sensors

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Electric/Magnetic

Using Magnetic Sensor ICs In Highly Magnetic Environments

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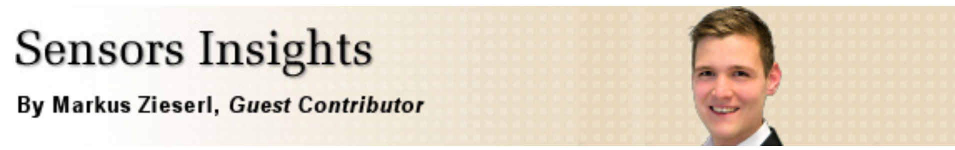

Magnetic position sensors are one of the electronics industry's technological success stories. In industrial and automotive applications in particular, the magnetic sensor's ability to withstand the dust, dirt, grease, vibration and humidity that commonly disable optical encoders – the best known alternative contactless type of position sensor – is highly valued. The industry's most familiar device for measuring linear or angular displacement, the potentiometer, suffers in addition from the effects of mechanical wear, a common source of premature failure. By contrast with both the optical encoder and the potentiometer, a magnetic position sensing system is far more durable and operates significantly more reliably no matter how dirty, damp or unstable the operating conditions.

And yet, a stubborn question about the reliability of the magnetic position sensor lingers in the minds of some industrial and automotive system designers. These engineers often design systems for use in an environment containing powerful sources of magnetism, such as motor drives and high-voltage power transmission lines. Surely the huge magnetic forces unleashed by these systems in, for instance, the enclosed space of a car body or a wind turbine will swamp the weak field generated by the target magnet with which a Hall effect sensor is paired?

This creates a taxing problem for system designers, but only if they are using magnetic position sensors with no inherent immunity to the effect of unwanted external ('stray') magnetic fields. As this article will show, built-in immunity provides a complete protection against the magnetic power of motor drives and power cables and guarantees safe and reliable operation without any need for expensive and bulky counter-measures.

The Characteristics Of Stray Magnetic Fields

Stray magnetic fields may be generated by magnets, motors, transformers or any current-carrying conductors such as electric power lines. They are of growing concern in one sector of the automotive industry in particular: the number and the strength of the stray magnetic fields is greater in electric and hybrid-electric vehicles (EVs and HEVs) than in conventional cars powered by an internal combustion engine (ICE).

In cars with an ICE, the sources of stray fields are mainly located under the hood (bonnet). In EVs and HEVs, stray fields are certainly present under the hood. But crucially, these vehicles also have large battery packs for powering the traction system. In passenger cars, for optimal weight distribution this heavy battery is commonly mounted centrally beneath the wheels, in a recess underneath the cabin. Another common position for the battery is in the rear of the car, beneath the trunk (boot).

This means that cables are required to carry large amounts of current, as much as 400A at full load when the vehicle is accelerating from the battery to one, two, or four electric motors. In order to deliver power to the electric motor(s) driving the front wheels, these cables must pass close to safety-critical systems such as the gas (accelerator) and brake pedals (see figure 1). In modern 'drive by wire' systems, the movement of these pedals as the driver progressively engages or re-leases them is measured in real time by rotary position sensors: The sensors feed their output to electronic control units (ECUs) which control the actuation of the brakes or throttle.

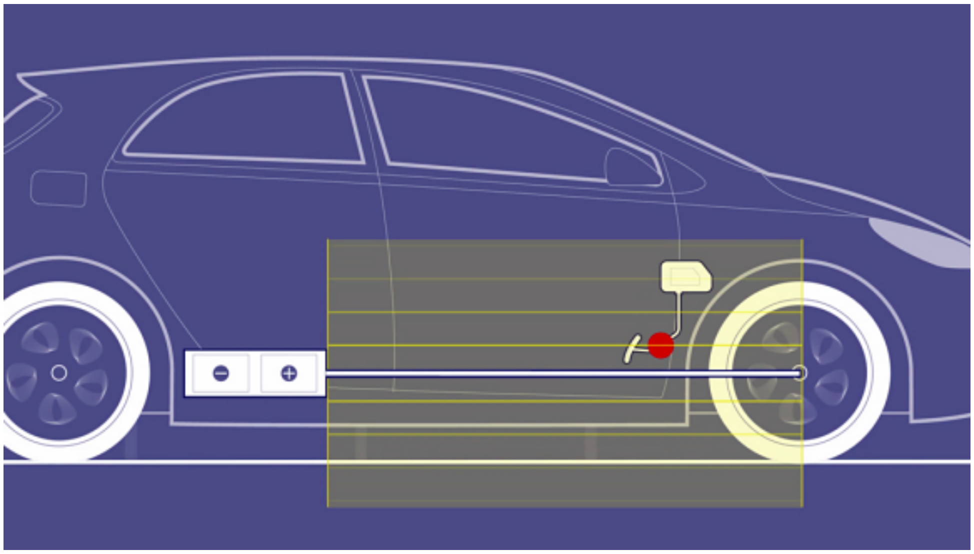

Fig. 1: The extent of the stray magnetic field from a high-voltage power line in an EV or HEV is easily large enough to affect safety-critical systems such as the brake pedal.

The problem of stray magnetism is not, however, confined to EVs and HEVs. Many new ICE cars, as well as EVs and HEVs, feature an electric power steering (EPS) system. The EPS's motor, which applies assistive power to the steering mechanism, also generates a strong magnetic field around the position sensor used to continuously measure the angle of the rotor. The sensor's outputs enable the motor control system to commutate the motor properly so as to maximize torque and minimize noise and vibration.

Car manufacturers are worried because a stray magnetic field of sufficient strength can cause conventional magnetic position sensors, if unprotected, to produce distorted or false output signals. A very strong stray field can in some cases even damage the sensor permanently. And this is of vital importance, because brake pedal, gas pedal, and steering systems present a severe risk to the life of the driver, passengers, and other road users should they fail, and the position sensor plays a critical role in each one. The consequences of a false reading of the brake pedal's displacement for instance, registering a small displacement when the driver has actually stamped the pedal to the floor in order to perform emergency braking could be catastrophic.

Not surprisingly, therefore, the car industry has moved to tighten the specifications governing the safe operation of systems that might be exposed to stray magnetic fields. Standards such as ISO 26262 (functional safety) and ISO 11542-8 (immunity to magnetic fields) are meant to eliminate the risk of failure including failure due to stray magnetic fields.

In fact, the car industry sets tough quality standards even for cabin components with no safety implications, such as knobs and buttons that might traditionally have been controlled by a simple potentiometer. Many industrial applications have similarly stringent requirements for safety and reliability. System designers using magnetic position sensors must therefore know before they even start a new design how they are going to guarantee their system can withstand the powerful force of external magnetic stray fields.

Costs Of Mechanical Counter Measures

When using a conventional magnetic position sensor, design engineers are forced to take counter-measures to protect it from stray magnetic fields. Since the stray fields are present most of the time, a popular counter-measure is to shield the sensor with special material: metal alloys with high magnetic permeability, such as permalloy or mu-metal, are commonly used. Unfortunately, the problem with these materials is that they do not block the magnetic field. Instead, they absorb the field, providing a path for it to keep it at a known distance from the sensor (see figure 2).

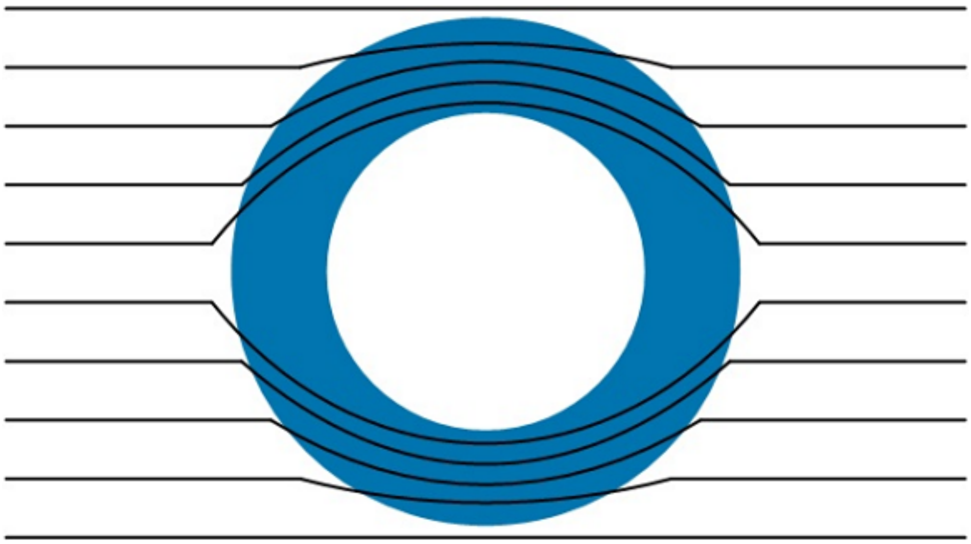

Fig. 2: A magnetic shield changes the shape of every magnetic field in its vicinity.

But this absorption effect is not selective, it can equally affect the magnetic field of the sensor's paired magnet (mounted on the object measured by the sensor, such as a motor's rotor, or a shaft attached to a gas or brake pedal). This has the potential to distort the position measurements of the sensor.

To avoid this unwanted effect on the paired magnet's field, a minimum distance has to be maintained between it and the shielding material. This then increases the size of the complete sensing system, which must be big enough to accommodate an otherwise useless air gap between the sensor and the shielding material.

There is another considerable disadvantage to the shielding method of protection: the special metal alloys are very expensive, and markedly increase the bill of materials of the system, and also its weight. They also make assembly more complicated and expensive.

Finally, there is an easily ignored cost to the time taken to design, evaluate, and verify a shielding design that can guarantee compliance with the appropriate safety standards. This can take months of development effort as engineers look for the appropriate trade-off between protection and cost.

How Built-In Immunity Eliminates Expensive Counter Measures

It would, then, be preferable to build a position sensing system that benefited from the durability and reliability of magnetic technology, but that did not bear the burden of the expensive counter-measures described above. And in fact, this is possible when using a magnetic position sensor with built-in immunity to even the strongest stray magnetic fields (up to a huge 50mT).

For one example, sensor manufacturer ams offers system designers built-in immunity via differential sensing technology. An ams magnetic position sensor such as the AS5147 has four integrated Hall elements in a north/east/south/west configuration. These elements are only sensitive to changes in the magnetic field in the z dimension, and do not measure magnetism in the x and y dimensions. This means that they are inherently immune to stray magnetic field changes in the x and y dimensions.

The four Hall elements generate four sinusoidal waveforms when a diametrically magnetized (two-pole) magnet rotates over them. Each signal is phase-shifted by 90° from its neighbor.

Differential amplification is applied to the two opposing pairs of Hall elements, that is, the pairs 180° from each other. This results in one sine and one cosine signal, both with doubled amplitude. These signals are digitized, and the digital signals are processed by an integrated CORDIC (COor-dinate Rotation DIgital Computer) digital block, which executes a mathematical arctangent function. Its output is an angle measurement and a measurement of the magnitude of the sensed magnetic field (see figure 3).

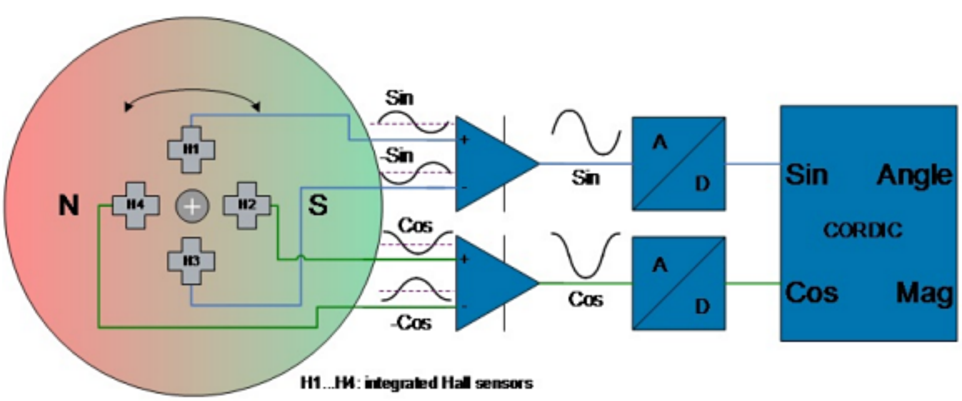

Fig. 3: The principle of operation of a differential sensing architecture.

The differential principle of operation cleverly offsets any stray (external) magnetic field. This is because the effect of an external field will be (except to a negligible degree) the same on all four Hall elements. Since the sensor calculates position based on the difference between the output of the two pairs of Hall elements – not on the absolute output from any single Hall element – it does not matter if a stray field raises the total magnetic field strength at the sensor many orders of magnitude above that generated by the sensor's paired magnet alone. The sensor's output will remain completely undistorted (see figure 4).

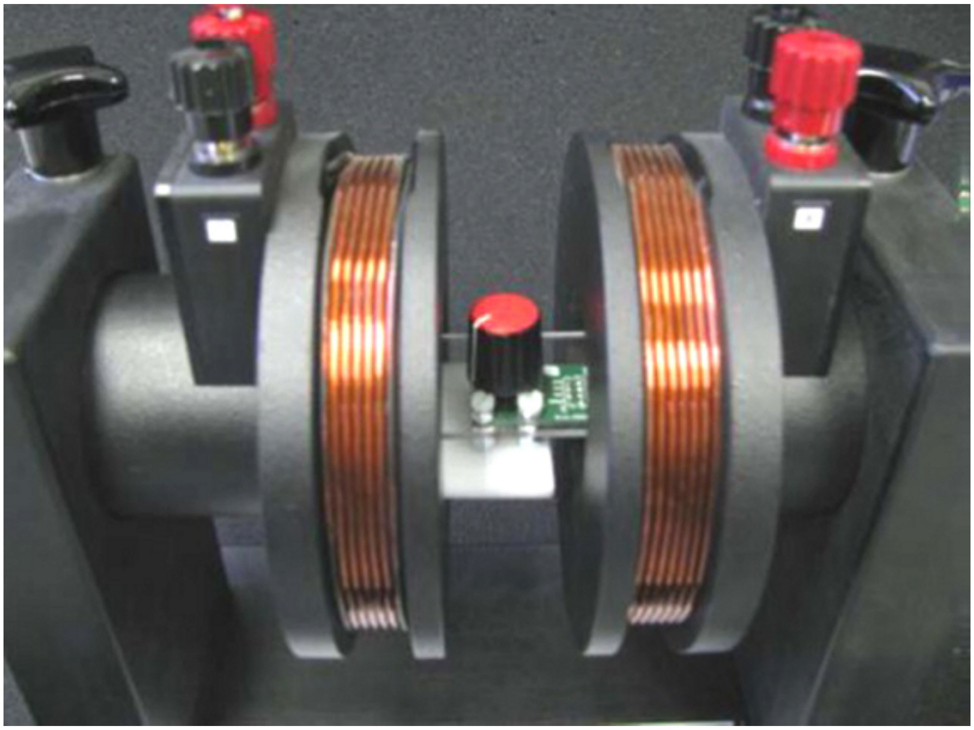

Fig. 4: An ams position sensor's operation is unaffected even by the very strong magnetic fields generated within a Helmholtz coil.

Using a sensor based on the differential sensing principle offers various advantages:

- The design engineer knows that the sensor is unaffected by stray fields by design. This saves the cost of developing and implementing a verified shielding design.
- It eliminates the need for shielding materials, which reduces the cost, size and weight of the entire system.
- It provides more easily verified and documented evidence to support manufacturers' ISO 26262 and ISO 11542-8 compliance programs.

As demand for vehicles with wholly or partly electric drivetrains starts to ramp up, encouraged by governments' de-carbonization initiatives, the number of vehicles carrying powerful magnetic fields is only set to grow. This demands that users of magnetic position sensors should pay closer attention than ever before to the value of built-in immunity to magnetic interference.

Summary

By contrast with the optical encoder and the potentiometer, which are older technologies for position sensing, a magnetic position sensing system is far more durable, and operates far more reliably no matter how dirty, damp or unstable the operating conditions.

And yet, a stubborn question about the reliability of the magnetic position sensor lingers in the minds of some industrial and automotive system designers. These engineers often design systems for use in an environment containing powerful sources of magnetism, such as motor drives and high-voltage power transmission lines. It is reasonable to ask whether the huge magnetic forces unleashed by these systems in, for instance, the enclosed space of a car body or a wind turbine will swamp the weak magnetic field generated by the target magnet with which a Hall effect sensor is paired.

This creates a taxing problem for system designers – but only if they are using magnetic position sensors with no inherent immunity to the effect of unwanted external ('stray') magnetic fields. As this article shows, built-in immunity provides a complete protection against the magnetic power of motor drives and power cables and guarantees safe and reliable operation without any need for expensive and bulky counter-measures.

About the Author

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