

TRANSMISSION GEAR TOOTH SENSING

By Kevin Maffei
Allegro MicroSystems

Introduction

Transmission applications have diverse conditions to consider for optimal speed sensing design-in and performance. Sensed targets are primarily made of ferromagnetic material, but magnetic encoders are used in a small percentage of the application sockets. Solutions include both two- and three-wire output interface protocols and may include rotational direction and fault reporting for ASIL compliance, in addition to standard speed information.

Key Parameters

Design-in of an Allegro speed or speed and direction sensor into a transmission is simple. The two key mechanical parameters that must be given close attention are listed below:

1. Alignment of the sensor branded package face with the target teeth.
2. Distance between the sensor branded package face and the target tooth.
 - A. This distance is frequently referred to as the sensor to target "air gap".

The radial sensing image, Figure 1, depicts a good mechanical sensor-to-target alignment. Four mechanical factors work together to form good alignment:

1. Sensor branded face points to target teeth.
2. Center of the sensor branded face is aligned with the center of the target.
3. During target rotation, the teeth pass over the branded face of the sensor such that they move in a pin 1 to pin 2 or pin 2 to pin 1 direction.
4. Air gap between sensor and target teeth is within datasheet limits.

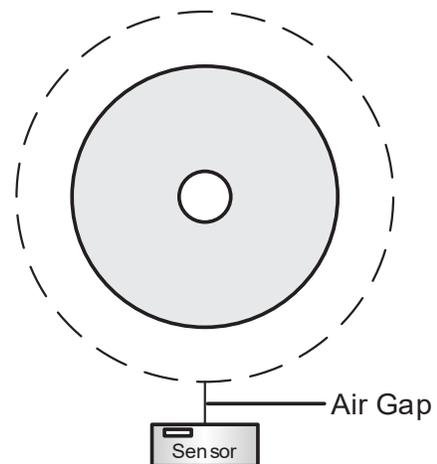
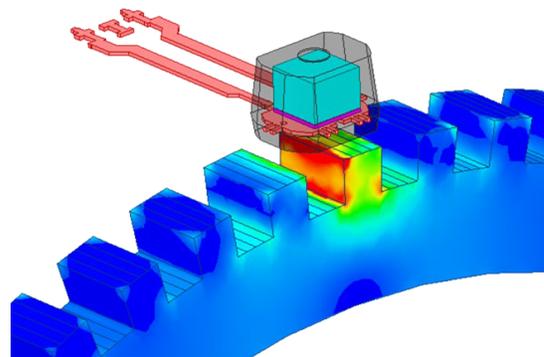


Figure 1: System mechanics

Environmental Factors

The many changing conditions that a transmission is subject to will create a challenge for a magnetic sensor to overcome in order to continue to output reliable speed and/or speed and direction information. Temperature changes cause materials to change in size, impacting the sensor-to-target air gap. This change may happen while the target is in rotation or while stationary and both situations must be handled without interruption. With a relatively high vehicle weight, large forces are exerted to create acceleration and deceleration. These large forces cause sudden movements inside a transmission that can change air gap in a sudden or gradual manner with respect to the speed of the target being sensed. Cold starts of vehicle movement may cause a shaft to lift as it starts to spin, or a vehicle transitioning from one gear to another are periods when undesirable target movement may occur. This undesired movement of targets being sensed can confuse a transmission control unit (TCU) and therefore handling of these movements should be considered.

Air Gap Range

Understanding the range of air gaps that a sensor may operate at is a key parameter during design of a system. This range is impacted by many factors related to the design of the target to be sensed, and because of this, a reference target design is included in all the pertinent device datasheets. Allegro sensors are designed to maintain an equal air gap ability over the temperature extremes of the automotive industry.

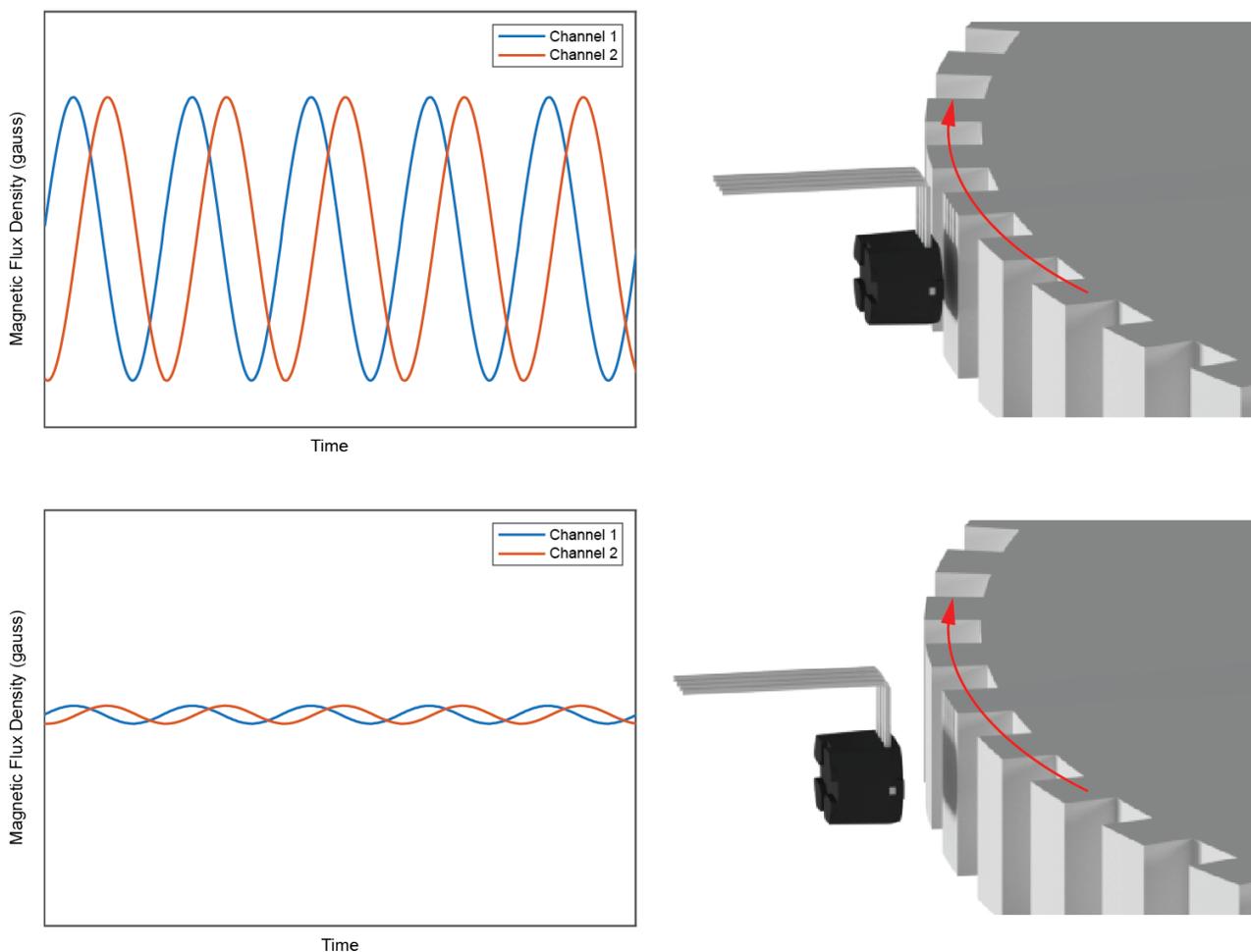


Figure 2: Air Gap Range (click images for animation)

Gradual Air Gap

Transmission sensors are primarily dynamic threshold detectors. This method of signal processing allows for sensor learning, which translates to the ability to update output switching thresholds as the target teeth pass by. Updating thresholds based on new information gained inherently provides the ability for an uninterrupted output signal during gradual air gap movements that may occur on the system level. A gradual air gap movement may be repetitive, for example, a target rotating on- and off-center axially or in the case of runout, radially as depicted in the example shown.

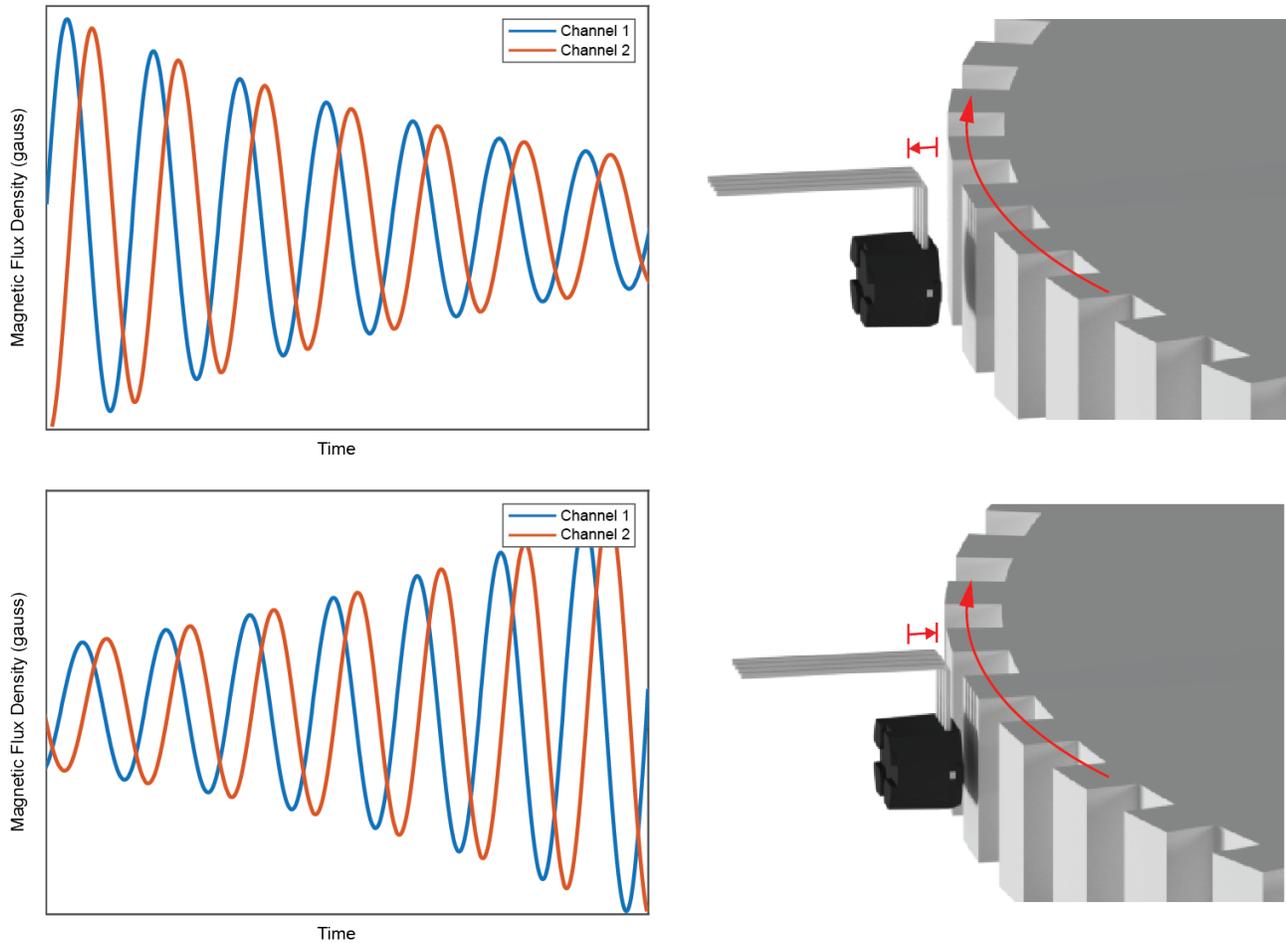


Figure 3: Gradual Air Gap (click image for animation)

Sudden Air Gap

Sudden air gap refers to changes in air gap that occur within the rotational span of a single tooth-valley pair. In cases where movement is large enough in magnitude, the detection thresholds may not be crossed. This extreme event would ordinarily cause a permanent loss of speed and direction information, although today, Allegro transmission sensors include advanced event-based algorithms to recover the speed and direction output quickly, only causing a momentary output signal disruption to an extreme system-level condition.

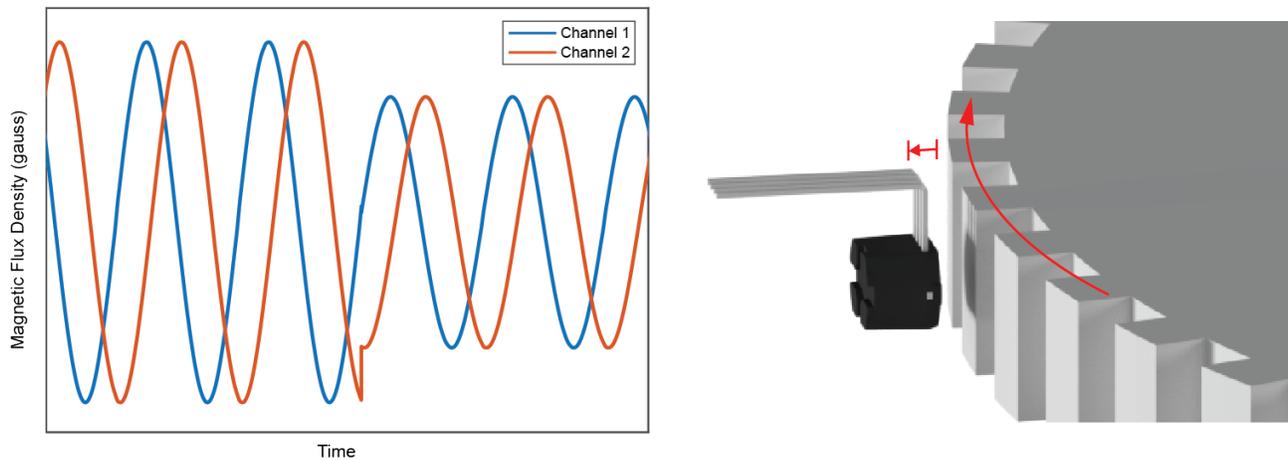


Figure 4: Sudden Air Gap (click image for animation)

Direction Change

Target direction of rotation detection is possible due to the physical location of sensing elements. This physical position of the sensitive elements facilitates phase relationship between sensor channels. A phase relationship can be interpreted as a vertical separation between channels at any given time. This separation information is used to determine target direction of rotation. However, a target direction of rotation change may be angular target vibration and not a true direction change. To verify a direction change, the sensor must observe a certain amount of consistent same direction rotation. This amount of consistent same direction rotation can be flexible to give information as soon as possible or be delayed based on the high and low vibration detection option.

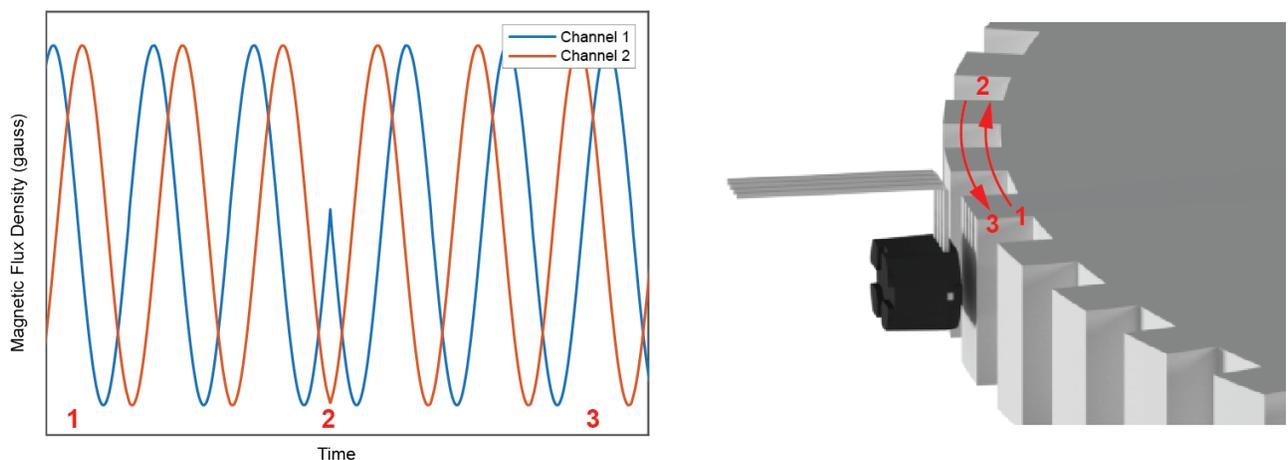


Figure 5: Direction Change (click image for animation)

Vibration

Vibration of a transmission gear can present as air gap vibration, angular vibration, or a combination of both. Under the correct conditions, a transmission sensor vibration signal can look like a normal rotational signal. Allegro transmission sensors use industry leading low and high vibration detection algorithms to distinguish vibration from normal rotation and suppress output during vibration.

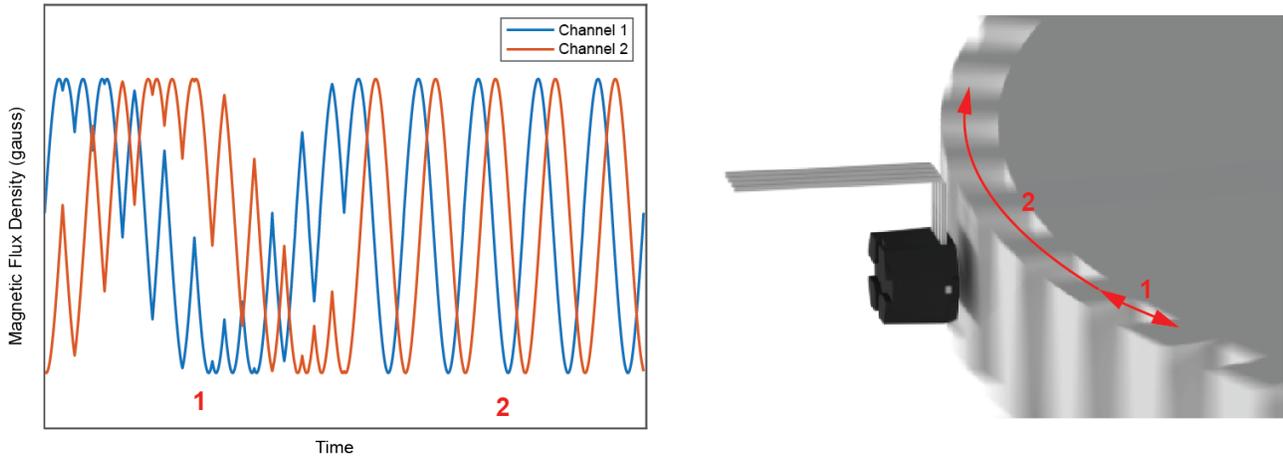


Figure 6: Vibration (click image for animation)

Conclusion

All the above factors can occur, often within a single application socket. Therefore, the industry-leading, time-proven algorithms Allegro includes on their transmission ICs have been designed to handle the most stringent application conditions.

Revision History

Number	Date	Description	Responsibility
-	April 22, 2021	Initial release	K. Maffei

Copyright 2021, Allegro MicroSystems.

The information contained in this document does not constitute any representation, warranty, assurance, guaranty, or inducement by Allegro to the customer with respect to the subject matter of this document. The information being provided does not guarantee that a process based on this information will be reliable, or that Allegro has explored all of the possible failure modes. It is the customer's responsibility to do sufficient qualification testing of the final product to ensure that it is reliable and meets all design requirements.

Copies of this document are considered uncontrolled documents.