TDK expands sensor business

May 2017

Extensive sensor competence from a single source

The expansion of networking in the world of electronics demands that its senses are sharpened and extended: a growing number of physical properties must be detected and measured by an increasing number of sensors with ever greater precision. Across all industries, the demand for sensor technology is rising accordingly. TDK offers a wide range of innovative solutions.

Regardless of whether for a smart car, smart grid or smart home: TDK offers an expanding range of sensors and sensor solutions, not only for the markets of the future such as IoT and Industry 4.0, but also for established automotive and industrial application fields. The portfolio includes products for sensing temperatures, pressures, currents, and magnetic fields, and thus positions, angles, acceleration rates and much more.

TDK had begun to expand its range of sensors significantly as early as 2009, when its magnetic field sensors were joined by the broad range of EPCOS temperature and pressure sensors. As part of its growth strategy, the company has now been concentrating even more intensely on sensor technology.

Technology offensive in sensor market

Early 2016 saw the acquisition of Micronas, the manufacturer of Hall-effect sensors. By combining its own expertise in tunnel magneto resistance (TMR) sensors with Micronas' competence in Hall sensors, TDK is now expanding its business in the field of magnetic field sensors. The high-sensitivity Hall and TMR sensors enable both dynamic and static magnetic fields to be sensed, making them ideal for determining positions and angles.

TDK sensor and applications portfolio

Product brand **Sensor type**	**Sensor technology**	**Automotive**	**Industrial & Energy**	**Consumer**	**Communications**
		INTERNET OF THINGS			
		Smart Car, eMobility, Powertrain, Safety, Comfort	Smart Grid, Smart Building, Automation, Robotics, Power Transmission, Medical	Wearables, Smart Home, Home Appliances, Gaming	Smartphones, Tablets, Infrastructure
TDK, EPCOS **Temperature sensors**	NTC PTC	●	●	●	●
EPCOS **Pressure sensors**	Piezo-resistive	●	●	●	●
TDK **Current sensors**	Magnetic	●	●		
TDK **Gear tooth sensors**	Magnetic	●	●		
TDK **TMR angle sensors**	Magnetic	●	●		
Micronas **Hall sensors & switches**	Magnetic	●	●		
Tronics **Inertial sensors**	MEMS Magnetic	●	●		

In December the acquisition of a majority share in Tronics Microsystems followed, which specializes in inertial sensors and MEMS solutions. Thanks to its new technological competence and innovative strength, Tronics is opening the door

to the fast-growing market for inertial sensors, with which acceleration and rotational speeds can be measured, among others, enabling multi-sensor functionality to be implemented in a single component. TDK is working on the assumption that integrated systems will continue to establish themselves as key components in industrial and automotive electronics, avionics and in the IoT.

In May 2017 TDK acquired InvenSense, a provider of MEMS sensor platforms. InvenSense combines MEMS sensors such as acceleration sensors, gyros or compass sensors with integrated systems for the sensing of movement and sound, and also with its own algorithms and embedded software. This optimizes the precision of the results obtained from the sensor systems.

The focus on sensor technology and the continually expanding range of products is also now reflected in the company structure. In April 2017 TDK consolidated its sensor activities in the newly established Sensor Systems Business Company (SSBC). "Sensor technology is a multi-faceted market with enormous growth potential. By 2020 we want to quadruple the sales of TDK sensors to about 200 billion yen, i.e. more than 1.6 billion euros," says Noboru Saito, Director of the TDK SSBC.TDK is marketing its continually expanding portfolio of sensors under the umbrella of the SSBC, which includes not only temperature and pressure sensors and magnetic field sensors, but also MEMS microphones and IoT systems. Combined sensor products with multiple sensor functions also increase the attractiveness of the TDK sensor portfolio, which is currently being marketed under the product brands, TDK, EPCOS, Micronas and Tronics (see Table).

TDK on the way to becoming Sensor Solutions Provider

In order to offer customers even more competitive advantages TDK will in future rely increasingly on modular sensor solutions and innovative packaging technologies – including the relevant software and ASICs, depending on the product. TDK is strengthening its activities in this field and has acquired ICsense, an ASIC specialist. In addition, TDK is leveraging its existing sensors and technologies in order to develop innovative sensors for new applications – such as MEMS inertial sensors for automotive and industrial applications or magnetic field sensors for consumer electronics.

Temperature sensors May 2017

World's largest portfolio of NTC thermistors

Sensors for temperature measurement can be found in every field of electronics applications. Apart from simple measurement in thermometers, they are used for open- and closed-loop process control as well as for the protection of valuable systems where critical temperatures have to be detected, for example, in the drives of electric vehicles.

The negative temperature coefficient (NTC) of special ceramics is used to measure temperatures. The electrical resistance of these ceramics diminishes as the temperature rises. With these NTC thermistors, TDK is a global market leader and offers not only a uniquely broad product range, but also the competence to customize the characteristic curves and the resistance values of NTC thermistors for a wide range of applications.

The ceramic mixtures and the material combinations of leads and coatings are a decisive factor with regard to durability and particularly to long-term stability. Only if the combinations are optimally matched, can the constant parameters be realized, thereby ensuring low tolerances over a long period. EPCOS temperature sensors therefore have special epoxy coatings or are encapsulated in glass. In tests compliant with IEC 60068-2-67 (1000 h, 85 °C and 85 percent relative humidity) these variants feature a resistance change of less than two percent compared to the resistance value at 25 °C.

The right NTC thermistor for every application

NTC thermistors are available in a very wide range of designs – often also in customer-specific versions – in order to meet the needs of the many different devices, equipment and systems they are used in. This mainly concerns the housing as well as the terminal configuration.

EPCOS NTC sensor element for the measurement of temperatures up to 650 °C. It is specified for automotive applications and qualified to AEC-Q200.

Reliable measurement of temperatures up to 650 °C

The measurement of high temperatures was previously the preserve of platinum elements. These, however, are expensive and, in comparison with NTC thermistors, they exhibit a relatively flat characteristic curve. As an alternative, TDK offers an innovative EPCOS NTC sensor element designed for measuring temperatures up to 650 °C.

The 650-degree high-temperature sensor is based on a glass-encapsulated high-temperature ceramic with connection pads on a ceramic carrier. The new NTC sensor element offers high-precision measurement with a temperature tolerance of just ±1 K at 200 °C. The high-temperature sensor is qualified to AEC-Q200 and specified for use in automotive electronics, for example in exhaust gas recirculation systems. In electrical drives the sensors are able to monitor the temperature of fuel cells. But applications can also be found in household electronics, for example in ovens with catalytic cleaning.

Embedding temperature protection with chip-NTC thermistors

IGBT modules in inverters must deliver maximum possible efficiency. For this reason, they are operated at their upper temperature limit. Precise monitoring of the operating temperature is necessary in order to prevent damage to the semiconductors. For this purpose, TDK has developed a special wafer-based EPCOS chip NTC thermistor, which can be embedded directly into the IGBT modules. Furthermore, these components save space because no special pads are necessary for soldering them to the semiconductor substrate. For wafer-based NTC thermistors, the configuration of the electrical terminals is crucial, because – unlike conventional SMD components - they are not located on the sides of the component, but on the upper and lower surfaces. In this way, they enable the lower terminal to have a direct and very even contact with the semiconductor substrate when using conventional semiconductor processes. The upper terminal is contacted by means of conventional bonding. Due to the tight thermistor tolerance of just ±1.5 K at 100 °C, IGBT modules can be operated at temperatures very close to the performance limits without premature derating and can thus be used more efficiently. This NTC thermistor solution is also suitable for new generations of semiconductors, such as those based on SiC.

This EPCOS NTC thermistor features gold-plated contact surfaces on the top and bottom and can be embedded into IGBT modules.

Multilayer NTC and PTC thermistors complete the range

In addition to monolithic types, TDK also offers EPCOS multi-layer NTC thermistors in SMD design for temperature sensing, as well as PTC (positive temperature coefficient) thermistors which are named after their extremely steep characteristic curve. Whereas the multilayer NTC thermistors are intended for mounting on printed circuit boards and are used mainly for monitoring heat-sensitive semiconductors, PTC thermistors are used primarily for sensing temperature limits – integrated, for example, into the windings of motors in order to detect overheating.

Pressure sensors May 2017

Solution competence from die to system

The highest precision pressure measurement possible is a prerequisite for the automation of many industrial processes and is playing an increasingly important role in the introduction of Industry 4.0 concepts. At the same time, the demand for pressure sensors is continuously rising, especially in the automotive industry. As many as 20 pressure sensors are needed in the drive train alone – consisting of the combustion engine and exhaust system – to minimize fuel consumption and at the same time meet the ever more stringent emission requirements.

TDK is a competent supplier of pressure sensing solutions. From the development and production of miniaturized sensor dies (elements) to housed, application- and customer-specific pressure transmitters (systems), all TDK pressure sensor elements are based on the piezoresistive principle. This is characterized by high precision and exploits the physical effect by which pressure causes changes in the electrical resistance of a piezoresistive material (silicon) that are linear over a wide range.

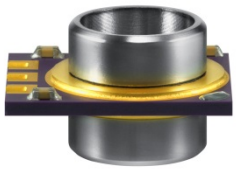
For this purpose, the miniaturized sensor dies contain four integrated piezoresistors in a bending plate, which are connected as a Wheatstone bridge and deliver an analog output voltage that is directly proportional to the pressure. TDK is able to manufacture tiny elements that have an area of just 0.65 x 0.65 mm, or have extremely low profiles of just 0.24 mm.

The latest generation of EPCOS pressure sensor elements has dimensions of just 0.65 x 0.65 mm and is suitable for absolute pressure measurement from 0 to 10 bar.

In order to achieve the highest possible mechanical stability, the dies are mounted on glass substrate. Depending on the design, this means that absolute or differential pressures can be measured. Additional options for the design of the elements, such as the solderable metallization of the back side of the glass bodies for better bond to substrate or the passivation of the back side of the elements. Furthermore, as improved corrosion protection, the bonding pads can also be gold-plated.

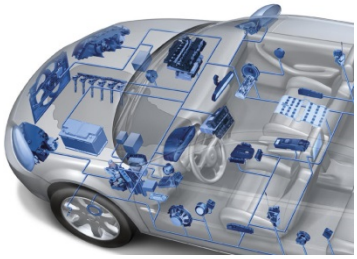
Ideally suited to automotive applications

Based on the sensor elements (dies), pressure transmitters (systems) are manufactured that use an ASIC to perform the calibration and signal conditioning. In this way, the output voltages of 0.5 V to 4.5 V or output currents of 4 mA to 20 mA that are typical for industrial applications can be implemented. Likewise SENT (single edge nibble transmission) digital interfaces such as can also be integrated for automotive applications, as in the case of the TDK MiniCell® series of pressure transmitters. Especially for automotive applications, the pressure sensors have to be highly resistant to aggressive media such as exhaust gases or fuels. For this reason, the MiniCell series is designed with a stainless steel membrane that protects the electronics and sensitive sensor element. The pressure is transmitted by an oil filling between membrane and die. Thanks to their metallic encapsulation, these MiniCell transmitters also offer excellent shielding against EMI.



MiniCell® pressure transmitter for differential pressure measurement. This series is extremely robust and features high resistance to aggressive media.

TDK also manufactures application- and customer-specific sensor systems that feature specially designed plastic housings and terminal configurations for pressure and data lines, e.g. for monitoring diesel particulate filters. During operation, these filters become increasingly clogged with soot particles. The pressure sensor detects the resulting rise in exhaust gas pressure, and the regeneration of the filter is initiated. The particle filter is then burned clean by a brief increase in the temperature and the supply of oxygen. TDK also has also developed special fuel-resistant pressure sensors for the monitoring and control of the pressure in fuel tanks. They measure the pressure of fuel lines into order to achieve an optimal and energy-saving control of the fuel pumps.



Magnetic field sensors

May 2017

A broad portfolio of solutions

TDK is successful in the field of magnetic sensors and offers a wide range of products for a large variety of applications – including current sensors, gear tooth sensors and TMR angle sensors.

TDK current sensors are based on high-performance TDK ferrite materials and play a key role, for example, in energy management systems and Industry 4.0 applications. Special types, for example, are designed for demanding applications in a high current range from 30 A to 600 A.

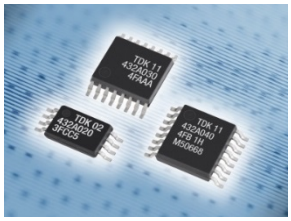
TDK gear tooth sensors, on the other hand, are highly sensitive rotation sensors. These enable the use of more efficient fuel injection systems in vehicles and thus help to improve engine performance. TMR angle sensors are also gaining importance.

The CCT series of clamp AC current sensors with its new CCT406393-600-36 type for 600 A can meet the high-current sensing needs of energy management systems (EMS) for buildings, factories, stores and communities.

TMR angle sensors for maximum precision and reliability

Of all magnetoresistive effects, the TMR effect is characterized by its high output voltage, low temperature drift and high precision. Originally, TDK employed this technology for the manufacture of read/write heads for hard disks, establishing extensive and globally recognized competence in TMR products.

On this basis, the company has developed a host of innovative sensors for automotive applications. In the series production of TMR magnetic field sensors, which has been running since 2015, different layers are separated and structured on a silicon wafer – comparable with a CMOS production process. By this process, TMR elements are linked in a series connection to form one resistor element. Such resistors are usually connected in groups of four to form a Wheatstone bridge.



The TDK TMR angle sensors comply with ASIL-D and can thus also be used in safety-related applications such as electric power steering or brake systems.

At a supply voltage of 5 V the differential output voltage can be as high as 3 V, enabling it to be fed directly to a microcontroller with integral ADC. The number of structural elements needed for the signal conditioning is significantly reduced due to the absence of amplifiers, resistors and capacitors. In view of the growing demands on functional safety this is a huge advantage, since the monitoring of the sensors is greatly simplified.

TMR sensors can be used in systems that meet the requirements of ASIL-D (Automotive Safety Integrity Level D, the highest safety requirements) according to the ISO 26262 standard. They are can be used up to therefore suitable for such safety-releated applications as electric assisted steering and braking. A further outstanding feature of the TMR sensors is their high angle precision, which is adjustable. Depending on the magnetic field strength, residual angle errors of less than 0.2 degrees can be achieved over the vehicle service life (17 years) and a temperature range (-40°C to 175°C).

The current TDK TMR sensor product range covers simple angle sensors, rotational speed sensors and linear sensors for power steering systems, wipers, clutch and gearbox positioners, pedals and throttle valves and many other applications.

Hall-effect sensors May 2017

All-rounders for automotive electronics

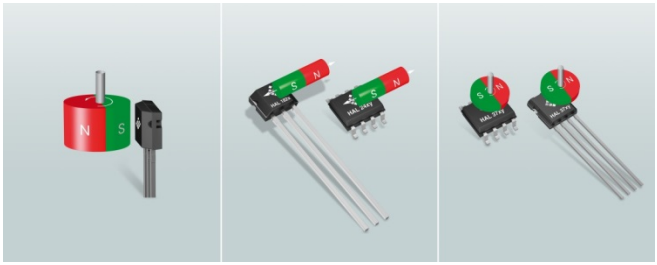
Micronas, the manufacturer of Hall-effect sensors acquired by TDK, has now been renamed TDK-Micronas and its portfolio of products is being marketed under the Micronas product brand. A large number and variety of sensor applications can be implemented in automotive and industrial electronics using Micronas Hall sensors − from the commutation of brushless DC electric motors, to the precise measurement of steering angles.

The combination of Hall sensor and permanent magnet allows a host of variables such as rotational speed, angle, rotation, fill level, pressure, torque or current to be measured. Compared to other technologies, Hall sensors have the advantage that they are not sensitive to dust, contamination or water, provided they are optimally enclosed. As they make no physical contact with the object being measured, they experience virtually no wear and are therefore extremely reliable.

Hall switches

When a magnet is brought near to the sensor, the measured magnetic field strength is compared with a threshold value. As soon as this value (switching point) is exceeded, the switching status changes at the output of the sensor which, depending on its type, exhibits unipolar, bipolar or latch-switching behavior.

For this purpose, TDK offers two families of Micronas switches: the programmable switches of the HAL 10xy and HAL 15xy series with predefined characteristic values. The HAL 15xy series was designed primarily for automotive applications and meets the requirements for functional safety according to ISO 26262. This switch is available in TO92 or SOT23 packages as 3-wire or 2-wire versions. The latter has a current source output and therefore only needs two supply cables. Typical applications are end position detection and rotational speed measurement. Hall switches are increasingly replacing conventional microswitches, for example in seat belt buckles. Moreover, they can be used in combination with a motor controller for the commutation of brushless DC electric motors.



Micronas Hall sensors. From left to right: Hall switch for rotational speed measurement, linear Hall sensors for position and movement sensing, and 2D Hall sensors for direct angle sensing.

Linear Hall-effect sensors

Path measurements or the measurement of rotary movements require the more complex Micronas linear Hall sensors with linear output characteristics which output a signal that is proportional to the magnetic field strength. This signal can be provided as an analog output voltage, a pulse width modulated signal (PWM) or in the SENT protocol. The TDK portfolio includes four programmable linear Hall sensor series. The output characteristic can be linearized with the aid of as many as 32 grid points. This enables tolerances of the magnets or of the mechanical design to be fully compensated.

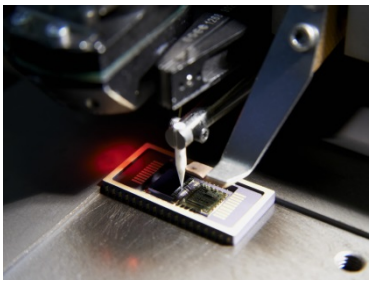
The latest generation of Micronas HAL 24xy sensors has diagnostics capability and was designed for precise distance measurement up to 40 mm and for angle measurements up to 180 degrees. Designed for use in particularly safety-

critical drive-by-wire applications, the HAR 24xy sensor variant can offer a redundancy function. In this case, two independent sensor chips (dual-die) are integrated into a single TSSOP package. Applications include magnetic field measurements and the substitution of conventional potentiometers that are prone to wear. In vehicle applications linear Hall sensors are used in particular for detecting pedal positions or steering torque.

Direct angle sensors

Whereas linear sensors (1D) measure only the absolute magnetic field, direct angle sensors (2D) are also capable of capturing the field vector. In addition to the magnetic field component perpendicular to the chip surface, vertical Hall elements measure the components in the chip plane. From this, the internal signal processing calculates angle and position information.

The Micronas HAL 37xy series of sensors uses the in-house 3D-HAL technology and offers a high degree of measuring accuracy. Apart from the output characteristic, the main characteristics can be adapted to the magnetic circuit by programming the non-volatile memory. The HAC 37xy is equipped with integral capacitors, in order to achieve the best EMC properties, saving both money and space, and also to facilitate applications without printed circuit boards. HAR 37xy is the dual-die version of the HAL 37xy series. Typical areas of application include high-precision measurement of magnetic field orientation or linear movement of up to 40 mm and angles of up to 360 degrees. Direct angle sensors are ideally suitable for the detection of the position of the throttle valve or clutch pedal.



Inertial sensors

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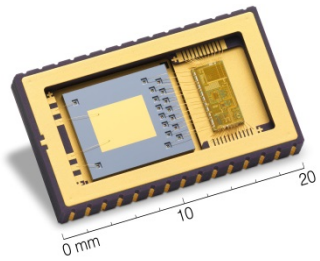
High-precision positioning

Inertial sensors enable position, orientation, acceleration and speed to be determined very precisely in just a single component. Autonomous vehicles, robots, drones and many IoT applications rely on such aids. With the acquisition of the majority share in the inertial sensor and MEMS specialist, Tronics, TDK has strengthened its innovativeness and expanded its range of sensors and will market these components under the Tronics brand.

The range of products offers system designers a series of high-precision sensor products, on which MEMS gyros and accelerometers are based. The latest development is the Tronics GYPRO3300, with which TDK is setting new standards for compact MEMS gyros that can determine angle changes in three dimensions. The GYPRO® series of sensors consists of a MEMS die and an IC accommodated in a robust 30-pin ceramic package.

Best-in-class: automotive requirements far exceeded

The GYPRO3300 is factory-calibrated and temperature-compensated by means of an integral temperature sensor, enabling it to operate with stability and precision over a wide temperature range. It delivers a 24-bit signal via a serial peripheral interface (SPI), and the bias instability and angle deviation exhibit excellent values of just 0.8° /h and 0.1° / √h, respectively. These values far exceed the requirements of the automotive industry.



Thanks to their high precision and stability, Tronics GYPRO® inertial sensors are particularly suitable for demanding tasks involving the sensing of positions and angles.

With its excellent performance in a single-chip solution, the Tronics GYPRO3300 qualifies as best-in-class and also offers compact dimensions of just 19.6 mm x 11.5 mm x 3.7 mm. This MEMS gyro is therefore suitable for extremely demanding applications such as the stabilization of oil drilling platforms, aircraft navigation, attitude and heading reference systems (AHRS), as well as advanced driver assistance systems (ADAS). The compact MEMS inertial sensors are based on the Tronics Magellan process technology that offers a new level of integration, enabling the measurement of as many as 6 axes in a single chip.