Pedal Position Sensing

Pedal Position Sensing Using Hall Effect Sensors

Application Note

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1 Introduction

This application note is dedicated to magnetic sensor solutions for pedal position sensing. We first present the typical requirements and trends seen for this application. Next, we outline the common sensing principles that are currently in use and list their major benefits and drawbacks. Infineon's magnetic sensors are particularly suited for the demanding requirements of pedal position sensors and their main features are presented. The last section is dedicated to some particular aspects of magnetic pedal position sensors such as magnetic circuit design, temperature stability, reliability and interfacing and it is shown how Infineon's magnetic sensors help our customers to tackle the issues arising in tomorrow's pedal position sensors.

2 Pedal Position Sensing Requirements

The gas pedal is a mechanism allowing to control the power put into the engine of a car. This control variable is used to determine the amount of gas flow through the throttle into the cylinders of a gasoline internal combustion engine. Historically, the throttle is actuated directly by the driver through the gas pedal, and accordingly there was a mechanical connection between the two (e.g. Bowden cable). Nevertheless, the throttle position had to be sensed already in those systems in order to know the proper amount of fuel to be injected.

Starting in the 1990s, the first electronic throttle control (ETC) systems were introduced, which did not use a physical link between gas pedal and throttle anymore but replaced it by a complete electronic control system with pedal sensor, throttle sensor and actuator as well as the necessary control unit (drive-by-wire, also known as E-gas). ETC is a technology that allows advanced features including cruise control and vehicle stability control to be implemented more easily and is extensively used in today's cars. Since the proper functioning of the ETC system is safety relevant, the safety requirements on the gas pedal sensors are relatively demanding.

An ongoing trend drives vehicle manufacturers towards more driving comfort. Those requirements translate in tight gas pedal sensor specifications, including high linearity, low hysteresis as well as small offset and sensitivity drift over lifetime and temperature to name just a few in order to maintain the smooth feel of controlling one’s engine.

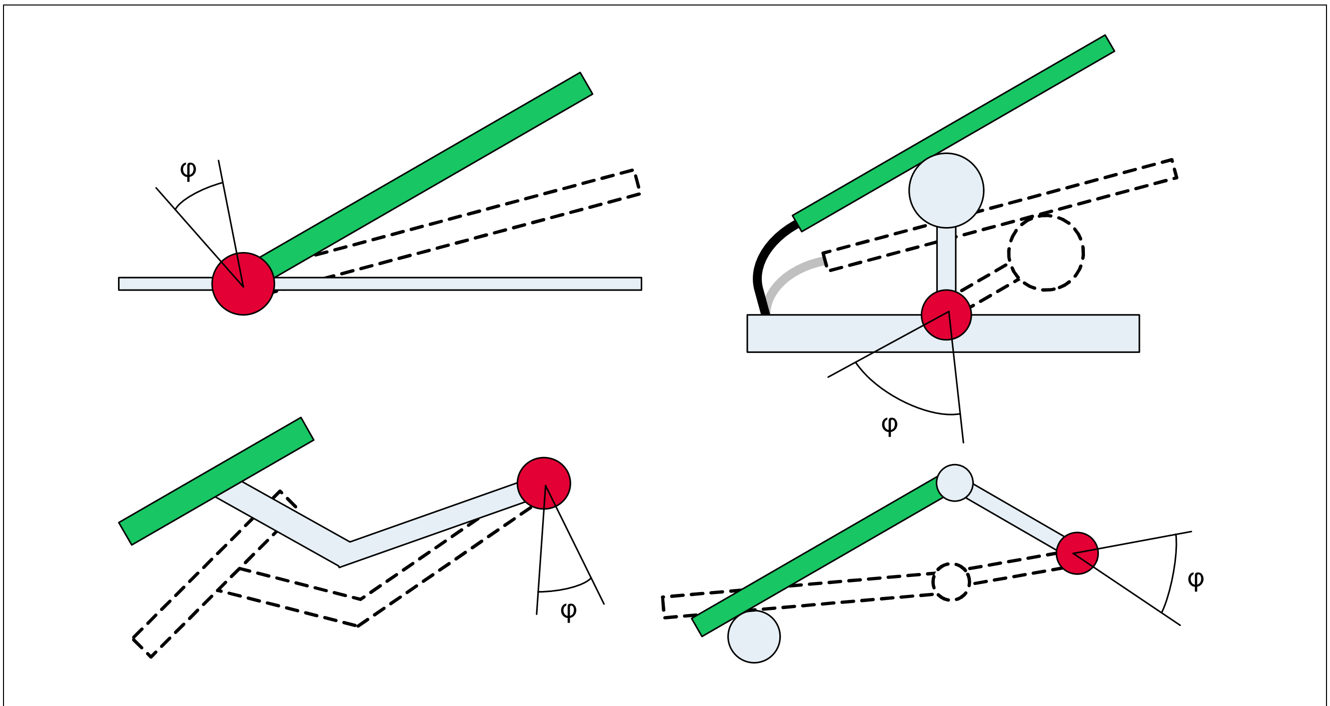

Figure 1 Some possible (simplified) pedal position designs with the sensor position indicated in red. The measurement range is mostly below 60°.

Additionally to these tight requirements on accuracy, modern gas pedal sensors need to become more reliable. On one hand, this is due to the safety requirements already outlined above. Short-circuit and wire breakage detection, redundancy and digital interfaces with error detection algorithms are typical features that allow to address this. On the other hand, gas pedal systems become more and more integrated in order to reduce system space and weight as well as material cost. A drawback of these more embedded gas pedal sensors is the increased cost for exchanging a defective sensor because it becomes less easy to access. For those reasons, modern gas pedal sensors require technologies with even lower failure rates, favoring contactless sensor principles such as magnetic sensors.

3 Measurement Principles

We are now looking more closely on three possible measurement principles, one contacting (potentiometer) and two non-contacting ones (inductive and Hall effect)

3.1 Potentiometers

Potentiometers are widely used as a cheap means for measuring rotational positions. They can be readily implemented in many applications, including many in the automotive environment. Historically, position sensors for various angle detection applications were served by potentiometers, e.g. throttle valves, pedal position, EGR valve position etc. The main advantages of potentiometers include their

- Ease of implementation
- Low price
- Analog output, no signal processing needed
- Ease to add additional channels to increase reliability

However, the potentiometers also have several drawbacks

- High wear & failure rates
- Nonlinearities occurring later in lifecycle
- No digital coding possible
- Bad signal-to-noise ratio
- Redundant channels are worn out in parallel
- Expensive if reliability is improved with special treatments

The drawbacks of potentiometers became more and more of an issue lately for the gas pedal sensor application, the main reason being the increased safety and reliability requirements. The automotive environmental conditions for gas pedal sensors include high temperatures, vibrations and shocks and exposure to water and gases, which can all lead to early failure of potentiometers.

Normal wear is another problem: Potentiometers typically allow about 5 to 10 mio full cycles, but as the gas pedal is mostly used in a specific angle range of some degrees only, the abrasion is biggest in this limited range. Before failing, nonlinear behavior can be observed due to wear of the resistive tracks and material build-up on the wipers, and unfortunately the worst effect is exactly in the driving range in which the sensor is used most. Finally, being a passive device, neither wire breakages and overvoltage nor internal defects can be detected and communicated to the ECU by the potentiometric sensors.

To sum up, potentiometers are a suitable solution for systems where low cost is key and reliability and safety can be traded off. Since the electronic throttle control system is a safety relevant application, most new sensors are based on contactless principles nowadays.

3.2 Inductive Sensors

One way of measuring a rotational position in a contactless way is by using an inductive principle. Transmit coils send a signal, which is coupled back through a rotor into receiver coils. These coils are typically integrated on a simple printed circuit board (PCB) and an IC is used to both generate the excitation signal and decode the received signal. The sensor output is flexible and can be both analog and digital, and redundancy can be achieved by integrating a second setup with a separate decoding IC on the same PCB. Although being cheap and robust, some drawbacks limit the use of this system for throttle valve sensors: The entire sensor design is rather large and can't be further shrinked. The sensors are susceptible to electromagnetic interference and the limited number of suppliers tend to increase the selling price for this sensor type. Additionally, the need for an increase in integration density favors the use of more compact magnetic sensor designs.

3.3 Magnetic Systems

Following a general trend towards contactless technologies, magnetic systems also moved into the focus for pedal position sensors. Hall-effect based magnetic sensors, fully integrated on silicon, have since achieved a considerable share in this application, owing to their large list of advantages:

- Non contacting sensor principle
- No wear, highly reliable
- Direct replacement of potentiometers possible
- Digital outputs & coding possible
- Various output protocols available, including Single Edge Nibble Transmission (SENT) and Pulse Width Modulation (PWM)
- Advanced protocols allow error detection
- Excellent signal to noise ratio
- Redundancy possible
- Wire breakage, short circuit detection

The main disadvantages of the magnetic systems are the following

- Magnetic circuit needed
- Sensor needs to compensate temperature
- Stress affects sensor performance

Many manufacturers of gas pedal sensors have managed to develop their own solution of a magnetic circuit, mostly using linear Hall sensors with a surrounding ring magnet for gas pedal angle detection. The first designs were mainly targeting a reliable replacement of potentiometers, delivering an equivalent analog output. These one-to-one replacements are now continually replaced by more advanced sensors with digital interfaces, which allow higher resolution, additional status information and even temperature information to be transmitted to the ECU. Modern magnetic sensors incorporate a wealth of features to increase reliability and safety, as for example error detection and correction of on-chip EEPROM, Cyclic Redundancy Checks (CRC) in the SENT protocol or the detection of open wires and short circuits.

Figure 2 Two examples of gas pedals with non-contacting sensors: Using an inductive principle (left) and a design using the Hall effect (right). Image sources: Hella KGaA Hueck & Co. press image; AB Elektronik, internet publication

The drift of magnetic circuits with temperature has been successfully tackled with user programmable linear Hall sensors. The newest generation of Infineon's linear Hall sensors, for example, allows fully deterministic, state of the art second order temperature compensation of the sensitivity. Humidity and the subsequent swelling of molding material of the sensor module may lead to drift of mechanical stress on the silicon chip. The origin of stress drift can only be treated in a limited way, but advanced stress compensation is successfully used to avert stress dependent signal drifts.

Another magnetic sensing solution we need to mention here is based on magnetoresistive (MR) sensors. This sensor family includes a variety of anisotropic magnetoresistance (AMR) and giant magnetoresistance (GMR) based devices. Other than Hall effect sensors, they are used to detect the angle of a magnetic field and not the flux density. Solutions exist to detect in plane magnetic fields with reasonable accuracy, and main applications are angle sensors for 180° up to full 360°. For the gas pedal application, however, as the measurement angle is often limited well below 90°, linear Hall sensors are sufficient and due to their excellent programmability and possibility to be calibrated accurately, allow to achieve better accuracy than their MR-based counterparts which often have residual errors on the order of +/- 1°, which is already a 5% error for a 40° measurement range.

3.4 Other Technologies

Yet other technologies can be imagined to sense the position of a pedal, including optical systems or incremental encoders. Although these technologies might be leading in some aspects (e.g. resolution, linearity), their drawbacks in important fields (such as cost, reliability, high-temperature capability, etc.) are so prohibitive that these sensors are currently not prevalently used in the gas pedal sensor application.

Table 1 Overview of performance indicators for different gas pedal position sensing principles

	Potentiometric	Inductive	Magnetic
Reliability	Contacting principle, prone to wear	Contactless, good	Contactless, good
Cost	Low	Higher, needs PCB	Higher, no PCB needed
Size	Large	Large, needs PCB	Medium, no PCB needed
Interfacing	Analog only	Digital I/F possible	Analog & Digital available
Calibration	Easy	Complex	Medium
Temperature Drift	Negligible	Small	Can be compensated
Noise	Poor	Medium	Good
Resolution	Bad	Good	Good
Error detection	None	Can be incorporated	Various safety features implemented
Redundancy	Additional tracks, but parallel wear	Additional tracks & IC possible	Easy to assemble two redundant sensors

4 Infineon's Linear Hall Sensors

Infineon offers a variety of linear Hall sensors with different programming, package and interface options. This section gives a general overview of our sensor portfolio. For more detailed information, please refer to the datasheets of each product.

Table 2 Overview of Infineon's linear Hall sensors

	Programming	Package	Interface
TLE4990	Fuses	PG-SSO-4-1	Analog
TLE4997	EEPROM	PG-SSO-3-10	Analog
TLE4998P	EEPROM	PG-SSO-3-10 PG-SSO-4-1 PG-SSO-3-9	PWM
TLE4998S	EEPROM	PG-SSO-3-10 PG-SSO-4-1 PG-SSO-3-9	Digital, SENT
TLE4998C	EEPROM	PG-SSO-3-10 PG-SSO-4-1 PG-SSO-3-9	Digital, SPC

4.1 TLE4990

The TLE4990 is Infineon's basic linear Hall sensor with analog signal processing and fuse programmability. The sensor is end-of-line programmable, meaning that its gain and sensitivity can be set in a two-point calibration in the module. Due to its thin PG-SSO-4-1 package, it fits in small air gaps. The TLE4990 has been field-proven in the last years and is well established for automotive applications such as the topic application of this application note, gas pedal position sensing.

4.2 TLE4997

The TLE4997 has been designed to improve on some of the shortcomings of an analog compensation scheme as the one used in the TLE4990 and most competitor products, including offset and sensitivity drifts over temperature, range of the programmable parameters and accuracy. The signal processing of the TLE4997 is entirely shifted to the digital domain, making the influence of the programmed parameters completely deterministic. Temperature effects of the Hall probe can readily be compensated for using a pre-calibration in Infineon's fabrication. The TLE4997 is also the first sensor on the market that offers independent, programmable parameters for both first and second order temperature coefficients of the application sensitivity, which is especially useful compensating magnetic circuits as used in gas pedal applications as is shown in **Chapter 5.1**. The TLE4997 has an analog, ratiometric output and can be used as a robust replacement for potentiometers. It comes in a small 3-pin PG-SSO-3-10 package and is therefore suited for use in the limited space inside magnetic circuits such as the ones present in gas pedal position sensors.

4.3 TLE4998P

The TLE4998 family is the successor of the TLE4997, providing innovations on the interface side. The signal processing concept is basically based on the TLE4997 design, offering high-precision analog-to-digital signal conversion and a deterministic digital signal processing. The TLE4998P features a PWM interface, in which the duty cycle carries the Hall signal information. It offers 12-bit resolution on the output, and combined with an accurate detection on the microcontroller side, leads to a higher accuracy than what is achievable by an analog interface. More details on interfacing are given in **Chapter 5.6**.

4.4 TLE4998S

The TLE4998S is equivalent to the TLE4998P except for the interface, which is implemented as SAE's Single Edge Nibble Transmission (SENT) standard. SENT offers a low cost alternative to CAN and LIN, but still incorporates a coded digital signal transmission with a Cyclic Redundancy Check (CRC) to check the validity of a transmission. Apart from an industry-leading 16-bit Hall value, the transmitted SENT frame includes 8-bit temperature information and a 4-bit sensor status information. These features are useful for the gas pedal application, too: Cutting-edge accuracy leads to higher precision of gas pedal information and better smoothness. The temperature information can be used for plausibility checks. The status information finally allows for a massive improvement of overall system safety since information on open wires, short circuits and sensor-internal defects can be transmitted within this status nibble.

4.5 TLE4998C

The TLE4998C finally features a Short PWM Code (SPC) Protocol, which is an extension to the standard SENT protocol and therefore offers all the advantages already present in the TLE4998S such as high resolution, status, temperature and CRC information. The sensor does however not send out the measured values indefinitely, but only after being triggered by the ECU. This functionality allows a synchronized transmission of data. The protocol additionally incorporates the possibility to select out of up to four sensors, which are connected to a single bus line. The economical benefits of this solution are further outlined in **Chapter 5.6**.

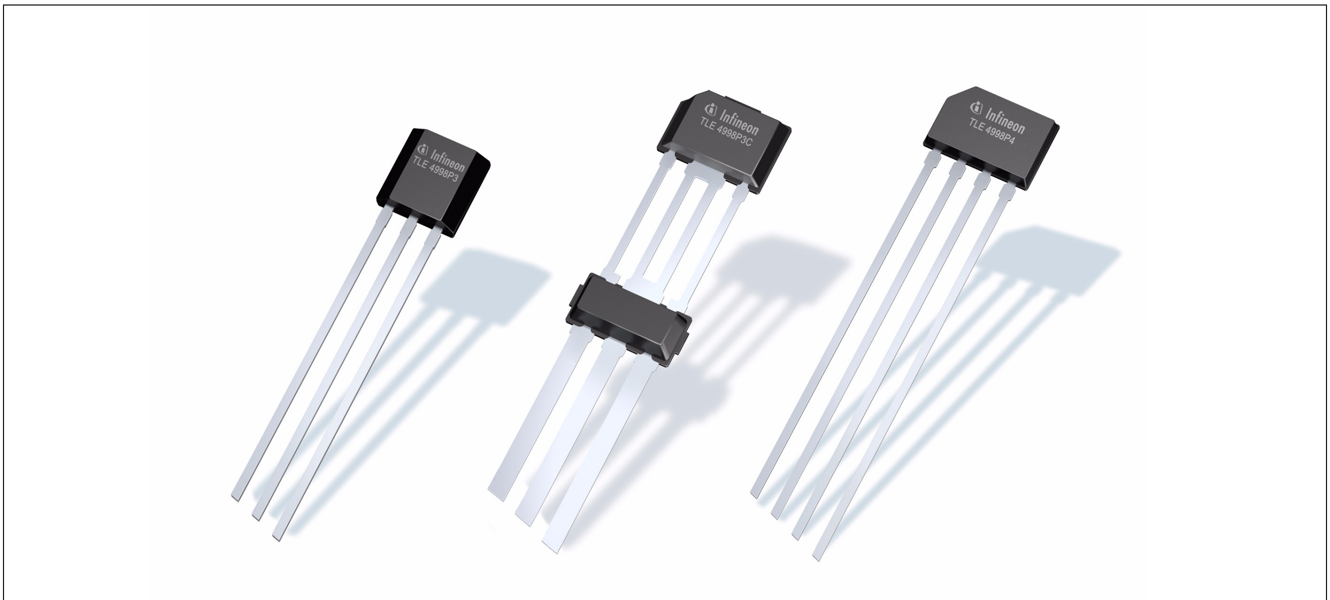

Figure 3 The packages in Infineon's linear Hall sensor family (Taking the TLE4998P types as example): PG-SSO-3-10, PG-SSO-3-9 with integrated capacitors and PG-SSO-4-1.

5 Magnetic Pedal Position Sensors

We are now looking more closely on possible questions arising during the design of magnetic position sensors, such as magnetic circuit design, interfacing or reliability.

5.1 Magnetic Circuitry

What determines the overall achievable performance of a magnetic gas pedal sensor is not exclusively determined by the sensor IC performance alone, but depends to a large extent on the chosen magnetic circuitry. Here we give a review of magnetic circuits used by manufacturers for this kind of application, covering angular ranges of approximately 50°, although many gas pedal sensor designs may need even less angular range than this. Design criteria such as achievable signal linearity, low temperature drifts, independence of mechanical tolerances and process variations, magnetic insusceptibility to external fields, number of mechanical pieces and reuse of existing parts of the applicaton (shafts, bearings, etc.) are all aspects that must be considered in the design of the magnetic circuit.

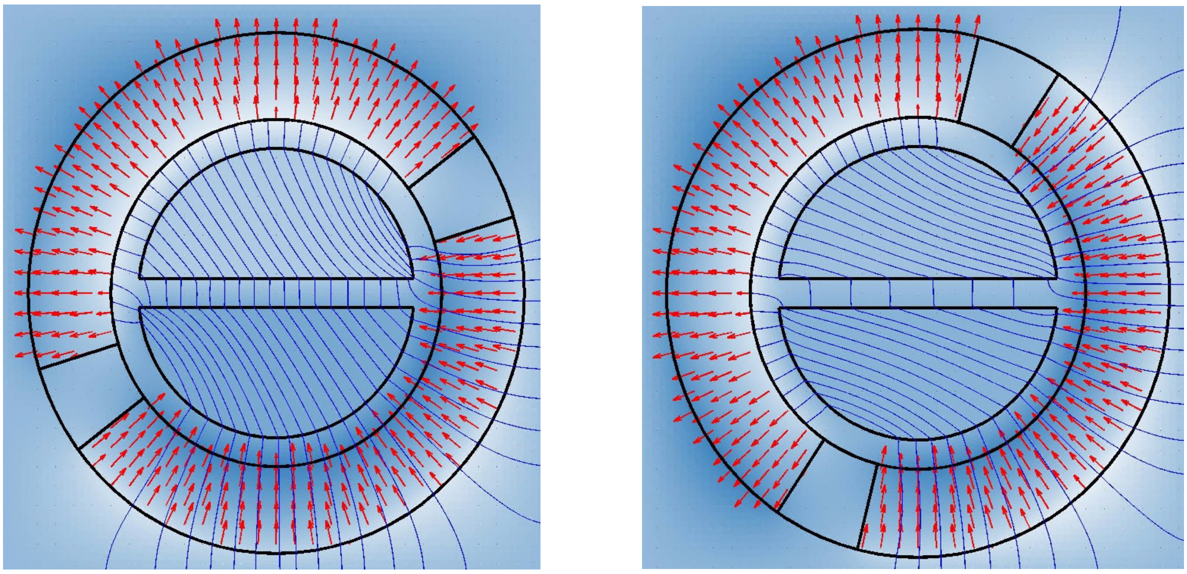

Figure 4 One possible magnetic circuit for high linearity over a large angular range

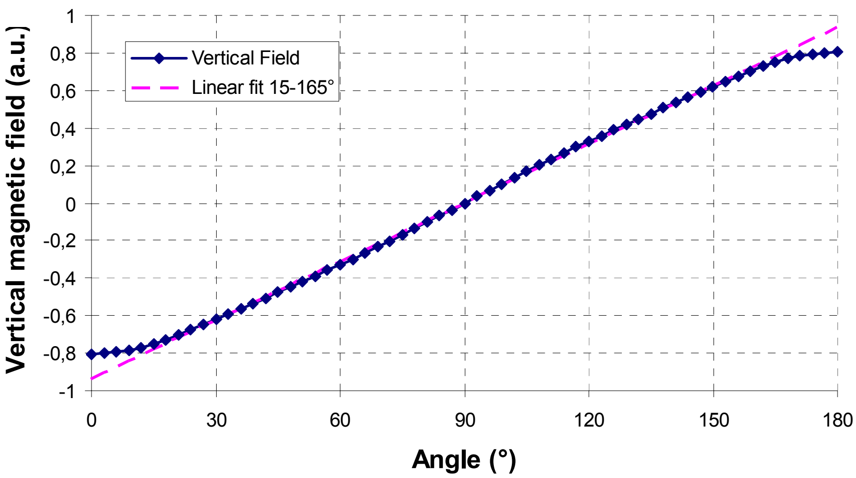

Figure 5 Output signal (vertical component of the magnetic flux density in the inner airgap) of the magnetic circuit shown in Figure 4. High linearity is obtained over a range of more than 120°

Figure 4 shows a basic design possibility to achieve a linear transfer function between angle and magnetic field. The design is based on two ring magnets with opposite radial magnetization, which are linked to the main pivot axis of the gas pedal. Inside, two half-cylinders made out of soft magnetic material are located, having a high magnetic permeability. As can be seen in the figure, the magnetic field lines are essentially perpendicular in the inner gap. Their density (a measure of the magnetic flux density in a particular location) varies linearly with the angle over a wide angular range. Figure 5 shows a typical transfer characteristic that can be obtained in such a system. The linear range extends over a range of more than 120°, which is why this type of magnetic circuit can be used in applications like throttle position sensing. Our application note about throttle position sensing [1] gives more details about this type of magnetic circuit, including aspects of flux boosting and temperature compensation. For gas pedals, since the angular range to be covered is often smaller, we can employ an easier magnetic circuit.

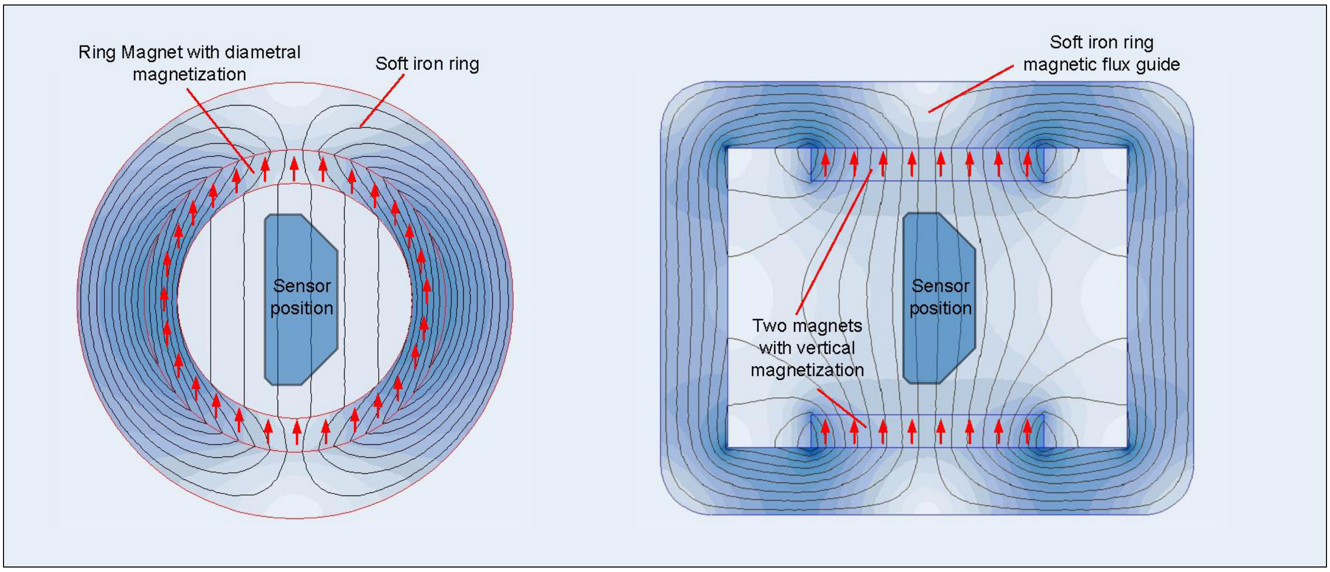

Figure 6 Two of the easiest conceivable magnetic circuits producing a sinusoidal output

Figure 6 shows alternative magnetic circuit designs. The first one consists of a ring magnet, surrounded by some soft magnetic material to both guide the field lines from north to south pole as well as to shield the circuit from external magnetic fields. It can be seen that the flux lines inside the ring are very homogeneous, so there is only a small variation in the magnetic flux density if the parts are slightly misplaced mechanically. One problem with this solution is the fact that the sensor output is inherently sinusoidal, having a decent linearity around its zero position, but having increasing deviation for higher angles.

The second circuit of **Figure 6** uses two small permanent magnet plates attached to a soft iron core having the same function as for the ring type, i.e. guiding the flux and shielding. At first, the shape of the field lines seem to be less desirable since they are no longer perfectly parallel. Although more parallel field lines could be achieved in the center by extending the width of the overall structure, it turns out that this design actually offers a neat possibility to linearize the otherwise sinusoidal output. This can be achieved by slightly offsetting the sensor position within the air gap. The desired effect should lead to a higher magnetic flux in the most deflected positions compared to the idle position. Now, due to the barrel-shaped flux lines, it is exactly this effect that we find if the sensor is placed off-centered: The signal is attenuated in the area around the center position while when moving closer to any of the two poles, we have an increased signal. **Figure 7** shows possible circular paths that the active sensing element can follow when placed off-centered. The corresponding magnetic flux densities orthogonal to this path (i.e. the signal measured by a linear Hall sensor) are then shown on the right side of **Figure 7**. It can be seen that when placed in the center position, the output follows a sinusoidal path as expected. The further off-centered the sensor is placed, the more linear the signal becomes around the zero position, until it finally overcompensates. To further investigate which offset is best, we can look at **Figure 8** showing the non-linearity with respect to a straight line through the 0° and 30° points, which are chosen as a reasonable range to be covered in gas pedal sensors. The non-linearity is expressed as a percentage of this 30° full range. We can see (especially in the figure showing only the 0° - 30° region) that an off-center circle diameter of about 2mm results in the least error, being well below 1% (corresponding to 0.3°).

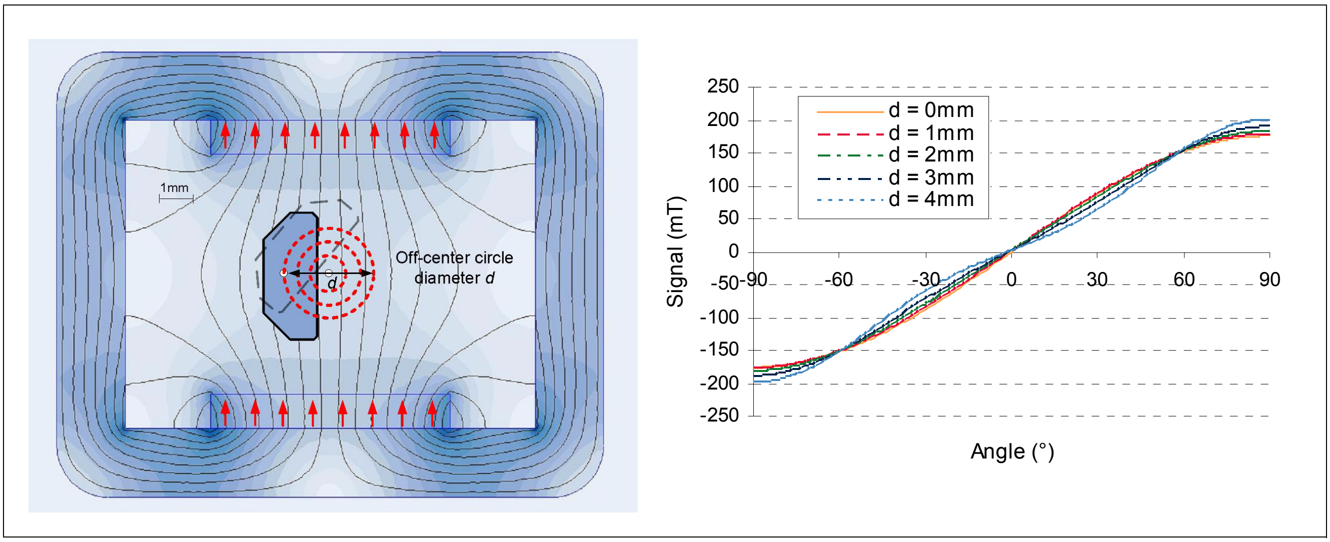

Figure 7 Being off-centered, the active sensor surface now describes a circle when being turned

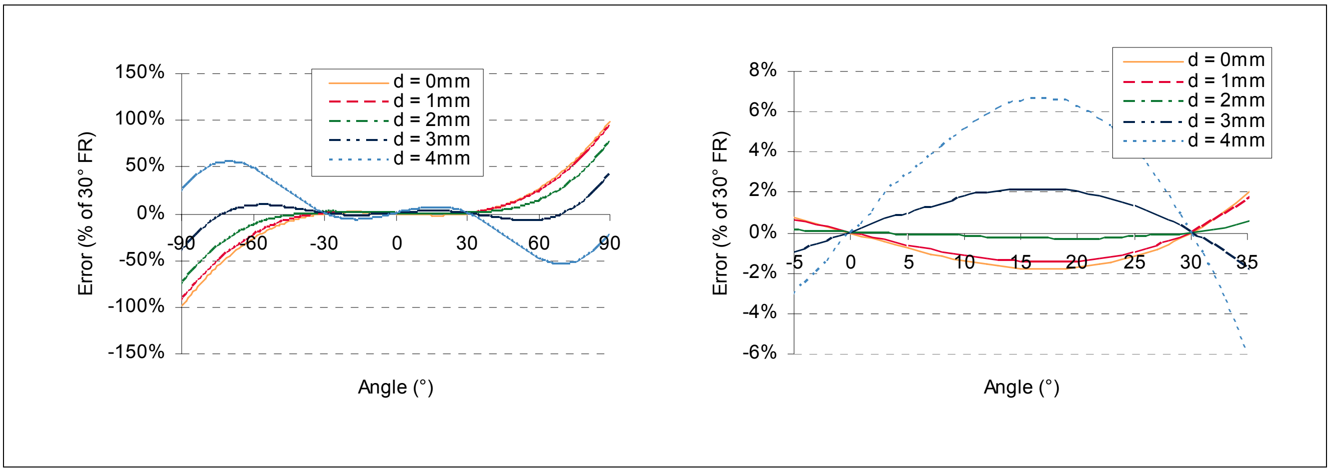

Figure 8 Using an off-centered sensor as shown in Figure 7, the otherwise sinusoidal output can be linearized. The nonlinearity error is shown in terms of the 0° - 30° full range.

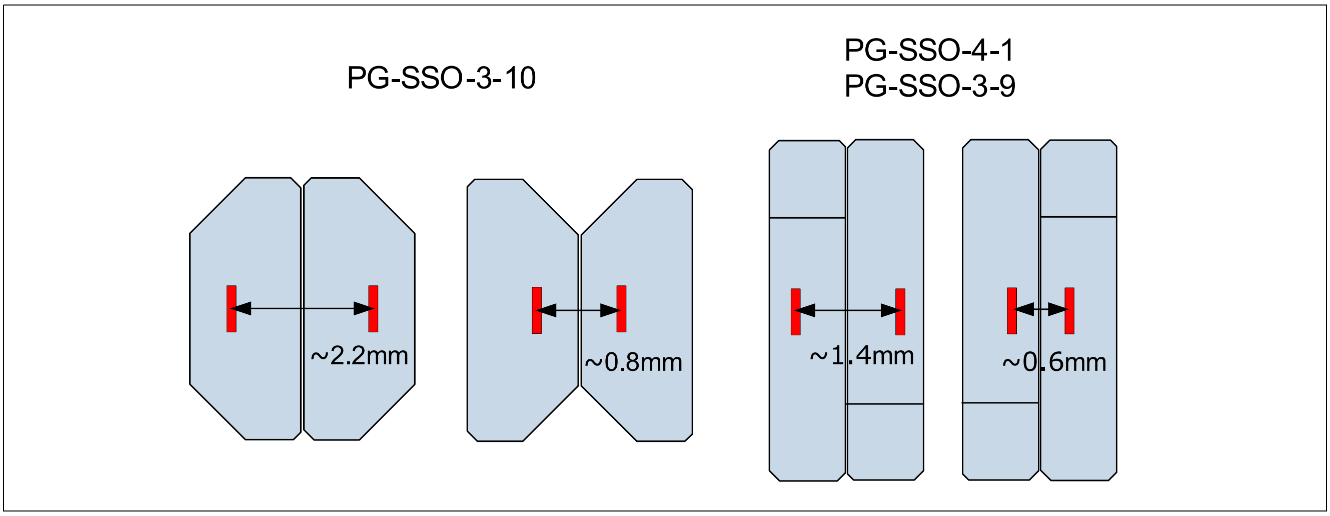

Figure 9 Depending on the package and the way the sensors are arranged back-to-back, different horizontal Hall-plate distances can be achieved

As mentioned before, the gas pedal sensor application generally uses two sensors for redundancy. This means that it is not possible to place both sensors at the center position within the magnetic circuit. What can be a problem in other magnetic circuits is now actually a favourable effect. Taking our linear Hall sensor packages (PG-SSO-4-1, PG-SSO-3-10 and PG-SSO-3-9), it is possible to achieve different offsets between the sensor elements automatically. Some arrangements are shown in **Figure 9**.

One drawback of offsetting the sensor is the fact that the overall system is now more sensitive to relative misalignments between the magnetic circuit and the sensor. In **Figure 10** we can see the influence of offsetting the off-center circle (here, d = 2 mm) in both the x- and y-direction. While a misalignment in the horizontal direction (off x) does not affect the output heavily, it is mainly vertical misalignments (off y) that can lead to some error. To have a reasonable tradeoff between sinus linearization and insensitivity to misalignments, a slightly smaller off-center circle diameter is therefore a good choice.

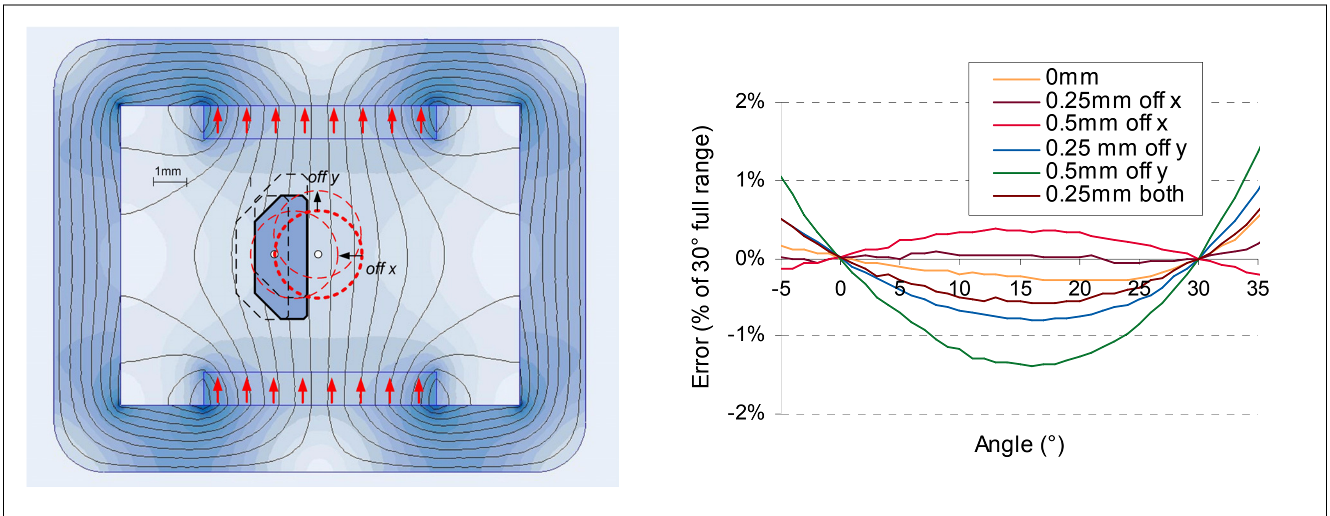

Figure 10 Mechanical misplacement can lead to nonlinearity errors. Here, the influence of offsetting the sensor in both x- and y-direction are shown for an off-center circle diameter d of 2mm.

5.2 Linearity of the IC

Linear Hall sensors profit of a well understood Hall probe design which leads to excellent linearity, independent of temperature and lifetime. Typical measured integral non-linearity (INL) error values of magnetic sensors used to be in the order of ±0.1% of the magnetic field range (MFR). Infineon's TLE4997 and TLE4998 now have a *specified* INL error of ±0.1%, the typical achievable results being even considerably lower. Therefore, the main contribution to nonlinear behaviour comes from the magnetic circuit previously discussed.

5.3 Temperature Stability

The pedal position application requires high accuracy not only at room temperature, but also at low ambient temperature or at levels above 100°C. The drift of the output characteristic of magnetic sensors over temperature has been a problem for some time. The reason for this drift is twofold: On the one hand, the Hall probe itself does not exhibit an inherently stable behaviour in the whole temperature range. On the other hand, the application circuit has some dependency on temperature as well, which stems from a decrease in magnet strength at high temperature, impacts of changing airgaps, etc. Two important components can be identified in the drift of a magnetic sensor over temperature:

- Offset Drift
- Sensitivity Drift

Since the sensitivity drift is a multiplicative error that scales with the sensed magnetic field, this error is the least important close to 0mT field. To achieve best possible temperature stability over the whole measurement range, the best choice is to map the 0mT reading to the most critical position of the measurement range. In the case of the gas pedal application, this point corresponds to the idle position. An offset in this position would lead to a wrong interpretation in the ECU, which could think that the driver already presses the gas pedal when in reality he's not: Absolute errors in the idle position need to be avoided. From a temperature stability point of view, it is therefore a good choice to map the 0mT angle to the idle position. This is in fact the reason why in the previous chapter about magnetic circuits, we have not used a symmetric range around the 0mT position to investigate the linearity, but the range between 0° and 30°. In practice, there is a tradeoff between non-linearity errors and sensitivity drift errors, and one may as well chose a range with slightly negative fields at the idle position such as -5° to 25°.

Infineon offers sensors with compensation algorithms for both offset and sensitivity drifts. The TLE4997 and TLE4998 implement an offset compensation so that the sensors have an outstanding stability of the zero field output. The magnetic offset drift over temperature is an important performance measure for maximum accuracy in the idle position. Infineon's linear Hall sensors exhibit industry-leading offset drift performance. The corresponding angle error can be deduced via the sensitivity of the magnetic circuit, which is roughly on the order of 3mT/° for systems as the ones depicted in **Chapter 5.1**. A drift of 100µT then corresponds to only 0.03° angle error, which is even exceeded by the typical performance of the TLE4997.

Since the sensitivity is affected by both the Hall probe *and* the application, its compensation parameters are available to the customer. Independent parameters for linear and quadratic compensation can be programmed by the customer and excellent stability over temperature can therefore be achieved. We have dedicated user guides on how to find and program those compensation parameters **[2]**, **[3]**.

5.4 Noise

The achievable resolution of systems based on linear Hall sensors has long been limited by noise on the sensor output, in such a way that no advantage over potentiometers could be achieved in this respect. Infineon's TLE4997 high accuracy linear Hall sensor has improved this measure considerably and specifies a peak-to-peak noise smaller than 0.1% of the field range. The possibility of coding information in a digital interface has further lowered the achievable noise. Infineon's TLE4998 with SENT interface has a specified peak-to-peak noise of 2.5LSB12, which corresponds to 0.06% of the full range. Typical measured root-mean-square (RMS) noise levels are as low as 0.01% of field range for the TLE4998.

5.5 Reliability

Due to cost and environmental reasons, a general trend in powertrain design goes towards more integrated and embedded systems, reducing build space and weight. Unfortunately, systems that have been easily accessible before are now highly integrated and can't be changed comfortably anymore, leading to higher cost if failed parts need to be replaced. This is true to some extend for gas pedal sensors, too, where the position sensor is densely packed with the gas pedal. It goes without saying that reliability is a key requirement needed to support this trend, which led to the shift towards contactless systems already discussed above. Position sensors based on the Hall effect are well suited to those systems, allowing significantly more repetitions than comparable systems based on contacting principles and being robust against mechanical shocks and vibrations.

Additionally to the inherent reliability of the magnetic sensors, manufacturers often make use of redundancy for the throttle valve sensor since the drive-by-wire feature is safety relevant. Infineon's analog linear Hall sensor TLE4997 can be readily used to replace the typical potentiometer setup having two units with double output characteristics. For future systems, the TLE4998S is a viable candidate: Additionally to the other features, the sensor transmits status information, an unparalleled 16-bit digital signal value, temperature information and a cyclic redundancy check nibble in its SENT protocol, achieving even higher levels of safety through signal integrity checks.

5.6 Interfacing

Classic throttle position sensors, including the ones using potentiometers, have an analog output and are connected to the A/D converter input of a microcontroller. The TLE4997 is an excellent possibility for a one-to-one replacement of potentiometers, leading to low cost and risk for design changes on the microcontroller side.

The TLE4998P can be employed to economize the A/D interface on the microcontroller, only requiring a common capture & compare (CAPCOM) unit to sample the sensor's PWM signal. The PWM protocol interpretation is extremely simple and does not require an extensive signal processing. Higher resolution can be achieved and because the output is no more ratiometric but consists of an open drain stage, the sensor does not need a regulated 5V supply. The logic high level can be chosen as the microcontroller supply, so no level shifting is required.

The TLE4998S features the SENT protocol (SAE J2716), a low-cost alternative to CAN and LIN interfaces. Being a true digital protocol, it allows higher data resolution than PWM or analog interfaces. The system implementation of a SENT interface can be done for example using Infineon's TC1797 microcontroller. It uses 4 Local Timer Cells in the General Purpose Timer Unit, coupled with one direct memory access (DMA) controller per SENT channel. A typical load of less than 1% per channel is estimated for the whole SENT decoding routine in this TriCore at 180MHz. If a PCP is used for the decoding, the PCP load would amount for less than 5% at that same frequency.

The last interfacing option is offered by the TLE4998C, featuring a Short PWM Code (SPC) format. This format allows some degree of command communication from the microcontroller to the sensor. Three modes are available:

- Sync mode: The sensor sends a standard SENT frame after being triggered by the microcontroller
- ID mode: Up to four sensors can be connected to the same microcontroller input line and are individually triggered using varying master pulse lengths. Cables and connectors, microcontroller input ports, CAPCOM units, interrupts and DMA channels can be saved in this variant among others
- Dynamic range selection: The sensor's input sensitivity can be dynamically chosen

We have a dedicated application note giving details on how to implement SPC functionality on an Infineon TriCore microcontroller [4].

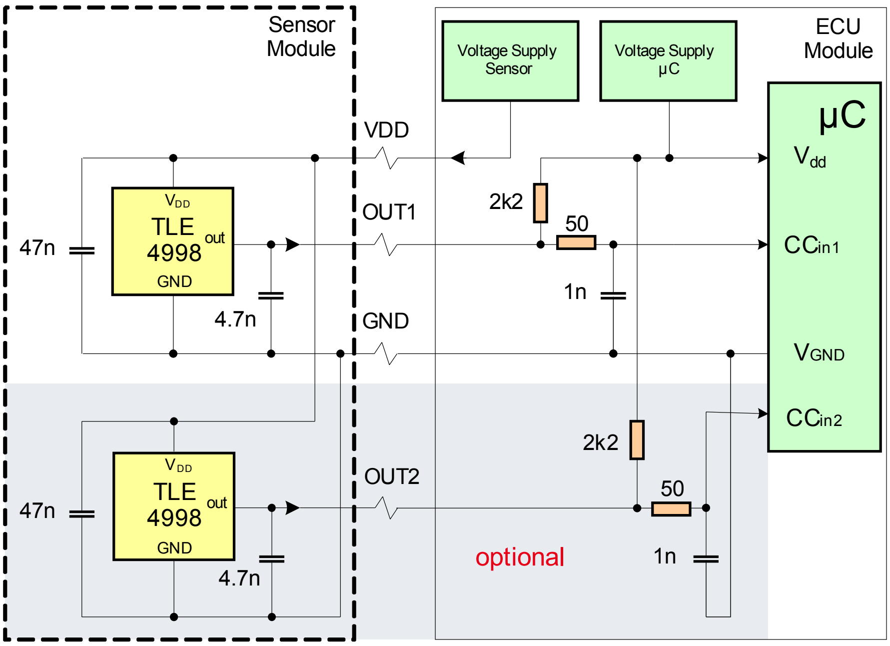

Figure 11 Application Circuit for the TLE4998. Although optional, the second sensor is usually incorporated in gas pedal sensors for redundancy reasons. The proposed application circuits for the TLE4990 and TLE4997 can be found in the respective datasheets

6 Conclusion

Infineon's portfolio of high precision, programmable linear Hall sensors is a perfect match to today's challenging requirements of high reliability, high accuracy gas pedal position sensors. Both analog and digital interfacing options are available to match the different control unit designs, programmable parameters on the chip's EEPROM offer a high degree of customization and state of the art digital compensation ensures a proper functioning even under extreme environmental conditions as seen in automotive applications. That's why we believe Infineon's linear Hall sensors are the right choice for our customers' magnetic gas pedal sensor designs.

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Terminology

AMR	Anisotropic magneto resistance
CAN	Controller Area Network
CAPCOM	Capture / Compare Unit
CRC	Cyclic Redundancy Check
DMA	Direct Memory Access
ECU	Electronic Control Unit
EEPROM	Electrically Erasable Programmable Read Only Memory
EGR	Exhaust Gas Recirculation
ETC	Electronic Throttle Control
GMR	Giant Magneto Resistance
IC	Integrated Circuit
iGMR	Integrated Giant Magneto Resistance
LIN	Local Interconnect Network
MR	Magneto Resistance
PCB	Printed Circuit Board
PCP	Peripheral Control Processor
PWM	Pulse Width Modulation
RMS	Root Mean Square
SAE	Society of Automotive Engineers
SENT	Single Edge Nibble Transmission
SPC	Short PWM Codes

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