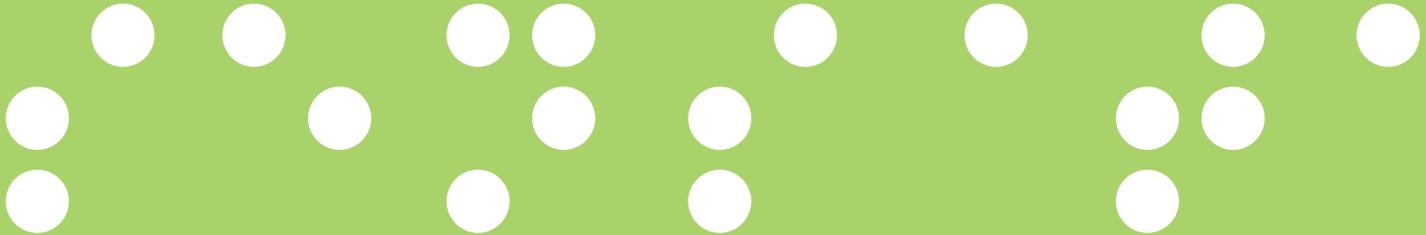


# POWERTRAIN SENSORS



  
**Sensata**  
Technologies

TECHNOLOGIES

The World Depends on Sensors and Controls



**More than a supplier – a partner.**

Satisfaction. Much more than just a word for Sensata: it is the objective of every step we take. Our customers and their needs are central to every consideration.

The fast adaptations of customer wishes by direct communication with one of our specialists in the field or in engineering are part of our daily work. Business-to-business processes form the basis for individual optimized solutions. An optimal solution is for us always a cost-effective solution. We never lose sight of costs no matter what we are considering. Does this sound intriguing? Then contact us at [www.sensata.com](http://www.sensata.com).

**Sensata Technologies: about us.**

Sensata Technologies provides leaders in the global automotive, appliance, aircraft, industrial, and HVAC markets with sensing and protection solutions. Our mission is to improve safety, efficiency, and environment protection for millions of people every day. Headquartered in Attleboro, Massachusetts, Sensata Technologies has nine technology and manufacturing centers in eight countries, and sales offices throughout the world.

## SENSATA TECHNOLOGIES

### *For tomorrow's Powertrain needs*

Mobility has always been an important factor. The invention of the combustion engine enhanced mobility substantially – but it brought challenges to our society as well.

The use of combustion engines has grown tremendously since their invention – all around the globe. But the ever-growing mass of engines leads to traffic congestions, increasing consumption of fossil fuels, and pollution of the air we breathe. Initiatives from industry and governments address these aspects, allowing comfortable journeys, environmentally friendliness, and lowest fuel consumption.

Over 100 years of innovative engineering, deploying the latest available technologies, has resulted in ultra-efficient engines connected to smoothly operating transmissions for enjoyable rides, and the innovations will continue in the future.

*New-generation GDI engines strive for 20% improvement in fuel economy, compared to conventional spark-ignited engines.*



#### **Engines – state-of-the-art technology.**

Spark-ignited engines have developed towards electronically controlled injection systems. Combined with sophisticated ignition systems, these engines inject fuel accurately at the right time and right quantity – either in the inlet manifold or directly in the combustion chamber, with pressures increasing for each new generation.

Diesel engines are no longer slow from self-ignition in pre-chambers and smoky from unbalanced air-fuel mixtures. Today, they are desired by many for their high torque and engine-speed range, resulting in great power – while complying with exhaust-emission standards. At higher costs than spark-ignited engines, diesel engines have become a worthwhile alternative for those who travel longer distances or drive heavier vehicles – burning 30 % less fuel.



### Development of transmissions.

Transmissions that were formerly manually operated and initially only easy for experienced drivers to change the gear selection, have been developed to automatic gear changes – often even with the option for a sportive or economy ride. The transmissions switch gears fast, without a torque interruption, and minimum loss of efficiency. A variety of options, for different engines and platform types, is available – e.g., low-cost automated manuals, classic (planetary) automatics, as well as continuously variable transmissions and dual-clutch transmissions.



### Long term.

Although consumer and government behavior vary by region in the world, all have one thing in common: the desire to avoid pollution of the environment and to use fossil fuels longer. For the future, various concepts are under discussion, like synfuel and sunfuel, whereby eventually dependency on fossil fuels will no longer exist and the contribution to global warming can be totally eliminated. Longer-term strategies are even developing fuel cells running on hydrogen derived from, e. g., water and having emissions containing only water vapor.



### At focus: the exhaust.

Since the late seventies, development has no longer been focused on ignition, injection, and combustion, but also on exhaust-gas post-treatment. Where there was once a three-way catalyst to clean up constituents like unburned hydrocarbons and incompletely burned gases like carbon monoxide and nitrogen oxides, since the late nineties, catalysts to clean up these nitrogen oxides and other pollutants like particulates, are becoming commonly used. These systems are small chemical factories and contribute to cleaner exhaust gases and better health for human society.

*The NO<sub>x</sub>-emission reduction from Euro 6 will increase health benefits by approximately 60 to 90 % with respect to Euro 5.*



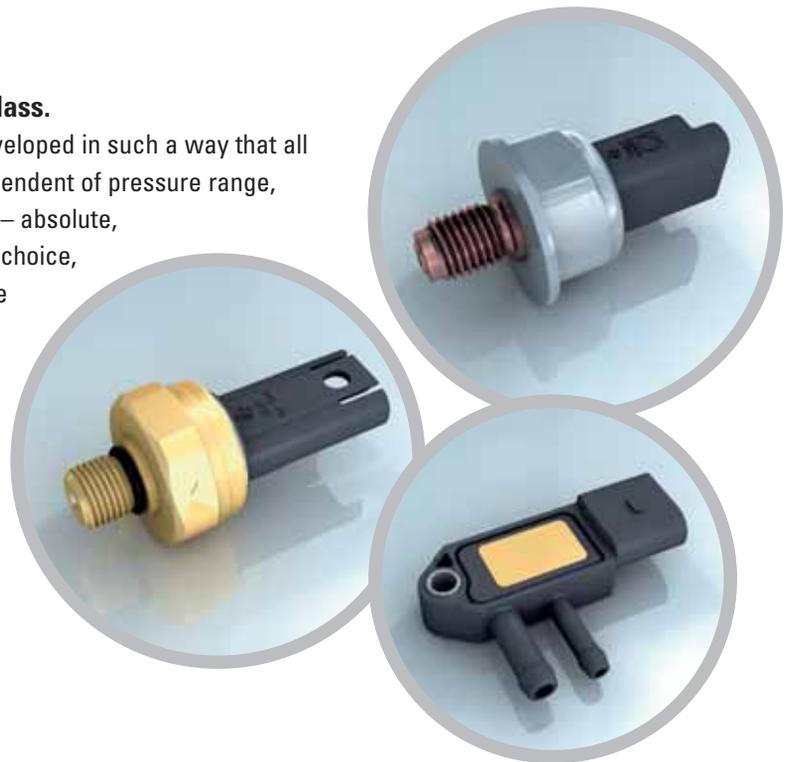
## SENSATA SENSORS FOR POWERTRAIN

### *The perfect connection*

A key element is electronics. With their help, systems can be controlled optimally under their operating conditions. In doing this, sensors measure and deliver the input needed for the electronic controls: physical parameters are measured, such as, e.g., pressure, flow, or gas concentration and converted into electronic signals. Did you know, that Sensata Technologies has been developing sensors for the automotive industry for more than 25 years? These sensors have been produced for air-conditioning, engine, transmission, suspension, exhaust-gas post-treatment, brakes, and other systems – for all automotive manufacturers and, most of all, their system suppliers. This has resulted in a broad sensor capability, including pressure, acceleration, force, position, speed, flow, and gas sensors, and in great expert knowledge.

#### **Sensata Technologies pressure sensors: Top class.**

Sensata Technologies' pressure-sensor line has developed in such a way that all Powertrain applications can be or are served, independent of pressure range, from 1 bar to 2800 bar, and independent of principle – absolute, relative or differential. The basis is a rich technology choice, from micro-electromechanical systems to capacitive ceramic and micro-fused strain gauges on metal membranes. Sensata Technologies' sensors can be found everywhere: measuring 100-millibar differential highly corrosive exhaust-gas pressures on a diesel particulate filter to 2400-bar diesel fuel in Euro 5 common-rail injection systems or operating inside a transmission in contact with 150 ° Celsius hot fluid.



#### **Sensata Technologies: You've got the choice.**

Besides pressure sensors, Sensata Technologies offers many other sensors for Powertrain applications. And, if such sensors do not exist today, Sensata Technologies is developing these for global applications, as we have done for cylinder pressure sensors integrated into a diesel glow plug to measure combustion pressure or as we are doing now for gas sensors able to measure NO<sub>x</sub>.

*Sensata has already produced over 500 million pressure sensors.*



# SENSATA ENGINE SOLUTIONS

## *A closer look to pressure sensor technologies*

There are various pressure-sensor technologies, but not all are suited for automotive applications. The technologies that have established themselves for automotive applications for many years have in common the fact that they offer high accuracy and stability, are robust against environmental influences, are reliable, and are available at an affordable cost in high volumes. The most widely used pressure-sensor technologies utilize transducer materials from silicon, ceramic, or stainless steel, which are robust against aggressive media.

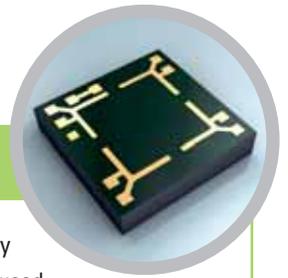
### **Focussed on MEMS-based pressure sensors.**

Silicon is an ideal material for integrating piezo-resistive resistors, which are often combined with the integration of signal conditioning. Especially at low pressures, these concepts can be provided at low cost. Silicon or MEMS (micro-electromechanical systems) have a high sensitivity and are very small.



### **CERAMIC SENSING ELEMENTS**

A ceramic substrate and diaphragm are plated with metal that serves as electrodes. Both ceramic parts are united by a glass seal, maintaining a well-controlled gap, with both metal electrodes forming an electrical capacitance. Applying pressure will cause a change in the gap between substrate and diaphragm, resulting in a change in capacitance of the sensing element.



### **PIEZO-RESISTIVE SENSING ELEMENTS**

The piezo resistive structures are formed in monolithic silicon by using standard semi-conductor manufacturing processes, also used for mass production of solid state integrated circuits. After processing of the resistive structures and metallization for interconnection, wet etching techniques are used to create a thin pressure diaphragm at the location of the stress sensitive piezo-resistive structures.

In terms of cost-effective packaging techniques, the silicon element is either bonded to glass, silicon, or ceramic (by means of a flexible epoxy). The maximum pressure allowed is limited by the adhesion of the silicon element. Higher pressures impose design changes and associated costs, making other technologies preferred.

### **First choice: Ceramic Capacitive Pressure Sensors (APT).**

Ceramic transducers using a capacitive measurement principle have proven to be the world's first choice for medium pressure ranges. Capacitive transducers are well known for their high sensitivity and low power consumption. The material is impervious against harsh media, and the transducer is very stable over a wide temperature range.

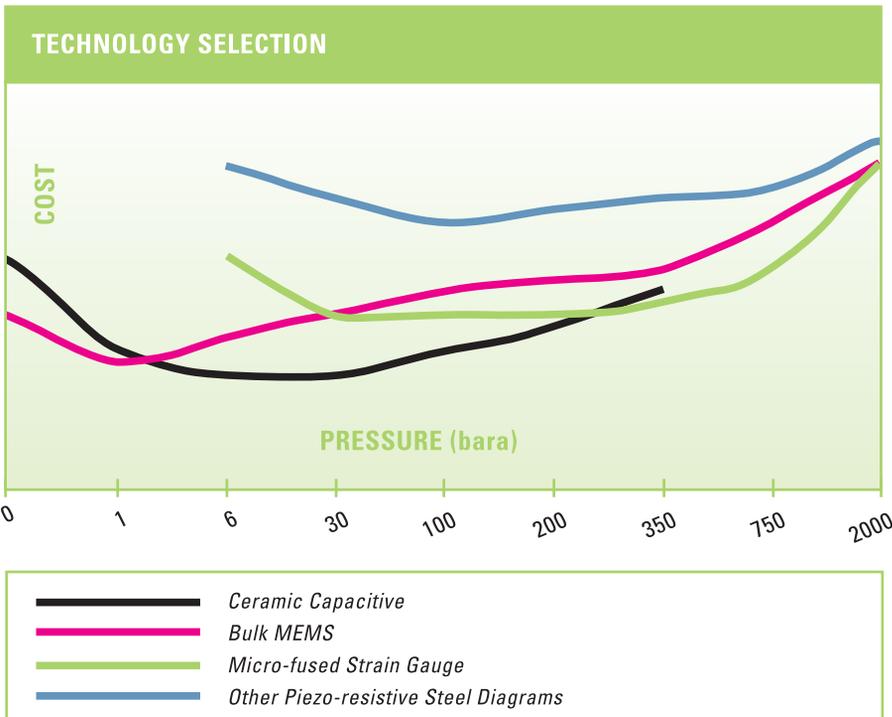
Packaging is very simple, by clamping the ceramic transducer in a metal can and using an elastomere seal for medium pressures. High-pressure drives changes to the design of elastomere seal, which add costs and eventually reach physical limits, making other technologies preferred.

**Best performance: Micro-fused Strain Gauge Pressure Sensors (MSG).**

Finally, steel membranes with piezo-resistive resistors have been adopted as the common transducers for high pressures. Various concepts exist. All have in common the fact that the piezo-resistors are placed on a metal diaphragm, where stresses or strain from deflection under pressure induce the piezo-resistance effect. The difference is in the realization of the resistors, where a compromise among stable performance over temperature, minimum drift over its life time, high sensitivity, and lowest cost has to be made.



Also here, packaging is rather simple, as the diaphragm can be constructed in one part with the port interface.



**STRAIN GAUGES**

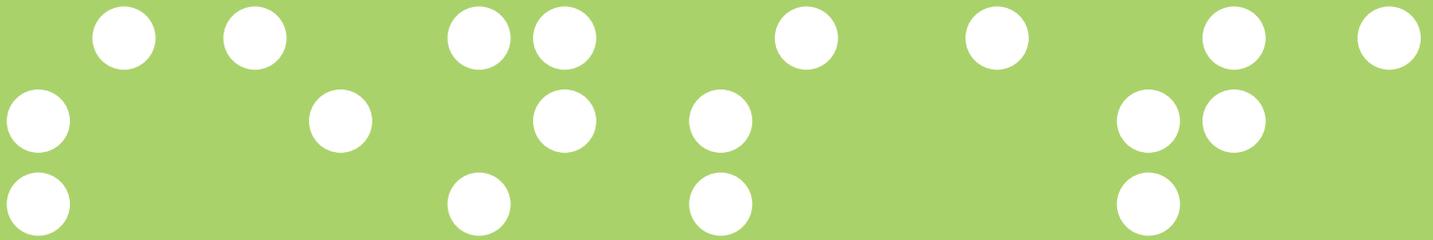


Sensata Technologies use bulk micromachined silicon strain gauges that are glass fused to a steel diaphragm. These strain gauges are realized in monolithic silicon in a batch process. One (6 or 8 inch diameter) silicon wafer will yield thousands of strain gauge elements.

But it is not only offering a capable technology for a certain pressure range that led to the automotive industry's choices. Just as important is the ability to manufacture in high volume at very competitive costs. Sensata Technologies has built a portfolio that contains all of these leading pressure-sensor technologies combined with manufacturing strategies to deliver the highest quality at an affordable cost. That's what makes Sensata Technologies' pressure sensors the preferred choice for the global automotive industry.

*Sensata Technologies doesn't just make sensors, we make solutions.*





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