



XENSIV™ – sensing the world

Sensor solutions for automotive, industrial,
consumer and IoT applications

Edition 2024

www.infineon.com/xensiv



Content

Introduction	4
About XENSIV™ sensor solutions	4
Ask the XENSIV™ developer community	5
Applications	6
Sensors in body electronics	6
Sensors in powertrain systems	7
Sensors in chassis, safety and ADAS	8
Magnetic sensors in efficient transmission systems	9
Sensors in Electric Power Steering (EPS)	14
Challenges for engine sensors in hybrid powertrains	20
Sensors in smart industry	25
Sensors in smart homes	26
Sensors in smart buildings	27
Light vehicles	28
Commercial, construction and agricultural vehicles (CAV)	28
Magnetic current sensors	29
Magnetic sensors	35
Magnetic switches	36
3D magnetic sensors	42
Linear sensors	45
Angle sensors	49
Magnetic speed sensors	54
Pressure sensors	68
Absolute pressure sensors (MAP and BAP)	70
Side crash detection (SAB)	74
Tire pressure sensors (TPMS)	75
Pressure sensors for consumer and IoT	76
MEMS microphones	78
MEMS microphones technology	79
MEMS microphones for automotive	80
MEMS microphones for consumer	83

Radar sensors	85
Radar sensors for automotive	86
Automotive radar 24GHz	86
Automotive radar 60GHz	87
RASIC™ automotive radar 77/79GHz	88
Radar sensors for IoT & consumer devices	89
60GHz radar sensors for consumer and IoT	91
24GHz radar sensors	98
Environmental sensors	100
PAS CO2 sensors	100
Intuitive sensing	102
Design support	103
Connected sensor kit	103
Shields2Go	104
Sensor 2GO kits	107
Evaluation boards – for simple and easy evaluation	108
Add ons for Sensor 2GO kits and Shield2Go	109
Online simulation tools	111
ISO 26262 – Functional Safety (FuSa)	112
Dependability is the key driver for the megatrend towards autonomous driving	113
Packages	114

Infineon XENSIV™ – sensing the world

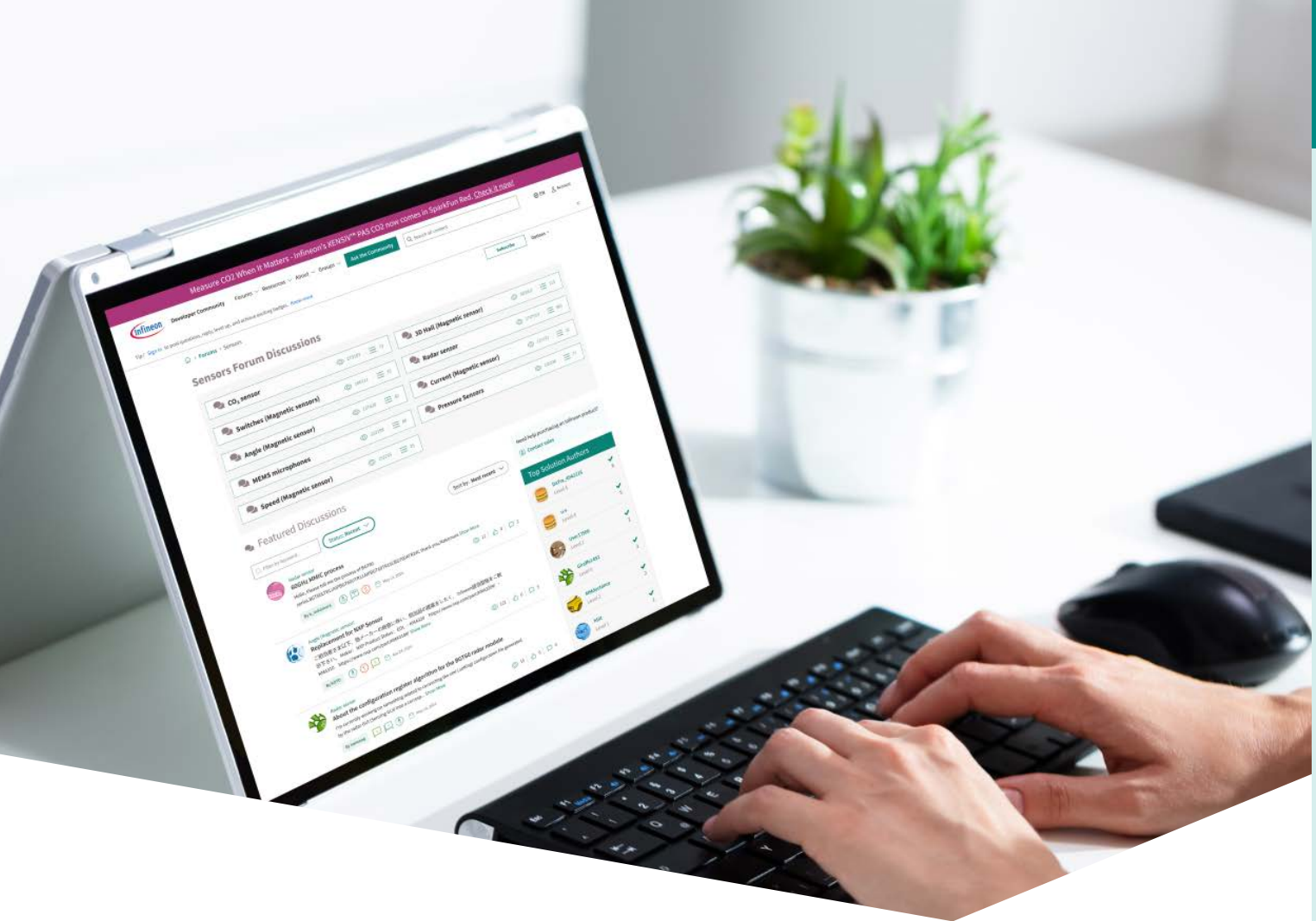
Infineon's XENSIV™ family was developed to meet today's sensing challenges in automotive, industrial, consumer and IoT applications. Building on the company's in-depth system understanding, it is the broadest portfolio of sensor types on the market, giving customers the widest selection of ready-to-use solutions offering fast time-to-market. Spanning magnetic sensors, current sensors, pressure sensors, MEMS microphone sensors, environmental sensors, 3D image sensors (REAL3™) and radar sensor MMICs (RASIC™ for automotive), XENSIV™ ensures the perfect fit for all performance and integrity needs – regardless of the industry.

XENSIV™ sensors are designed to “smartify” lives by enabling “things” to “see”, “hear”, “feel” and “understand” their environment. They empower customers to build more intelligence into their designs, thus paving the way for new and compelling applications offering more intuitive interaction and contextual awareness. Infineon also joins forces with its ecosystem partners to jointly develop innovative, synergized use cases that give customers a clear market lead in emerging areas such as robotics, autonomous driving and building automation. With industry's broadest sensor portfolio Infineon enables customers' AI systems to reliably gather data for best informed decisions.

Building on the 40 years of experience that Infineon has clocked up in developing sensor products and its world-leading sensing technology portfolio, XENSIV™ delivers exceptional accuracy and best-in-class measurement performance. All XENSIV™ sensors are designed for the utmost in reliability. Enhanced design and production standards coupled with extended testing under the harshest conditions are reflected in the field-proven quality of this portfolio. Because of this robustness, customers worldwide can rely on XENSIV™ for system stability, durability and integrity over their entire product lifetime. This is a key success factor for safety-critical applications in automotive designs, for instance.

In addition, customers have the added reassurance of a proven track record. Over the past 10 years, Infineon has shipped more than 20 billion units and clearly demonstrated its ability to develop ready-to-use sensor solutions that match real-world, customer-specific needs while optimizing system design overall. Looking ahead, Infineon is committed to a path of continuous innovation and technology excellence to keep its customers ahead of the sensing curve.





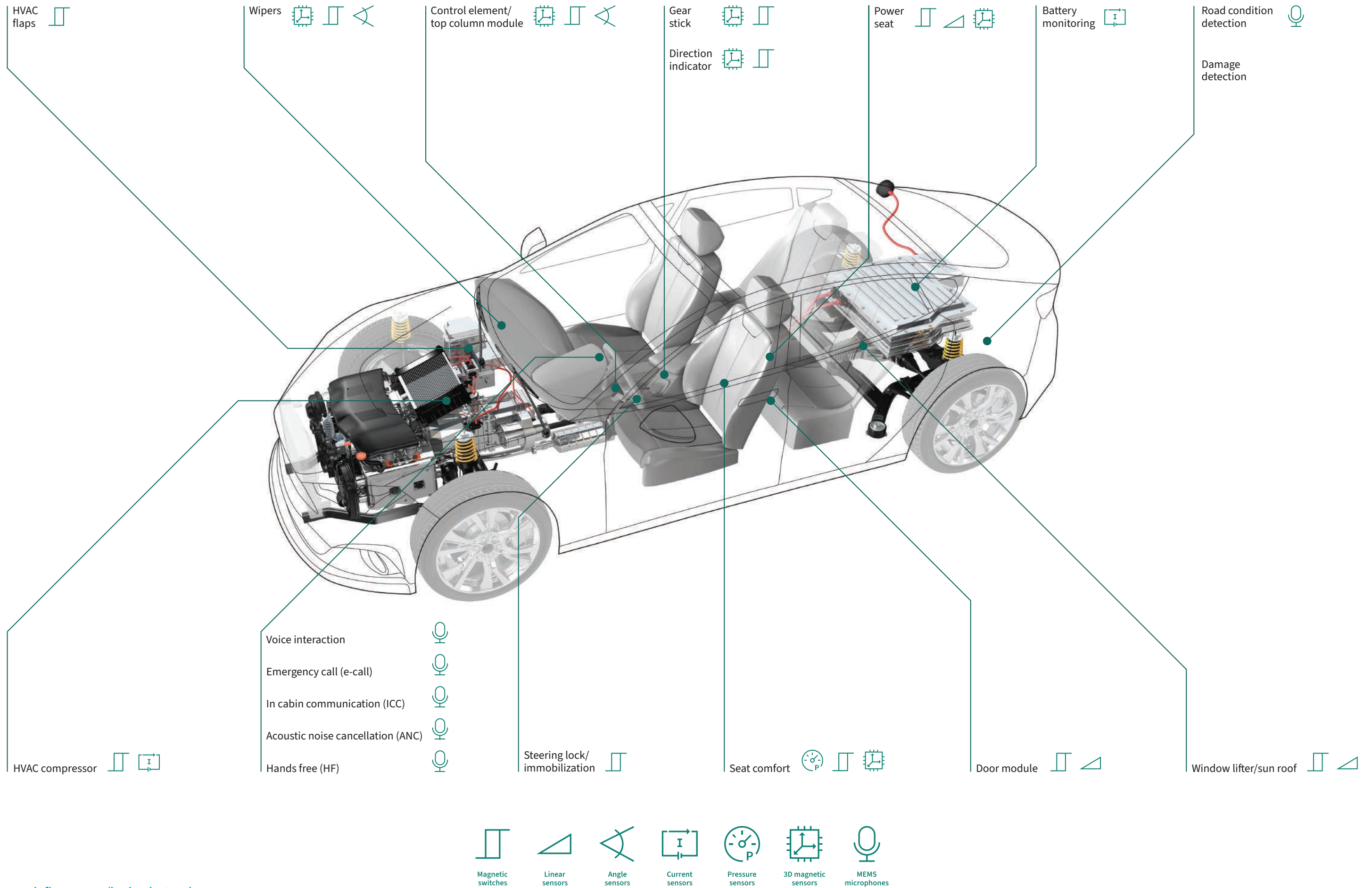
Ask the Infineon developer community

The Infineon developer community offers 24/7 self-service and lightning fast responses to customer demands. Any user, anywhere, anytime – any subject. The community is well-organized due to its multi-channel strategy. Unlike unmoderated forums, the developer community is based on high quality content that is professionally moderated and reviewed.

Check it out and be part of the [XENSIV™ sensor community](#).






















XENSIV™ sensors in body electronics





XENSIV™ sensors in powertrain systems

Engine


















- Crankshaft 
- Camshaft position 
- Manifold air pressure 
- Secondary air valve 
- Turbo charger   
- Throttle position  
- Variable valve position 
- HEV electric motor  
- Pedal position   
- Exhaust gas recirculation (EGR)   

Battery monitoring for EV 


HV battery disconnect for xEV 



On board charger (OBC) 


Transmission

- Clutch position 
- Clutch actuator  
- Transmission speed 
- Transmission actuator  
- Transmission gear position   
- Oil pump   
- Park lock  
- Gear stick   

DC-DC converter 

Barometric air pressure 

Starter generator  

Transfascase 

 Magnetic switches


 Linear sensors

 Angle sensors

 Current sensors






 Pressure sensors


 Speed sensors




 3D magnetic sensors

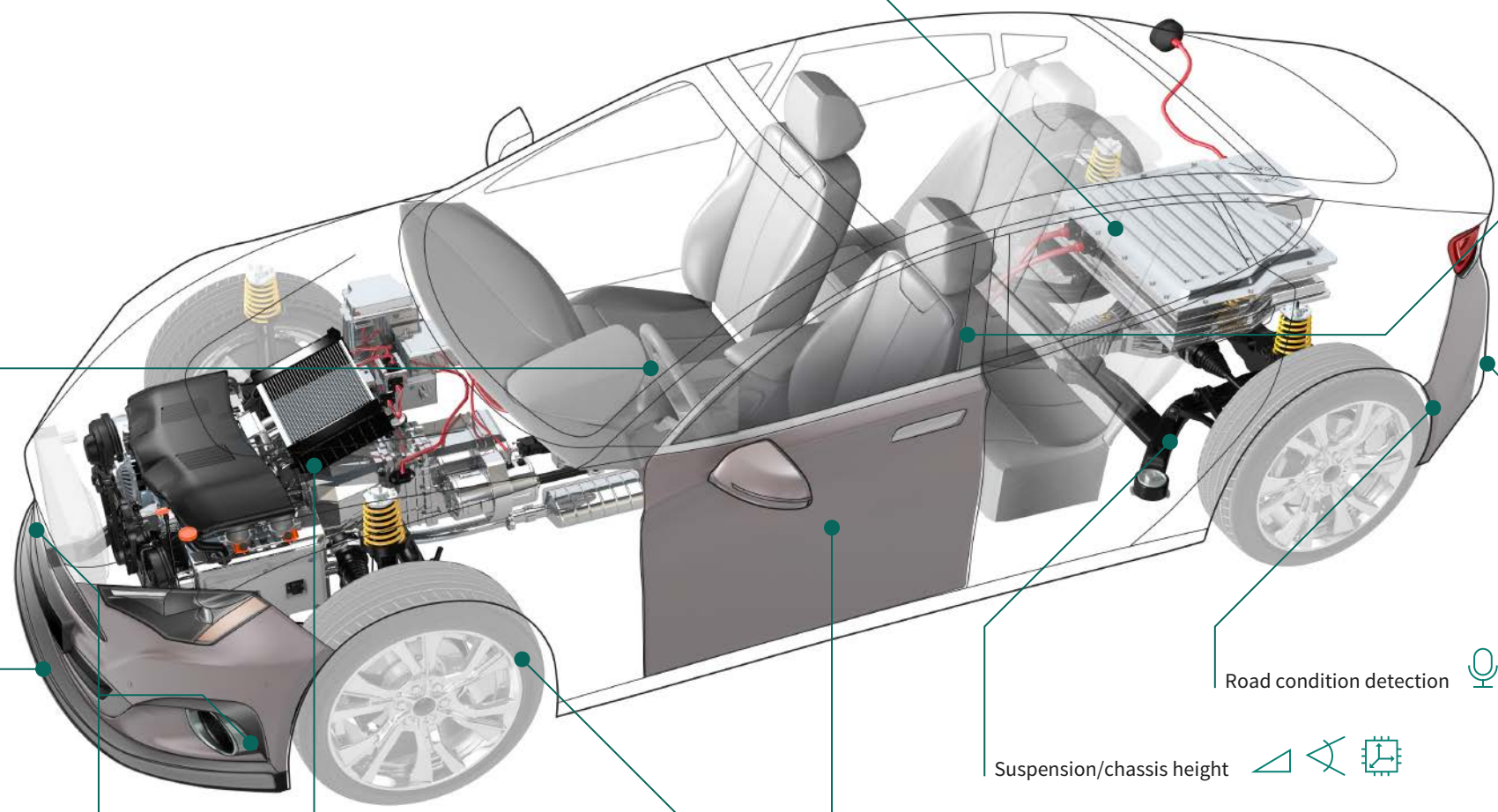
XENSIV™ sensors in chassis, safety and ADAS


Electric power steering (EPS)




- Steering torque 
- Rotor position  
- Steering angle  


Battery monitoring for EV 

- Seatbelt buckle 
- Seat position system 
- Belt pretensioner 



Road condition detection 


Suspension/chassis height   


Side crash detection 


Brake booster   

Wheel speed 


Brake pedal    


Tire pressure monitoring system (TPMS) 










Brake light switch 

Indirect TPMS system (iTPMS) 

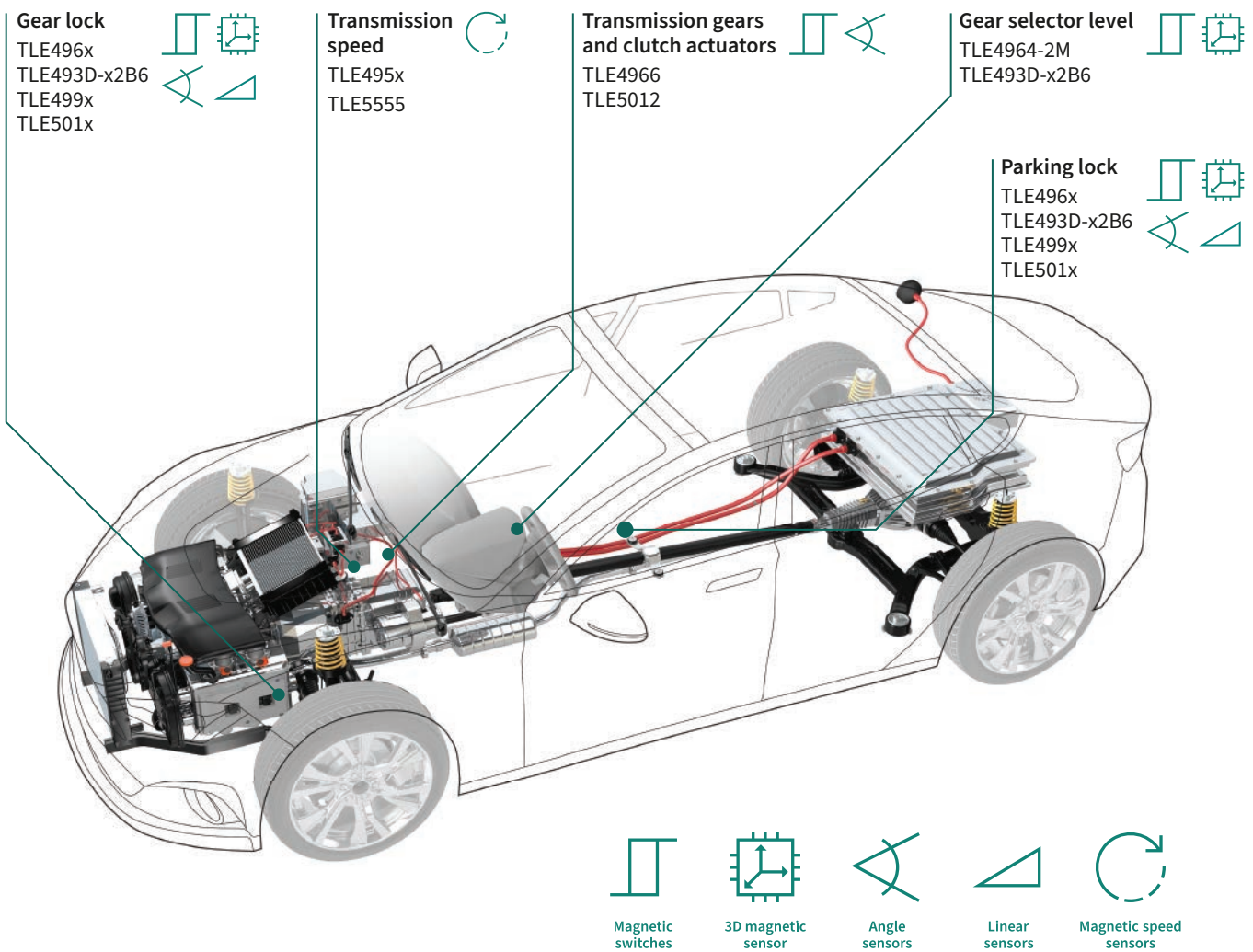
Radar 

Pedestrian protection 

Emergency vehicle detection/autonomous parking (at the four vehicle corners) 

-  Magnetic switches
-  Linear sensors
-  Angle sensors
-  Pressure sensors
-  Tire pressure sensor (TPMS)
-  3D magnetic sensors
-  Radar sensors
-  Speed sensors
-  MEMS microphones

Magnetic sensors in efficient transmission systems



The automotive industry faces the challenge of transitioning towards electro-mobility while also meeting global emissions regulations calling for higher fuel efficiency and lower CO₂ emissions

The transmission transfers engine torque to the wheels as the driver presses the accelerator pedal. An efficient system should enable reduced parasitic losses, a long last gear ratio, and aggressive torque converter lock-up schedules (zero slip).

Other essential aspects for modern transmission systems include driving performance and comfort – both of which strongly influence customer purchasing decisions. Automatic transmission architectures (AT, DCT, CVT) have the potential to answer all of these requirements, delivering a smooth driving experience and

improved efficiency while at the same time meeting all safety standards with an increased focus on drivability, launch feel, and shift quality over the whole automotive lifecycle.

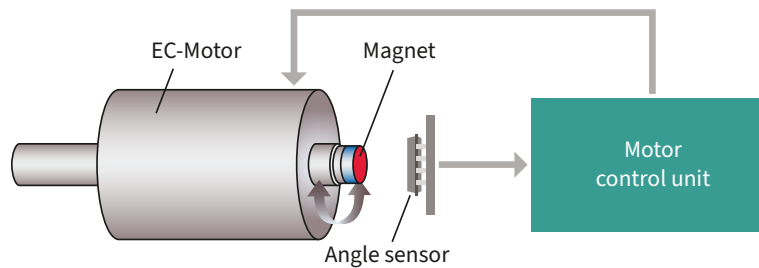
Reliable, accurate sensors are key success factors in many different transmission applications enabling improved system performance and superior control.

Infineon offers a wide range of accurate sensors for all automatic transmissions in hybrid and electric vehicles. These sensors improve transmission system performance as well as safety and driving comfort levels, opening the way for manufacturers to migrate from combustion engines to hybrid and fully electrified powertrains.

Actuation and motor commutation

Transmission actuators directly influence the controllability, dynamics, size, cost, and efficiency of transmission systems. The performance, efficiency, and controllability of transmission actuators can be significantly

improved by integrating rotor position sensors that provide exact position information for motor commutation, especially in conditions with highly dynamic torque (e.g. electric oil pumps).



Infineon has a broad portfolio of position sensors for motor commutation to address a wide range of requirements based on commutation type, accuracy, interface and system cost requirements. We offer all magnetic sensor technologies with in-house production; thus,

our customers can choose between Hall sensors, AMR (Anisotropic Magneto Resistive), GMR (Giant Magneto Resistive) or TMR (Tunnel Magneto Resistive) sensors in order to find the best-fit solution for their application.

Magnetic switches

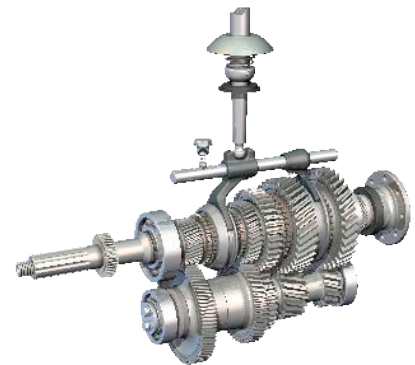


- High temperature stability of the magnetic threshold
- **Highest accuracy and proven quality**
- Easy drop-in replacement
- **Low power consumption** enabling energy-efficient systems

Angle sensors



- Wide portfolio of **analog (sin/cos) and digital angle sensors**
- Support STD digital interface HSM IIF & SPI
- High accuracy MR sensors
- Low power consumption
- **ISO 26262-compliant**
- Grade 0 available



Product	Ordering code	Description
TLE5012B E1000	SP001166960	Digital GMR angle sensor with SPI + incremental encoder interface or Hall switch emulation output
TLE5014SP16 E0001	SP004232096	ISO 26262-compliant (ASIL C-metric), programmable GMR angle sensor with PWM, SENT or SPC, SPI output.
TLE5501 E0001	SP001621824	Tunneling Magneto Resistive (TMR) angle sensor with analog sin/cos output.
TLE5009A16 E2210	SP001296114	Fast Giant-Magneto Resistive (GMR) angle sensor family with analog sin/cos output with built amplifier.
TLE5109A16 E2210	SP000956966	Fast Anisotropic Magneto Resistive (AMR) angle sensor family with analog sin/cos output with built amplifier.
TLE4964-2M	SP000923330	Integrated highly accurate Hall effect switch with superior supply voltage capability, additional product derivatives available.

Gear selector lever

There are different sensing solutions for gear selector devices on the market, depending on the mechanical implementation of the lever movements/positions and the design. Common to all is the ability to detect the discrete position – in other words, the selected operating mode – of the automatic transmission system. Contactless sensing solutions are standard and have a major share in this application field due to their reliability and functional safety gains compared with mechanical switches or potentiometers. Hall switch arrays are often used but pure angular and 3D Hall solutions are also common.

TLE496x-xM are integrated Hall-effect sensors, which ensure an easy-to-use and cost-effective solution for position sensing applications. Especially when high temperature stability of the magnetic threshold is required.

Our innovative 3D Hall sensor family TLx493D senses the magnetic field in three dimensions allowing to build a gear stick system using only two 3D Hall sensors instead of an array of Hall switches. The benefit of the 3D Hall technology together with the high accuracy and the small package enable extremely compact system designs.

Magnetic switches



- **Highest accuracy and proven quality**
- Easy drop-in replacement
- **Low power consumption** enabling energy-efficient systems
- **High supply voltage range** and load dump capability to ensure cost-effective designs

3D magnetic sensors



- Component reduction due to 3D magnetic measurement principle
- **Best accuracy-package size fit**
- Very low power consumption
- Supporting platform approach due to high flexibility and configurability
- Supporting **ISO 26262-compliant** systems

Product	Ordering code	Description
TLE4964-2M	SP000923330	Integrated highly accurate Hall effect switch with superior supply voltage capability, additional product derivatives available.
TLE493D-P2B6 A0	SP005557415	High accuracy low power 3D magnetic Hall sensor with I ² C interface, additional product derivatives available.

Parking lock and gear fork

Parking brakes are used in all kinds of transmission types and will continue to be part of battery-powered electric vehicles in future. The position of the parking lock is controlled by a magnetic position sensor that detects the positions “P engaged” and “P not engaged”.

One gear is locked mechanically to avoid that the car moves, while parked. A linear movement is needed, activated by an electrical motor. Therefore, a rotation is transferred to linear movement, which offers many sensing solutions. We know about magnetic angle

sensor, magnetic switches and magnetic linear position sensor.

Gear forks are a similar use cases. They control the engagement and disengagement of different gears in a transmission using a linear movement. Position sensors are used to ensure that a gear fork operates smoothly and safely when switching gears. Different designs with Hall switches as well as linear, angle, or 3D Hall sensors are possible for both applications based on the overall system implementation of the OEM.

Magnetic switches	Angle sensors	3D magnetic sensors	Linear sensors
<ul style="list-style-type: none"> – Highest accuracy and proven quality – Easy drop-in replacement – Low power consumption enabling energy-efficient systems – High temperature stability of the magnetic threshold 	<ul style="list-style-type: none"> – Wide portfolio of analog (sin/cos) and digital angle sensors – Support STD digital interface HSM IIF & SPI – High accuracy MR sensors – Low power consumption – ISO 26262-compliant 	<ul style="list-style-type: none"> – Component reduction due to 3D magnetic measurement principle – Best accuracy-package size fit – Very low power consumption – Supporting platform approach due to high flexibility and configurability – ISO 26262-compliant 	<ul style="list-style-type: none"> – Enables highly accurate angular and linear position detection as well as current measurements – High linear and ratio-metric push-pull rail-to-rail output signal – Low drift of output signal over temperature and lifetime – ISO 26262-ready/-compliant

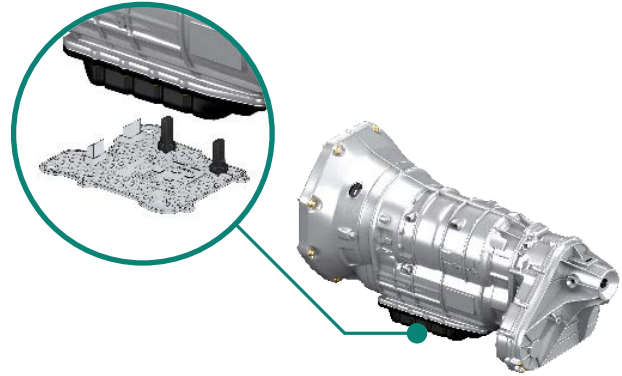
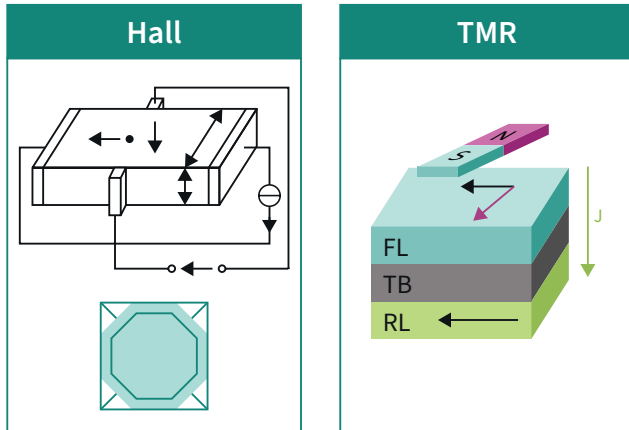
Product	Ordering code	Description
TLE5012	SP001205296	GMR digital angle sensor
TLE5501-E0001	SP001621824	TMR analog sensor
TLE4964-xM	SP000923326	Switch
TLE4961-xM	SP000923322	Latch
TLE4961-1L	SP000848038	Latch
TLE4963-xM	SP000930182	Latch
TLE4968-1M	SP000923334	Latch
TLE4966-xG	SP002983188	Double Hall
TLE4997x	SP000902756	Linear Hall
TLE4998x	SP000476468	Linear Hall
TLE4999x	SP002662500	Linear Hall
TLE493D-P2B6 A0	SP005557415	3D magnetic Hall sensor



Transmission speed sensors

Infineon's transmission speed sensors address all automatic transmission systems (DCT, ECAT, CVT, AMT) as well as hybrid concepts, DHT, and new EVs. Our sensors have been designed to provide excellent performance in the most challenging gears of the transmission

systems. Our portfolio of transmission speed sensors is based on two different technologies chosen specifically to deliver the robustness and flexibility required for transmission applications.



Hall-based technology sensors:

- Currently most widely used technology worldwide for speed and position sensing
- Reliable, robust, and easy to use without saturation or flipping, easy to use with back-biased applications

TMR-based technology sensors:

- Combine the high sensitivity and excellent jitter performance of MR technologies
- Combine the robustness and user friendliness of Hall sensors with low-cost ferrite magnets

Two-wire current interface sensors or three-wire voltage interface sensors provide speed information and, depending on the protocol, direction information to the TCU via a PWM protocol.

Product highlights

- Wide and stable product portfolio of magnetic speed sensors
- Two wire current interface and three wire voltage interface available to fit all transmission system in the market including DHT and new 2-gears EV concepts
- Speed and direction detection via PWM output protocol available
- ISO ready and ISO compliant versions supporting ASIL D on system level
- High magnetic sensitivity & large operating airgap
- Fast start-up and dynamic self calibration principle
- High vibration suppression capability
- From zero speed up to high frequencies
- Easy to use for magnetic encoders and ferromagnetic wheel applications

Product	Ordering code	Description
TLE4953C	SP001952920	Two-wire current interface differential speed sensor family with direction detection and active vibration suppression. Additional product derivatives available.
TLE4955C	SP001952972	Two-wire current interface differential speed sensor with direction detection and the highest active vibration suppression. Additional product derivatives available.
TLE4959C	SP001671650	Three-wire voltage interface differential speed sensor family with and without direction detection and active vibration suppression. Additional product derivatives available.
TLE5555	Reference page 65	State-of-the-art two-wire differential TMR speed sensor, offering all features required in latest automatic transmission application, additionally offering all advantages of top-read mounting, both technically and commercially.

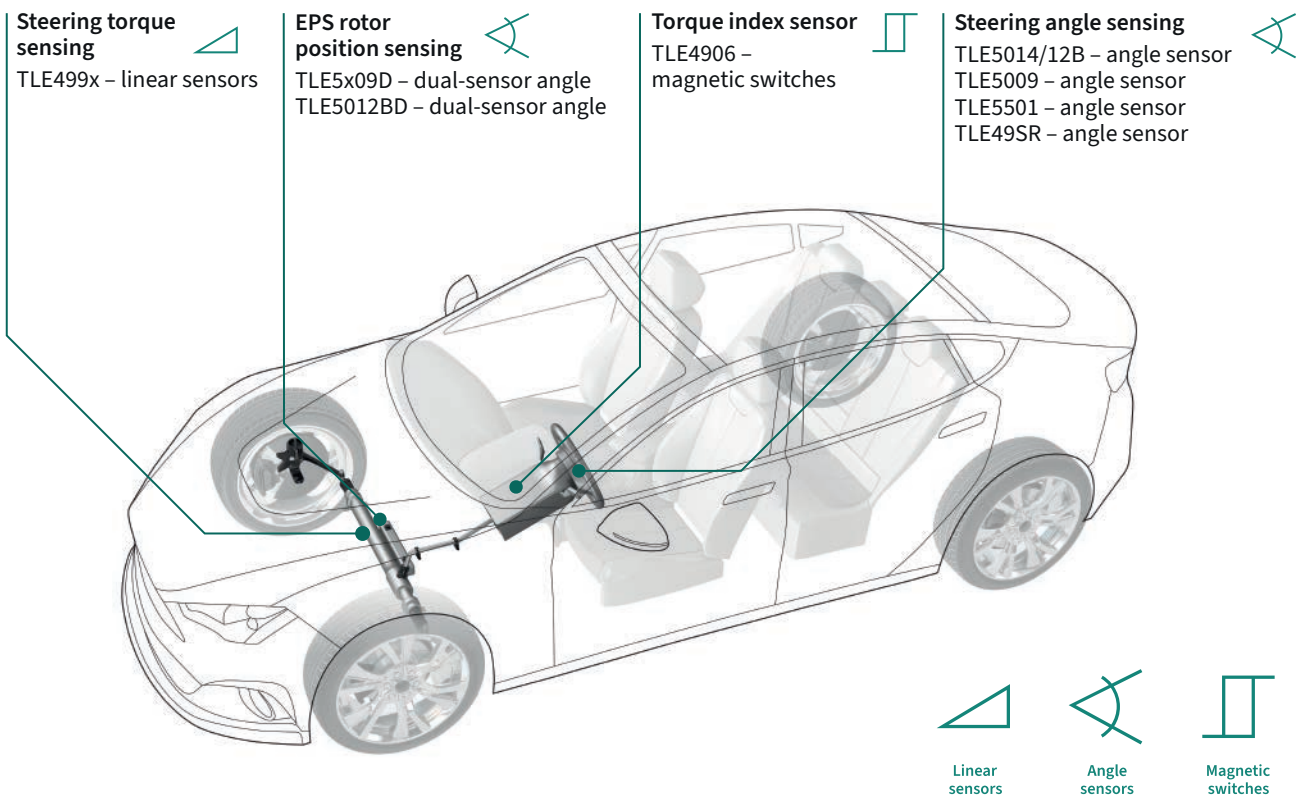
Sensors in electric power steering (EPS)

Magnetic position sensors for highest energy efficiency and functional safety in electric power steering (EPS)

Compared to conventional hydraulic power steering solutions, electric power steering (EPS) enables higher energy efficiency, increased steering functionality and reduced space requirements in passenger vehicles.

The functionality of EPS is based on several system-side position sensors, that measure the steering torque input from the driver, the rotor position of the EPS motor, that moves the steering rack and the steering wheel's absolute position.

Typical application for Infineon magnetic position sensors in EPS



Position sensor applications in EPS are safety-related with the highest safety level. The ISO 26262 standard sets high requirements for the diagnostic coverage of random failures and the avoidance of systematic failures in order to reach the highest safety rating on system level resulting in a safety classification of the category ASIL D.

These demanding specifications can typically be achieved by using redundant sensors as well as comparing their signals in a microcontroller.

Infineon offers dual-sensor solutions with two redundant sensors in the place of one for all position sensor applications in EPS. Our dual-sensor package integrates two magnetic position sensors with separate supply pins and separate signal outputs. They are electrically independent thanks to galvanic isolation. This means that the two sensors work independently, thereby increasing system reliability.

PRO
SIL

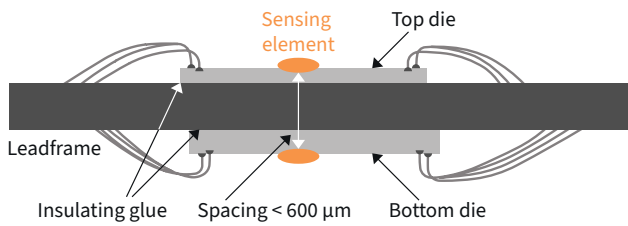
ISO 26262
compliant

PRO
SIL

ISO 26262
ready

Magnetic position sensors for the ultimate in energy efficiency and functional safety in electric power steering (EPS)

Side view of Innovative stack-mounted dual-sensor technology with bonding wires



Thanks to the use of innovative stack-mounting technology, the devices of the angle sensor family combine two independent sensors within standard and space-saving TDSO packages which are only about 1 mm thick. It has the same width and length as a conventional single-sensor package. Compared to the

Transparent 3D-graph of dual-sensor TDSO-16-2 package



common approach of side-by-side sensor placement, the advantages of the top-bottom placement include a more homogeneous magnetic field over the sensing elements and a significantly smaller footprint. This saves precious space and cuts down on expense in safety-critical applications.

Steering torque sensors

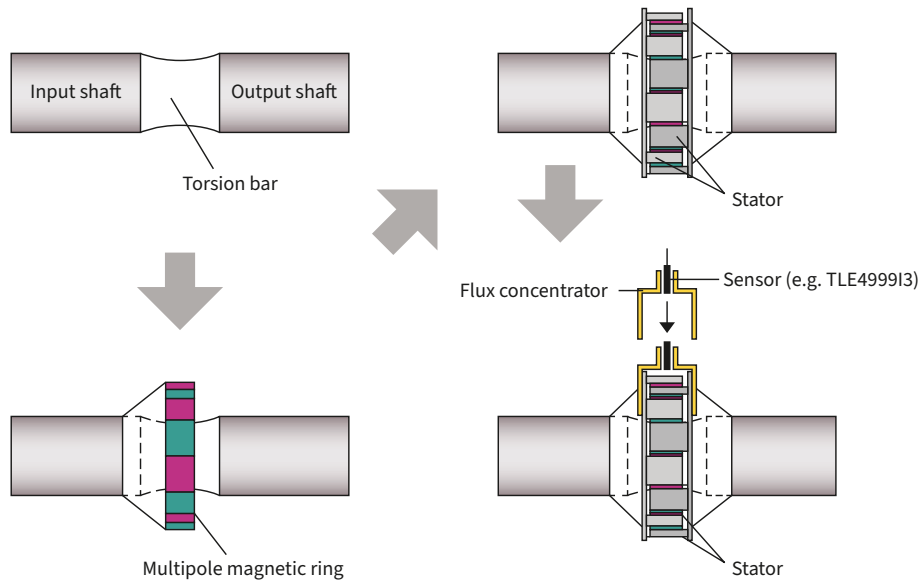
In the field of steering torque sensing, Infineon XENSIV™ TLE499x series offers highly accurate linear Hall sensors for magnetic torque sensing assembly. In order to support a maximum of compatibility with various

Electronic control unit (ECU) designs, the TLE499x sensors feature PWM, SENT, SPC, PS15 or ratiometric analog output. They are available in leaded packages, as well as 1 mm thick dual- or single-sensor SMD packages.

TLE4997x	Programmable linear Hall sensor with temperature compensation and ratiometric analog output. Available in a 3-pin leaded package (without integrated capacitors) and an 8-pin dual- or single-sensor SMD package.
TLE4998x	Programmable linear Hall sensor with digital stress and temperature compensation and PWM, SENT or Short-PWM-Code (SPC) output. Available in a 3- or 4-pin leaded package (with or without integrated capacitors) and an 8-pin dual- or single-sensor SMD package.
TLE4999I3	Programmable dual channel linear Hall sensor with PS15 interface. Developed compliant to ISO 26262 for safety requirements rated up to ASIL D. Available in a 3 pin leaded package.
TLE4999Cx	Programmable dual channel linear Hall sensor with Short-PWM-Code (SPC) interface. Developed compliant to ISO 26262 for safety requirements rated up to ASIL D. Available in an 8-pin dual- or single-sensor SMD package, 4-pin leaded package sensor is already available.

Magnetic position sensors for the ultimate in energy efficiency and functional safety in electric power steering (EPS)

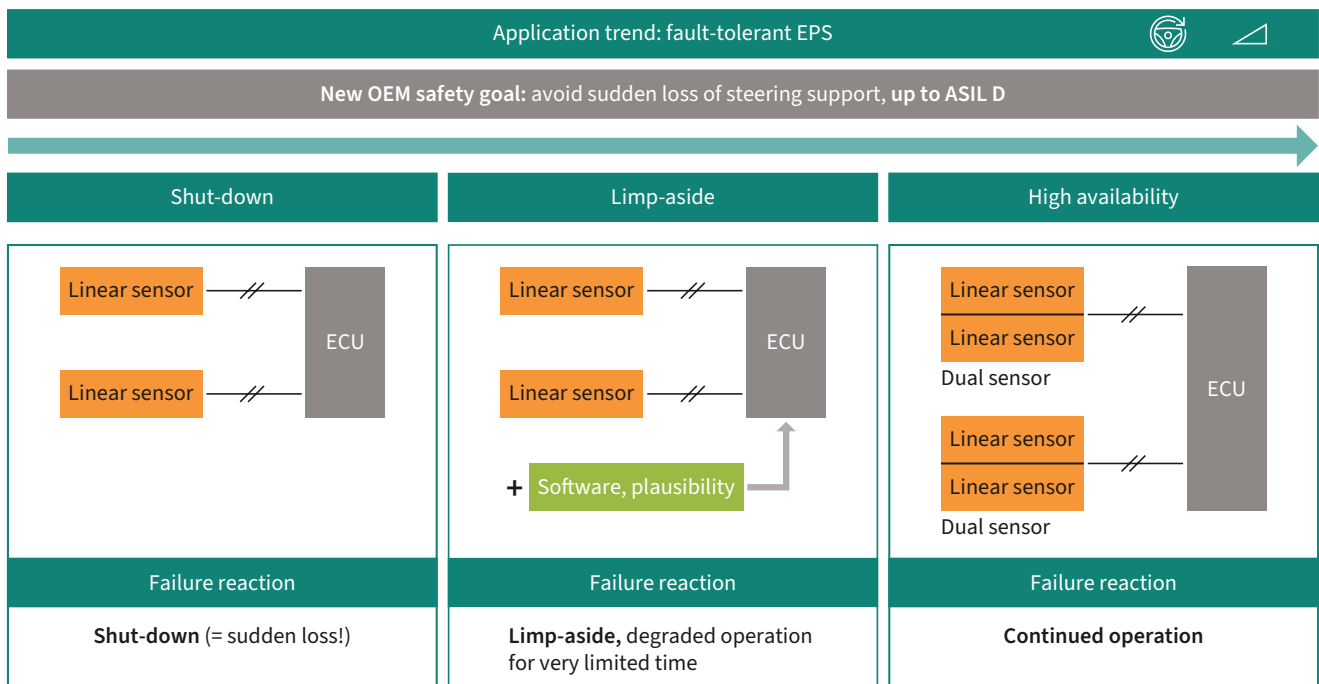
Magnetic torque sensing assembly



Conventional EPS systems, which use two linear Hall sensors for ASIL D compliance, have to shut-down in the event of a loss of one sensor signal. Therefore, the trend in EPS systems is to increase availability by implementing additional sensor signals or plausibility mechanisms. To support this trend towards high-availability EPS functionality, Infineon recommends the usage of two TLE4998xD dual-sensors or two TLE4999x, each of

them with two highly accurate redundant Hall measurement channels (main and sub) integrated on one single chip. In case of one TLE4998xD or TLE4999x signal loss, the remaining dual-sensor (TLE4998xD) or the single die two channels (TLE4999x) in the system provides continued operation of the EPS, avoiding an immediate system shut-down.

Application trend: High availability

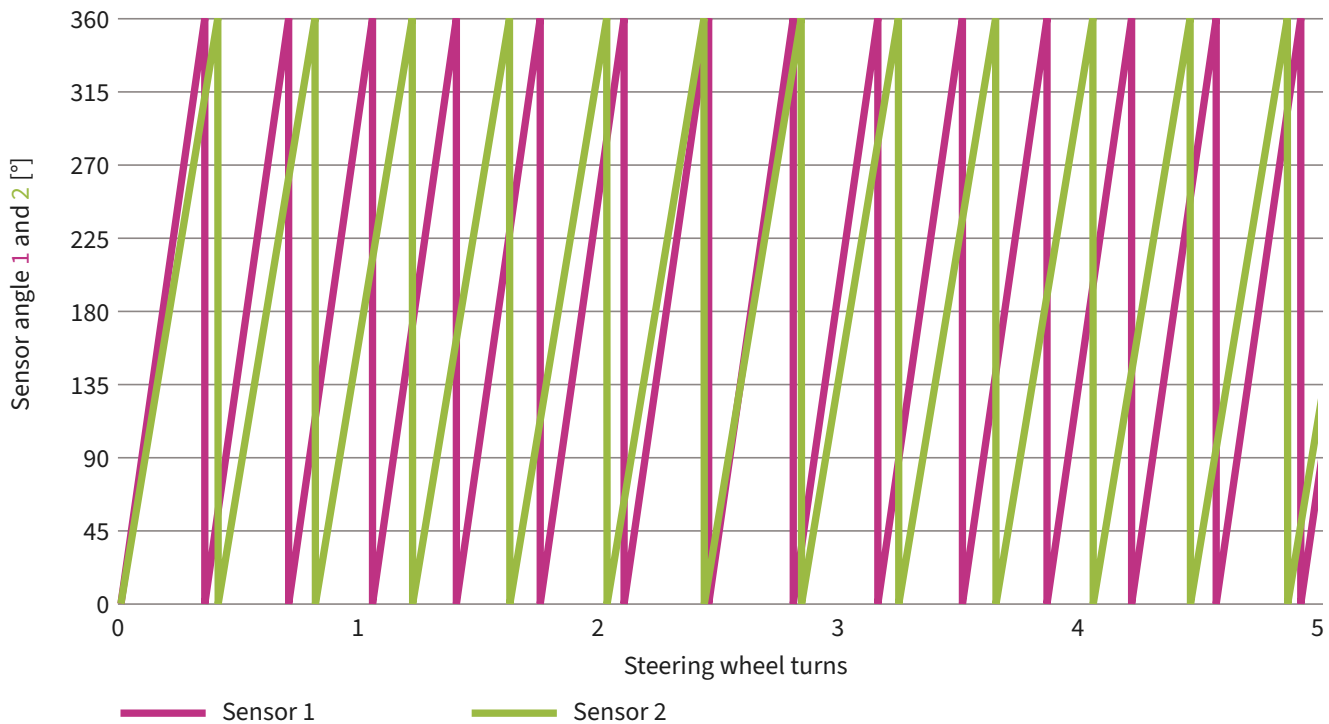


Steering angle sensors

The absolute steering angle position is an input for the Electric stability program (ESP) and other driver assistance systems. A typical module design used for steering angle measurement is a design featuring gear wheels with a slightly different number of teeth.

The angular positions of the gear wheels are measured by two angle sensors, where the absolute steering wheel position is calculated from those positions via the Vernier principle.

Schematic steering angle sensor module and illustration of the Vernier principle



Steering angle sensors

The angle sensors for absolute steering angle measurement are available as a single-sensor SMD package for conventional designs, which achieve the ASIL D rating via a plausibility calculation of the two angle sensor signals as a result of a significant movement of the

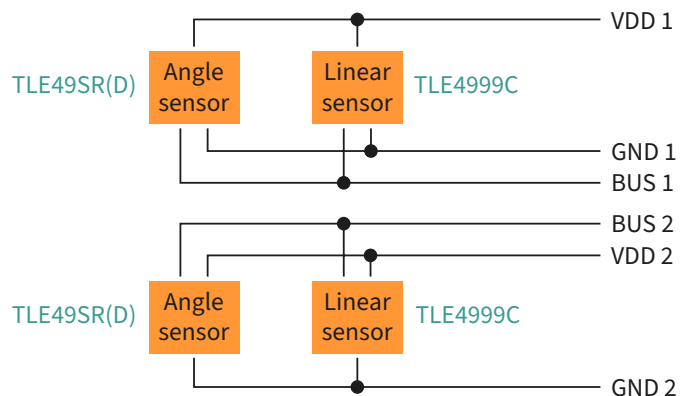
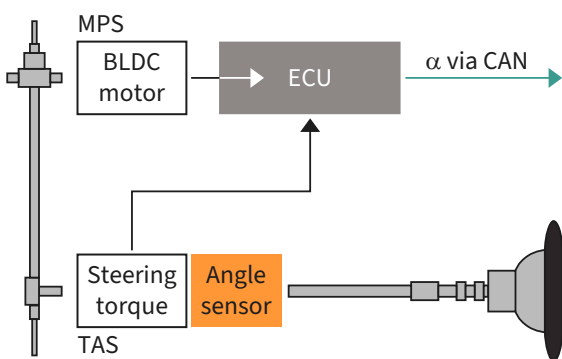
steering wheel. The sensors are also available in dual-sensor packages for module designs, that support an ASIL D rated steering angle directly at power-on (ASIL D from start).

TLE5009(D)	Fast Giant-Magneto Resistive (GMR) angle sensor with analog sin/cos output. Available in an 8-pin single, 16-pin single- and dual-sensor SMD package.
TLE5109A16(D)	Fast Anisotropic Magneto Resistive (AMR) angle sensor with analog sin/cos output. Available in an 8-pin single, 16-pin single- and dual-sensor SMD package.
TLE5014(D)	ISO 26262-compliant (ASIL C metric), programmable GMR angle sensor with PWM, SENT or SPC output. Supports Torque-Angle-Sensor (TAS) module bus configuration with TLE4998C. Available in a 16-pin single- and dual-sensor SMD package.
TLE5501	ISO 26262-compliant (ASIL D metric) Tunneling Magneto Resistive (TMR) angle sensor with analog sin/cos output. Available in an 8-pin single SMD package. Decoupled bridges for redundant external angle calculation and highest diagnostic coverage.
TLE49SR(D)	ISO 26262-compliant (ASIL C metric) Stray field robust Hall angle sensor with PSI5, PWM, SENT or SPC output. Supports Torque-Angle-Sensor (TAS) module bus configuration with TLE4999C. Available in a 3-pin leaded or 8-pin single- and dual-sensor SMD package.

Infineon angle sensors support steering angle sensor configurations with an on-board microcontroller, as well as satellite sensor designs, due to a broad variety of supported communication interfaces. In particular, the SPC interface allows the connection of angle

sensor(s) and linear Hall sensor(s) on a bus line in combined torque-angle-sensor (TAS) modules. Compared to conventional designs with separate torque sensor and angle sensor modules, this configuration reduces the cost of wiring and saves module space.

Schematic TAS module set-up and SPC bus configuration of the TLE49SR(D) and TLE4999C

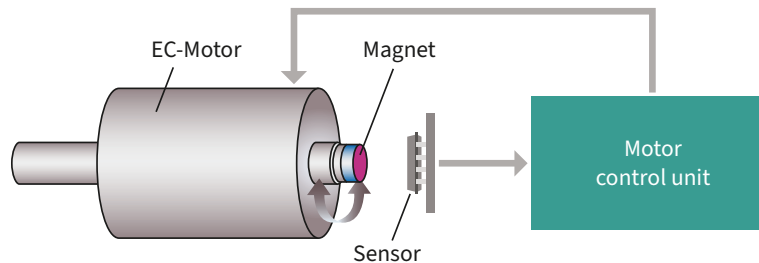


EPS rotor position sensors

The motor, that drives the steering rack in an EPS system is usually a highly efficient brushless DC (BLDC) motor, which relies on a fast and accurate position sensor for commutation. In this application, short

latency and high accuracy are essential, as these sensor parameters have a significant impact on torque stability and the energy efficiency of the motor.

Schematic of BLDC motor with a magnetic position sensor for commutation



A correct commutation of the EPS motor has to be ensured, in order to avoid a blocked steering or the erratic steering support. This application is also classified in the category of ASIL D. To achieve this high level of functional safety, Infineon offers angle sensors in the dual-sensor package that allow the integration of two redundant sensors in the place of one.

The TLE5309D, in particular, meets the highest functional safety requirements by using a combination of AMR (Anisotropic-Magneto-Resistance) and GMR (Giant-Magneto-Resistance) technology, which not just offers redundancy, but also integrated diversity in a single product.

Depending on the overall EPS system architecture, the motor position sensor can be directly mounted on the steering ECU, or connected via a cable in a satellite configuration.

The very high level of sensor accuracy required for highest energy efficiency, comparable to the performance of costly resolver solutions, is typically achieved by implementing a continuous calibration algorithm on the steering ECU. By monitoring the sensors output signals and calculating the compensation parameters during operation, this algorithm compensates any drift that occur over temperature and lifetime.

TLE5009A16(D)	Fast dual-GMR angle sensor with analog sin/cos output. Available in a 16-pin dual-sensor SMD package.
TLE5109A16(D)	Fast dual-AMR angle sensor with analog sin/cos output. Available in a 16-pin dual-sensor SMD package.
TLE5309D	Combined AMR and GMR sensor for integrated diversity, featuring fast analog sin/cos output. Available in a 16-pin dual-sensor SMD package.
TLE5012BD	Digital GMR angle sensor with SPI + incremental encoder interface or Hall switch emulation output. Available in a 16-pin dual-sensor SMD package.



Challenges for engine sensors in hybrid powertrains

The prospect of emissions penalties as of 1 January 2021 is prompting many manufacturers to switch to lower-carbon drive systems. Electric cars have become a key talking point on everyone's agenda – especially in California, where a very promising startup recently (February 2020) secured a higher market capitalization than the biggest European car manufacturer.

But there is a wide playing field between conventional combustion engines and all-electric cars, presenting less radical pathways towards achieving the EU fleet-wide average emission target for new cars of 95 g CO₂/km. Scaling from models with a 12 V belt starter generator through integrated 48 V starter generators to high-power 400 V drives, hybrid cars have the potential to drastically reduce noise in urban areas.

Combustion engines in these hybrid cars face a number of specific challenges when the car is being driven by the electric motor. We will be taking a closer look at them in this article. Time to explore the many additional functions a single crankshaft sensor has to fulfill in a hybrid motor...

Car manufacturers across the globe are expanding their portfolio of drive systems. Even looking beyond the fuel cells and synthetic fuels of tomorrow, there is still a huge number of hybrid options spanning the gap between combustion engines and electric motors.

These options range from stop-start combustion engines, where the motor shuts off for a few seconds at a red light and then cold starts, to plug-in hybrids that can easily drive 50 kilometers in all-electric mode before the combustion engine kicks in as the battery runs low or the vehicle is travelling at high speeds on a highway.

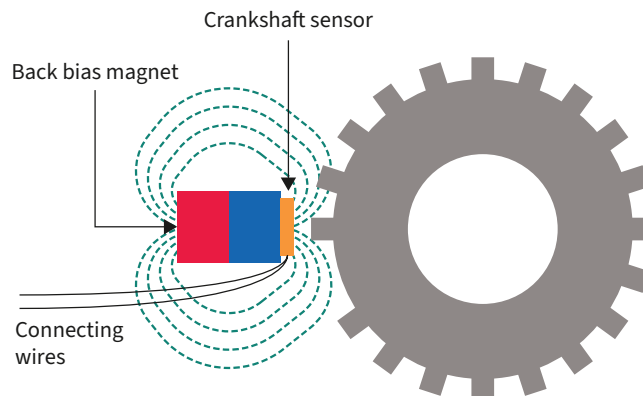
Two different implementations of even the most recent stop-start systems have already been brought to market. In one instance, the combustion engine starts again as if it had not been driven for an hour. The second solution monitors the movement of the engine as it comes to a stop, so when the engine starts up again, the car already knows the position of the crankshaft and the next cylinder to be fired. If we look at the starter generator attachment points on the drive shaft, or the points where the clutch connects different motors to the drive axle, we quickly see that the combustion crankshaft assembly options are virtually limitless.

Drive interplay as experienced by the driver

To maximize acceptance of new electric drive systems, manufacturers must win over former combustion enthusiasts with ease of operation and a predictable, smooth driving experience free of “nasty surprises”.

It’s important that a combustion engine can spring smoothly and almost imperceptibly into action – as already experienced at traffic lights or in traffic jams in start-stop mode. Here, it is essential that the car knows the angle of the crankshaft at all times. If the car stops for three minutes in a traffic jam, the crankshaft sensor is able to ignore a slight temperature drift or, ideally, compensate for it. During a 30-minute drive on rough roads with a crankshaft that is free to move when decoupled from traction wheels, however, the sensor could incorrectly count a slight shake or vibration of a tooth or, in the worst case, interpret these movements as a new, valid signal.

Diagram of a sensor module



The following is a list of functions that help sensors to accurately count teeth.

The conventional stop-start algorithm

The “smallest” solution for reducing fuel consumption involves switching off the engine. It is already widely deployed and available as a conventional stop-start algorithm. This function is able to correctly interpret short stops in congested traffic or at red lights and can compensate for small temperature drifts. Magnets are subject to very strong temperature drifts, which can change the magnetic field by up to 40 percent

To ensure a combustion engine can glide into action, it is important that the sensor does not incorrectly count any of the teeth moving past it. It is imperative that the sensor:

- Does not miss any teeth
- Does not count any additional teeth
- Does not mistake the rotational direction

These criteria are broken down inside the crankshaft sensor as there is basically a magnet inside the sensor housing and the field lines of this magnet are modulated by the teeth as they spin past.

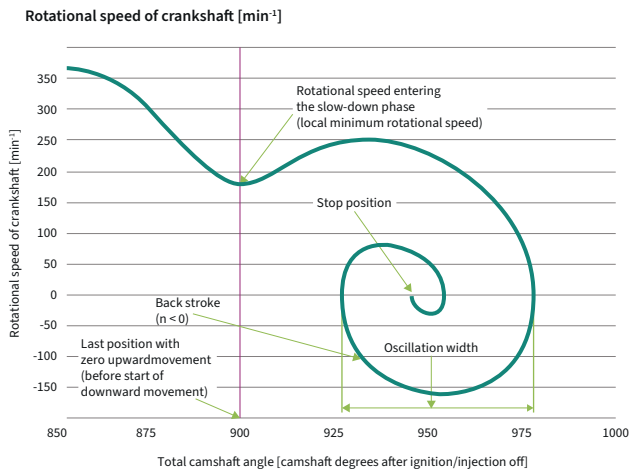
As such, the sensor’s performance is ultimately determined by fluctuations in magnetic field strengths. And these are dependent on a number of factors including the air gap between the sensor and the trigger wheel and the temperature. To ensure we do not get side-tracked by the various mechanical and electrical details, this paper focuses primarily on the mechanical components that are relevant to the sensor’s performance.

over the given temperature range. In the case of crankshafts with well-fitting bearings, the next most significant factor to impact sensor behavior is electrical in source. Number three in the lineup are changes in the air gap between the trigger wheel on the crankshaft and the sensor module on the engine block.

Ideally, the sensor remains fully calibrated and when the combustion engine starts again, it is able to correctly output the position and rotational direction of the crankshaft as soon as the first tooth of the trigger wheel spins past.

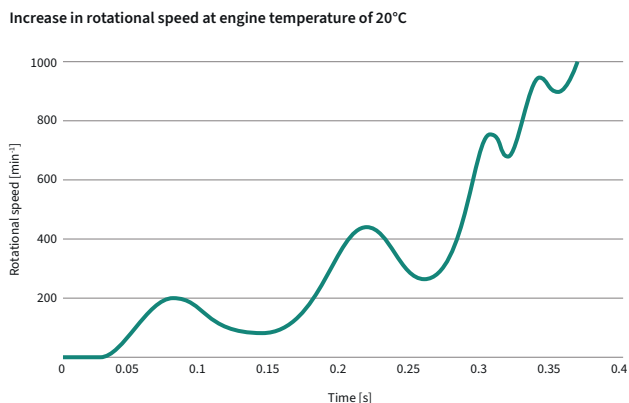
This functionality can be implemented without any modifications to the architecture of a combustion engine. All it requires is a slightly larger starter battery and starter motor and modifications to the software in the controller.

Diagram of the crankshaft coming to rest when ignition is shut off [1]



Figures 2 and 3 show how the disengaged crankshaft comes to a stop when the ignition is turned off as well as the quickest possible start for an Otto engine when compressed air is still in the cylinder (known as a direct start).

Diagram showing how a crankshaft starts turning again after a direct start [1]



Vibrations while stationary

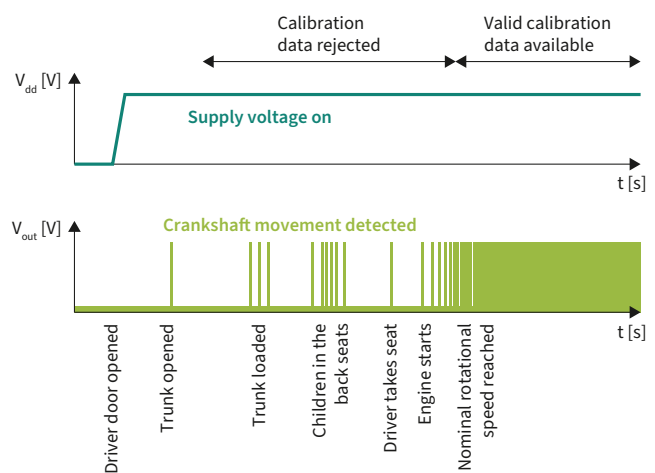
Modern cars carry out a range of self-diagnostic checks as soon as the driver's door is opened. This reduces the amount of time it takes for a warning lamp to light up. A lot of other things can happen, however, from the moment the car door is opened to the time the car pulls away. The car can be loaded, for example, or children have to be buckled into their seats. As such, it is completely normal for the car to rock slightly while stationary. These slight movements travel through the drive wheels,

transmission and clutch and cause the crankshaft trigger wheel to turn. In some unfortunate situations, this can result in the crankshaft sensor picking up a valid magnetic signal.

To overcome this issue, an algorithm has been implemented in the sensor to delete calibration data generated before the engine is switched on.

If we take just a brief look at the wide range of hybrid architectures, it quickly becomes clear that this add-on function will help car manufacturers to identify and ignore any inaccurate calibration data.

Signal output by the crankshaft sensor when a car is being loaded

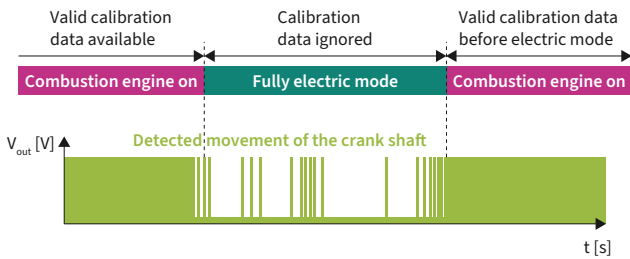


As figure 4 shows, we can draw several conclusions from the sensor's output signals over time. Firstly, we can see that the nominal rotational speed was not reached as soon as the sensor was activated. Consequently, the calibration data gathered up to the time where the nominal rotational speed was achieved can be reset without difficulty. Secondly, we see that this procedure can be repeated multiple times if the sensor does not identify a tooth for a certain period of time.

Hybrid algorithm

A new function is required for a "big" plug-in hybrid solution. To correctly identify the position of the crankshaft trigger wheel, an algorithm has been implemented in the sensor that detects slower, sub-nominal crankshaft rotation and, in conjunction with other monitoring functions, prevents incorrect calibrations. New calibration data is only accepted when the system is operating normally.

Signal output by the crankshaft sensor when driving in electric mode



This function enables every crankshaft vibration to be captured with the corresponding signals for forward and backward movement without the crankshaft sensor

Improved crankshaft sensor enables other components to last longer

As the crankshaft sensor always provides reliable information, the sizing of components required to restart the combustion engine can be reduced. The starter generator usually turns the crankshaft for several rotations until the home position of the crankshaft has been detected and a minimum rotational speed in excess of several hundred rotations has been reached. With an advanced crankshaft sensor, the fuel can be injected and ignited in just half a rotation. Starting the engine in this way requires only a fraction of the battery energy needed for a cold start.

incorrectly responding to supposed changes to the mechanical setup such as a shift in the air gap or some other mechanical misalignment.

Collectively, the algorithms named here enable the movements of the crankshaft trigger wheel to be accurately observed and tracked. The engine control unit knows at all times which stroke each piston is on and how much time is left until the next ignition (based on the crankshaft angle).

If the algorithms are correctly aligned, the system will operate correctly, ensuring that the engine warning light stays off.

Manufacturers can thus choose between a longer service life for the starter and battery, or size down and save costs and weight, which – in turn – translates into a slight drop in consumption.

This design also enables a great driving experience as the combustion engine starts easily and smoothly without creating any negative impressions.

More precise switching points with differential camshaft sensor

As part of its XENSIV™ family of sensors, Infineon Technologies has developed active Hall sensors specifically for camshaft and crankshaft applications. These devices can help to optimize the drive experience while extending service life. Installed on the camshaft, the XENSIV™ TLE4929C, for instance, can compensate for production and assembly tolerances on the supplier and manufacturer sides thanks to its programmable switching threshold. This ability means that this position sensor improves angle accuracy on both on the camshaft and the crankshaft.

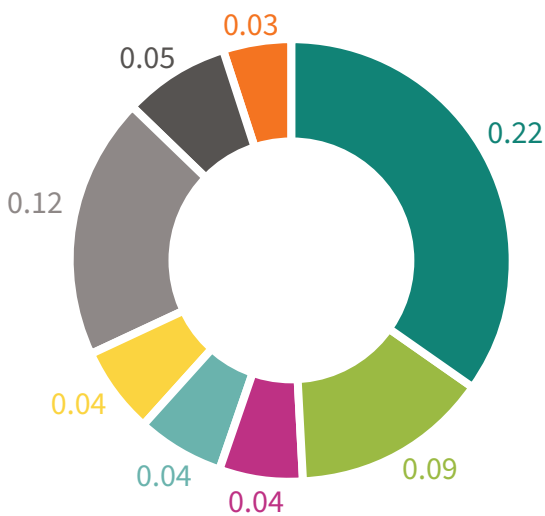
First of all, it should be noted here that differential Hall sensors, by their very physical nature, only switch when the centerline of the tooth is in front of the sensor.

Starting from the centerline of the tooth and moving out, the following tolerances must be taken into account:

- Mechanical tolerances on the tooth itself cause the magnetic center to deviate from the mechanical center
- Mechanical assembly tolerances for the module on the engine block account for the largest deviation
- Mechanical installation tolerances for the magnet and sensor in the module also have to be added
- It goes without saying that the installed magnets are not 100% homogenous; nor are they magnetized at a perfect 90° angle
- Finally, there are also electrical tolerances within certain limits that are attributable to the sensor manufacturer.

Breakdown of position errors by category

Error distribution in degrees for camshaft



- Mechanical tolerance: Module (± 0.5 mm)
- Mechanical tolerance: Magnet (± 0.2 mm)
- Mechanical tolerance: Sensor (± 0.1 mm)
- Mechanical tolerance: Chip (± 0.1 mm)
- Magnetization tolerance for the magnet
- Electrical tolerance of switching threshold
- Temperature drift of sensor
- Non-compensated mechanical stress

Systematic errors are compensated for by the engine control unit and are not included in the above list. They include signal propagation delays, which are already accounted for in the control unit's timer.

All of the components listed above result in a random error, which at best resolves itself but, at worst, can represent a massive fault. To meet the accuracy requirements of today's systems, modern sensors allow switching thresholds to be individually set. The module manufacturer can do this at relatively low cost by individually calibrating the switching point of the module at the end of the production process. It can also be done on the dry engine itself at a slightly higher cost.

The benefit for the car manufacturer here is that the calibration also compensates for their own production tolerances. In contrast, the tier 1 supplier can only compensate for the module itself; the OEM's installation error is not mitigated at all.

A cost-benefit analysis for the required tolerances and resulting calibration cost is advisable.

The actual calibration process is very simple: At a mid-point in the switching threshold, suitable systems are used to measure the misalignment between the mechanical center of the tooth and the actual electrical edge. After this, the systematic errors are subtracted and the remaining offset is programmed and permanently stored in the sensor as the programmable switching threshold.

As shown in figure 6, this method can be used to eliminate nearly all sources of error and improve the overall accuracy from $\pm 0.6^\circ$ camshaft to $\pm 0.1^\circ$ camshaft.

Summary

The combustion engine has had its day. From 2020 to 2025, all major car manufacturers worldwide will develop and launch their last hybrid platforms. After this, even the last remaining development engineers working on combustion engines and possibly also transmissions will have to find a new home in the emerging fields of fuel cell, battery and electric drive technologies.



The combustion engines developed today will be around for several decades to come. As such, it is vital that the technology used in these models is reliable, long-lasting, and up to date. Luckily, the challenges that hybrid engines and, in particular, crankshaft and camshaft sensors face in these systems are already known and being successfully addressed by Infineon.



Overview of Infineon XENSIV™ crankshaft sensors


- [TLE4929C-XA_x](#) – first-generation low-jitter, Hall-based crankshaft sensor.
- [TLE4929C-XVA](#) – second generation includes several further crankshaft protocols (by number 14) and a time watchdog to overcome start-up vibrations. In addition, this device is available with nickel plating for the first time.
- [TLE4929C-XHA](#) – third generation includes an additional dedicated hybrid watchdog and a new calibration feature to meet increased absolute phase accuracy requirements.




XENSIV™ sensors in smart industry






Barometric pressure sensing 
Wind speed sensing 

Solar panel tracking 
Solar inverter current 



Proximity detection 
Control elements 


Absolute and incremental rotary encoder 










Rear/tear and vibration detection 
Predictive maintenance 
Pneumatics 

Robot brushless direct current (BLDC) and position sensing 
Robot sensing/tank level measurement 
Tank/fluid level sensing 
Electric commutated (EC) motor 
Valve position 

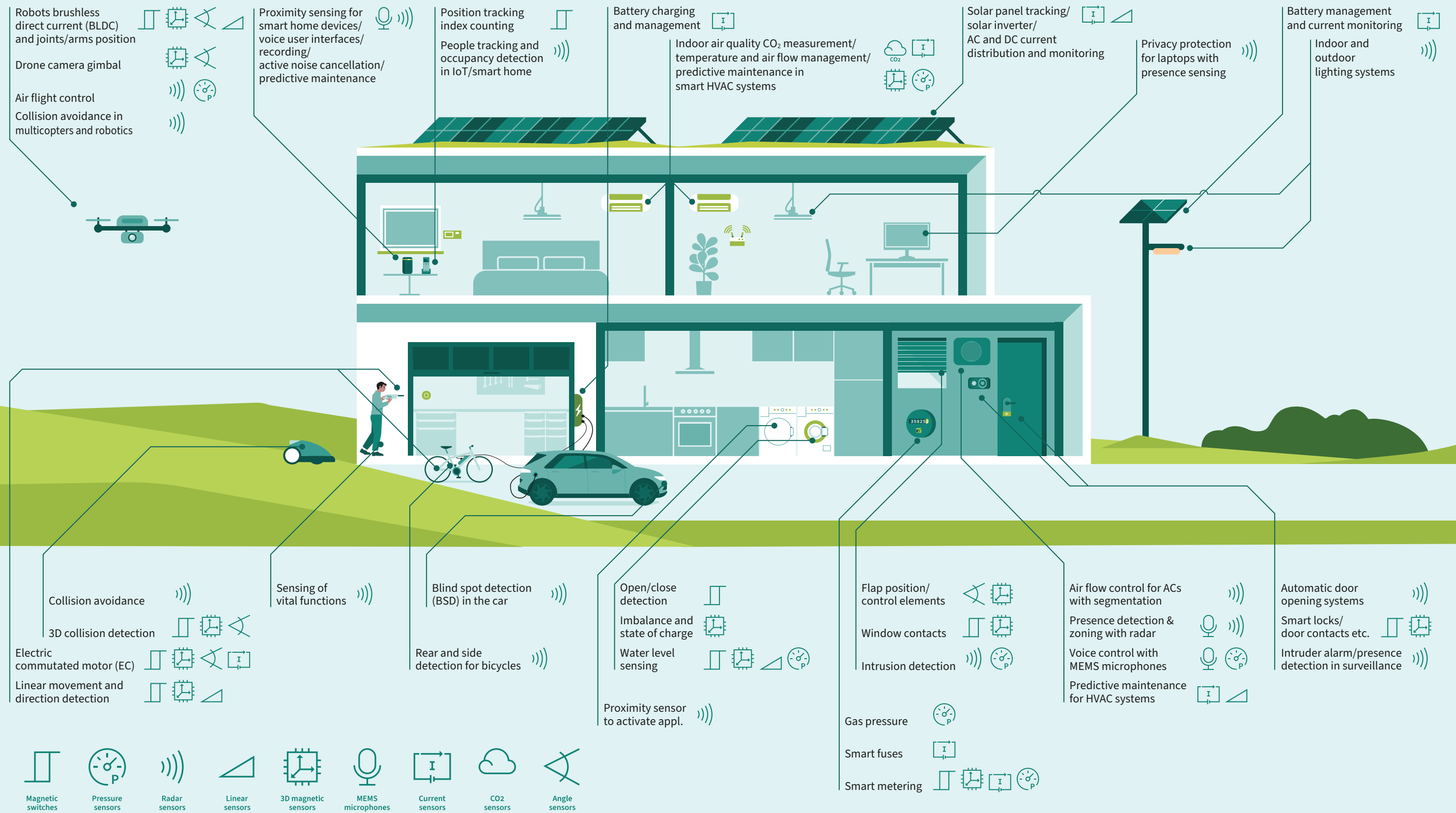
Smart metering 
Smart fuses 

Charger and battery management 
Plug detection in chargers 

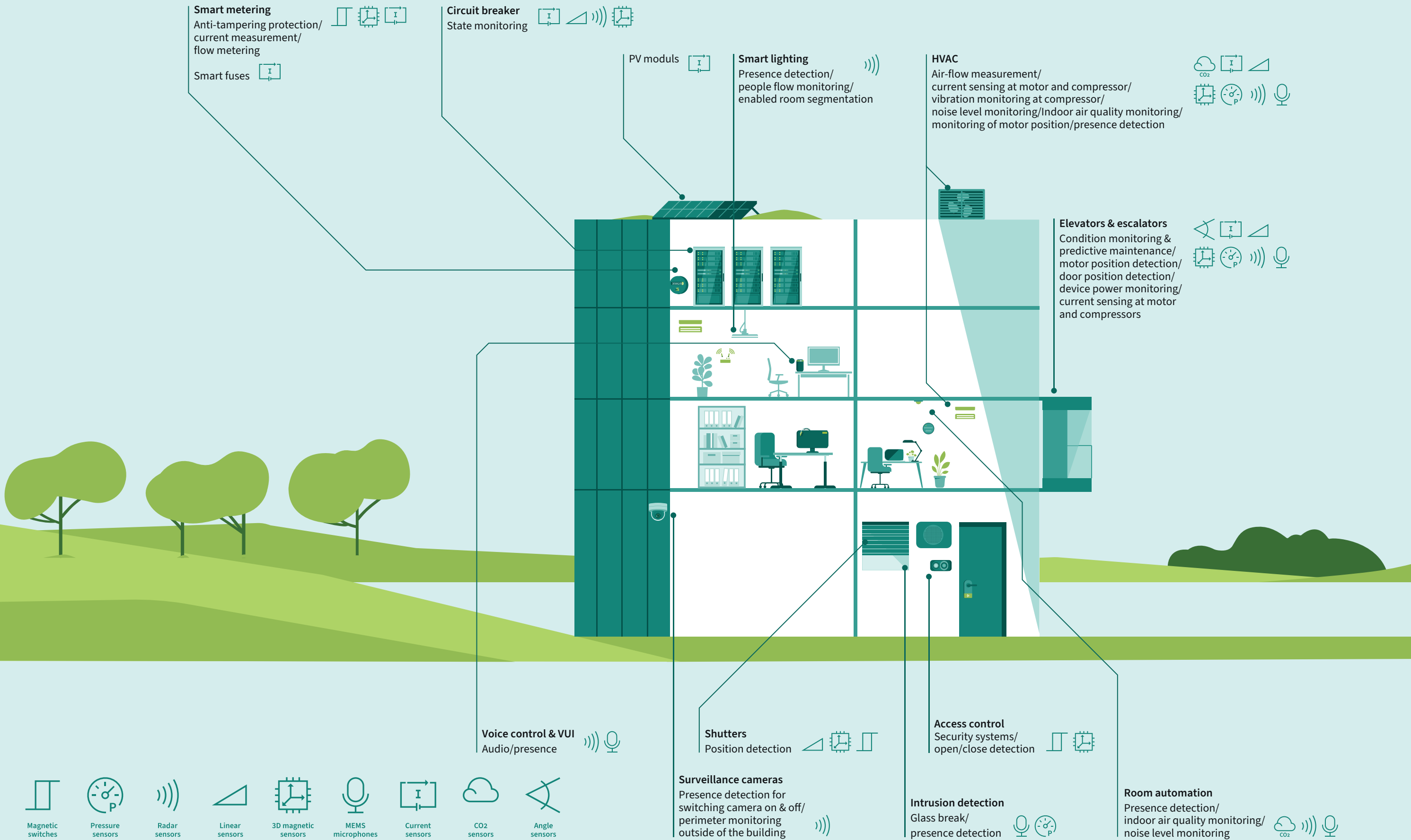
Gear wheel speed sensor 

-  Magnetic switches
-  Pressure sensors
-  Radar sensors
-  Linear sensors
-  3D magnetic sensors
-  MEMS microphones
-  Current sensors
-  Speed sensors
-  Angle sensors

XENSIV™ sensors in smart homes



XENSIV™ sensors in smart buildings



Trusted semiconductor solutions for light electric vehicles (LEV)

Infineon, a leader in power semiconductors, enables efficient, reliable, and smart solutions for e-mobility, minimobility, and micromobility markets, preparing for the ramp-up of light electric vehicles worldwide, such as:

- **Micromobility:** electric bicycle (e-bike)/kick-scooter
- **Electric powered 2/3 wheelers (ePTW):** e-moped, e-scooter, e-rickshaw, e-motorcycle
- **MicroEV:** electric microcars, low-speed electric vehicles (LSEV), neighborhood EV (NEV), electric quadricycle
- **Other electric transporters:** (e.g. e-forklift, e-golf cart, e-ATV) with less than 200 V batteries

Contrasting to automotive (passenger car) requirements, L-category (light) vehicles (though often also



on-road) require different sets of safety and qualification standards. As an example, the newest motorcycle standards place more responsibility on the operator rather than the vehicle itself to mitigate risks. Infineon considers mission profiles of different end applications and offers suitable non-automotive and automotive components for this wide range of use cases.

LEVs, powered by batteries, differ from traditional vehicles with bus voltages ranging from 28 V to 168 V. They share common components like motor inverters and battery management systems, and increasingly feature smart electronics.

www.infineon.com/lev



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Stay ahead in the commercial, construction, and agricultural vehicles (CAV) market with Infineon's eco-friendly solutions with high reliability and low TCO. Embrace autonomous technologies for safer, uninterrupted operations. Our electrification solutions not only

help you ensure compliance with emissions regulations, but also boost efficiency. Experience 24/7 functionality and data-driven navigation, and join the forefront of industry transformation.

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Current sensors

XENSIV™ – high-precision coreless current sensors for automotive and industrial

Used to measure both AC and/or DC currents, Infineon's current sensors provide accurate and stable current measurement up to 120 A or 31 mT respectively. Our magnetic current sensors include either an integrated current rail in the package for low currents or measure the magnetic field of an external current rail for medium to high currents. The products are intended for use in 48 V, as well as high voltage and/or wide bandgap applications such as traction inverters, industrial drives, photovoltaic inverters, or EV charging systems.

Infineon's XENSIV™ family of high-precision coreless open-loop current sensors are less bulky, and cost less compared to core-based current sensors. Based on Infineon's precise and stable Hall effect current sensor IC technology, the current sensor analog output signal is highly linear over temperature and lifetime. Due to lacking an iron core or a flux concentrator, the sensor signal shows neither hysteresis nor does it suffer from saturation.

The differential current sensor measurement with two Hall cells ensures high accuracy even in a noisy environment like crosstalk from adjacent current lines or magnetic stray fields. System designers can program the sensitivity of the sensor as well as the threshold levels

of the two dedicated overcurrent signals and therefore adapt them to individual requirements without any external components. The contactless current sensor IC also provides a warning signal in case of an over- or under-voltage condition for the supply voltage.

Product portfolio

Infineon's product portfolio includes wide bandgap current sensors for both industrial and automotive application needs. Our current sensors achieve high accuracy using the Hall effect, which enables current measurements from DC to AC with an internal bandwidth of up to 240 kHz without being disturbed by external magnetic fields.

On the one hand, we have the current sensors with an integrated current rail. The sensors in the TISON package allow the accurate measurement with high frequencies and small impact on the phase shift of the current signal. On the other hand, our current sensors for external current rails are non-invasive Hall effect current sensors and provide safe and reliable solutions for power electronics since there is no additional power dissipation. Our selection of isolated, non-contact current sensors can be used for current detection and monitoring in SiC and GaN applications, including motor control applications.

TLI4971

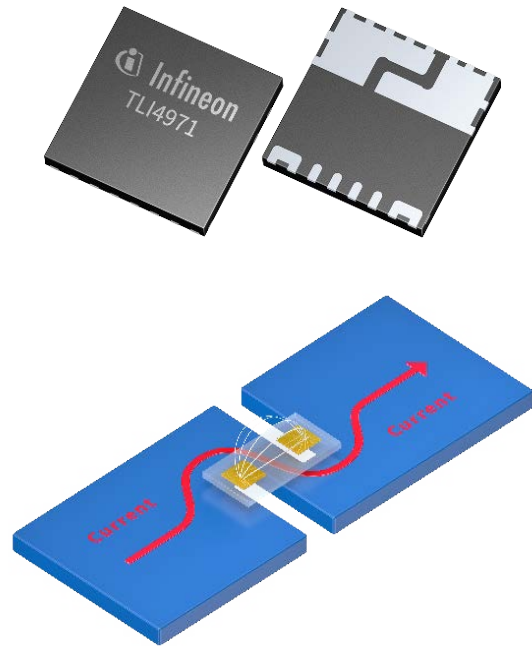
High-precision coreless sensors for industrial application

Features

- Integrated current rail with typical 220 $\mu\Omega$ insertion resistance enables ultralow power loss
- Small form factor, 8 × 8 mm SMD, for easy integration and board area saving
- Highly accurate, scalable, DC and AC current sensing
- Bandwidth of 240 kHz enables wide range of applications
- Very low sensitivity error over temperature (< 2.0%)
- Excellent stability of offset over temperature and lifetime
- Galvanic functional isolation up to 1150 V peak V_{IORM} , partial discharge 3500 V_{RMS} , 4 mm clearance and creepage
- Differential sensor principle ensures superior magnetic stray field suppression
- Two independent fast Over-Current Detection (OCD) pins with configurable thresholds enable protection mechanisms for power circuitry (typical 0.7 μs)
- Pre-calibrated sensor

Applications

- Energy storage systems
- Electrical drives (up to 975 V_{pk})
- Photovoltaic inverter
- General purpose & GaN-based inverters
- Chargers
- Power supplies



TLE4971

High-precision coreless current sensor for automotive and industrial applications

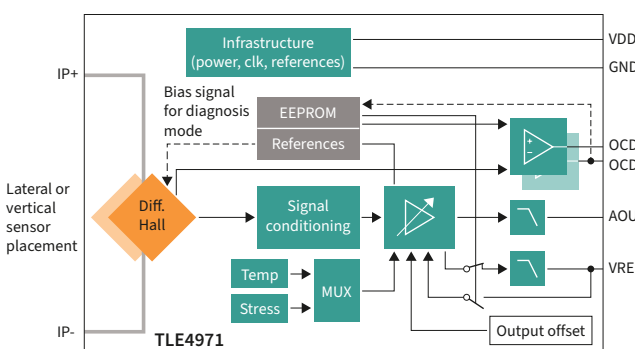
The Infineon TLE4971 is a high-precision current sensor for bi-directional AC and DC measurements. The device has an analog interface and two fast over-current detection outputs that support the power circuitry's protection. Galvanic isolation is provided due to magnetic sensing principle.

Infineon's well-established and robust monolithic Hall technology enables accurate and highly linear measurement of currents with a full scale up to 120 A. Negative effects, like saturation and hysteresis, commonly known from core-based sensor techniques, are not present in the Infineon open loop, coreless sensors principle. The smart current rail design (double U-shape) combined with a differential signal sensing makes the current sensor robust against stray fields. The sensor is shipped as a fully calibrated product without requiring any customer end-of-line calibration. It comes in a small 8 × 8 mm TISON-8 leadless package, which allows standard SMD assembly. The sensor can be reprogrammed for many parameters enabling the customer to achieve maximal adaption for his application requirements, such as industrial drives, xEV auxiliary drives, PV inverter, DC fast charger and On-Board-Charger (OBC).

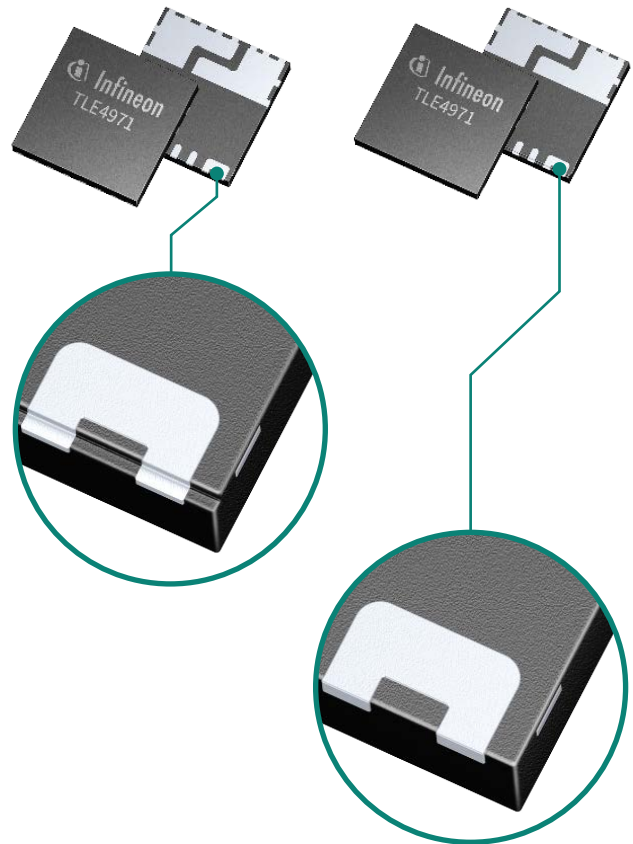
Features and benefits

- Measurement up to 70 A_{RMS} at 690 V_{RMS}
- Typical error at 25°C < 2%
- Current rail resistance at 220 μΩ and inductance < 1 nH specified typ
- Analog output signal (with typ. 210 kHz) bandwidth
- Fast (<0.7 μs) overcurrent detection up to 2 × I_{FSR}
- AEC-Q100 Grade 1 qualified (125°C)
- Ultra-low power loss due to minimal resistance of current rail

Block diagram



Difference between TISON-8-6 and TISON-8-5



- Reliable current measurement over lifetime (no re-calibration)
- Functional isolation for high-voltage application
- Easy and compact package allows high-power density design
- Pre-programmed variants for 25, 50, 75 and 120 A
- High accuracy, low noise analog output

The integrated primary conductor (current rail) with very low insertion resistance and inductance minimizes the power loss and enables miniaturization of the sensing circuit. The analog output (AOUT) can be configured in single-ended, semi-differential, and fully-differential mode together with the voltage reference pin (VREF)

Two separate overcurrent pins (OCD1/OCD2) provide a fast output signal in case the current exceeds a pre-set threshold.

TLE4972 / TLE4973

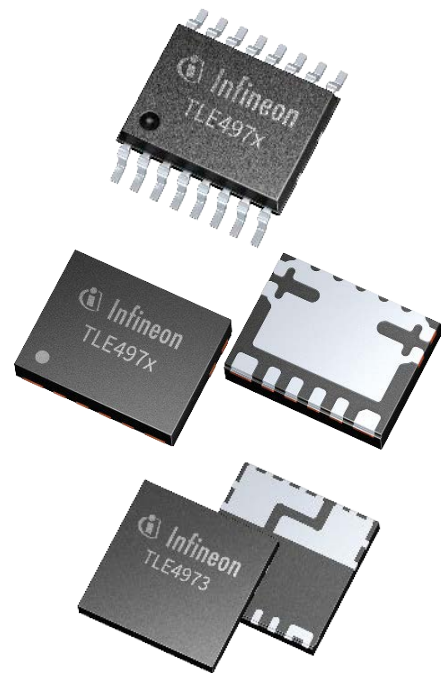
High-precision coreless current sensors for automotive and industrial applications

The Infineon TLE4972 product family of coreless magnetic current sensors specifically addresses requirements for current sensing in automotive applications. The well-established and robust Hall technology enables accurate and highly linear current measurements of the magnetic field induced by the current. With its compact design and diagnosis modes, the TLE4972 is ideal for xEV applications like traction inverters used in hybrid and battery-driven vehicles, as well as for battery main switches.

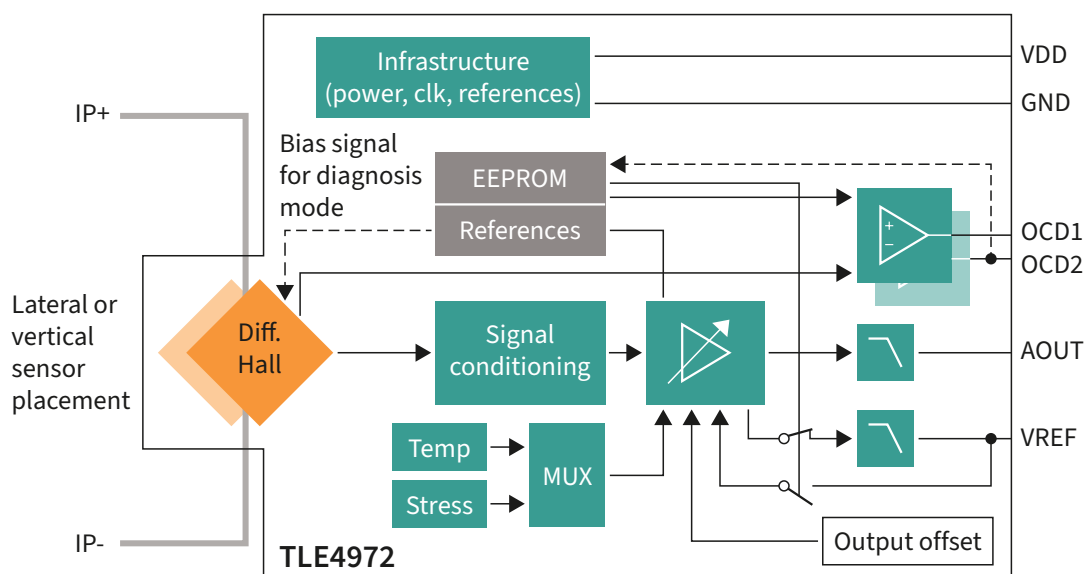
Features and benefits

- Hall based coreless magnetic current sensor
- AC and DC sensing
- Two dedicated pins for overcurrent detection
- Scalable sensitivity
- ISO 26262-compliant
- ASIL B as SEooC
- Typical bandwidth of 210 kHz
- High accuracy up to 2 kA
- Very low error over temperature and lifetime
- Protection against overcurrent events for fast switching technologies, e.g. SiC
- No saturation or hysteresis effects
- Very low power losses through sensing structure
- Ideal for platform designs
- Fast reaction time of analog sensor output
- Simplified functional safety assessment

Infineon expanded the sensor portfolio with a new family of 5 V current sensors TLE4973. The new sensors will be available in three different packages to cover a wide range of applications in the automotive and industrial market. Target applications include traction inverter for xEV, auxiliary drives, PV inverter and on-board-charger (OBC).



Block diagram



Current sensors – overview

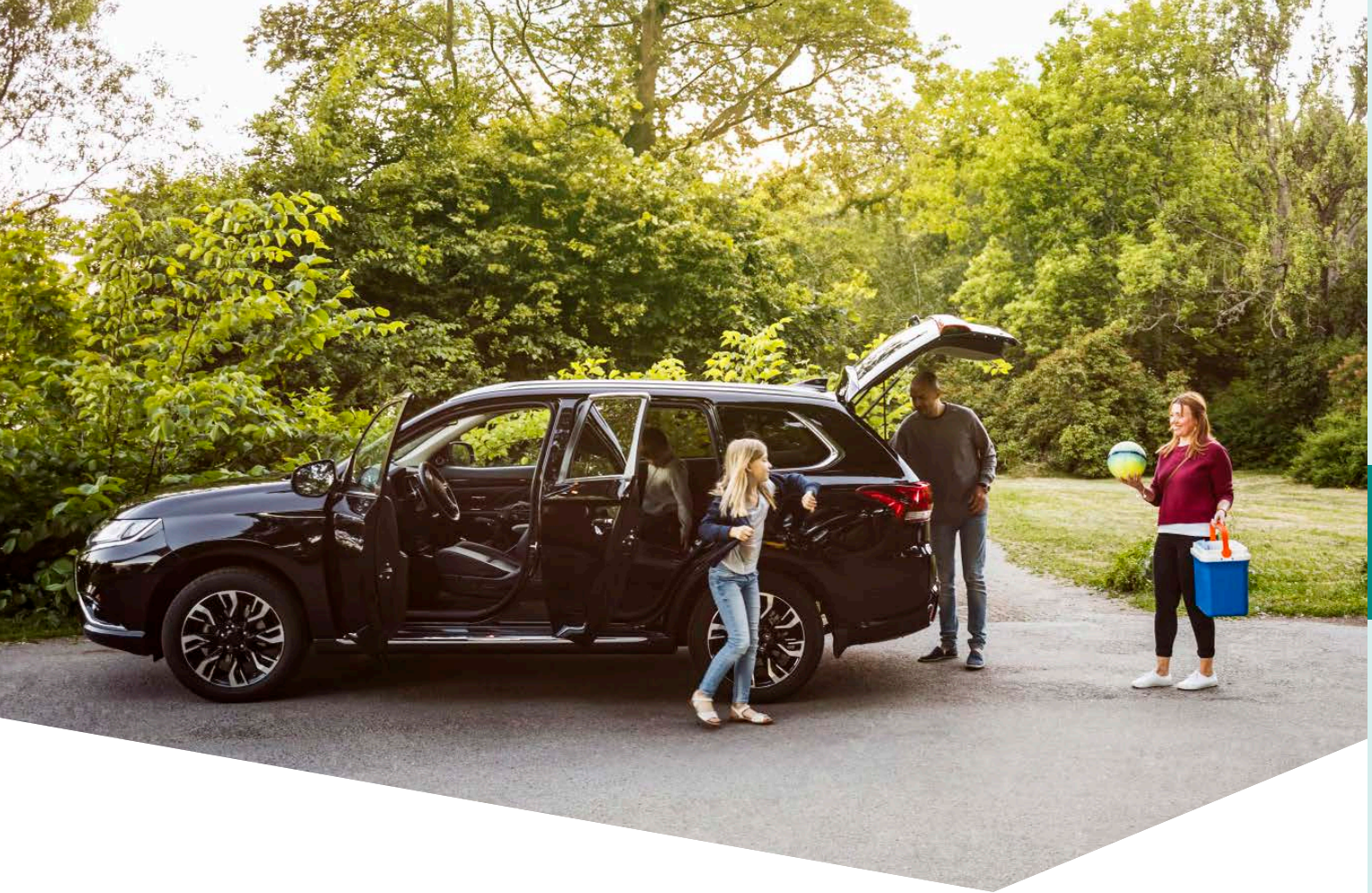
Product	Current range [A]	Bandwidth typ. [kHz]	Sensitivity [mV/A]	Accuracy [%]	Output noise density [$\mu\text{A}/\sqrt{\text{Hz}}$]	Classification	Industrial	Automotive	Supply [V]	Current Rail	Package
TLI4971 family											
TLI4971-A025T5-E0001	25	240	48	< 2	350	IEC 62368-1	✓	–	3.3	Internal	TISON-8-5
TLI4971-A050T5-E0001	50	240	24	< 2	350		✓	–	3.3	Internal	TISON-8-5
TLI4971-A075T5-E0001	75	240	16	< 2	350		✓	–	3.3	Internal	TISON-8-5
TLI4971-A120T5-E0001	120	240	10	< 2	350		✓	–	3.3	Internal	TISON-8-5
TLI4971-A025T5-U-E0001	25	240	48	< 2	350	UL1577/ IEC 62368-1	✓	–	3.3	Internal	TISON-8-5
TLI4971-A050T5-U-E0001	50	240	24	< 2	350		✓	–	3.3	Internal	TISON-8-5
TLI4971-A075T5-U-E0001	75	240	16	< 2	350		✓	–	3.3	Internal	TISON-8-5
TLI4971-A120T5-U-E0001	120	240	10	< 2	350		✓	–	3.3	Internal	TISON-8-5
TLE4971 family											
TLE4971-A025N5-E0001	25	210	48	< 2	260	AEC-Q100	✓	✓	3.3	Internal	TISON-8-5
TLE4971-A050N5-E0001	50	210	24	< 2	260		✓	✓	3.3	Internal	TISON-8-5
TLE4971-A075N5-E0001	75	210	16	< 2	260		✓	✓	3.3	Internal	TISON-8-5
TLE4971-A120N5-E0001	120	210	10	< 2	260		✓	✓	3.3	Internal	TISON-8-5
TLE4971-A025N5-U-E0001	25	210	48	< 2	260	AEC-Q100/ UL 1577	✓	✓	3.3	Internal	TISON-8-5
TLE4971-A050N5-U-E0001	50	210	24	< 2	260		✓	✓	3.3	Internal	TISON-8-5
TLE4971-A075N5-U-E0001	75	210	16	< 2	260		✓	✓	3.3	Internal	TISON-8-5
TLE4971-A120N5-U-E0001	120	210	10	< 2	260		✓	✓	3.3	Internal	TISON-8-5
TLE4971-A025T5-E0001	25	210	48	< 2	260	AEC-Q100/ ISO 26262-compliant	✓	✓	3.3	Internal	TISON-8-6
TLE4971-A050T5-E0001	50	210	24	< 2	260		✓	✓	3.3	Internal	TISON-8-6
TLE4971-A075T5-E0001	75	210	16	< 2	260		✓	✓	3.3	Internal	TISON-8-6
TLE4971-A120T5-E0001	120	210	10	< 2	260		✓	✓	3.3	Internal	TISON-8-6
TLE4971-A025T5-U-E0001	25	210	48	< 2	260	AEC-Q100/ ISO 26262-compliant/ UL 1577	✓	✓	3.3	Internal	TISON-8-6
TLE4971-A050T5-U-E0001	50	210	24	< 2	260		✓	✓	3.3	Internal	TISON-8-6
TLE4971-A075T5-U-E0001	75	210	16	< 2	260		✓	✓	3.3	Internal	TISON-8-6
TLE4971-A120T5-U-E0001	120	210	10	< 2	260		✓	✓	3.3	Internal	TISON-8-6
TLE4972 family											
TLE4972-AE35D5	31 [mT]	210	39 ¹⁾ [mV/mT]	1	90 [nT/ $\sqrt{\text{Hz}}$]	AEC-Q100/ ISO 26262-compliant	✓	✓	3.3	external	TDSO-16
TLE4972-AE35S5	31 [mT]	210	39 ¹⁾ [mV/mT]	1	90 [nT/ $\sqrt{\text{Hz}}$]		✓	✓	3.3	external	VSON-6

1) Can be reprogrammed by customer

Current sensors – overview

Product	Current range [A]	Bandwidth typ. [kHz]	Sensitivity [mV/A]	Accuracy [%]	Output noise density [$\mu\text{A}/\sqrt{\text{Hz}}$]	Classification	Industrial	Auto-motive	Supply [V]	Current Rail	Package
TLE4973 family											
TLE4973-A025T5-S0001	27.5	210	65.5	< 2	290	ISO 26262-compliant/ AEC-Q100	✓	✓	5.0	Internal	TISON-8-6
TLE4973-A050T5-S0001	55	210	32.8	< 2	290		✓	✓	5.0	Internal	TISON-8-6
TLE4973-A075T5-S0001	82.5	210	21.8	< 2	290		✓	✓	5.0	Internal	TISON-8-6
TLE4973-A120T5-S0001	132	210	13.7	< 2	290		✓	✓	5.0	Internal	TISON-8-6
TLE4973-R025T5-S0001	27.5	210	65.5	< 2	290		✓	✓	5.0	Internal	TISON-8-6
TLE4973-R050T5-S0001	55	210	32.8	< 2	290		✓	✓	5.0	Internal	TISON-8-6
TLE4973-R075T5-S0001	82.5	210	21.8	< 2	290		✓	✓	5.0	Internal	TISON-8-6
TLE4973-R120T5-S0001	132	210	13.7	< 2	290		✓	✓	5.0	Internal	TISON-8-6
TLE4973-R025T5-S0010	27.5	210	65.5	< 2	290		✓	✓	5.0	Internal	TISON-8-6
TLE4973-R050T5-S0010	55	210	32.8	< 2	290		✓	✓	5.0	Internal	TISON-8-6
TLE4973-R075T5-S0010	82.5	210	21.8	< 2	290		✓	✓	5.0	Internal	TISON-8-6
TLE4973-R120T5-S0010	132	210	13.7	< 2	290	✓	✓	5.0	Internal	TISON-8-6	
TLE4973-R025T5-U-S0010	27.5	210	65.5	< 2	290	ISO 26262-compliant/ AEC-Q100/ UL 1577	✓	✓	5.0	Internal	TISON-8-6
TLE4973-R050T5-U-S0010	55	210	32.8	< 2	290		✓	✓	5.0	Internal	TISON-8-6
TLE4973-R075T5-U-S0010	82.5	210	21.8	< 2	290		✓	✓	5.0	Internal	TISON-8-6
TLE4973-R120T5-U-S0010	132	210	13.7	< 2	290		✓	✓	5.0	Internal	TISON-8-6
TLE4973-AE35D5-S0001	34 [mT]	210	53 ¹⁾ [mV/mT]	1	70 [nT/ $\sqrt{\text{Hz}}$]	ISO 26262-compliant/ AEC-Q100	✓	✓	5.0	external	TDSO-16
TLE4973-RE35D5-S0001	34 [mT]	210	53 ¹⁾ [mV/mT]	1	70 [nT/ $\sqrt{\text{Hz}}$]		✓	✓	5.0	external	TDSO-16
TLE4973-RE35D5-S0010	34 [mT]	210	53 ¹⁾ [mV/mT]	1	70 [nT/ $\sqrt{\text{Hz}}$]		✓	✓	5.0	external	TDSO-16
TLE4973-AE35S5-S0001	34 [mT]	210	53 ¹⁾ [mV/mT]	1	70 [nT/ $\sqrt{\text{Hz}}$]		✓	✓	5.0	external	VSON-6
TLE4973-RE35S5-S0001	34 [mT]	210	53 ¹⁾ [mV/mT]	1	70 [nT/ $\sqrt{\text{Hz}}$]		✓	✓	5.0	external	VSON-6
TLE4973-RE35S5-S0010	34 [mT]	210	53 ¹⁾ [mV/mT]	1	70 [nT/ $\sqrt{\text{Hz}}$]		✓	✓	5.0	external	VSON-6

1) Can be reprogrammed by customer



Magnetic sensors

Exceptionally precise magnetic sensors comprising industry-leading switches, linear, angle, 3D and speed sensors

Infineon XENSIV™ sensors are exceptionally precise thanks to an industry-leading magnetic technology portfolio. Our benchmark and innovative magnetic sensor portfolio is the perfect fit for numerous customer applications in automotive, industrial and consumer markets. We offer all magnetic sensor technologies with in-house production, thus our customers can choose between Hall sensors, AMR (Anisotropic Magneto Resistive), GMR (Giant Magneto Resistive) or TMR (Tunnel Magneto Resistive) sensors in order to find their best-fit solution for their application.

Generally, magnetic sensors measure the strength and/or direction of an applied magnetic field which is generated by e.g. ferromagnetic materials and magnets, inductive coils like in motors, etc. The information on the measured field is processed within the sensor and converted into strength, position, speed, angular and/or direction information. The processed sensor information is transmitted to the application via specific analog or digital interfaces. A wide range of sensors is equipped with additional safety and diagnostic features, and ISO 26262-compliant developed.

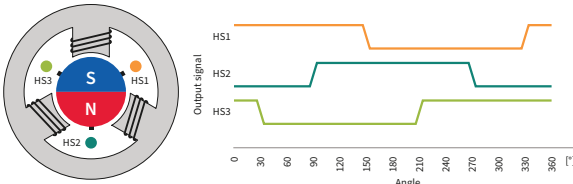
Our portfolio includes a broad range of ISO 26262-compliant products meeting safety requirements as SEoC (Safety Element out of Context) up to the highest safety level of ASIL D, which are well perceived within the market and used in a wide range of automotive and industrial safety applications.

Magnetic switches

Broadest energy saving portfolio of high precision magnetic switches for automotive, industrial and consumer applications TLE/TLI/TLV4961, TLE/TLI/TLV4964, TLE/TLI/TLV4968 Energy-efficient magnetic switch family for up to 32 V

The TLE/TLI/TLV496x-xM/L family of magnetic switches saves energy and enables designers to create precise and compact systems. With an operational current consumption of just 1.6 mA, TLE/TLI/TLV496x-xM/L products can cut energy consumption by up to 50 percent, compared with similar competitor products. Thanks to its small magnetic hysteresis, the family paves the way for precise switching points in systems. The integrated temperature profile compensates magnetic drifts and enables stable performance over temperature and lifetime.

TLE/TLI/TLV496x-xM products come in the smallest SOT23 package, thus reducing height by 10 percent compared with on the market predecessor products. The sensors also feature an integrated functionality test for better system control.



Features

- Current consumption of just 1.6 mA
- 3 to 32 V supply voltage range (over voltage up to 42 V)
- 7 kV ESD protection (HBM)
- Overtemperature and overcurrent protection
- Temperature compensation
- Smallest SOT23 package on the market
- Dedicated products for industrial applications (TLI496x) and consumer (TLV496x)
- AEC-Q100 qualified

Applications

- Window lifter
- Power closing
- Gear stick
- Seat belt
- BLDC commutation
(e.g. wiper, seat belt pretensioner, pump, seating)
- Service robots
- Power tools
- White goods

Product	Type	Operating point B_{OP} [mT]	Release point B_{RP} [mT]	Hysteresis ΔB_{HY} [mT]	Automotive	Industrial	Consumer	Package
TLE4961-1M/L	Latch	2.0	-2.0	4.0	✓	✓	✓	SOT23/SSO-3-2
TLE4961-2M	Latch	5.0	-5.0	10	✓	✓	✓	SOT23
TLE4961-3M/L	Latch	7.5	-7.5	15	✓	✓	✓	SOT23/SSO-3-2
TLE4961-4M	Latch	10.0	-10.0	20	✓	✓	✓	SOT23
TLE4961-5M	Latch	15.0	-15.0	30	✓	✓	✓	SOT23
TLE4964-1M	Switch	18.0	12.5	5.5	✓	✓	✓	SOT23
TLE4964-2M	Switch	28.0	22.5	5.5	✓	✓	✓	SOT23
TLE4964-3M	Switch	12.5	9.5	3.0	✓	✓	✓	SOT23
TLE4964-4M	Switch	10.0	8.5	1.5	✓	✓	✓	SOT23
TLE4964-6M	Switch	3.5	2.5	1.0	✓	✓	✓	SOT23
TLE4964-5M	Switch	7.5	5.0	2.5	✓	✓	✓	SOT23
TLE4968-1M/L	Bipolar	1.0	-1.0	2.0	✓	✓	✓	SOT23/SSO-3-2
TLI4961-1M	Latch	2.0	-2.0	4.0	-	✓	✓	SOT23/SSO-3-2
TLV4961-1M	Latch	2.0	-2.0	4.0	-	-	✓	SOT23
TLV4961-3M	Latch	7.5	-7.0	15.0	-	-	✓	SOT23
TLV4964-1M	Switch	18.0	12.5	5.5	-	-	✓	SOT23
TLV4964-2M	Switch	28.0	22.5	5.5	-	-	✓	SOT23

TLE/TLI4963, TLE/TLI4965

5 V high-precision automotive/industrial Hall-effect sensor

TLE/TLI496x-xM are integrated Hall-effect sensors specially designed for highly accurate applications. The sensors provide an easy-to-use and cost-effective solution for position sensing applications, requiring high temperature stability of the magnetic threshold.

Target applications for TLE/TLI496x-xM are all low-power applications requesting a precision magnetic latch or switch with a broad operating temperature range.

Features

- 3.0 to 5.5 V operating supply voltage
- Low current consumption 1.4 mA
- ESD protection 4 kV HBM
- Active error compensation (chopped)
- High stability of magnetic thresholds
- Low jitter (typ. 0.35 μ s)
- Operating temperature range:
 - from -40 to +170°C (TLE496x-xM)
 - from -40 to +125°C (TLI496x-xM)
- Small SMD package SOT23
- TLE: AEC-Q100 qualified
- TLI: JEDEC qualified

By offering an excellent magnetic behavior Infineon's switches are ideally suited for:

- Index counting application with a pole wheel
- Rotor position detection (BLDC motors)
- Open/close detection



Product	Type	Operating point B_{OP} [mT]	Release point B_{RP} [mT]	Hysteresis ΔB_{HY} [mT]	Automotive	Industrial	Consumer	Package
TLE4963-1M	Latch	2.0	-2.0	4.0	✓	✓	✓	SOT23
TLE4963-2M	Latch	5.0	-5.0	10.0	✓	✓	✓	SOT23
TLE4965-5M	Unipolar switch	7.5	5.0	2.5	✓	✓	✓	SOT23
TLI4963-1M	Latch	2.0	-2.0	4.0	–	✓	✓	SOT23
TLI4963-2M	Latch	5.0	-5.0	10.0	–	✓	✓	SOT23
TLI4965-5M	Unipolar switch	7.5	5.0	2.5	–	✓	✓	SOT23

TLV496x-xTA / TLV496x-xTB

Precise Hall-effect sensor for consumer applications in leaded package

The TLV496x-xTA/B Hall-effect sensor family comprises a line of magnetic switches for contactless position sensing. The sensors are specially designed to provide

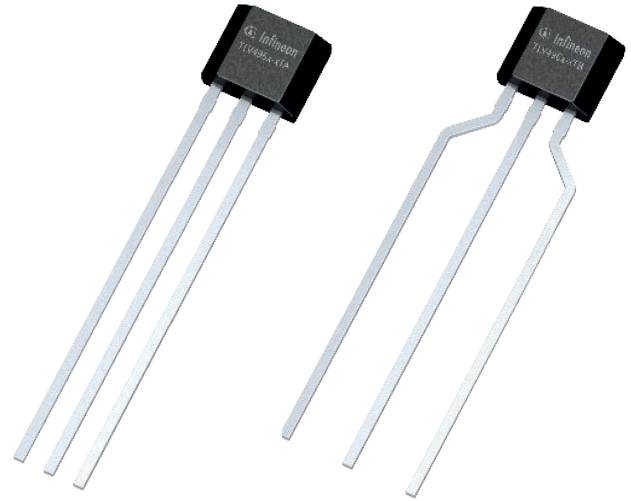
an easy-to-use and cost-effective solution for position sensing applications.

Features

- 3.0 to 26 V operating supply voltage
- Low current consumption 1.6 mA
- ESD protection 4 kV HBM
- Operating temperature range from -40 to +125 °C
- Leaded package TO92S

Applications

- BLDC motor commutation for consumer devices (e.g. e-bikes, fans, aircons)
- Position detection e.g. flaps and control buttons



Product	Type	Operating point B_{OP} [mT]	Release point B_{RP} [mT]	Hysteresis ΔB_{HY} [mT]	Consumer	Package
TLV4961-1TA	Latch	2.0	-2.0	4.0	✓	TO92S-3-1
TLV4961-1TB	Latch	2.0	-2.0	4.0	✓	TO92S-3-2
TLV4961-3TA	Latch	7.5	-7.5	15.0	✓	TO92S-3-1
TLV4961-3TB	Latch	7.5	-7.5	15.0	✓	TO92S-3-2
TLV4964-4TA	Unipolar switch	10.0	8.5	1.5	✓	TO92S-3-1
TLV4964-4TB	Unipolar switch	10.0	8.5	1.5	✓	TO92S-3-2
TLV4964-5TA	Unipolar switch	7.5	5.0	2.5	✓	TO92S-3-1
TLV4964-5TB	Unipolar switch	7.5	5.0	2.5	✓	TO92S-3-2
TLV4968-1TA	Bipolar switch	1.0	-1.0	2.0	✓	TO92S-3-1
TLV4968-1TB	Bipolar switch	1.0	-1.0	2.0	✓	TO92S-3-2



TLx4966 xG family Two-in-one double Hall-effect sensor

Our XENSIV™ TLx4966 xG family features two integrated, calibrated sensor elements for detecting direction and counting indexes in one device. This two-in-one feature eliminates the need for a second sensor, which in turn cuts engineering and production costs. Using just one sensor ensures perfect alignment of the sensor elements raising system quality and reliability.

Features

- Two Hall probes in one package
- Excellent matching between the two Hall probes
- Hall plate distance of 1.45 mm
- Outstanding quality
- Information on direction and speed
- TSOP6 package
- AEC-Q100 qualified

Applications

- Window lifter
- Sunroof
- Automatic tailgate
- Automated doors
- Sun blinds

TLE4966V-1G

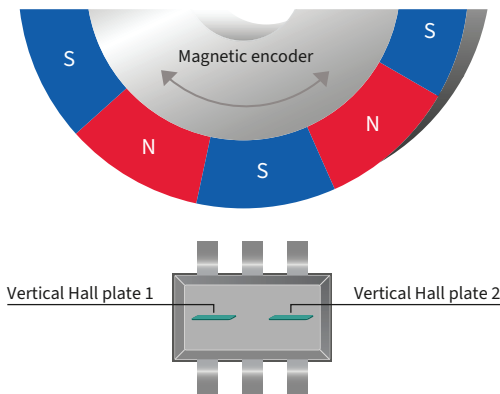
Vertical dual-Hall switch

The Infineon vertical double Hall-effect switch TLE4966V-1G is a further development of the TLX4966-xG family. Completely new is the vertical orientation of the Hall plates resulting into in-plane field sensitivity which enables entirely new application layouts. Designed in a new technology, this device offers high voltage capabilities with very small

current consumption. The product can be operated from unregulated power supplies, which offers our customers unique freedom of design for their system. This product is AEC-Q100 certified and enables our customers to build systems for the highest automotive quality requirements.

Features

- Saves space
- Easy mounting of sensor and PCB board
- Allows increased mounting flexibility
- Enables new, compact system designs



Product	Type	Output	Operating point B_{OP} [mT]	Release point B_{RP} [mT]	Hysteresis ΔB_{HY} [mT]	Automotive	Industrial	Consumer	Package
TLE4966G	Double Hall, speed and direction output	Speed and direction	7.5	-7.5	15	✓	✓	✓	TSOP6/SSO-4-1
TLE4966L	Double Hall, speed and direction output	Speed and direction	7.5	-7.5	15	✓	✓	✓	TSOP6/SSO-4-1
TLE4966-2G	Double Hall, two independent outputs	2 x speed	7.5	-7.5	15	✓	✓	✓	TSOP6
TLE4966-3G	Double Hall, speed and direction output	Speed and direction	2.5	-2.5	5.0	✓	✓	✓	TSOP6
TLE4966V-1G	Vertical double Hall, speed and direction output	Speed and direction	2.5	-2.5	5.0	✓	✓	✓	TSOP6
TLI4966G	Double Hall, speed and direction output	Speed and direction	7.5	-7.5	15	–	✓	✓	TSOP6

TLE49x6 / TLI49x6 / TLV49x6 family

High-precision magnetic switches

The TLE49x6, TLI49x6, and the TLV49x6 family comprises high-precision, unipolar Hall-effect switches and latches for different magnetic sensitivities.

Features

- Broad, successful family concept
- Best in class quality
- Chopped Hall system for high sensitivity
- High jitter performance
- SMD and leaded packages
- Open collector or current interface
- Temperature compensation
- Up to 18 V supply
- Dedicated products for industrial (TLI49x6) and consumer applications (TLV49x6)
- AEC-Q100 qualified (TLE products)

TLE/TLI/TLV49x6 products have proven success in many automotive, industrial and consumer applications. The family includes two-wire sensors with a current interface.

Applications

- Power closing
- Gear stick
- Seat belt
- HVAC flap
- BLDC commutation
- 2-wheeler application

Product	Type	Operating point B_{OP} [mT]	Release point B_{RP} [mT]	Hysteresis ΔB_{HY} [mT]	Automotive	Industrial	Consumer	Package
TLE4906K	Unipolar switch	10.0	8.5	1.5	✓	✓	✓	SC59/SSO-3-2
TLE4906L	Unipolar switch	10.0	8.5	1.5	✓	✓	✓	SC59/SSO-3-2
TLE4906-2K	Unipolar switch	18.0	12.5	5.5	✓	✓	✓	SC59
TLE4906-3K	Unipolar switch	28.0	22.5	5.5	✓	✓	✓	SC59
TLE4946K	Latch	14.0	-14	28	✓	✓	✓	SC59
TLE4946-1L	Latch	15.0	-15	30	✓	✓	✓	SSO-3-2
TLE4946-2K	Latch	2.0	-2.0	4.0	✓	✓	✓	SC59/SSO-3-2
TLE4946-2L	Latch	2.0	-2.0	4.0	✓	✓	✓	SC59/SSO-3-2
TLE4976-1K	Unipolar switch/ Current interface	9.25	7.25	2.0	✓	✓	✓	SC59
TLE4976-2K	Unipolar switch/ Current interface	4.5	2.7	1.8	✓	✓	✓	SC59
TLV4976-2K	Unipolar switch/ Current interface	4.5	2.7	1.8	-	-	✓	SC59



3D magnetic sensors

Infineon's 3D magnetic sensors (TLx493D-xxBx) combine high-accuracy magnetic field measurements with an extremely compact footprint and exceptionally low power consumption (typ. 7 nA). Our sensors open up a lot of exciting new use cases including innovative human-machine interfaces in the form of industrial joysticks, ergonomic pushbuttons on domestic appliances and highly precise position control in robotics.

XENSIV™ TLE493D-P2B6 is our latest magnetic 3D sensor enabled by new and improved accuracy. It is the best product for high performance applications with respect to pricing and package size.

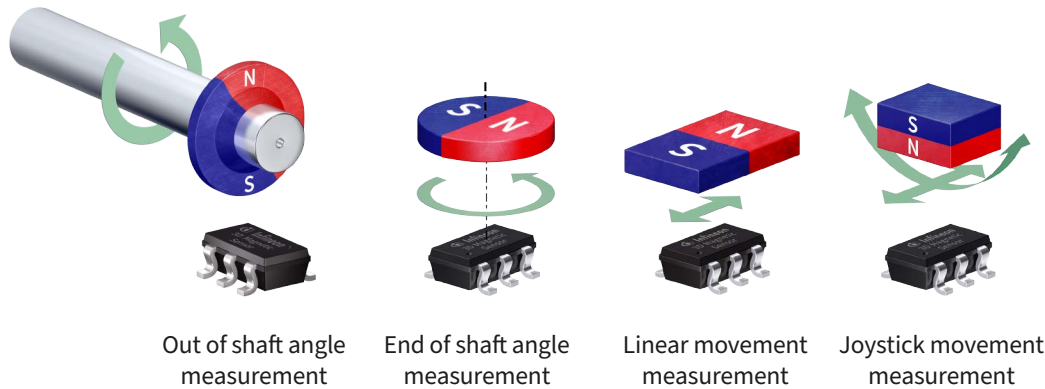
The TLE493D-P2B6 has an extremely low current and wake-up function in a small package. Also the sensor provides options for configuration to fit best to customer requirements (e.g. data communication, definition of measurements, etc.). The safety manual supports functional safety applications. The configurability of the sensor is used in application platforms to adapt to end customer wishes. TLE493D-P2B6 is available in 4 different address variants ending with A0, A1, A2 or A3. It's possible to connect up to 4 sensors to one I²C bus.

3D magnetic sensors

For consumer and industrial markets

The TLx493D-xxBx sensor realizes accurate three-dimensional sensing with extremely low power consumption in a small package. Capable of detecting the magnetic field in the x, y, and z-direction, the sensor is ideally suited for the measurement of linear, rotation, or 3-dimensional movements. Thanks to its small package

and low power consumption, the TLx493D-xxBx can be used in new applications, replacing potentiometer and optical solutions. Featuring contactless position sensing and high-temperature stability of the magnetic measurement, the sensor allows systems to get smaller, more accurate, and more robust.



Out of shaft angle measurement

End of shaft angle measurement

Linear movement measurement

Joystick movement measurement

Features

- 3D magnetic sensing
- Integrated temperature sensing
- Low current consumption
 - 7 nA in power-down mode
- 2.8 to 3.5 V operating supply voltage
- Digital communication via a 2-wire standard I²C interface
- Bx, By and Bz linear field measurement up to ±160 mT
- JESD47 qualified
- 12-bit data resolution for each measurement direction
- Various resolution options from 32 to 130 μT/LSB₁₂
- Operating temperature range from -40 to +125°C

Product	Temperature range	Qualification	Linear magnetic range	Resolution	I _{DD}	Update rate XYZ measurement	Package	Ordering code
TLI493D-A2B6	-40 ... 105°C	JESD47	±100 mT ±160 mT	7.7 or 15.4 LSB ₁₂ /mT	7 nA – 3.4 mA	up to 8.4 kHz	TSOP6	SP001689844
TLI493D-W2BW A0 TLI493D-W2BW A1 TLI493D-W2BW A2 TLI493D-W2BW A3	-40 ... 125°C	JESD47	±50, ±100 or ±160 mT	7.7, 15.4 or 30.8 LSB ₁₂ /mT	7 nA – 3.4 mA	up to 11.6 kHz	WFWLB-5-2	SP005409964 SP005409966 SP005409968 SP005409970
TLV493D-A1B6	-40 ... 125°C	JESD47	±130 mT (typ)	10.2 LSB ₁₂ /mT	7 nA – 3.7 mA	up to 3.3 kHz	TSOP6	SP001286056
TLV493D-A2BW	-20 ... 85°C	JESD47	±50, ±100 or ±160 mT	7.7, 15.4 or 30.8 LSB ₁₂ /mT	7 nA – 3.4 mA	up to 11.6 kHz	WFWLB-5-2	SP005542151

New features

- Advanced operation modes to provided a high flexibility
- Short mode range setting, focusing on the half of the magnetic range, ensuring higher accuracy
- Higher update frequency allows for an application field that requires faster update speed
- Angular mode (for x and y measurement only)

Applications

- Anti tempering protection in smart meters
- Joysticks
- CCTV-control, game consoles
- Control elements e.g. white goods multifunction knobs
- Ergonomic push- and control buttons on domestic appliances and power tools
- Position control in robotics
- Smart lock position detection

3D magnetic sensors

For automotive applications

Infineon's TLE493D-x2B6 enables automotive control element applications within the passenger compartment or under the hood with a temperature range of -40 to +125°C, with linear magnetic range requirements up to ±160 mT.

Features

- 3D magnetic sensing
- Integrated temperature sensing
- 2.8 to 3.5 V operating supply voltage
- Low current consumption
 - 7 nA in power-down mode
 - Up to 10 power modes
- Digital output via a 2-wire standard I²C interface
- Bx, By and Bz linear field measurement ±160 mT
- AEC-Q100 qualified
- 12-bit data resolution for each measurement direction
- Various resolution options from 65 to 130 μT/LSB₁₂
- Operating temperature range from -40 to +125°C



Applications

- Control elements for infotainment/navigation systems, air-conditions, multifunctional steering wheels, seat controls
- Top column modules e.g. direction indicator, wiper control
- Gear stick position sensing
- Multi-function knobs
- Pedal/valve position sensing

Product	Temperature range	Qualification	Linear magnetic range	Resolution	I _{DD}	Update rate XYZ measurement	Wake-up	Package	Ordering code
TLE493D-A2B6	-40 ... 125°C	AEC-Q100	±160 mT ±100 mT	130 μT/LSB ₁₂ 65 μT/LSB ₁₂ ¹⁾	7 nA – 3.4 mA	Up to 8.4 kHz	No	TSOP6	SP001689848
TLE493D-W2B6 A0 TLE493D-W2B6 A1 TLE493D-W2B6 A2 TLE493D-W2B6 A3	-40 ... 125°C	AEC-Q100 ISO 26262-ready	±160 mT ±100 mT	130 μT/LSB ₁₂ 65 μT/LSB ₁₂ ¹⁾	7 nA – 3.4 mA	Up to 8.4 kHz	Yes	TSOP6	SP001655334 SP001655340 SP001655344 SP001655348
TLE493D-P2B6 A0 TLE493D-P2B6 A1 TLE493D-P2B6 A2 TLE493D-P2B6 A3	-40 ... 125°C	AEC-Q100/ ISO 26262-ready	±160 mT ±100 mT	130 μT/LSB ₁₂ 65 μT/LSB ₁₂ ¹⁾	7 nA – 3.4 mA	Up to 11.6 kHz	Yes	TSOP6	SP005557415 SP005557413 SP005557411 SP005557408

1) Short range mode

The XENSIV™ sensor TLE493D-A2B6 features include a sensor address read-back feature for additional communication verification, a short range mode focusing to half of the magnetic range, ensuring higher accuracy, and an angular mode (for x and y measurement only).

With the TLE493D-W2B6/ P2B6 A0-A3, a 3D sensor family with an enhanced dynamic wake-up feature was developed. Four pre-programmed address options (A0-A3) are available, enabling a fast start-up initialization when used in I²C bus configurations.

Our sensors include enhanced test options, and safety documentation is available to enable the usage of this sensor in the context of ASIL B systems.

Compared to the previous products of this family the TLE493D-P2B6 A0-A3 family offers enhance precision in x-, y-, z- sensing direction, while otherwise featuring the same dynamic wake-up features, programmability, and test options like TLE493D-W2B6 A0-A3.



ISO 26262 ready



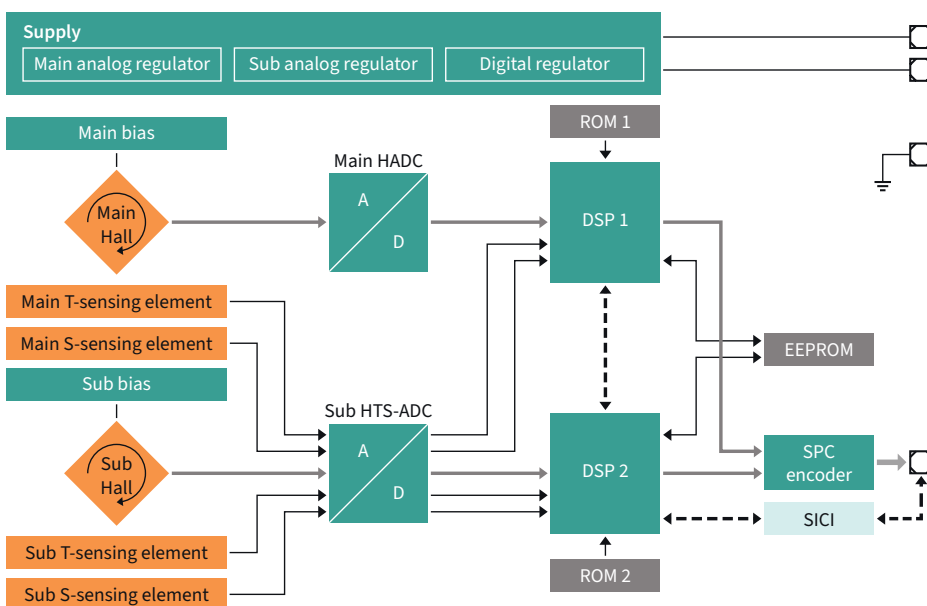
Linear sensors

Programmable dual channel linear Hall sensor with fast SPC interface for high precision applications

Infiniteon's TLE4999C8 is a programmable dual channel linear Hall sensor designed to meet the requirements of safety critical automotive and industrial applications. It is developed in full compliance with ISO 26262 by means of two sensor elements included within one monolithic silicon design. In order to fulfill the state-of-the-art safety requirements on system level and enable ASIL D system developments the sensor cells are designed in a complementary way. Their signals follow two independent analog paths. Each signal path has its own digital signal processing unit to ensure maximum independency (redundancy respectively). The sensor offers a multi-point calibration with up to 9 selectable set points for enhanced linearization of the output signal. For an easy and flexible adaptation to non-linearity of magnetic circuit design, the chip provides 5 different calibration

characteristics. TLE4999C features a digital Short-PWM-Code (SPC) interface, with a bus-capability for up to 4 sensor ICs on a single data output. The communication interface with min. 0.5 μ s unit time guarantees a fast transmission of complete 2 channel data signal in less than 500 μ s. The additionally implemented frame holder circuit enables the synchronicity of multiple sensors (e.g. in combination of angle sensors) via a SPC bus. The chip offers a 12, 14 and 16-Bit resolution of the output signal, ensuring highest flexibility and superior noise performance.

Highest accuracy over a wide temperature range and lifetime is achieved by an integrated digital temperature- and stress-compensation. The chip is available in a thin 8-pin SMD single sensor package.



Features

- Fully ISO 26262-compliant, supports ASIL D systems
- < 2 % sensitivity drift, < 100 μ T offset drift overtemperature and life time
- Integrated digital temperature- and stress-compensation
- Fast digital SPC interface (unit time 0.5–3.0 μ s)
- Multi-point calibration with up to 9 linearization set points

Key benefits

- High diagnostic coverage, ISO 26262-compliance and dual sensor cell integration enable development of fail operational systems
- Multi-point calibration for better fit into various magnetic circuit designs
- Easy system integration due to programmability of several sensor parameters

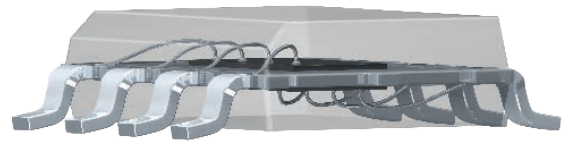
Applications

Automotive safety critical applications

- Electric power steering
- Linear movement position sensing
- Pedal position
- Electric throttle control
- Seat rail adjustment
- Headlight adjustment

Industrial applications

- Small home appliances
- Joystick applications



ISO 26262-ready / compliant dual channel linear sensors

Sales name	Interface	Magnetic linear range [mT]	Sensitivity	Sensitivity drift [%]	Gain	Magnetic offset drift [μ T] ¹⁾	Classification	Ordering code	Package
TLE4997A8D	Analog ratiometric	50, 100, 200	± 60 mV/mT default for 100 mT range, with gain 1.5	± 3	± 4	< ± 400	ISO 26262-ready	SP000902760	TDSO-8
TLE4998P8D	Digital interface PWM	50, 100, 200	± 48 LSB ₁₂ /mT default for 100 mT range, with gain 1.5	± 2	± 4	< ± 400	ISO 26262-ready	SP000902776	TDSO-8
TLE4998S8D	Digital interface SENT	50, 100, 200	± 48 LSB ₁₂ /mT default for 100 mT range, with gain 1.5	± 2	± 4	< ± 400	ISO 26262-ready	SP000902784	TDSO-8
TLE4998C8D	Digital interface SPC	50, 100, 200	± 48 LSB ₁₂ /mT default for 100 mT range, with gain 1.5	± 2	± 4	< ± 400	ISO 26262-ready	SP000902768	TDSO-8
TLE4999I3	Digital interface PSi5	12.5, 25	± 147.5 LSB ₁₃ /mT default for 25 mT range, with gain 1.5	± 2	± 7.59	< ± 100 / < ± 200 ²⁾	ISO 26262-compliant	SP001689862	SSO-3
TLE4999C8 (TLE4999C8-S0001)	Digital interface SPC	25, 50	± 36.875 LSB ₁₂ /mT default for in 50 mT range, with gain 1.0	± 2	± 7.59	< ± 100 / < ± 200 ²⁾	ISO 26262-compliant ASIL D (ASIL C)	SP002662500 (SP005727371)	TDSO-8
TLE4999C4 (TLE4999C4-S0001)	Digital interface SPC	25, 50	± 36.875 LSB ₁₂ /mT default for in 50 mT range, with gain 1.0	± 2	± 7.59	< ± 100 / < ± 200 ²⁾	ISO 26262-compliant ASIL D (ASIL C)	SP003420076 (SP005727375)	SSO-4

1) Maximum drift over temperature and life time

2) Main channel/sub channel



ISO 26262
compliant



ISO 26262
ready

TLE499x family: programmable analog/digital single channel linear Hall sensor family

Infineon's family of TLE499x linear Hall ICs is tailored to the needs of highly accurate angular and linear position detection and current measurement applications. Each product measures the vertical component of a magnetic field and outputs a signal that is directly proportional to the magnetic field. These programmable linear Hall sensors come with different interface options: TLE4997 features ratiometric analog output, while TLE4998P comes with pulse width modulation (PWM), TLE4998S with single edge nibble transmission (SENT), and TLE4998C with short PWM codes (SPC).

Features

- Best-in-class accuracy with low drift of output signal temperature range lifetime (including stress compensation in TLE4998)
- Programmable transfer function (gain, offset), clamping, bandwidth, and temperature characteristics
- AEC-Q100 qualified
- Available in various packages including SSO-3-9 with two integrated capacitors to improve ESD and ESC behavior
- TLE4997, TLE4998 ISO 26262-ready

These high-precision 12-bit resolution linear Hall sensors feature EEPROM memory for flexible programming across a wide range of parameters.

Thanks to digital signal processing based on a 20-bit DSP architecture plus digital temperature compensation, these sensors deliver outstanding temperature stability compared with similar compensation methods. TLE4998 also includes stress compensation to withstand stress effects from the package, such as moisture, thus ensuring best-in-class accuracy over the device's lifetime.

Applications

- Detecting linear and angular position
- Detecting pedal and throttle position
- Steering torque measurement
- Headlight leveling
- High-current sensing
- Seat position and occupant detection
- Suspension control
- Detecting gear stick/lever positions
- Detecting liquid levels in fuel tanks
- Current sensing e.g. for battery management

Product	Programm.	Number of pins	Sensitivity (programmable range)	Magnetic offset	Supply voltage (extended range)	Automotive	Classification	Interface	Package
TLE4997	EEPROM	3/Single die SMD 8	±12.5 to ±300 mV/mT	< ±400 μT	5 V ±10% (7 V)	✓	–	Analog	SSO-3-10 TDSO-8
TLE4998P	EEPROM	3/4/ Single die SMD 8	±0.2 to ±6%/mT	< ±400 μT	5 V ±10% (16 V)	✓	ISO 26262-ready	PWM	SSO-3 SSO-4 SSO-3 (2 capacitors) TDSO-8
TLE4998S	EEPROM	3/4/ Single die SMD 8	±8.2 to ±245 LSB ₁₂ /mT	< ±400 μT	5 V ±10% (16 V)	✓	ISO 26262-ready	SENT	SSO-3 SSO-4 SSO-3 (2 capacitors) TDSO-8
TLE4998C	EEPROM	3/4/ Single die SMD 8	±8.2 to ±245 LSB ₁₂ /mT	< ±400 μT	5 V ±10% (16 V)	✓	ISO 26262-ready	SPC	SSO-3 SSO-4 SSO-3 (2 capacitors) TDSO-8

1) 147.44 LSB₁₃ converts to 294.88 LSB₁₂



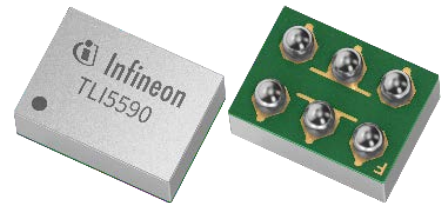
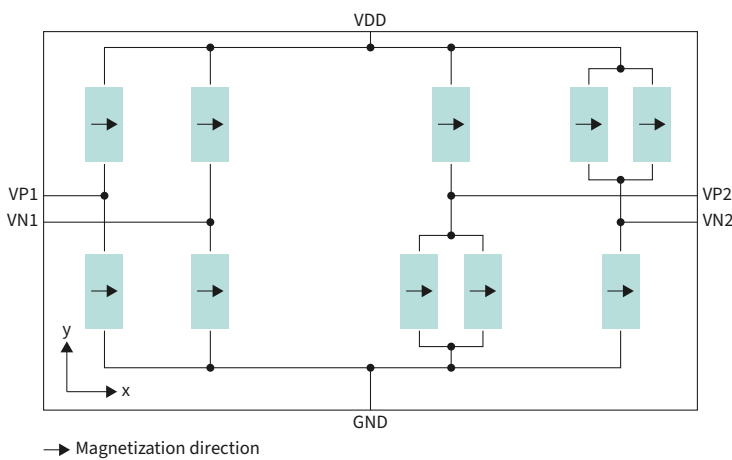
ISO 26262
ready

Linear TMR sensor

For consumer and industrial markets

The TLI5590-A6W is a dual-channel radiometric gradiometer designed for highly precise measurements. It meets the JEDEC JESD47K standard for industrial and consumer use. Its compact, green packaging facilitates miniaturized design and detailed measurements. The device achieves exceptional accuracy, surpassing $10\ \mu\text{m}$ when coupled with an appropriate magnet for linear or rotary encoder. Additionally, it ensures superior channel matching with less than 5 % variation across the full magnetic input spectrum of $\pm 5\ \text{mT}$.

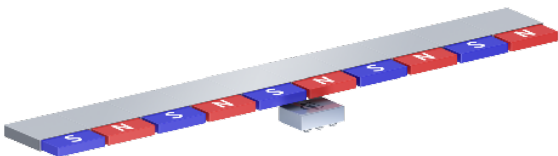
Block diagram



Features

- High signal-to-noise ratio allows small and cost-effective magnet design
- Low power consumption is beneficial for battery supplied applications
- High temperature-stable measurements make it perfect choice for use in harsh environments
- Hysteresis-free transfer characteristic allows accurate sensing where fast changing direction changes occur
- Higher integration density reduces the sensor size to support miniaturization and position sensing in microsystems

Linear position measurement

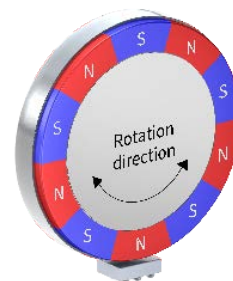


TMR technology enhances position sensing with its precise, high signal-to-noise ratio, enabling the use of smaller, cost-effective magnets. Its low power consumption suits battery-powered devices, while its hysteresis-free characteristic ensures accuracy during rapid directional changes. High integration density also allows for the miniaturization of sensors, making TMR ideal for compact applications.

Applications

- Linear and angular incremental position sensing in industrial and consumer applications with highest accuracy requirements
- Lens positioning for zoom and focus adjusting in cameras

Rotary position measurement



Product	Temperature range [°C]	Sensitivity bridge 1/2	Linear magnetic range [mT]	Interface	Current	Supply voltage [V]	Package	Ordering code
TLI5590-A6W	-40 to 125	18/9 mV/V/mT	± 5	Analog	1 mA @ 3.3 V	1–5.5	WFWLB-6-3	SP005631773

Angle sensors

Compact designs in small outline packages – at highest functional safety

Highest variety – low end to high end, standardized and specialized in various technologies: GMR, AMR and TMR

Angle sensors detect the orientation of an applied magnetic field by measuring sine and cosine angle components with monolithically integrated magneto resistive elements.

Infineon offers a large variety of high-precision angle sensors in all common technologies such as AMR (Anisotropic Magneto-resistive), GMR (Giant Magneto-resistive) and also TMR (Tunnel Magneto-resistive). The xMR technologies are complementary. Addressing any kind of rotation applications, Infineon's sensor portfolio consists of products with analog and digital outputs, as single and dual-chip variants and as products for safety-relevant applications. The two-channel analog TMR angle sensor TLE5501, the digital GMR angle sensor family TLE5014 and the high-precision AMR-based TLE5109 products are among the latest additions to the growing sensor portfolio, which includes all common technologies and is designed for both, industrial and automotive applications.

Infineon's TLE5501, is a fast analog TMR-based angle sensor dedicated to automotive applications. Their

fields of use range from steering angle applications, with the highest functional safety requirements, to motors for wipers, pumps and actuators and electric motors in general.

The TLE5109A16 AMR based products address the need for very precise, fast and yet cost-efficient angle measurement at the highest functional safety levels in automotive and industrial applications. These include position measurement in brushless DC motors (BLDC) for pumps, wipers or brakes, position measurements of valves, flaps or pedals and steering angle measurement.

Infineon's broad portfolio of GMR sensors are ideal for a wide range of angle applications, such as BLDC motors or steering angle sensors. They are pre-calibrated and ready-to-use. Different levels of signal processing integration from the straight forward TLE5012B to the highly complex and programmable TLE5014 enable designers to optimize system partitioning.

The large portfolio of Infineon angle sensors is equally suited to meet ready-to-use industrial and consumer applications like robotics or gimbal and highly safety critical automotive applications such as braking or steering.

GMR, AMR and TMR based angle sensors

Product	Technology	Die configuration	Sin/cos output	Angle output	Second interface	Accuracy	Classification	Package
TLE5009	GMR	Single die	Analog sin/cos	-	-	0.9°	ISO 26262-ready	DSO-8
TLE5009A16(D)	GMR	Dual die	Analog sin/cos	-	-	1.0°	ISO 26262-ready	TDSO-16
TLI5012B	GMR	Single die	SSC (SPI)	SSC (SPI)	PWM/IIF/SPC/HSM	1.9°	JESD47	DSO-8
TLE5012B(D)	GMR	Single & dual die	SSC (SPI)	SSC (SPI)	PWM/IIF/SPC/HSM	1.0°	ISO 26262-ready	DSO-8/ TDSO-16
TLE5014C16(D)	GMR	Single & dual die	-	SPC	-	1.0°	ISO 26262-compliant	TDSO-16
TLE5014P16(D)	GMR	Single & dual die	-	PWM	-	1.0°	ISO 26262-compliant	TDSO-16
TLE5014S16(D)	GMR	Single & dual die	-	SENT	-	1.0°	ISO 26262-compliant	TDSO-16
TLE5014SP16(D)	GMR	Single & dual die	-	SPI	-	1.0°	QM ISO 26262-compliant	TDSO-16
TLE5109A16(D)	AMR	Single & dual die	Analog sin/cos	-	-	0.5°	ISO 26262-ready	TDSO-16
TLE5309D	AMR + GMR	Dual die	Analog sin/cos	-	-	AMR 0.5°, GMR 1.0°	ISO 26262-ready	TDSO-16
TLE5501	TMR	Single die	Analog sin/cos	-	-	1.0°	ISO 26262-compliant	DSO-8

SPI = Serial peripheral interface
IIF = Incremental interface
PWM = Pulse width modulation



ISO 26262
compliant

ISO 26262
ready

TMR based angle sensors

Tunneling Magneto Resistive (TMR) technology is offering high sensing sensitivity with a high output voltage, reducing the need for an internal amplifier. Thus, the sensor can be connected directly to the microcontroller without any further amplification.

TLE5501

Infineon's TMR sensor TLE5501 is available in two versions.

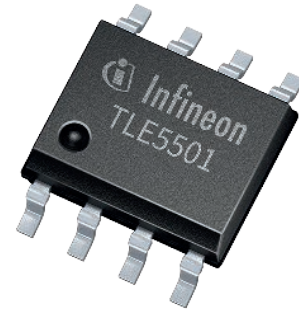
TLE5501 – product versions with different pin out:

- TLE5501 E0001: pin-compatible to TLE5009 automotive qualified acc. AEC-Q100
- TLE5501 E0002: decoupled bridges for redundant external angle calculation and highest diagnostic coverage, realizing ISO 26262-compliant development ASIL D

Features

- Large output signals of up to 0.37 V/V for direct microcontroller connection
- Discrete bridge with differential sine and cosine output
- Very low supply current: ~2 mA
- Magnetic field range (20–100 mT)
- Typ. angle error ~ 1.0° (over temperature and lifetime)
- DSO-8 package
- AEC-Q100, grade 0: $T_A = -40 \dots +150^\circ\text{C}$ (ambient temperature)
- For TLE5501 E0002:
 - Reaching ASIL D with just one single sensor chip
 - ISO 26262-compliant development ASIL D

In addition, TMR technology shows a very low temperature drift, reducing external calibration and compensation efforts. The TMR technology is also well known for its low current consumption.



Applications

- Steering angle sensor
- BLDC motor commutation (e.g. wipers, pumps and actuators)
- Angular position sensing for e.g. robotics or gimbal
- Electric motors
- Industrial automation
- Safety applications

GMR based angle sensors

TLE5014(D)

Digital GMR sensor with an easy-to-use plug-and-play concept for highest functional safety applications

All XENSIV™ TLE5014 angle sensors are available as single and dual die products. The products come pre-configured and pre-calibrated as plug-and-play sensors and are easy to use. Customers can choose between the interfaces SENT, PWM, SPC, and SPI. On top of those protocol options, the sensors can be adapted to any kind of application setup via their programmable E²PROM interfaces. TLE5014 magnetic angle sensors meet ISO 26262 ASIL C for the single die and ISO 26262 ASIL D for the dual die versions.

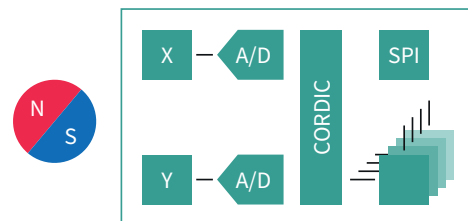
Features

- Easy-to-use, plug-and-play sensors, pre-configured and pre-calibrated
- Offering high flexibility:
 - Available as single and dual die products
 - 12-bit digital interface with protocol options PWM, SENT, SPC and SPI
 - E² PROM and look-up table for customer configuration and calibration
- High angle accuracy: max. 1.0° over temperature and lifetime
- High voltage capability up to 26 V
- Development fully compliant with ISO 26262
 - Developed acc. ASIL D level
 - Dual die sensors reaching ASIL D, single die sensors ASIL C metrics
- Safety manual and safety analysis summary report available on request

Applications

- Steering angle sensing (SAS)
- Motor commutation
- Rotor position measurement
- Pedal position
- Safety applications
- Any other kind of high-accuracy position measurement

All products are ready for applications with the highest functional safety requirements. The sensors show an extremely small angle error of less than 1° across the entire temperature profile and lifetime. This is particularly helpful in applications with the need for very accurate position sensing such as steering angle sensing or motor commutation. Further application areas range from rotor position measurement, electric power steering (EPS), pedal position to any other kind of position measurement.



1) More information on PRO-SIL™, see page 112

GMR based angle sensors

TLE5012B(D), TLI5012B

GMR sensor with integrated angle calculation and multiple interfaces

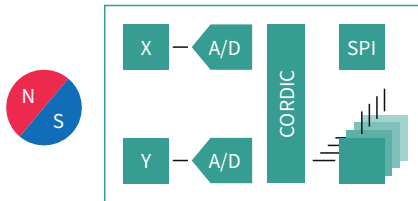
Features

- Integrated angle calculation with CORDIC algorithm
- 15-bit representation of calculated angle value
- High update rate up to 43 μ s (23 kHz)
- Range of selectable interfaces
- SPI compatible Synchronous Serial Communication (SSC)
- Bi-directional communication up to 8 Mbit/s
- Pulse Width Modulation (PWM)
- Hall Switch Mode (HSM) for motor commutation
- Incremental Interface (IIF)
- Temperature compensation and auto-calibration algorithm
- Diagnostic function for sensor elements and circuitry with PRO-SIL™ support
- Dual die SMD package (redundancy)
- ISO 26262-ready
- Available as single and dual die product
- Industrial version TLI5012B in line with JEDEC JESD47



Applications

- Steering angle
- Brushless DC motor commutation, i.e. electric power steering (EPS)
- Rotary switches
- General angular sensing
- Incremental or absolute magnetic encoders
- Gimbals, drones, robots



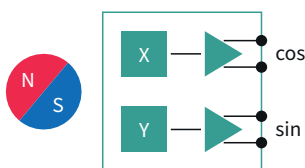
AMR based angle sensors

TLE5109A16(D)

Analog AMR sensor with temperature compensation

Features

- Features a differential or single-ended analog interface for sine and cosine values
- Internal temperature drift compensation for gain and offset
- Also available as a dual-sensor package
- ISO 26262-ready
- Available as single and dual die product



PRO
SIL  ¹⁾

ISO 26262
compliant

¹⁾ More information on PRO-SIL™, see page 112

Combined AMR and GMR based angle sensors

TLE5309D

Dual angle sensor combining AMR and GMR technology

The TLE5309D is a diverse redundant angle sensor with analog outputs. It combines a Giant Magneto Resistance (GMR) sensor for full 360° angle range with an Anisotropic Magneto Resistance (AMR) sensor for high precision in a flipped configuration in one package. Sine and cosine angle components of a rotating magnetic field are measured by Magneto Resistive (MR) elements. The sensors provide analog sine and cosine output voltages that describe the magnetic angle in a range of 0 to 180° (AMR sensor), and 0 to 360° (GMR sensor), respectively.

Summary of features

- Separate supply pins for AMR and GMR sensor
- Diverse redundant design with one GMR sensor (top die) and one AMR sensor (bottom die) in one package
- Low current consumption and very fast start up
- 360° contactless angle measurement
- Immune to air gap variations due to MR based sensing principle
- Operating ambient temperature:
-40 ... +125°C/-40 ... +150°C (TLE5309DHT)

Potential applications

The TLE5309D angle sensor is designed for angular position sensing in safety critical automotive applications. Its high accuracy and 360° measurement range combined with short propagation delay makes it suitable for systems with high speeds and high accuracy demands such as brushless DC (BLDC) motors for actuators and electric power steering systems (EPS). At the same time

The differential MR bridge signals are independent of the magnetic field strength, and the analog output is designed for differential or single ended applications.

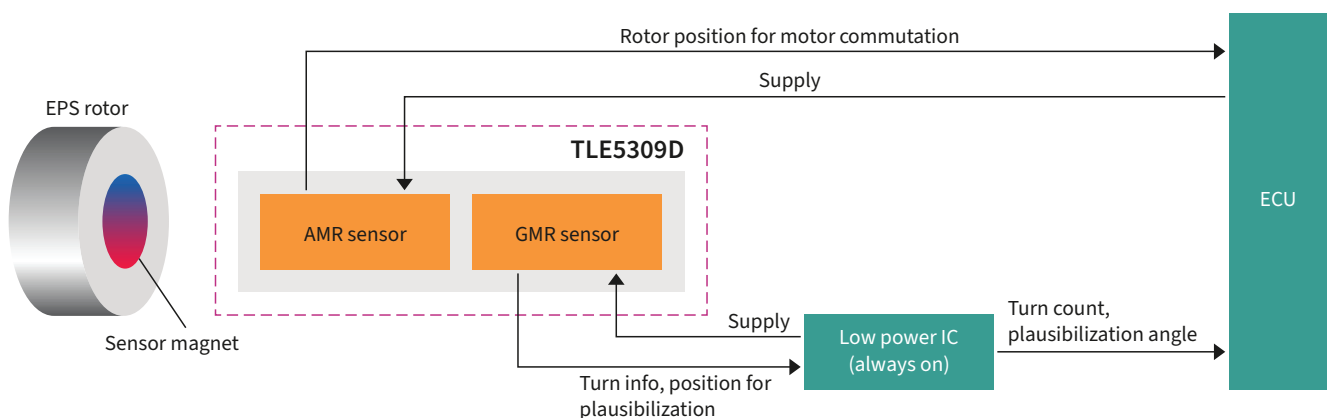
The output voltages are designed to use the dynamic range of an A/D-converter using the same supply as the sensor as voltage reference. Both sensor ICs are supplied independently by separate supply and ground pins.



its fast start-up time and low overall power consumption enables the device to be employed for low-power turn counting. Extremely low power consumption can be achieved with power cycling, where the advantage of fast power on time reduces the average power consumption.

- BLDC motors for electric power steering (EPS)
- Low-power turn counter

Diagnostic functions in combination with AMR and GMR diversity supports ASIL D applications





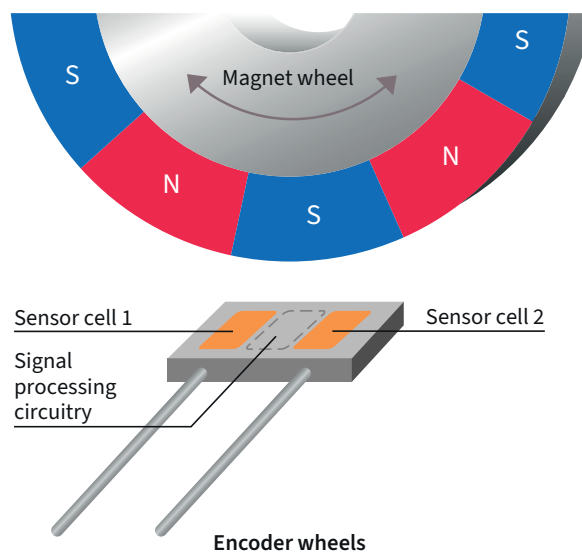
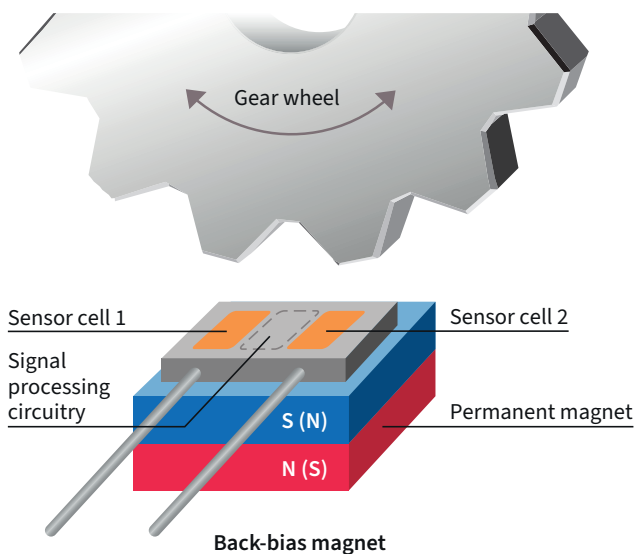
Magnetic speed sensors

Easy to use, robust and cost-effective sensors for speed measurement

Infineon’s Hall-, GMR- and TMR-based magnetic speed sensors are designed to measure speed in safety and powertrain applications such as speedometers, ABS, camshafts/crankshafts, and automatic transmissions. They are also used in similar applications in the industrial sector. The sensors use a ferromagnetic gear tooth

or encoder structure to measure linear or rotational speed and position. Hall sensor measuring rotational speed with a gear tooth and a magnetic encoder wheel. The majority of sensors also feature additional benefits such as integrated capacitors for high EMC robustness and the highest levels of ESD protection.

Typical application of a magnetic differential sensor



TLE4922

Highly robust, easy-to-use mono-Hall speed sensor with twist-independent mounting

This sensor is specially designed to provide an easy-to-use, robust and cost-effective solution for vehicle or industrial speed sensing applications. The TLE4922 can therefore, be back-biased using a simple, low-cost bulk magnet, while providing a good air gap performance

Features

- Large operating air gap capability
- Flexible mounting (also known as twist-independent mounting)
- Hidden adaptive hysteresis
- Low current consumption
- Reverse magnetic polarity capability
- Advanced protection technology
 - Reverse voltage protection at VS-pin
 - Short-circuit protection
 - Overtemperature protection
- Wide operating temperature ranges of $-40^{\circ}\text{C} \leq T_j \leq \pm 150^{\circ}\text{C}$
- High ESD robustness up to ± 4 kV HBM
- 3-wire PWM voltage interface

and switching accuracy. Its hidden adaptive hysteresis and calibration algorithm enable good accuracy over air gap jumps and immunity to vibration and run-out events.



Applications

- Industrial applications
- Two-wheeler and automotive vehicle speed

TLE4927C E6547

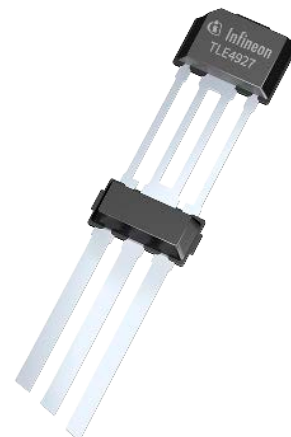
Differential Hall effect crankshaft sensor with hidden adaptive hysteresis

Infineon's TLE4927C detects the motion and position of ferromagnetic and permanent magnet structures by measuring the differential flux density of the magnetic field. A self-calibration mode ensures optimum accuracy in running mode in just a few transitions after start up. The sensor combines a fast power up time with

high accuracy and sensitivity for large operating air gaps. Qualified for automotive temperature range and meets the requirements of harsh environmental conditions prevalent in automotive applications. The TLE4927C comes with the SSO package with two integrated capacitors.

Features

- Differential Hall speed sensor to measure speed and position of tooth/pole wheels
- Easy to use single chip solution in SSO-3-92
- Symmetrical switching point in the middle of the tooth/magnetic pole
- South and north pole pre-induction possible
- Digital output signal (voltage interface)
- Fast start-up time
- Reverse voltage protection at VS-pin
- Short-circuit and over temperature protection of output
- Automotive operating temperature range



TLE4929

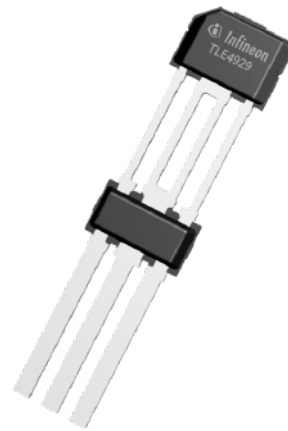
Fully programmable crankshaft sensor with direction detection

The TLE4929 is an active differential Hall sensor ideally suited for crankshaft applications and similar industrial applications, such as a speedometer or any speed sensor with excellent accuracy and low jitter capabilities. It as well addresses new requirements for crankshaft speed sensing from hybrid powertrains. An advanced vibration detection algorithm ensures valid sensor data for any hybrid powertrain traction. This improves efficiency of the engine start and helps to avoid misfiring

Features

- Differential Hall speed sensor to measure speed and position of tooth/pole wheels
- Ease of use single chip solution in SSO-3-52
- Switching point in the middle of the tooth enables backward compatibility
- Robustness over magnetic stray-field due to the differential sensing principle
- Precise miss fire detection through excellent jitter performance
- Dedicated hybrid engine algorithm keeps combustion engine calibrated during an electric drive cycle
- Digital output signal with programmable output-protocol including diagnosis interface
- Direction detection and stop-start-algorithm
- High accuracy and low jitter
- High sensitivity enables large air gap
- End-of-line programmable to adapt engine parameters
- Can be used as a differential camshaft sensor
- Pre-programmed version TLE4929C-XAN available, TLE4929C-X2A available for 2-wheeler applications
- Automotive operating temperature range

or ECU error messages caused by wrongly calibrated sensor data. Also, the compatible 3-pin-package allows a one-to-one-replacement of the former generation of crankshaft sensors without direction detection, TLE4924/25/26/27/28, widely backward compatible functionality through flexible EEPROM configuration of parameters, means former TLE492x-family can be mimicked.



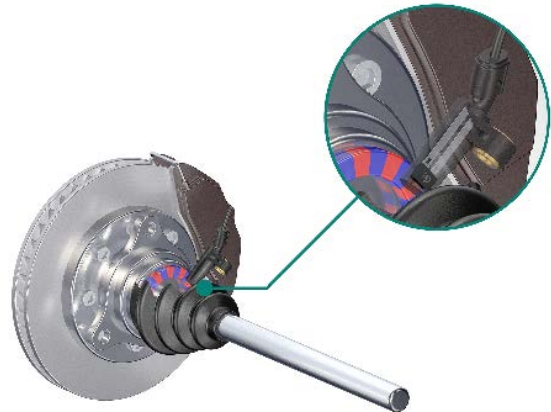
Product	Sensor technology	Classification	Direction detection	Automotive	Industrial	Protocol	RoHS
TLE4922	Mono-Hall	AEC-Q100	–	✓	✓	Single pulse	✓
TLE4927	Differential Hall	AEC-Q100	–	✓	✓	Single pulse	✓
TLE4929	Differential Hall	AEC-Q100	✓	✓	✓	PWM, Single pulse	✓

Safety first – wheel speed sensors

Nowadays, wheel speed sensors have to support an ever-growing list of applications. Years ago, ABS systems simply needed to know if a wheel was blocked, and then ESC used the accurate speed of all four wheels for its corrections. Since then, an increasing number of modules in the car take the wheel speed into account for their intelligent functions. The electrical parking brake, for example, needs to know about every inch a car moves when it's supposed to be stationary, and iTPMS uses sophisticated algorithms to determine if a wheel lacks air pressure, and even the central locking locks the doors after a couple of meters and the radio turns up the volume in line with increasing speed. All of the above rely on accurate information from the wheel speed sensor.

Applications

- Wheel speed sensing in automotive applications
- Antilock braking systems (ABS)
- Electronic stability programs (ESP)
- Automatic transmissions
- iTPMS TLE5041plusC, TLE5045iC and TLE5046SiC



TLE4941plusC / TLE4942-1C / TLE4943C My car, how fast and far does it drive?

The TLE4941plusC, our bestseller is an industry standard for wheel speed sensing. TLE4942-1C and TLE4943C are complementing this sensor with additional direction information using PWM or AK protocol, respectively.

As a single chip sensor it magnetically measures the cars wheel speed with its differential Hall technology, making it the ideal all-purpose sensor, equally suitable for pole wheel and steel wheel applications. These sensors are immune towards any kind of undesired magnetic stray fields, ferromagnetic particles or other disturbances, because of their differential principle.

Features

- Family of Hall sensors available with and without direction detection
- Excellent stray field robustness

Applications

- Pole wheel applications
- Steel/tooth wheel applications by using back bias magnet



Product	Sensor technology	Pole wheel	Steel wheel	Classification	Direction detection	Protocol	iTPMS
<u>TLE4941plusC</u>	Hall differential	✓	✓	ISO 26262-compliant	–	Standard	–
<u>TLE4942-1C</u>	Hall differential	✓	✓	ISO 26262-compliant	✓	PWM	–
<u>TLE4943C</u>	Hall differential	✓	✓	–	✓	AK	–



ISO 26262
compliant

TLE5045iC / TLE5046SiC

High end GMR wheel speed sensors

The TLE5045iC/TLE5046SiC is our next generation wheel speed sensor family, based on GMR technology. The family consists of a designed-to-cost speed-only TLE5045iC, and a high-end TLE5046SiC providing not only direction detection but also offering true “zero-speed” capability as well as possibilities of self-diagnostics.

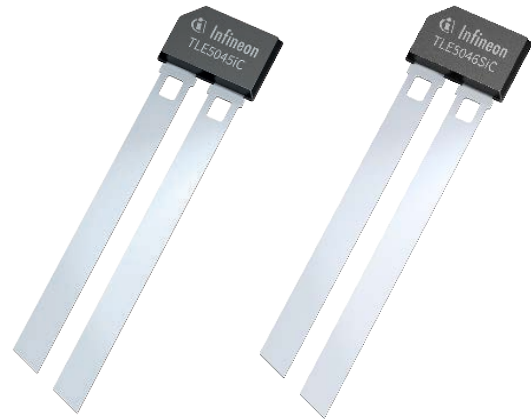
Features

- One family of speed sensors for all wheel speed sensing applications in same package
- Best in class in sensitivity, jitter and duty cycle, independent from magnetic target wheel
- “Zero speed” capability
- ISO 26262-compliant ASIL B development, supporting ASIL D systems
- Multiple protocol variants with and without self-diagnosis functionality
- Integrated circuitry for improved EMC and ESD robustness even without external capacitor

Applications

- Pole wheel applications
- Autonomous driving (e.g. park assist)

TLE5045iC and TLE5046SiC are developed according ISO 26262 to fulfill ASIL B, supporting ASIL D systems. The TLE5046SiC with direction detection is available with PWM or AK protocol.



Product	Sensor technology	Pole wheel	Steel wheel	Classification	Direction detection	Protocol	iTPMS
<u>TLE5045iC</u>	iGMR differential	✓	–	ISO 26262-compliant	–	Standard	✓
<u>TLE5046SiC-PWM</u>	iGMR differential	✓	–	ISO 26262-compliant	✓	PWM	✓
<u>TLE5046SiC-AK</u>	iGMR differential	✓	–	ISO 26262-compliant	✓	AK	✓

TLE4953C

Two-wire transmission speed sensor

The differential Hall sensor TLE4953C can detect direction and was developed specifically to meet the needs of high-end transmission applications. Its jitter performance and high sensitivity enables designers to create high-accuracy systems with excellent vibration suppression. Adaptive hysteresis and the dynamic

Features

- Detection of rotation direction
- Highly accurate speed measurements from zero to 12 kHz over large operating air gaps
- Excellent vibration suppression
- Broad operating temperature range
- AEC-Q100 qualified

Applications

- Automatic transmission systems
- Industrial speed sensing using current interface

TLE4955(C)

Leading the way in vibration robustness

TLE4955 family of differential Hall sensors specially designed to meet the latest requirements in transmission vibration suppression. It provides best-in-class vibration suppression for applications, that require a two-wire current interface. The TLE4955 family provides a similar algorithm plus dynamic self-calibration, jitter

Features

- Detection of rotation direction
- Best-in-class vibration suppression
- Highly accurate speed measurements from zero to 12 kHz over large operating air gaps
- Broad operating temperature range
- Four different interface protocols
- AEC-Q100 qualified

Applications

- Automatic transmission systems
- Industrial speed sensing using current interface

self-calibration algorithm ensure outstanding measurement results with both fine and coarse target wheels. As with other Infineon speed sensors, the south and north poles can be pre-inducted. TLE4953 features a current interface and comes in a two-wire package with an integrated 1.8 nF overmolded capacitor for improved EMC.



and sensitivity levels as our proven TLE4953, thus ensuring accurate speed measurements in the harshest of environments for both fine and coarse target wheels. Designers can choose different interface protocol versions.



TLE4959C, TLE4959C-FX

State-of-the-art three-wire transmission speed sensor with direction detection

With our TLE4959 you now can also address your 3-wire applications with the latest state-of-the-art technology of IFX transmission sensors. Differential Hall sensor TLE4959 is your choice when you need a 3-wire-sensor with direction detection and active vibration suppression. Beside it's outstanding air gap and best of class Hall jitter performance, with it's high immunity against

strayfields it is the ideal match not only for traditional transmissions but also particularly for hybrid applications.

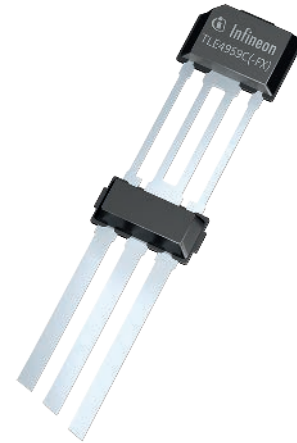
While TLE4959C is provided with the standard protocol, the FX version gives access to different protocols (e.g. speed only) as it is to be programmed at the customer's premises.

Features

- Active vibration suppression
- Highly accurate speed measurements from 0 Hz to 10 kHz over large operating air gaps (up to 20 k for -FX)
- Common three-wire voltage interface
- Broad operating temperature range
- AEC-Q100 qualified
- FX version customer programmable (protocol, hysteresis level)

Applications

- Automatic (hybrid) transmission systems



TLE4959-5U, TLE4959-5U-FX

State-of-the-art 4-wire transmission speed sensor with direction detection

XENSIV™ TLE4959-5U and TLE4959-5U-FX are 4-wire voltage interface differential Hall speed sensors for transmission speed applications with vibration suppression and direction detection output. The FX version flexible in terms of protocol, it offers customer programmable EEPROM.

State-of-the-art 4-wire transmission speed sensor with direction detection. The TLE4959-5U (FX) is an

integrated differential Hall speed sensor ideally suited for transmission applications. Its basic function is to provide rotational speed and direction of rotation information to the transmission control unit. Sophisticated vibration suppression with excellent air gap performance. TLE4959-5U (FX) includes a sophisticated algorithm which actively suppresses vibration while keeping excellent air gap performance.

Features

- Voltage interface
- Active vibration suppression
- Direction detection output
- Dynamic self-calibration
- 0 Hz capability
- FX: flexible protocol through customer programmable EEPROM

Target applications

- Automatic transmission applications
- Transmission applications with speed with direction detection



TLE4983 / TLE4984

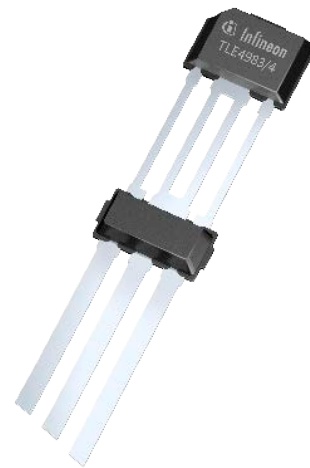
Mono-Hall based camshaft speed and position sensors

The TLE4983C, TLE4984C are active Hall sensors ideally suited for camshaft applications in automotive. Its basic function is to map either a tooth or a notch of a gear into a unique electrical output state, while the magnetically bipolar TLE4983C can map also a magnetic encoder wheel. The implemented electrical trimming option for post-fabrication trimming sets the sensor's switching points. This ensures its true power on capability (TPO)

Features

- True power on functionality (TPO)
- Programmable switching points
- Pre-programmed temperature coefficient for SmCo back-bias magnet
- Single chip solution in SSO-3-9 package
- Twist independent mounting (TIM) for larger fabrication tolerances
- Advanced performance by dynamic self-calibrating principle
- High accuracy and high stability of the magnetic switching points
- High resistance to mechanical stress
- Digital output signal (voltage interface)
- Short-circuit protection
- Enhanced ESD performance
- AEC-Q100 qualified

even in the case of production spreads such as different magnetic configurations or misalignment. Additionally, a self-calibration algorithm has been implemented to achieve optimum accuracy during normal running operation. The TLE4984C/83C come in a three-pin package SSO-3-9 that has two integrated capacitors for enhanced EMC and micro break performance.



TLE4986

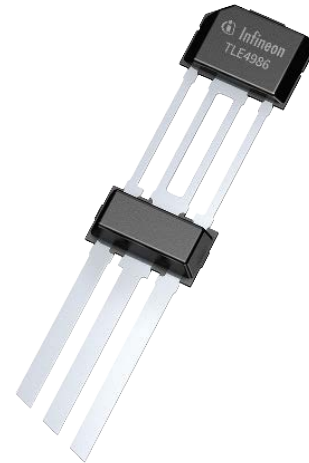
Mono-Hall based camshaft speed and position sensor

The TLE4986C is an active Hall sensor ideally suited for camshaft applications and similar industrial applications such as speedometer. Its basic function is to map either a tooth or a notch into a unique electrical output state. It has an electrical trimming option for post-fabrication trimming in order to achieve true power on (TPO) capability even in the case of production spreads

Features

- Hall switching sensor to measure speed or phase of pole/tooth wheels
- Digital output signal (voltage interface)
- Mono-cell chopped Hall system
- TPO true power on functionality
- TIM twist independent mounting
- Dynamic self-calibrating algorithm
- IST individual switching threshold
- End-of-line programmable switching points
- EEPROM for various algorithm options
- TC of back-bias magnet pre-programmed
- High resistance to mechanical stress
- Enhanced immunity against ESD and EMC
- Improved μ -cut capability
- Enhanced operating temperature range
- Module package SSO-3-52

such as different magnetic configurations or misalignment. Additionally, a self-calibration algorithm has been implemented to achieve optimum accuracy during normal running operation, which by its EEPROM is adaptable in various performance affecting parameter. It comes in a three-pin SSO-3-52 package for the supply voltage and an open drain output.



TLE4988C

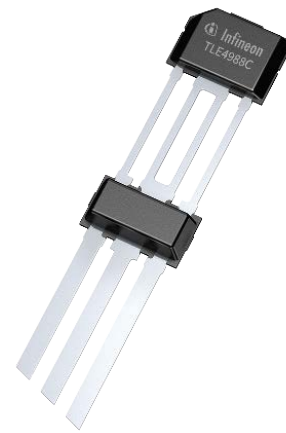
Mono-Hall based camshaft speed and position sensor with reduced dependence on rare-earth backbias magnets

The Infineon XENSIV™ TLE4988C products feature advanced camshaft sensing performance and improved application adaption. One major benefit of the advanced sensor performance is the reduced dependence from rare-earth backbias magnets for module manufacturers. The TLE4988C has proven right performance with a ferrite backbias magnet for all relevant parameters such as phase jitter, phase accuracy or speed effect across key temperature, air gap and rpm ranges. With automatic in car TPO calibration

a most accurate start up sensing in real application environment is ensured addressing tolerances of ferromagnetic wheels and magnetic encoders, as well as mounting tolerances of the sensor. Infineon's TLE4988C products are available optimized for the use with three different backbias magnet materials, such as Fe, SmCo and NdFeB. All products come inside the well-established camshaft sensor package SSO-3-52, allowing low design switch effort in terms of package and performance compatibility with predecessor products.

Features

- Digital output signal (voltage interface)
- True power on functionality (TPO)
- Auto TPO – automatic in car calibration
- Improved switching level/phase accuracy
- TC range including ferrite
- High speed digital interface for diagnosis / test
- Twist independent mounting (TIM)
- EEPROM for algorithm options and ID
- Increased ESD and EMC immunity, improved μ Cut feature
- Digital magnet temperature compensation
- Mechanical stress compensation
- Module package SSO-3-52



Product	Sensor technology	Magnet TC	Automotive	Industrial	Protocol	RoHS
TLE4983	Mono-Hall	SmCo	✓	✓	Single pulse	✓
TLE4984	Mono-Hall	SmCo	✓	✓	Single pulse	✓
TLE4986	Mono-Hall	SmCo	✓	✓	Single pulse	✓
TLE4988	Mono-Hall	SmCo, NdFeB, Fe	✓	✓	Single pulse	✓

TLE5555iC(B)

State-of-the-art TMR transmission speed sensor for pole/toothed wheel in top/side read configuration with/without back-bias magnet

The TLE5555iC is a differential magnetic speed sensor based on tunnel magnetoresistance (TMR) sensing technology. This technology enables best-in-class jitter and air gap performance and allows sensing flexibility in top and side read configuration. Its basic function is providing information about the rotational speed and the direction of the rotation to the transmission control unit. Therefore, the sensor family includes a sophisticated algorithm which actively suppress vibration. The output has been designed as a two-wire current interface based on a PWM (pulse width modulation) principle. The TLE5555iC operates without external components and is fully EMC-compliant thanks to its capacitor integrated on silicon level.

Features

- High magnetic field sensitivity enables ultra-low jitter over high operating air gap range
- Two wire PWM current interface
- Direction detection
- Vibration suppression (active via protocol suppression; passive via adaptive hysteresis)
- Differential sensing principle enables magnetic stray field robustness
- Equipped with sintered ferrite back-bias magnets and algorithm optimized for toothed wheel applications
- Package options for top and side read mounting make bending of sensor leads obsolete
- EMC robust without the need of capacitors on sensor leads
- Comprehensive digital diagnostic interface, enabling readout of internal signals and electronic chip ID
- Customer configurable EEPROM in FX version

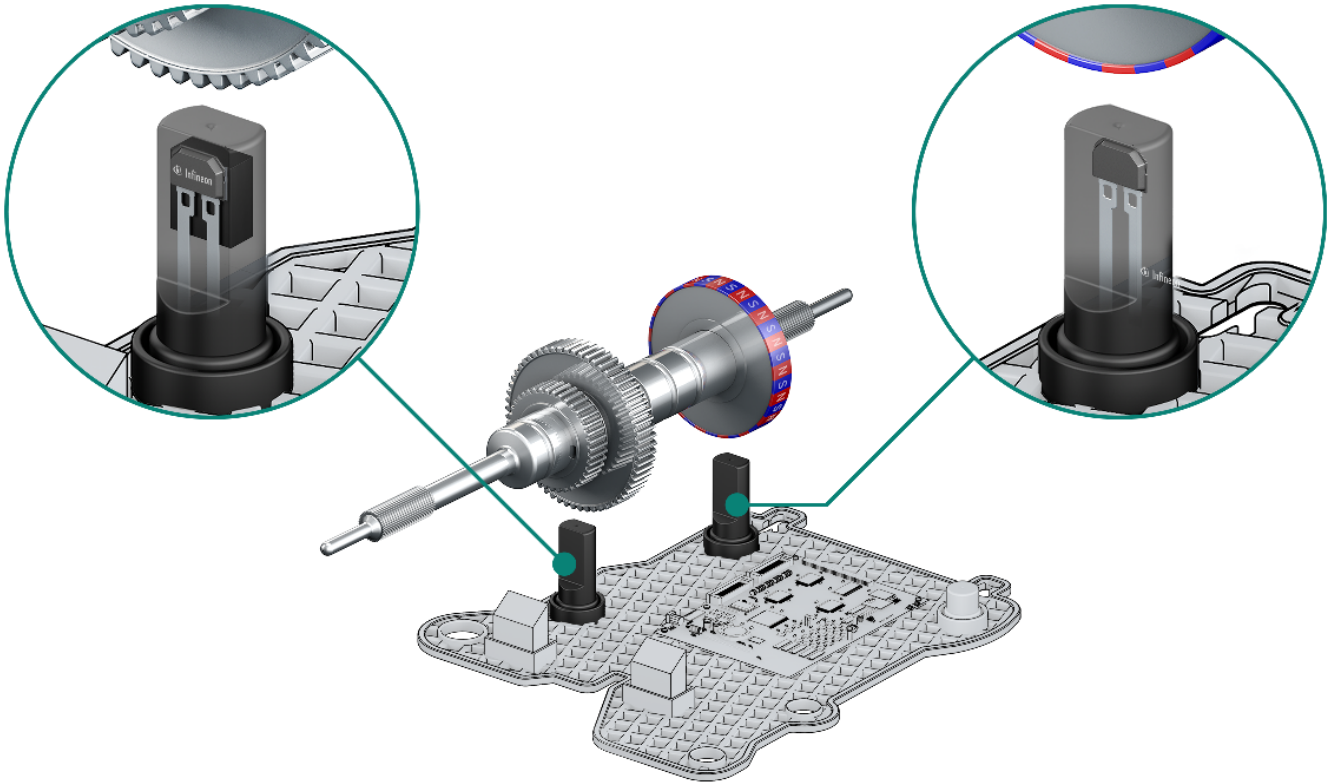
Potential applications

- Ideal for the use in harsh environments, particularly automotive transmissions
- Suitable for all kinds of transmission systems including DHT (dedicated hybrid transmission) and EV (electric vehicle) concepts

The "iCB-top" family members are designed for toothed wheel applications and have a ferrite back-bias magnet attached. It comes in a RoHS compliant two-pin-package, qualified for automotive usage. It is recommended to use the iCB-top within an overmolded module. For magnetic encoder (ME) applications, other sensors – called ME family – are available.

High flexibility is offered by the FX version which provides a programmable EEPROM. This sensor offers many protocol options established in transmission applications over the last decades. Additionally, it offers to configure the sensor algorithm (e.g. magnetic threshold, vibration robustness) to fully optimize the sensor performance to the target wheel.










Available variants

Product	Description	Classification	SP Number	Package
TLE5555iC ME E0	For polewheel (top + side-read), E0 protocol	ISO 26262-compliant	SP003883456	SSO-2-51
TLE5555iC ME E1	For polewheel (top + side-read), E1 protocol		SP005832719	SSO-2-51
TLE5555iC ME E4B	For polewheel (top + side-read), E4B protocol		SP005829763	SSO-2-51
TLE5555iCB E0-top	For steelwheel (top-read), E0 protocol, incl. backbias magnet		SP003883500	SSOA22-2-51
TLE5555iCB E1-top	For steelwheel (top-read), E1 protocol, incl. backbias magnet		SP005401486	SSOA22-2-51
TLE5555iCB E4B-top	For steelwheel (top-read), E4B protocol, incl. backbias magnet		SP005832705	SSOA22-2-51

Wheel speed sensing overview

	Icon/ Description	TLE4941plusC	TLE4942-1C	TLE4943C	TLE5041plusC	TLE5045iC	TLE5046SiC
Automotive	Wheelspeed	✓	✓	✓	✓	✓	✓
Industrial		✓	-	-	-	-	-
Sensor technology		Diff. Hall	Diff. Hall	Diff. Hall	iGMR	iGMR	iGMR
Improved air-gap/jitter performance		-	-	-	✓	✓	✓
Direction information available		-	✓	✓	-	-	✓
Type of hysteresis ¹⁾		H	H	H	H	H	H
		F	F	A	F	A	A
Interface ²⁾	# of pins	2	2	2	2	2	2
	Interface	C	C	C	C	C	C
	Protocol	S	P	AK	S	S	P/AK
Electrostatic Discharge (ESD)	Human Body Model (HBM)	12 kV	12 kV	12 kV	12 kV	12 kV	12 kV
Package without external integrated capacitor		-	-	-	-	✓	✓
Package with integrated capacitor		✓	✓	✓	✓	-	-

1) H = Hidden; F = Fixed; A = Adaptive

2) AK = AK protocol; C = Current; S = Single pulse; P = PWM protocol

Powertrain speed sensing overview

	Icon/ Description	TLE4922	TLE4929	TLE4953	TLE4955	TLE4959	TLE5555	TLE4983/ TLE4984	TLE4986	TLE4988
Automotive	Wheelspeed	✓	-	-	-	-	-	-	-	-
	Transmission	✓	✓	✓	✓	✓	✓	-	-	-
	Engine	✓	✓	-	-	-	-	✓	✓	✓
Industrial		✓	✓	-	-	-	-	-	-	-
Sensor technology		Mono-Hall	Diff. Hall	Diff. Hall	Diff. Hall	Diff. Hall	iTMR	Mono-Hall	Mono-Hall	Mono-Hall
Improved air-gap/ jitter performance		-	✓	-	-	✓	✓	-	✓	✓
Direction information available		-	✓	✓	✓	- / ✓ ³⁾	✓	-	-	-
True Power On (TPO)		-	-	-	-	-	-	✓	✓	✓
Twist Independent Mounting (TIM)		✓	-	-	-	-	-	✓	✓	✓
Vibration suppression algorithm included		-	✓	✓	✓	✓	✓	-	-	-
Type of hysteresis ¹⁾		H	H/V	V	V	V	V	H	H	V/H
		A	A/F	A	A	A	A	F	P/A	P/A
Interface ²⁾	# of pins	4	3	2	2	3/4	2	3	3	3
	Interface	V	V	C	C	V	C	V	V	V
	Protocol	S	S/P	P	P	S/P	P	S	S	S
Electrostatic Discharge (ESD)	Human Body Model (HBM)	3 kV	6 kV	12 kV	12 kV	6 kV	12 kV	4 kV	6 kV	6 kV
Package without external capacitor on leads		✓	-	-	-	✓	✓	-	-	-
Package with capacitor on leads		-	✓	✓	✓	✓	-	✓	✓	✓

1) H = Hidden; V = Visible; F = Fixed; A = Adaptive; P = Programmable

2) C = Current; V = Voltage interface; S = Single pulse; P = PWM protocol

3) Depending on derivative



Pressure sensors

For automotive, industrial and consumer applications – ensure the perfect fit for all performance and integrity needs

Infineon XENSIV™ pressure sensors measure the pressure of air and gases across various industries and applications. In their function as a pressure transducer sensor, they convert physical pressure into an electric signal. Infineon XENSIV™ pressure sensors combine the functions of sensing (via a pressure sensor element) and conversion into an electrical signal (via an absolute pressure transducer and signal processing) in one integrated silicon device.

The sensor element and its integrated circuits (IC) are the heart of pressure sensor technology. Infineon's small pressure sensor IC chips support various applications with best-in-class performance. Infineon is one of the world's largest semiconductor pressure sensor and transducer manufacturers, thanks to a varied portfolio of absolute air pressure sensor ICs. Our comprehensive family of XENSIV™ sensors includes a wide selection of pressure-sensitive sensors tailored specifically to the automotive, consumer and industrial sectors. XENSIV™ sensors are compact, designed to save energy, and offer a rapid time-to-market – a perfect fit for any performance and integrity need.



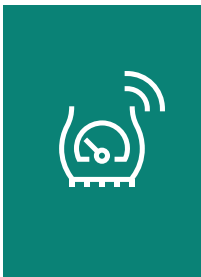
Infineon XENSIV™ BAP sensors are calibrated for specific automotive applications, especially for BMS thermal runaway detection, pneumatic seats and electronic engine control. The BMS sensors are ISO 26262-compliant and support highest ASIL requirements on system level.



Powertrain systems have to fulfill the constantly increasing stringent media requirements. Environmental legislation aims to deliver cleaner air by ensuring a steady global decrease in CO2 emissions. Thanks to their accurate measurement capability, Infineon MAP and turbo MAP product with analog or digital interface enable engines to meet these requirements.



Typical safety-related automotive pressure sensing applications such as side impact and pedestrian protection call for the highest quality and accuracy standards with full ISO 26262 compliance. Every year thousands of pedestrians are severely injured in traffic due to slow or failing sensing elements. Our Infineon XENSIV™ safety pressure sensor family includes integrated pressure sensors that tick all these boxes with PSI5 peripheral sensor interfaces for safety-critical use cases. Our sensors support new safety systems, increasing the protection of pedestrians and car occupants in the event of a collision.



Infineon's tire pressure sensors perform all of the functions necessary to implement a state-of-the-art module for a Tire Pressure Monitoring System (TPMS). As part of our XENSIV™ pressure sensors portfolio, our SP49 TPMS sensor ICs are easy to integrate and feature a microcontroller, sensors, wireless communication, and convenient peripherals. They only need a few passive components and a battery to complete a full automotive TPMS sensor assembly.



Our family of digital barometric pressure sensors also gives designers the best choice when it comes to mobile and wearable devices. Highlights include small form factors to facilitate system integration, highest precision and relative accuracy over a wide temperature range, fast read-out speeds via the serial I²C/SPI interface, and low power consumption to ensure longer battery lifetimes.



Absolute pressure sensors (MAP and BAP)

Highest accuracy and precision on the smallest footprint and energy bill

Infineon's pressure sensors offer the highest quality and accuracy for safety-relevant automotive, industrial, or consumer lifestyle applications. Typical safety-related automotive pressure sensing applications such as side-impact and pedestrian protection call for the

highest quality and accuracy standards with full ISO 26262 compliance. Our XENSIV™ family includes integrated pressure sensors that tick all these boxes with PSI5 peripheral sensor interfaces for a safety-critical use case.

KP21x / KP22x – Analog manifold air pressure sensor family (MAP + turbo MAP)

Features

- Manifold air pressure measurement – MAP and turbo MAP
- Excellent accuracy of up to 1.0 kPa over a large temperature range
- Ratiometric analog voltage output proportional to the applied pressure
- Output signal fully compensated over pressure and temperature
- Pressure range from 10 to 400 kPa
- Temperature range from -40 to +140°C
- Output clamping (optional)
- Complete product family available with multiple transfer function
- Reverse polarity protection
- Green SMD package



KP23x – Analog barometric air pressure (BAP) sensor family

Features

- Absolute air pressure measurement
- Excellent accuracy of 1.0 kPa over a large temperature range
- Ratiometric analog voltage output proportional to the applied pressure
- Output signal fully compensated across pressure and temperature range
- Pressure range from 15 to 165 kPa
- Temperature range from -40 to +125°C
- Serial service interface
- Open bond detection (OBD) for supply and GND
- Reverse polarity protection
- Green SMD package

KP276 – Media robust MAP sensor with digital interface

Features

- Media robustness for current automotive requirements
- Digital single edge nibble transmission (SENT) interface (282 clock ticks)
- Excellent accuracy of $\pm 0.77\%$ FSS
- Temperature range -40 to +170°C (170°C for 20 min. max., 150°C operating)
- Integrated NTC temperature sensor functionality with fast start up time (typ. 10 ms)
- Green SMD package

Integrated pressure sensor ICs for manifold and barometric air pressure

Product	Max. accuracy [kPa]	Max. operating temperature [°C]	Automotive	Industrial	Classification	Pressure range [kPa]
KP21x	1.0	140	✓	✓	–	10 ... 150
KP22x	2.5	140	✓	✓	–	10 ... 400
KP23x	1.0	125	✓	✓	–	15 ... 115
KP236N6165	1.0	125	✓	✓	–	60 ... 165
KP276	3.0	150 (170 time limited)	✓	✓	–	10 ... 400

KP46x – Digital barometric air pressure family in new DFN-8 package

Features

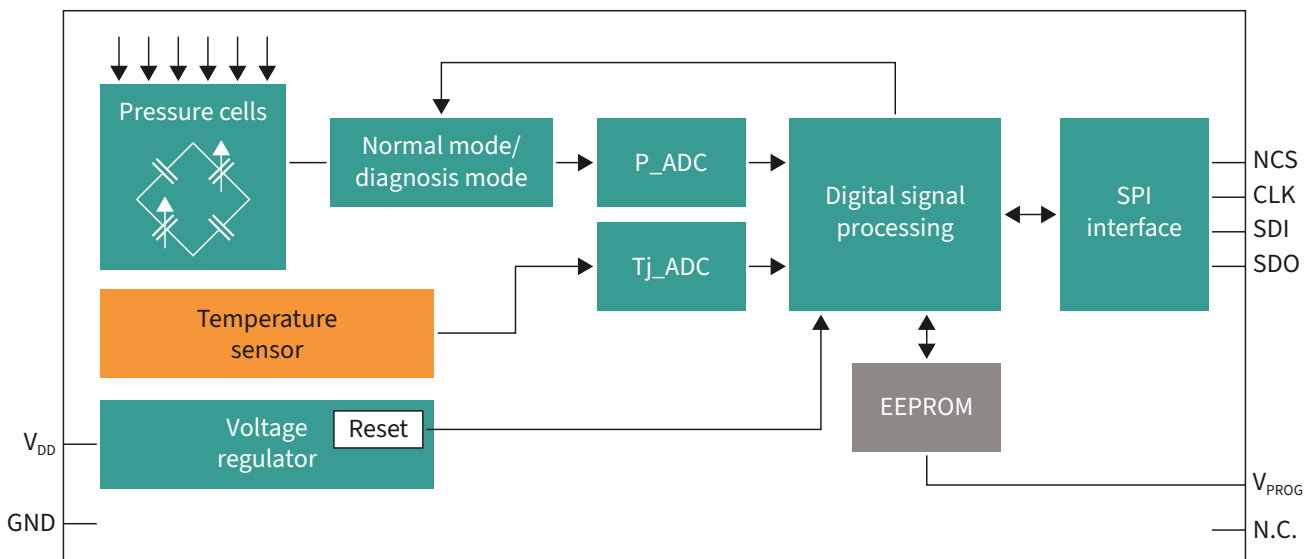
- High accuracy pressure sensing
- Pressure range according to different application needs:
 - ECU/MAF (40–115 kPa)
 - Pneumatic seats (60–165 kPa)
 - BMS thermal runaway (45–200 kPa)
- ISO 26262 compliance for KP467 (ASIL B)
- Operating ambient temperature range -40 ... +125°C, KP467 up to 105°C
- Best-in-class low power consumption with dedicated power-down mode for energy saving
- 10-, 12- or 14-bit resolution pressure and temperature values via SPI interface and backwards compatibility to legacy devices KP25x and KP264
- KP467 with autonomous low-power monitoring (LPM) feature for pressure event detection and host wake-up
- Integrated signal path diagnosis features
- Green, small 4.5x5.1 mm 8-pin DFN package for all KP46x



Applications

- KP464/KP464E for ECU and mass airflow sensing to control fuel supply and injection, for air management and ignition
- KP465 for higher pressure levels e.g. within compressed air in fuel-cell applications
- KP466 for pneumatic seat comfort application
- KP466P for pneumatic seat comfort application and thermal runaway detection in battery management system for xEVs
- KP467 for thermal runaway detection in battery management system for xEVs

Block diagram KP46x



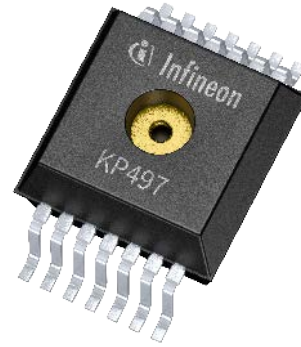
Product	Operating pressure range [kPa]	P-accuracy -40°C [kPa]	P-accuracy 0 ... +85°C [kPa]	P-accuracy +125°C [kPa]	T-accuracy +25 ... +85 [°C]	Supply current I_{VDD} [mA]	Supply current power down I_{VDD_PD} [μ A]	Classification
KP464	40 ... 115	± 1.5	± 1.0	± 1.5	± 3	3.5 (without SPI comm.)	10	AEC-Q103
KP464E	40 ... 115	± 1.5	± 1.0	± 1.5	± 3	3.5 (without SPI comm.)	10	AEC-Q103
KP465¹⁾	60 ... 320	± 5.0	± 3.0	± 5.0	± 3	3.5 (without SPI comm.)	10	AEC-Q103
KP466	60 ... 165	± 4.0	± 1.0	± 2.0	± 3	5 (without SPI comm.)	10	AEC-Q103
KP466P	60 ... 165	± 1.5	± 1.0	± 1.5	± 3	5 (without SPI comm.)	10	AEC-Q103
KP467	45 ... 200	± 3.0 kPa (lifetime) ± 1.5 kPa (0h) $\pm 4\%$ of LPM threshold (± 2 kPa max.)			± 3	– 3.5 mA (on mode without SPI comm.) – typ. 50 μ A (in LPM)	10	AEC-Q103 ISO 26262-compliant

1) Coming Q1/2025

KP497 – Advanced digital barometric air pressure and acceleration sensor

Features

- Pressure range for thermal runaway detection: 20–250 kPa
- Integrated acceleration sensor for battery shock monitoring
- ISO 26262-compliant (ASIL A)
- High accuracy pressure sensing
- Operating ambient temperature range -40 ... +105°C
- Ultra low power consumption with dedicated power-down mode for energy saving
- Autonomous low-power monitoring (LPM) feature for event detection and host wake-up



Applications

- KP497 calibrated for thermal-runaway-detection in battery management systems for xEVs by sensing critical air pressure
- Determination of the economical value of the battery over the course of its life cycle in relation to mechanical influences and shocks; with that essential part of the information for battery passport for xEVs and for reprocessing and reuse of batteries

Product	Operating pressure range [kPa]	P-accuracy [kPa]	T-accuracy [°C]	Typ. supply current power down at 25°C I_{VDD_PD} [μA]	Classification
KP497 ¹⁾	20 ... 250	±2	±3	0.24	AEC-Q100 ISO 26262-compliant

1) Coming Q1/2025

PRO
SIL 

ISO 26262
compliant

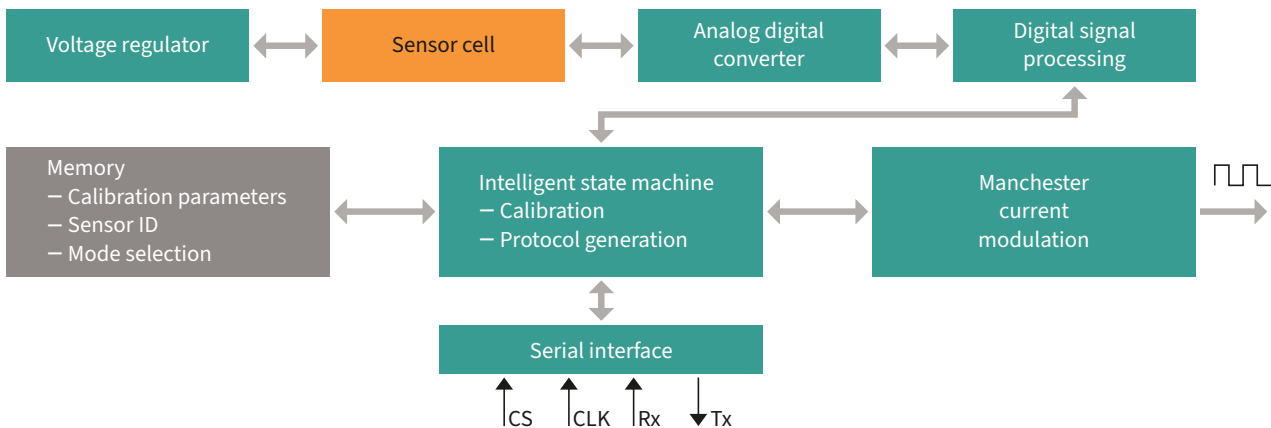
Side Crash Detection (SAB)

KP200 / KP201 / KP204

PSI5 PRO-SIL™ ready pressure sensor ICs for side crash detection and pedestrian protection

Features

- Two-wire interface with on-chip current modulator for PSI5 communication
 - Fully PSI5 compliant with support for multiple modes
 - Synchronous or asynchronous data transmission
 - EEPROM for unique ID number, calibration and mode selection
 - Serial service interface for EEPROM programming
 - On-chip voltage regulator
 - Reverse polarity protection
 - Fully AK-LV29 and AK-LV38 compliant
 - Patented on-chip diagnosis of pressure cells and circuitry
 - PRO-SIL™ support in line with IEC 61508 and ISO 26262
 - Green SMD package
- KP201 qualified for higher operating temperatures up to 125°C
 - KP204 with 4-hole lid supporting insect intrusion protection



Integrated pressure sensor ICs for manifold and barometric air pressure

Product family KP20x	Key features of KP201 and KP204	Classification
<u>KP200</u> / <u>KP201</u> / <u>KP204</u>	KP201 qualified for higher operating temperatures up to 125°C KP204 with 4-hole lid supporting protection against insect intrusion	ISO 26262-ready

PRO
SIL 

ISO 26262
ready

1) More information on PRO-SIL™, see page 112

Tire Pressure Sensors (TPMS)

SP49 – Tire pressure monitoring sensors

The Infineon SP49 product family provides highly integrated devices which perform all functions for a wheel module of a tire pressure monitoring system (TPMS) suited for high-volume applications. The devices measure pressure in the range from 100 kPa up to 920 kPa and acceleration between -600g and 600g as well as temperature and supply voltage. Furthermore, they feature an efficient power management and an integrated microcontroller. An integrated LF receiver and RF transmitter allows wireless communication.

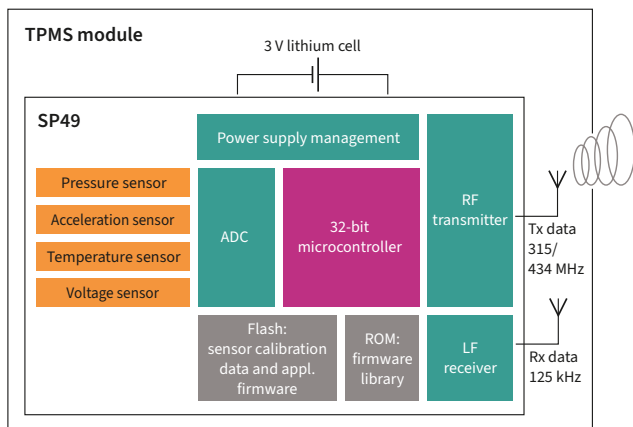
For wired data transfer, the hardware master/slave I²C interface can be used. Further wired interfaces such as UART, SPI or PWM can be realized in software. Infineon technical leadership in MEMS technology and Patented Glass-Silicon-Glass MEMS pressure sensor with best-in-class media compatibility ensures industry leading performance TPMS.

Features

Patented Glass-Silicon-Glass MEMS pressure sensor with best in class media compatibility

- Industry-standard power efficient 32-bit Arm[®] Cortex[®] 1)
- 19 kB of flash memory for the application code and/or user data storage; also usable for a bootloader
- 1 kB RAM plus 192 bytes of retention RAM
- Best in class lifetime charge consumption

1) ARM[®] and Cortex[®] are trademarks of ARM limited, UK

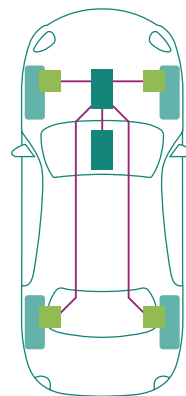


Customer benefits

Optimized for battery-powered applications, the system controller with flexible wake-up and power management, ultra-low power down current and the wide range of supply voltage ensures a long-lasting battery lifetime (for typical TPMS applications 10 years with a CR2032 battery). Together with the possibility to generate a wake-up from the integrated Interval timer, SP49 products are perfectly suited for standalone remote pressure sensing solutions demanding low charge consumption. For such applications, the LF receiver with wake-up capability and best-in-class sensitivity provides the possibility of on-demand measurements.

SP49 has the tailored ASIC which optimized for the following new intelligent tire features.

- On-tire auto-position-sensing (APS)
- Tire filling assist
- Tire burst detection
- Load detection



SP49 fully supports all necessary requirements for a tire pressure monitoring system (TPMS)

Product table

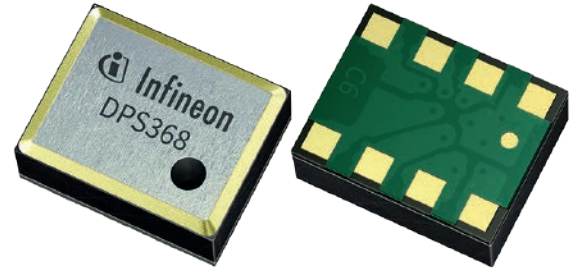
Product variant	Product name	Pressure range [kPa]	Flash size for code [kB]	Package	Ordering code
SP490-01-11	SP49	920	19	DSOSP-14-84	SP005878909
SP490-01-12	SP49i	920	19	DSOSP-14-84	SP005825051
SP49T-05-12	SP49iTruck	1600	19	DSOSP-14-84	SP005957469

Pressure sensors for consumer and IoT

DPS368 – Digital barometric pressure sensor for mobile and wearable devices

Infineon's digital barometric pressure sensor DPS368 is the best choice for mobile and wearable devices due to its small form factor, high precision, and low power consumption. Pressure sensing is based on capacitive technology, which guarantees ultrahigh precision (± 2 cm) and excellent relative accuracy (± 0.06 hPa) over a wide temperature range. The sensor's internal signal processor converts the output from the pressure and temperature sensor elements to 24-bit results. Each pressure sensor has been calibrated individually and contains calibration coefficients. The coefficients are used in the application to convert the measurement results to true pressure and temperature values. The sensor has a FIFO that can store the last 32 measurements. Since the host processor can remain in a sleep mode for a longer period between readouts, a FIFO can reduce the system power consumption. Sensor measurements and calibration coefficients are available via the serial I²C/SPI interface.

DPS368 offers the best-in-class resolution (± 2 cm), a very fast read-out speed, and low current consumption. The sensor can be used in harsh environments, as it is robust against water (IPx8 - 50 m underwater for 1 hour), dust and humidity. The small package size saves up to 80 percent of the space and makes the DPS368 ideal for mobile applications and wearable devices.



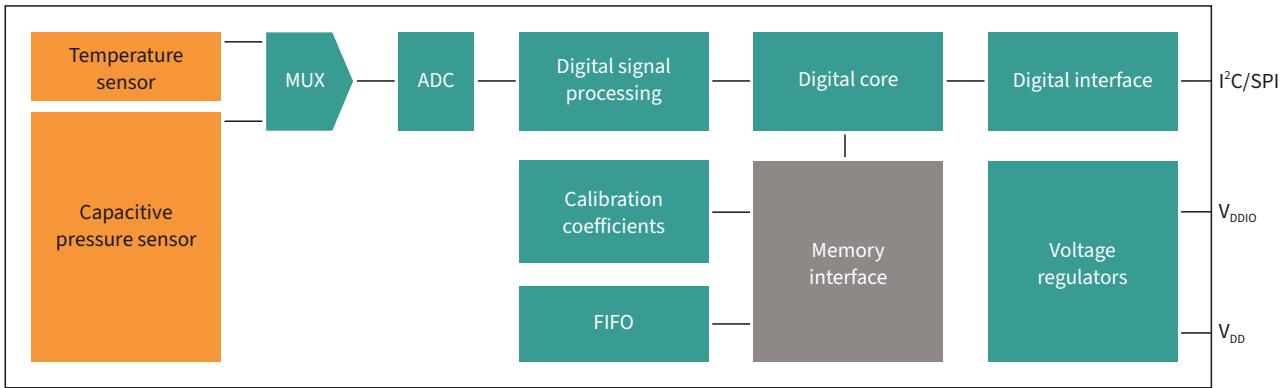
Typical applications

- Drones: altitude detection and height stability
- Health and fitness: accurate elevation gain and step counting (e.g. for smartwatches)
- Outdoor Navigation: GPS start-up time/accuracy improvement; dead reckoning (e.g. in tunnels)
- Indoor navigation: floor detection e.g. in shopping malls and parking garages
- Smart home: micro weather forecasting; room temperature control; intruder detection
- Airflow control: Smart filter replacement alarm (e.g. in home appliances); predictive maintenance
- Health care: fall detection; respiratory devices; smart inhalers

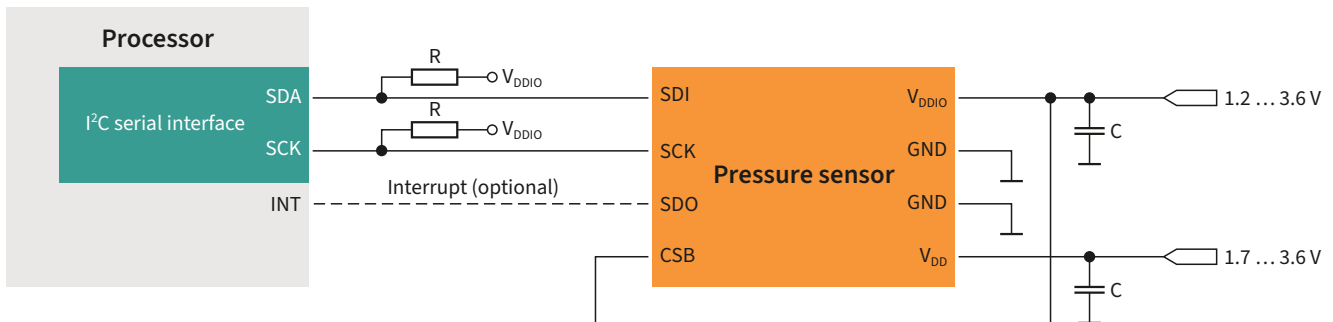
Key product features

Package size	2.0 x 2.5 x 1.1 mm
Operating pressure range	300 ... 1200 hPa
Operating temperature range	-40 ... 85°C
Pressure level precision	± 0.002 hPa (or ± 0.02 m)
Relative accuracy	± 0.06 hPa (or ± 0.5 m)
Absolute accuracy	± 1 hPa (or ± 8 m)
Temperature accuracy	0.5°C
Pressure temperature sensitivity	0.5 Pa/K
Measurement time	3.6 ms (low precision); 27.6 ms (standard mode)
Average current consumption @ 1 Hz sampling rate	1.7 μ A pressure measurement, 1.5 μ A temp. measurement, standby 0.5 μ A
Supply voltage	V_{DDIO} : 1.2–3.6 V; V_{DD} : 1.7–3.6 V
Operating modes	Command (manual), background (automatic), standby
Interface	I ² C and SPI, both with optional interrupt

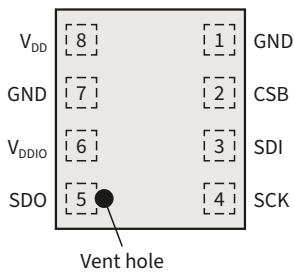
Functional block diagram



Application circuit example (in I²C configuration)



Pin configuration (top view)



Pin	Name	Function
1	GND	Ground
2	CSB	Chip select
3	SDI	Serial data in/out
4	SCK	Serial clock
5	SDO	Serial data out
6	VDDIO	Digital interface supply
7	GND	Ground
8	VDD	Analog supply

Infineon inside pressure sensor partners

Building upon its best-in-class technology, Infineon offers a full range of barometric pressure sensors as chipsets. Infineon's network of global partners offers customers a comprehensive portfolio of Infineon inside pressure sensors that will propel performance to the next level even for the most demanding applications.

Visit www.infineon.com/pressure-sensor-partners to learn more and purchase our partner solutions.





MEMS microphones for consumer, industrial, and automotive applications

Infineon XENSIV™ MEMS microphones redefine a growing number of use cases

XENSIV™ MEMS microphones are setting new performance benchmarks across a growing number of industries. These innovative silicon microphones are designed to extend the benefits of the lowest possible self-noise (high SNR) and lowest distortion to an ever-expanding number of applications.

Dedicated digital and analog MEMS mics

Our digital and analog MEMS microphones for consumer applications bring a studio-quality audio experience to smartphone or earbud form factors, for instance. Our automotive-qualified solutions, on the other hand, enable the best audio performance in harsh automotive environments improving the in-cabin user experience and passenger comfort. Additionally, they enhance autonomous driving features and contribute to road safety.

MEMS for consumer and industrial applications

Infineon's XENSIV™ MEMS microphones are designed for capturing audio signals with unprecedented precision and quality. The microphones comprise Infineon's MEMS microphone chips and ASICs which are the world's best-selling microphone components.

Due to advanced technical characteristics, high-quality standards, and robustness at the chip level, XENSIV™ MEMS microphones add 'hearing' to many consumer applications (earbuds, headphones, wear-

ables, smart speakers, laptops, tables, etc.) as well as in industrial and medical applications (predictive and preventive maintenance, security, patient monitoring systems, etc.).

High-SNR MEMS microphones play a pivotal role in AI audio applications like STT (speech-to-text), by capturing nuanced voice data.

MEMS microphones for automotive applications

We also offer high-performance MEMS microphones qualified to the AEC-Q103-003 automotive quality standard. They are suited for all applications inside and outside the car where the best audio performance in harsh automotive environments is required. The extended availability of these silicon devices matches the typical long lifecycle of a vehicle.

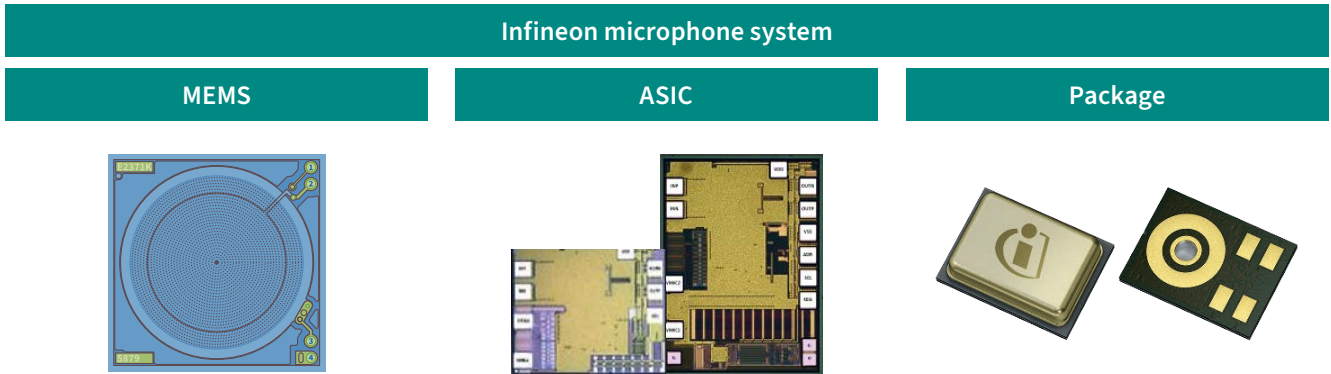
Typical applications include speech (hands-free /e-call /ICC), voice commands with microphone arrays and beamforming, active and road noise cancellation, and detection of event sounds, sirens, contact, and road conditions.

The extended availability of these silicon devices matches the typical long lifecycle of a vehicle., revolutionizing the use of ATV microphones for a wide range of applications.

MEMS microphones technology

Infinion's XENSIV™ MEMS microphones are designed for capturing audio signals with unprecedented precision and quality. The microphones are comprised of

Infinion's MEMS microphone chips and ASICs which are not without reason the world's best-selling microphone components.



Infinion owns all building blocks of MEMS microphones allowing to develop MEMS, ASIC and package combina-

tions which achieve the best possible performance and are optimized to each application.

Infineon XENSIV™ MEMS microphones shape the industry on the technology level

MEMS microphones use an electrically charged backplate and a membrane to form a capacitive sound transducer. The flexible membrane moves proportional to the amplitude and frequency of incoming sound waves.

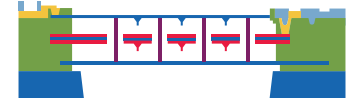
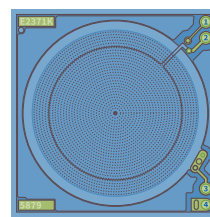
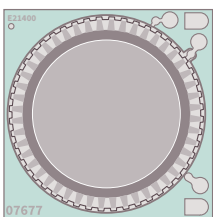
The resulting change in voltage is measured, processed and output by an integrated analog or digital ASIC. Infineon distinguishes two main MEMS technologies:

Single Backplate technology (SBP)

Single Backplate technology (SBP) represents an industry standard for mid-end microphones with its simplicity and robustness. The SBP technology offers the best performance-to-cost ratio especially for small package sizes and SNR values up to 69 dB SNR.

Sealed Dual Membrane (SDM)

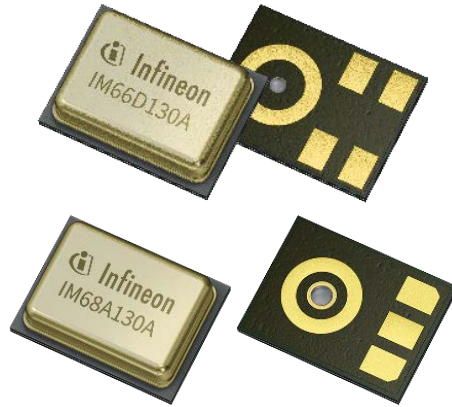
Sealed Dual Membrane (SDM) is Infineon's revolutionary MEMS microphone technology that utilizes two membranes and a charged stator to create a sealed low-pressure cavity and a differential output signal. The architecture enables ultra-high SNR (up to 75 dB SNR) and very low distortions and delivers high ingress protection (IP57) at a microphone level. Select SDM technology for best-in-class acoustic performance in medium and larger packages.



MEMS microphones for automotive applications

Qualified according to automotive standard, AEC-Q103-003

As part of our comprehensive XENSIV™ microphone family, we also offer automotive microphones, especially tested and qualified to the stringent needs of the automotive use cases. These microphones close the gap in the automotive industry, providing the best possible fit for automotive applications.



Special features and benefits of automotive qualified microphones

- Full automotive qualification according to AEC-Q103-003
- Increased operating temperature range up to +105°C ¹⁾
- Environmental robust up to IP57 ¹⁾
- Narrow sensitivity matching for enhanced performance of beam-forming arrays
- Flat frequency and stable phase response down to 7 Hz for optimal performance in acoustic noise cancellation (ANC) applications ¹⁾
- Very high AOP for high wind-noise robustness ensures stable performance in extremely loud environments of exterior use cases ¹⁾

- Best in class audio performance (SNR, AOP, THD) for optimum speech quality and capture of distortion-free audio signals in loud environments such as inside a car

¹⁾ Depending on selected product. See parameter table below for details.

Customer benefits of automotive qualified microphones

Cost saving	<ul style="list-style-type: none"> – Reduced re-qualification cost for Tier 1 due to minimized risk of qualification fails – Longer available parts enable platform concepts at Tier1/OEM
Quality	<ul style="list-style-type: none"> – Quality assured for the whole vehicle life by running qualification tests at three different temperatures over the full operating temperature range (-40°C ... +105°C) – Compliance with AEC-Q103 and automotive style documentation (PPAP, Qual report, ...) simplifies OEM discussions (no waivers needed)
Performance	<ul style="list-style-type: none"> – Characterization data over full temperature range provides full transparency of acoustic behavior and avoids late discrepancies – Best in class audio performance leads to increased speech intelligibility and improved satisfaction of the end user
Flexibility	<ul style="list-style-type: none"> – Extended temperature range allow flexible use in different operational areas (internal and external) and various applications – High acoustic-overload-point (AOP) allows flexible placement inside/outside the vehicle
Service and knowledge	<ul style="list-style-type: none"> – Good reputation of Infineon-Automotive simplifies product selection procedures with OEMs – Premium services with our worldwide support teams shortens the learning curve and design-in cycles – Fast FAR handling, including high traceability, facilitates efficient incident management

Parameter table: Digital microphones

Key parameters	IM67D130A IM67D120A Optimized for speech	IM66D130A IM66D120A Optimized for ANC and speech	IM64D130A IM64D121A Optimized for mid performance use cases	IM63D135A Optimized for external application
Signal-to-noise ratio (SNR)	67 dB(A)	66 dB(A)	64 dB(A)	63 dB(A)
Sensitivity	-36 / -26 dB FS	-36 / -26 dB FS	-36 / -26 dB FS	-41 dB FS
Acoustic overload point AOP (THD = 10%)	130 / 120 dB SPL	130 / 120 dB SPL	130 dB SPL	135 dB SPL
Frequency range	28 Hz ... 20 kHz	7 Hz ... >20 kHz	7 Hz ... >20 kHz	7 Hz ... >20 kHz
Package	4.0 x 3.0 mm ²	3.50 x 2.65 mm ²	3.50 x 2.65 mm ²	3.50 x 2.65 mm ²
Operating temp.	-40°C ... +105°C	-40°C ... +105°C	-40°C ... +105°C	-40°C ... +105°C
AEC-Q103-003 qualification	Yes	Yes	Yes	Yes
Environmental robustness	–	IP57	IP57	IP57
Status	Active & preferred	Active & preferred	Active & preferred	Active & preferred

Parameter table: Analog microphones

Key parameters	IM68A130A Optimized for ANC	IM64A130A Optimized for mid performance use cases
Signal-to-noise ratio (SNR)	68 dB(A)	64 dB(A)
Sensitivity	-38 dB V	-38 dB V
Acoustic overload point AOP (THD = 10%)	130 dB SPL	130 dB SPL
Frequency range	10 Hz ... 18 kHz	10 Hz ... 18 kHz
Package	3.35 x 2.50 mm ²	3.35 x 2.50 mm ²
Operating temp.	-40°C ... +105°C	-40°C ... +105°C
AEC-Q103-003 qualification	Yes	Yes
Environmental robustness	IP57	IP57
Status	Active & preferred	Active & preferred

Typical applications for automotive MEMS microphones in-cabin and outside of the vehicle



Speech: Hands free / e-call / ICC
 Enabling distortion free audio capturing for all speech related application thanks to the high SNR and low distortions.
Recommended products:
 IM66D1x0A, IM68A130A, IM64D1xxA, IM64A130A

Interior



Speech: Microphone arrays / beamforming
 Improved beam forming and noise suppression capabilities of microphone arrays, due to the narrow sensitivity and phase matching.
Recommended products:
 IM67D1x0A, IM66D1x0A

Interior



Speech recognition / voice commands
 Best speech intelligibility for speech recognition due to high SNR and low distortions.
Recommended products:
 IM67D1x0A, IM66D1x0A, IM68A130A

Interior



Active and road noise cancellation (ANC / RNC)
 Enabling a quiet environment for comfortable travels with best ANC performance, thanks to the flat and stable frequency and phase response at lowest frequencies.
Recommended products:
 IM66D1x0A, IM68A130A

Interior



Event sound detection / siren detection
 Contributing to road safety, by detecting sounds like sirens from emergency vehicles or even dangerous road conditions even thanks to the large dynamic range and high acoustic overload point.
Recommended products:
 IM63D135A, IM66D130A, IM68A130A

Exterior











Voice recognition / external interaction
 Allowing external interaction via voice commands and good speech intelligibility due to high SNR and low distortions (THD)
Recommended products:
 IM66D130A, IM63D135A

Exterior

MEMS microphones for consumer applications

XENSIV™ MEMS microphones feature ultra-low self-noise (high SNR), extremely low distortions (THD) even at high sound pressure levels (SPL), very tight part-to-part phase and sensitivity matching, a flat frequency response with a low LFRO (low frequency roll-off) and an ultra-low group delay. Combined with selectable

power modes and their very small package size, Infineon XENSIV™ MEMS microphones are a perfect match for consumer electronics with excellent audio capturing functionalities and also for selected industrial applications such as predictive maintenance and security.









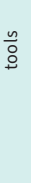
Low-noise capturing of the faintest sounds	High SNR	Wide dynamic range			Robustness	Integrated ingress protection and filters for RF suppression ensure stable performance in challenging environments
Enables best-in-class transparent hearing and active noise cancelling functionality					Low power consumption	Selectable power modes for long-lasting battery life
Low signal distortions even at high sound pressure levels	High AOP				Low part variability	Better manufacturability and performance with low group delay for multi-mic applications
Handling of high signal peaks for reliable ANC performance (e.g. concerts, traffic, tap noise)					Quality	Highest qualification standards and 100% test coverage during manufacturing

XENSIV™ MEMS product portfolio

	Infineon model	Main features	Interface	Package size [mm]	SNR	AOP (1/10%THD)	Current	Sensitivity	LFRO [Hz]
Digital	IM69D130	High SNR and high AOP	PDM	4.00 x 3.00 x 1.20	69 dB(A)	128/130 dB SPL	980 µA @ 3.072 MHz	-36 dBFS	28
	IM69D120	High SNR and sensitivity	PDM	4.00 x 3.00 x 1.20	69 dB(A)	118/120 dB SPL	980 µA @ 3.072 MHz	-26 dBFS	28
	IM69D127	High performance in small size	PDM	3.60 x 2.50 x 1.00	69 dB(A)	123/127 dB SPL	980 µA @ 3.072 MHz	-34 dBFS	40
	IM69D128S	Ultra-low current consumption	PDM	3.50 x 2.65 x 1.00	69 dB(A)	125/128 dB SPL	520 µA @ 3.072 MHz	-37 dBFS	30
	IM70D122	High SNR and sensitivity	PDM	3.50 x 2.65 x 1.00	70 dB(A)	120/122 dB SPL	980 µA @ 3.072 MHz	-26 dBFS	30
	IM72D128	Ultra-high SNR	PDM	4.00 x 3.00 x 1.20	72 dB(A)	126/128 dB SPL	980 µA @ 3.072 MHz	-36 dBFS	20
Analog	IM73D122	Ultra-high SNR & sensitivity	PDM	4.00 x 3.00 x 1.20	73 dB(A)	120/122 dB SPL	980 µA @ 3.072 MHz	-26 dBFS	20
	IM68A130	Small package and low LFRO	Single ended	3.35 x 2.50 x 0.98	68 dB(A)	118/130 dB SPL	110 µA @ 2.75 V	-38 dBV	10
	IM70A135	High SNR & high AOP	Differential	3.50 x 2.65 x 1.00	70 dB(A)	132/135 dB SPL	170 µA @ 2.75 V	-38 dBV	37
	IM73A135	Ultra-high SNR & high AOP	Differential	4.00 x 3.00 x 1.20	73 dB(A)	132/135 dB SPL	170 µA @ 2.75 V	-38 dBV	20

All XENSIV™ consumer microphones have bottom port. Due to SDM (Sealed Dual Membrane) XENSIV™ microphone deliver IP57 ingress protection on the component level for better manufacturability and robustness against water and dust.

XENSIV™ MEMS microphone boards

Product	Description	SP No.	OPN No.	Board
EVAL_AHNB_DIGITALV01	Digital XENSIV™ MEMS microphones evaluation board		EVALAHNB DIGITALV01TOBO1	        
EVAL_AHNB_ANALOGV01	Analog XENSIV™ MEMS microphones evaluation board	SP005568087	EVALAHNBANALOGV01TOBO1	
EVAL_IM69D120_FLEXKIT	The flex evaluation kits allow simple and easy evaluation of XENSIV™ MEMS microphones. One microphone of the respective type is mounted on each flex board. A flex board can be easily connected to an audio testing setup with the included adapter board via a 6-position ZIF connector. Each kit includes five flex boards and one adapter board.	SP002153026	EVALIM69D120FLEXKITTOBO1	
EVAL_IM69D130_FLEXKIT		SP002153022	EVALIM69D130FLEXKITTOBO1	
KIT_IM68A130V01_FLEX		SP005728206	KITIM68A130V01FLEXTOBO1	
KIT_IM69D127V11_FLEX		SP005403891	KITIM69D127V11FLEXTOBO1	
KIT_IM69D128SV01_FLEX		SP005744505	KITIM69D128SV01FLEXTOBO1	
KIT_IM70A135V01_FLEX		SP005728204	KITIM70A135V01FLEXTOBO1	
KIT_IM70D122V01_FLEX		SP005826638	KITIM70D122V01FLEXTOBO1	
KIT_IM72D128V01_FLEX		SP005429924	KITIM72D128V01FLEXTOBO1	
KIT_IM73A135V01_FLEX		SP005415695	KITIM73A135V01FLEXTOBO1	
KIT_IM73D122V01_FLEX		SP005728208	KITIM73D122V01FLEXTOBO1	

Features, applications and use cases for MEMS microphones for consumer

Features

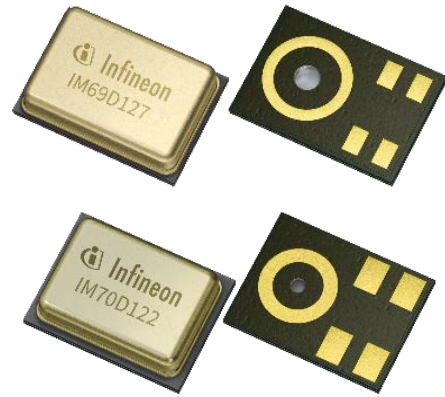
- Ultra-low self-noise / ultra-high SNR
- Selectable power modes for longer battery life
- Sealed Dual Membrane (SDM) technology with ingress protection at microphone level
- Extremely low distortions (THD) even at high sound pressure levels
- High dynamic range and very high acoustic overload points (AOP)
- Very tight part-to-part phase and sensitivity matching
- Flat frequency response with a low LFRO (low frequency roll-off)
- Ultra-low group delay for multi-mic applications
- Very small package sizes for various applications

Typical use cases

- Studio quality audio capturing for communication devices
- Low latency wide band audio signal capturing for Active Noise Cancellation (ANC) and transparent hearing functionality
- Small form factor & current consumption for battery and size constraint devices
- Multi-microphone (array) based beamforming and source separation for audio zoom features and multi user audio capturing
- High range, far field voice pickup for multi room applications
- Capturing of audio signals in loud environments, such as outdoor
- Audio pattern detection for predictive and preventive maintenance and security

XENSIV™ MEMS microphone partners

Building upon the superior XENSIV™ MEMS microphone performance, Infineon's extensive network of global partners offers customers a comprehensive portfolio of XENSIV™ MEMS microphone-based reference designs, as well as Infineon inside MEMS microphones that will propel audio performance to the next level even for the most demanding applications.



Applications

- TWS earbuds
- ANC headphones
- Smart speakers
- Conference speakers
- Laptops / tablets
- Wearables
- AR/VR devices
- Cameras
- Video doorbells
- Smart home
- Smart infrastructure
- Home appliances
- Industrial applications
- Medical applications



Infineon
Partner Program

[Learn more about our partners.](#)



Radar sensors for consumer, industrial and automotive applications

Giving technology the ability to “see”

Radar offers a host of advantages over passive infrared (PIR) technology in motion detection applications. These include greater accuracy and more precise measurement of detected objects, paving the way for new capabilities in speed detection and motion sensing. These advanced capabilities enable all sorts of “things” such as robots, cars, smart home devices and even lights to “see” their surroundings and respond dynamically.

Market leader in radar chips, we offer a wide portfolio of mmWave radar sensors as part of our XENSIV™ family. Designed to support different industrial, consumer and automotive applications, Infineon’s millimeter wave (mmWave) radar portfolio offers both FMCW as well as Doppler radar sensors supporting 24 GHz, 60 GHz and 77/79 GHz. In addition, customers can rely on us for the full range of automotive radar 24 GHz, 60 GHz and 77/79 GHz front-end MMICs (RASIC™) supporting everything from warning functions (e.g. LCA/BSD) to active safety systems such as Automatic Emergency Braking (AEB) and even to dynamic driving tasks like ACC.

Automotive radar 24GHz

XENSIV™ 24GHz pulsed doppler radar transceiver BGT24ATR22

The BGT24ATR22 is a Monolithic Microwave Integrated Circuit (MMIC) for 24GHz radar applications. It provides building blocks for analog signal generation and

reception, operating in the frequency range from 24 GHz up to 24.25 GHz.

Key features

- 24GHz radar transceiver
- 2 Tx channels
- 2 Rx channels
- Low-phase noise VCO
- Automatic frequency control
- Automatic DC offset compensation
- State machine with ultra-low power modes
- 12-bit ADC
- Digital radar data processing unit
- Temperature range: -40°C to +105°C
- VQFN-32 RoHS compliant, leadless package

Applications

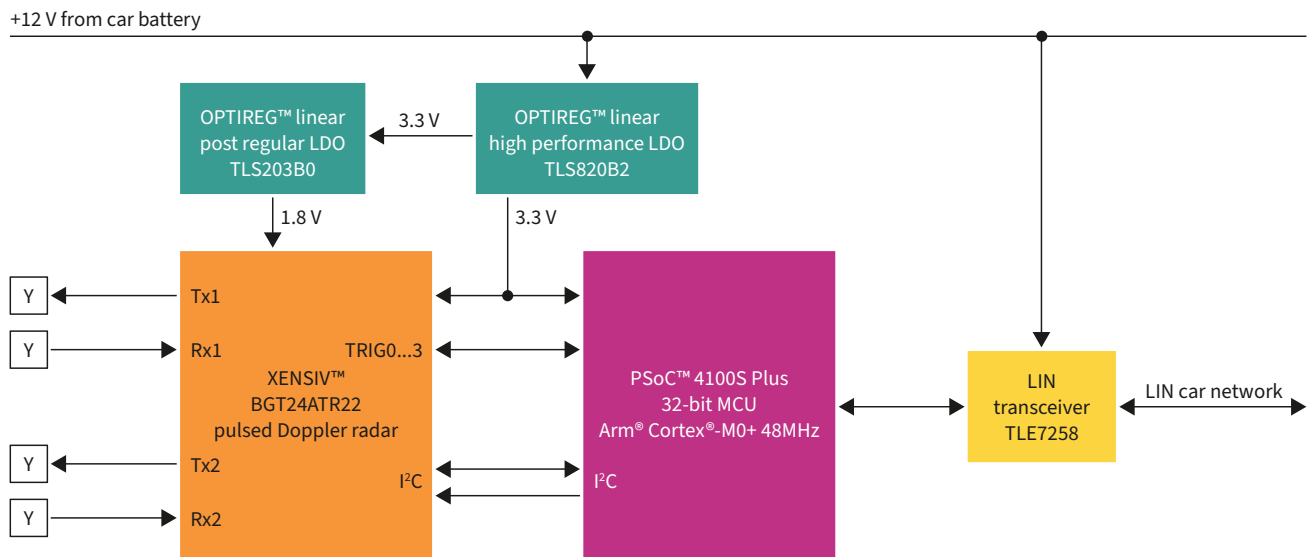
- Automotive short-range radar
- Hands-free trunk and door opening
- Motion detection
- Touchless switches



Benefits

- Compact PCB design due to high level of integration
- Ultra-low power consumption modes for 24/7 use cases
- Low system costs due entry-level only microcontrollers
- Autonomous motion sensing
- Globally approved 24GHz radar with excellent characteristics for robust and reliable performance in harsh environmental conditions

Smart trunk opener system diagram



24 GHz – Product overview

Product	OPN	Qualification	Frequency min Frequency max	NF	Packages
BGT24ATR22	BGT24ATR22E6433XUMA1 2	AEC-Q100	24–24.25	NFSSB: 13 dB @ 1 kHz	VQFN-32-9

Automotive radar 60GHz

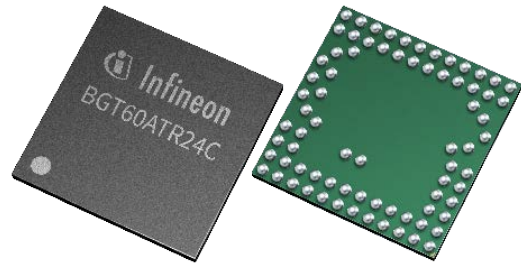
XENSIV™ 60GHz radar sensor for automotive enables highly reliable in-cabin monitoring systems

XENSIV™ BGT60ATR24C, an automotive 60GHz radar sensor, enables ultra-wide bandwidth FMCW operation in a small package. Sensor configuration and data acquisition are enabled with a digital interface and the

integrated state machine enables independent data acquisition with power mode optimization for lowest power consumption.

Summary of features

- 60GHz radar sensor for FMCW operation
- 4GHz bandwidth
- 2Tx/4Rx channels
- Digital interface for chip configuration and radar data acquisition
- Optimized power modes for low-power operation
- Integrated state machine for independent operation
- AEC-Q100/101 qualified

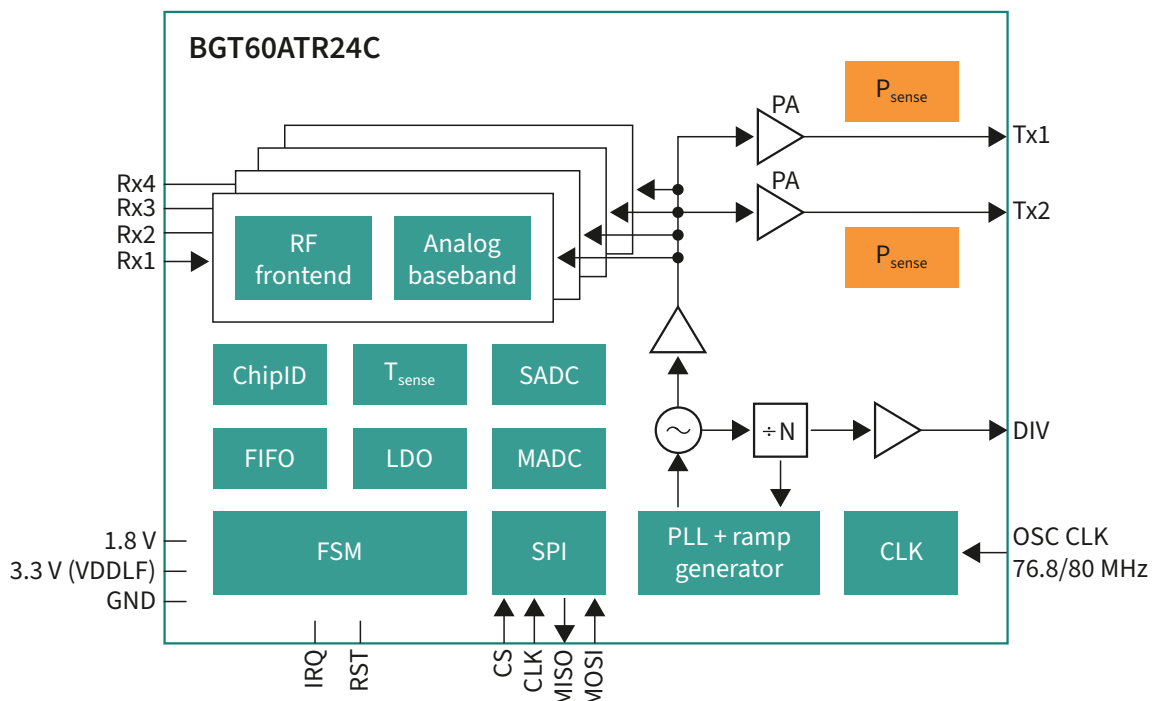


Benefits

- Low power consumption
- Accurate and robust performance
- Excellent thermal management
- Size and space optimized solution

Potential applications

- Radar frontend for gesture sensing
- High resolution FMCW radars
- Short range sensing operations
- Hidden sensing applications behind radome



60 GHz – Product overview

Product	Frequency [GHz]	SP number	Packages
BGT60ATR24C	58-62	SP005350514	VFWLB-76-1
SHIELD_60ATR24ES_01	58-62	SP005448216	VFWLB-76-1

RASIC™ automotive radar 77/79GHz

Front-end ICs for automotive radars

RXS81xxx – family of transceiver MMICs for 77GHz automotive radar

Infinion has been delivering automotive 77GHz radar products for over 10 years. Infineon’s family of radar transceiver MEMs (RASIC™) addresses the needs of 77/79GHz radar for all safety-critical applications from Automatic Emergency-Braking (AEB) to high-resolution radars in automated driving. It supports for precise distance measurement and simultaneous transmitter operation for MIMO.

RXS81xxx is a highly integrated device that performs all functions of a radar front-end in a single device – from FMCW signal conditioning to generation of digital receive data output. On-chip sensors for temperature, output power and multiple monitoring circuits allow for calibration and monitoring. Controlling the MMIC is done via SPI.

Infinion offers a complete suite of 77/79GHz radar chipsets consisting of

- Radar 77GHz transceiver MMIC (RASIC™) with RXS81xxx
- Radar MCU family featuring radar signal processing units (2nd generation AURIX™ TC3xx)
- Radar system power supply with numerous safety functions (TLF3068x)

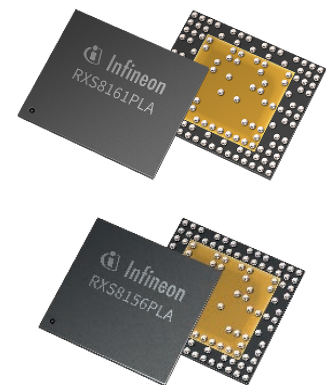
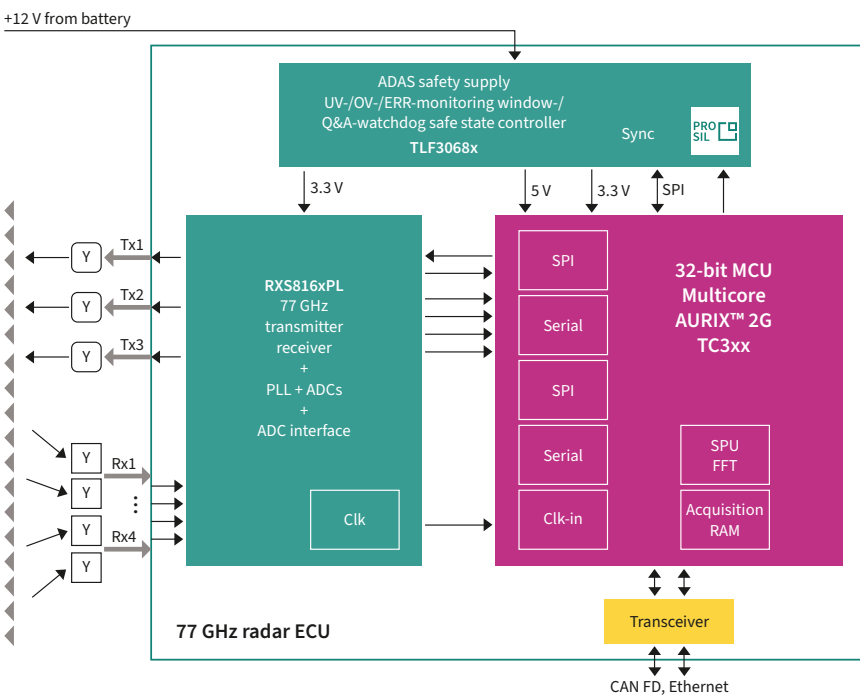
Customer benefits:

- One 77/79GHz radar platform supporting all types of automotive radar applications
- Scalability by cascading multiple MMICs and MCUs enabling most advanced sensors
- Flexibility through numerous configuration parameters
- ASIL C support reducing customer R&D efforts

77 GHz – Product overview

Product	Config.	Key benefits	Features
RXS816xPL	3Tx4Rx	RXS8161PLx: Standalone transceiver MMIC RXS8162PLD: Transceiver MMIC for cascaded setup	<ul style="list-style-type: none"> – Transmit channels (2Tx or 3Tx, up to 1 GHz BW within 76–77GHz) – Receive channels: 4Rx – Integrated PLL (Phase Locked Loop) – Sequencer enabling the execution of a user-defined ramp configuration – Integrated Analog-to-Digital Converter (ADC) – Integrated calibration functionality – Build-in monitoring functionality – Compliant to ISO 26262; capable for up to ASIL C
RXS8156PLA	2Tx4Rx	RXS8156PLA: Cost-optimized transceiver MMIC	

Please be aware that 77/79GHz radar products are not available via Infineon’s distribution partners.



ISO 26262 compliant

Radar sensors for IoT & consumer devices

As market leader in radar chips, we offer a wide portfolio of mmWave radar sensors as part of our XENSIV™ sensor family – including Doppler radar as well as FMCW radar systems. This portfolio includes the smallest 24 GHz MMIC in the market as well as the most integrated and largest 24GHz radar transceiver family

currently available. These radar chips are designed to support different industrial, smart home, and consumer applications. In addition, we also offer radar sensors in the 60 GHz range, which are used in consumer products such as the Google Pixel 4 smartphone.

Motion detection with radar offers significant advantages over PIR and other motion-sensing technologies

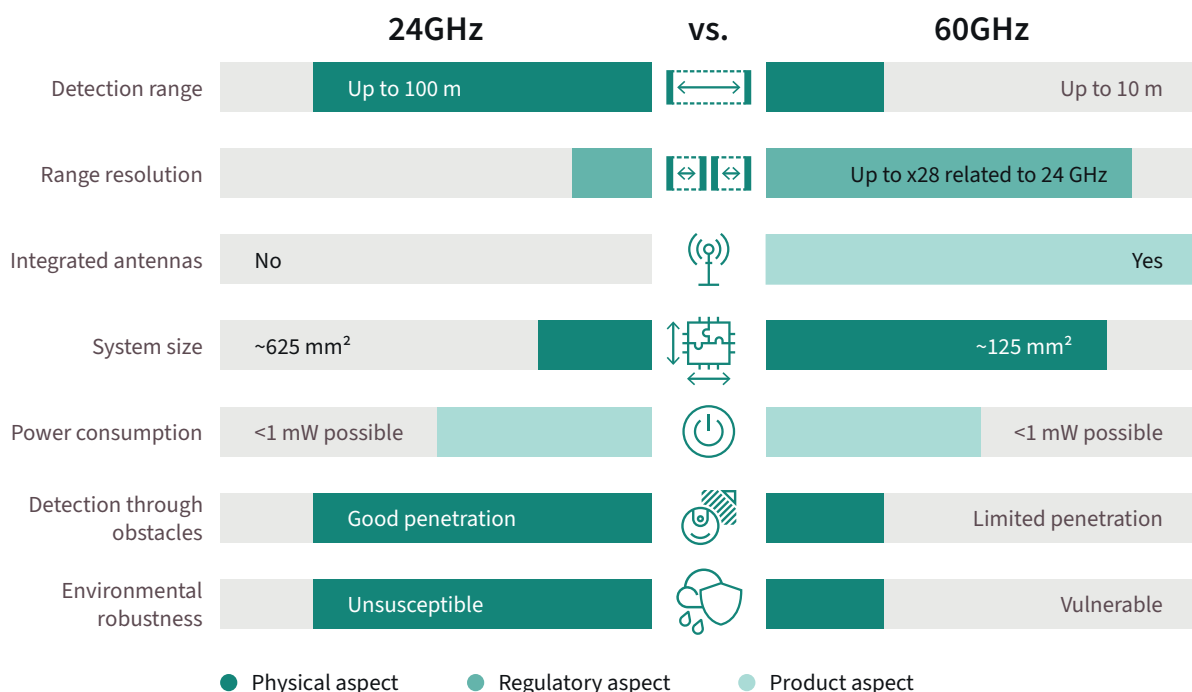
With our 24 and 60GHz radar sensors, we cover a wide range of applications. Many of them are based on motion detection triggering systems like lighting solutions, automatic doors, camera and security systems, or smart home devices. In contrast to other motion detection technologies like PIR, radar technology offers significant advantages.

These include smaller system sizes, greater accuracy, and more precise measurements of detected objects. In addition, radar can also determine the direction of a moving object, speed of an object, distance, and depending on the antenna configuration, even the position of a moving object.















When to use 24GHz or 60GHz radar technology

In the 24 GHz range, the bandwidth for FMCW radar operations covers 250 MHz within the regulated ISM band. In the 60 GHz regime, an unlicensed ultra-wide-band of up to 7 GHz can be used for short-range applications. Consequently, 60GHz FMCW radar systems can offer a better resolution and therefore allow additional

use cases such as human tracking and segmentation. Even gesture control, material classification, or the monitoring of various vital functions (respiration, heartbeat, or even blood pressure) is possible with radar technology due to micromotion detection.



Radar implementation can bring several benefits to different applications:

<p>Smart Home</p>  <p>Robust, discreet, small</p>	<p>Door opening</p>  <p>Direction of travel to remove false opening</p>	<p>Security</p>  <p>Security camera and doorbells</p>	<p>Lighting</p>  <p>Indoor and outdoor. Resistant to harsh weather</p>
<p>Monitors and laptops</p>  <p>Small, hidden, sensitive</p>	<p>Home appliances</p>  <p>Activate displays and control it with gestures</p>	<p>Air conditioners</p>  <p>Track people to move the airflow away from them</p>	<p>Smart speaker</p>  <p>Eliminate keyword based activation</p>
<p>TV</p>  <p>Safe energy & OLED lifetime by turning off</p>	<p>Gaming and VR</p>  <p>Enhance gaming experience</p>	<p>Smart toilet</p>  <p>Presence sensing and water level detection</p>	<p>Service robots</p>  <p>Robust, small footprint, accurate</p>
<p>Robotics</p>  <p>Safety, accuracy and efficiency</p>	<p>Sleep monitoring systems</p>  <p>Breathing & heart rate measurement</p>		

Summary of key benefits

- Direction, proximity, and speed detection
- Segmentation and tracking functionalities
- Target positioning
- Detection through non-conductive materials
 - Product design flexibility
 - Anonymous sensing
- Maintains operation through harsh environmental conditions such as rain, snow, fog, dust, etc.
- Sensitive enough to capture breathing and heartbeat
 - Radar can feel presence & vital functions
- Radar performance parameters can be adjusted
 - Adaptable to different application requirements

60GHz radar sensors for consumer and IoT

Infineon's innovative XENSIV™ 60GHz radar chip enables things to see and revolutionizes the human-machine interface.

Product portfolio

Product	SP	OPN	Description	Packages
BGT60LTR11AIP	SP005537624	BGT60LTR11SAIPXUMA1	XENSIV™ 60GHz first completely autonomous radar sensor for motion sensing	UF2BGA-42
BGT60LTR11SAIP	SP005832449	BGT60LTR11SAIPXUMA1	XENSIV™ 60GHz first completely autonomous radar sensor for motion sensing	
DEMO BGT60LTR11AIP	SP005422969	DEMOBGT60LTR11AIPTOBO1	Demonstration kit (Shield + 60 GHz baseboard)	
SHIELD_BGT60LTR11AIP	SP005422968	SHIELDBGT60LTR11AIPTOBO1	Shield fitting on 60 GHz baseboard	
SHIELD_AUTONOM_BGT60	SP005630363	SHIELDAUTONOMBGT60TOBO1	Shield for autonomous operation of BGT60LTR11AIP; directly fits on Arduino MKR board	
REF_BGT60LTR11AIP	SP005636053	REFBGT60LTR11AIPTOBO1	Reference design	
S2GO RADAR BGT60LTR11	SP005594890	S2GORADARBGT60LTR11TOBO1	Shield2Go version	
BGT60TR13C	SP002262606	BGT60TR13CE6327XUMA1	XENSIV™ 60GHz radar sensor for advanced sensing	VF2BGA-40
DEMO BGT60TR13C	SP005728718	DEMOBGT60TR13CTOBO1	XENSIV™ 60GHz radar sensor demo board for advanced sensing	
BGT60UTR11AIP	SP005407929	BGT60UTR11AIPXUMA1	XENSIV™ highly integrated 60GHz FMCW radar sensor	VF2BGA-28
DEMO BGT60UTR11AIP	SP005745304	DEMOBGT60UTR11AIPTOBO1	XENSIV™ BGT60UTR11AIP 60GHz radar sensor FMCW demo board	

[BGT60LTR11AIP](#) – XENSIV™ 60GHz first completely autonomous radar sensor for motion sensing

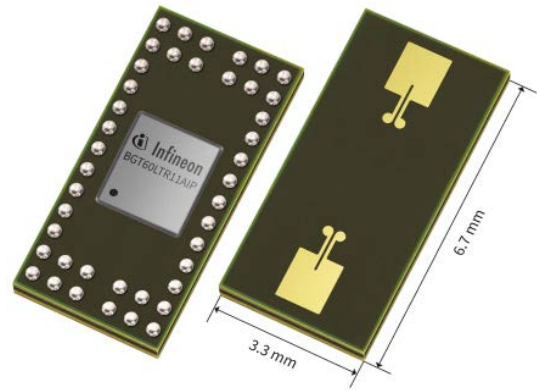
The BGT60LTR11AIP is a fully integrated microwave motion sensor including Antennas in Package (AIP) as well as builtin detectors for motion and direction of motion. A state machine enables operation of the device without any external microcontroller. In this autonomous mode, it detects a human target up to 7 m with a low power consumption of less than 2 mW. The BGT60LTR11AIP enables radar technology for everyone, since it does not require know-how in RF, antenna design, or radar signal processing. These features make the small-sized radar solution a compelling smart and cost-effective replacement for conventional PIR sensors in low power or battery-powered applications. Also, with its small form factor, Infineon's highly integrated radar sensor solutions bring innovative, intuitive sensing capabilities to many applications.

Radar has been demonstrated to be a powerful sensor for short-range motion detection. Through reliable presence and absence detection, smart devices equipped with radar sensors become more energy efficient and therefore smart and more sustainable. Users can also benefit from vacancy detection in applications such as televisions. For example BGT60LTR11AIP has been implemented in Samsung's Frame TV 2021, which puts the TV from art mode into sleep mode when there is no person nearby for a user-specified time. This function not only saves energy, but also displays lifetime. BGT60LTR11AIP has a high sensitivity and can detect if a person is present and if the device needs to be ready – similar to a screensaver that deactivates the PC monitor after a certain time without mouse or keyboard input and reactivates it as soon as new input is noticed.

Through this reliable presence and absence detection, Infineon's 60GHz radar powers the design of truly smart, energysaving devices. Find out more at: www.infineon.com/green-energy

Key features

- 3.3 x 6.7 x 0.56 mm package size
- 1Tx 1Rx Antennas in Package (AIP) with 80° field of view
- Built-in motion detector
- Built-in direction of motion detector
- Multiple modes of operation incl. a completely autonomous mode
- Adjustable performance parameters: detection sensitivity, hold time and frequency of operation
- FR4 material for PCB design is sufficient



Target application

- Smart building and smart home
- Home appliances
- Smart home security
- Room air conditioners
- Automated door openers
- Smart entrance counter solution
- Displays such as TVs, monitors, laptops or tablets
- Lighting systems and lighting control

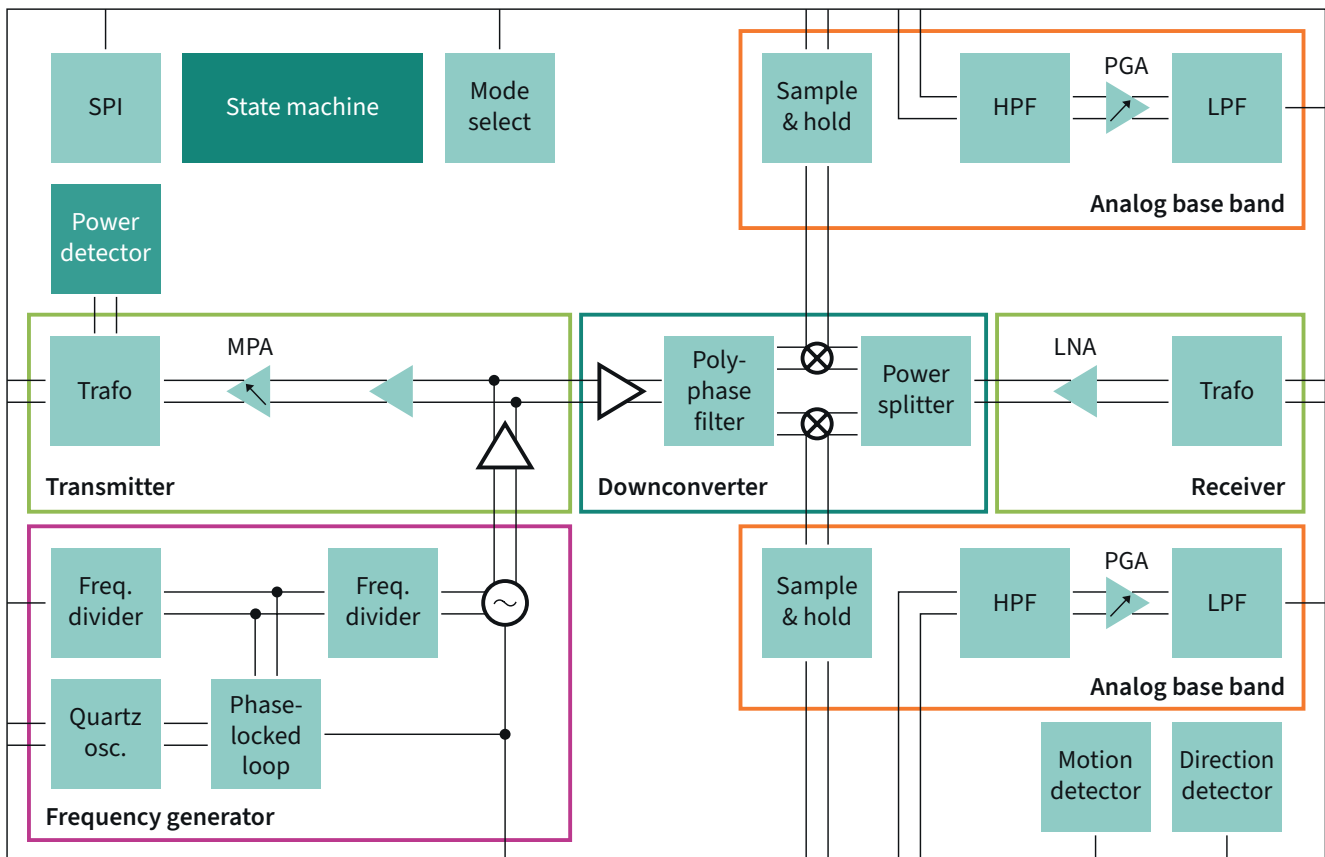
Key benefits

- Autonomous mode
 - Up to 7 m detection range
 - Less than 2 mW power consumption
 - Requires minimal external circuitry incl. crystal, LDO and some resistors capacitors

Adding a M0 MCU extends flexibility

- Up to 14 m detection range (SPI mode)
- Less than 2 mW power consumption possible

Block diagram of the BGT60LTR11AIP



DEMO BGT60LTR11AIP

For evaluation of the completely autonomous 60GHz radar sensor MMIC for motion sensing

This demo features Infineon's first completely autonomous radar sensor – the BGT60LTR11AIP. The 60GHz radar MMIC is a fully integrated microwave motion sensor including Antennas in Package (AIP) as well as integrated detectors for motion and direction of motion. A state machine enables operation of the device without any external microcontroller. In this autonomous mode, it detects a human target up to 7 m with a low-power consumption of less than 2 mW. These features make the small-sized radar solution a compelling, smart and cost-effective replacement for conventional PIR sensors in low-power or battery-powered applications.

For evaluation of the BGT60LTR11AIP MMIC, this demo includes the BGT60LTR11AIP shield as well as the Infineon Radar Baseboard MCU7.

The BGT60LTR11AIP shield can be attached to an Arduino MKR board or the included Infineon Radar Baseboard MCU7. Infineon's Toolbox supports this platform with a demonstration software and a Radar GUI to display and analyze acquired data in time and frequency domain. It further enables to change various performance parameters of the BGT60LTR11AIP in order to evaluate this radar sensor.



BGT60TR13C – XENSIV™ 60GHz radar sensor for advance sensing

Enablement of horizontal and vertical angular measurement

The BGT60TR13C MMIC is a 60GHz radar sensor with integrated antennas and comes with one transmitting and three receiving antennas. Thanks to the Antennas in Package (AIP) concept, the antenna design complexity at the user end can be eliminated and the PCB designed with standard FR4 materials.

BGT60TR13C offers innovative and intuitive sensing capabilities

With its small form factor and low power consumption, BGT60TR13C MMIC brings innovative, intuitive sensing capabilities to many applications. Based on the developed algorithm the MMIC can serve established as well as new applications and use cases without intruding on

Key features

- Integrated Finite-State-Machine (FSM)
- Very fast chirp speed: 400 MHz/μs
- High Signal-To-Noise Ratio (SNR)
- Ultra-wide bandwidth > 5 GHz
- FMCW operation
- Integrated L-shaped antennas + small package size (6.5 x 5.0 x 0.9 mm³)
- < 5 mW (duty cycling according to released FCC waiver)

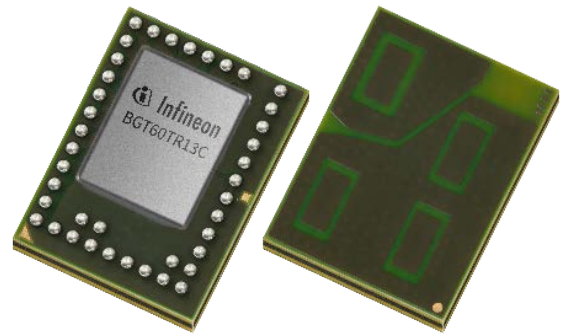
Key benefits

- Allows semi-autonomous operation
- Highly configurable modulation and power modes
- MCU only needs to configure sensor and fetch data
- High velocity resolution
- People can be detected up to 15 m
- High sensitivity allows submillimeter level motion detection
- Allows simultaneous measurement of target range and velocity
- High accuracy of range measurements
- Reduced interference with other sensors
- L-shape enables horizontal and vertical angular measurements
- Thanks to small package size, PCB area can be saved + design-in process simplified
- Reduces average power consumption
- Optimized power modes for low power consumption

privacy. Thanks to its feature-set, the MMIC can measure velocity, angle, horizontal as well as vertical.

BGT60TR13C has been demonstrated to be a powerful sensor for:

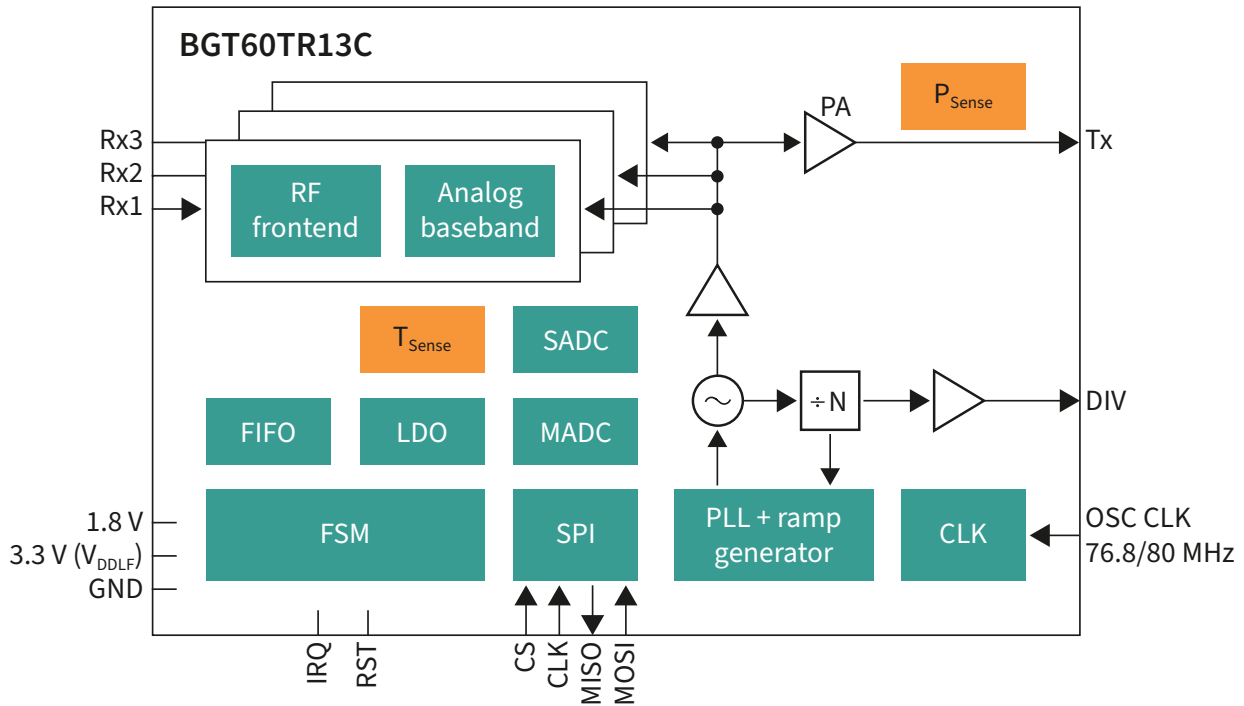
- Presence detection/segmentation/tracking: BGT60TR13C enables human presence detection, tracking, and segmentation while providing extremely high accuracy in detecting micro and macro motions
- Gesture Sensing: BGT60TR13C ensures detection of submillimeter motions
- Vital sensing: BGT60TR13C is able to track vital signs in consumer electronics, healthcare as well as industrial applications



Target application

- Smart TVs
- Smart speaker
- Smart home
- Smart building
- Elderly monitoring
- Vital sensing
- Home appliances

Block diagram of the BGT60TR13C



DEMO BGT60TR13C

Getting started with the XENSIV™ 60G Hz demo board for advanced sensing

BGT60TR13C offers innovative and intuitive sensing capabilities

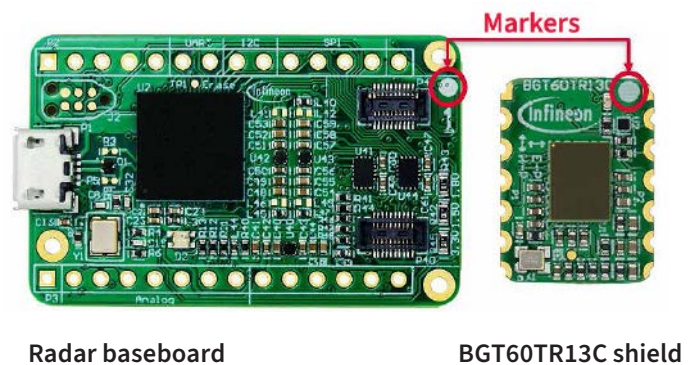
This demo board features Infineon's XENSIV™ 60GHz radar sensor BGT60TR13C and consists of a radar baseboard as well as a BGT60TR13C shield.

The radar baseboard is a 40.64 x 25.4 mm² printed circuit board (PCB). Its main purpose is to provide a generic sensor interface for BGT60TR13C MMIC. The central microcontroller unit (MCU) can perform radar data processing or forward the sensor data to a USB interface or an Arduino MKR interface.

Several benefits come along with the BGT60TR13C demoboard:

- Flexible platform selection
- Variable connector options, and option to solder onto other PCBs
- Highly flexible configuration on FMCW modulation
- Power consumption can be optimized according to use case

The BGT60TR13C shield presents a minimized form factor of 17 x 12.7 mm² and comes with an integrated BGT60TR13C Antenna-in-Package (AIP) radar chip of 6.5 x 5.0 x 0.85 mm³. Moreover, the shield contains a digital interface for configuration and transfer of the acquired radar data to a microcontroller board. The shield is optimized for fast prototyping designs and system integrations as well as initial product feature evaluations. In addition, it offers developers the flexibility to choose their own platform depending on their preferred use cases.



BGT60UTR11AIP – Highly integrated 60GHz radar sensor for consumer electronics and IoT applications

The BGT60UTR11AIP is optimized for low power consumption and system cost optimization. With its compact size of only 16 mm², it is suitable for integration into the smallest devices. The MMIC is manufactured using Infineon's B11 SiGe BiCMOS technology, ensuring excellent RF performance.

Its 5.6 GHz ultra-wide bandwidth allows FMCW operations with extremely high resolution. The detection of sub-mm movements ensures not only extremely sensitive presence and motion detection up to a range of 15 m, but also enables mm precise range measurements, 1D gestures as well as the measurement of vital signs such as breathing rate and heart rate.

Features

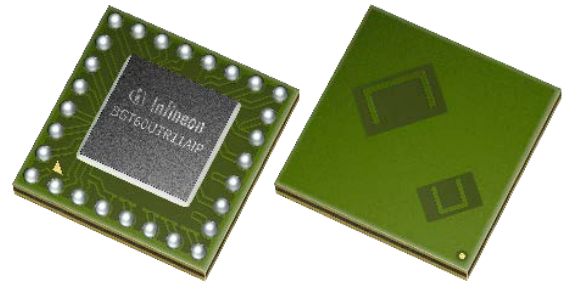
- 60GHz radar operating with 6 GHz bandwidth and ramp speed of up to 400 MHz/μs
- Antenna in package (AIP) with ±60° Field of View (FoV)
- Integrated finite state machine (FSM) for low power consumption and real-time operation
- 4 MSps ADC sampling rate
- Single 50 MHz SPI for chip configuration and data transfer
- Broadcast mode to trigger and configure multiple devices

Benefits

- High sensitivity to detect sub-mm movements for human presence detection and vital sensing applications
- High bandwidth for precise distance measurements with mm accuracy
- Small size for integration into space-constrained environments
- Low power consumption for battery-driven applications

The sensor features a 50 MHz digital SPI interface for configuration and data transfer, while an integrated state machine enables real-time data acquisition without requiring constant interaction with the processor. With three different power modes, users have flexibility to optimize between performance and power consumption. The BGT60UTR11AIP's sub-mA average current consumption makes it suitable for battery-powered devices.

For first evaluation of the radar sensor, we offer the DEMO BGT60UTR11AIP as well as the [Radar Development Kit \(RDK\)](#), which can be downloaded via the [Infineon Developer Center \(IDC\)](#).



Applications

- Smart building devices such as door locks, smart doorbells and air conditioners
- Smart home devices such as smart speakers and thermostats
- Smart appliances such as refrigerators and kitchen machines
- Healthcare devices such as baby monitors and sleep tracker
- Service robots such as vacuum cleaners and lawn mowers
- Security devices such as motion detectors and IP cameras
- Wearables such as headphones and smartwatches
- TVs and notebooks

DEMO BGT60UTR11AIP – Getting started with the XENSIV™ BGT60UTR11AIP 60GHz radar sensor FMCW demo board

This demo board features Infineon's 60 GHz XENSIV™ radar sensor BGT60UTR11AIP. It consists of a Radar Baseboard MCU7 Plus and a BGT60UTR11AIP sensor shield. The board can be used for product feature evaluations, fast prototyping and radar algorithm development with the BGT60UTR11AIP.

The BGT60UTR11AIP MMIC has integrated antennas and is equipped with one transmit and one receive antenna. With its compact size of only 16 mm² and extremely high FMCW performance (5.6 GHz bandwidth), this radar sensor is suitable for a wide range of applications.

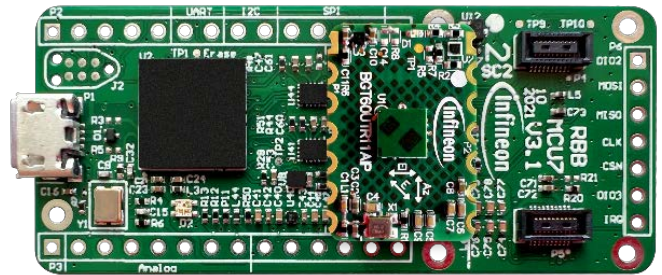
The DEMO BGT60UTR11AIP board is supported by our [Radar Development Kit \(RDK\)](#), which can be downloaded from the [Infineon Developer Center \(IDC\)](#). It contains the Radar Fusion GUI for an instant display

Features of BGT60UTR11AIP shield

- 19 mm x 12.7 mm small form factor
- Digital SPI interface for configuration and data transfer to an MCU
- Standard FR4 laminate
- Castellated holes on the PCB edges for additional signal access
- MCU-controllable LED on board indicating radar sensor status

Benefits

- Flexible platform selection
- Variable connector options, and option to solder onto other PCBs
- Highly flexible configuration on the FMCW modulation
- Advanced functionalities by SPI configuration or further signal processing
- Power consumption can be optimized according to the radar use case



of the radar signals as well as predefined applications such as presence detection or distance measurement. For further development of application specific radar algorithms C, C++, Python and MATLAB interfaces are provided.

Features of Radar Baseboard MCU7 Plus

- 59 mm x 25.4 mm size
- Can perform radar data processing Arm® Cortex®-M7 processor or forward the sensor data to a USB interface or an Arduino MKR interface
- Hi-Speed USB 2.0 interface
- Operates with [Radar Development Kit](#) and radar fusion GUI

Applications

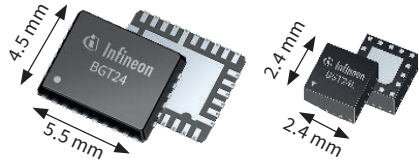
- Smart building devices such as door locks, smart doorbells and air conditioners
- Smart home devices such as smart speakers and thermostats
- Smart appliances such as refrigerators and kitchen machines
- Healthcare devices such as baby monitors and sleep tracker
- Service robots such as vacuum cleaners and lawn mowers
- Security devices such as motion detectors and IP cameras
- Wearables such as headphones and smartwatches
- TVs and notebooks

24GHz radar sensors

Infineon BGT24M / BGT24L family of MMIC chips

Infineon's range of 24 GHz industrial radar chips provides five configurations of transmit and receiver channels, ensuring that there is a chip to support your specific application. From basic applications such as motion detection in security systems, which only

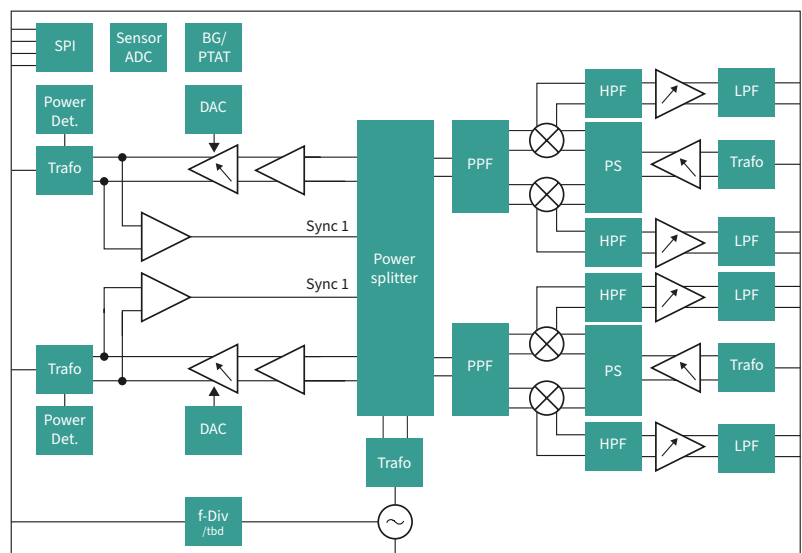
requires one transmit and one receive channel, to more complex applications like 3D positioning, which requires two or more receive channels, our range of radar chips supports all of your requirements.

Features	Infineon MMIC	Benefits
<ul style="list-style-type: none"> – 24GHz ISM band operation for motion, speed, direction movement and distance measurements – Five 24 GHz chips available – Highly integrated MMICs 		<ul style="list-style-type: none"> – Long-range distance detection of moving objects up to 50 m – Wide range speed detection up to ± 100 km/h – Low BOM costs

Product	Configuration	Features
BGT24MTR11	1Tx + 1Rx	<ul style="list-style-type: none"> – Measures, not just motion, but also speed, direction, and distance – Low power MMICs for energy saving
BGT24MTR12	1Tx + 2Rx	<ul style="list-style-type: none"> – Privacy protection
BGT24LTR11	1Tx + 1Rx	<ul style="list-style-type: none"> – Small form factor – Adaptable to different application requirements
BGT24LTR22	2Tx + 2Rx	<ul style="list-style-type: none"> – Resistance to moisture, dirt, and temperature – Highly integrated chips eliminating costly external components – Increased area coverage – Discrete design

The BGT24LTR22 key features

- 24GHz transceiver MMIC
- Fully integrated low phase noise VCO
- Integrated analog base band stage with programmable gain and filter settings
- Bi-directional pin for synchronization
- Built in temperature compensation circuit for VCO stabilization, no PLL needed
- Low power consumption
- Fully ESD protected device
- Single ended RF and IF terminals
- Single supply voltage 1.5 V



24 GHz partner modules

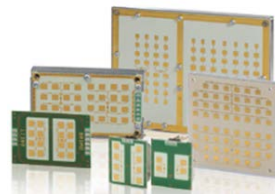
Partnering with the leading radar solution providers enables Infineon to connect our customers looking for turnkey solutions and design support for a complete range of applications. Utilizing our strong network of

partners, the radar portfolio is extended to include a range of easy-to-integrate modules. Each of them contains Infineon's 24 GHz MMIC.

Features

- Complete module, including radar MMIC, antenna options, MCU signal processing options, and SW options (Doppler, FSK and FMCW versions available)

Partner modules using Infineon chips



Module (RF module; RF module + MCU including SW)

Benefits

- Ease of design
- Turnkey solution, no need for test and certification

By integrating Infineon's 24GHz MMIC chip into the partners easy-to-use and simple-to-integrate modules the complexity and time to market for a range of applications such as smart home automation, camera

& security systems, air conditioners, UAVs, robotics, and smart lighting, are reduced.

XENSIV™ radar sensors partners

Visit www.infineon.com/24GHzPartners to view our network of partners who provide modules and design support for all 24 GHz industrial applications.



Infineon Partner Program

Do you have a question?

Visit our Community to inquire, share and connect www.infineon.com/radar-sensor-community.



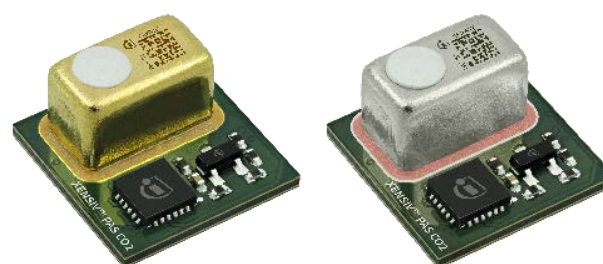
XENSIV™ PAS CO2 sensors

High performance in a small size – disruptive CO₂ sensors based on photoacoustic spectroscopy (PAS)

CO₂ measurement contributes to improvements in health, comfort and productivity as well as energy efficiency. Even at moderate levels, CO₂ can have a negative impact on health and productivity, causing drowsiness and headaches. Fortunately, smart indoor air quality sensors can “smell” rising levels of CO₂ and either alert the user or trigger a system response. Awareness of indoor air quality is further increasing as a result of the COVID-19 pandemic, making accurate, affordable monitoring solutions like PAS CO₂ more important than ever. Given the correlation between CO₂ and aerosol concentration, CO₂ sensors can contribute mitigating the transmission of airborne illnesses such as COVID-19, cold or influenza. Furthermore, CO₂ sensors can facilitate demand controlled ventilation, leading to improvements in energy efficiency and significant savings on energy bills.

Accurate, real-time CO₂ measurement thanks to superior MEMS technology

Widespread adoption of real CO₂ sensors has so far been hampered by size, performance and cost constraints. Infineon’s PAS CO₂ sensors leverage photoacoustic spectroscopy (PAS) technology to provide an exceptionally small, highly accurate and cost-effective sensing solution. Infineon’s leading position in MEMS technology is the foundation for this unique and accurate CO₂ detection approach. Reliable CO₂ measurements



enable smart monitoring of indoor air quality, facilitating improvements in health, productivity and overall well-being. These features make the PAS CO₂ sensors ideal for Heating, Ventilation and Air Conditioning applications as well as for integration into consumer IoT devices such as air purifiers, thermostats, baby monitoring devices, wake-up alarms and smart speakers.

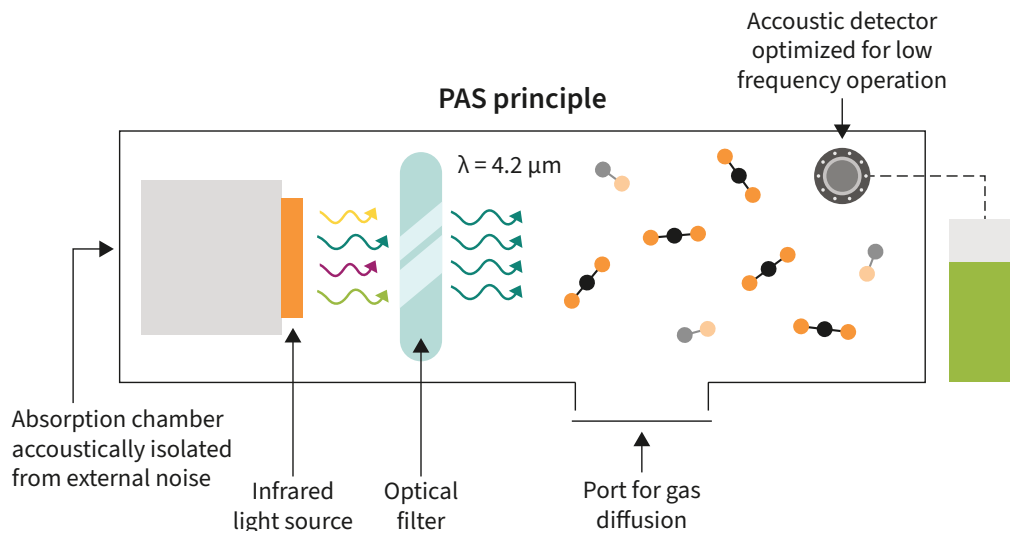
Disruptive environmental sensor technology from Infineon

PAS CO₂ integrates on the PCB a photoacoustic transducer, including an acoustic detector, infrared source and optical filter; a microcontroller for signal processing and a MOSFET chip to drive the infrared source. The exceptional sensitivity of the acoustic detector coupled with the integrated PCB design reduce space requirements by more than 75 percent compared to nowadays state-of-the-art NDIR CO₂ sensors.

The PAS (photoacoustic spectroscopy) principle:

The sensor is characterized by a disruptive measurement principle called PAS (photoacoustic spectroscopy). It works as follows: pulses of infrared light pass through an optical filter tuned to the CO₂ absorption wavelength. The CO₂ molecules absorb

the filtered light, causing them to shake and generate a pressure wave with each pulse. This is called the photoacoustic effect. The sound is then detected by an acoustic detector optimized for low frequency operation and converted to a CO₂ concentration reading by the microcontroller.



Features

- Exceptionally small form factor (14 x 13.8 x 7.5 mm³)
- SMD package delivered in tape and reel
- Advanced compensation and self-calibration algorithms
- Various configuration options (e.g. sampling rate, baseline calibration) and interfaces (UART, I²C, PWM)
- Dust-proof design in compliance with ISO 20653:2013-02
 - Enhanced durability & minimized maintenance requirements

Benefits

- Space savings in customers' end products
- High-quality data and compliance with smart building standards
- Cost-effective high-volume assembly and easy system integration
- Plug & play for fast design-to-market
- Customer flexibility thanks to configuration options
- Fullfilment of WELL™ Building Standard
 - Increased energy efficiency & enhanced real estate value

Applications

- HVAC (Heating, Ventilation and Air Conditioning) systems
- Smart home appliances such as air purifiers, air conditioners and thermostats
- Consumer devices for air quality monitoring such as personal assistants and CO₂ traffic lights
- Smart indoor lighting



Aircon



HVAC blower



Smart NFC thermostat



Smart speaker



Smart home



HVAC flap



Smart building



Smart lighting

Product overview

Product	Accuracy	Interfaces	Operating range [ppm]	Supply voltage [V]
PASCO2V01	± (30 ppm +3%) of reading between 400 ppm and 5000 ppm	I ² C, UART and PWM	0–32000	3.3–12
PASCO2V15	± (50 ppm +5%) of reading between 400 ppm and 3000 ppm	I ² C, UART and PWM	0–32000	3.3–5

Learn more and ask questions:

[XENSIV™ PAS CO₂ sensor community](#)



Intuitive sensing

Giving things human-like senses for a better contextual awareness

Imagine a world where technology is unobtrusive and seamlessly integrated into our lives. Where intentional/deliberate communication between people and devices is no longer necessary. In this world, there is no need to push buttons or issue commands in order to activate devices, because technology is capable of interpreting implicit intentions and context. This enhances the user experience and makes it more natural – it almost seems like the devices around us intuitively understand what we want them to do. At Infineon, this future is already becoming reality. We develop sensor solutions that enable simple and effortless user interactions with all kinds of smart devices. Bridging the gap between the real and digital worlds, our technology is developed to make life easier, safer, greener and more efficient.

Our intuitive sensing solutions are at the very core of this mission. Reflecting our belief that the essential value of sensor technology lies in making our lives more convenient through seamless, natural interactions between people and sensing devices, our aim is to leave you free to focus on what really matters in life.

Choose your type of sense

Thanks to industry-leading technologies Infineon XENSIV™ sensors are exceptionally precise. They are the perfect fit for various customer applications in automotive, industrial and consumer markets.

Pressure sensors

Our digital barometric pressure sensors give designers the best choice when it comes small form factors, highest precision and accuracy over a wide temperature range, fast read-out speeds and low power consumption.

Radar sensors

Radar supports existing applications while providing features that enable completely new use cases. It measures velocity, range and angle, both horizontal and vertical, for precise position mapping and 3D tracking.

MEMS microphones

MEMS microphones overcome existing audio chain limitations and are designed for applications where low self-noise (high SNR), wide dynamic range, low distortions and a high acoustic overload point are required.

PAS CO2 sensors

Leveraging photoacoustic spectroscopy (PAS), Infineon has developed an exceptionally small CO2 sensor that overcomes existing size, cost and performance challenges.

Today, sensors already enable interactions between people and devices

This interaction often depends on the interpretation and merging of information from different sources. Machines cannot yet read our minds and do not always have the information necessary to correctly evaluate a given situation. So, we sometimes have to explicitly tell devices what we want them to do. This can be inconvenient and time-consuming. Inspired by human nature, Infineon intuitive sensing solutions are designed to take the complexity out of our interaction with devices.

Reflecting a holistic approach, we combine different sensors with state-of-the-art software to create a comprehensive picture of the world around us. By fusing several smart sensors into one coherent intelligent system, our intuitive sensing solutions simplify complex technical processes and enable people to effortlessly interact with devices. These smart devices intuitively sense the world around them, determining what is expected and needed from them.

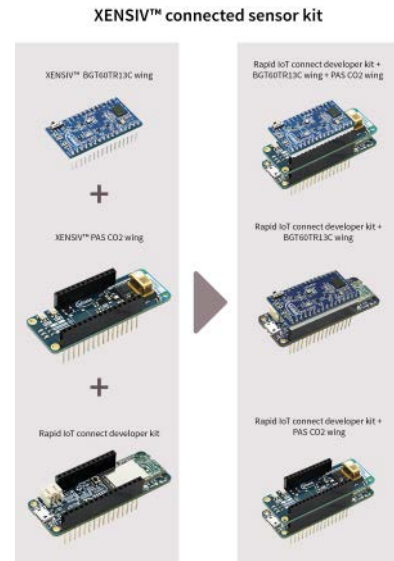
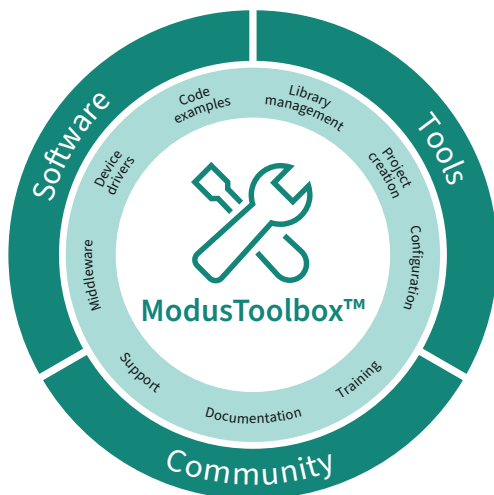
XENSIV™ connected sensor kit

Rapid IoT prototyping experience enabled by XENSIV™ sensors

The XENSIV™ connected sensor kit enables rapid development of a custom solution built on Infineon products. The CSK supports customers in testing sensor-driven IoT products and use cases as well as in prototyping. It offers a real-time sensor evaluation with custom configurations and cloud-based sensor data visualization with sensor fusion. The development kit supports use cases based on XENSIV™ 60GHz radar and PAS CO2 with DPS368 pressure sensor (Sense), PSoc™ 6 microcontroller embedded processing (Compute), connectivity via Infineon AIROC™ CYW43012 Wi-Fi and Bluetooth® Combo (Connect) and hardware security with OPTIGA™ Trust M (Secure). Code examples and sensor libraries are available in the Infineon software ecosystem ModusToolbox™ to help customers create use case-specific application codes for new product offerings.

Key features

- Small form-factor (22.5×63×30 mm) adafruit feather compatible design
- AC and DC sensing
- Wi-Fi and Bluetooth 5.0-compliant combo radio module
- Power optimized design, deployable with battery
- Interchangeable sensor wings – 60GHz radar, PAS CO2
- Seamless integration into ModusToolbox™
- FCC and CE certified



Key benefits

- Ideal for prototyping battery-powered IoT devices due to optimized power consumption. Suited for customer field trials.
- Rapid development and deployment via code examples in ModusToolbox™ for presence detection, entrance counter, air quality measurements. Enabler for Multi-sensor data fusion.
- Secure cloud device onboarding and management with OPTIGA™ Trust M. Secure kit provisioning (unique user ID).

The Infineon Rapid IoT Connect SOM platform deployed on the XENSIV™ CSK provides hardware, firmware, and cloud artifacts to enable rapid onboarding to the Internet of Things. Bidirectional XENSIV™ sensor to cloud data communication is securely enabled. The XENSIV™ CSK is a pre-implemented Infineon Prototyping Sensor System that makes it possible to provision, monitor and manage Infineon hardware remotely. Sensor2cloud kit set up takes 10 minutes with 12 months free user access to a dedicated cloud demo platform for sensor data collection and interpretation as well as sensor data download.

Product	Description	OPN No.
XENSIV™ <u>KIT CSK PASCO2</u>	Rapid prototyping platform for use cases based on Infineon's XENSIV™ PAS CO2 sensor	KITCSKPASCO2TOBO1
XENSIV™ <u>KIT CSK BGT60TR13C</u>	Rapid prototyping platform for use cases based on Infineon's XENSIV™ 60GHz radar sensor	KITCSKBGT60TR13CTOBO1



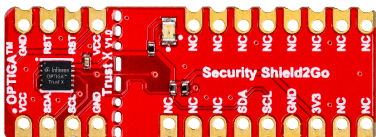

Shields2Go

Infineon's Shield2Go boards offer a unique customer and evaluation experience

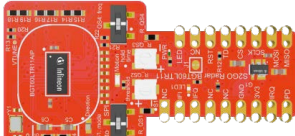



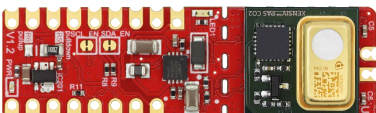

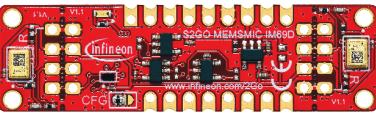

The boards are equipped with one Infineon IC and come with a ready-to-use Arduino library. Customers can now develop their own system solutions by combining 2GO boards together with Infineon MyIoT adapters.

MyIoT adapters are gateways to external hardware solutions like Arduino and Raspberry PI, which are popular IoT hardware platforms. All this enables the fastest evaluation and development of the IoT system.

Security

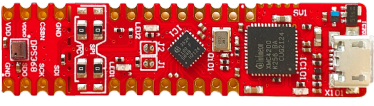



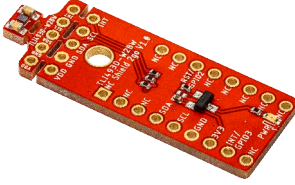

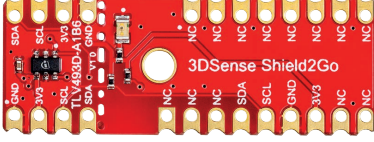

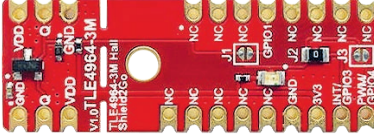

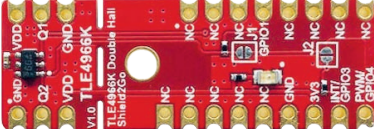

	<p>Product name: OPTIGA™ Trust E Security Shield2Go Sales name: S2GO_Security_OPTIGA_E Ordering code: SP001820138</p>	<p>Product information</p> 
	<p>Product name: OPTIGA™ Trust X Security Shield2Go Sales name: S2GO SECURITY OPTIGA X Ordering code: SP002349576</p>	<p>Product information</p> 

Sensors

	<p>Product name: S2GO Radar Sensor BGT60LTR11 Sales name: S2GO RADAR BGT60LTR11 Ordering code: SP005594890</p>	<p>Product information</p> 
	<p>Product name: XENSIV™ 60GHz radar autonomous shield Sales name: SHIELD_AUTONOM_BGT60 Ordering code: SP005630363</p>	<p>Product information</p> 
	<p>Product name: PASCO2V01 Shield2Go Sales name: SHIELD PASCO2 SENSOR Ordering code: SP002851544</p>	<p>Product information</p> 
	<p>Product name: IM69D130 Microphone Shield2Go Sales name: S2GO MEMSMIC IM69D Ordering code: SP002851544</p>	<p>Product information</p> 

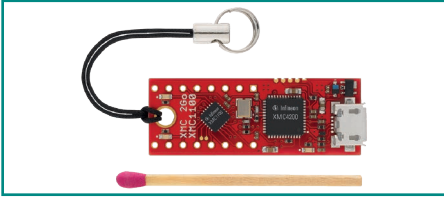
Shields2Go

Sensors

	<p>Product name: KIT_DPS368_2GO Sales name: KITDPS3682GOTOB01 Ordering code: SP005729572</p>	<p>Product information</p> 
	<p>Product name: TLE493DW2B6 3DSense Shield2Go Sales name: S2GO_3D_TLE493DW2B6-A0 Ordering code: SP004308594</p>	<p>Product information</p> 
	<p>Product name: TLI493D-W2BW 3D Sense Shield2Go in small WFVLB-5-2 package (1.13 mm x 0.93 mm x 0.59 mm) Sales name: S2GO_3D_TLI493DW2BW-A0 Ordering code: SP005410385</p>	<p>Product information</p> 
	<p>Product name: TLV493D 3D Sense Shield2Go Sales name: S2GO_3D-SENSE_TLV493D Ordering code: SP001823678</p>	<p>Product information</p> 
	<p>Product name: TLE4964-3M Hall Sense Shield2Go Sales name: S2GO_HALL_TLE4964-3M Ordering code: SP004308590</p>	<p>Product information</p> 
	<p>Product name: TLE4966K Double Hall Shield2G Sales name: S2GO_2_HALL_TLE4966K Ordering code: SP004308598</p>	<p>Product information</p> 

Shields2Go

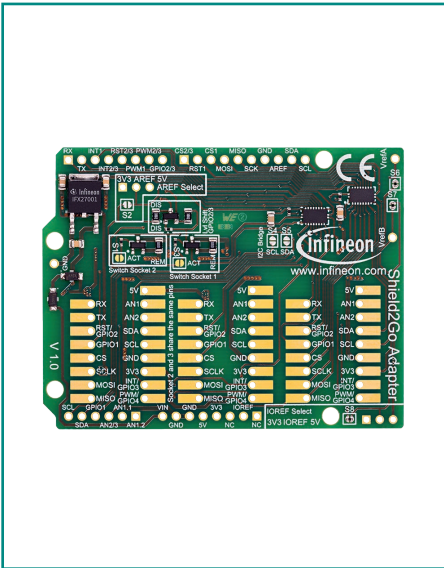
Microcontroller



Product name: XMC 2Go Kit
Sales name: KIT_XMC_2GO_XMC1100_V1
Ordering code: SP001199544

Product information

MyIoT – Adapter



Product name: MyIoT Adapter
Sales name: MYIOTADAPTERTOBO1
Ordering code: SP002434972

Infineon’s 2Go boards offer a unique customer and evaluation experience – the boards are equipped with one Infineon IC and come with a ready-to-use Arduino library. Customers can now develop their own system solutions by combining 2Go boards together with Infineon MyIoT adapters.

MyIoT adapters are gateways to external hardware solutions like Arduino and Raspberry PI, which are popular IoT hardware platforms. All this enables the fastest evaluation and development of IoT system.

Product information

XENSIV™ Sensor Shield for Arduino



Product name: XENSIV™ Sensor Shield for Arduino
Sales name: SHIELD_XENSIV_A
Ordering code: SP006018677

Infineon’s XENSIV™ Sensor Shield provides seamless hardware compatibility between sensors, microcontroller and connectivity products. When paired with a MCU / Wi-Fi base board via the Arduino UNO interface, the board enables developers to quickly evaluate and develop with environmental sensors like:

- 60 GHz radars
- PAS CO2 sensor
- PDM microphones
- Pressure sensors
- 6-axis IMU
- 3-axis magnetometer
- Temperature and humidity

The shield also features a TFT display (80x160), and OPTIGA™ Trust-M secure element, and a QWIIC connector for additional peripheral expandability.

Product information

Sensor 2GO kits

Ready to use, budget-priced plug- and play boards

Already equipped with a sensor combined with an Arm® Cortex®-M0 CPU. The Sensor 2GO kits provide a complete set of on-board devices, including an on-board debugger. Build your own application and gadget with the Sensor 2GO kits.

<p>Automotive pressure sensor 2GO kit</p> <p>Product name: KP215F1701-PS2GO-KIT KP229E3518-PS2GO-KIT KP236-PS2GO-KIT KP254-PS2GO-KIT KP276-PS2GO-KIT</p> <p>Ordering code: SP002676652 SP002676656 SP002676664 SP002676664 SP005910372</p>	<p>Product information</p> 
<p>3D magnetic sensor 2GO kit</p> <p>Product name: TLE493D-A2B6 MS2GO TLE493D-W2B6 MS2GO TLV493D-A1B6 MS2GO</p> <p>Ordering code: SP001707582 SP001707578 SP001707574</p>	<p>Product information</p> 
<p>Angle sensor 2GO kit</p> <p>Product name: TLE5012B_E1000_MS2GO TLI5012B_E1000_MS2GO TLE5012B_E5000_MS2GO TLE5012B_E9000_MS2GO</p> <p>Ordering code: SP002133956 SP002133960 SP002133964 SP002133968</p>	<p>Product information</p> 
<p>TLI4971 current sensor 2GO kit</p> <p>Product name: TLI4971_MS2GO</p> <p>Ordering code: SP005345474</p>	<p>Product information</p> 
<p>TLE4973 current sensor 2GO kit</p> <p>Product name: TLE4973 MS2GO</p> <p>Ordering code: SP006039680</p>	<p>Product information</p> 
<p>Speed sensor 2GO kit</p> <p>Product name: TLE4922 MS2GO</p> <p>Ordering code: SP003029974</p>	<p>Product information</p> 
<p>TLE4966 Hall switches 2GO kit</p> <p>Product name: TLE4966 MS2GO</p> <p>Ordering code: SP005406992</p>	<p>Product information</p> 

Evaluation boards – for simple and easy evaluation

MEMS microphones flex evaluation kits

Product name:	Ordering code:
EVAL_IM67D120_FLEKKIT	SP005560671
EVAL_IM67D130_FLEKKIT	SP005537489
EVAL_IM69D120_FLEKKIT	SP002153026
EVAL_IM69D127_FLEKKIT	SP005403891
EVAL_IM69D130_FLEKKIT	SP002153022
EVAL_IM70A135_FLEKKIT	SP005728204
EVAL_IM72D128_FLEKKIT	SP005429924
EVAL_IM73D135_FLEKKIT	SP005415695
KIT_IM66D120A_FLEX	SP005934515
KIT_IM66D130A_FLEX	SP005880176
KIT_IM68A130A_FLEX	SP005834257

Product information



Current sensors evaluation boards

Product name:	Ordering code:
TLE4971 EVAL 120A	SP005343588
TLE4972 EVAL INLAY	SP005632138
TLE4972 EVAL LAT BAR	SP005632140
TLE4972 EVAL STD PCB	SP005632136
TLE4973 EVAL 120A	SP006015313
TLE4973 EVAL INLAY	SP005853842
TLE4973 EVAL LAT BAR	SP005853844
TLE4973 EVAL STD PCB	SP005853840
TLE4973 EVAL VER BAR	SP005853847
TLI4971 EVAL 120A	SP005876845

Product information



MEMS microphones for ATV plug and play boards

Product name:	Ordering code:
EVAL AHNB DIGITALV01	SP005955184
EVAL AHNB ANALOGV01	SP005568087

Product information



TMR linear sensors evaluation boards

Product name:	Ordering code:
TLI5590 SATELLITE	SP005857647
TLX559X EVAL KIT	SP006007354

Product information









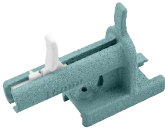





PAS CO2 sensor evaluation boards

Product name:	Ordering code:
EVAL_CO2_5V_SENSOR2GO	SP006037148
EVAL_CO2_5V_MINIBOARD	SP006037150
EVAL_PASCO2_SENSOR2GO	SP005582413
EVAL_PASCO2_MINIBOARD	SP005577475









Product information



Add ons for Sensor 2GO kits and Shield2Go

	<p>Joystick for all 3D magnetic sensor 2GO kits and Shield2Go Product name: JOYSTICK FOR 3D 2 GO KIT Ordering code: SP001491834</p>	<p>Product information</p> 
	<p>Rotate knob for all 3D magnetic sensor 2GO kits, Angle sensor 2GO kits and 3D magnetic sensor Shield2Go Product name: ROTATE KNOB 3D 2 GO KIT Ordering code: SP001504602</p>	<p>Product information</p> 
	<p>Linear slider for all 3D magnetic sensor 2GO kits and Shield2Go Product name: LINEAR-SLIDER 2GO Ordering code: SP002043034</p>	<p>Product information</p> 
	<p>Out of shaft adapter for all 3D magnetic sensor 2GO kits and Shield2Go Product name: OUT OF SHAFT FOR 3D 2 GO Ordering code: SP003475178</p>	<p>Product information</p> 
	<p>Linear control trigger for all 3D magnetic sensor 2GO kits and Shield2Go Product name: POWER_DRILL2GO Ordering code: SP005350194</p>	<p>Product information</p> 
	<p>Human machine interface (HMI) direction indicator for all 3D magnetic sensor 2GO kits and Shield2Go Product name: DIR_INDICATOR2GO Ordering code: SP005350196</p>	<p>Product information</p> 
	<p>HMI mini control with 4 directions and 360° rotation for all 3D magnetic sensor 2GO kits and Shield2Go Product name: MINI_CONTROL2GO Ordering code: SP005350192</p>	<p>Product information</p> 

Add ons for Sensor 2GO kits and Shield2Go

	<p>OpenClose adapter for Hall switch Shield2Go Product name: OPENCLOSE2GOHSTOB01</p>	<p>Product information</p> 
	<p>Play2Go for 3D magnetic sensor Product name: PLAY2GO Ordering code: SP005731811</p>	<p>Product information</p> 
	<p>Contactless switch array for all 3D magnetic sensor 2GO kits and Shield2Go Product name: Contactless switch array Ordering code: Simply use our 3D printing files, link to, and start your 3D print.</p>	<p>Product information</p> 
	<p>Spindle2Go for all 3D magnetic sensor Shield2Go Product name: SPINDLE2GO Ordering code: SP005989689</p>	<p>Product information</p> 

Choose the best fit magnetic sensor solution from broadest portfolio

Our sensor simulation tools allow you to compare products in application conditions. The tools are easy-to-use and will guide you in identifying the most suitable Infineon XENSIV™ - sensor combined with the best-fit magnet.

 <p>Current sensor</p>	<p>XENSIV™ – Current sensor simulation tool</p> <p>Define and optimize the current sensing structure for your system. The tool supports design of lateral and vertical insertions for PCB (2 to 10 layer stack) or bus-bar based applications. The simulation will provide insertion resistance, field transfer factor, sensitivity range, measurement range and power dissipation as well as cross-talk in case of a 3-phase system.</p> <p>Direct link to the Current Sensor Simulation Tool: https://currentsensorsim.infineon.com/</p>
 <p>3D magnetic sensor</p>	<p>XENSIV™ – 3D magnetic sensors simulation tool</p> <p>3D magnetic field sensor for smaller, more accurate and robust designs. The sensor family, with low current consumption and cost-optimized design, specifically addresses the needs of new magnetic sensor applications in consumer, industrial and automotive. They are ideally suited for the measurement of three dimensional movement within a magnetic field, linear slide movement as well as 360° angle rotation.</p> <p>Direct link to the 3D Magnetic Sensors Simulation Tool: https://www.infineon.com/3dsim</p>
 <p>Magnetic switches</p>	<p>XENSIV™ – Magnetic switches simulation tool</p> <p>Discover Infineon's broad energy saving portfolio of Hall switches in smallest package. Simulate your Hall switch applications and see the results in an accurate simulation of the magnetic field and the switching behavior of the Hall switch in the application.</p> <p>Direct link to the Hall Switches Simulation Tool: https://www.infineon.com/hallsim</p>
 <p>Angle sensor</p>	<p>XENSIV™ – Magnetic angle sensor simulation tool</p> <p>Highest variety - low end to high end, standardized and specialized in all four magnetic technologies: Hall, GMR, AMR and TMR. This tool calculates the valid distance from the magnet surface to the sensor and the assembly error, given certain parameters: magnetic properties, sensor specification and assembly tolerances.</p> <p>Direct link to the Angle Sensors Simulation Tool: https://www.infineon.com/anglesim</p>
 <p>Speed sensors</p>	<p>Speed sensor solution tool</p> <p>Infineon's innovative SPEED SENSOR SOLUTION TOOL will provide a sensor recommendation for your tooth wheel and back bias magnet geometry. The sensors are ranked according their expected maximum air gap capability. Customer constraints like enhanced strayfield immunity, the necessity for a direction channel, or the sensor interface are considered in the selection process.</p> <p>Direct link to the Speed Sensor Solution Tool: https://speedsensortool.infineon.com</p>

All simulation tools can be easily accessed via this link: <https://www.infineon.com/xensiv-simulation-tools>

ISO 26262 – Functional Safety (FuSa)

Dependable electronics based on Functional Safety

Automotive Functional Safety – we ease the process for integrating safety features with our safety guidelines and services.

Infineon provides dependable electronics to support today's safety-relevant systems and future fail-operational systems as essential components that allows customers fulfilling their safety requirements on application level. Highly integrated systems equipped with safe electronic semiconductors are essential for key application areas like connectivity, electromobility and higher levels of automated driving. The ISO 26262 set of standards sets out requirements and guidance for products in order to be integrated in an automotive safety applications.

- Discover Infineon's products with ISO 26262 classification

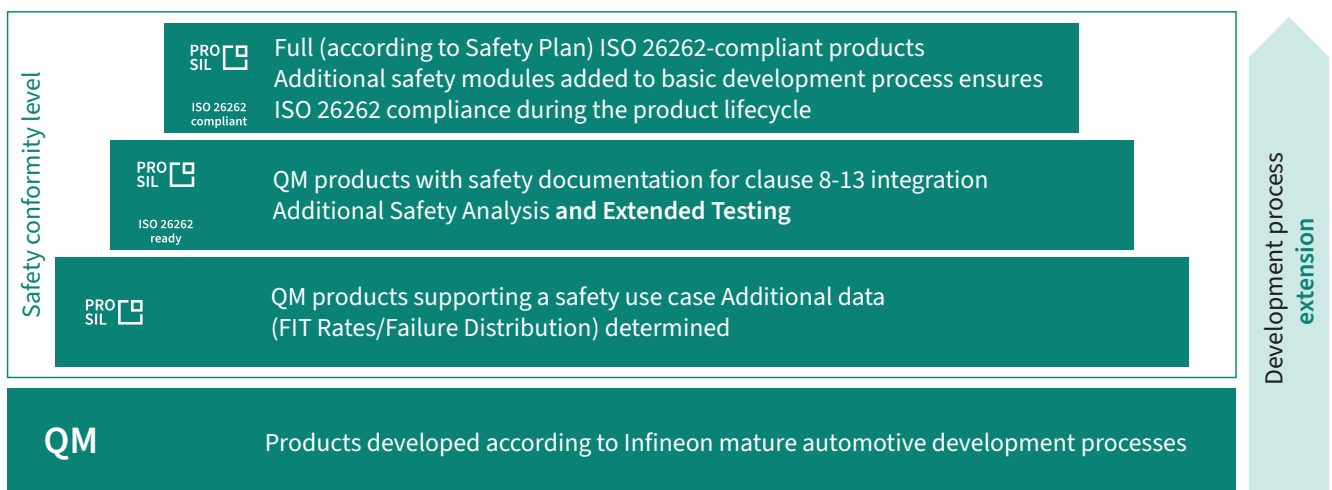
With our holistic approach towards functional safety, Infineon is responding to the increased complexity and strict requirements that make functional safety projects costly and time-consuming. We provide the necessary products, including documentation and supporting information, for easing the integration and reduce the effort at system integrator level.

Benefit from:

- Innovative solutions for automotive safety-related applications
- Improve time-to-market through comprehensive safety documentation of ISO 26262-compliant products
- Reduce the integrator's efforts with ISO 26262-compliant and -ready products
- Broad portfolio of ISO 26262-compliant products already available
- Newly developed automotive parts will primarily be part of an ISO 26262-compliant development flow

Safety conformity levels:

- PRO-SIL™ ISO 26262-compliant devices meet all relevant requirements for semiconductors as defined in the ISO 26262 series of standards for automotive functional safety.
- The PRO-SIL™ ISO 26262-ready marking designates QM devices that can be integrated into a safety-related application by customer usage of the ISO 26262:2018 clause 8-13 class II hardware evaluation.
- The Infineon automotive Ensured Compliance process framework has been certified by SGS-TÜV Saar for process compliance with ISO 26262:2018 as of April 2022. This certification underpins our focus on automotive functional safety.



Dependability is the key driver for the megatrend towards autonomous driving

The future car is fully connected and always online. It is all-electric and autonomous. At Infineon, we believe that it takes both to realize it- technology and trust.

The increased need for safe electronic systems in vehicles, that drivers and passengers can rely on, are the foundation of trust and shape the future towards higher levels of automated driving.

Winning trust of tomorrow's passengers starts with dependable electronics that enable highly available, dependable, robust, safe and secure systems that operate in all conditions.

Infineon is your trusted partner offering all relevant ingredients for your dependable systems – automotive quality, Functional Safety, cybersecurity, innovative products, system understanding and operational excellence.

Dependable electronics based on quality

As vehicles become more reliant on electronic components, the demand for safe and reliable systems is growing. Especially the rising levels of automated driving depend on the trust that drivers and passengers have towards the quality and reliability of each component. The complexity and requirements in the automotive industry will continue to grow in terms of quality and dependability to keep vehicles running safely and smoothly over 15 years of lifetime.

Infineon's passion in high quality and dependable products create a portfolio with superior performance and unmatched durability through our Zero defect mentality. We go beyond the standards to fit the real application requirements.

Upgrade your automotive systems and applications with our high-quality semiconductor components for your design.

Dependable electronics based on quality

Automotive quality beyond the standards with a zero defect mindset

The complexity and functionalities of vehicles will continue to grow, thus driving the need for dependable electronics with quality being one of its key ingredients. We are convinced that our passion in quality creates a product portfolio that meets the high-quality requirements and leads to highly reliable and robust products.

How Infineon differentiates as a quality leader:

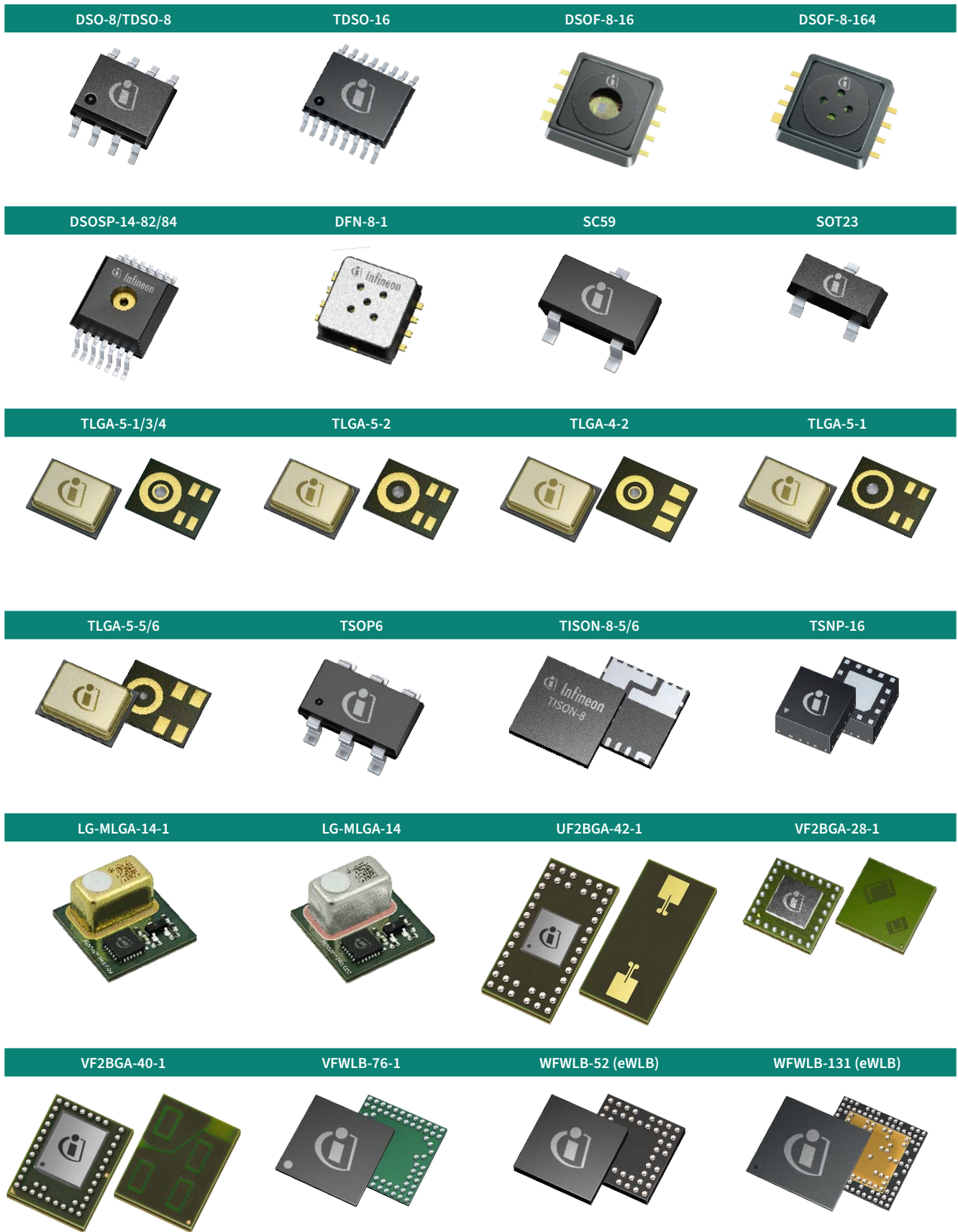
1. Our goal is to go beyond standards to better fit real application requirements: from intensive screening methods to detect production defects, to advanced AEC Q100/101 tests where required, to sub 1dpm validation to achieve low dpm rates.
2. Our track record of achievements, such as multiple quality awards from our customers Toyota (Honor Quality Award in 2020) & Continental (Supplier of the year in 2019) prove that we consistently achieved outstanding quality targets in the automotive industry.
3. Infineon offers the highest customer service, which includes a regional network of failure analysis labs and strong localized competencies, technical trainings and regional quality analysis lab capabilities with state of the art failure analysis.
4. Meeting customer needs through best-in-class product requirements, design, manufacturing and testing: We integrate quality criteria in the development processes (e.g. RDDF), Design rules (e.g. ADeGo), materials, large manufacturing processes and process controls, proprietary testing and screening methods.

Infineon's Zero Defect mentality is built upon:

- We produce 24/7/365 at sub dpm level: translated into a year's timeline: we deliver Zero Defect for all but the last 3 seconds of a year
- We deliver sub ppm quality levels
- 90% of our products are already Zero Defect

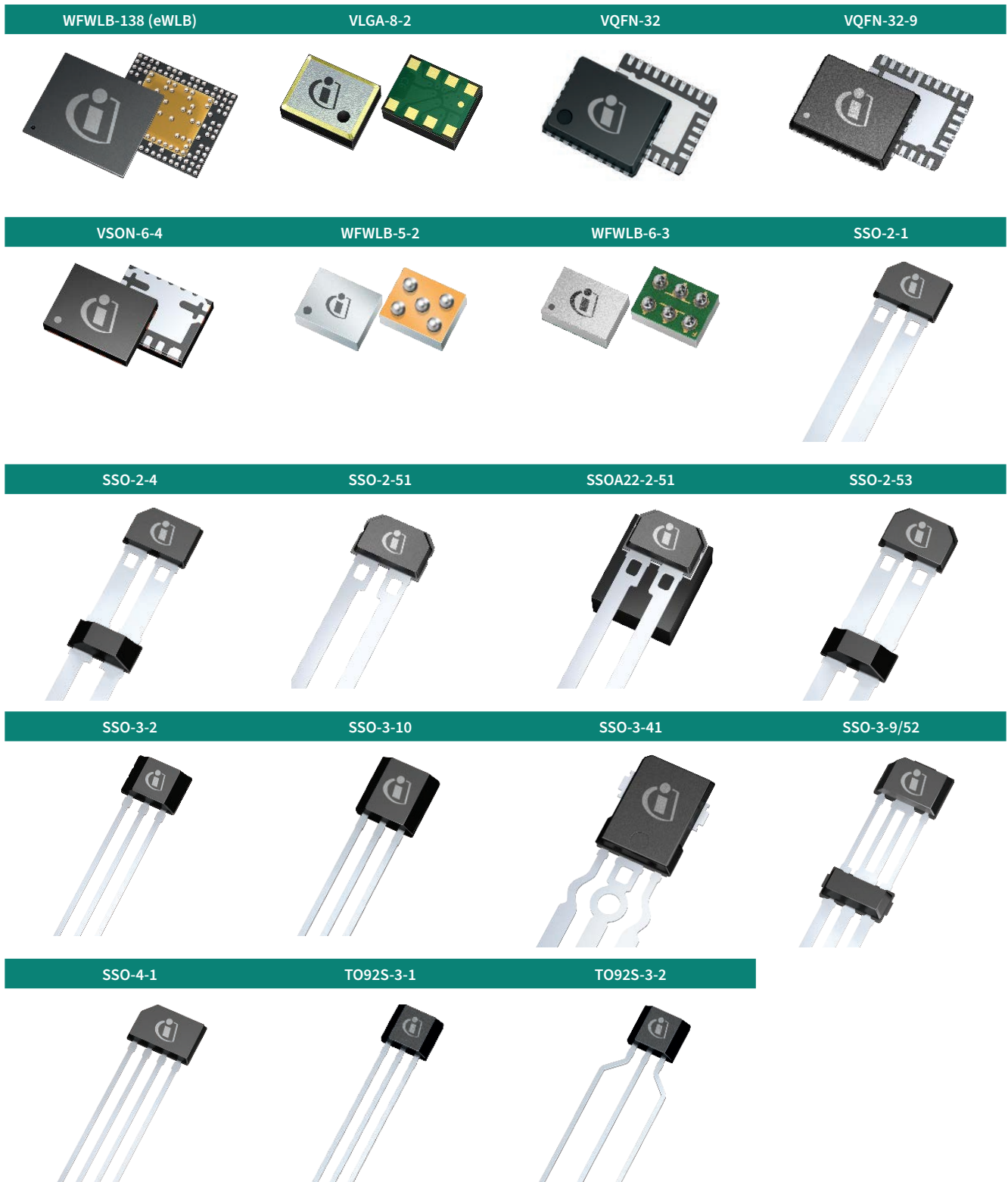
We go beyond the standards to better fit the real application requirements.

Packages



For further information on Infineon packages, please visit our website at www.infineon.com/cms/en/product/packages/

Packages



For further information on Infineon packages, please visit our website at www.infineon.com/cms/en/product/packages/

Where to Buy

Infiniteon distribution partners and sales offices:

www.infineon.com/WhereToBuy

Service Hotline

Infiniteon offers its toll-free **0800/4001** service hotline as one central number, available 24/7 in English, Mandarin and German.

Germany	0800 951 951 951 (German/English)
China, mainland	4001 200 951 (Mandarin/English)
India	000 800 4402 951 (English)
USA	1-866 951 9519 (English/German)
Other countries	00* 800 951 951 951 (English/German)
Direct access	+49 89 234-0 (interconnection fee, German/English)

* Please note: Some countries may require you to dial a code other than "00" to access this international number, please visit www.infineon.com/service for your country!

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Public

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We reserve the right to change this document and/or the information given herein at any time.

Additional information

For further information on technologies, our products, the application of our products, delivery terms and conditions and/or prices, please contact your nearest Infineon Technologies office (www.infineon.com).

Warnings

Due to technical requirements, our products may contain dangerous substances. For information on the types in question, please contact your nearest Infineon Technologies office.

Except as otherwise explicitly approved by us in a written document signed by authorized representatives of Infineon Technologies, our products may not be used in any life-endangering applications, including but not limited to medical, nuclear, military, life-critical or any other applications where a failure of the product or any consequences of the use thereof can result in personal injury.