INNOVATION WITH PURPOSE

SYSTEM-LEVEL APPLICATION CONSIDERATIONS FOR MAGNETIC SPEED SENSORS

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INTRODUCTION

The use of a noncontact, active, speed sensor integrated circuit (IC) greatly simplifies system design-in of a magnetic speed sensor. Although these ICs are designed to operate under a wide variety of system factors, the cautious automotive designer must contemplate certain more-subtle system considerations. This application note discusses a number of these subtle influences, focusing on the more peripheral phenomena and scenarios not explicitly linked to the intended target movement and resulting magnetic input signal.

DESIGN CONSIDERATIONS

Some of the many typical design decisions and considerations when working with magnetic sensors include:

- Electrical interface
  - □ Two-wire vs. three-wire output communication protocols
  - □ Voltage and current requirements
- Operational air gap range
- Target design
  - □ Ring magnet encoder
  - □ Ferromagnetic target
- Magnetic biasing
  - □ Allegro offers "ATSxxxxx" products, which include a correctly applied magnet needed to sense ferromagnetic gears (back-bias)
  - □ Allegro offers "Axxxxx" products for customers who want to use their own magnet or a ring magnet encoder (front-bias)
- Mechanical sensor
  - □ Sensor IC encapsulation (e.g., overmold)
  - □ Sensor orientation tolerance
  - □ Electrical contacts
- Electromagnetic compatibility

These typical design decisions above are not discussed in this application note. For information about these more-typical topics, refer to sensor-specific datasheets, other applications notes, or local applications support.

SENSING LOCATION

When placed in a system, the face of a magnetic sensor must be positioned toward and adjacent to the target features of interest. Based on the expected behavior of the mechanical system, it may make sense to adjust the sensor position or the sensor orientation with respect to the target. For example, gravity may cause a gear on a shaft to sag toward location B in Figure 1; whereas, during higher gear speeds, the axis of rotation may bias the gear toward location D.

In general terms, mechanical loading may cause target movement, which in turn may have some positional impact on the sensor and target relationship. If movement of the rotational axis causes movement from B toward D, it would be advantageous to position the sensor at either position A or position C. The goal is to position the sensor such that the magnetic system is minimally impacted by mechanical movements.

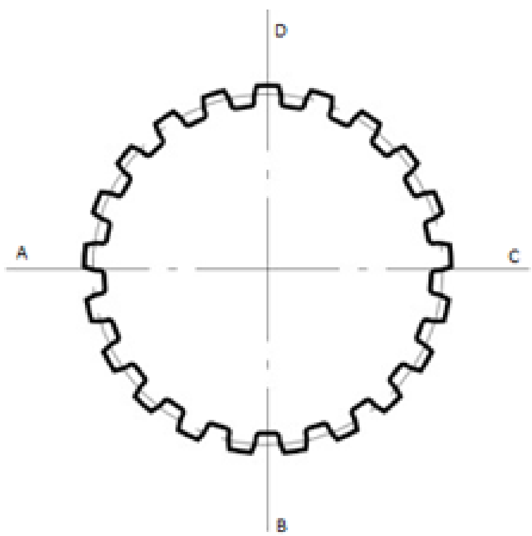

Figure 1: Target With Identified Sensor Locations

TARGET MANUFACTURING

A magnetic sensor can only perform as well as the target to be sensed allows. Variations in the target itself impact the performance of the sensor. Here, the impact of target variations is considered without respect to tooth and valley dimensions. (To understand appropriate tooth and valley dimensions for a specific sensor, refer to the relevant Allegro datasheet.)

Any tooth or valley variation along dimensions t and t_V or tooth-to-tooth variations in dimension h_T may impact sensor performance (see Figure 2). These three parameters of the target combine to impact speed accuracy, pitch deviation, operational air gap range, tooth edge repeatability, and dynamic air gap handling. These mechanical parameters can be related to electrical parameters by referencing Figure 3. From the figure, parameters t and t_V have the largest impact at the zero-crossing point of the processed magnetic signal. Parameter h_T has the largest impact on the signal at the peak and valley.

Precise control of these parameters will help improve the performance of the magnetic system and, therefore, the overall system function and information that can be extracted from it.

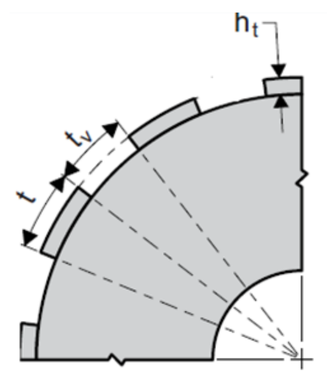

Figure 2: Target Mechanical Definitions

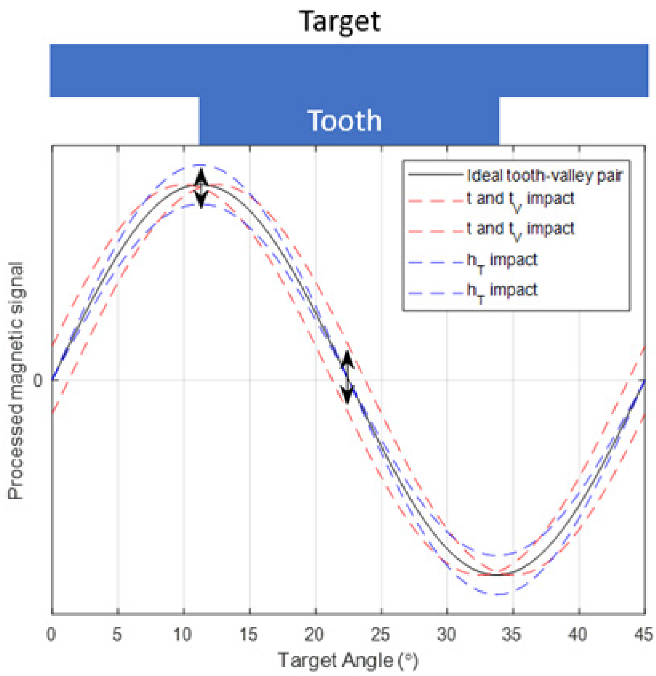

Figure 3: Processed Magnetic Signal Impact

Magnetic flux permeability varies by material. Therefore, to avoid magnetic flux concentration differences as the teeth pass by the sensor, the target wheels should be produced in a way that makes the material consistent for each tooth on the target.

Target teeth that have any small valleys or defects—such as due to fixturing during creation—are not recommended. Because the tooth is the region of the target that comes closest to the sensor during operation, small valleys may negatively impact sensor performance. Any defects or small valleys that exist in target teeth are likely to be detected by a magnetic sensor.

HIGH-SPEED EFFECTS

The relevant Allegro sensor datasheet indicates the intended bandwidth of operation. In applications that use a ferromagnetic target with a back-biased sensor, the magnetic field changes quickly as the teeth and valleys pass by the sensor, which introduces eddy currents. These eddy currents impact the maximum operational air gap performance of the magnetic system by reducing the available magnetic flux at the sensor sensitive element. Eddy currents are target-dependent and are more affected by the linear velocity of the target than the magnetic signal frequency. In general, this means that the larger the target diameter, the greater the expected impact to air gap performance.

In applications that use aluminum as a nonferromagnetic material in the gap between the sensor and the target, eddy currents will accumulate on the aluminum, which will further impact magnetic flux availability as linear velocity increases.

FERROMAGNETIC DEBRIS

Ferromagnetic debris within a sensing environment, such as metal shavings in transmission fluid, are an extremely volatile factor in magnetic sensing. While a small amount of fine powder has a negligible effect, a relatively large splinter of iron moving between sensor and target can severely warp the signal. Between all the potential shapes, sizes, and quantities of debris and all their possible movements, the variety of distortions is practically endless.

Ultimately, the best way to mitigate the risk of this phenomenon is to eliminate or prevent the existence of debris. However, if its presence is unavoidable, there are still steps that can be taken, such as intelligent positioning of the sensor. Due to gravity, debris is likely to settle at the bottom of the environment in most cases, so it follows to avoid placing the sensor where gravity would attract debris.

FERROMAGNETIC MATERIAL

Ferromagnetic material intended to be present in or around the sensing environment can have unintended effects on the magnetic signal. Ideally, a magnetic sensor would be used with a simple target in an empty vacuum. In practical application, however, sensors are often packed into cramped spaces with many moving parts, and the impact that the moving parts have on the magnetic system must be considered. For example, although the uniform iron disk attached to the target in Figure 4, right, may negatively impact the magnetic biasing of the sensor, the holes in the disk in Figure 4, left, would most likely introduce a second periodic signal, which would critically obscure the gear teeth that are intended to be sensed by the IC.

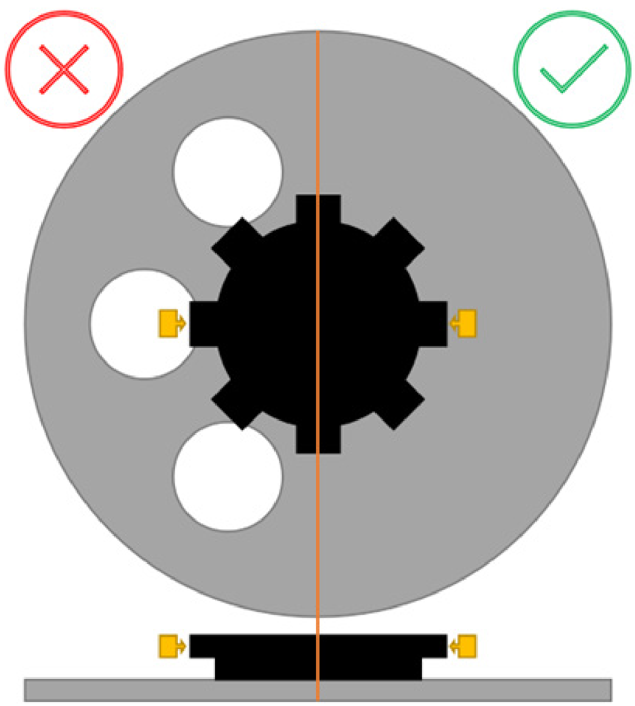

Figure 4: Sensor Placement Tradeoffs

UNDESIRED INTERFERING MAGNETIC FIELDS

The operation of a magnetic sensor IC can be compromised by introduction of interfering magnetic fields. Therefore, the system design should consider undesired sources of magnetic signal—be they persistent or dynamically generated.

When using a back-biased sensor system, inadvertently magnetized ferromagnetic target features can cause persistent unintentional magnetic fields. A magnetic field emanating from a target tooth adds an undesired component to the desired field from the permanent magnet of the sensor. An unintentional magnetic field of sufficient magnitude will disrupt sensor operation. Magnetization of a target (dependent on material) may occur during manufacturing if electromagnets are used to manipulate the target or if permanent magnets are allowed to contact the target for an extended period of time.

Dynamic magnetic fields may be generated from other system elements, such as high-current cabling, electric motors, or solenoids. Magnetic fields created by nearby field-generating elements can also act as added noise to the desired sensed magnetic fields and, at a certain magnitude, can compromise proper sensor IC operation. Differential sensors provide some inherent protection from common-mode stray fields; however, the best factor to mitigate impact is, ultimately, distance from these sources.

MECHANICAL STRESS

Hall-effect sensors are sensitive to mechanical stress due to a piezoelectric effect that may occur after the sensor IC is packaged inside the application sensor housing. This stress changes the sensitivity of the Hall element itself. These sensitivity changes are most apparent when differential sensors with Hall elements are located near the edge of the IC package. Applications most impacted by this effect are those that use a differential sensor to provide a corrected output signal for a target that has teeth sized larger than twice the distance from the outside-to-outside Hall plates of the sensor.

Although the effects of mechanical stress may not be observed at an ambient temperature, consideration of stress versus temperature is recommended.

CONCLUSION

When designing systems that use magnetic speed sensors, many subtle design considerations come into play, often within a single application socket. Although the industry-leading, time-proven algorithms included in Allegro sensors are designed to handle the most stringent application conditions, consideration for the factors mentioned in this application note will allow a system to operate with tighter limits on performance, which will make it easier to detect anomalies in the system or to detect system deterioration over time.

Revision History

Number	Date	Description	Responsibility
–	May 31, 2022	Initial release	K. Maffei, B. Benedix, E. Burdette