# Automotive Pressure Sensors

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## 1. Introduction

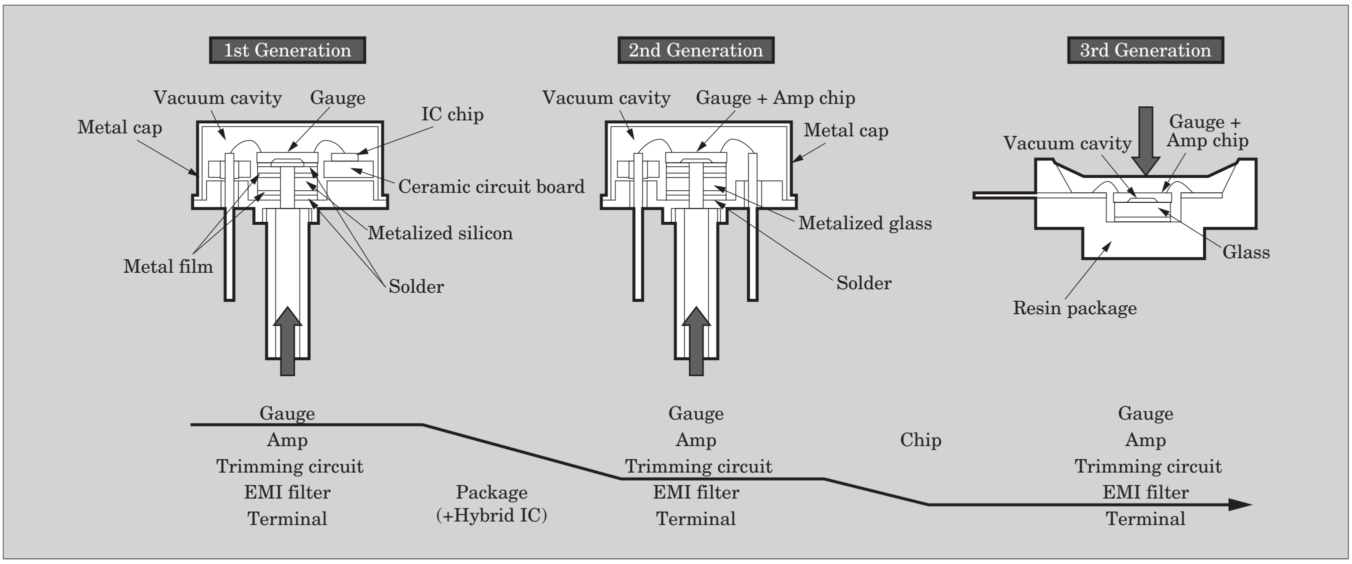
As the automotive industry moves to comply with global environmental regulations in Europe, North America, Asia and elsewhere, the industry is promoting efforts to boost the efficiency and to achieve higher control accuracy of engine systems. For the control of gasoline engines and diesel engines, a higher degree of accuracy is being required in pressure sensors in order to accurately monitor (measure) conditions such as the air volume and the exhaust gas pressure of the EGR (exhaust gas recirculation) system and to increase efficiency. Moreover, due to an increase in pressure sensor applications, such as the use of a barometric pressure sensor to perform altitude correction when driving at high-altitudes, automotive-use pressure sensors are required to have high accuracy and a low price.

In response to these requirements, Fuji Electric has developed an automotive pressure sensor with digital trimming that is fabricated using a CMOS (complementary MOS) process. Product development was based on the concept of providing an “all in single chip solution” and the commercialization of products was promoted with the goal of realizing the lowest possible product failure rate at low cost. This paper introduces Fuji Electric’s product lineup and future outlook for automotive pressure sensors.

## 2. Special Features

Figure 1 shows the technical trends of pressure sensor cell in Fuji Electric’s automotive pressure sensor cells. Fuji Electric’s first generation of mass-produced automotive pressure sensors in 1984 used pressure sensor chips equipped with only a gauge function, and other functions such as an amplifier circuit, trimming resistor and EMI filter were provided by packaging the sensor together with a hybrid IC. Subsequently, as of the second generation, a thin film trimming resistor for trimming was built-in to the chip. In the newly developed pressure sensor as the third generation, a vacuum cavity is fabricated by means of anodic bonding of glass and silicon, and the device construction consists of connection terminals and a resin package housing a sensor chip and its built-in functions only. The material for the resin package was selected based on considerations such as

Fig.1 Technical trends of pressure sensor cell



adhesion to the connection terminals and temperature stability.

### 2.1 Pressure sensor chip

The pressure sensor chip developed by Fuji Electric is shown in Fig. 2. This chip was realized using Fuji Electric's proprietary MEMS (micro-electronics and mechanical system) technology and is provided with the following functions.

1) A function for converting pressure into strain
2) A function for providing a vacuum cavity
3) A function for converting a change in resistance into an electrical signal

Fig.2 Pressure sensor chip

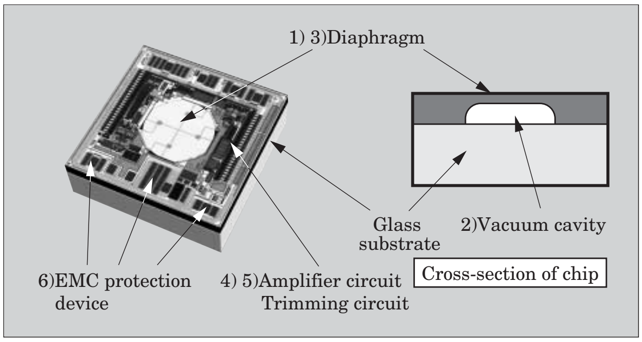



Table 1 Absolute maximum ratings

| Item | Symbol | Unit | Standard specification |
|---|---|---|---|
| Overvoltage | $V_{max}$ | V | <16.5 V |
| Storage temperature | $T_{sto}$ | °C | −40 to +135 |
| Proof pressure | $P_{max}$ | %F.S. | 200 |
| Burst pressure | $P_{burst}$ | %F.S. | 300 |
| International EMC standards | JASO D00-87, CISPR25, ISO11452-2, ISO7637 | | |

Table 2 Standard specifications

| Item | Symbol | Unit | Standard specification |
|---|---|---|---|
| Operating voltage | $V_{cc}$ | V | 5±0.25 |
| Operating current | $I_{cc}$ | mA | <10 |
| Operating temperature | $T_{op}$ | °C | −40 to +135 |
| Output voltage | $V_{out}$ | V | 0.5 to 4.5 |
| Measurement pressure range*1 | $P_{op1}$ | kPa | 10 to 120 |
| | $P_{op2}$ | kPa | 20 to 250 |
| | $P_{op3}$ | kPa | 50 to 300 |
| | $P_{op4}$ | MPa | up to 20 *2 |
| Sink current | $I_{sink}$ | mA | 1 |
| Source current | $I_{source}$ | mA | 0.1 |
| Pressure error | $V_{per}$ | %F.S. | <1.0 |
| Temperature error | $V_{ter}$ | %F.S. | <1.5 |

*1 : The pressure range can be set to an arbitrary value with the diaphragm thickness.
*2 : 20 MPa high-pressure products are presently under development.

4) A function for amplifying electrical signals
5) A function for adjusting electrical signals to specific characteristic values and then maintaining that adjustment
6) A function for protecting electrical signals from external noise

In particular, compared to a conventional bipolar process, the use of a CMOS process enables this pressure sensor chip to achieve a higher degree of EMC protection (such as overvoltage, ESD, EMI, and surge protection), as is required of automotive-use devices.

Figure 2 shows the pressure sensor chip developed by Fuji Electric. A diaphragm that realizes the abovementioned functions 1) and 3) is formed in the center of the silicon chip. Also, technology for anodic bonding to the glass substrate provides the abovementioned function 2), and ensures high reliability by maintaining a high vacuum condition for an extended period of time. Moreover, an amplifier circuit and trimming circuit for supplying functions 4) and 5) are provided at the periphery of the diaphragm. The absolute maximum ratings and standard specifications for a pressure sensor that uses this chip are shown in Tables 1 and 2, respectively.

### 2.2 Concept of the product lineup

Fuji Electric's automotive pressure sensors are based on the concepts shown in Fig. 3 and this product

Fig.3 Concept of pressure sensors

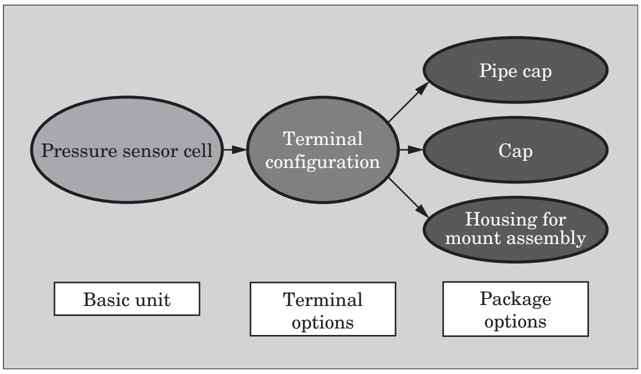
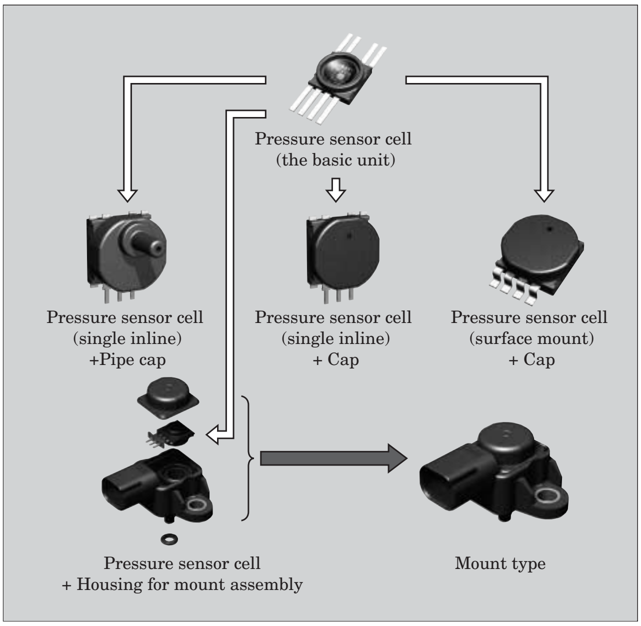



Table 3 Examples of automotive pressure sensor applications

| Application | | Pressure range | Remark |
|---|---|---|---|
| Engine | Manifold pressure | 120 kPa | Commercial production |
| | Turbocharged pressure | 250 kPa | |
| | Diesel | 300 kPa | |
| | EGR | 250 kPa | |
| | Barometric pressure | 120 kPa | |
| Air conditioner | R134a | 5 MPa | Under development |
| | $CO_2$ | 20 MPa | |
| Oil actuator | Brake system | 5 MPa | Under development |
| | Power steering | 5 MPa | |
| CVT | | 10 MPa | Under development |

Fig.4 Packages for Fuji Electric's lineup of pressure sensors




lineup is configured from the combination of a pressure sensor cell, terminal configuration and package option. Table 3 lists example applications of automotive pressure sensors.

(1) Pressure sensor cell

A pressure sensor cell houses the pressure sensor chip and provides the capability for outputting sensor signals from the pressure sensor chip to the exterior. The pressure sensor cell is the most basic unit in Fuji Electric's pressure sensor products. The package material was selected based on assumed usage in such automotive applications as the measurement of intake manifold suction, EGR exhaust gas pressure and the like, and chemical compatibility with materials such as gasoline, diesel gasoline, lubricant and the like. This pressure sensor cell forms the basis of Fuji Electric's standard package lineup of pressure sensor products. Even among products of different terminal configurations, final package shapes and pressures ranges, because all pressure sensor cells are manufactured on the same production line, a significant reduction in production cost is achieved.

(2) Terminal configuration

The terminal configuration of the pressure sensor cell can be selected to support a particular application in which the pressure sensor chip will be mounted. Figure 4 shows examples of Fuji Electric's standard specifications. Single inline, surface mount and other types of terminal configurations can be supported.

(3) Package options

In response to various requests from customers, the pressure sensor cell package supports the attachment of hardware for the mechanical interface (pipe, cap, mount type) to a particular application. Figure 4 shows Fuji Electric's standard product series. The pipe and cap type are examples of applications in which the pressure sensor will be mounted on a printed circuit board, and the mount type is an example suitable for installation on an engine. A new high-voltage package is currently under development.

## 3. Conclusion

This paper has described the product concept behind Fuji Electric's automotive pressure sensor products and introduced the product lineup that has been developed.

Environmental and safety regulations of various countries throughout the world are expected to lead to increasingly severe requirements for the accuracy, quality and price of automotive pressure sensors in the future, and Fuji Electric remains committed to the development of world-class automotive pressure sensor technology and products.