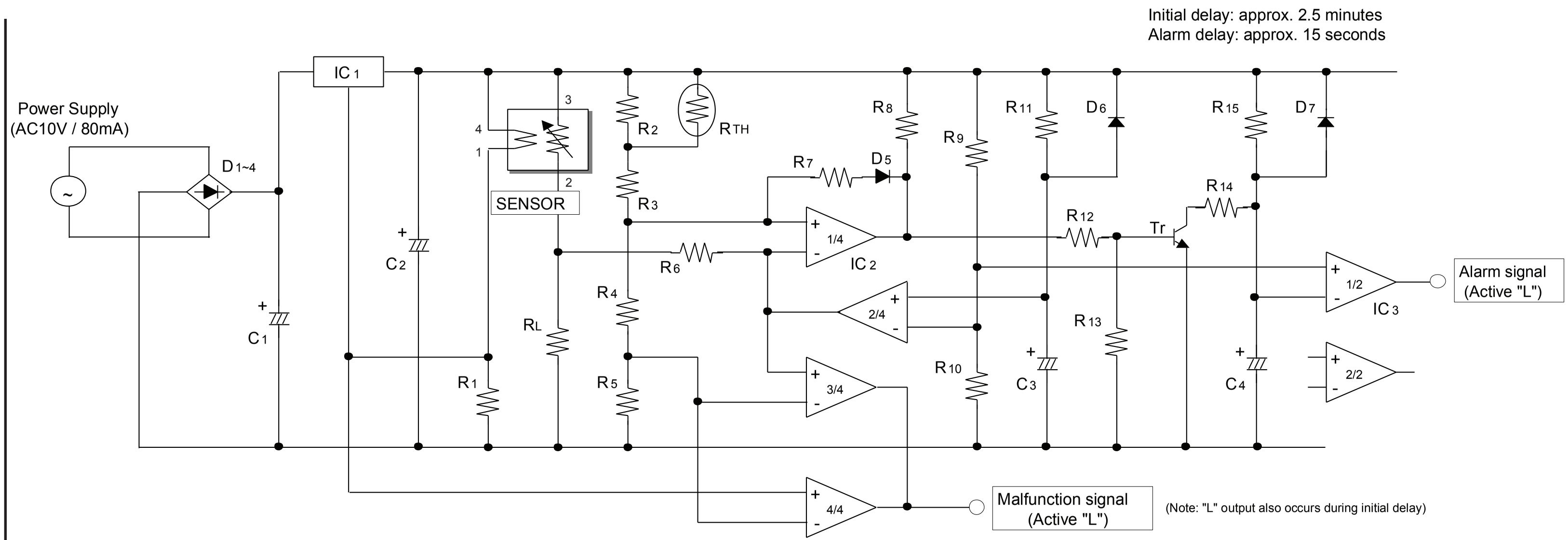
Appendix 1 - Example application circuit for gas detector using classified TGS2610



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		R_9	Resistor	10kΩ, 5%, 1/8W			D_1	Rectification diode	S5566G	Toshiba
R_{TH}	NTC thermistor	5kΩ, B=4100			R_{10}	Resistor	10kΩ, 5%, 1/8W			D_2	Rectification diode	S5566G	Toshiba
R_L	Resistor	(See Table 1), 1%, 1/8W			R_{11}	Resistor	470kΩ, 5% 1/8W			D_3	Rectification diode	S5566G	Toshiba
R_1	Resistor	3.57Ω, 1%, 1/2W			R_{12}	Resistor	10kΩ, 5%, 1/8W			D_4	Rectification diode	S5566G	Toshiba
R_2	Resistor	7.5kΩ, 1%, 1/8W			R_{13}	Resistor	10kΩ, 5%, 1/8W			D_5	Small signal diode	1S1488	Toshiba
R_3	Resistor	1.0kΩ, 1%, 1/8W			R_{14}	Resistor	10kΩ, 5%, 1/8W			D_6	Small signal diode	1S1488	Toshiba
R_4	Resistor	4.32kΩ, 1%, 1/8W			R_{15}	Resistor	470kΩ, 5% 1/8W			D_7	Small signal diode	1S1488	Toshiba
R_5	Resistor	86.6Ω, 1%, 1/8W			C_1	Electrolytic capacitor	470μF/25V			Tr	NPN transistor	2SC2603	Mitsubishi
R_6	Resistor	10kΩ, 5%, 1/8W			C_2	Electrolytic capacitor	10μF/10V			IC_1	Voltage regulator	MC78M05CT	Motorola
R_7	Resistor	130kΩ, 5%, 1/8W			C_3	Electrolytic capacitor	470μF/10V, 10%			IC_2	Comparator	LM339	Motorola
R_8	Resistor	10kΩ, 5%, 1/8W			C_4	Electrolytic capacitor	470μF/10V, 10%			IC_3	Comparator	LM393	Motorola