# Relative Pressure Sensor for Automobile Fuel Tanks

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**ABSTRACT**

In recent years, there has been increasing regulation to reduce the environmental burden of automobiles. One example of such regulation is the requirement to detect fuel leaks in the United States. Fuji Electric has developed a relative pressure sensor for automobile fuel tanks capable of being directly mounted to a pipe inside the engine room. The sensor is used for controlling vaporized fuel exhaust suppression devices that recover vaporized fuel to incinerate it in the cylinder. Based on our 6th-generation compact pressure sensor technology, we have successfully improved resistance to vaporized fuel, enhanced protective functions and reinforced EMC to both ensure durability and achieve high-precision detection.



## 1. Introduction

Automobiles have come to be demanded strictly to reduce the environmental burden in addition to the provision of safety and comfort. One example is the obligatory requirement to detect fuel leaks by on-board diagnostics (OBD) regulations in the U.S. market. Emission of vaporized fuel into the atmosphere may cause danger of ignition due to static electricity or change into air pollutants through chemical reactions. These regulations are intended for suppressing leaks of vaporized fuel in order to reduce danger and environmental burden. For the purpose of meeting these regulations, Fuji Electric developed the relative pressure sensor that is capable of detecting the differential pressure between 2 points with one chip for detecting fuel tank leaks[(1)], which was commercialized in 2007.

For controlling fuel evaporative gas emission control units that return vaporized fuel to the cyclinder to incinerate it, we have now developed a relative pressure sensor for detecting the automobile fuel tank pressure (tank pressure sensor) that can be directly mounted in the evaporation line*1 .

## 2. Features of Tank Pressure Sensor

Figure 1 shows the external appearance of the tank pressure sensor. Conventionally, the basic concept of Fuji Electric's pressure sensors has been to maximize the features of the one chip technology for providing compact, high-reliability products. Tank pressure sensors incorporate additional new features as described below.

(1) Improvement of resistance to vaporized fuel

Vaporized fuel may cause deterioration of the die bond material that constitute pressure sensors and destruction failure arising from it. The tank pressure sensor has achieved resistance to pressure media containing vaporized fuel while ensuring the conventional high reliability by selecting a material not degenerated by contact with vaporized fuel.

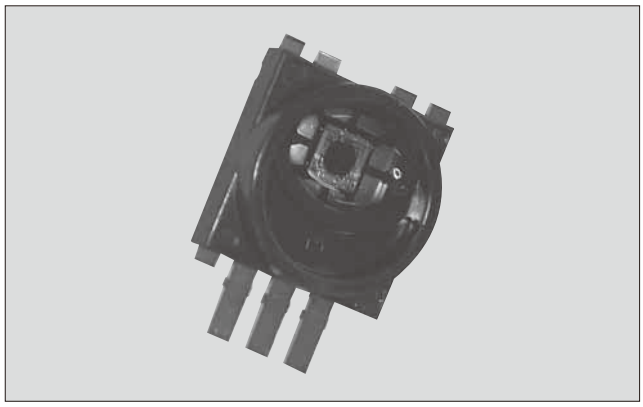

Fig.1 Appearance of tank pressure sensor

(2) Improvement of protective function

The tank pressure sensor, which is mounted inside an engine, is a relative pressure sensor that detects the differential pressure between the atmospheric pressure and the fuel pipe pressure, which subjects it to the constant risk of foreign objects from inside and outside the automobile. To deal with this problem, we have covered the both pressure receiving sides with a gelatinous protective material to achieve protection of the sensor chip from foreign objects and high-precision pressure detection at the same time. In addition, an air filter is provided on the atmospheric pressure receiving side of the sensor cell. Thus, the protective

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*1: Evaporation line: Fuel carrying line for returning vaporized fuel to a cyclinder to incinerate it

function against foreign objects from outside is further improved.

(3) Enhancement of EMC

Recently, various electronic devices are mounted on automobiles and enhancement of electromagnetic compatibility (EMC) against the electromagnetic noise from those devices is needed. We have followed the conventional technology of integrating the sensing unit, signal processing unit and surge protection device into one chip. Additionally, we have mounted a chip capacitor on it to achieve the improvement of EMC while maintaining the same size.

## 3. Structure of Tank Pressure Sensor

### 3.1 Pressure detection unit

Figure 2 shows the pressure detection unit. Part of the Si substrate is processed into a thin film by etching to form a diaphragm. On top of the diaphragm, piezoresistors made of diffusion line are provided and 4 piezoresistors constitute a Wheatstone bridge. The 3D etching technology at which Fuji Electric excels has made it possible to form a diaphragm in a round and isotropic shape with high precision, which ensures high sensitivity and resistance to excessive pressure.

Diaphragm pressure sensors detect the deformation generated by the pressure difference (differential pressure) between the 2 sides of the diaphragm as the resistance change of the piezoresistor formed on the surface. Conventional pressure sensors of Fuji Electric are absolute pressure sensors that measure the pressure with reference to a vacuum and the vacuum chamber is provided by bonding the glass spacer using the electrostatic bonding process. Meanwhile, the tank pressure sensor is provided with a pressure medium inlet port in the glass spacer to allow measurement of the differential pressure with the atmospheric pressure.

### 3.2 Signal processing circuit

Figure 3 shows the basic configuration of the signal processing circuit. The signal processing circuit uses the technology for the 6th-generation low pressure sensor (100 to 400 kPa)[2] developed in FY2010 for mass production. The circuit has been optimized for applying it to the tank pressure (−80 to +5 kPa). It is equipped with a high-precision amplifier that amplifies the voltage signal output from the Wheatstone bridge and adjustment circuit that corrects the sensor characteristics. It is also equipped with protective devices for protecting the internal circuit from surge waveforms generated by the engine control system of the automobile, static electricity in the assembly process and electromagnetic waves from outside.

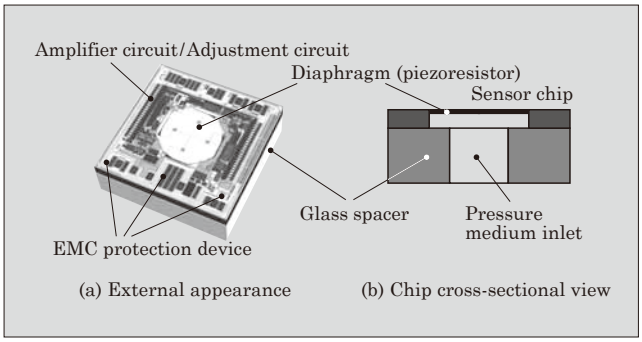


Fig.2 Pressure detection unit

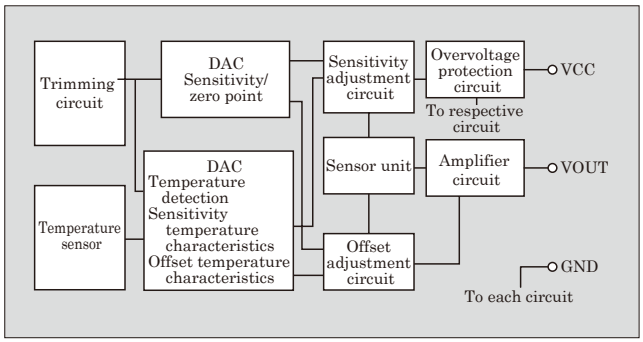


Fig.3 Basic configuration of signal processing circuit

### 3.3 Structure of sensor cell

Figure 4 shows the cross-sectional structures of the sensor cells in the pressure sensor (absolute pressure sensor) and tank pressure sensor (relative pressure sensor). Both sensor cells integrate a chip capacitor for improving EMC. The tank pressure sensor is provided with a pressure inlet port to measure relative pressure. In addition, for ensuring easy replacement with conventional products, dimensions at many points are designed to be the same.

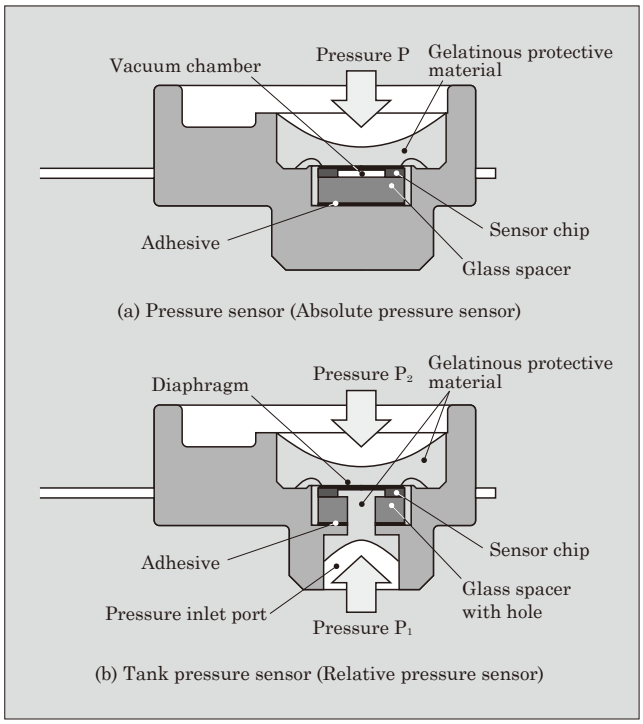


Fig.4 Cross-sectional structure of sensor cell

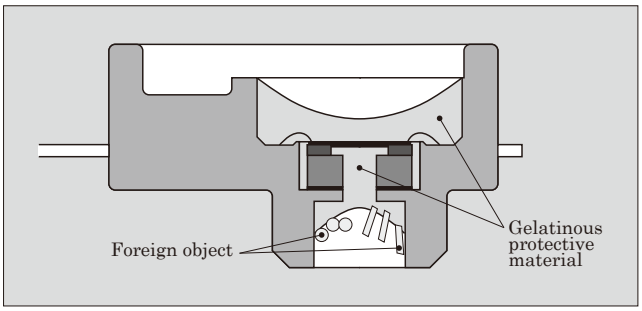


Fig.5 Protection from foreign objects by gelatinous protective material

Fuji Electric's sensor cells have the sensor chip attached by using a adhesive. The tank pressure sensor measures the pressure inside the fuel tank. Therefore, a new adhesive with resistance to fuel has been selected.

Furthermore, as shown in Fig. 5, the entire sensor chip is covered entirely with a gelatinous protective material, which allows for detection of the applied pressure while protecting the internal structure including the sensor chip and wire bonding against foreign objects from outside. This has achieved both higher precision of pressure detection and longer life of the product.

### 3.4 Outer housing structure

Figure 6 shows the cross-sectional structure of the package, which fixes the sensor cell with a resin adhesive to the resin housing case of a direct mount type. This structure can be directly mounted in the evaporation line and we call this an "outer housing structure." The resin adhesive used to fix the sensor cell also has the role of ensuring airtightness and prevents the air containing vaporized fuel entering through the pressure inlet port from flowing into the atmospheric pressure side. The pressure sensor uses an O-ring with the temperature characteristics taken into account for

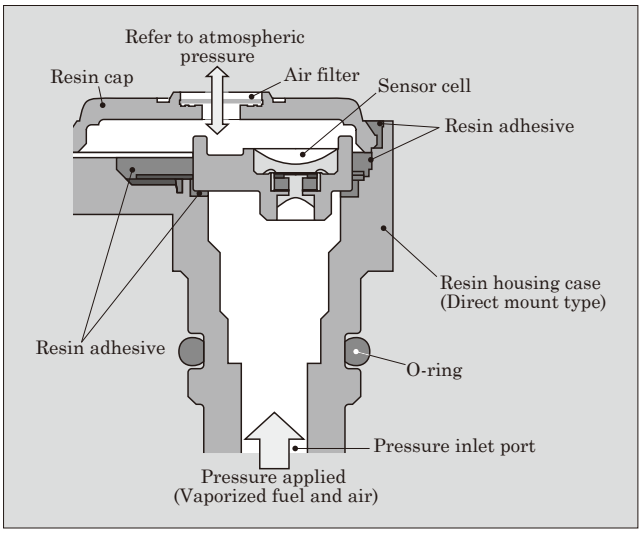


Fig.6 Outer housing structure

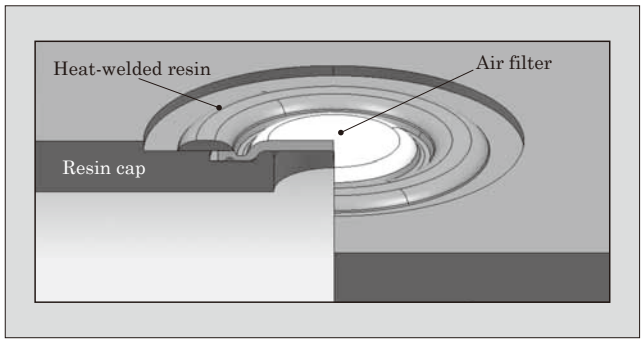


Fig.7 Cross-sectional view of air filter mounting part

ensuring the airtightness at the pressure port. On the other hand, the tank pressure sensor employs an O-ring with resistance to fuel, which has been confirmed to show durability against 32 types of fuel in various countries around the world as well as the temperature characteristics.

This outer housing can be mounted directly in an engine and accommodates various pressure ranges by changing of the internal sensor cell. In addition, the same shape of the outer housing allows the layout around the mounting and the wire harness part to be used without change as they are.

One side of the tank pressure sensor is open to the atmospheric pressure. The pressure sensor is mounted on the pipe in the engine room, so that the sensor is exposed to dust, rainwater, and muddy water, In an environment that allows easy entry of foreign objects and moisture, failure due to wire disconnection and short circuits resulting from such environmental conditions and sensor characteristic errors due to dew condensation and freezing are assumed to occur.

In order to address this problem, we use the gelatinous protective material for the sensor cell to protect the internal structure and provide a resin cap equipped with an air filter for the outer housing. Figure 7 shows a cross-sectional view of the air filter mounting part.

This filter is mounted on the resin cap by heat welding to ensure durability higher than the maximum load to the air filter assumed for use in the engine room. As durability of the filter itself, it satisfies the dust resistance (IP6KX) and water resistance (IPX9K) regulation according to the road vehicle IP test standards specified by the ISO 20653 and JIS D 5020.

This air filter has a property to allow passage of air only and not dust of large particle sizes or liquid. This filter is also water repellent and waterproof. By providing air filter on the resin cap at the atmospheric pressure side, stable pressure detection is realized in an engine room, which is exposed to the entry of dust and muddy water, without being affected by contamination.

### 3.5 Application to EGR and DPF

By using the sensor chip and sensor cell structure

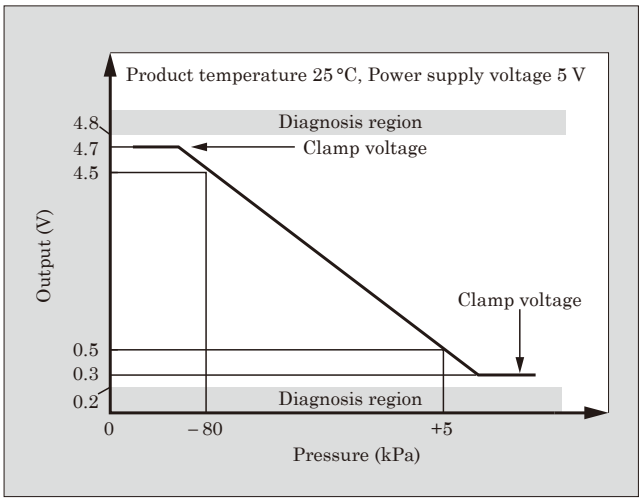


Fig.8 Pressure-output characteristics of tank pressure sensor

Table 1 Basic specifications of tank pressure sensor

| Item | Unit | Specification |
|---|---|---|
| Operating temperature range | °C | −40 to +135 |
| Operating pressure range*1 | kPa | −80 to +5 |
| Sensor output range | V | 0.5 to 4.5 |
| Interface | kΩ | Pull up = 300 or Pull down = 100 |
| Clamp region | V | < 0.3 / > 4.7 |
| Diagnosis region*2 | V | < 0.2 / > 4.8 |
| Sink current | mA | 1 |
| Source current | mA | 0.1 |
| Pressure error | %F.S. | < 1.5 |
| Temperature error | times | 2.0 (max.) |
| Applicable EMC standard | ISO 11452-2<br>(100 V/m, CW, 10 kHz to 2 GHz)<br>ISO 11452-4<br>(100 m, CW, 1 to 400 MHz)<br>ISO 7637 (Level IV) | |
| Applicable fuel | Gasoline<br>Diesel gass oil (DIN EN 590)<br>E10, E25, E85, M15, M100<br>Biodiesel (DIN EN 14214) | |
| Dust resistance of filter | IP6KX | |
| Water resistance of filter | IPX9K | |
| Terminal assign | (Output) - (GND) - (Power supply) | |

*1: Value for pressure applied through pressure inlet port
*2: Detection of power supply line disconnection and output line disconnection

and outer housing structure described previously, the tank pressure sensor has achieved high durability and high-precision detection performance less affected by air containing vaporized fuel or foreign objects. In addition, combining anti-corrosion treatment of the sensor chip allows them to be used for other applications with even harsher installation environment such as exhaust gas recirculation (EGR) or diesel particulate filter (DPF), which suppress generation and emission of environmentally hazardous substances including suspended particulate matters (SPMs), nitrogen oxides and sulfur oxides in exhaust gas.

## 4. Specifications

Figure 8 shows the pressure-output characteristics and Table 1 shows the basic specifications of the tank pressure sensor. The product is configured to have an outer housing structure.

## 5. Postscript

This paper has described the relative pressure sensor for automobile fuel tanks. In the future, the needs of pressure sensors for automotive applications are expected to further increase along with the environmental and safety regulations in various countries of the world. Meanwhile, the requirements for accuracy, quality, environmental friendliness and cost of products are estimated to be more stringent than ever. In order to meet these requirements, Fuji Electric have an intention of committing to constant development of the world's top-level technologies and products appreciated by customers.

### References

(1) Uematsu, K. et al. Development of Pressure Sensor Cell for Fuel Leak Detection. FUJI ELECTRIC REVIEW. 2007, vol.53, no.3, p.77-80.
(2) Nishikawa, M. et al. 6th Generation Small Pressure Sensor. FUJI ELECTRIC REVIEW. 2011, vol.57, no.3, p.103-107.