SENSORS FOR THE CONNECTED CAR

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MEGA TRENDS SUCH AS CONNECTING IN-VEHICLE SYSTEMS, CAR-TO-CAR AND CAR-TO-INFRASTRUCTURE, AUTOMATED DRIVING, NEW MOBILITY CONCEPTS AND STRICTER EMISSION LEGISLATION REQUIRE MORE NETWORKING AND A HIGHER LEVEL OF PROCESS CONTROL.

Therefore many vehicle systems are advanced from open-loop control to closed-loop control strategies. This increases the number and relevance of sensors. This TE white paper describes relevant trends and provides examples of innovative automotive sensors which support closed-loop control functions in exhaust gas after-treatment, transmission and battery monitoring.

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1 – INTRODUCTION

Globally, the automotive industry is experiencing a major transition, part of which is a continuous incremental process that has been going on for a long time but another part is quite disruptive. For many years now **driving safety** has improved by adding new functions and systems. The overall **efficiency** of each model generation is improved over the previous one and the level of **comfort** is also rising. Behind all this are **electronics** (hardware and software), in particular an increasing level of **networking** plus the rather recent trend to **electrify the powertrain** and a growing number of ancillary **component**s which are required in combination with an internal combustion engine (ICE).

Networking itself has two levels:

- On a **vehicle-internal level** it is the strategy of interconnecting a large number of electronic control units (ECUs) and sensors to facilitate new and more sophisticated functions such as advanced driver assistance systems (ADAS). Today cars can have between 60 and 100 sensors. Over the next five to ten years the number of sensors is expected to double. In other words, the number of sensors will grow beyond the high number of ECUs which are integrated in modern cars. This increasingly complex network is also driven by the pressing need to increase the control quality over a number of car systems. For instance, charge exchange, fuel injection and exhaust gas after treatment require ever higher control levels to meet future emissions and efficiency regulations limiting the average fleet CO_2 emission per kilometer.
- On a **vehicle-external level** networking means to integrate the vehicle into the modern digital data flow that is facilitated by wireless communication and the internet. In a first step cars are enabled to seamlessly link up with mobile devices such as smartphones to make information and apps thus available in the car. In a second step, however, cloud/internet service-based information becomes available by making the car itself part of the Internet of Things (IoT). The rationale is to offer improved driver support and an overall better traffic flow by extending the horizon and scope of information far beyond the driver's line of sight and limited background information. Groundbreaking changes such as automated driving will strongly depend on higher internal and external networking levels in order to achieve optimum safety, efficiency and comfort.

→ Cars around the globe shall offer **greater driving safety, better fuel efficiency, lower emission levels and a smoother ride.**

→ The global automotive mega trends of safer, greener, more comfortable, connected, electrified and automated all heavily rely on **automotive-grade electrical interconnection and sensor technology.**

→ **Modern vehicles are connected vehicles.**

The growing number of sensors in the vehicle is a direct result of high expectations. Networking is the technical path to fulfilling them. Data from many systems, sub-systems and functions need to be exchanged within a complex network of electrical interfaces to increase the level of process control.

By delivering precise information on position, condition, speed and many more parameters, in-vehicle sensors provide the foundation for making vehicles safer, greener and more comfortable. Digital sensor protocols will be needed instead of point-to-point wiring to efficiently coordinate all these data flows.

With the advent of automated driving both levels of the connected vehicle will further gain in importance: More in-vehicle sensing provides data which will also be needed for automated driving while the external connection extends the vehicle horizon and improves the database for automation.

A simple example can explain why that is so: Sensors measuring temperature and humidity, for instance, are currently used within clearly defined use cases. The temperature level serves as a trigger to give a warning to the driver if there is a risk of icy roads. The heating, ventilation, and air conditioning (HVAC) control needs to know the level of humidity to avoid fogging. In a vehicle with the capability of automated driving, however, temperature and humidity can also be used to classify the road condition. If the road is wet or snowy, this means there will be less grip (low mu) and the automation will, for instance, need to apply the brakes earlier in order to avoid a collision during a phase of automated driving. Thus, even seemingly “straightforward” sensors can become relevant in new ways.

Therefore the success story of vehicle sensors will continue. TE Connectivity (TE) is at the heart of it. TE provides core technology for establishing durable interconnections, plus innovative signal generation via sensors.

→ **TE is a signal path specialist.**

2 | INNOVATIVE SENSORS FOR INCREASED PROCESS CONTROL

Sensors provide the raw data which is needed to advance from simple open-loop control strategies to closed-loop control. This is a trend which is mostly fueled by the need to bring down vehicle emissions, and to increase fuel efficiency.

While **open-loop control** relies on average parameters of the component or process that needs to be controlled, **closed-loop control** factors in the real behavior of the component over its lifetime. Manufacturing tolerances, ageing and drift of a component, for instance, will be factored in as part of a closed-loop control and can thus be compensated. Challenging control tasks like the dosing of aqueous urea solution within a selective catalytic reduction (SCR) system will not have the required precision to avoid nitrogen oxide (NOx) emissions without sensor data.

→ **Without automotive sensors there is no control. Without control there is no greener and cleaner.**

The following examples show how innovative sensors can facilitate closed-loop control in automobiles (and trucks in some cases). In addition the short technology profiles below make clear that automotive sensors need a special feature profile.

Depending on their application, automotive sensors have to meet very stringent requirements for ruggedness, reliability, accuracy, weight/mass, dimensions, economy and – last but not least – their electrical interface. As a result sensors need to be specifically designed for automotive use and they need to be verified, certified and manufactured to the most demanding and exacting standards.

→ **Automotive sensors need to be designed for their use case.**

→ **Sensors for automotive applications need to be automotive-grade sensors.**

It is one of TE's added strengths that its scope of expertise comprises both detailed **sensor know-how** and profound **electrical interconnection know-how**. In the case of automotive sensors this twin-expertise helps to design a complete system inclusive of the important electrical interface (vibration, low-cycle fatigue, dirt and fluid ingress!) which can greatly influence a sensor's reliability in real-world applications.

→ **Even the best sensor will only be as reliable as its electrical interface.**

TE has built its reputation as a leading global automotive and vehicle sensor specialist on application-design principles, testing and manufacturing processes, which together ensure product quality with an optimal cost-benefit ratio.

→ **The growing importance of automotive sensors makes uncompromising quality a must.**

A | Urea pressure sensing

The combustion process in diesel engines results in the formation of NOx. As the potential for reducing engine-out NOx emissions is limited due to several conflicting developments targets, NOx emissions need to be reduced in a separate stage. In line with the increasingly demanding NOx emission regulations worldwide, a growing number of diesel cars and trucks is equipped with an SCR system.

To facilitate NOx conversion an aqueous urea solution (also called diesel emission fluid, or DEF) is injected into the exhaust gas flow of a diesel engine. In the exhaust flow the urea converts into ammonia which then reacts with the NOx content and breaks it down into harmless nitrogen and water. To ensure an optimal conversion rate of the nitrogen oxides in the exhaust gas, the amount of injected urea needs to be constantly adjusted to the NOx content in the exhaust gas flow which varies with the engine load and operation. If this control is not precise enough, two things can happen:

- If too much urea is injected, ammonia will be emitted from the tailpipe.
- If too little urea is injected, NOx will slip through the SCR system.

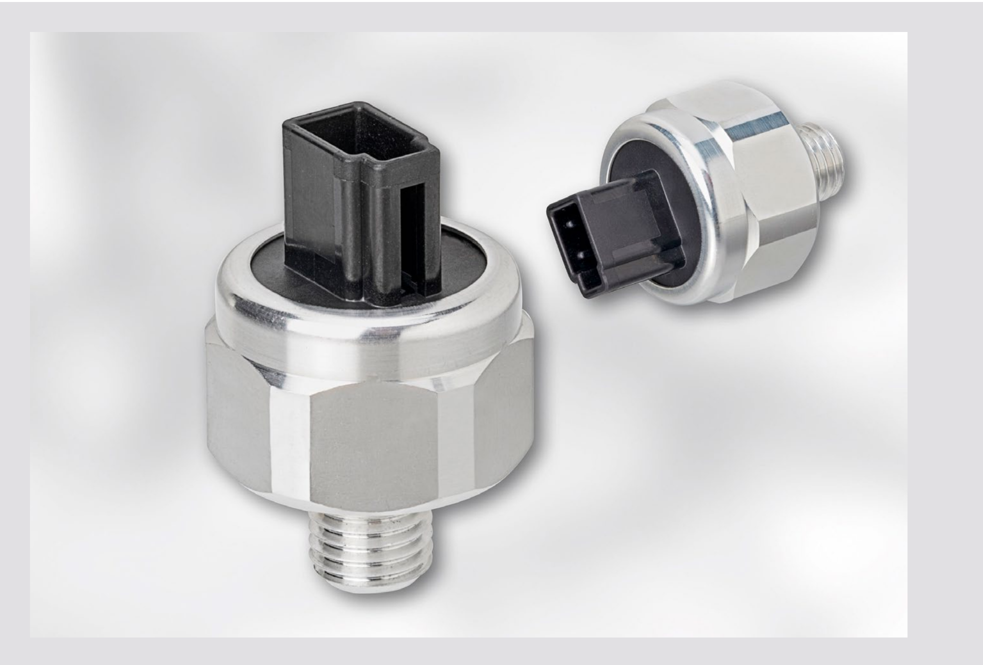
One parameter of this control function is to factor in the actual urea pressure in the pipe leading to the urea injector. TE's urea pressure sensor technology is already proven for this purpose in trucks. The new automotive urea pressure sensor makes this function available to cars.

Based on a piezoresistive measuring principle, the urea pressure sensor features a custom ASIC (i.e. an Application-Specific Integrated Circuit), which processes diaphragm reflection to measure absolute fluid pressures of up to 13 bar or sealed gage pressure. The sensor's stainless steel wetted surfaces are fully compatible with the aggressive chemistry of the fluid. Despite its small size the sensor has a data storage possibility. Overall it measures pressure with an accuracy in the range of 2%. Interface options are analog or the digital SENT protocol.

Thanks to a silicone oil chamber, transferring the medium pressure to the steel diaphragm, the TE urea pressure sensor has been successfully tested up to 1000 freezing cycles. It is freeze-proof, which addresses a concern of vehicle manufacturers as the urea solution freezes easily and can damage some pressure sensor designs.

The new automotive urea pressure sensor broadens the TE SCR sensor portfolio which also includes a high-performance urea quality sensor that is also a urea concentration sensor (DEF sensor), which is used as an integral part of NOx emission control and compliance strategy.

B | Transmission oil pressure sensor



Efficiency and comfort of automatic transmissions strongly depend on hydraulic actuation, controlled by hydraulic valves. Applications include standard automated transmission (AT), continuously variable transmission (CVT) and dual clutch transmission (DCT). A sensor serves to monitor the correct transmission oil pressure at all times to ensure correct valve action.

Transmission sensors have to function reliably in one of the most severe automotive environments. In a "wet" application (i.e. fully integrated within a transmission) the sensor is exposed to aggressive hot transmission oil and metal particles stemming from mechanical abrasion.

TE's new rugged transmission oil pressure sensor is designed for full integration and functions reliably in this environment. At only 18 grams of mass the new sensor measures up to 100 bar, withstands pressure peaks of up to 200 bar, and features a burst pressure of greater than 500 bar. Overall the sensor delivers an accuracy in the range of ±2%.

The innovative semiconductor strain gage uses Krystal Bond technology to achieve its high level of robustness. As a result the sensor's proof pressure is at least twice the operating pressure, making the sensor tolerant to pressure peaks. Packaged in a steel housing the lightweight component can be used oil-submersed and functions at operating temperatures between -40 °C and 140 °C.

As a safety-relevant product the sensor is automotive safety integrity level (ASIL) B ready in the standard version and can meet ASIL C if required. The sensor output can either be an analog signal or a digital SENT signal.

C | Battery monitoring via Hall effect current sensing

Integrated current sensor (l) and coreless current sensor (r)

Vehicle electrification poses new challenges to managing energy flows in the car. Ensuring a sufficient supply of electric energy to the vehicle board net, for instance, has a high priority. Measuring a battery's state of charge (SOC) and state of health (SOH) is therefore a key part of battery management solutions. Information on the SOC is also needed to activate the optimal hybrid operating strategy in a hybrid vehicle. An important safety feature in vehicles with a high-voltage electrified powertrain is a battery disconnect unit (BDU), which separates the battery from the vehicle net in case of a faulty current flow. Another use case is inverter control.

TE offers two current sensor versions, based either on Hall sensing only, or on Hall sensing in combination with shunt measurement. Both sensor versions measure currents between -350 amps and +350 amps (i.e. both directions of current flow during either charging or discharging). However, different current operating ranges are also possible. They are designed for integration into the BDU. The operating temperature is -40 °C to 85 °C for both sensor versions. Interface options include analog, SENT, LIN and CAN. If required, both sensors can be sealed to an IP rating.

The coreless Hall sensor measures the current flow via an open-loop Hall principle with an accuracy of 1.75 amps +1.5 % over the complete measurement range. It has 1 ms response time at the signal out.

The integrated current sensor provides a redundant measurement as it combines the Hall sensing with a precise shunt (low-resistance path). At 25 °C the integrated Hall sensor has an accuracy of 1% of the current measurement value. An additional NTC temperature measurement is part of shunt temperature compensation. This sensor is already being used within a series passenger vehicle application as part of current flow monitoring in a 48 volt mild hybridization.

3 | SUMMARY

To transport passengers safely and efficiently, vehicles need data. Today's cars can sense and respond to changing conditions, inside and out. TE sensors help provide the data for control, adaptation and response of vehicle functions that increase safety, comfort and efficiency. For instance, TE sensors facilitate real-time closed-loop control which is applied to increase the control level over vehicle systems and processes. Global trends such as automated driving, connecting the vehicle and electrification will lead to more sensors being used in the car and to more electrical interfaces. TE is ready to support this trend with sensors that are designed and manufactured to exacting specifications, and are often customized. Together with customers, TE is working to solve today's and tomorrow's biggest application challenges in new and creative ways.

For detailed information, please click on **Connected Car** and **Sensors**

ABOUT TE CONNECTIVITY

TE Connectivity (NYSE: TEL) is a $12 billion global technology leader. Our connectivity and sensor solutions are essential in today's increasingly connected world. We collaborate with engineers to transform their concepts into creations – redefining what's possible using intelligent, efficient and high-performing TE products and solutions proven in harsh environments. Our 72,000 people, including over 7,000 engineers, partner with customers in close to 150 countries across a wide range of industries.

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