MECHANICAL SHIFT OF SWITCH POINT

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INTRODUCTION

The mechanical shift of switch point is a specification that provides detail necessary to predict the location of an output edge with respect to the integrated circuit (IC) package and the target feature. This application note illustrates how to apply this specification. Although the ATS694LSG sensor IC is used as the example, the principles presented here are applicable across the A1694 and ATS694 [1] crankshaft position sensor ICs and the previous generation of A1658 and ATS658 products.

REFERENCE SPECIFICATION AND HALL-ELEMENT LOCATIONS

The location of the mechanical shift of switch point is defined in Table 1, Figure 1, and Figure 2 for the A1694 and ATS694 sensor ICs and predecessors A1658 and ATS658.

Table 1: Specification from ATS694 Datasheet [1]

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Unit [2]
Performance Characteristics						
Mechanical Shift of Switch Point	d_{ST}	Distance from target feature center to IC center when the switch point [$V_{PROC(ST)}$] occurs (will be shifted an additional 0.5× T_{TARGET} due to asymmetric Hall element; see Figure 1 and Figure 2).	–	0.5	–	mm

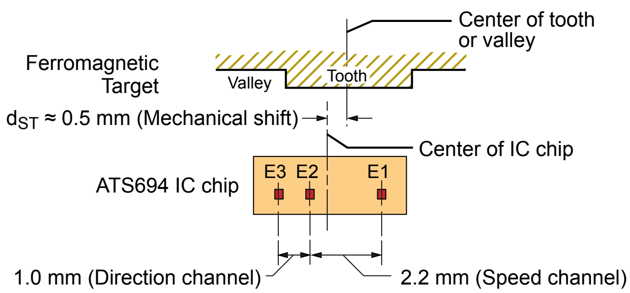


Figure 1: Definition of mechanical shift of switch point.

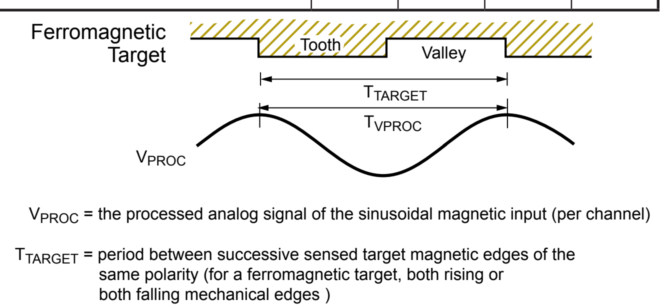


Figure 2: Definition of T_{TARGET}.

[1] https://www.allegromicro.com/-/media/files/datasheets/ats694-datasheet.ashx

[2] 1 G (gauss) = 0.1 mT (millitesla)

The mechanical shift of switch point is governed by device timing and layout as follows:

- Because output events occur at a threshold of 50% of the ***Speed*** channel—the span between Hall elements E1 and E2 in Figure 3—the output events occur when the mechanical midpoint of transducers E1 and E2 is generally aligned to the midpoint of the target switching feature.
- Placement of the Hall elements within the package head is asymmetric; the mechanical midpoint of E1 and E2 is located 0.5 mm left of the center line in the image shown in Figure 3. This is the mechanical shift of switch point.

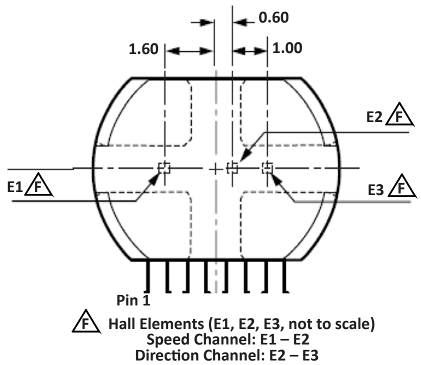


Figure 3: Hall element locations in SG package diagram.

SIMULATION DEFINITIONS

The examples used here employ the ATS694LSG sensor IC with speed and direction output and a representation of the Allegro MicroSystems Reference Target 60-0. Details of the elements of interest are shown in Figure 4 and Figure 5.

Key definitions are as follows:

- Air gap between the target and the branded face of the Allegro MicroSystems package is 1 mm.
- Zero degrees is established with the SG package centered on the tooth.
- Positive rotation is defined as target movement that passes in the direction from E3 toward E1 (Pin 4 toward Pin 1 in Figure 3).

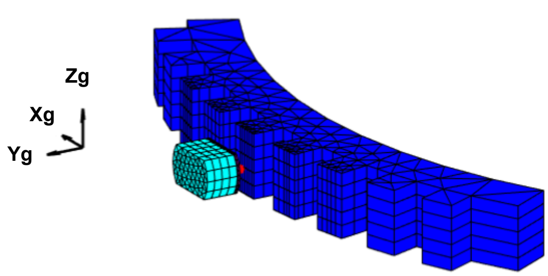


Figure 4: Isometric view.

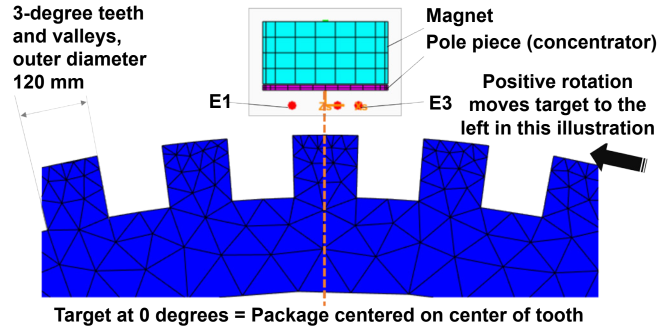


Figure 5: Simulation elements — Zero degrees is established with the SG package centered on the tooth. Positive rotation is defined as the target passing from E3 to E1 (Pin 4 to Pin 1).

MATHEMATICAL PREDICTION

To align the midpoint of the speed channel to the midpoint of the target tooth, compute the expected target angle change (Θ, see Figure 6) needed in a right triangle as:

Equation 1: $$\tan(\Theta) = 0.5\text{ mm}/(\text{radius} + \text{air gap})$$

For the A1694 and ATS694 products and predecessors A1658 and ATS658, Equation 1 is rewritten as:

Equation 2: $$\Theta = \text{atan}[0.5\text{ mm}/(\text{radius} + \text{air gap})]$$
$$\Theta = \text{atan}(0.5\text{ mm}/61\text{ mm})$$
$$\Theta = 0.47\text{ degrees.}$$

The same result is achieved for an arc length of 0.5 mm instead of tangential motion of 0.5 mm.

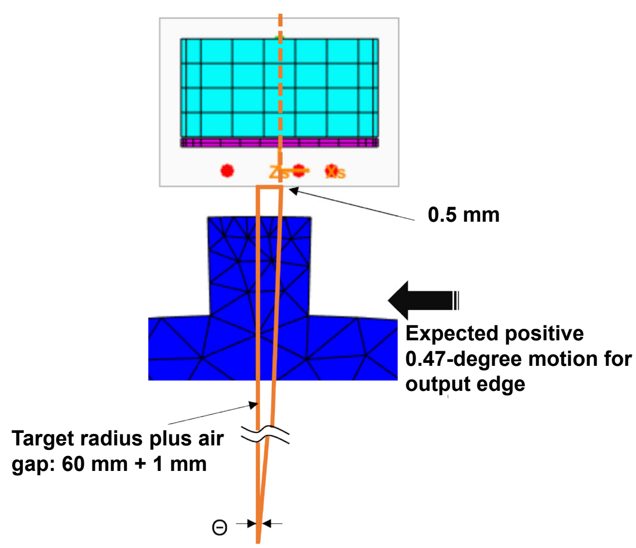
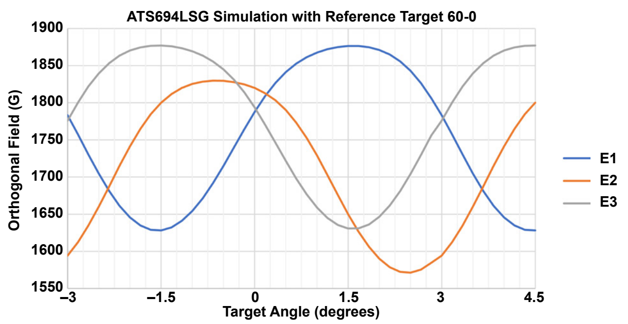


Figure 6: Computations of angular shift.

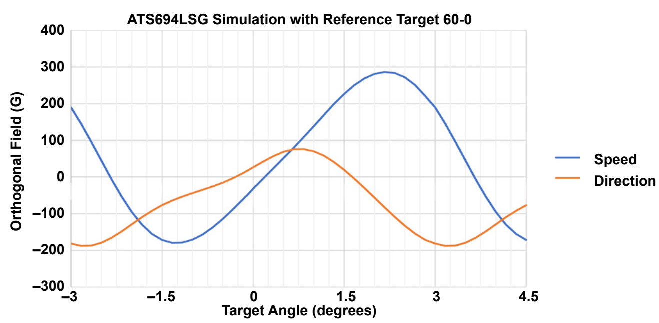
SIMULATION PREDICTION

Simulations of the sensed magnetic signal at the three transducers are shown in Figure 7, top. The two differential magnetic channels in Figure 7, center, are computed from the individual transducer simulations. The normalized signals in Figure 7, bottom, help to validate the definition of positive rotation: With positive rotation, as the target angle increases, the behavior of the Direction channel ***leads*** the Speed channel. [Recall—positive rotation is defined as target movement that passes in the direction from Pin 4 to Pin 1 (E3 to E1).]

Individual Transducers



Computed Differential Fields (Channels)



Normalized Differential Fields (Channels)

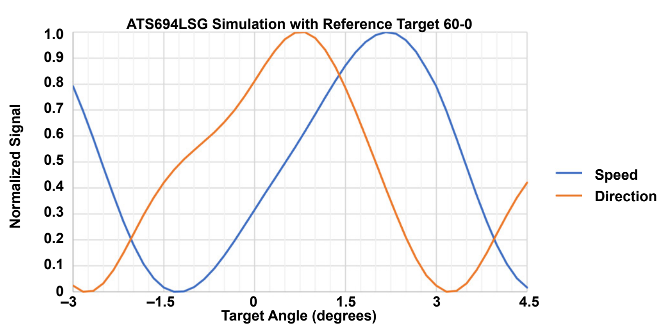


Figure 7: Simulation results.

Application of a 50% switching threshold to the normalized speed channel predicts the approximate locations of IC output edges (see Figure 8), with occurrences at:

- 0.5 degrees from the center of the tooth; and
- 0.47 degrees from the center of the valley.

Minor variations can be attributed to simulation resolution and expected variation versus air gap due to actual magnetic profiles.

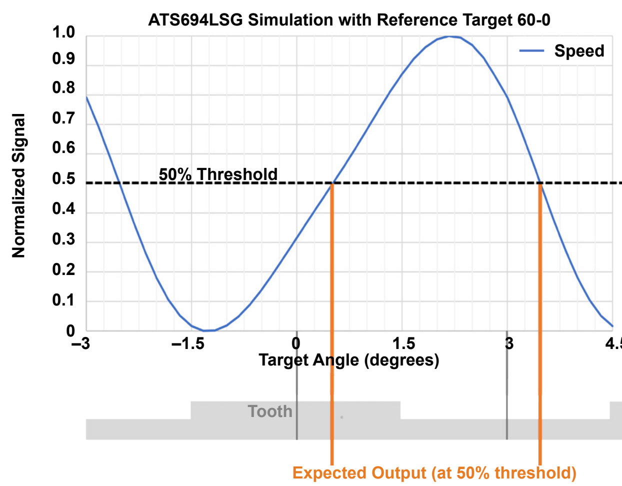


Figure 8: Predicted edge locations from simulation results.

CONCLUSION

The mathematical predictions and simulations provided in this application note should be used as guidance for integration of Allegro MicroSystems A1694 and ATS694 crankshaft position sensor ICs and predecessors A1658 and ATS658.

Revision History

Number	Date	Description	Responsibility
–	July 26, 2021	Initial release	Eric Burdette
1	July 8, 2024	Removed broken links and updated footnote numbering (page 1)	Eric Burdette