FIGARO

an ISO9001 company

Technical Information for Combination Methane and Carbon Monoxide Sensors

The Figaro TGS3870-F00 sensor is a small bead-type metal oxide semiconductor. The sensor's miniature size and cyclic heater operation enable its single sensing element to be highly selective to both carbon monoxide and methane and to show low power consumption.

See also Technical Brochure "Technical Information on Usage of TGS Gas Sensors for Explosive/Toxic Gas Alarming".

TGS3870 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 and 15ppm of carbon monoxide; other characteristics shown in this brochure have not been confirmed by UL as part of component recognition.*

1. Specifications

1-1 *Features*

* Miniature size and low power consumption
* High sensitivity and selectivity to both methane and carbon monoxide (CO)
* Low sensitivity to alcohol vapor
* Long life and low cost

1-2 *Applications*

* Combination methane and CO detectors

1-3 *Structure*

Figure 1 shows the structure of TGS3870-F00. A heater coil and an electrode are embedded in a small bead of SnO_2 sensing material. The heater is connected to pin Nos. 1 and 3 while the electrode is connected to pin No. 2. Both the heater and the electrode are composed of Pt wire and are spot welded to sensor pins (made of Ni-Fe 42% alloy).

The sensor base is made of PBT (polybutylene terephthalate), and the sensor cap is made of stainless steel. The upper opening in the cap is covered with a double layer of 100-mesh stainless steel gauze (SUS316) and the sensor cap also has a silica gel/ activated charcoal filter for reducing the influence of interference gases.

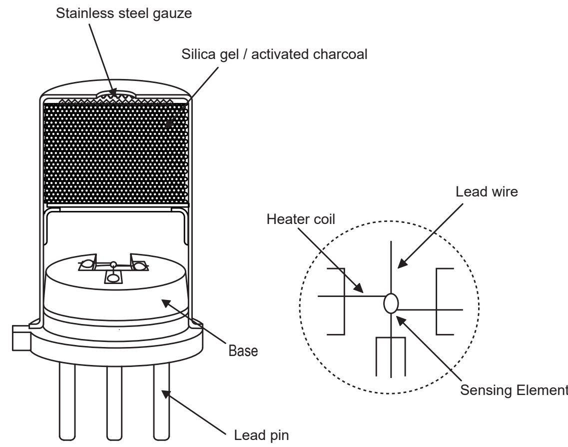

Figure 1 - Sensor structure

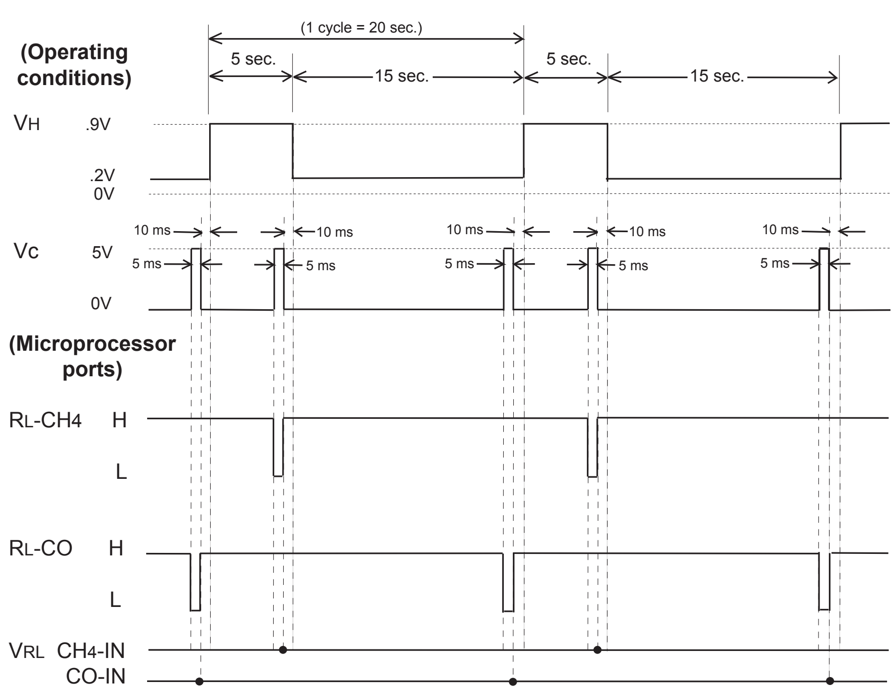

Figure 2 - Timing chart

1-4 *Specifications*

<table>
<tr><td colspan="3">Model number</td><td colspan="2">TGS3870-F00</td></tr>
<tr><td colspan="3">Sensing principle</td><td colspan="2">MOS type</td></tr>
<tr><td colspan="3">Standard package</td><td colspan="2">Plastic base and metal can</td></tr>
<tr><td colspan="3">Target gases</td><td colspan="2">Methane and Carbon Monoxide</td></tr>
<tr><td colspan="3">Typical detection range</td><td colspan="2">Methane 1~25% LEL
Carbon monoxide 50~1,000ppm</td></tr>
<tr><td rowspan="3">Standard circuit conditions</td><td>Heater voltage</td><td>V_H</td><td colspan="2">V_{HH} = 0.9V±3% for 5 sec.
V_{HL} = 0.2V±3% for 15sec.</td></tr>
<tr><td>Circuit voltage</td><td>V_C</td><td colspan="2">5.0±0.2V DC pulse</td></tr>
<tr><td>Load resistance</td><td>R_L</td><td colspan="2">variable (>0.75kΩ)</td></tr>
<tr><td rowspan="8">Electrical characteristics under standard test conditions</td><td>Heater resistance</td><td>R_H</td><td colspan="2">3Ω±0.3Ω at room temp.</td></tr>
<tr><td rowspan="3">Heater power consumption</td><td rowspan="3">P_H</td><td>120mW</td><td>V_{HH} = 0.9V DC</td></tr>
<tr><td>11mW</td><td>V_{HL} = 0.2V DC</td></tr>
<tr><td>38mW</td><td>average</td></tr>
<tr><td rowspan="2">Sensor resistance</td><td rowspan="2">R_S</td><td colspan="2">0.3kΩ~5.0kΩ in 3000ppm methane</td></tr>
<tr><td colspan="2">2kΩ~40kΩ in 200ppm CO</td></tr>
<tr><td rowspan="2">Sensitivity (change ratio of Rs)</td><td rowspan="2">β</td><td>0.44~0.7</td><td>$\frac{R_S (3000ppm\ CH_4)}{R_S (1000ppm\ CH_4)}$</td></tr>
<tr><td>0.3~0.8</td><td>$\frac{R_S (300ppm\ CO)}{R_S (200ppm\ CO)}$</td></tr>
<tr><td rowspan="3">Standard test conditions</td><td colspan="2">Test gas conditions</td><td colspan="2">Target gas in air
at 20±2°C, 65±5%RH</td></tr>
<tr><td colspan="2">Circuit conditions</td><td colspan="2">V_{HH} = 0.9V±2% for 5 sec.
V_{HL} = 0.2V±2% for 15 sec.
V_C = 5.0±0.02V DC pulse</td></tr>
<tr><td colspan="2">Conditioning period before test</td><td colspan="2">≥5 days</td></tr>
</table>

<u>NOTE</u>: *Caution should be exercised in the selection of the load resistor (R_L) to ensure that power consumption (P_S) does **<u>not</u>** exceed 15mW.*

$$P_S = (V_{RS})^2/R_S$$

P_S reaches max. value when: $R_L = R_S$

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

$$R_S = \frac{(V_{RS} - 0.5V_H)}{(V_C - V_{RS})} \times R_L$$

Mechanical Strength:

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

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

<u>Vibration</u> - vertical amplitude=1.5mm, frequency=10~500Hz, duration= 3 hours, direction=x,y,z (all)

<u>Shock</u> - acceleration-100G, repeat 5 times

1-5 *Dimensions*

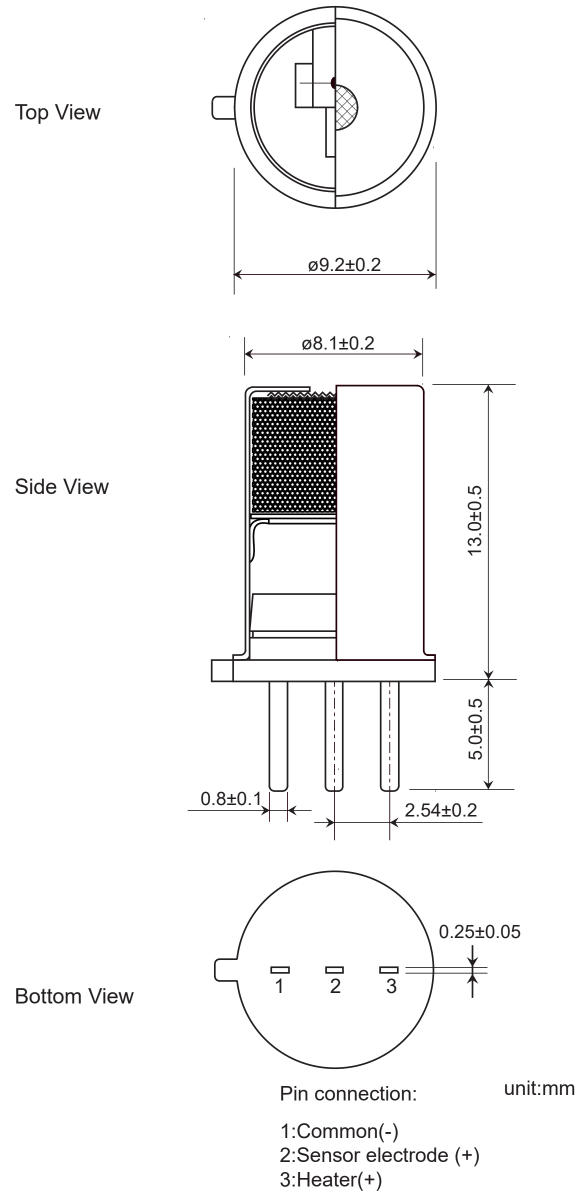

Figure 3 - Dimensions

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 *Standard test conditions*

Standard test conditions for all data shown in this brochure were as follows:

Preheating of sensor: 5 days
V_H (H/L): 0.9V/0.2V (see timing chart, Fig. 2)
V_C: 5.0V pulse (see timing chart, Fig. 2)

1-7 *Basic measuring circuit*

The sensor requires two voltage inputs: heater voltage (V_H) and circuit voltage (V_C). The sensor has three pins: Pin #3--heater (+), Pin #2--sensor electrode (+), and Pin #1--common (-). To maintain the sensing element at specific temperatures which are optimal for sensing two different gases, heater voltages of 0.9V and 0.2V are alternately applied between pins #1 and #3 during a 20 second heating cycle (*see Fig. 2*).

Circuit voltage (V_C) is applied between both ends of the sensor (Rs) and a load resistor (R_L), which are connected in series, to allow measurement of voltage (V_{RS}) as shown in Figure 4.

Circuit voltage (Vc) should be applied only at the moment when the signal is taken from the sensor (*please refer to Fig. 2*):

*for methane--5.0V for 5msec. following V_H of 0.9V for 4.985 sec.
*for CO--5.0V for 5 msec. following V_H of 0.2V for 14.985 sec.

Caution: Do not apply a constant circuit voltage (5.0V) or the sensor would not exhibit its specified characteristics.

2. Basic Sensitivity Characteristics

2-1 *Sensitivity to various gases*

Figures 5a and 5b show the sensor's relative sensitivity to various gases. Figure 5a shows the characteristics for methane sensing, while Figure 5b shows the characteristics for sensing of CO. The Y-axis for each figure shows the ratio of sensor resistance in various gases (Rs) to the sensor resistance in 3000ppm of methane (Fig. 5a) and in 150ppm of CO (Fig. 5b).

As shown by Figure 5a, TGS3870-F00 shows very good sensitivity to methane and good selectivity when compared with hydrogen.

Excellent sensitivity to CO is shown in Figure 5b as evidenced by the sharp drop in sensor resistance as CO concentration increases. Selectivity is also quite

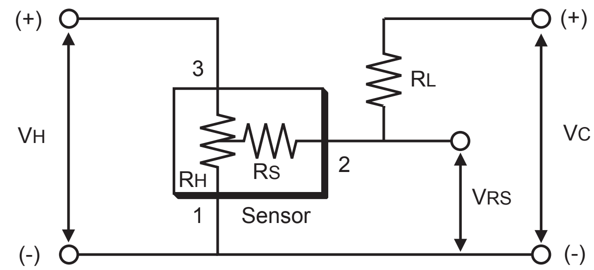

Figure 4 - Basic measuring circuit

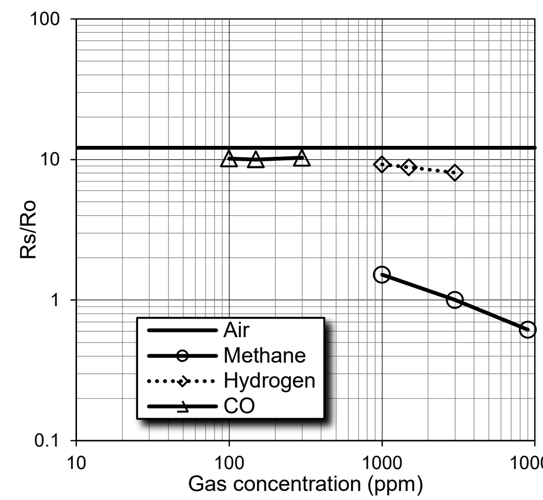

Figure 5a - Sensitivity to various gases for methane sensing
(Ro = Rs in 3000ppm of CH_4, V_H =0.9)

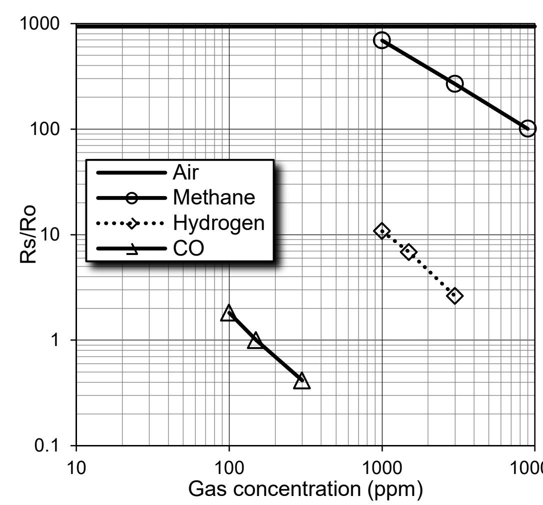

Figure 5b - Sensitivity to various gases for CO sensing
(Ro = Rs in 150ppm of CO, V_H =0.2)

good. In comparison to CO, sensitivity to hydrogen is very low as indicated by the extremely high concentrations of hydrogen required to approximate very low CO levels. Cross-sensitivity to methane is very low according to its high resistance values.

2-2 *Temperature dependency*

Figures 6a and 6b show the temperature dependency of TGS3870-F00. The Y-axis shows the ratio of sensor resistance for gas concentrations under various atmospheric conditions (Rs) to the sensor resistance at 20˚C and 65%RH (Ro) for 3000ppm of methane (Fig. 6a) and for 150ppm of CO (Fig. 6b).

An inexpensive way to compensate for temperature dependency would be to incorporate a thermistor in the detection circuit. Separate compensation circuits should be prepared for CO and methane sensing.

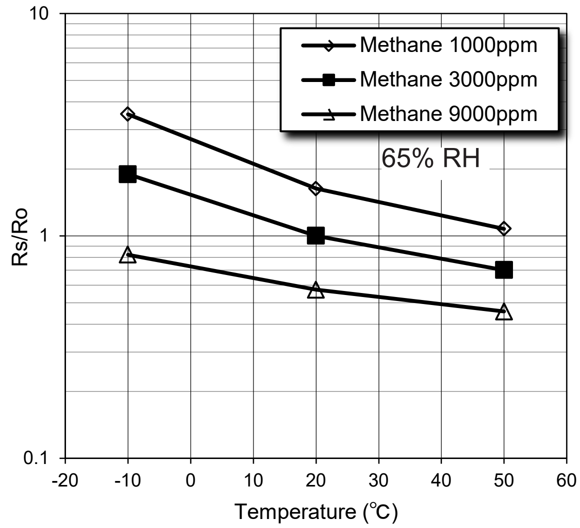

Figure 6a - Temperature dependency for methane sensing
(Ro = Rs in 3000ppm of CH_4 at 20˚C/65%RH, V_H =0.9)

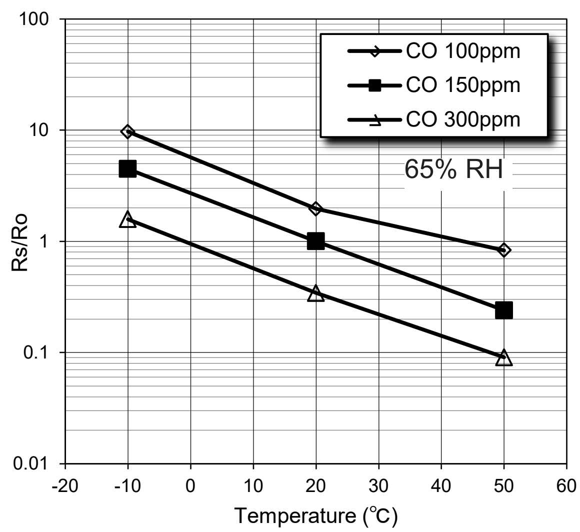

Figure 6b - Temperature dependency for CO sensing
(Ro = Rs in 150ppm of CO at 20˚C/65%RH, V_H =0.2)

2-3 *Gas response*

Figures 7a and 7b show the change patterns of sensor resistance (Rs) when the sensor is inserted into and later removed from 3000ppm of methane and 150ppm of carbon monoxide respectively. Measurements were taken every 20 seconds.

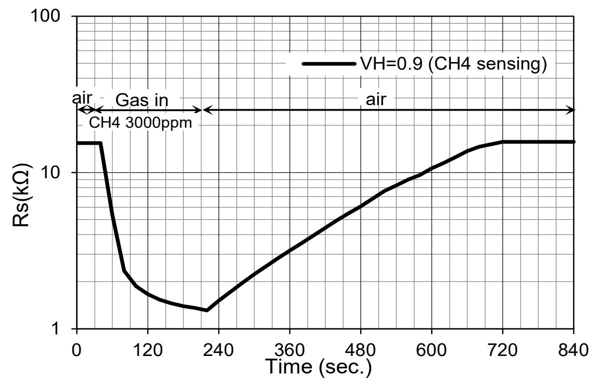

Figure 7a - Gas response speed - methane

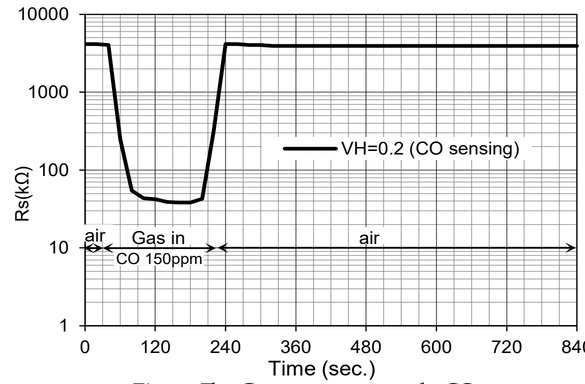

Figure 7b - Gas response speed - CO

2-4 *Long-term stability*

Figures 8a and 8b show long-term stability data for TGS3870-F00. Test samples were energized in normal air and under standard circuit conditions (*see p.4*). Measurement for confirming sensor characteristics was conducted under standard test conditions (20˚C, 65%RH). The initial value was measured after two days of energizing in normal air at standard test conditions (*see p.4*). The Y-axis shows the ratio between measured sensor resistance and the initial (Day 0) resistance value in 3000ppm of methane (Fig. 8a) and in 150ppm of CO (Fig. 8b).

The characteristics for both CO and methane sensing are very stable for more than 350 days.

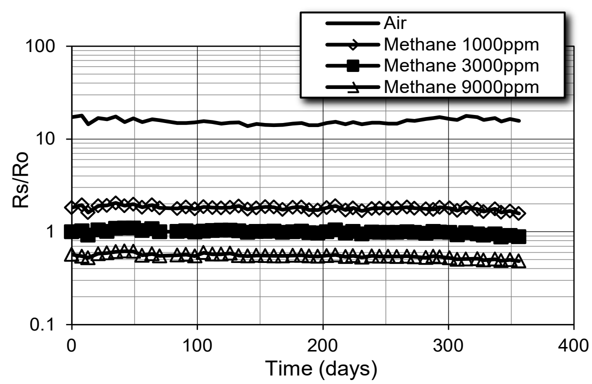

Figure 8a - Long term stability for methane sensing
(Ro = Rs in 3000ppm of CH_4 at Day=0, V_H =0.9)

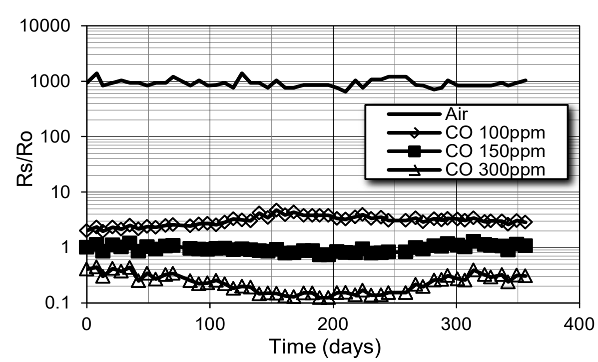

Figure 8b - Long term stability for CO sensing
(Ro = Rs in 150ppm of CO at Day=0, V_H =0.2)

3. Cautions

3-1 *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
The sensor has polarity. An incorrect Vc connection may cause significant detrioration of long term stability. Connect Vc according to specifications.

9) Soldering
Sensors should be manually soldered--wave soldering is not recommended. The high heat generated during wave soldering may deform the resin parts and damage the sensor (e.g. the pressure-fitted sensor cap may separate from the base). For sensors with a filter cap (such as TGS3870-F00), deformation may create a gap between the sensor cap and base, alllowing interference gases to bypass the filter.

3-2 *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 <u>not</u> 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.

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