INNOVATION WITH PURPOSE

BENEFITS OF DYNAMIC THRESHOLD FEATURE IN ATS16351PSM, GMR BACK-BIASED SPEED SENSOR IC

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INTRODUCTION

The Allegro ATS16351PSM [1] is a True-Power-On-State (TPOS) sensor providing the speed and position of a rotational ferromagnetic target. It incorporates giant magnetoresistance (GMR) structures and is packaged with a custom magnetic circuit designed to switch in response to the magnetic signals induced by the target.

Like many Allegro speed sensors, the switching thresholds of the ATS16351PSM can be programmed to accurately adjust and maintain the offset between the electrical and mechanical edge (conventionally called the hard-edge offset, HEO) to a desired value, allowing for mechanical mounting tolerance compensation. This method is fully described in an application note (AN296175). [2]

Dynamic threshold is a unique patented feature implemented in the ATS16351PSM that improves the HEO accuracy over air gap [3] even further and makes this device one of the most accurate on the market.

The benefits of dynamic threshold are described in this application note.

HARD-EDGE OFFSET (HEO)

In application, the HEO is obtained by measuring the angle difference between the electrical output edges and the mechanical target edges. The HEO for the rising magnetic signal (B_{OP}) is usually a negative value, indicating that the electrical output transition occurred before the mechanical target edge was detected by the sensor. The HEO for the falling magnetic signal (B_{RP}) is generally a positive value, indicating that the electrical output switched after the mechanical target edge passed through the sensor.

HEO is easily visualized in Figure 1, where the normalized magnetic signal of an Allegro 8× reference target is represented over one period with its mechanical profile. From this plot, it can be observed that lowering the switching threshold will increase the offset between the electrical edges and those of the mechanical target (i.e., the HEO will increase), and increasing the switching threshold will bring the HEO close to 0.

As a note, HEO will depend on the mechanical target shape, and it is recommended to leave the switching threshold between 20% and 75% (0.2 and 0.75 in Figure 1) to ensure that the sensor will always accurately switch despite target irregularities or runout. A magnetic mapping of the application target should be performed to best define the correct switching-threshold level.

[1] https://www.allegromicro.com/en/products/sense/magnetic-speed/camshaft-sensor-ics/ats16351
[2] https://www.allegromicro.com/-/media/files/application-notes/an296175-ats679psl-speed-sensor-mounting-tolerance.pdf
[3] Air gap is the distance from the front package face of the device to the target tooth.

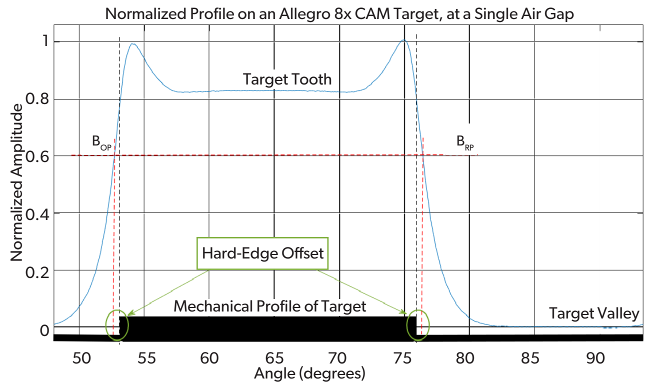

Figure 1: Hard-edge offset representation with an Allegro 8× reference target mapping.

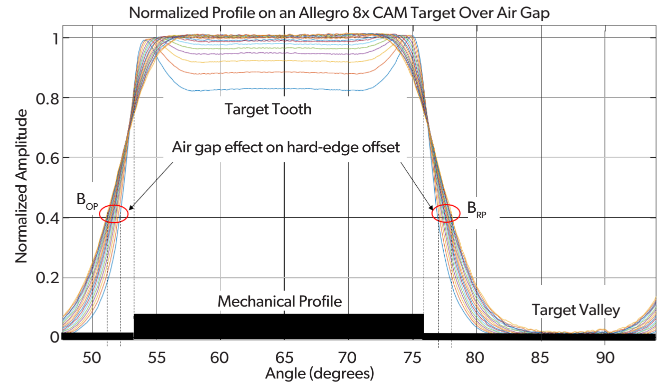

Figure 2: Hard-edge offset impact over air gap with an Allegro 8× reference target mapping.

AIR GAP LIMITATIONS WITH STANDARD THRESHOLD ADJUSTMENT METHOD

Although the exact desired HEO value can often be achieved—by adjusting the switching threshold at a given air gap, as shown in Figure 1—in application, the switching threshold alone does not always provide sufficient correction.

Mounting tolerance variations can result in differences between the threshold compensation air gap and the application air gap. These differences can be critical to accuracy because each air gap variation brings a different normalized magnetic profile (magnetic slope). Inaccuracy can result, affecting Hall-effect and GMR sensors alike. This phenomenon is illustrated in Figure 2, which plots the data for several air gaps (each color line represents mapping at a different air gap) using the same Allegro 8× reference target normalized mapping from the ATS16351PSM as used in Figure 1. As can be observed from Figure 2, when the switching threshold is set to 50% (0.5) or lower, the change in the magnetic behavior of the air gap requires a different HEO, with smaller air gaps leading to smaller HEOs.

In legacy solutions, to minimize the HEO inaccuracy that comes with air gap variations, a compromise is typically found between air gap range and threshold compensation. Such compromises constrain designers and limit the space for useful product application.

BENEFITS OF DYNAMIC THRESHOLD

The dynamic threshold feature implemented in the ATS16351PSM overcomes the limitations of legacy solutions by automatically adjusting the threshold level as a function of the mounting air gap, so that the HEO does not vary over the installation air gap in application.

The amount of threshold change as a function of air gap directly depends on the defined threshold level (low threshold implies larger HEO change over air gap, see Figure 2) and on the target shape. To accommodate wide application, the adaptive threshold feature of the ATS16351PSM offers a wide programming range. The recommended programming sequence is to define the B_{OP} and B_{RP} levels corresponding to the desired HEO at a given air gap, then to program the dynamic threshold code that achieves the desired result with the least change over air gap.

The benefits of dynamic thresholds are illustrated in Figure 3 and Figure 4 using one period of an Allegro 8× reference target and a switching threshold of 40% (0.4) for both B_{OP} and B_{RP}. In the plots, each bar represents the HEO at one air gap, with negative values indicating B_{OP} and positive values indicating B_{RP}. When dynamic threshold is not activated (Figure 3) , the HEO is approximately 1.20 degrees (–1.12 degrees for B_{OP} and +1.20 degrees for B_{RP}) at a medium air gap, and the HEO change over air gap is 0.7 degrees for B_{OP} and 0.45 degrees for B_{RP}. When dynamic threshold is activated (Figure 4), the HEO is approximately 1.25 degrees (–1.24 degrees for B_{OP} and +1.29 degrees for B_{RP}) at a medium air gap, and the HEO change over air gap is 0.32 degrees for B_{OP} and 0.19 degrees for B_{RP}. Accuracy over air gap improves by a factor of two due to the dynamic threshold compensation, as summarized in Table 1, and dynamic threshold activation has a very small effect on the HEO value at medium air gap (–1.12 degrees vs. –1.24 degrees for B_{OP} and +1.20 degrees vs. +1.29 degrees for B_{RP}).

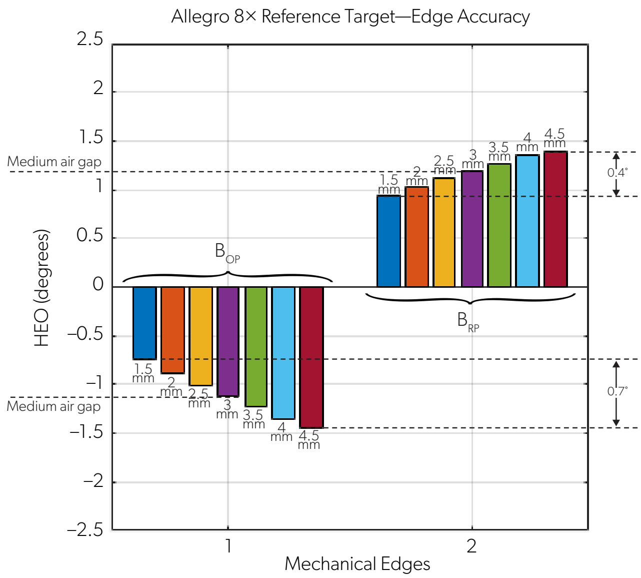

Figure 3: Hard-edge offset of ATS16351PSM output on Allegro 8× reference target, dynamic threshold not activated.

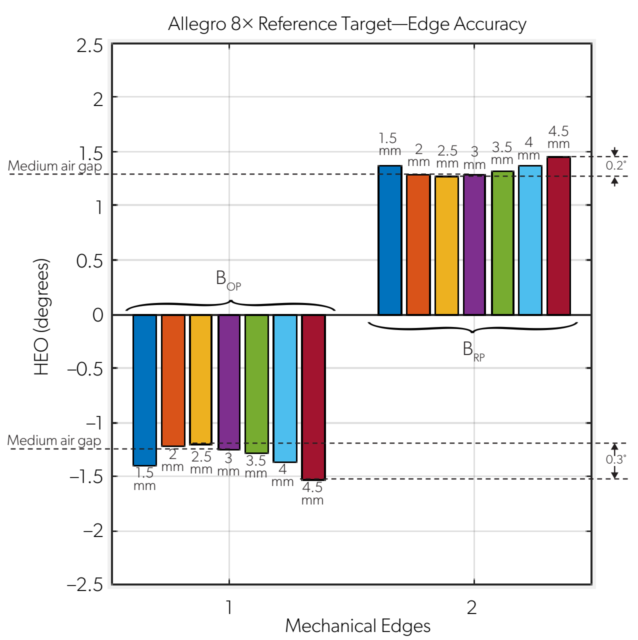

Figure 4: Hard-edge offset of ATS16351PSM output on Allegro 8× reference target, dynamic threshold activated and optimized.

Table 1: Dynamic Threshold Activated vs. Not Activated

The hard-edge offset (HEO) of the ATS16351PSM output is shown for sensing of an Allegro 8× reference target with the dynamic threshold feature not activated versus activated. The activated dynamic threshold feature achieves a 2× improvement in the HEO.

HEO on 8× Target	Dynamic Threshold NOT Activated		Dynamic Threshold Activated	
Air Gap (mm)	B_{OP} (°)	B_{RP} (°)	B_{OP} (°)	B_{RP} (°)
1.5	–0.75	0.94	–1.40	1.36
2.0	–0.88	1.03	–1.22	1.28
2.5	–1.01	1.12	–1.21	1.26
3.0	–1.12	1.20	–1.24	1.29
3.5	–1.23	1.27	–1.29	1.31
4.0	–1.35	1.35	–1.37	1.37
4.5	–1.45	1.40	–1.53	1.45
Delta Over Air Gap	**0.70**	**0.45**	**0.32**	**0.19**

Conclusion

The new dynamic threshold feature of the ATS16351PSM allows the user to adjust the threshold to the desired HEO value and to minimize the effect of air gap on edge accuracy, independently of the threshold level. A factor two improvement can be achieved using dynamic threshold, making the ATS16351 one of the most accurate and flexible speed sensors on the market.

For any further questions or support, contact an Allegro representative. [4]

[4] https://www.allegromicro.com/contact-us

Revision History

Number	Date	Description	Responsibility
–	July 26, 2022	Initial release	C. Gillet