



# XENSIV™ – Sensor use cases in transmission systems

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## Abstract

The automotive industry faces the challenge of transitioning towards electromobility while also meeting global emissions regulations calling for higher fuel efficiency and lower CO<sub>2</sub> emissions.

Optimized transmission systems are the key to achieving these goals and improving energy efficiency. In addition to modernizing transmission systems, manufacturers are also challenged to meet customer expectations regarding driving comfort and to also fulfill all safety requirements.

Reliable, accurate sensors are key success factors in many different transmission applications. This paper describes the most important sensor use cases enabling improved system performance and superior control.

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## 1. Introduction

The automotive industry faces the challenge of powering today's lifestyle while simultaneously reducing society's carbon footprint. The demand for alternative, more energy-efficient forms of mobility is increasingly pointing towards electromobility. Drivetrain electrification, whether in hybrid electric vehicles or – ultimately – fully electric vehicles, offers higher energy efficiency and zero tailpipe emissions.

Already today, as we transition towards increased electromobility, global emissions regulations such as EURO 7<sup>1</sup> are calling for greater fuel efficiency and fewer CO<sub>2</sub> emissions. Optimized transmissions systems have a vital role to play in meeting these regulation requirements and improving **energy efficiency**. This is because the transmission transfers engine torque to the wheels as the driver presses on the gas. An efficient transmission system must therefore enable reduced parasitic losses, a long last gear ratio, and aggressive torque converter lock-up schedules (zero slip). In addition to this, transmission systems are facing additional challenges from new electrification trends, and now also need to support the evolution of micro/mild/fully hybrid platforms, modular architectures, and improved shift quality in hybrids.

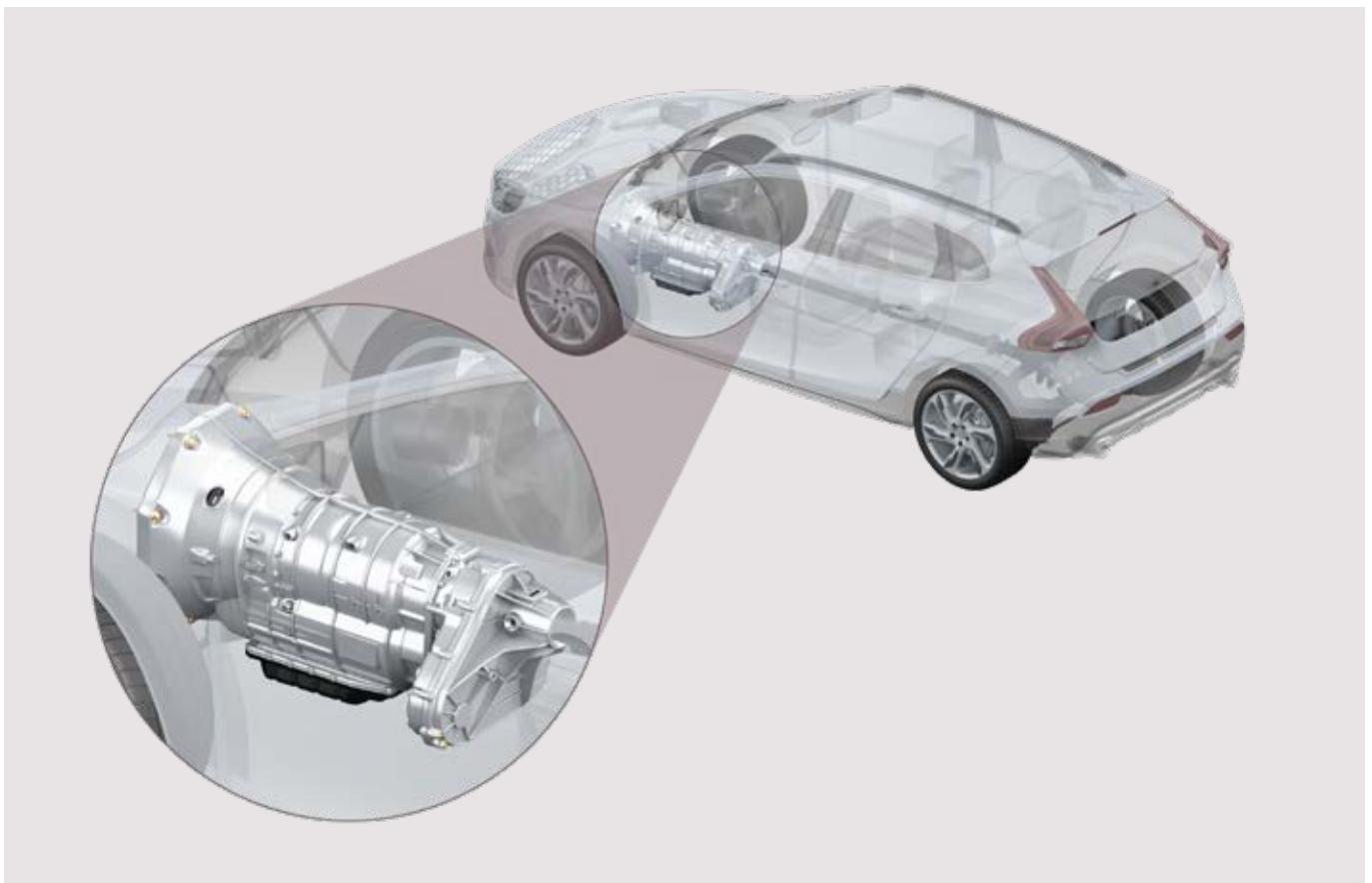


Figure 1: Schematic view of a transmission

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<sup>1</sup> [https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12313-European-vehicle-emissions-standards-Euro-7-for-cars-vans-lorries-and-buses\\_en](https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12313-European-vehicle-emissions-standards-Euro-7-for-cars-vans-lorries-and-buses_en)

In addition to energy efficiency, there are a raft of other important trends in transmission systems. Advanced automatic transmission systems are introducing **new safety concepts** that enable driver assistance functions and the development of autonomous vehicles. Other essential aspects for modern transmission systems include **driving performance** and comfort – both of which strongly influence customer purchasing decisions – as well as size and weight limitations. 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 and accurate sensors are the key success factor in the evolution of transmission systems. High-performance and efficient transmission systems require intelligent actuation systems that efficiently and smoothly change gears. Accurate speed and position sensors are essential for this function. Transmissions, however, are not a single application. They are made up of many different subsystems and sensors. 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. This paper summarizes the most important sensor use cases in transmissions: rotor position for motor commutation, speed sensing, parking lock position, and gear forks, as well as sensing solutions for gear selector devices.

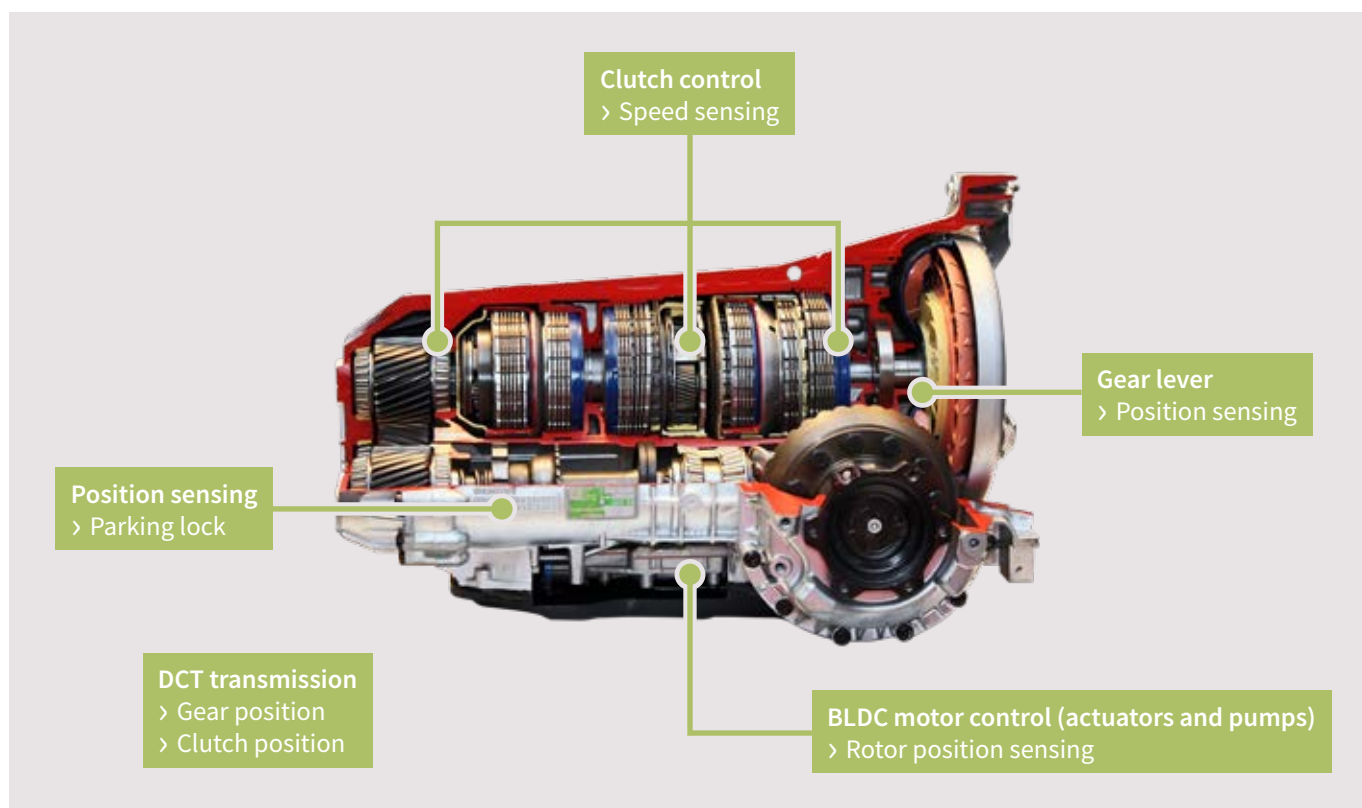


Figure 2: Transmission system: key components and sensing domains

## 2. Transmission actuation

Transmission actuators directly influence the controllability, dynamics, size, cost, and efficiency of transmission systems. Changes in the automotive industry have resulted in increasing numbers of more diverse drivetrain architectures. As a result, manufacturers are looking for optimal, technology-independent actuation solutions that meet different requirements but are still modular and can be adapted to almost any transmission. The more widespread use of efficient BLDC motors in actuators is enabling high dynamics and torque density on a minimal footprint with low noise levels and increased lift time. BLDC motors enable cost- and size-optimized electro-mechanical actuation in harsh, dynamic transmission ecosystems.

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). Position sensors are also fundamental for applications with high safety requirements or in use cases where a controlled start-up or reduced noise and vibration levels are required. Infineon has a broad portfolio of Hall switches and angle sensors for motor commutation, addressing different commutation types and responding to different accuracy, interface and system cost needs.

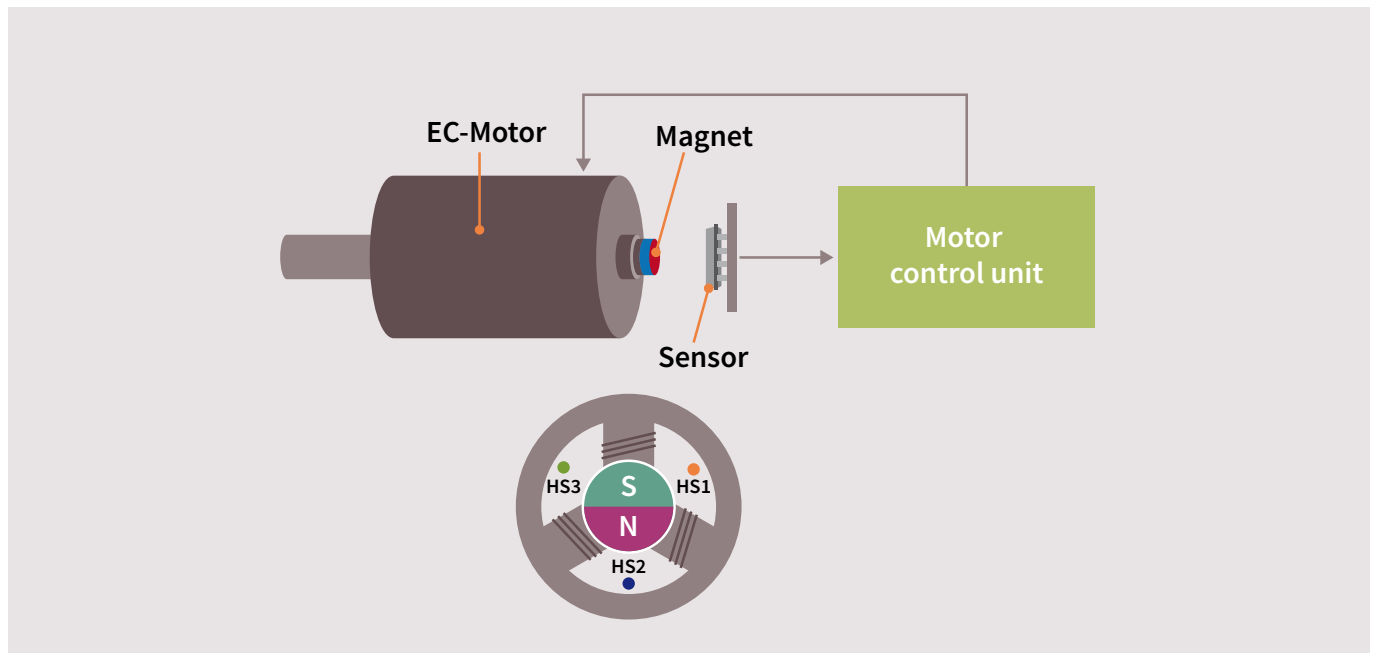


Figure 3: Typical set-up of motor control with end-of-shaft position angle sensor (above) and out-of-shaft position Hall latches (below).



## 3. Position sensing

### 3.1 Gear selector lever

The gear selector lever is the human-machine interface between the driver and the transmission system. The gear or driving mode is selected by moving the lever. In manual transmissions, the lever is mechanically coupled to the transmission. In automatic transmissions today, shift-by-wire systems without any mechanical connection are becoming the standard. In all cases and in all vehicle types (including electric vehicles), a sensor is needed to determine which gear or driving mode has been selected.

In manual transmissions, the reverse gear must be detected in order for the reversing lights to be turned on. To optimize fuel consumption, optional gear lever position detection can be used to display information to the driver, advising them to shift up or down a gear. In automatic transmissions, a sensor detects the shift position of either park, reverse, neutral, or drive (PRND). Manual switching options (up(+)/down(-)) are also supported.

In shift-by-wire systems, a sensing solution is mandatory as changes in transmission modes are achieved using electronic controls without any mechanical link between the gear shifting lever and the transmission. This effectively eliminates the need for a lever, but means that each position must be detectable. As a result, a wide range of designs can be found on the market for selecting the PRND driving mode, including rotary dials and switches. However, lever-like styles still seem to be favored by designers. This freedom also means that the gear selection device may not always be located in the center console. Top column levers located next to the steering wheel are also quite common with some OEMs.

There are lots of 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 common. Driving mode selection can be safety critical, so redundant implementations are often used.

### 3.2 Parking lock and gear fork

The parking lock is a safety and security mechanism designed to prevent a vehicle from moving unintentionally. It is also used as anti-theft protection. The parking lock is either controlled manually by the driver or automatically engaged when the gear lever is set to the “Park” position. Parking brakes are used in all kinds of transmission types and will continue to be part of battery-powered electric vehicles in future.

When the parking lock is engaged, the transmission is physically locked by a pawl that is pushed into a notched wheel on the shaft. This prevents the shaft and subsequently the vehicle wheels from rotating. When the parking lock is disengaged, the pawl is retracted and the shaft is free to move again. The position of the parking lock is controlled by a magnetic position sensor that detects the positions “P engaged” and “P not engaged”.

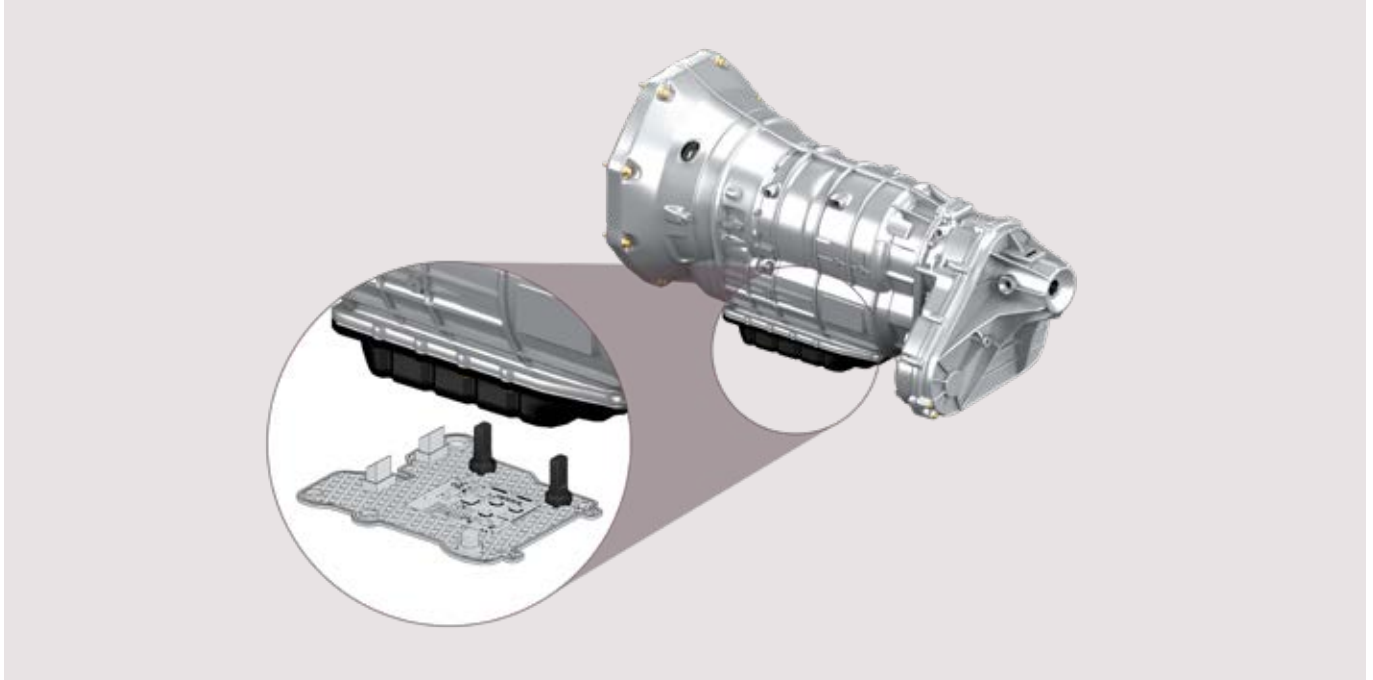
Gear forks are a similar use case here. They control the engagement and disengagement of different gears in a transmission using a linear movement. Position sensors are used to ensure that a gear fork operates smoothly and safely when switching gears. Different designs with Hall switches as well as linear,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





## 4. Speed sensing

Automatic transmissions select the appropriate gear ratio without any driver input. Transmission speed sensors provide information that is used to calculate the optimum gear ratio and detect the right moment to change gears. Furthermore, efforts to improve transmission efficiency have resulted in systems that can control the slippage in the torque converter and reduce shift time. To do that, accurate information on the speed of the transmission input and output is required.



**Figure 4:** Transmission speed sensor

Modern automatic transmissions also have to supply information on speed to additional control systems, for instance for decoupling the torque converter at standstill. This improves fuel consumption and reduces the load placed on the running gear. This information also has to be fed to new safety functions that reduce drive torque to prevent skidding on slippery roads and prevent unexpected gear shifting in curves.

Transmission speed sensors can detect direction. This has become essential in continuously variable transmissions (CVTs) because systems need to detect any belt slips to prevent damage to the gearbox. It is also required to support other applications such as hill holders, navigator systems, and start/stop functions. Transmission speed sensors have to be able to reliably detect if the shaft is stationary, detecting rotation down to 0 Hz. They must also be able to safely detect if the car is slowly rolling.

Metal tone wheels in the gearbox are usually used as targets for transmission speed sensors. However, it can be difficult to predict the general shape of the target wheel as this very much depends on the transmission supplier, the transmission type, and the dimensional needs of individual transmissions. Therefore, one of the main challenges facing transmission speed sensors is the different magnetic signals provided by a huge variety of possible gears (dented, stamped, helix or helical, for example). Another key issue specific to transmission applications is that transmission speed sensors have to cope with rotational vibrations and variations in the air gap caused by gear eccentricity or air gap shocks produced when gears are shifted. Sensors have to be robust to withstand vibrations but also extremely sensitive to deal with large air gaps and be able to sense through the transmission housing.

#### 4.1 Sensor Portfolio

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.

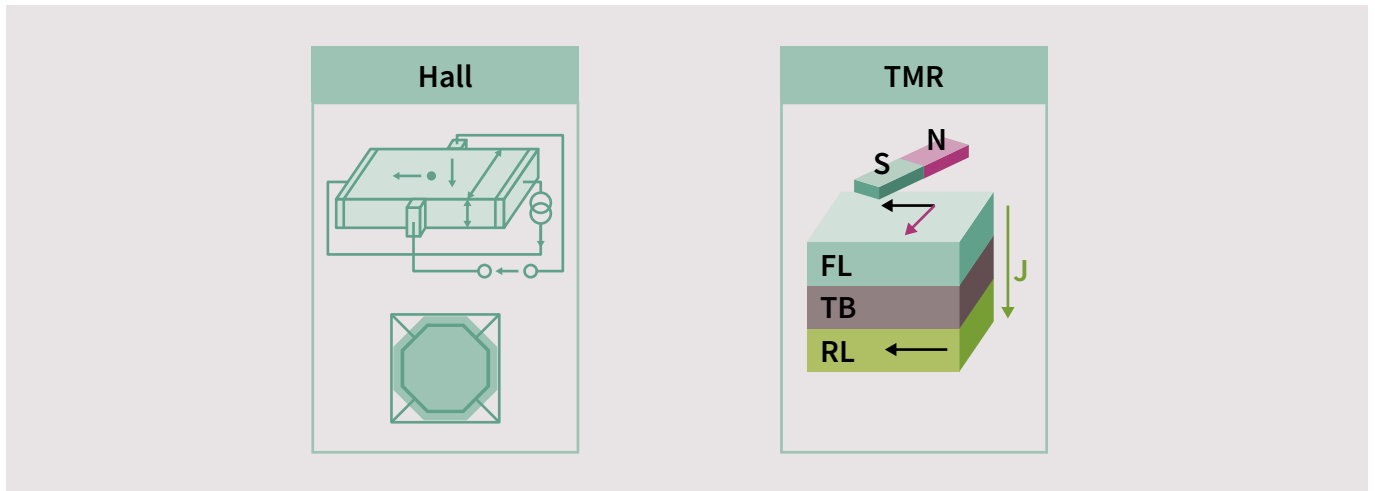


Figure 5: Transmission speed sensing technologies

#### 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.

## 5. Summary

Modern high-performance and efficient transmission systems need to meet evolving efficiency, safety, and driving comfort requirements. Intelligent actuation systems and precise position and speed sensing are key enablers in meeting these demands and also fulfilling customer expectations.

Infineon offers a wide range of magnetic sensors that satisfy the varied needs of different sensor use cases:

- › Hall switches (e.g. TLE4961-1M, TLE4968-1M) and angle sensors (e.g. TLE5012B, TLE5501) are used for rotor position sensing in motor commutation.
- › Linear sensors (e.g. TLE4997, TLE4998, TLE4999), Hall switches (e.g. TLE4964-3M), and 3D Hall sensors (e.g. TLE493D-P2B6) provide exact position sensing for gear selector lever, parking lock, and gear fork applications.
- › Speed sensors (e.g. TLE4959, TLE4955C, TLE4953C) accurately sense different gear geometries or magnetic encoders.

Infineon's broad portfolio of magnetic sensors is **complemented by** its excellent understanding of systems, enabling it to offer premium customer service worldwide and support system integrators during each lifecycle phase. Thanks to its zero-defect culture, Infineon's high-quality, automotive-qualified ICs can meet the challenges of working in tough environmental conditions. Long-term production plans and dual-production-site strategies ensure supply security over the entire automotive lifecycle.

## 6. Glossary

- › **Manual transmission (MT):** Manual actuation of the clutch and gear shifting. Widely used in Europe.
- › **Automated manual transmission (AMT):** Is based on electro-mechanical rather than hydraulic technology. The gearbox in an AMT car is a manual gearbox with an automated clutch and gear actuation.
- › **Electronically controlled automated transmission (ECAT):** Planetary gear set that uses a hydrostatic torque converter as a start-up coupling element. This system uses fluid coupling instead of a friction clutch and changes gear by hydraulically locking and unlocking a system of planetary gears.
- › **Double clutch transmission (DCT):** Efficient gear shifting without traction. This system uses two separate clutches for odd and even gear sets. Gears can be shifted without interrupting torque distribution to the road wheels. This is done by applying the engine's torque to one clutch at the same time as it is being disconnected from the other clutch. Widely used in Europe.
- › **Continuously variable transmission (CVT):** This system can change seamlessly through a continuous range of gear ratios using drive pulleys connected by a belt. The flexibility of a CVT with suitable control may allow the input shaft to maintain a constant angular velocity even as the output speed varies. Widely used in Asia.
- › **Dedicated hybrid transmission (DHT):** Optimized hybrid concepts developed with electrical drive motors and actuators.
- › **EV Transmission:** Two or more gear transmissions on an electric vehicle to improve efficiency and simplify the electric motor.



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