TARGET DESIGN FOR BACK-BIASED HALL SENSOR IC ATS667LSG

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INTRODUCTION

The ATS667 Hall-effect sensor ICs employs single Hall channel sensing in conjunction with signal compensation architecture to transmit transmission gear sensing data to the system. A ferromagnetic design is pivotal in ensuring precise, dependable, and robust gear-system operation. This application note aims to provide users with guidance on ferromagnetic target design and the relative impacts of varying key system parameters. In the following, the magnet designs are fixed by using an Allegro IC package with an integrated magnet.

Target parameters featured in simulations are as shown in Table 1 unless otherwise explicitly stated.

The data and graphs will show some of the properties of the desired signal shape and amplitude when parameters such as tooth length and valley width are varied. The information herein can be used as a general guide for coarsely predicting performance for a set of gear geometries; validation should always be done through applications analysis. For additional support, contact your local Allegro sales representative.

For guidance on target design for Allegro back-biased GMR element sensors, see AN296305: Target Design for Back-Biased GMR Sensor IC ATS19580LSN.

FREE DESIGN PARAMETERS

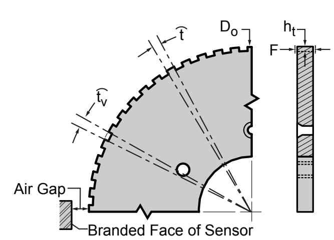
Multiple factors that influence Hall-effect IC performance with a ferromagnetic target include:

- Tooth shape (i.e. rectangular or triangular, and radius of edge)
- Tooth length
- Valley width
- Tooth height
- Target thickness
- Properties of integrated magnet (shape, material)

Target Material

The magnetic permeability of the target material is not discussed in this application note. For that information, refer to application note AN296132: Impact of Magnetic Relative Permeability of Ferromagnetic Target on Back-Biased Sensor Output, available at allegromicro.com.

Table 1: Parameter definitions for Allegro Reference Target 60-0.

Parameter	Symbol	Nominal Value	Units	Symbol Key
Outer Diameter	D_o	120	mm	
Target Thickness	F	6	mm	
Circular Tooth Length	t	3.14	mm	
		3	degrees	
Circular Valley Width	t_v	3.14	mm	
		3	degrees	
Tooth Height	h_t	3	mm	

SENSORS

Allegro's sensor IC, ATS667LSG, has been simulated, allowing for measurement of speed of rotating targets.

Table 2: Details of sensor IC used in simulations.

	ATS667LSG
Package Code	SG

Figure 1: Sensor IC package used in the simulation.

SIMULATION ENVIRONMENT

For each investigated parameter set, the magnetic signals sensed by the Hall element IC were analyzed for a range of angular positions and air gaps. The sensor IC contains a total of two Hall elements oriented in a row, in front of a back-biasing magnet, as shown in Figure 2.

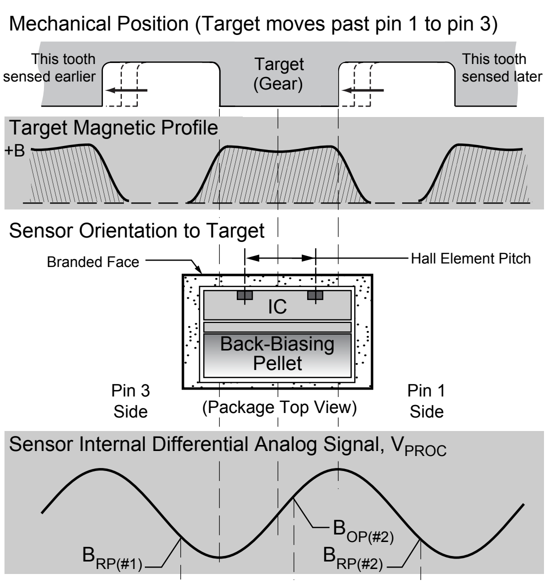


Figure 2: Definition of ATS667 sensor IC channels.

RESULTS

The data shown in the following sections are calculated as worst-case scenarios, and the air gap performance values are calculated from the simulation data using empirical data as benchmark.

MILLED TARGETS

The data presented here is from magnetic simulations, performed with the system shown in Figure 3.

The target simulated is from Table 1, where one or two variables are changed. The outer diameter of the target was held constant at 120 mm for all simulations in this section, as target diameter is not a significant factor in previously observed applications.

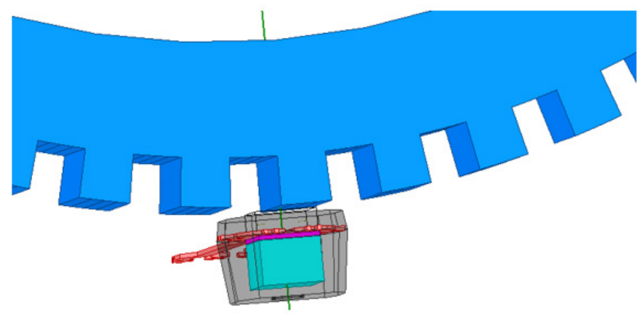


Figure 3: An example image from the simulation software. The steel target is blue and the magnet is turquoise.

ASSESSMENT 1 – TOOTH LENGTH AND VALLEY WIDTH

Two of the most important parameters for target design are tooth length and valley width—typically the maximum air gap is improved with larger spacing between teeth. Air gap performance specifications are defined as the distances between the target and Allegro branded package face.

The maximum air gap is strongly affected by increasing the valley width. This relationship is shown in Figure 4.

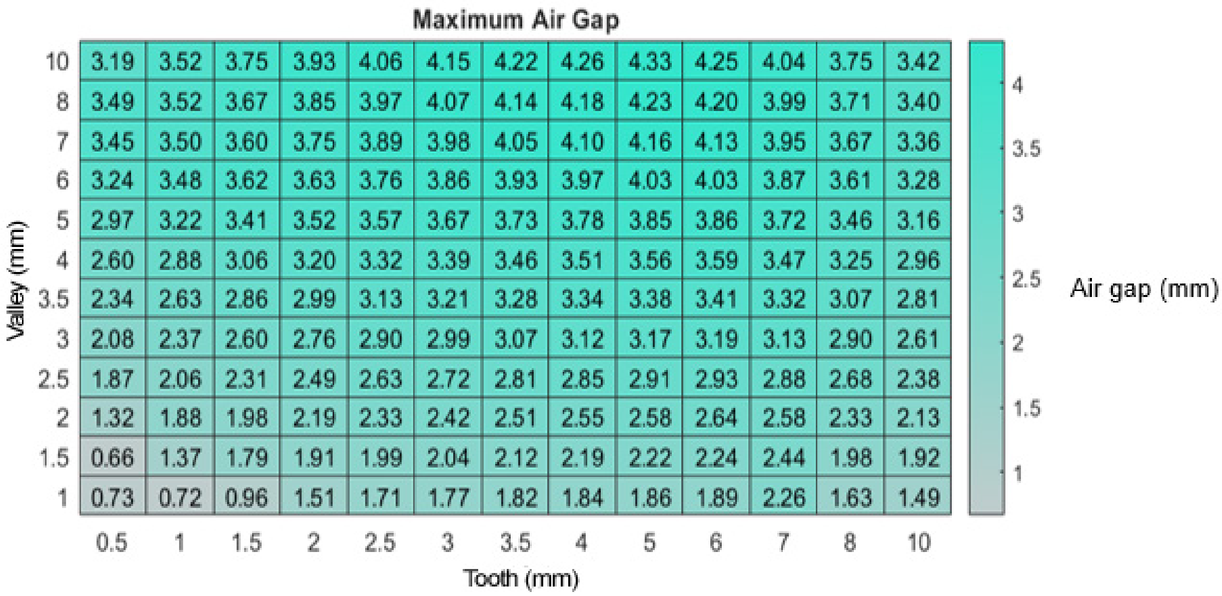


Figure 4: Maximum air gap as a function of tooth length and valley width for Allegro back-biased sensor IC for a target with an outer diameter of 120 mm.

ASSESSMENT 2 – TOOTH SHAPE

Figure 5 and Figure 6 show examples of targets with varied tooth shape, retaining a constant valley width, while changing angle of the tooth edge. Calculated maximum air gap is shown in Figure 7. The tooth angle here is defined relative to the target radius. For relatively small teeth and valleys, in this case 3.1 mm each, simulations show that increasing this angle initially improves maximum air gap performance up to an optimum tooth angle of 10° to 15°. This improvement can be understood to result from the increased valley space and is roughly equivalent to decreasing the tooth/ valley ratio (see Assessment 1).

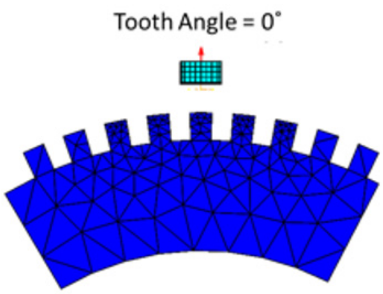


Figure 5: Example image of ferromagnetic target (blue) meshed for simulation with a tooth angle of 0°.

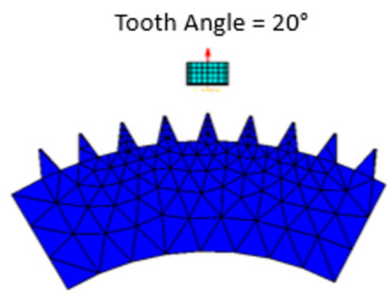


Figure 6: Example image of ferromagnetic target (blue) meshed for simulation with a tooth angle of 20° while retaining root valley width shown in Figure 8.

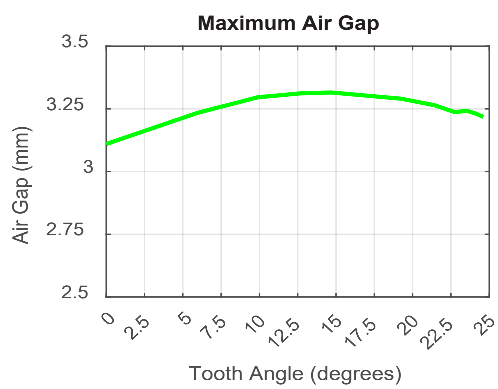


Figure 7: Maximum air gap as a function of tooth angle starting from the nominal condition (OD = 120 mm, 3.1 mm tooth, 3.1 mm valley, 3 mm tooth height) and decreasing the circular tooth length to increase the tooth angle.

Thus, simulating the same set of tooth angles but with a larger valley width, as shown in Figure 8, results prove this trend (Figure 9), with tooth angle having a less significant effect on maximum air gap.

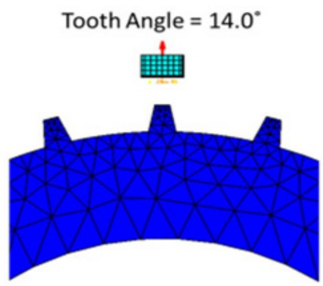


Figure 8: Example image of ferromagnetic target (blue) meshed for simulation with a tooth angle of 14°.

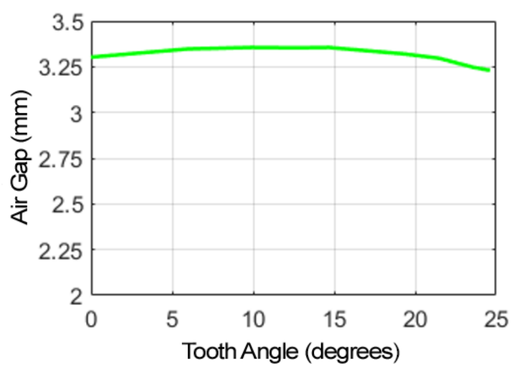


Figure 9: Maximum air gap as a function of tooth angle with OD = 120 mm, tooth length = 3.1 mm, and valley width = 5 mm.

ASSESSMENT 3 – TOOTH HEIGHT

Modifying the tooth height of the target effectively varies the relative air gap changes between teeth and valleys. As shown in Figure 11, the maximum air gap reaches a plateau where no further improvement can typically be achieved by increasing tooth height. The tooth height at which the plateau is reached will depend on the tooth length and valley width of the teeth.

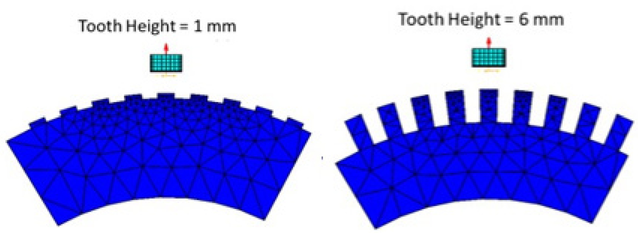


Figure 10: Example images of ferromagnetic targets (blue) meshed for simulation with varying tooth height.

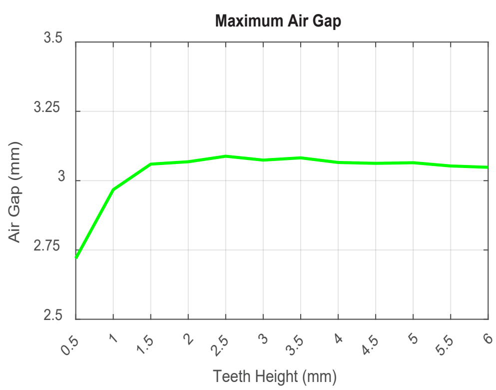


Figure 11: Maximum air gap as a function of tooth height with OD = 120 mm and tooth length and valley widths = 3.1 mm.

ASSESSMENT 4 – TARGET THICKNESS

The thickness of the ferromagnetic target is recommended to be greater than the thickness of the device package, 3 mm. The maximum air gap starts to decrease sharply once target thickness falls below recommended thickness. The above conclusions assume that the target is centered exactly over the Allegro sensor IC package face. When designing the target for an application, manufacturing related placement tolerances should be considered as well.

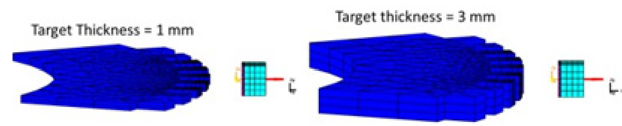


Figure 12: Example images of ferromagnetic targets (blue) meshed for simulation with varying target thickness.

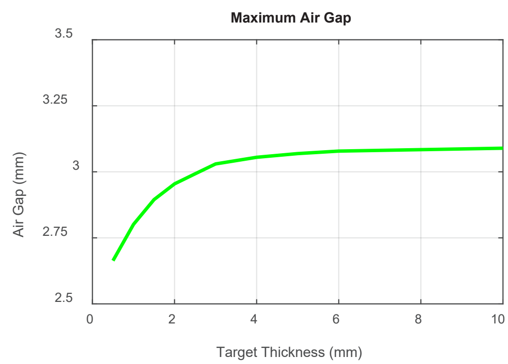


Figure 13: Maximum air gap as a function of target thickness with OD = 120 mm and tooth length = 3.1 mm and valley width = 3.1 mm.

CONCLUSIONS

This application note has detailed the impact of various target design parameters on the achievable maximum air gap with Allegro's ATS667LSG Hall back-biased transmission sensor IC, allowing for measurement of speed of rotating targets. By adhering to the recommendations outlined in this document, informed decisions regarding optimal target design can be made.

Prior to the start of production tooling, it is highly recommended to perform system verification testing. For additional support in evaluating the performance of Allegro's sensor IC components with specific targets, particularly for applications requiring high performance or large air gaps, contact your local Allegro sales representative.

The conclusions drawn throughout the document are qualitatively applicable to other Allegro back-biased sensors of the same Hall-element spacing and sensor IC package, the latter defining the integrated permanent magnet.

Revision History

Number	Date	Description
–	October 9, 2024	Initial release

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