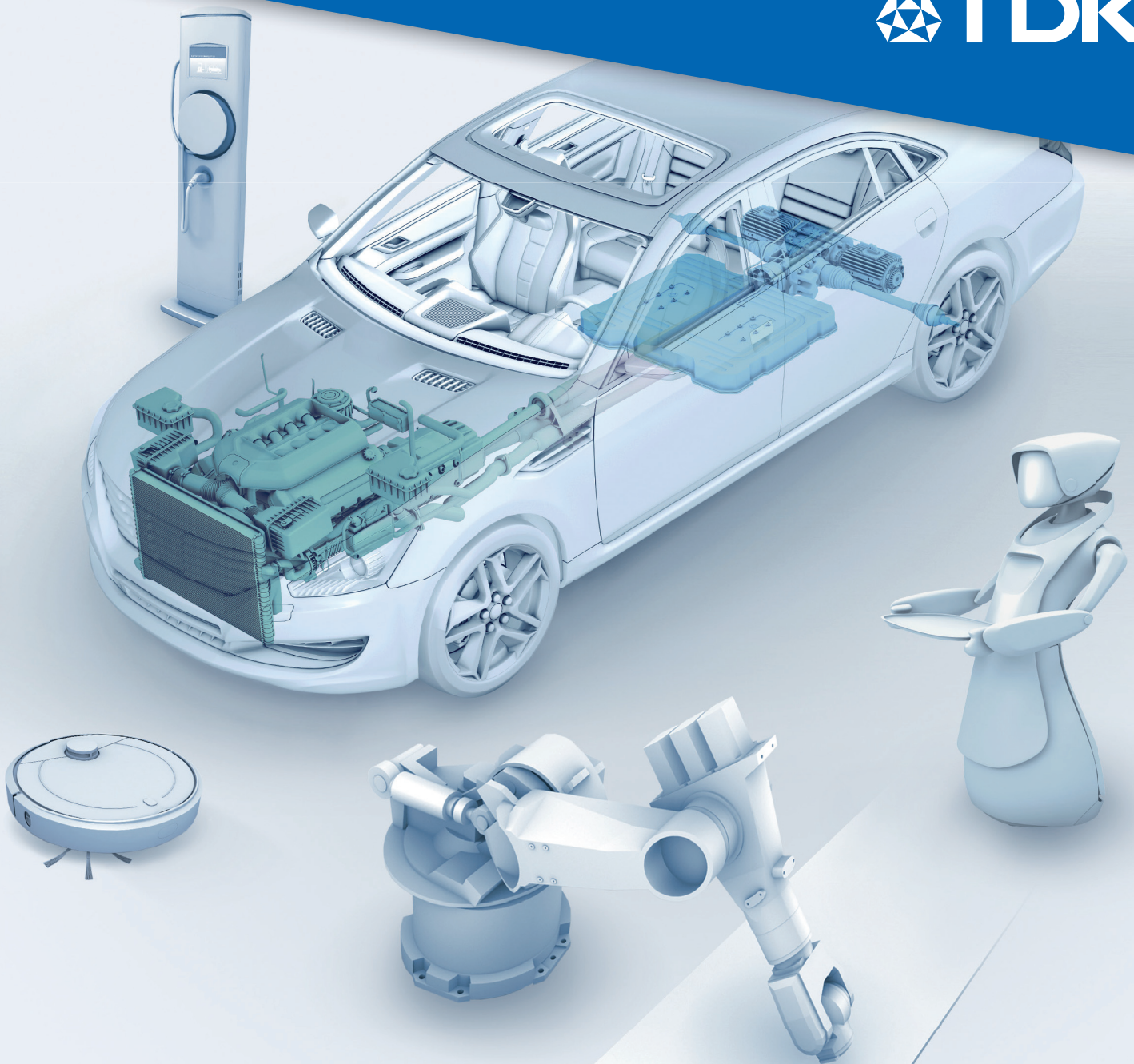


# Magnetic Sensors and Embedded Controllers

Hall sensors, TMR sensors, current sensors, and embedded motor controllers



# TDK's Sensor Portfolio

TDK's complete range of sensors, marketed under the product brands TDK, EPCOS, InvenSense, Micronas, and Tronics includes inertial, acceleration, temperature, pressure, current, and position sensors.

All information about sensors and sensor systems can be found in the TDK Product Center on [product.tdk.com](http://product.tdk.com).

Precise current sensors are indispensable for intelligent power in electric vehicles and smart grids. Temperature sensors and sensor systems are used to regulate the temperature of refrigerators and air-conditioning systems or to measure the temperature of operating fluids in motor vehicles, for example. Pressure sensors are used in a wide range of applications in automotive and industrial electronics, medical engineering, and environmental technology.

Motion-based devices detect and track an object's motion in three-dimensional space enabling key functions in many consumer electronic devices including mobile, wearable, Smart Home, and automotive and industrial devices. For high-performance requirements in motion sensing, TDK offers MEMS products, such as accelerometers and gyroscopes used in navigation, motion tracking and motion control, as well as optical stabilization.

## Magnetic Sensors and Embedded Motor Controllers

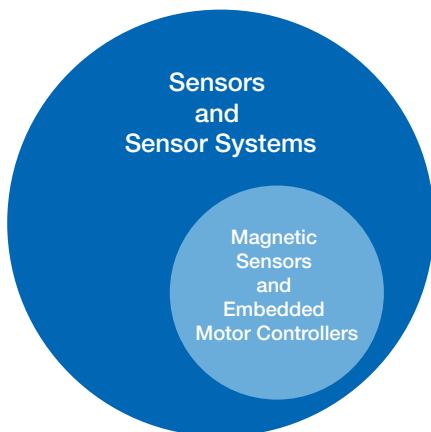
(shown in this catalog)

Magnetic-field sensors based on Hall or TMR technology can be found in almost any machine that needs to measure position, linear or rotational movement or even current.

TDK's complete range of magnetic sensor products, like Hall-effect sensors, TMR sensors, current sensors, and embedded motor controllers are marketed under the product brands TDK and Micronas.

Analog and mixed-signal ASICs, also employed in TDK's magnetic sensors, are marketed under the product brand ICsense.

TDK offers as well custom analog and mixed-signal ASIC design through ICsense.



# Contents

## Company and Products 2–18

Overview of Product Lines	3
Introduction to Hall-Effect Sensors	4
Introduction to TMR Sensors	5
Automotive Applications	6
Industrial Applications	16
Product Overview	18

## Hall Switches 20

HAL 1002	20
HAL 15xy	20

## Linear Hall Sensors 21–23

HAL 18xy	21
HAL 24xy	22
HAR 24xy	22
HAL 83x	23
HAC 830	23

## Magnetic Current Sensors 24–25

Introduction to Hall-Based Current Sensors	24
CUR 4000	25

## Angle Sensors 26–31

Introduction	26
HAL 30xy	28
HAL 37xy	28
HAR 37xy	29
HAC 37xy	29
HAL 39xy	30
HAR 39xy	30
HAC 39xy	31

## TMR Angle Sensors 34–42

Introduction	34
TAS2142/414x	36
TAA6140	37
TAB4140	38
TAD2140	39
TAD2141/4140	40
TAD2143	41
ASA 2310	42

## Embedded Motor Controllers 44–46

Introduction	44
HVC 4x	45
HVC 5x	46

# Overview of Product Lines

## Linear Hall Sensors

### HAL 8 Product Family

- $T_J = -40$  to  $170$  °C
- TO92UT or TO92UP package
- Programmable (EEPROM)
- Proven-in-use quality
- Temperature stability

### HAL 18 Product Family

- $T_J = -40$  to  $170$  °C
- TO92 package
- Ratiometric analog output
- Value optimized version (10 bit)

### HAL 24 Product Family

- $T_J = -40$  to  $170$  °C
- TO92, SOIC8, or TSSOP14 package
- Programmable (EEPROM)
- On-board diagnostic features
- Versatility and high precision

### HAL 830P

- Analog output

### HAC 830

- Integrated Caps
- Analog output

### HAL 835P

- Analog and PWM output
- High accuracy

### HAL 1870

- Programmable (EEPROM)
- PWM output

### HAL 1880

- Programmable (EEPROM)

### HAL 1881/82/83

- Pre-configured sensitivity (EEPROM)

### HAL 1890

- Programmable (EEPROM)
- SENT output

### HAL 2420/2421

- 2-point calibration
- Analog output

### HAL 2425

- 2-point calibration
- 16 setpoints linearization
- Analog output

### HAR 2425

- Dual-die version
- Analog output

### HAL 2455

- 16 setpoints linearization
- PWM output

### HAR 2455

- Dual-Die version
- PWM output

## Angle Sensors

### HAL 30 Product Family

- $T_A = -40$  to  $150$  °C
- SOIC8 package
- High-speed  $360^\circ$  contactless angle measurement
- Robust against magnetic stray fields

### HAL 3020

- Lower current consumption
- Cost-effective application

### HAL 3021

- Higher robustness against mechanical tolerances
- Support of closer air gaps and smaller magnets

## Hall Switches

### HAL 1002 Switch

- Open-drain output (3-wire)
- Chopper stabilized
- Highly precise customer-programmable switching points
- $T_J = -40$  to  $170$  °C
- TO92UT package

### HAL 15 Switch Family

- Open-drain output (3-wire) or current output (2-wire)
- Chopper stabilized
- Wide range of highly precise switching points
- $T_J = -40$  to  $170$  °C
- SOT23 and TO92UA package

## TMR Angle Sensors

### HAL 37 Product Family

- $T_A = -40$  to  $150$  °C
- SOIC8, TO92UP, or TO92UF package
- Programmable characteristics
- Diagnostic functions
- Measurement of angular and linear position

### HAL 371x

- 12-bit analog or PWM modulo output

### HAL 372x

- 12-bit analog output

### HAL 373x

- PWM and SENT output

### HAR 371x

- 12-bit analog or PWM modulo output
- Dual-die variant

### HAR 372x

- 12-bit analog output
- Dual-die variant

### HAR 373x

- PWM and SENT output
- Dual-die variant

### HAR 379x

- PWM and SENT (rev.4) output
- Dual-die variant

### HAC 371x

- 12-bit analog or PWM/SENT modulo output
- Integrated capacitors

### HAC 372x

- 12-bit analog output
- Integrated capacitors

### HAC 373x

- PWM and SENT output
- Integrated capacitors

## TMR Angle Sensors

### TAx Product Family

- Excellent angle accuracy
- High sensitivity
- High reliability and low FIT rates
- Wide magnetic field range

### Digital Output

#### TAD2140

- Integrated caps
- TO6 package

#### TAD2141/2142

- 1 System
- TSSOP16 package

#### TAD4140

- 2 Systems
- TSSOP16 package

### Analog Output

#### TAS2142, TAS414x

- Pure TMR bridge
- TSSOP8 / TSSOP16 and QFN16 package

#### TAA6140

- Differential amplifier
- TSSOP16 package

#### TAB4140

- Single-ended amplifier
- TSSOP16 package

## Magnetic Current Sensors

### HAL 39 Product Family

- $T_A = -40$  to  $150$  °C
- SOIC8, TO92UF, or SSOP16 package
- Accurate angular measurement up to  $360^\circ$
- Linear position detection
- 3D position detection
- Robust against magnetic stray fields
- Programmable characteristics
- Diagnostic functions

### HAL 3900

- SPI output

### HAL 3927

- 12-bit analog / SENT output

### HAL 3930/3935

- PWM/SENT/Switch output/ Low-power Mode

### HAL 3960

- 2-wire PWM output

### HAL 3970

- SPC output

### HAL 3980

- PSi5 output

### HAR 3900

- SPI output
- Dual-die variant

### HAR 3927

- 12-bit analog / SENT output
- Dual-die variant

### HAR 3930

- PWM/SENT/Switch
- Dual-die variant

### HAC 3930

- PWM/SENT output
- Integrated capacitors

### HAC 3980

- PSi5 output
- Integrated capacitors

## Magnetic Current Sensors

### CUR 40 Product Family

- High-precision contactless and core-less linear Hall-based current sensor
- Programmable
- SPI output
- $T_A = -40$  °C to  $150$  °C
- SOIC8 package

### CUR 4000

- Magnetic Flux Range:  $\pm 100$  mT

## Embedded Motor Controllers

### HVC 4x/5x Product Family

- $T_J = -40$  up to  $160$  °C
- All-in-one flexible integration of entire embedded Motor Control IPs
- Communication via e.g. UART, SPI, LIN2.x
- Dual Mode Supply Voltage: 5.4 V to 18 V, 40 V load dump fulfillment of Automotive OEM requirement specifications
- Internal Half-Bridges with charge pump

### HVC 422xF

- 2 KB SRAM, 32 KB Flash
- 6 x 0.5 A drivers
- QFN40 package

### HVC 442xF

- 4 KB SRAM, 64 KB Flash
- 6 x 0.5 A drivers
- QFN40 package

### HVC 5221D

- 2 KB SRAM, 32 KB Flash
- 4 x 0.5 A drivers
- QFN24 package

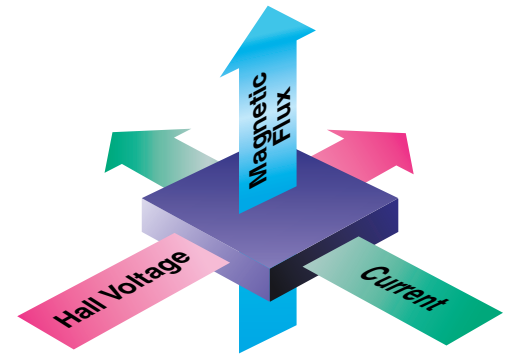
### HVC 5222C

- 2KB SRAM, 32KB Flash
- 3 x 1 A drivers
- QFN24 package

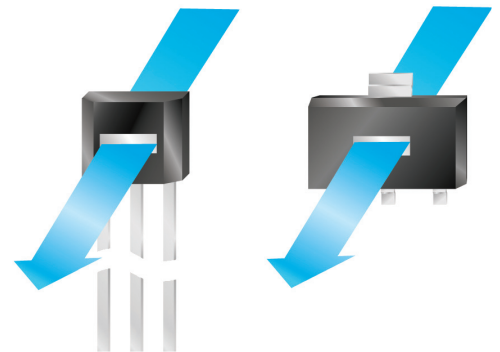
# Introduction to Hall-Effect Sensors



The Hall effect was named after its discoverer, the American physicist Edwin Herbert Hall. A Hall sensor detects magnetic fields perpendicular to a current-carrying conductor, creating an electrical voltage across the current flow direction. There are many possible applications of this physical principle allowing the strength of an external magnetic field to be determined and measured. Current measurements are possible as each conductor through which current flows creates its own a magnetic field which can be used to indirectly measure the current. Since the Hall effect is most pronounced in semiconductors, typically a small plate of semiconductor material is used as the Hall element.

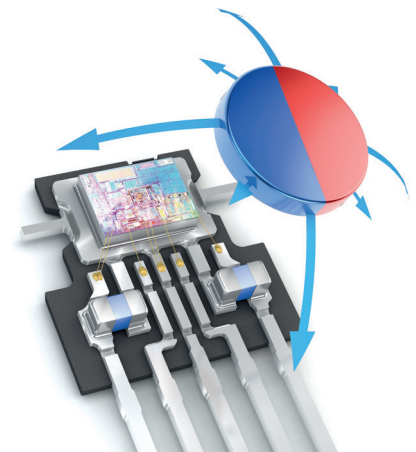


In a semiconductor die, the Hall voltage is generated by an external magnetic field acting perpendicular to the current direction. Hall sensors measure the component of the magnetic flux perpendicular to the chip surface.



In today's Hall sensors, the required evaluation electronics is normally integrated on the chip together with the Hall plate. Field lines that penetrate the Hall element vertically generate a proportional electrical voltage, which is processed by a digital signal processor and converted into a usable output format.

The first CMOS-based Hall sensors were pioneered and developed by what is now TDK-Micronas in the early 1990s. As the manufacturing process became cheaper, the ICs could be better integrated, allowing the design of more complex circuits. Now, digital and analog functions are combined on the same chip as mixed-signal integrated circuits.



Hall sensors process very low signal voltages and are therefore prone to offset drifts that can occur as a result of temperature and voltage fluctuations, as well as mechanical stress. To combat this, the active offset compensation limits the offset to only a few  $\mu\text{V}$  over the entire operating temperature. EMC robustness and voltage stability of the circuit was also improved. The result is a complete CMOS Hall sensor system that includes on-chip signal processing and nonvolatile memory integration.

In addition, by using both vertical and horizontal Hall elements, high-precision angle sensors and multidimensional magnetic field measurements are now possible: Vertical Hall elements detect magnetic field lines parallel to the sensor surface, while the horizontal Hall elements detect the vertical component impinging on the chip surface. This is crucial for use in the automotive industry which requires tighter integration and EMC optimization of components in automotive designs. Such sensors with integrated blocking capacitors must meet the functional safety requirements of ISO 26262. In safety-critical applications, high reliability can be achieved with the help of the redundancy principle by means of two independent semiconductor chips in a single package.

CMOS Hall sensors feature cost-effective monolithic integration of Hall element and evaluation circuit on a single chip. This makes them suitable for cost-sensitive applications or for detecting stronger magnetic fields.

## Introduction to TMR Sensors

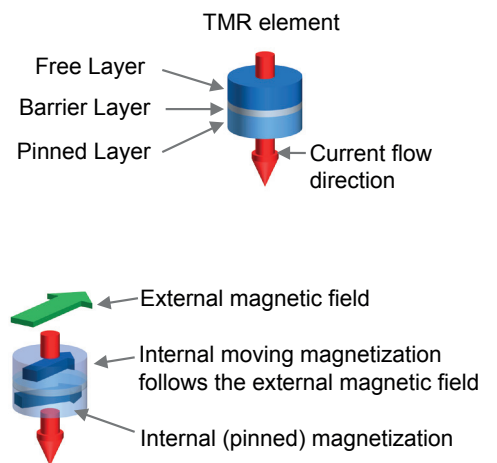
The tunnel magneto-resistive (TMR) technology is based on a quantum-mechanical effect. The magneto-resistive effect (MR) becomes apparent when the change of a magnetic field leads to a change in the electrical resistance. Thus, an electrical value can be easily derived from a magnetic value. TMR is a special form of MR technology where the so-called tunnel effect ensures a much greater change in resistance as soon as a magnetic field is applied. As a result, TMR sensors offer the advantage of higher sensitivity and accuracy.

In TMR sensors, a stack of magnetic material is separated in the middle by an electrical insulator – the so-called tunnel barrier. The direction of the magnetization of the free layer depends on the external magnetic field. The direction of the pinned layer remains unchanged. The resistance of the TMR element is proportional to the relative angle between free and pinned layer.

Compact components based on these technologies led to the adoption of microscopic MR read heads in hard-disk drives allowing for higher storage density. With the further development of TMR technology that utilized a manufacturing process similar to that of a CMOS, different layers are deposited and patterned on a silicon wafer. Consequently, TMR resistance elements are connected serially to form a resistance element. These resistors are usually arranged in groups of four, as a Wheatstone bridge circuit. This type of interconnection generates common electrical signals in automotive technology that can be evaluated directly or by means of downstream electronics (ASIC IC).

A key parameter for automotive applications is the sensor output voltage which can be read directly from conventional microcontrollers, and as a result, additional amplifier circuits, resistors and capacitors can be eliminated. TMR-based angle sensors, speed sensors and linear sensors can be used in various applications like power steering, wipers, clutch and gearbox actuators, pedals and throttle valves and many other position detection functions. The simple design of a TMR sensor has many advantages including more reliability resulting in better functional safety, and superior monitoring of sensor behavior during operation.

TMR sensors can be used in accordance with ISO standard 26262 to the highest level of safety (ASIL D level) in the automotive industry. Thus, they meet the safety standards to be installed, for example, in electric power steering and brakes. Another important feature is the very high angular accuracy that can be achieved. Depending on the magnetic-field strength, an angular accuracy of up to approx. 0.2 degrees can be achieved during the vehicle's lifetime and in the permitted chip temperature range (–40 °C to 175 °C). This performance is reflected in the increase in efficiency and noise reduction, especially for the control of electric brushless DC motors (BLDC).



Compared to magnetic-field sensors based on other technologies (Hall / AMR / GMR), TMR sensors have a better signal-to-noise ratio and score with unprecedented accuracy and very low power consumption.

TMR sensors offer reliable and stable performance over temperature and lifetime. As a result, TMR sensors are preferred in very demanding applications.

# Suggested Automotive Applications (Combustion Engine)

Pedal Position



Gear Shift Position



BLDC Motor Commutation



Throttle Valve



Adaptive Suspension System



Seat Position Detection



Seat-Belt Presence Detection



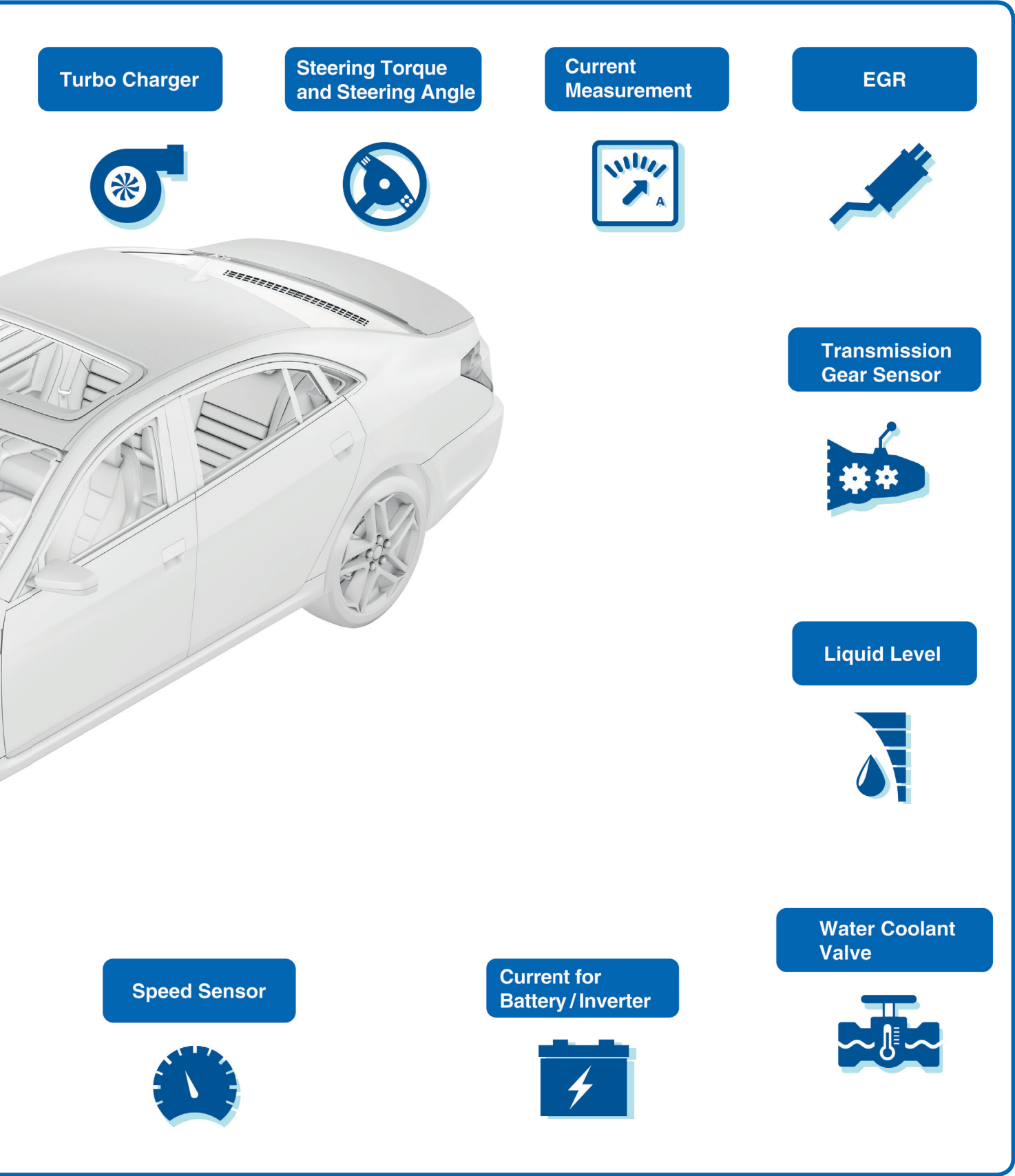
Motor Control / Rotor Position



Steering Motor Position



# and/or Electric Drive) with Hall Sensors or TMR Sensors



# Automotive Applications

## Combustion Engine

An increased demand for high energy efficiency and CO<sub>2</sub> reduction asks for optimized sensor and actuator solutions. TDK aims to provide solutions for all applications in a conventional car from battery management to exhaust valves through shift lever and pedal position sensors. TDK develops high-accuracy sensors designed to withstand harsh under-the-hood environments: insensitive to vibrations, temperature drift, and dirt.

### Application examples for cars with combustion engine

#### Active Pedal – Clutch

To improve safety, comfort, and responsiveness, modern systems like cruise control systems, electrical parking brake, start-stop functions, start lock and torque adjustment require a displacement sensor on the clutch master cylinder. The displacement sensor measures up to 40 mm travel. 2D Hall-effect sensors are a robust and cost-effective solution for this task. They bring reliability and high accuracy together with low air gap and temperature sensitivity. Additionally, EV and HEV drive the need for stray-field robustness addressed by HAL 3930.

Sensor Types: 2D Hall, TMR

Products inside:

- HAL 37xy
- HAL 3930

#### Active Pedal – Acceleration

Electronic throttle control replaces the mechanical link between acceleration pedal and throttle (drive-by-wire).

The Acceleration Pedal Sensor (APS) converts the driver's accelerator pedal effort into an electric signal and sends it to the engine control unit (ECU).

Two APS signals are checked for range and plausibility. The two sensors are completely independent, each one is supplied with a separate reference voltage (full redundancy). If one sensor fails, the other is used as a "limp-home" input, so the ECU will limit the maximum engine speed.

Linear Hall sensors with analog output are used to detect pedal courses with small angle (<20°). They bring reliability and high accuracy, especially to detect the accelerator idle position. They also provide small offset and sensitivity drift over lifetime and temperature.

Additionally, EV and HEV drive the need for stray-field robustness. Furthermore, an ISO 26262 compliant device is mandatory. Both requirements can be addressed by HAL 3930 or HAR 3930.

Sensor Types: 1D, 2D Hall

Products inside:

- HAL 830P
- HAL 2420
- HAL 3930, HAR 3930
- HAR 372x



**Powertrain Valves – Thermal Valves**

Small valves are deployed throughout the vehicle for instance for the water cooling circuit control.

Micronas 2D Hall-effect sensors provide a suitable solution for the measurement of the current valve position being robust against air gap and temperature variations. Additionally, EV and HEV drive the need for stray-field robustness covered by HAL 39xy and HAL 30xy sensor families.

HVC all-in-one integrated solutions offer a very small footprint while matching the power requirements for a BLDC drive in a single-chip solution without the need for external MOSFETs.

Especially the trend for integrated systems is driving the need of digital interfaces like SPI. HAL 3900 together with HVC enable the customer to provide thermal management systems with high integration.

Sensor Type: 2D Hall

Controller Type: HVC

Products inside:

- HAL 302x
- HAL 37xy
- HAL 3900
- HAL 3930
- HVC 4x, HVC 5x

**Powertrain Valves – Throttle**

In a gasoline internal combustion engine, the throttle is a valve that directly regulates the amount of air entering the engine, indirectly controlling the charge (fuel + air) burned on each cycle due to the fuel injector or carburetor maintaining a relatively constant fuel/air ratio.

In a diesel engine, the throttle is used to generate intake manifold vacuum.

Linear or 2D Hall sensors with analog output are used to detect the throttle position. They bring reliability and high accuracy together with small offset and sensitivity drift over lifetime and temperature.

Sensor Types: 1D, 2D Hall

Products inside:

- HAC 830
- HAL 2425
- HAR 37xy

**Battery Management**

A high-precision current sensor is required for Battery Management System structuring SOC (State of Charge) and SOH (State of Health) estimation. Hall-based magnetic-field sensors enable current measurements with high sensitivity and high accuracy in high-power applications with low output voltage drifts over temperature and a multiple magnetic-field range. The galvanically isolated power and sensing circuits are of particular benefit in 12/48V battery monitoring and start-stop systems.

Sensor Types: Current, 1D Hall

Products inside:

- CUR 4000
- HAL 2425

**Powertrain Valves – EGR**

In internal combustion engines, exhaust gas recirculation (EGR) is a nitrogen oxide (NOx) emission reduction technique used in petrol/gasoline and diesel engines. EGR works by recirculating a portion of an engine's exhaust gas back to the engine cylinders. Exhaust gas is routed back into the combustion chamber because the exhausted air is much hotter than the intake air. By sending warmer gas into the combustion chamber, the air/fuel mix does not have to do as much work to heat up and the engine can run more efficiently.

EGR valves require the measurement of linear movements in the range of  $\pm 12$  mm. 2D Hall-effect sensors provide a potential solution for the measurement of the current valve position being robust against air gap and temperature variations. This application is strongly moving to PCB-less designs driven by the temperature range requirements. This requires leaded devices with integrated capacitors.

Additionally, HEV drive the need for stray-field robustness. Furthermore, an ISO 26262 compliant device is mandatory. Both requirements can be addressed by HAL 3930 or HAC 3930.

Sensor Type: 2D Hall

Controller Type: HVC

Products inside:

- HAL 37xy
- HAC 37xy
- HAL 3930, HAC 3930
- HVC 4x, HVC 5x

**Liquid Level**

Hall sensors are used to detect the liquid level (e.g. brake fluid) in a tank. Linearization setpoints are required here.

Sensor Types: 1D, 3D Hall

Products inside:

- HAL 2455
- HAL 37xy
- HAL 3930
- HAL 3960

**Gear Position**

Commonly located inside the automatic transmission, the gear position sensor communicates the gear position to the vehicle's electrical system.

A combination of several linear Hall sensors (up to six) is deployed in each transmission. Recent developments use 2D position sensors as well. Analog or PWM output is required. Linearization setpoints are needed depending on the travel distance to measure. Functional safety requirements drive the need for digital output formats like SENT.

Sensor Types: 1D, 2D Hall, TMR

Products inside:

- HAL 188x
- HAL 8xy
- HAL 3930
- TAS2142, ASA 2310
- TAD214x

**Water / Oil Pumps – BLDC Motor**

Hall switches or TMR angle sensors are used to detect the rotor position for any type of pumps using a brushless DC motor (BLDC). To reduce the overall current consumption, the HAL 15xy 3-wire version with only 1.6 mA is preferred.

TMR sensors are located at end of shaft and provide a very high signal resolution and stability over temperature and can operate at very high speed. Additionally, HEV drive the need for stray-field robustness. This requirement can be addressed by HAL 302x

HVC products are very well suited to provide an efficient BLDC drive for auxiliary pumps.

Sensor Types: Hall switch, Fast 2D Hall, TMR

Controller Type: HVC

Products inside:

- HAL 302x
- HAL 15xy 3-wire
- TAS2142, ASA 2310
- TAD214x
- HVC 4x, HVC 5x

**Shift Lever Position**

Hall sensors are used to determine the current position of the gear shift lever. The application setup can be realized by different solutions: from simple rotary shifters up to joystick-type based solutions. Both setups require a 2D (rotary) or 3D (joystick or rotary with push-function) position detection.

Hall switches are used for extremely price-attractive solutions by placing several switches at each gear position.

Sensor Type: Hall switch, 3D Hall

Products inside:

- HAL 3900, HAR 3900
- HAL 3930, HAR 3930
- HAL 15xy 3-wire

**Turbo Charger**

The use of pressure charging to improve engine efficiency and therefore fuel economy within the normal range of driving conditions is becoming more and more popular. Magnetic-field sensors with analog output and SENT interface are used to detect the vane position which blocks or increases the air flow to the turbine. Hall sensors bring reliability and high accuracy together with low offset and sensitivity drift over lifetime and temperature.

This application is strongly moving to PCB-less designs driven by temperature range requirements. This requires leaded devices with integrated capacitors.

Additionally, EV and HEV drive the need for stray-field robustness. This requirement can be addressed by HAL 3930 or HAC 3930.

Sensor Types: 1D, 2D Hall

Products inside:

- HAC 37xy
- HAL 3930, HAC 3930
- HAC 830
- HAL 2425

# Automotive Applications

## Electric Drive

Today, a strong trend towards electromobility can be seen on the automotive market. Initially, hybrid vehicles (HEVs) emerged that had both a combustion engine and an additional supporting electric drive helping to reduce fuel consumption and thus emissions. Now, pure electric cars (EVs) with an adequate range have also arrived on the mass market.

In addition to common vehicle sensor technology, battery management, rotor position detection and parklock actuator control are of particular importance here. TDK offers magnetic-field sensors that are precisely tailored to these applications.

### Application examples for cars with electric drive

#### Battery Management

A high-precision current sensor is required for Battery Management System structuring SOC (State of Charge) and SOH (State of Health) estimation. Hall-based magnetic-field sensors enable current measurements with high sensitivity and high accuracy in high-power applications with low output voltage drifts over temperature and a multiple magnetic-field range. The galvanically isolated power and sensing circuits are of particular benefit in high-voltage battery monitoring systems of hybrid and electric vehicles (xEV). Battery thermal management is also essential for a long battery life.

Sensor Types: Current, 1D Hall

Products inside:

- CUR 4000
- HAL 2425

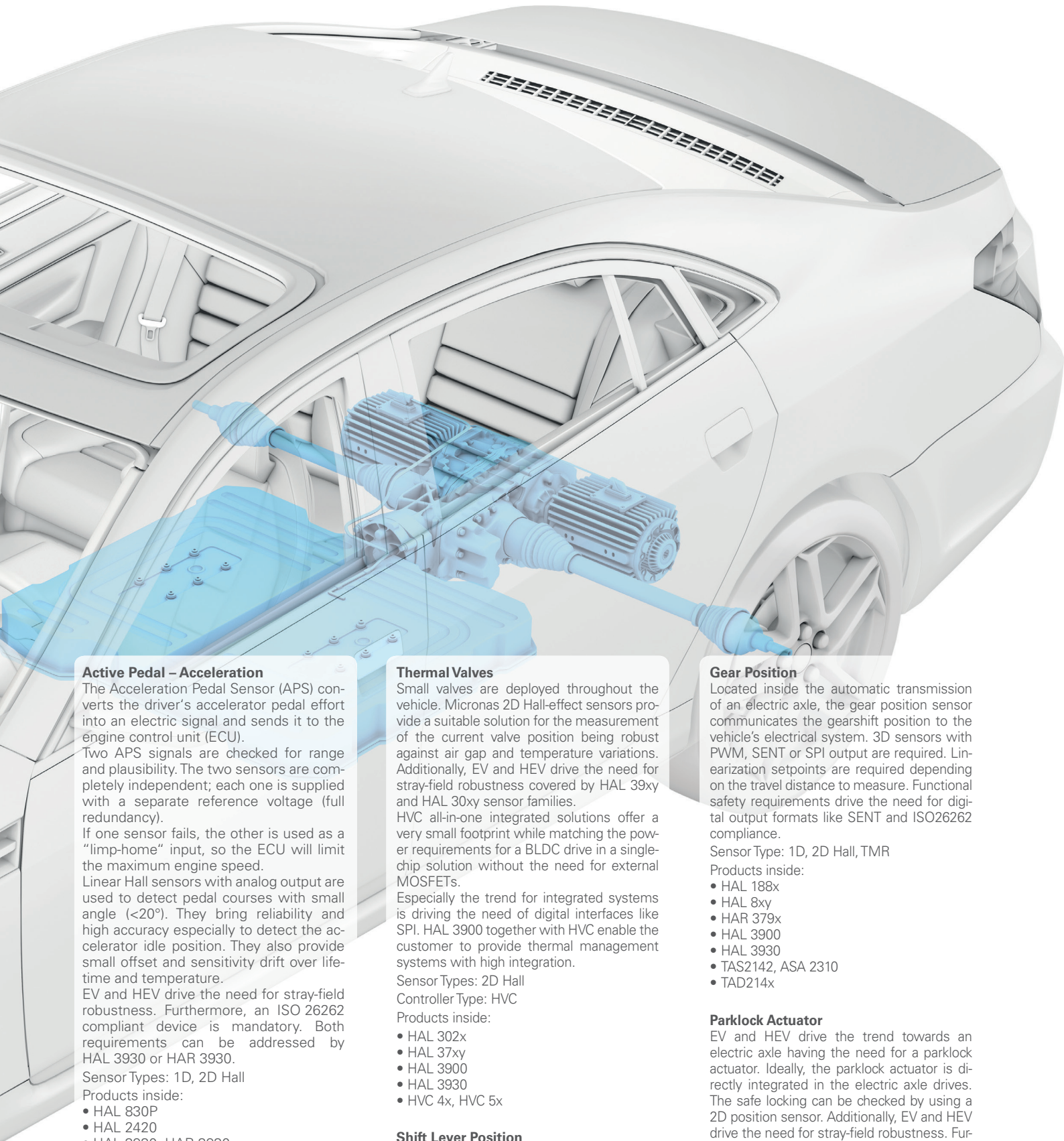
#### E-Axle Motor Position

Electric motors used for EV and HEV need accurate rotor position detection at high rotating speeds up to 150,000 RPM. TMR sensors provide a very low angular error and can be used in remote locations thanks to versions with amplified output.

Sensor Type: TMR

Products inside:

- TAS2142, ASA 2310
- TAB4140



#### Active Pedal – Acceleration

The Acceleration Pedal Sensor (APS) converts the driver's accelerator pedal effort into an electric signal and sends it to the engine control unit (ECU).

Two APS signals are checked for range and plausibility. The two sensors are completely independent; each one is supplied with a separate reference voltage (full redundancy).

If one sensor fails, the other is used as a "limp-home" input, so the ECU will limit the maximum engine speed.

Linear Hall sensors with analog output are used to detect pedal courses with small angle (<math><20^\circ</math>). They bring reliability and high accuracy especially to detect the accelerator idle position. They also provide small offset and sensitivity drift over lifetime and temperature.

EV and HEV drive the need for stray-field robustness. Furthermore, an ISO 26262 compliant device is mandatory. Both requirements can be addressed by HAL 3930 or HAR 3930.

Sensor Types: 1D, 2D Hall

Products inside:

- HAL 830P
- HAL 2420
- HAL 3930, HAR 3930

#### Liquid Level

Hall sensors are used to detect the liquid level (e.g. brake fluid) in a tank. Linearization setpoints are required here.

Sensor Types: 1D, 3D Hall

Products inside:

- HAL 2455
- HAL 37xy
- HAL 3930
- HAL 3960

#### Thermal Valves

Small valves are deployed throughout the vehicle. Micronas 2D Hall-effect sensors provide a suitable solution for the measurement of the current valve position being robust against air gap and temperature variations. Additionally, EV and HEV drive the need for stray-field robustness covered by HAL 39xy and HAL 30xy sensor families.

HVC all-in-one integrated solutions offer a very small footprint while matching the power requirements for a BLDC drive in a single-chip solution without the need for external MOSFETs.

Especially the trend for integrated systems is driving the need of digital interfaces like SPI. HAL 3900 together with HVC enable the customer to provide thermal management systems with high integration.

Sensor Types: 2D Hall

Controller Type: HVC

Products inside:

- HAL 302x
- HAL 37xy
- HAL 3900
- HAL 3930
- HVC 4x, HVC 5x

#### Shift Lever Position

Hall sensors are used to determine the current position of the gear shift lever. The application setup can be realized by different solutions: from simple rotary shifters up to joystick-type based solutions. Both setups require a 2D (rotary) or 3D (joystick or rotary with push-function) position detection.

Hall switches are used for extremely price-sensitive solutions by placing several switches at each gear position.

Sensor Types: Hall Switch, 3D Hall

Products inside:

- HAL 3900, HAR 3900
- HAL 3930
- HAL 15xy 3-wire

#### Gear Position

Located inside the automatic transmission of an electric axle, the gear position sensor communicates the gearshift position to the vehicle's electrical system. 3D sensors with PWM, SENT or SPI output are required. Linearization setpoints are required depending on the travel distance to measure. Functional safety requirements drive the need for digital output formats like SENT and ISO26262 compliance.

Sensor Type: 1D, 2D Hall, TMR

Products inside:

- HAL 188x
- HAL 8xy
- HAR 379x
- HAL 3900
- HAL 3930
- TAS2142, ASA 2310
- TAD214x

#### Parklock Actuator

EV and HEV drive the trend towards an electric axle having the need for a parklock actuator. Ideally, the parklock actuator is directly integrated in the electric axle drives. The safe position locking can be checked by using a 2D position sensor. Additionally, EV and HEV drive the need for stray-field robustness. Furthermore, an ISO 26262 compliant device is mandatory.

Sensor Types: 2D Hall, TMR

Controller Type: HVC

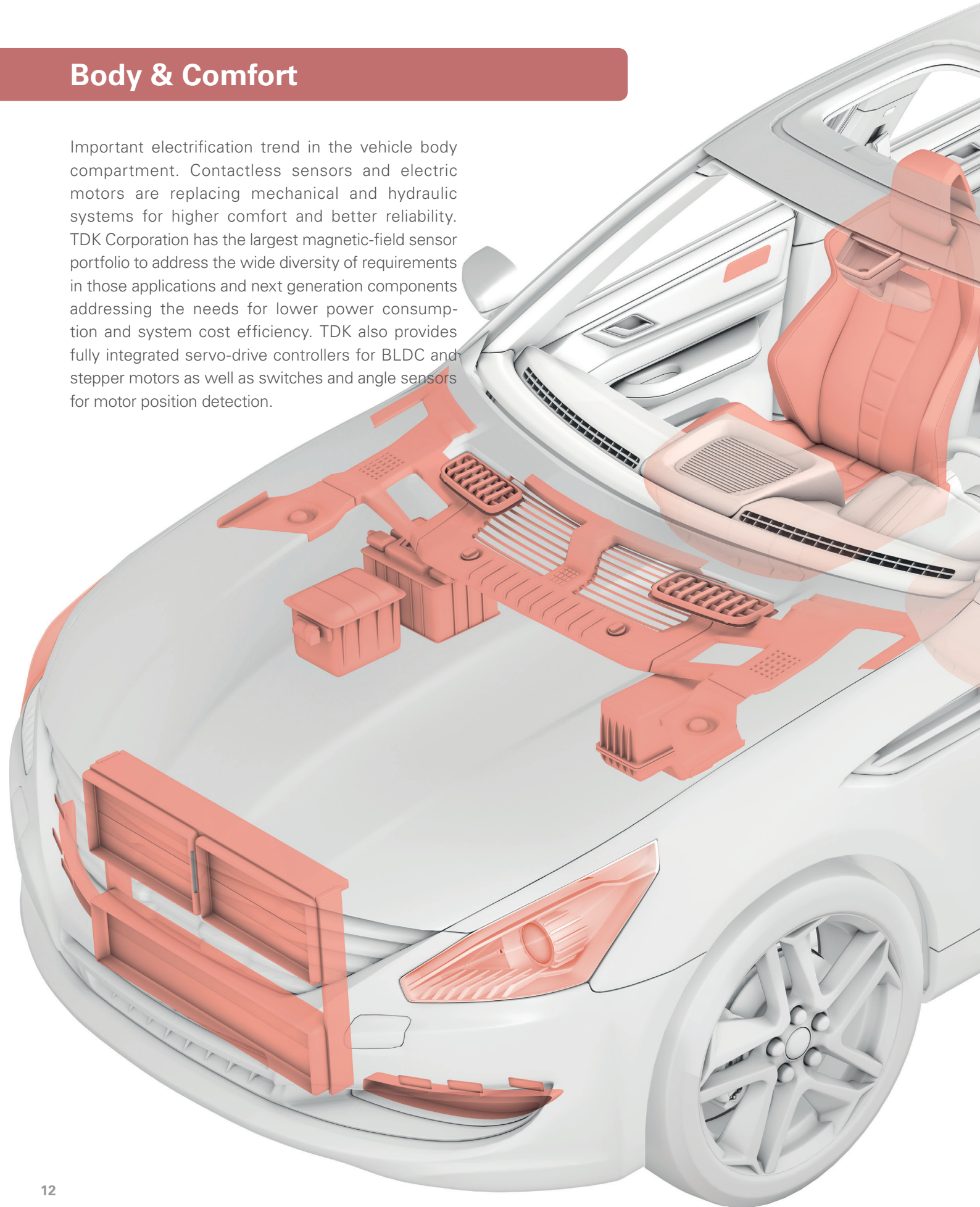
Products inside:

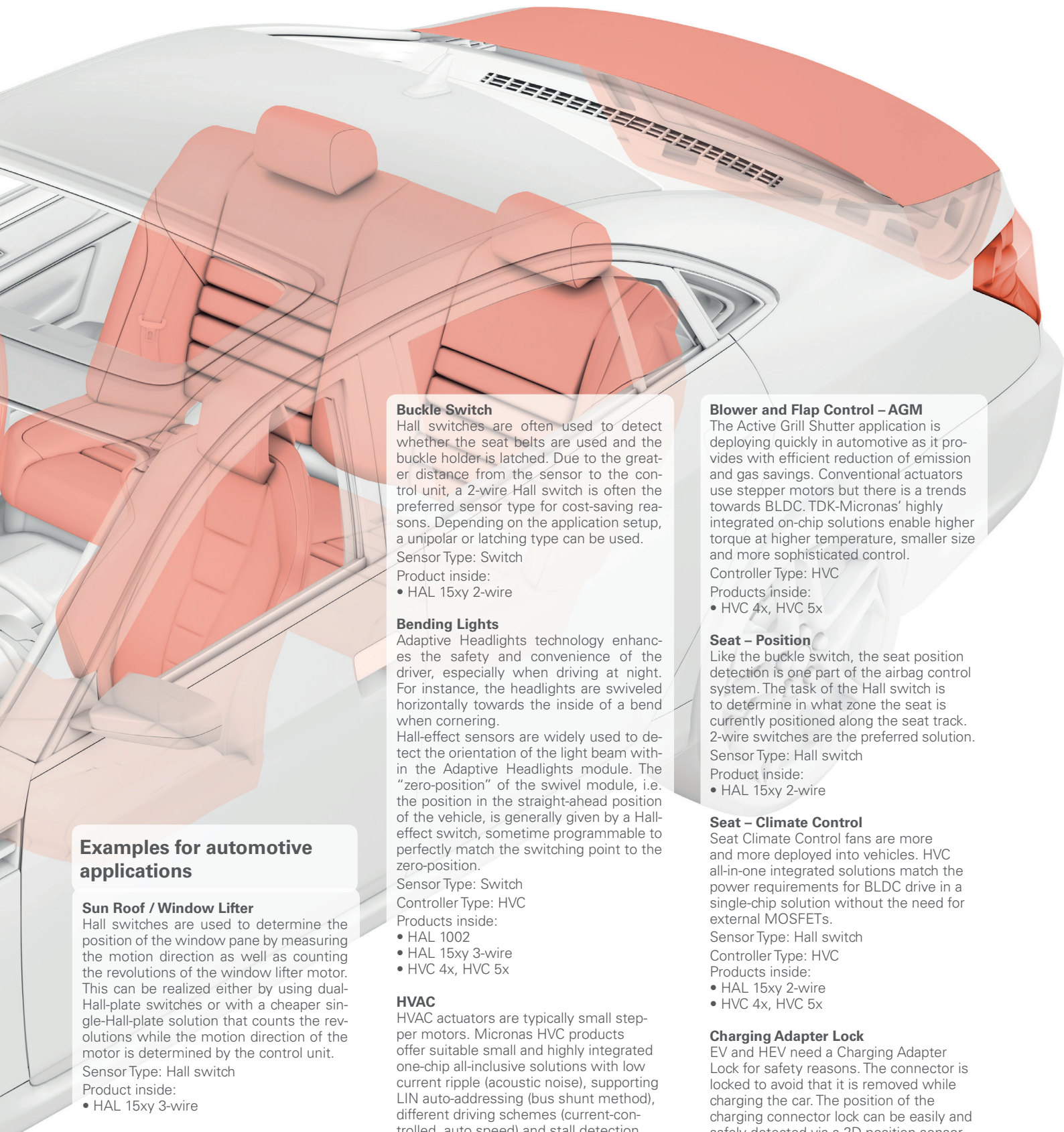
- HAR 37xy
- HAL 302x
- HAL 3900
- HAL 3930
- TAS2142, ASA 2310
- TAD214x
- HVC 4x, HVC 5x

# Automotive Applications

## Body & Comfort

Important electrification trend in the vehicle body compartment. Contactless sensors and electric motors are replacing mechanical and hydraulic systems for higher comfort and better reliability. TDK Corporation has the largest magnetic-field sensor portfolio to address the wide diversity of requirements in those applications and next generation components addressing the needs for lower power consumption and system cost efficiency. TDK also provides fully integrated servo-drive controllers for BLDC and stepper motors as well as switches and angle sensors for motor position detection.





## Examples for automotive applications

### Sun Roof / Window Lifter

Hall switches are used to determine the position of the window pane by measuring the motion direction as well as counting the revolutions of the window lifter motor. This can be realized either by using dual-Hall-plate switches or with a cheaper single-Hall-plate solution that counts the revolutions while the motion direction of the motor is determined by the control unit.

Sensor Type: Hall switch

Product inside:

- HAL 15xy 3-wire

### Door Lock

Hall switches are used to detect whether the car doors are locked or not. By skipping the third wire, the 2-wire sensor type is preferred for this kind of application in order to save costs.

Brushless actuators allow tamper-proof lock design.

Sensor Type: Hall switch

Controller Type: HVC

Products inside:

- HAL 15xy 2-wire
- HVC 4x, HVC 5x

### Buckle Switch

Hall switches are often used to detect whether the seat belts are used and the buckle holder is latched. Due to the greater distance from the sensor to the control unit, a 2-wire Hall switch is often the preferred sensor type for cost-saving reasons. Depending on the application setup, a unipolar or latching type can be used.

Sensor Type: Switch

Product inside:

- HAL 15xy 2-wire

### Bending Lights

Adaptive Headlights technology enhances the safety and convenience of the driver, especially when driving at night. For instance, the headlights are swiveled horizontally towards the inside of a bend when cornering.

Hall-effect sensors are widely used to detect the orientation of the light beam within the Adaptive Headlights module. The "zero-position" of the swivel module, i.e. the position in the straight-ahead position of the vehicle, is generally given by a Hall-effect switch, sometime programmable to perfectly match the switching point to the zero-position.

Sensor Type: Switch

Controller Type: HVC

Products inside:

- HAL 1002
- HAL 15xy 3-wire
- HVC 4x, HVC 5x

### HVAC

HVAC actuators are typically small stepper motors. Micronas HVC products offer suitable small and highly integrated one-chip all-inclusive solutions with low current ripple (acoustic noise), supporting LIN auto-addressing (bus shunt method), different driving schemes (current-controlled, auto speed) and stall detection.

Controller Type: HVC

Products inside:

- HVC 4x, HVC 5x

### Blower and Flap Control - LED Fans

Typically used for LED light cooling and mist removal, LED fans require efficient actuators with very small footprint. HVC all-in-one integrated solutions match the power requirements for BLDC drive in a single-chip solution without the need for external MOSFETs.

Controller Type: HVC

Products inside:

- HVC 4x, HVC 5x

### Blower and Flap Control – AGM

The Active Grill Shutter application is deploying quickly in automotive as it provides with efficient reduction of emission and gas savings. Conventional actuators use stepper motors but there is a trend towards BLDC. TDK-Micronas' highly integrated on-chip solutions enable higher torque at higher temperature, smaller size and more sophisticated control.

Controller Type: HVC

Products inside:

- HVC 4x, HVC 5x

### Seat – Position

Like the buckle switch, the seat position detection is one part of the airbag control system. The task of the Hall switch is to determine in what zone the seat is currently positioned along the seat track. 2-wire switches are the preferred solution.

Sensor Type: Hall switch

Product inside:

- HAL 15xy 2-wire

### Seat – Climate Control

Seat Climate Control fans are more and more deployed into vehicles. HVC all-in-one integrated solutions match the power requirements for BLDC drive in a single-chip solution without the need for external MOSFETs.

Sensor Type: Hall switch

Controller Type: HVC

Products inside:

- HAL 15xy 2-wire
- HVC 4x, HVC 5x

### Charging Adapter Lock

EV and HEV need a Charging Adapter Lock for safety reasons. The connector is locked to avoid that it is removed while charging the car. The position of the charging connector lock can be easily and safely detected via a 2D position sensor.

Sensor Type: 2D Hall

Products inside:

- HAL 3930, HAC 3930

### Wiper - Motor Position

A TMR sensor is located at the end of shaft to measure the rotor position of the BLDC wiper motor.

It provides a very high signal resolution and stability over temperature.

Sensor Type: Fast 2D Hall, TMR

Products inside:

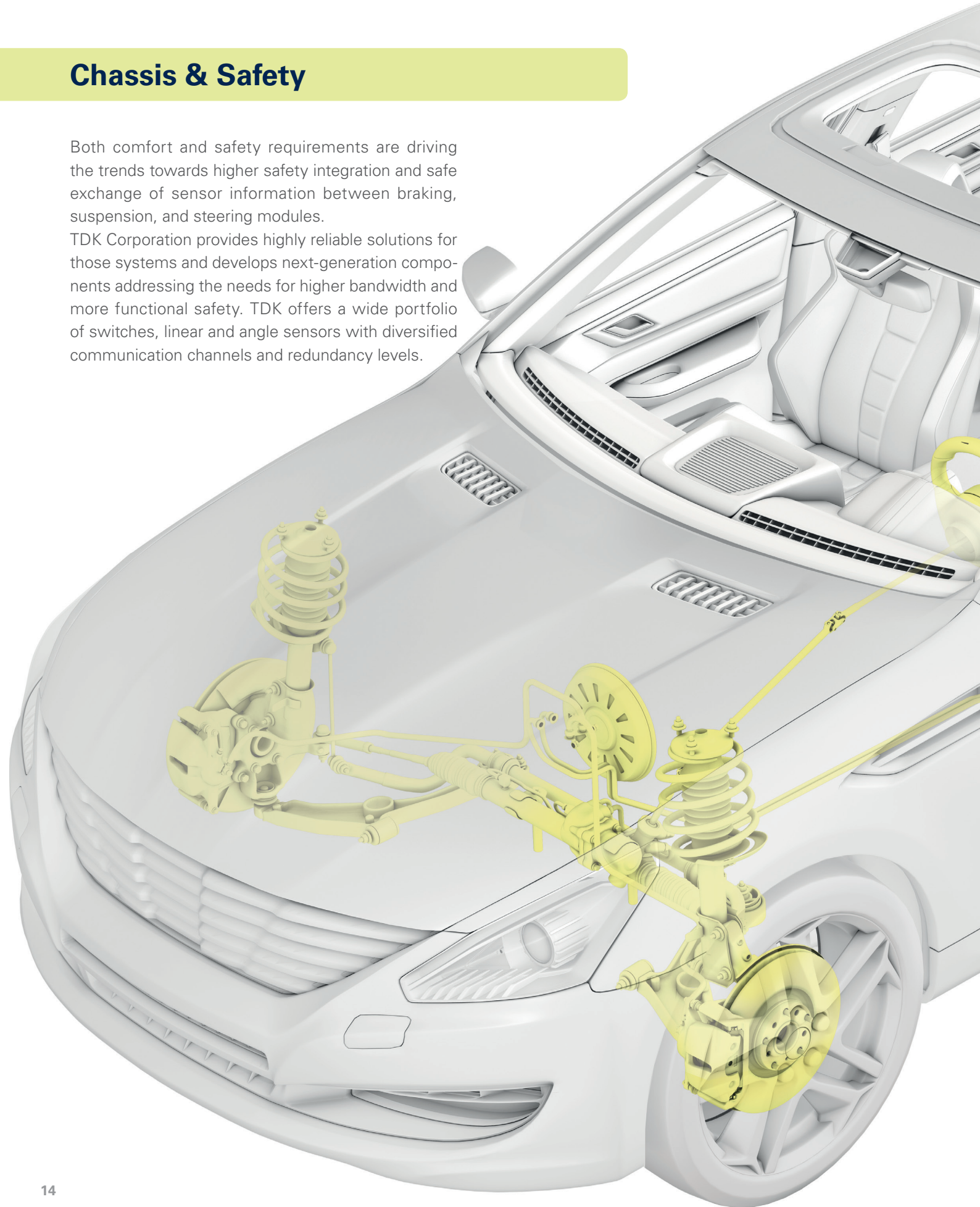
- HAL 302x
- TAS2142, ASA 2310
- TAD214x

# Automotive Applications

## Chassis & Safety

Both comfort and safety requirements are driving the trends towards higher safety integration and safe exchange of sensor information between braking, suspension, and steering modules.

TDK Corporation provides highly reliable solutions for those systems and develops next-generation components addressing the needs for higher bandwidth and more functional safety. TDK offers a wide portfolio of switches, linear and angle sensors with diversified communication channels and redundancy levels.



## Examples for automotive applications

### Steering Torque

Electronic Power Steering (EPS) systems are becoming prevalent in automotive systems to replace hydraulic assist power steering. The move to EPS systems is driven by the necessity for improving overall fuel efficiency, reducing system cost, improving driving experience with active cornering and adding safety features like driver drowsiness detection.

Steering torque information is always needed to drive the Steering Assist Motor. This is safety critical information – the applied torque has a direct influence on the driver's capability to steer the vehicle. Therefore, redundant information coming from two sensors is always needed. 1D Linear Hall sensors are used here to realize a magnetic-field amplitude measurement. Micronas solutions offer low-noise and low-offset-drift capabilities. Single- and dual-die solutions with analog or PWM output are available.

Sensor Type: 1D Hall

Products inside:

- HAL 835P
- HAR 24xy

### Steering Angle

Modern Electric Power Steering (EPS) systems require the measurement of the steering position. Hall-effect sensors measuring the 360° angular information are the suitable and cost-efficient solution for a contactless steering-position measurement. The devices support state-of-the-art interfaces like PWM, SENT, and SPC. 2D Hall-effect sensors are used, because 360° angular measurement is required. Stray-field robustness is now becoming more importance due to the car electrification.

Sensor Types: 2D Hall, TMR

Products inside:

- HAL 3930, HAR 3930
- HAL 3970, HAR 3970
- TAS2142, ASA 2310
- TAD214x

### Steering Motor – BLDC Motor

As part of the power steering system, Hall switches are used for BLDC motor commutation. To reduce the overall current consumption, the HAL1502 3-wire version with only 1.6 mA is preferred.

TMR sensors are located at the end of shaft. They provide a very high signal resolution with stability over temperature and support up to ASIL D safety standard thanks to signal redundancy (fail operational).

Sensor Types: Hall switch, Fast 2D Hall, TMR

Products inside:

- HAL15xy 3-wire
- HAL 3021
- TAS2142, ASA 2310
- TAS414x, ASA 2310
- TAD214x
- TAA6140

### Chassis Position Sensor

Chassis position sensors regulate the main lights for greater road safety. Depending on the load of vehicle, main headlights can blind oncoming traffic. The chassis position sensor determines the current position of the vehicle and adjusts the range of the main headlights accordingly. The CPS is an angular sensor requiring full 360° measurement range. This measurement range is usually split into four repeating 90° or three 120° segments. The interface is usually analog, PWM, or recently also PS15.

Sensor Type: 2D Hall

Products inside:

- HAL 3715, HAC 3715
- HAL 3930, HAC 3930
- HAL 3980, HAC 3980

### Buckle Switch

Hall switches are often used to detect whether the seat belts are used and the buckle holder is latched. Due to the greater distance from the sensor to the control unit, a 2-wire Hall switch is often the preferred sensor type for cost-saving reasons. Depending on the application setup, a unipolar or latching type can be used.

Sensor Type: Switch

Product inside:

- HAL 15xy 2-wire

### Liquid Level

Hall sensors are used to detect the liquid level (e.g. brake fluid) in a tank. Linearization setpoints are required here.

Sensor Types: 1D, 3D Hall

Products inside:

- HAL 2455
- HAL 37xy
- HAC 37xy
- HAL 3930
- HAL 3960

### Braking Pedal

The latest generation of braking systems is taking the next step towards brake-by-wire. Those systems do not have a vacuum booster anymore. This is especially mandatory for EVs. Firstly, a position sensor is required to detect that the brake pedal is pressed to generate the hydraulic pressure. Secondly, the brake light will be activated at the car's rear. For this, a 2D position Hall sensor can be used. If only the brake light activation is required, a 2-wire switch can be used.

Additionally, EV and HEV drive the need for stray-field robustness. Furthermore, an ISO26262 compliant device is mandatory. Both requirements can be addressed by HAL 393x or HAR 393x.

Sensor Types: 2D Hall, Hall switch

Products inside:

- HAL 15xy 2-wire
- HAR 37xy
- HAL 393x, HAR 393x

### Belt Starter Generator (BSG) Motor Control

A TMR sensor measures the position of the rotor over 360°. It is located at end of shaft and provides a very high signal resolution and stability over temperature, thus reducing the angle error over lifetime.

Sensor Type: Fast 2D Hall, TMR

Products inside:

- HAL 302x
- TAS2142

### Brake Booster Motor Control

A TMR sensor measures the position of the rotor over 360°. It is located at end of shaft and provides a very high signal resolution and stability over temperature, thus reducing the angle error over lifetime. Additionally, EV and HEV drive the need for stray-field robustness. Furthermore, an ISO 26262 compliant device is mandatory. Both requirements can be addressed by HAL 302x.

Sensor Type: Fast 2D Hall, TMR

Products inside:

- HAL 3021
- TAS2142, ASA 2310
- TAD214x
- TAD414x

### Light detection and ranging (LIDAR)

A TMR sensor measures the position of the spinning prism over 360° in an off-axis or end-of-shaft configuration. This angular information is used for the BLDC computation. As well, due its very high angular resolution and accuracy, it is used to measure the specific angle of a laser beam reflected by an object.

The HVC drives the BLDC motor which spins the LIDAR prism.

Sensor Type: TMR

Controller Type: HVC

Products inside:

- TAS2142, ASA 2310
- TAD214x
- HVC 4x, HVC 5x

# Industrial Applications

## Attractive Robotics

Robotics is set to be the next wave of growth for the electronic industry. TDK's sensors and motor controllers offer solutions for many kinds of different robots.

### Industrial Robotic Arm

Initiatives such as Industry 4.0 and Made in China 2025 as well as the emergence of 5G communication accelerate the adoption of collaborative robotic arms with associated sensors and actuators in factories. Precise displacement, angle and motor control are key to the deployment of such robots – This is also the focus of our sensors and actuators.

- Motor control and position: HVC and TMR
- Joint Angle measurement: HAL 3900, TAD2141
- Stroke measurement: HAL 3900

### Personal & Toys

From a small toy or pet robot to an humanoid service robot, a large diversity of robots are expected to join our homes, retailers & companies. TDK focuses here to provide with adequate motor control solutions.

- Motor control and position: HVC and TMR

### Home Care

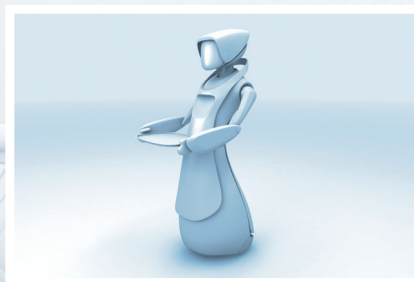
Already deployed in mass production, those robots are helping us into our daily activities at home. Efficient motor control and precise position detection is required. Motor position: TMR

- Motor control and position: HVC and TMR
- Lift or bump detection: Switches

### AGV (Automated Guided Vehicle), AMR (Automated Mobility Robot)

Already deployed in factories of large e-commerce companies, those robots are set to become the solution for warehousing, order processing but also to solve the "last-mile delivery" issue for the e-commerce industry. MSBG is making sure that its e-mobility solutions are adapted to this growing segment

- Motor position: TMR
- Motor control: HVC
- Door lock, lift and bump detection: Switches





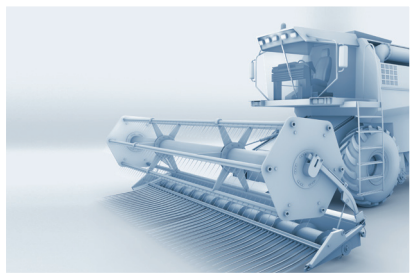
## Attractive Mobility



Presently, we see an increase in the share service of electric vehicles smaller than cars such as electric scooters, electric bikes, and senior cars (electric carts). These micromobilities integrate all transportation means into one mobility service (MaaS: Mobility as a Service). TDK aims to contribute to the development of the next-generation mobility society including MaaS by applying technologies, trends, and know-how related to the micromobility industry. In addition, TDK strives to offer semiconductor solutions for special utility and recreational vehicles.

### Light E-mobility

- Torque sensor: TMR
- Motor commutation: HVC, TMR, Fast 2D Hall, Switches
- Acceleration grip: 2D Hall, TMR



### Utility Vehicles / Recreational Vehicles / Boats / Agriculture & Heavy Machinery

- Pedal: 1D Hall
- Throttle: 2D Hall
- Torque & angle sensor: TMR, 2D Hall
- Joystick: 3D Hall
- Knob, thumbwheel, slider, paddle: 1D Hall

## Attractive Energy



Due to the increasing environmental awareness and the demand for renewable energy, the development of high-efficiency power electronics is required to improve the production, conversion, and storage of this "green" energy. With various types of current sensors, TDK is able to offer solutions for specific needs such as for battery management or surge-protection systems.

### Attractive Energy

- Energy conversion and storage (PV solar, Battery Energy storage System (BESS))
- BMS sensor: CUR 4000, 1D Hall
- Surge protection: switches
- UPS (Uninterrupted Power Supply): CUR 4000

Hall Switches

Variant	Magnetic Characteristics Typical @ 25 °C		Type				Typical temperature coefficient			Configuration		Package		Current Consumption			Supply Voltage		Application Range							
	B <sub>ON</sub> - [mT]	B <sub>OFF</sub> - [mT]	Unipolar	Unipolar Inverted	Bipolar	Latching	0 ppm/K	-300 ppm/K	-1000 ppm/K	-1200 ppm/K	2-Wire	3-Wire	SOT23	TO92UT <sup>3/4)</sup>	I <sub>SUP</sub> = 1.6 mA	I <sub>SUP</sub> = 7 mA	I <sub>SUPlow1</sub> = 2...5 mA	I <sub>SUPlow2</sub> = 5...7 mA	I <sub>SUPhigh</sub> = 12...17 mA	V <sub>SUP</sub> = 2.7...24V	V <sub>SUP</sub> = 3...24V	V <sub>SUP</sub> = 4.5V... 8.5 V	Position Detection	RPM Measurement	Brushless DC motors	
HAL 10xy	HAL 1002	Programmable		•	•						•		•		•				•							
HAL 15xy <sup>1)</sup>	HAL 1501	0.4	-0.4			•					•	•	•	•					•				•	•	•	•
	HAL 1502	2.5	-2.5				•				•	•	•	•					•				•	•	•	•
	HAL 1503	5.5	3.7	•				•			•	•	•	•					•				•	•	•	•
	HAL 1504	7.6	-7.6						•		•	•	•	•					•				•	•	•	•
	HAL 1505	13.5	-13.5							•	•	•	•	•					•				•	•	•	•
	HAL 1506	18.9	17.3	•						•	•	•	•	•					•				•	•	•	•
	HAL 1507	28.2	23.9	•				•			•	•	•	•					•				•	•	•	•
	HAL 1508 <sup>2)</sup>	-5.5	-3.7	•					•		•	•	•	•					•				•	•	•	•
	HAL 1509	3.7	5.5		•						•	•	•	•					•				•	•	•	•
	HAL 1510	12	7	•						•	•	•	•	•					•				•	•	•	•
	HAL 1561	4	-4				•				•	•	•	•					•				•	•	•	•
	HAL 1562	12	-12				•				•	•	•	•					•				•	•	•	•
	HAL 1563	7.6	9.4		•						•	•	•	•					•				•	•	•	•
	HAL 1564	4.1	6		•						•	•	•	•					•				•	•	•	•
	HAL 1565	6	4.1	•							•	•	•	•					•				•	•	•	•
HAL 1566	9.4	7.6	•							•	•	•	•					•				•	•	•	•	

<sup>1)</sup>ISO 26262 compliant    <sup>2)</sup>north pole sensitive    <sup>3)</sup>straight or spread leads    <sup>4)</sup>standard 15.7 ± 0.2 mm or long lead length 21 ± 0.2 mm  
 For consumer/industrial applications, please contact TDK-Micronas for 3-wire versions with a junction temperature range from -40 °C to 140 °C.

TMR Angle Sensors

Variant	Angle Error	Output						Special Features	Temp. Range	Functional Safety		Magnetic-Field Range	Detection Range	Package			
		Analog Sin & Cos			Digital					Redundancy	Self-Diagnosis			TSSOP8	TSSOP16	QFN16	TO6
		Analog Differential	2 x Analog Single-ended, amplified	3 x Analog Single-ended, amplified	SENT, PWM, ENC, UVW	SPI, PWM, ENC, UVW	SENT/ PWM, UVW/ ABZ/ SPI	No. of Outputs	No. of TMR Bridges			Integrated DSP (FSM)	Integrated Capacitors				
TAS2142	±0.6° or less	3.0 V <sub>PP</sub>						4	2			•	•	•	•	•	•
TAS4140	±0.6° or less	1.5 V <sub>PP</sub>						8	4			•	•	•	•	•	•
TAS4142	±0.8° or less	3.0 V <sub>PP</sub>						8	4			•	•	•	•	•	•
TAB4140	±0.8° or less		•					8	4			•	•	•	•	•	•
TAA6140	±0.8° or less			•				6	6			•	•	•	•	•	•
TAD2140	±0.2° or less				•			2	2	•	•	•	•	•	•	•	•
TAD2141	±0.2° or less					•		2	2	•	•	•	•	•	•	•	•
TAD4140	±0.2° or less						•	4	4	•	•	•	•	•	•	•	•
TAD2143 <sup>1)</sup>	±0.2° or less						•	2	2	•	•	•	•	•	•	•	•

<sup>1)</sup>Industrial grade only available

TMR Front-End ICs

Variant	Programmable	Input / Output				Functional Safety	Configuration					Electrical Characteristics		Package		
		Number of Inputs	Number of Outputs	Analog Sin & Cos			Self-Diagnosis	Overvoltage Detection	Undervoltage Detection	Open VSUP Detection	Open GND Detection	Overcurrent Detection	V <sub>SUP</sub> [V]		I <sub>OUT</sub> (typ.) [mA]	
Analog Differential, amplified	Analog single-ended, amplified															
ASA 23xy	ASA 2310	•	4	4	•	•	•	•	•	•	•	•	•	•	•	•

Magnetic Current Sensors

Variant	Programmable	Magnetic Range		Output			Configuration				Electrical Characteristics		Package	Application		
		B <sub>min</sub> [mT]	B <sub>max</sub> [mT]	Analog	SPI	SENT	Overvoltage Detection	Undervoltage Detection	Open VSUP Detection	Open GND Detection	V <sub>SUP</sub> [V]	I <sub>OUT</sub> (max) [mA]				
CUR 40xy	CUR 4000	•	±100	±100	•	•	•	•	•	•	•	•	•	•	•	•

### Linear Hall Sensors

Variant		Magnetic Range		Type								Configuration					Electrical Characteristics		Config.			Package					Application Range												
		Programmable	B <sub>min</sub> [mT]	B <sub>max</sub> [mT]	Setpoints	Analog	PWM	PSi5	SPI	SENT	SPC	Integrated Capacitors	Redundancy Function	Stray-Field Compensation	Overvoltage Detection	Undervoltage Detection	Open VSUP Detection	Open GND Detection	Overcurrent Detection	V <sub>SUP</sub> [V]	I <sub>OUT</sub> (max) - [mA]	2-Wire	3-Wire	TO92UA	TO92UT	TO92UP	TO92UF	SOIC8	TSSOP14	SSOP16	Linear Movement	Current Measurement	Rotary Position	Levelling	Force/Pressure	Torque Measurement			
HAL 8xy	HAL 830P	•	±30	±100	2	•								•	•	•	•	•	4.5 to 5.5	1.2	•		•							•	•	•	•	•	•				
	HAC 830	•	±30	±100	2	•					•			•	•	•	•	•	4.5 to 5.5	1.2	•			•						•	•	•	•	•	•				
	HAL 835P	•	±15	±150	2	•	■							•	•	•	•	•	4.5 to 5.5	1.2	•			•						•	•	•	•	•	•				
HAL 18xy	HAL 1870	•	±20	±160	0		■							•	•			•	4.5 to 5.5	5	•	•							•	•	•	•	•	•					
	HAL 1880	•	±20	±160	0	•								•	•			•	4.5 to 5.5	1	•								•	•	•	•	•	•					
	HAL 1881	•	-50	+50	0	•								•	•			•	4.5 to 5.5	1	•	•							•	•	•	•	•	•					
	HAL 1882	•	-80	+80	0	•								•	•			•	4.5 to 5.5	1	•	•							•	•	•	•	•	•					
	HAL 1883	•	-100	+100	0	•								•	•			•	4.5 to 5.5	1	•	•							•	•	•	•	•	•					
	HAL 1890	•	-100	+100	0					•				•	•			•	4.5 to 5.5	1	•	•							•	•	•	•	•	•					
	HAL 24xy	HAL 2420	•	±25	±200	2	•								•	•	•	•	•	4.5 to 5.5	1.2	•		•			•		•	•	•	•	•	•	•	•			
	HAL 2421 <sup>1)</sup>	•	±25	±200	2	•								•	•	•	•	•	4.5 to 5.5	1.2	•		•					•	•	•	•	•	•	•	•				
	HAL 2425	•	±25	±200	16	•								•	•	•	•	•	4.5 to 5.5	1.2	•		•			•		•	•	•	•	•	•	•	•	•			
	HAR 2425	•	±25	±200	16	•					•			•	•	•	•	•	4.5 to 5.5	1.2	•					•		•	•	•	•	•	•	•	•	•	•		
	HAR 2455	•	±25	±200	16		■							•	•	•	•	•	4.5 to 5.5	1.2	•		•			•		•	•	•	•	•	•	•	•	•	•		

<sup>1)</sup> T<sub>J</sub> = -40 °C to 140 °C    ■ Programmable PWM frequency    ◆ Programmable: see data sheet

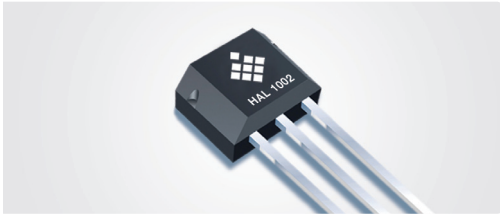
### Angle Sensors

HAL 30xy	HAL 302x	•	±5	±250	-	•								•	•	•	•	•	•	3.0 to 5.5	10	•																				
HAL 37xy	HAL 3715	•	±20	±100	33	•								•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAL 3725	•	±20	±100	33	•								•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAL 3726	•	±20	±100	33	•								•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAL 3727	•	±20	±100	33	•								•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAL 3735	•	±20	±100	33		■			•				•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAL 3736	•	±20	±100	33		■			•				•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAL 3737	•	±20	±100	33		■			•				•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
HAR 37xy	HAR 3715	•	±20	±100	33	•					•			•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAR 3725	•	±20	±100	33	•					•			•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAR 3726	•	±20	±100	33	•					•			•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAR 3727	•	±20	±100	33	•					•			•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAR 3735	•	±20	±100	33		■			•				•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAR 3736	•	±20	±100	33		■			•				•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAR 3737	•	±20	±100	33		■			•				•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAR 3795	•	±20	±100	33		■			•				•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
HAR 3796	•	±20	±100	33		■			•				•	•	•	•	•	•	4.5 to 5.5	1.2	•																					
HAR 3797	•	±20	±100	33		■			•				•	•	•	•	•	•	4.5 to 5.5	1.2	•																					
HAC 37xy	HAC 3715	•	±20	±100	33	•					•			•	•	•	•	•	•	4.5 to 5.5	1.2	•					•															
	HAC 3725	•	±20	±100	33	•					•			•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAC 3726	•	±20	±100	33	•					•			•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAC 3727	•	±20	±100	33	•					•			•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAC 3735	•	±20	±100	33		■			•				•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
	HAC 3736	•	±20	±100	33		■			•				•	•	•	•	•	•	4.5 to 5.5	1.2	•																				
HAL 39xy	HAL 3900	•	±10	±130	33					•				•	•	•	•	•	•	3.0 to 5.5	-	•																				
	HAL 3927	•	±20	±130	33	•				•				•	•	•	•	•	•	4.5 to 5.5	1.1	•																				
	HAL 3960	•	±10	±130	33		■							•	•	•	•	•	•	4.0 to 11	-	•																				
	HAL 3930	•	±10	±130	33		■				•			•	•	•	•	•	•	3.0 to 18	20	•																				
	HAL 3970	•	±10	±130	33					•				•	•	•	•	•	•	3.0 to 16	20	•																				
	HAL 3980	•	±10	±130	33					•				•	•	•	•	•	•	4.0 to 11	-	•																				
HAC 39xy	HAC 3930	•	±10	±130	33		■			•																																

# HAL<sup>®</sup> 1002



## In-System Programmable Hall Switch



### Functions

The HAL 1002 is the optimal system solution for applications, such as:

- Position detection

### Application Examples

- Endposition detection
- Liquid-level detection
- Electronic fuse
- Bending lights

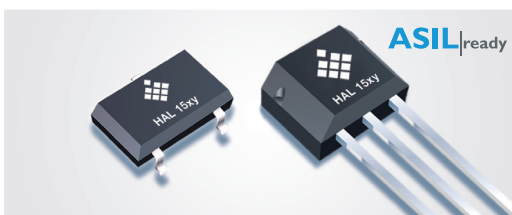
### Features

- Operates from  $-40\text{ °C}$  up to  $170\text{ °C}$  junction temperature
- High-precision Hall switch with programmable switching points and switching behavior
- Switching points programmable from  $-30\text{ mT}$  up to  $150\text{ mT}$  in steps of  $0.5\%$  of the magnetic field range
- Multiple programmable magnetic characteristics in a non-volatile memory (EEPROM) with redundancy and lock function
- Temperature characteristics are programmable for matching all common magnetic materials
- Programming through modulation of the supply voltage
- Operates from  $4.5\text{ V}$  up to  $5.5\text{ V}$  supply voltage in specification and functions up to  $8.5\text{ V}$
- Operates with static magnetic fields and dynamic magnetic fields up to  $2\text{ kHz}$
- Magnetic characteristics are extremely robust against mechanical stress effects
- Overvoltage and reverse-voltage protection at all pins
- Short-circuit protected push-pull output
- High ESD performance:  $8\text{ kV}$
- EMC optimized design
- Package: TO92UT-2

# HAL<sup>®</sup> 15xy



## First ISO 26262 Compliant Low-Power Hall Switch Family



### Application Examples

The HAL 15xy sensor family is a potential system solution for applications, such as:

- Endposition detection
- Brushless DC motor commutation
- Revolutions per minute (RPM) or other rotary measurements

### Features

- 3-wire version with a short-circuit protected open-drain output
- 2-wire version with current output
- Very low current consumption of typ.  $1.6\text{ mA}$  (3-wire)
- Wide supply voltage operation from  $2.7\text{ V}$  to  $24\text{ V}$  (3-wire)
- Overvoltage protection capability up to  $40\text{ V}$
- Available in the smallest SOT23 and TO92UA package
- Highest ESD performance up to  $\pm 8\text{ kV}$  (HBM)
- Reverse-voltage protection at supply pin ( $-18\text{ V}$ )
- Operating with static and dynamic magnetic fields up to  $12\text{ kHz}$  at lowest output jitter of typ.  $0.72\text{ }\mu\text{s}$  (RMS). Customized versions are possible up to  $93\text{ kHz}$ .
- AEC-Q100 qualification
- ASIL-B ready (SEooC according to ISO 26262), compliant with additional functional safety features like power-on self-test
- Wide junction temperature range from  $-40\text{ °C}$  to  $170\text{ °C}$ , especially designed for operation in harsh environments
- Magnetic characteristics are robust against mechanical stress
- Broad variety of temperature-compensated constant switching points
- Package: SOT23 or TO92UA

# HAL<sup>®</sup> 18xy



## Linear Hall-Effect Sensor Family – Programmable or with Fixed Sensitivity



### Features

- Operates from –40 °C up to 170 °C junction temperature
- Linear Hall-effect sensors with ratiometric analog, PWM, or SENT output
- Various programmable magnetic characteristics with non-volatile memory
- Digital signal processing
- Continuous measurement ranges from ±20 mT to ±160 mT
- Temperature characteristics programmable for matching all common magnetic materials
- Programming via supply voltage
- Lock function and built-in redundancy for EEPROM memory
- Operates from 4.5 V up to 5.5 V supply voltage
- Operates with static magnetic fields and dynamic magnetic fields up to 5 kHz
- Overvoltage and reverse-voltage protection on VSUP pin
- Magnetic characteristics extremely robust against mechanical stress
- Short-circuit protected output
- Package: TO92UA

### Application Examples

HAL 18xy is a potential system solution for applications such as:

- Linear movement
- Distance measurements
- Gear position sensor

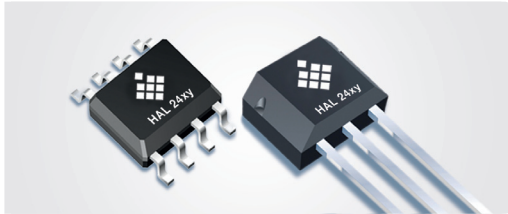
Type	Sensitivity [mV/mT]	Output
HAL 1880	programmable	analog
HAL 1881	50	analog
HAL 1882	31.25	analog
HAL 1883	25	analog
HAL 1870	programmable	PWM
HAL 1890	programmable	SENT

**Note:** HAL 188y can replace HAL 182y.

# HAL<sup>®</sup> 24xy



## Precise and Robust Programmable Linear Hall-Effect Sensor Family



### Features

- High-precision linear Hall-effect sensor with ratiometric 12-bit analog output
- 16 setpoints for various output signal characteristics (HAL 2425, HAL 2455)
- High immunity against HBM ESD (8 kV)
- Multiple customer-programmable magnetic characteristics in EEPROM with redundancy and lock function
- Programmable temperature compensation for sensitivity and offset
- Magnetic field measurements in the range up to 200 mT
- Low output voltage drifts over temperature.
- Open-circuit (ground and supply line break detection), overvoltage and under-voltage detection
- Programmable output clamping function
- Digital readout of temperature and magnetic field information in calibration mode
- Operates from 4.5 V up to 5.5 V supply voltage in specification
- Operates with static magnetic fields and dynamic magnetic fields up to 2 kHz
- Overvoltage and reverse-voltage protection at all pins
- Short-circuit protected push-pull output
- Package: SOIC8 or TO92UT

### Applications

The HAL 24xy is a potential system solution for applications such as:

- Angular measurement: throttle position, pedal position, steering torque, and EGR
- Current sensing

### Family Overview

- HAL 2420 Analog output, 2-point calibration
- HAL 2421 Low-Noise,  $T_J=140\text{ }^\circ\text{C}$
- HAL 2425 Analog output, 2-point calibration, 16 setpoints linearization
- HAL 2455 PWM output (up to 2 kHz), 16 setpoints linearization

# HAR<sup>®</sup> 24xy



## Precise and Robust Programmable Linear Hall-Effect Sensor Family – with Redundancy Functionality



### Features

- High-precision linear Hall-effect sensor with ratiometric 12-bit analog output (HAR 2425) or PWM output (HAR 2455)
- Dual-die Hall-effect sensors for true redundancy
- 16 setpoints for various output signal characteristics
- High immunity against HBM ESD (8 kV)
- Multiple customer-programmable magnetic characteristics in EEPROM with redundancy and lock function
- Programmable temperature compensation for sensitivity and offset
- Magnetic field measurements in the range up to 200 mT
- Low output voltage drifts over temp.
- Open-circuit (ground and supply line break detection), overvoltage and under-voltage detection
- Programmable output clamping function
- Digital readout of temperature and magnetic field information in calibration mode
- Operates from 4.5 V up to 5.5 V supply voltage in specification
- Operates with static magnetic fields and dynamic magnetic fields up to 2 kHz
- Overvoltage and reverse-voltage protection at all pins
- Short-circuit protected push-pull output
- Package: TSSOP14

### Applications

The HAR 24xy is a potential system solution for applications such as:

- Angular measurement: throttle position, pedal position, steering torque, and EGR
- Distance and linear movement measurements in safety critical applications
- Current sensing

### Family Overview

- HAR 2425 Analog output, 2-point calibration, 16 setpoints linearization
- HAR 2455 PWM output (up to 2 kHz), 16 setpoints linearization

# HAL<sup>®</sup> 83xP



## Programmable Linear Hall-Effect Sensor Family



### Features

- High-precision linear Hall-effect sensor with 12-bit analog output
- Programmable temperature compensation for sensitivity
- Open-circuit (ground and supply line break) detection with 5 kΩ pull-up and pull-down resistor, overvoltage and undervoltage detection
- Programmable clamping function
- Programming and operation of multiple sensors at the same supply line
- High immunity against ESD
- Operates from 4.5 V up to 5.5 V supply voltage in specification and functions up to 8.5 V
- Overvoltage and reverse-voltage protection at all pins, short-circuit protected push-pull output
- Magnetic field measurement range from ±15 mT up to ±150 mT (HAL 835P)
- Flexible analog / PWM output (HAL 835P)
- Programmable low-pass filter at 80 Hz (less noise) or 2 kHz (faster response) (HAL 835P)
- Offset drift over temperature less than ±0.2% of  $V_{SUP}$  (±0.1% for HAL 835P)
- Package: TO92UT

### Applications

The HAL 83xP is a potential system solution for applications such as:

- Linear movement
- Angle detection
- Accelerator pedal
- Throttle position
- Steering torque
- Exhaust gas recirculation
- Turbo charger

**Note:** HAL 830P can replace HAL 805, HAL 815, or HAL 817

HAL 835P can replace HAL 810 or HAL 825

<b>HAL 830P</b>	Analog output, 30 mT to 100 mT range
<b>HAL 835P</b>	Analog and PWM output, 15 mT to 150 mT range additional features

# HAC<sup>®</sup> 830



## Robust Multi-Purpose Linear Hall-Effect Sensor with Integrated Capacitors



### Features

- High-precision linear Hall-effect sensor with 12-bit analog output
- Integrated capacitors for improved electromagnetic compatibility (EMC) and PCB-less applications
- Programmable temperature compensation for sensitivity
- Open-circuit (ground and supply line break) detection with 5 kΩ pull-up and pull-down resistor, overvoltage and undervoltage detection
- Programmable clamping function
- Programming and operation of multiple sensors at the same supply line
- High immunity against HBM ESD
- Operates from 4.5 V up to 5.5 V supply voltage in specification and functions up to 8.5 V
- Overvoltage and reverse-voltage protection at all pins, short-circuit protected push-pull output
- Magnetic field measurement range from ±30 mT up to ±100 mT
- Package: TO92UP

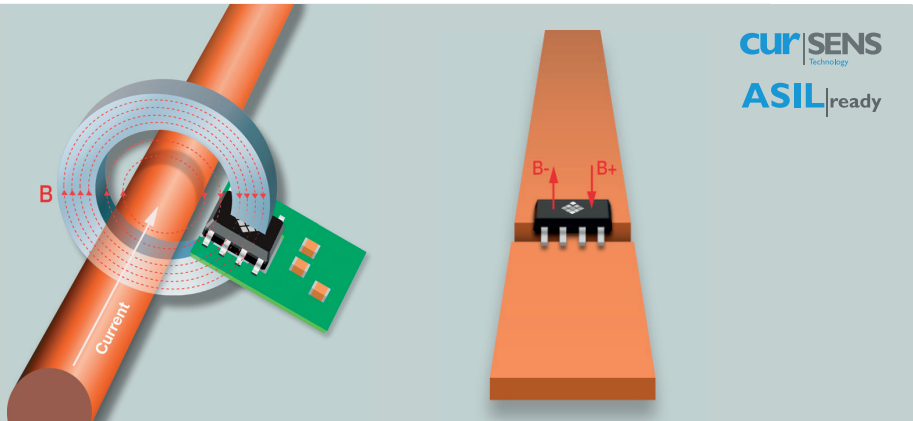
### Applications

The HAC 830 is a potential system solution for applications such as:

- Linear movement
- Angle detection
- Accelerator pedal
- Throttle position
- Steering torque
- Exhaust gas recirculation
- Turbo charger

# Current Sensing

## Hall-Effect-Based High-Precision Current Sensors



The CUR 4000 is a single-axis contactless magnetic-field sensor for galvanically isolated DC and AC current measurements and can be used in high-voltage battery monitoring systems of hybrid and electric vehicles (xEV).

A flexible Multi-Hall-Array allows linear or differential magnetic-field sensing for contactless and precise current sensing up to  $\geq 2000$  A.

CUR 4000 can be used for different module concepts like core-based or coreless. In the linear modes of CUR 4000, a configurable array of Hall elements enables highly accurate measurements for core-based stray-field robust sensor-module designs. The differential mode enables small coreless and stray-field robust system designs without shields.

Read-out of the complete Hall array provides an output-offset temperature-drift below  $\pm 0.05$  percent full scale. Furthermore, the sensor delivers a hysteresis-free output signal. A non-linearity error of  $\pm 0.2$  percent and a noise performance of  $\pm 0.005$  percent full scale allows precise current measurements with a signal bandwidth of up to 8 kHz.

Current sensing modules equipped with the CUR 4000 can be programmed directly in-circuit by a microcontroller via SPI interface.

CUR 4000 is defined as ASIL-B ready SEooC (Safety Element out of Context) according to ISO 26262.

Major characteristics like gain and offset, etc. can be adjusted to the magnetic circuitry by programming the non-volatile memory. The device is qualified according to AEC-Q100-Rev-H and is designed for automotive applications with operation in an ambient temperature range ( $T_A$ ) of  $-40$  °C up to  $+150$  °C.

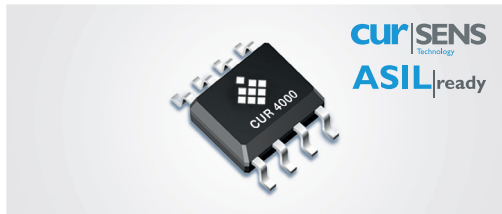
CUR 4000 is available in a small eight-pin SOIC8 SMD package.



# CUR 4000



## High-Precision Programmable Closed-Loop Current Sensor



### Functions

CUR 4000 provides a potential system solution for current measurement.

### Applications Example

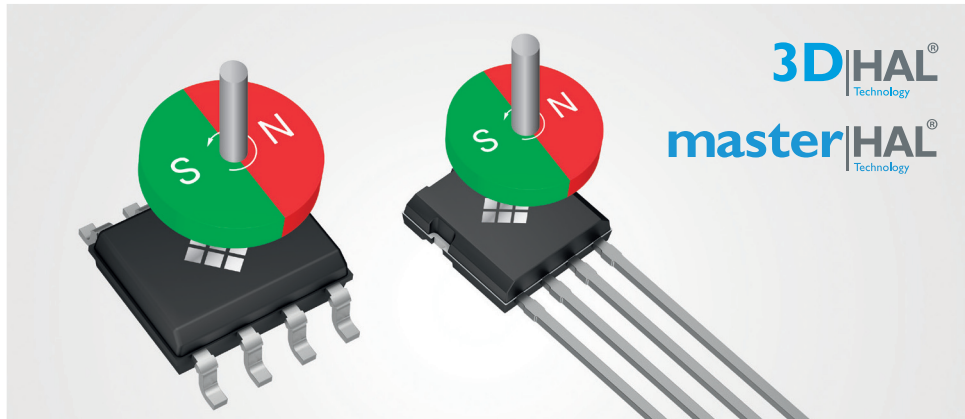
- xEV battery monitoring
- Stationary battery management

### Features

- Non-intrusive, galvanically isolated contactless current measurement
- High-precision, linear magnetic-field sensing with flexible Hall plates array for core-based current sensing
- Differential magnetic-field (stray-field compensated) coreless current sensing without shields
- ASILB ready (SEooC according to ISO 26262)
- Signal bandwidth up to 8 kHz
- Total system error <1 %
- Programmable linearization with 33 equidistant or 17 variable setpoints
- Programmable adjustment and temperature compensation for gain and offset
- Low-power mode with wake-up functionality
- SPI interface for calibration, test, and debugging via microcontroller
- Digital 16-bit readout of magnetic-field information via SPI (up to 5 MHz)
- $\pm 100$  mT magnetic-field range
- Operates from  $-40$  °C up to  $150$  °C ( $T_A$ )
- Operates from 3.0 V up to 5.5 V
- Programmable clamping threshold
- Over-/undervoltage detection on VSUP
- Overtemperature supervision
- Reverse-/overvoltage protection at VSUP
- Magnetic-field-out-of-range detection
- SOIC8 SMD package
- Qualified according to AEC-Q100-Rev-H

# 3D HAL<sup>®</sup> Technology from TDK-Micronas

## Stray-Field Robust Position Detection



In the area of position detection in Automotive or Industrial applications, the requirements to sensors are steadily increasing. Their accuracy and reliability in harsh environments has to grow steadily. For applications measuring small distances (up to 6 mm) or small angle ranges (up to 60°), established linear (1D) Hall-effect sensors could show excellent and reliable performance.

For larger ranges, a new technology is needed. To this end, TDK-Micronas has developed the Hall sensor family HAL 37. With this family, angle measurements, formerly only to be done with on-chip flux concentrators or complex dual-package AMR (Anisotropic Magneto Resistance) sensors, can now be implemented in a CMOS process. Contrary to the AMR technology, measurements of angles up to 360°, as well as linear distances can both be realized.

As a next step, stray-fields are a big challenge for magnetic-field sensors. The motors and power lines in hybrid electric vehicles (HEVs) and battery electric vehicles (BEVs) carry high currents and can generate magnetic fields that interfere with magnetic-field sensors. Today, a modern Hall-effect sensor must offer robust stray-field immunity conforming to the latest ISO 11452-8 standard and related OEM requirements.

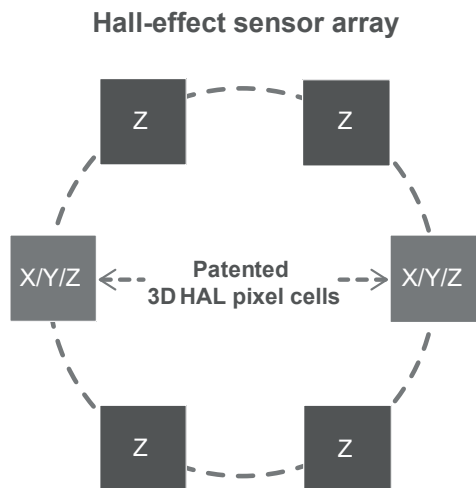
Overall, the various family members support different output formats like ratiometric analog, PWM, SENT, SPI, PSI5, and SPC. The devices can be easily adapted to the different applications by providing easy programmability. Key parameters like offset, gain, zero angle, output offset and gain, setpoints for linearization and clamping levels can be stored in the built-in memory.

Today, the product family consists of the second-generation HAL 37xy and the third-generation HAL 39xy. The new HAL 30xy sensor family consists of angle sensors especially designed for motor position sensing.

**License Note:** HAL/HAC/HAR 37xy and HAL/HAC/HAR 39xy use licenses of Fraunhofer Institute for Integrated Circuits IIS.

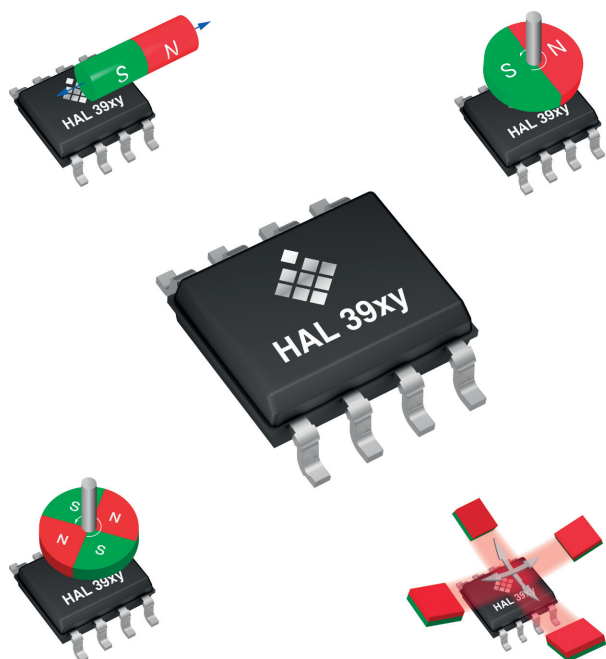
### Stray-Field Compensation with HAL 39

The requirement for stray-field immunity is addressed by the HAL 39 family. Its unique stray-field concept is based on an array of vertical and horizontal Hall plates using the patented 3D HAL pixel cell. The highly flexible sensor array enables design engineers to select the best stray-field compensation for any given measurement task.



The HAL 39xy family offers four different measurement modes:

- Linear position detection with stray-field compensation
- Rotary 360° angle detection with stray-field compensation
- Rotary 180° angle detection with stray-field compensation, including gradient fields
- Real 3D magnetic field measurement ( $B_x, B_y, B_z$ )



# HAL<sup>®</sup> 302x



## Fast Stray-Field Robust Motor Position Sensor Family with Analog Output



### Functions

HAL 302x provides a potential system solution for:

- Rotary position measurement for BLDC motor commutation

### Applications Examples

- Clutch and transmission actuators
- Starter/generator systems
- Electromechanical brake booster
- Electric pumps
- Electric valves

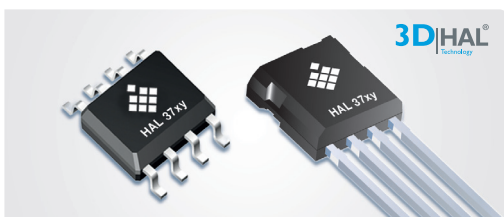
### Features

- High-speed 360° contactless angle measurement
- EMC robust differential or single-ended sine/cosine analog output signals
- Non-ratiometric or ratiometric analog outputs related to the supply voltage
- Robust against DC and AC magnetic stray fields (according to ISO 11452-8:2015)
- SEooC ASIL C ready according to ISO 26262:2018 to support Functional Safety applications (The device can be integrated in automotive safety related systems up to ASIL D)
- Various integrated diagnostic mechanisms ensure correct operation and enable simplified external safety supervision
- Operates from 3.0 V up to 5.5 V supply voltage
- Fast response time and high output BW for applications up to 150,000 rpm
- Operates from –40 °C up to 170 °C junction temperature ( $T_A = 150$  °C)
- Programming via the sensor's output pin. No additional programming pin required
- Programmable characteristics in a non-volatile memory (EEPROM) with redundancy and lock function
- Configurable signal processing parameter, like output gain, offset, (absolute) 0-angle, orthogonality and magnetic signal bandwidth
- Overvoltage and reverse-voltage protection
- Under- and overvoltage detection of  $V_{SUP}$
- Crossbar switch for signal routing (pin assignment for output signals)
- Passive wire-break detection working with external pull-up or pull-down resistor
- On-chip temperature sensor for over-temperature supervision
- Qualification according to AEC-Q100

# HAL<sup>®</sup> 37xy



## Programmable Hall-Effect Sensor Family for Rotational or Linear Position Detection based on 3D HAL<sup>®</sup> Technology



### Functions

HAL 37xy provides a potential system solution for functions such as:

- Rotary movement detection
- Linear movement detection

### Applications Examples

- EGR valve position
- Clutch pedal position
- Gear selector
- Cylinder and valve position sensing
- Non-contact potentiometer

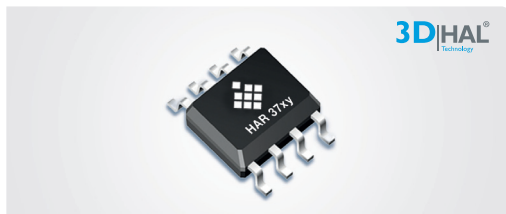
### Features

- Measurement extremely robust against temperature and stress influence
- Operating with magnetic field amplitudes down to  $\pm 20$  mT with an angular accuracy of  $\pm 0.5\%$  FS (digital output, X-Y Hall plates)
- ASILB ready (SEooC according to ISO 26262)
- 12 bit ratiometric linear analog output for HAL 372x
- HAL 371x with modulo 90°/120° for chassis systems
- 0.2 kHz to 2 kHz PWM (up to 12 bit) or 12 bit SENT output for HAL 373x
- Programmable arbitrary output characteristic with up to 33 setpoints
- Operates from  $V_{SUP} = 4.5$  V up to 5.5 V
- Operates from  $T_A = -40$  °C up to 150 °C
- Programming via the sensor's output pin
- Programmable characteristics in EEPROM with redundancy and lock function
- 2<sup>nd</sup>-order temperature-dependent offset of programmable for X/Y- or Z-channel
- On-board diagnostics
- Short-circuit protected push-pull output
- Over-/reverse-voltage protection and under- and overvoltage detection at  $V_{SUP}$
- Wire-break detection with pull-up and pull-down resistor
- Package: SOIC8 or TO92UP

## HAR<sup>®</sup> 37xy



### Programmable Hall-Effect Sensor Family based on 3D HAL<sup>®</sup> Technology – with Redundancy Functionality



#### Features

- Measurement extremely robust against temperature and stress influence
- Operating with magnetic field amplitudes down to  $\pm 20$  mT with an angular accuracy of  $\pm 0.5\%$  FS (digital output, X-Y Hall plates)
- ASIL-B ready (SEooC according to ISO 26262)
- 12 bit ratiometric linear analog output for HAR 372x
- HAR 371x with modulo  $90^\circ/120^\circ$  for chassis systems
- 0.2 kHz to 2 kHz PWM (up to 12 bit) or 12 bit SENT output for HAR 373x
- HAR 379x: SENT SAE J2716 rev. 2016 protocol:
  - H.1: Two 12 bit fast channels (position & temperature or magnetic amplitude)
  - H.2: 12 bit fast channel
  - H.4: 12 bit secure single sensor
- Programmable arbitrary output characteristic with up to 33 setpoints
- Operates from  $V_{SUP} = 4.5$  V up to 5.5 V
- Operates from  $T_A = -40$  °C up to 150 °C
- Programming via the sensor's output pin
- Programmable characteristics in EEPROM with redundancy and lock function
- 2<sup>nd</sup>-order temperature-dependent offset of programmable for X/Y- or Z-channel
- On-board diagnostics
- Package: SOIC8

#### Functions

HAR 37xy provides a potential system solution for functions such as:

- Rotary movement detection
- Linear movement detection

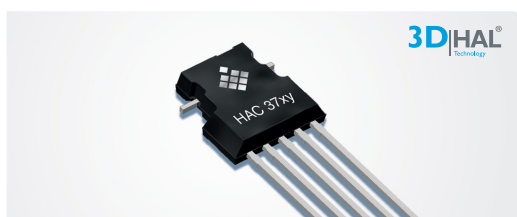
#### Applications Examples

- EGR valve position
- Clutch pedal position
- Gear selector
- Cylinder and valve position sensing
- Non-contact potentiometer

## HAC<sup>®</sup> 37xy



### Programmable Hall-Effect Sensor Family based on 3D HAL<sup>®</sup> Technology – with Integrated Capacitors



#### Features

- Measurement extremely robust against temperature and stress influence
- Integrated capacitors for improved EMC behavior and PCB-less applications
- Operating with magnetic field amplitudes down to  $\pm 20$  mT with an angular accuracy of  $\pm 0.5\%$  FS (digital output, X-Y Hall plates)
- ASIL-B ready (SEooC according to ISO 26262)
- 12 bit ratiometric linear analog output for HAC 372x
- HAC 371x with modulo  $90^\circ/120^\circ$  for chassis systems
- 0.2 kHz to 2 kHz PWM (up to 12 bit) or 12 bit SENT output for HAC 373x
- SENT SAE J2716 rev. 2016 protocol:
  - H.1 Format: Transmission of position and temperature or magnetic-field amplitude on fast and slow channel
  - H.2 Format: Three data nibbles
  - H.4 Format: Secure channel format
- Programmable arbitrary output characteristic with up to 33 setpoints
- Operates from  $V_{SUP} = 4.5$  V up to 5.5 V
- Operates from  $T_A = -40$  °C up to 150 °C
- Programming via the sensor's output pin
- Programmable characteristics in EEPROM with redundancy and lock function
- 2<sup>nd</sup>-order temperature-dependent offset of programmable for X/Y- or Z-channel
- On-board diagnostics
- Wire-break detection with pull-up and pull-down resistor
- Package: TO92UF

#### Functions

HAC 37 provides a potential system solution for functions such as:

- Rotary movement detection
- Linear movement detection

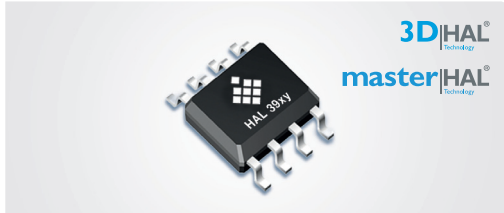
#### Applications Examples

- EGR valve position
- Turbocharger Actuator Position
- Position detection in Transmission Systems
- Cylinder and valve position sensing
- Non-contact potentiometer

# HAL<sup>®</sup> 39xy



## Programmable Hall-Effect Sensor Family for 3D Position Detection – with Stray-Field Compensation



### Features

- Accurate angular measurement up to 360° and linear position detection
- 3D position detection
- Robust against magnetic stray fields
- ASIL-B ready (SEooC according to ISO 26262)
- Wide supply voltage range: 3.0 V to 18 V
- Configurable output slew rates
- 0.1 kHz to 2 kHz PWM frequency
- Separate switch output (HAL 3930)
- SENT according to SAE J 2716 rev. 4
- Support of three different SENT frames
  - H.1: Two 12 bit fast channels (position & temperature or magnetic amplitude)
  - H.2: 12 bit fast channel
  - H.4: 12 bit secure single sensor
- SPC interface with ID selection mode, rolling counter, temperature information
- SPI interface (slave) with low-power modes
- PSI5 interface according to rev. 2.3
- 2-wire PWM interface
- $T_A = -40\text{ °C}$  up to  $150\text{ °C}$
- SOIC8 package

### Functions

HAL 39xy provides a potential system solution for functions such as:

- Rotary movement detection
- Linear movement detection
- 3D position detection

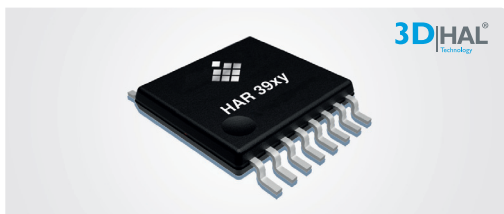
### Applications Examples

- Active Pedal
- Valve position (e.g. EGR)
- Liquid level
- Gear position
- Shift Lever Position
- Turbo-charger actuators
- Charging Adapter Lock
- Chassis Position

# HAR<sup>®</sup> 39xy



## Programmable Hall-Effect Sensor Family based on 3D HAL<sup>®</sup> Technology – with Redundancy Functionality



### Features

- Accurate angular measurement up to 360° and linear position detection
- Redundancy Functionality
- 3D position detection
- Robust against magnetic stray fields
- ASIL-B ready (SEooC according to ISO 26262)
- Wide supply voltage range: 3.0 V to 18 V
- Configurable output slew rates
- 0.1 kHz to 2 kHz PWM frequency (HAR 3930)
- Separate switch output (HAR 3930)
- SENT according to SAE J 2716 rev. 4
- Support of three different SENT frames
  - H.1: Two 12 bit fast channels (position & temperature or magnetic amplitude)
  - H.2: 12 bit fast channel
  - H.4: 12 bit secure single sensor
- SPI interface (slave) with low-power modes
- $T_A = -40\text{ °C}$  up to  $150\text{ °C}$
- SSOP16 or SOIC8 package

### Functions

HAR 39xy provides a potential system solution for functions such as:

- Rotary movement detection
- Linear movement detection
- 3D position detection

### Applications Examples

- Active Pedal
- Valve position (e.g. EGR)
- Gear position
- Shift Lever Position
- Steering angle

# HAC<sup>®</sup> 39xy



## Programmable Hall-Effect Sensor Family based on 3D HAL<sup>®</sup> Technology – with Integrated Capacitors



### Features

- Accurate angular measurement up to 360° and linear position detection
- Integrated capacitors for improved electromagnetic compatibility (EMC) and PCB-less applications
- 3D position detection
- Robust against magnetic stray fields
- ASILB ready (SEooC according to ISO 26262)
- Wide supply voltage range: 3.0 V to 18 V
- Configurable output slew rates
- 0.1 kHz to 2 kHz PWM frequency
- SENT according to SAE J 2716 rev. 4
- Support of three different SENT frames
  - H.1: Two 12 bit fast channels (position & temperature or magnetic amplitude)
  - H.2: 12 bit fast channel
  - H.4: 12 bit secure single sensor
- PSI5 interface according to rev. 2.3
- $T_A = -40\text{ °C}$  up to  $150\text{ °C}$
- TO92UF package

### Functions

HAC 39xy provides a potential system solution for functions such as:

- Rotary movement detection
- Linear movement detection
- 3D position detection

### Applications Examples

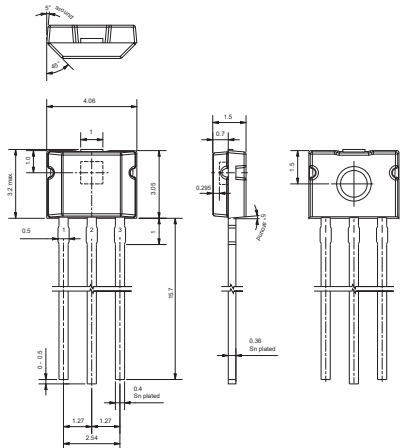
- Valve position (e.g. EGR)
- Liquid level
- Gear position
- Turbo-charger actuators
- Charging Adapter Lock
- Chassis Position

## HAL 39xy Family Overview

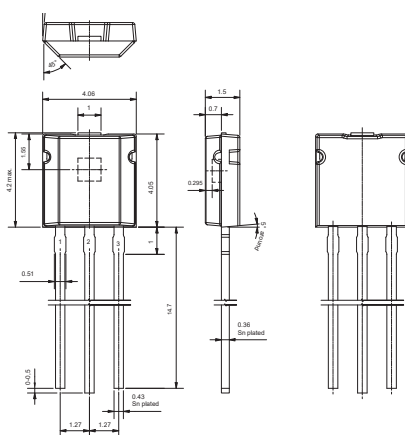
Type	Output Format	Output Signals	Other Features
HAL 3900 / HAR 3900	SPI	Up to two angles or values of $B_x$ , $B_y$ , and $B_z$	<ul style="list-style-type: none"> <li>• Low-power mode with wake-up by magnetic field / position information change / wake-up pin</li> <li>• 16-bit data with CRC and rolling counter</li> <li>• 5 MHz SPI</li> </ul>
HAL 3927 / HAR 3927	Analog / Modulo / SENT	Up to two angles or values of $B_x$ , $B_y$ , and $B_z$	<ul style="list-style-type: none"> <li>• Programmable interpolator for a smoother DAC analog output and reduced out-of-band noise</li> </ul>
HAL 3930 / HAC 3930 / HAR 3930	PWM / SENT / Switch	Up to two angles	<ul style="list-style-type: none"> <li>• Push-pull or open-drain output</li> <li>• Programmable switching levels (HAL 3930 / HAR 3930 only)</li> </ul>
HAL 3960	PWM	One angle	<ul style="list-style-type: none"> <li>• 2-wire PWM</li> </ul>
HAL 3970	SPC (Short PWM Code)	One angle and temperature	<ul style="list-style-type: none"> <li>• Secure rolling counter</li> <li>• Enhanced 12-bit serial message</li> </ul>
HAL 3980 / HAC 3980	PSI5 rev. 2.3	One angle and angular speed	<ul style="list-style-type: none"> <li>• PSI5 rev. 2.3 and support of frames of rev. 1.3</li> <li>• Asynchronous mode, synchronous parallel and universal bus mode, variable time-triggered bus mode</li> </ul>

# Package Information for Hall Switches, Linear Hall Sensors, Current Sensors, and Angle Sensors

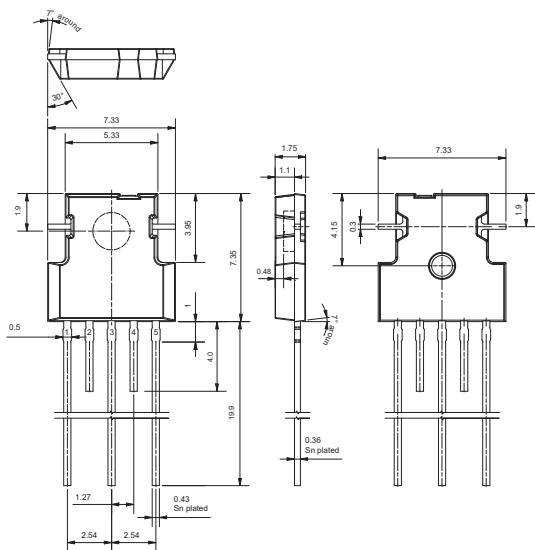
TO92UA



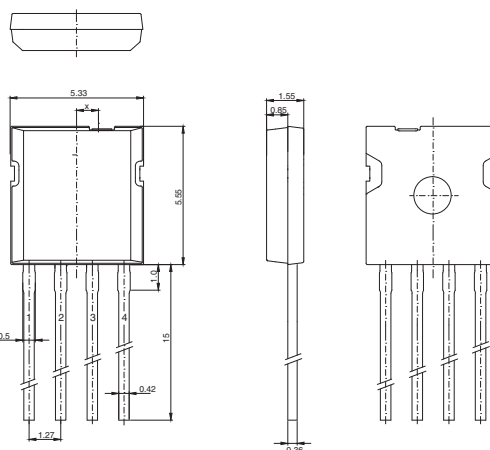
TO92UT



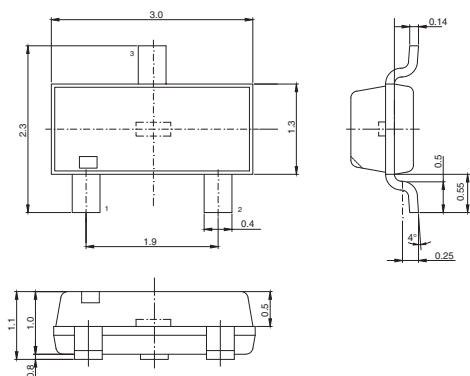
TO92UF



TO92UP



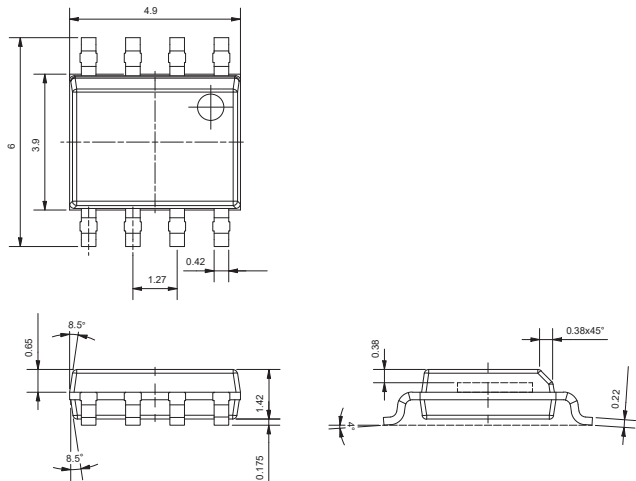
SOT23



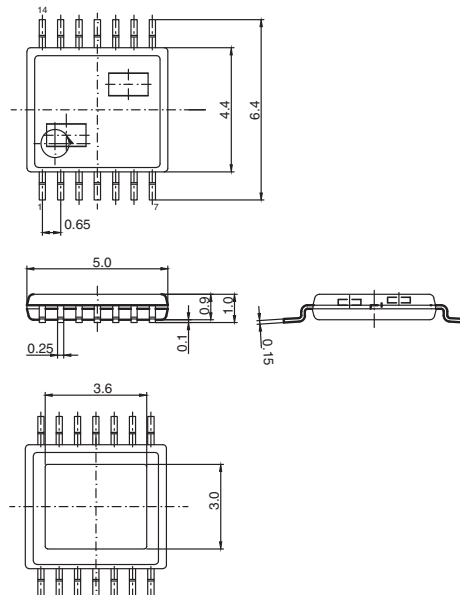


# Package Information for Hall Switches, Linear Hall Sensors, Current Sensors, and Angle Sensors

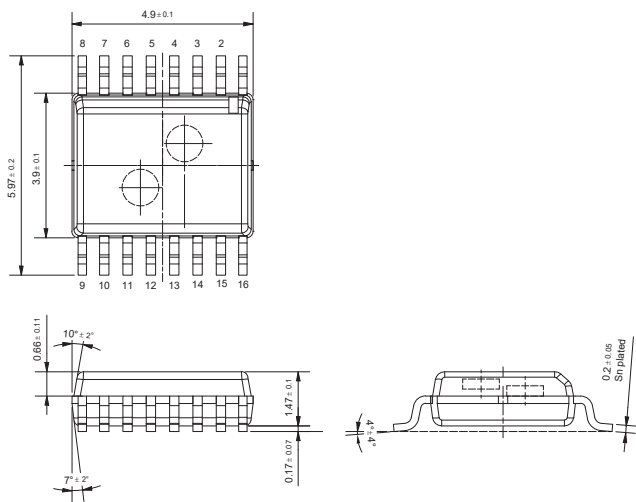
SOIC8



TSSOP14



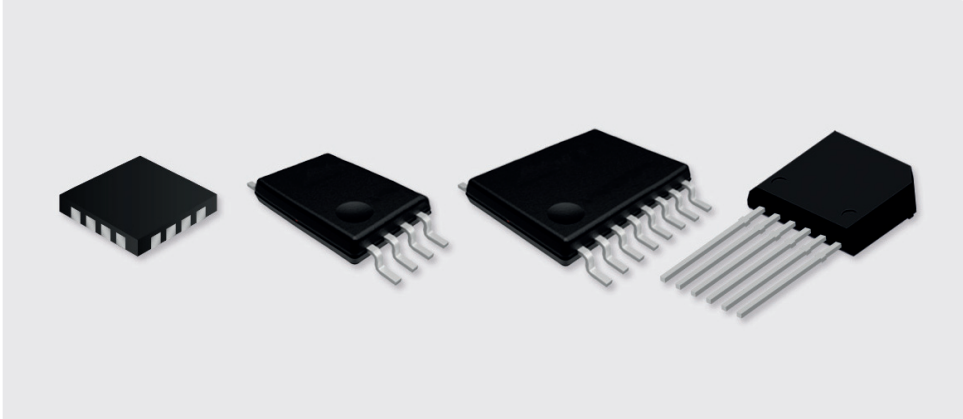
SSOP16



# TMR Angle Sensors from TDK



## High-Precision TMR Sensors

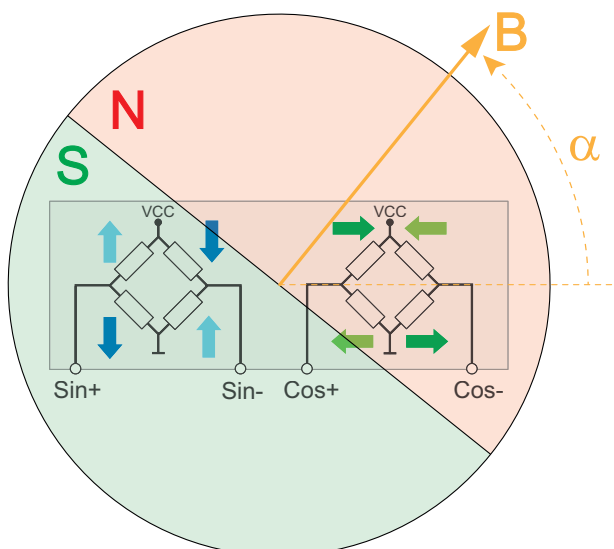


### Functional Description

A TMR angle sensor from TDK is composed of a number of individual TMR elements forming the four branches of a Wheatstone bridge, where the fixed layers of the elements within each branch are identically aligned.

Applying a rotating magnetic field in the plane of the Wheatstone bridge allows to tap periodic voltage signals from the two bridges that are phase-shifted by  $90^\circ$ . These four signals finally allow to unambiguously extract the orientation of the stimulating field, i.e., the angular position of the rotating permanent magnet.

The arrows show the sensitive magnetic-field directions of the TMR bridge structure. If the external magnetic field direction is parallel to the sensitive magnetic field direction, their resistance is minimal. If they are anti-parallel, resistance is maximal. The phase difference of the output signals is  $90^\circ$ .



Wheatstone bridge structure of a TMR sensor



### TMR Angle Sensors with Analog Output – the TAS/TAA/TAB Series

The TAS/TAA/TAB series comprises highly sensitive analog sensors. They are able to measure angles up to 360° with high accuracy and stability in a wide range of temperature and magnetic-field variations. TAS2142 (1 system) and TAS414x (2 systems) are pure TMR bridge angle sensors providing SIN/COS outputs. In combination with the ASA 2310 “TMR Analog Front-End” or with a microcontroller and a small piece of software, these sensors offer outstanding angular measurement performance in industrial and safety-critical automotive applications.

In addition to redundancy, TAB4140 and TAA6140 include an output amplification, well suited for remote applications.

### TMR Analog Front-End IC – ASA 2310

The ASA 2310 is designed to interface with the high-precision analog TMR sensors of the TAS family and allows high-speed angle sensing applications with rotation speeds of up to 650,000 rpm.

### TMR Angle Sensors with Digital Output – the TAD Series

The TAD series angle sensors allow an absolute angle measurement of up to 360°, offering high sensitivity and best angle accuracy needed for demanding automotive and industrial applications. The internal digital signal processing allows outstanding angular measurement performance, stability in a wide temperature range and increased functionality. The sensors are pre-calibrated at manufacturing and additionally offer in-application calibration modes. The “Static Compensation” targets the elimination of angle errors caused by mechanical misalignment between magnet and sensor. In 360° multi-turn operation, the TAD sensors achieve excellent angle accuracy by using the “Dynamic Compensation” mechanism, which eliminates magnetic, temperature, and life-time effects.

The sensors support various output Interfaces, such as UVW (Hall Switch Emulation Mode), PWM, ENC (Encoder Mode or ABZ), SPI, and SENT. To reduce system costs and to provide automotive system level EMC/ESD protection, one variant also integrates six capacitors and one resistor.

#### Application examples:

- Absolute rotary angle sensor
- EPS motor-shaft angle sensor
- EPS angle sensor
- Throttle position sensor
- Resolver replacement

#### Application example:

Motor rotor position detection for electric vehicles (BLDC, PMSM, PMSR, ...) in a safety-relevant environment with long wire-harness between sensor and ECU.

#### Application examples:

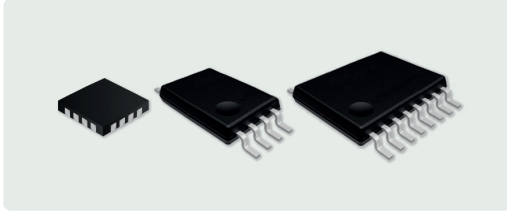
- Absolute angle sensor
- BLDC motor commutation  
e.g. for EPS
- Resolver replacement



Example of rotor position detection in an end-of-shaft configuration

# TAS2142, TAS414x

## TMR-Bridge Angle Sensors with Analog Output for Position Sensing Applications



### Application Examples

TAS2142 (1 system), TAS414x (2 systems) are a potential system solution for applications, such as:

- Absolute rotary angle sensor
- EPS motor-shaft angle sensor
- EPS angle sensor
- Throttle position sensor
- Resolver replacement

### Features

- Specialized angle sensor for use under harsh environmental conditions.
- High reliability and low FIT rates allow operation in safety-critical applications
- Simple circuitry and low number of external components allow fast and easy development.
- Diagnostic capability through direct monitoring of the sensor elements.
- In combination with simple algorithms running in microcontrollers, the remaining very low angular drift over temperature can be compensated and allows to be operated in the complete magnetic-field range without any changes in angular precision.

### Physical Characteristics

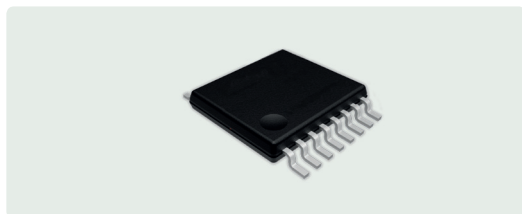
- Recommended supply voltage range:  $V_{SUP} = 3\text{ V to }5.5\text{ V}$
- High output: 600 mVpp/V
- Current consumption: 3.1 mA max. (1 system) / 6.2 mA max. (2 systems) at 5 V
- Wide temperature range:  $-40\text{ }^{\circ}\text{C to }+150\text{ }^{\circ}\text{C}$
- Wide magnetic-field range:
  - 20 mT to 80 mT (standard range)
  - 80 mT to 120 mT with lower accuracy
  - higher magnetic fields with restrictions
- Angle accuracy:  $\pm 0.6\text{ to }0.8\text{ deg. }(-40\text{ }^{\circ}\text{C to }+150\text{ }^{\circ}\text{C})$
- Small single-mold packages available:
  - TSSOP8 for TAS2142
  - TSSOP16 and QFN16 for TAS414x
- AEC-Q100 qualified

### Benefits

- Very high output voltages allow direct connection to ADCs without amplifier
- Direct connection to microcontrollers reduce BOM cost
- Very stable signals (over temperature and lifetime) – no need for re-calibration
- Sensor allows high diagnostic coverage and is recommended for safety critical applications
- Supports ASIL B by TAS2142 and ASIL B(D) by TAS414x (system level ASIL D).
- Suitable for operation for high accurate low- or high-speed position sensing or motor control applications

# TAA6140

## Sixfold Full-Bridge TMR Angle Sensor with Differential Amplifier



### Features

- Three independent TMR sensors with integrated amplifiers provide high redundancy
- Differential Amplifier/Single-ended output (Sin/Cos)
- High reliability and low FIT rates allow operation in safety-critical applications
- In combination with simple algorithms running in microcontrollers, the remaining very low angular drift over temperature can be compensated and allows to be operated in the entire magnetic-field range without any changes in angular precision.

### Application Examples

TAA6140 is a potential system solution for safety-critical applications, such as:

- Absolute rotary angle sensor
- EPS motor-shaft angle sensor
- Steering wheel angle sensor
- Pedal position sensor
- Throttle position sensor

### Physical Characteristics

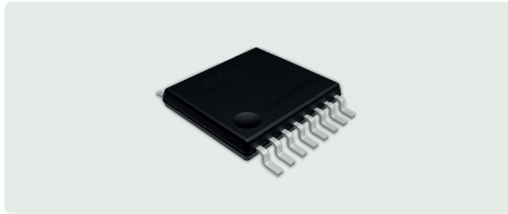
- Recommended supply voltage range: 4.5 V to 5.5 V
- Current consumption: 17.3 mA at 5 V (maximum value)
- Wide temperature range:  $-40\text{ }^{\circ}\text{C}$  to  $+150\text{ }^{\circ}\text{C}$
- Wide magnetic-field range:
  - 20 mT to 80 mT (standard range)
  - 80 mT to 120 mT (extended range)
  - higher magnetic fields with restrictions
- Angle accuracy:  $\pm 0.8\text{ deg.}$  at standard range
- TSSOP16 package
- AEC-Q100 qualified

### Benefits

- Sensor signals prepared for simple read-out by ADC
- Fast response, high angular accuracy suitable for fast and accurate motor-control applications
- Very stable position measurement (over temperature and lifetime) – no need for re-calibration
- Integrated amplifier reduces BOM and application cost
- Sensor is optimized for safety-critical applications

# TAB4140

## Fourfold Full-Bridge TMR Angle Sensor with Single-Ended Amplifier/Differential Output



### Features

- Redundant TMR sensors with integrated amplifiers for safety-critical applications
- Single-ended Amplifier/Differential output (Sin+/Sin-/Cos+/Cos-)
- High reliability and low FIT rates allow operation in safety-critical applications
- In combination with simple algorithms running in microcontrollers, the remaining very low angular errors can be compensated and allows operation in the entire magnetic-field range without any changes in angular precision.

### Application Examples

TAB4140 is a potential system solution for applications, such as:

- EPS motor-shaft angle sensor
- Steering Wheel Angle Sensor
- Pedal Position Sensor
- Throttle Position Sensor

### Physical Characteristics

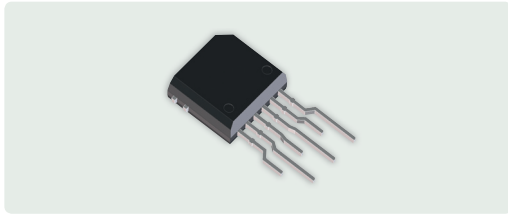
- Supply voltage range: 3 V to 5.5 V
- Current consumption: 9.0 mA at 5 V (typical value)
- Wide temperature range: -40 °C to +150 °C
- Wide magnetic field range:
  - 20 mT to 80 mT (standard range)
  - 80 mT to 120 mT (extended range)
- Angle accuracy:  $\pm 0.6$  deg. at standard range
- TSSOP16 package
- AEC-Q100 qualified

### Benefits

- Sensor operation with harness can be supported
- Fast response, high angular accuracy suitable for fast and accurate motor-control applications
- Very stable position measurement (over temperature and lifetime) – no need for re-calibration
- Integrated amplifier reduces BOM and application cost
- Completely independent between sensor1 and sensor2

# TAD2140

## High-Precision TMR Angle Sensor with Digital Output (1<sup>st</sup> Generation)



### Application Examples

TAD2140 is a potential system solution for PCB-less applications such as:

- General angular sensing
- Electrical commutated motors (e.g. actuators for Electric Power Steering (EPS) or E-clutch)
- Steering angle measurements (e.g. used in EPS)
- Rotary switches

### Features

- TMR Sensor with integrated signal processing, resistor and capacitors in one System-in-Package (SIP)
- Various and configurable digital outputs:
  - UVW (Hall switch emulation with extrapolator)
  - PWM
  - ENC (encoder mode, ABZ)
  - SENT SAE J2716 revision 3
- High EMC/ESD performance for automotive system level EMC
- ASIL B ready device with several diagnostic functions and status reporting
- Angle error compensation: static compensation and dynamic compensation
- Internal diagnostic capability for high diagnostic coverage
  - Continuous self-tests in operation:
    - Magnet loss detection
    - Maximum rotation speed detection
    - Over-/undervoltage detection
    - Internal sensor failure
    - Signal processing supervision
- Compliant to ISO 26262: ASIL B

### Physical Characteristics

- Wide operating temperature range:
  - $T_A = -40\text{ °C}$  to  $157\text{ °C}$
  - $T_J = -40\text{ °C}$  to  $175\text{ °C}$
- Wide magnetic-field range:
  - 20 mT to 80 mT (standard range)
  - 80 mT to 120 mT with lower accuracy
- Angle error:
  - $\pm 0.3^\circ$  (Full rotation at standard range, over lifetime)
  - $\pm 0.7^\circ$  (Non-full rotation at standard range, over lifetime)
- TO6 6-pin package (SIP)
- AEC-Q100 qualified (Grade 0)

### Benefits

- Fast response, high angular accuracy, and advanced compensation algorithms suitable for fast and accurate motor control applications
- Optimized for leadframe assembly (PCB less) to reduce BOM cost
- Integrated components allow system level EMC capabilities without need for external components
- Self-Teach-in feature allows compensation of system level errors
- Very stable position measurement (over temperature and lifetime) – no need for re-calibration
- UVW mode with extrapolator allows use of same setup (sensor and magnet) for different motor topologies (pole pair numbers)
- Dual interface use for redundant communication channels (e.g. ENC and SENT at same time)

# TAD2141, TAD4140

High-Precision TMR Angle Sensors with Digital Output  
(1<sup>st</sup> Generation)



## Application Examples

TAD2141 (1 system), TAD4140 (2 systems) are potential system solutions for applications such as:

- BLDC motor commutation e.g. for EPS
- Absolute angle sensor
- Resolver replacement

## Features

- TAD2141: TMR sensor with integrated signal processor unit
- TAD4140: Dual, independent TMR Sensors with integrated signal processor units
- Angle error compensation: static compensation and dynamic compensation
- Various and configurable digital outputs:
  - UVW (Hall switch emulation with extrapolator)
  - PWM
  - ENC (encoder mode, ABZ)
  - SPI
- Internal diagnostic capability for high diagnostic coverage
- Continuous in operation self-tests:
  - Magnet loss detection
  - Maximum rotation speed detection
  - Over/undervoltage detection
  - Internal sensor fails
  - Signal processing supervision
  - Register CRC
- Self-teach-in feature for angle errors
- Compliant to ISO 26262: TAD2141 rated ASIL B and TAD4140 rated ASIL D

## Physical Characteristics

- Wide operating temperature range:
  - $T_A = -40$  to  $+150$  °C (Automotive Grade)
  - $T_J = -40$  to  $+175$  °C (Automotive Grade)
- Wide magnetic field range:
  - 20 mT to 80 mT (standard range)
  - 80 mT to 120 mT with lower accuracy
- Angle error supports  $\pm 0.3^\circ$  (Full rotation at standard range)
- Angle error supports  $\pm 0.7^\circ$  (Non-full rotation at standard range)
- TSSOP16 package for TAD2141 and TAD4140
- AEC-Q100 qualified (Grade 0)

## Benefits

- Fast response, high angular accuracy, and advanced compensation algorithms suitable for fast and accurate motor control applications
- TAD4140 provides redundant position sensing and contributes to continuous function
- Self-Teach-in Feature allows compensation of system level errors
- Very stable position measurement (over temperature and lifetime) – no need for re-calibration
- UVW mode with extrapolator allows use of same setup (sensor and magnet) for different motor topologies (pole pair numbers)



# TAD2143

## High-Precision TMR Angle Sensor with Digital Output



### Application Examples

TAD2143 is a potential system solutions for industrial applications such as:

- BLDC motor commutation
- Absolute angle sensor

### Features

- TMR sensor with integrated signal processor unit
- Angle error compensation: static compensation and dynamic compensation
- Various and configurable digital outputs:
  - UVW (Hall switch emulation with extrapolator)
  - PWM
  - ENC (encoder mode, ABZ)
  - SPI
- Internal diagnostic capability for high diagnostic coverage
- Continuous in operation self-tests:
  - Magnet loss detection
  - Maximum rotation speed detection
  - Over/undervoltage detection
  - Internal sensor fails
  - Signal processing supervision
  - Register CRC
- Self-teach-in feature for angle errors
- Industrial grade only available

### Physical Characteristics

- Wide operating temperature range:
  - $T_A = -40\text{ °C}$  to  $125\text{ °C}$
  - $T_J = -40\text{ °C}$  to  $150\text{ °C}$
- Wide magnetic-field range:
  - 20 mT to 80 mT (standard range)
  - 80 mT to 120 mT with lower accuracy
- Angle error:
  - $\pm 0.3^\circ$  (Full rotation at standard range, over lifetime)
  - $\pm 0.7^\circ$  (Non-full rotation at standard range, over lifetime)
- TSSOP16 package

### Benefits

- Fast response, high angular accuracy, and advanced compensation algorithms suitable for fast and accurate motor control applications
- Self-Teach-in Feature allows compensation of system level errors
- Very stable position measurement (over temperature and lifetime) – no need for re-calibration
- UVW mode with extrapolator allows use of same setup (sensor and magnet) for different motor topologies (pole pair numbers)

# ASA 2310

## TMR Analog Front-End IC



### Functions

ASA 2310 is a potential system solution for interfacing with analog TMR sensors.

### Application Examples

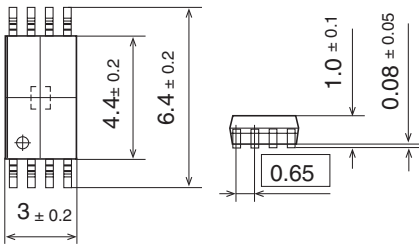
- Brushless DC (BLDC) and permanent-magnet synchronous motor (PMSM) commutation in a safety-relevant environment with long wire-harness between sensor and ECU
- Traction motor rotor position for electric vehicles (BLDC, PMSM, PMSR,...)
- EPS motor
- Replacement of resolvers
- Brake booster
- LIDAR mirror

### Features

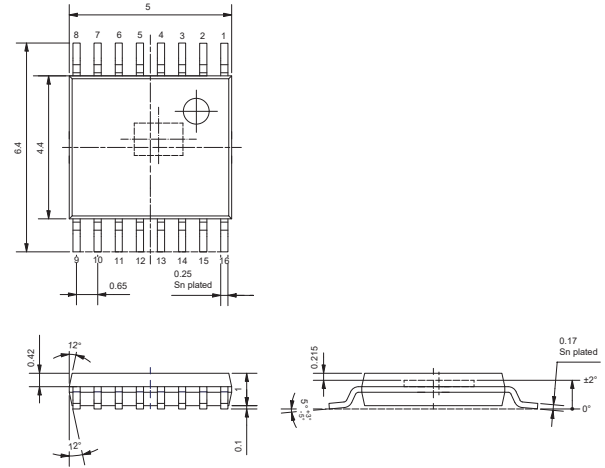
- Support of various TMR full- and half-bridges from TDK
- Optimized signal conditioning for TMR signals, like output gain, offset, 0-angle and orthogonality correction
- Easy-to-use differential or single-ended SIN/COS outputs for remote sensing applications with best-in-class EMC performance
- Fast response time of max. 3  $\mu$ s and high output bandwidth for applications up to 650,000 rpm
- Various analog output configurations
  - Differential or single-ended SIN/COS analog output signals
  - Non-ratiometric or ratiometric analog outputs related to the supply voltage
- SEooC ASIL B ready according to ISO 26262:2018 to support Functional Safety applications (Metrics (PMHF, SPFM, LFM) according to ASIL C)
- Intrinsic signal conditioning with on-chip calibration and integrated safety monitoring reduce effort on ECU side
- Flux-less self-test
- Operates from 3.0 V up to 5.5 V supply voltage
- Low current consumption of typ. 5.5 mA
- Operates from  $-40$  °C up to 170 °C junction temperature (Max. Ambient Temperature:  $T_A = 150$  °C)
- Programming via the IC's output pin.  
No additional programming pin required
- Overvoltage and reverse-voltage protection
- Under- and overvoltage detection of  $V_{SUP}$
- Passive wire-break detection working with external pull-up or pull-down resistors
- On-chip temperature sensor for overtemperature supervision
- Integrated, protected supply for the external TMR bridges
- Various integrated supervision features of the external TMR bridges
- Small  $3 \times 3$  mm<sup>2</sup> DFN12 SMD package
- AEC-Q100 qualification

# Package Information for TMR Products

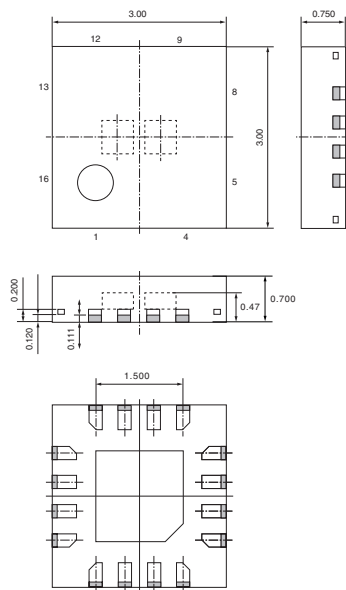
TSSOP8



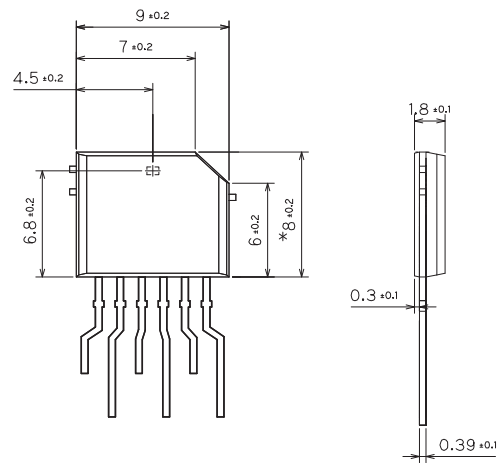
TSSOP16



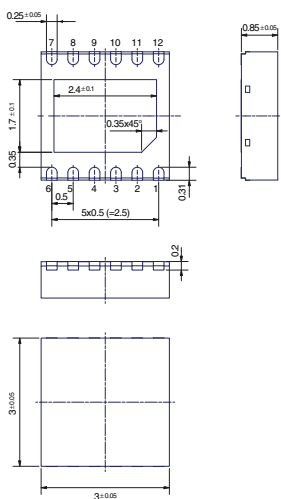
QFN16



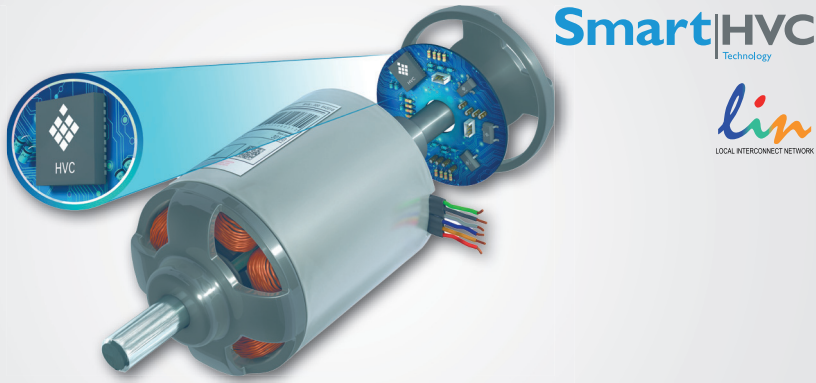
T06



DFN 12



# Introduction to Embedded Motor Controllers



The Micronas embedded motor controller family combines an industry standard Arm® Cortex®-M3 microcontroller core and a wide range of additional functions which, up to now, could only be realized via a combination of several discrete semiconductor parts.

The HVC family is designed as an embedded controller for smart actuators. It features advanced integration for compact and cost-effective system designs for use in automotive applications and beyond (industrial, consumer, instrumentation, etc.).

Replacement of conventional mechanical drive by “on-demand” electric drive and a general adoption of a more efficient solution to control electrical motors are the main reasons for a growing demand for cost-effective system solutions for electrical motor control and drive. Long lifetime reliability, reduction of weight as well as overall dimension, and flexibility to easily adapt to several types of motors and applications are additional key issues which have to be addressed especially for automotive applications. Thanks to their better efficiency, lower acoustic- and electrical noise, brushless DC (BLDC) are gaining a significant share of the electrical motors by replacing conventional motors.

Micronas embedded motor controllers integrate almost all surrounding circuits needed for driving electrical motors. In addition to the UART interface, the built-in networking capabilities enable the deployment of LIN bus control compliant to LIN-2.x for a wider range of applications like e.g. cross-linked smart actuator. Reducing the number of external components to a minimum, the product’s flexible peripherals allow direct controlling of brushless, brush-type DC- and stepper electrical motors, either by means of six fully integrated half-bridges or by controlling three external MOSFET half-bridges. Thanks to this flexibility in driving the electrical motor, the HVC controllers provide an effective system solution for both small and medium sized electrical motors, enabling a common product platform by a family concept. This gives our customers a decisive competitive edge because they are much faster at the implementation stage and need fewer resources in the development process of their various applications.

### HVC variants

	Flash	RAM	Drivers	Package
HVC 422xF	32 KB	2 KB	6 × 0.5 A	QFN40
HVC 442xF	64 KB	4 KB	6 × 0.5 A	QFN40
HVC 5221D	32 KB	2 KB	4 × 0.5 A	QFN24
HVC 5222C	32 KB	2 KB	3 × 1.0 A	QFN24

Embedded Controller

Stepper Motor Control

BLDC Motor Commutation

# HVC 4x



## Embedded Motor Controllers for Smart Actuators



### Features

- Six integrated half-bridges up to 6 x 500 mA or 1000 mA (depending on configuration)
- Temperature range up to  $T_A = 150^\circ\text{C}$  (Automotive Grade 0)
- Supply voltage: 5.4 V ... 18 V, Load dump up to 40 V
- High-performance 32-bit Arm<sup>®</sup> Cortex<sup>®</sup>-M3, running at up to 20 MHz
- Memory:
  - up to 4 kbyte RAM
  - up to 64 kbyte Flash
  - On-chip NVRAM with wear leveling
- Logic modules dedicated for controlling BLDC or BDC motors
- Comparators with integrated virtual star point and reference currents
- Digital and window watchdog timers with different, independent clocks
- 12-bit multi-channel ADC
- Programmable gain amplifier
- 16-bit free-running counter with three capture/compare-modules
- Two 16-bit timers
- Enhanced PWMs (EPWMs), providing edge/center-aligned signals with non-overlapping capability
- SPI and enhanced LIN 2.x UART
- LIN 2.x transceiver
- Integrated temperature sensor
- Active EMI suppression hardware
- Several diagnosis and protection functions such as:
  - Integrated H-bridge diagnostic features
  - Internal protection for non-overlapping bridge activation
  - Clock/temperature/supply supervision
  - Overvoltage/Overcurrent protection
- Power saving modes
- Package: QFN40 - 6x6

### Functions

HVC 4x is the enhanced system solution to drive stepper, BLDC or up to two BDC motors for various applications in the automotive environment, like grille shutter, HVAC flaps, LED headlight & fan and much more, as well as in the industrial environment, enabling smart mechatronical actuators.

The Micronas HVC 4x embedded motor controller family enables cost-effective realization of powerful and compact DC motor (BLDC or stepper) control. The HVC 4422F offers extended memory size to address the OEM diagnostic requirements and allows operation in high-temperature environments. An integrated Memory Protection Unit (MPU) supports RTOS requirements. Powered by a high-performance 32-bit Arm<sup>®</sup>  $\mu\text{C}$  core (Arm<sup>®</sup> Cortex<sup>®</sup>-M3) and integrating high-performance analog functions, the HVC economically addresses growing challenges in the automotive market and beyond (industrial, consumer, instrumentation, etc.). The flexible peripherals of the product provide all means to directly control brush-type, stepper (bipolar or three phase), or brushless direct current (BLDC) motors via integrated high-performance half-bridges without the need for external components.

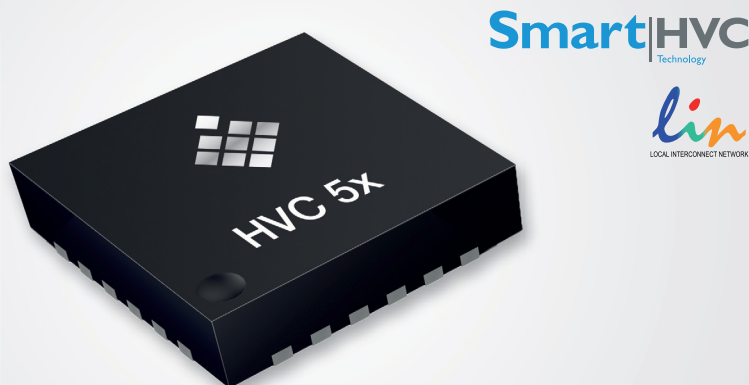
Beside timers/counters, interrupt controller, multichannel A/D converter, SPI, and enhanced PWMs with diagnosis functions, this device contains an advanced LIN UART interface with a LIN 2.x transceiver with provisions for voltage regulators for direct connection to a 5.4 V to 18 V automotive power supply. The support of various power management modes makes it possible to adjust current consumption according to system needs. The HVC further features a flash program memory with a size of up to 64 kbytes, providing high flexibility in code development, production ramp-up, and in-system code update.

Various integrated digital and analog circuit units such as comparators with virtual star point reference, current scaling or an embedded programmable gain amplifier allow users to further minimize the number of external components. The computation capacity supports complex motor control algorithms such as Space Vector Modulation (SVM) for Permanent Magnet Synchronous Motors (PMSM) in addition to six-step commutation with sensor feedback or sensorless control as well as various stepping configurations. The setup makes the adaption to new motor types fast and easy.

# HVC 5x



Embedded Motor Controllers for Smart Actuators



## Features

- 4 x 500 mA (HVC 5221D) or 3 x 1 A (HVC 5222C) peak current half-bridge drivers
- Temperature range up to  $T_A = 125^\circ\text{C}$  (Automotive Grade 1)
- Supply voltage range from 6 V to 18 V (transient from 4.5 to 40 V)
- 3.3 V, 15 mA supply for peripherals
- 32-bit Arm<sup>®</sup> Cortex<sup>®</sup>-M3 CPU core
- 20 MHz system clock, 35 kHz watch-dog oscillator
- 32 KB flash memory with 2 KB SRAM
- 12-bit, 1  $\mu\text{s}$  ADC for internal and external measurements
- 2 x 8-bit current DAC for motor current limiting from 2 mA to 500 mA
- 12-bit PWM generators with center- and edge alignment and ADC triggering
- 16-bit timers for input and output PWM signal handling
- 7 GPIOs for application interface
- LIN Transceiver for auto-addressing using the bus shunt method\*
- Small thermally efficient QFN24 package

## Functions

HVC 5x is the enhanced system solution to drive stepper, BLDC or up to two BDC motors for various applications in the automotive environment, like grille shutter, HVAC flaps, LED headlight & fan and much more, as well as in the industrial environment, enabling smart mechatronic actuators.

After serving a rapidly growing market with our popular HVC 4223F and HVC 4420F fully programmable, automotive motor drivers, TDK-Micronas is proud to announce the first members of the next-generation HVC 5x devices: the HVC 5221D and HVC 5222C. These devices present an evolution from the “one size fits all” approach of their HVC 4x predecessors to serve the same applications with a focus on smaller size, lower cost, and less external components. In addition, the HVC 4x and HVC 5x families are allowing TDK-Micronas to offer our customers a dual wafer fab sourcing strategy with largely compatible devices.

While the HVC 5221D is targeted at stepper and brushed DC-motor applications with four 500 mA motor terminals, the HVC 5222C is focused on three-phase brushless motor applications with peak currents up to 1 A. To maintain compatibility to the HVC 4x generation, the new devices use the same Arm<sup>®</sup> Cortex<sup>®</sup>-M3 based microcontroller with 32 KB flash memory and 4 KB of RAM with largely the same peripheral motor-control features and LIN bus connectivity as their predecessors.

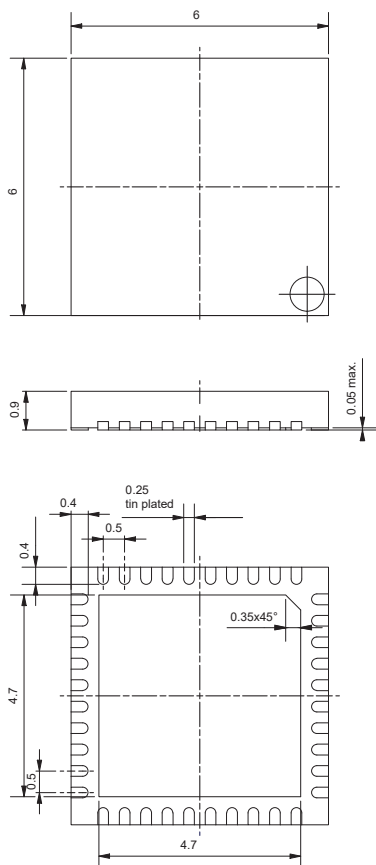
The general-purpose I/O pins (GPIOs) have been reduced to seven and some power supply pins have been eliminated to reduce the bill of material (BOM). A WAKE input and an external reset pin have been added to increase application flexibility.

Additional features, such as differential input channels, digital timers, capture-compare units, and an SPI interface enable integration of application functions as well as TDK-Micronas’ large portfolio of Hall switches or 2D/3D sensors for more precise motor control.

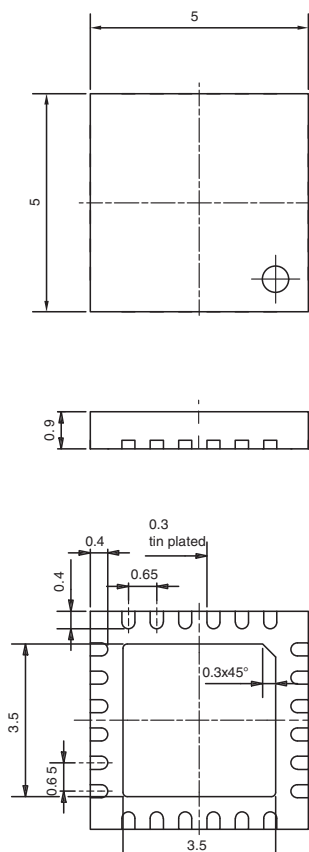
The HVC 5221D, HVC 5222C, as well as all future HVC 5x devices with higher currents and more memory all come in a pin-compatible, thermally efficient 5 mm x 5 mm QFN24 package.

# Package Information for Embedded Motor Controllers

QFN40 - 6x6



QFN24 - 5x5



# Additional Information

## Trademarks

- 1D HAL
- 2D HAL
- 3D HAL
- curSENS
- easyLIN
- HAL
- HAC
- HAR
- masterHAL
- SmartHVC

Please be sure to request delivery specifications that provide further details on the features and specifications of the products for proper and safe use. Please note that the contents may change without any prior notice due to reasons such as upgrading.



# Contact

## TMR Angle Sensors

### **Contact for TMR angle sensors in Europe**

TDK Europe GmbH  
D-81617 Munich (Germany)  
Phone +49 89 540 200  
E-mail: [info@eu.tdk.com](mailto:info@eu.tdk.com)  
[www.tdk.eu](http://www.tdk.eu)

### **Contact for TMR angle sensors in the Americas**

TDK Corporation of America  
475 Half Day Road  
Lincolnshire, IL 60069-2934  
USA  
Phone: (847) 699-2299  
[www.us.tdk.com](http://www.us.tdk.com)

Hall Switches, Linear Hall Sensors,  
Angle Sensors, Magnetic Current Sensors,  
and Embedded Motor Controllers

### **Contact for Micronas products worldwide**

TDK-Micronas GmbH  
Hans-Bunte-Strasse 19  
D-79108 Freiburg (Germany)  
Phone +49 761 517 0  
[www.micronas.tdk.com](http://www.micronas.tdk.com)

All information about sensors and sensor systems can be found in the TDK Product Center on [product.tdk.com](http://product.tdk.com).

## About TDK Corporation

TDK Corporation is a world leader in electronic solutions for the smart society based in Tokyo, Japan. Built on a foundation of material sciences mastery, TDK welcomes societal transformation by resolutely remaining at the forefront of technological evolution and deliberately “Attracting Tomorrow.” It was established in 1935 to commercialize ferrite, a key material in electronic and magnetic products. TDK’s comprehensive, innovation-driven portfolio features passive components such as ceramic, aluminum electrolytic and film capacitors, as well as magnetics, high-frequency, and piezo and protection devices. The product spectrum also includes sensors and sensor systems such as temperature and pressure, magnetic, and MEMS sensors. In addition, TDK provides power supplies and energy devices, magnetic heads and more. These products are marketed under the product brands TDK, EPCOS, InvenSense, Micronas, Tronics and TDK-Lambda. TDK focuses on demanding markets in automotive, industrial and consumer electronics, and information and communication technology. The company has a network of design and manufacturing locations and sales offices in Asia, Europe, and in North and South America. In fiscal 2022, TDK posted total sales of USD 15.6 billion and employed about 117,000 people worldwide.

## About TDK-Micronas

TDK-Micronas is the center of competence for magnetic-field sensors and CMOS integration within the TDK group. TDK-Micronas has gained operational excellence for sensors and actuators production in over 25 years of in-house manufacturing. It has been the first company to integrate a Hall-effect based sensor into CMOS technology in 1993. Since then, TDK-Micronas has shipped over six billion Hall sensors to the automotive and industrial market. The operational headquarters are located in Freiburg im Breisgau (Germany). Currently, TDK-Micronas employs around 1,000 people.



