Non-chopper-stabilized versus chopper-stabilized bipolar latching Hall-effect sensors

Test results show significantly higher performance can be achieved using a quad hall element and proprietary programming without chopper stabilization.

Introduction

Honeywell Sensing and Control has developed a high sensitivity and fast response bipolar latching sensor by using a quad Hall element and proprietary programming without chopper stabilization. This new design offers several benefits including high sensitivity, repeatability, and fast response time, that all contribute to an efficient BLDC motor design.

This paper shows the results of a low gauss latch competitive evaluation performed by Honeywell, between Honeywell's non-chopper-stabilized SS460S bipolar latching Hall-effect sensor and five chopper-stabilized competitor products. Tests include response time, repeatability, and sensitivity to air gap. The results indicate that Honeywell's SS460S Hall-effect sensor delivers better performance, offering a 10- to 20-microsecond (μs) faster response time, compared to the chopper-stabilized sensor samples, including two parts that offer higher sensitivity than the Honeywell SS460S sensor.

Low Gauss Latch Competitive Evaluation

Samples

1.	Honeywell[A]	SS460S
2.	Micronas[B]	HAL202jQ-K
3.	Melexis[B]	US1881LUA
4.	Diodes[B]	AH3761-PG-B
5.	Allegro[B]	A1220EUA
6.	Infineon[B]	TLE4946 (See Addendum for test results.)

[Note A] Most nominal sample from a group of 30 were used for this test.

[Note B] A random sample from competitive products were chosen for this test.

Test Configuration Setup

A circular target with 48 magnetic pole pairs was used to trigger the product samples. The samples were placed in the magnetic field as close to each other as possible and centered in the Y-axis (as shown in Figure 1 and a close-up of the parts shown in Figure 2). The tests were performed at a 0.020 inch air gap.

Figure 1. Circular target

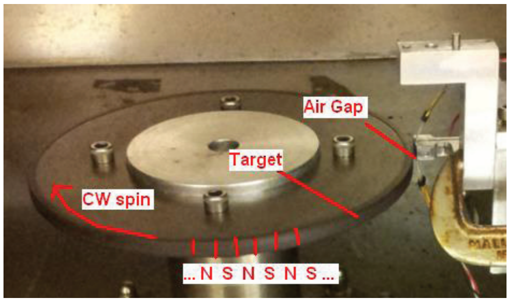


Figure 2. Close-up view

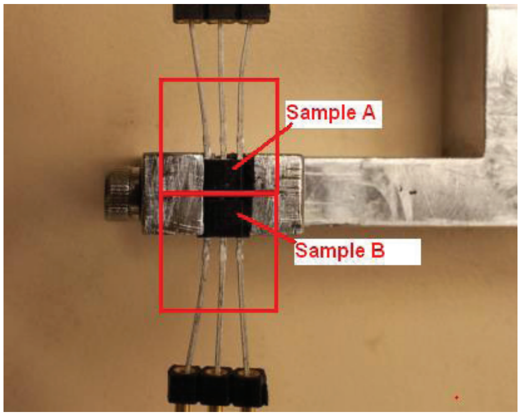
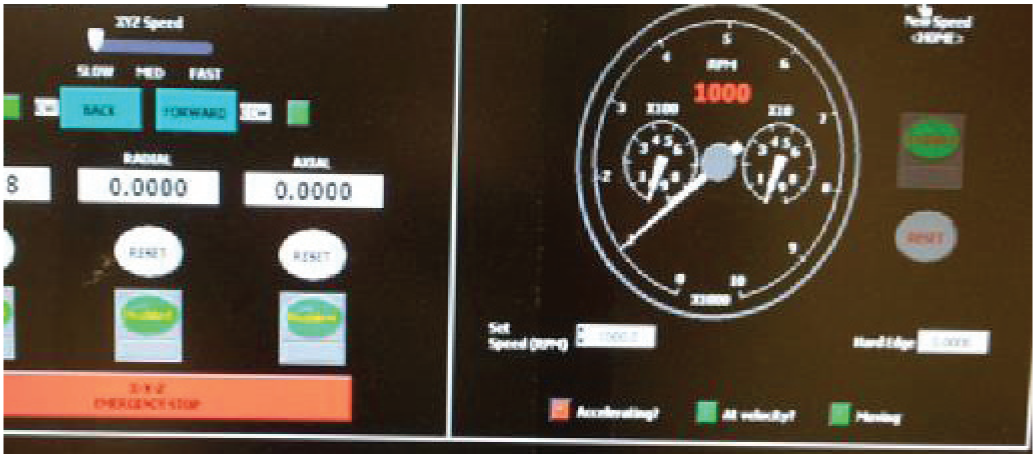


Figure 3. A custom software application was used to precisely control target rotation and sample position.



All results were measured against a Top Dead Center (TDC) trigger that has a very fast response time. Using this method, the exact individual target (48 in total on the target wheel) was used for all measurements, that eliminates the variation between individual targets.

Results

Response Time Estimate

To calculate the response time, the target was revolved at various frequencies, clockwise and counterclockwise, with a 0.020 inch sense gap. The target's angle of rotation was measured at the point where the sensor output switched.

Frequency	Direction		Edge 1	Edge 2	Edge 3	Edge 4	Edge 5
500	CCW		3.336	7.11	10.831	14.647	18.379
500	CW		3.468	7.271	10.991	14.751	18.527
		estimated real edge	3.402	7.1905	10.911	14.699	18.453
		transition angle	0.132	0.161	0.16	0.104	0.148
1000	CCW		3.345	7.107	10.838	14.64	18.369
1000	CW		3.469	7.265	10.996	14.74	18.529
		estimated real edge	3.407	7.186	10.917	14.69	18.449
		transition angle	0.124	0.158	0.158	0.1	0.16
2000	CCW		3.343	7.105	10.818	14.594	18.357
2000	CW		3.476	7.273	10.996	14.775	18.529
		estimated real edge	3.4095	7.189	10.907	14.6845	18.443
		transition angle	0.133	0.168	0.178	0.181	0.172
4000	CCW		3.285	7.065	10.788	14.528	18.313
4000	CW		3.51	7.29	11.017	14.825	18.542
		estimated real edge	3.3975	7.1775	10.9025	14.6765	18.4275
		transition angle	0.225	0.225	0.229	0.297	0.229

When the target is sufficiently slow, the response time is much faster than the moving magnetic field of the target so the expected latency between the 0 gauss level angle and the angle of the field detection depends on the test setup and product sensitivity. When the target is faster, the angle recorded is a combination of the magnetic field latency and the response time of the sensor.

In this example, the Edge 1 results show that the angle of the transition remains fairly stable at the lower frequencies of 500 RPM to 2000 RPM. At 4000 RPM, the angle shifts due to the response time of the sensor, increasing about 0.06° over the entire angle of the transition. At 4000 RPM, 0.06° angle is equivalent to 2.5 μs (0.06° /360° /4000 RPM x 60s). Therefore, the estimated response time is half the transition increase or about 1.25 μs** total.

** Please note that a sensor's response time is based on target type, air gap, and temperature. This value is not intended to be used as a specification; it is merely an observed value specific to this test configuration.

Response to Magnetic Field

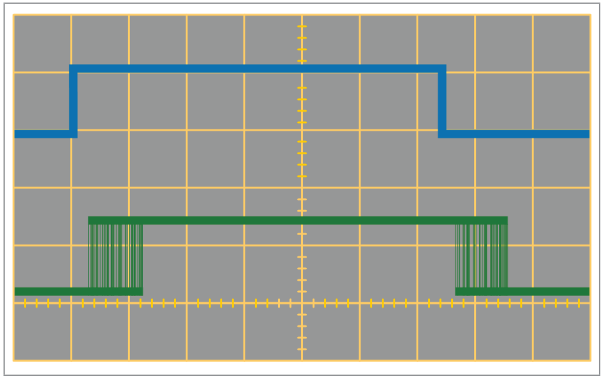
The samples were mounted and centered so the two samples – Honeywell's SS460S and one competitor product – were in the same magnetic field of the tester and offset from the actual center of the field by an equal distance. In this configuration, both samples experience the same environment so that a direct comparison can be made. The target was rotated at 5000 RPM and multiple scans (approximately 100) were obtained with an oscilloscope to observe the sensor's reaction to the target. The waveforms of samples 2, 3, and 4 showed a wide edge, indicating these samples did not switch at the same point. These results suggest that the competitive sample devices do not provide repeatable results. The Honeywell sample, as well as samples 5 and 6, did not show any variation (no heavy white edge), indicating good repeatability.

All samples exhibited a slower response time when compared to the Honeywell product. Samples 2, 3, 4, 5, and 6 all exhibited a delay in response time between 10 µs and 30 µs. This delayed response time is due to the chopper stabilization process.

In all scope graphs below:

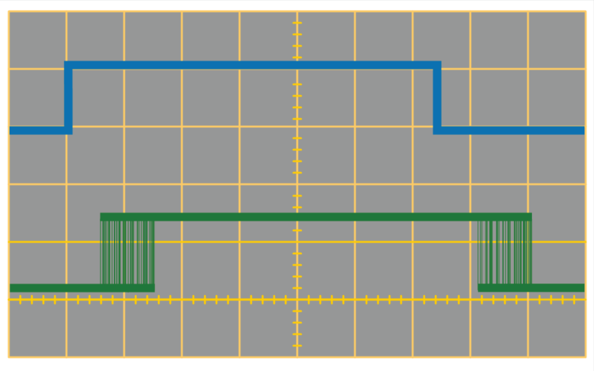
- Honeywell sensor is the top scope trace
- Competitor device is the lower trace
- 100 sweeps displayed
- Horizontal scale: 20 µs/grad
- Vcc = 24 Vdc
- 0.020 in air gap to target

Figure 4. Micronas (Sample 2)



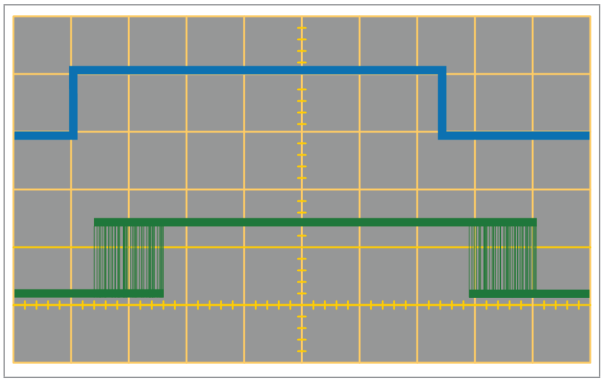
The Micronas sensor sample shows an 8 µs to 32 µs slower response time versus the Honeywell sensor. Testing also shows a variance in actuation of 20 µs.

Figure 5. Melexis (Sample 3)



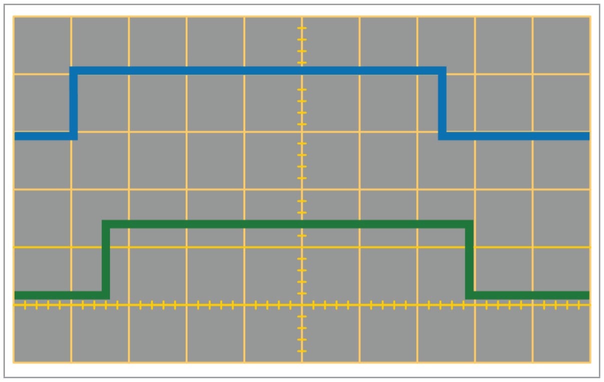
Test results show the Melexis sensor has a 13 µs to 30 µs slower response time compared to Honeywell's sensor. Testing also shows a variance in actuation of 10 µs to 12 µs.

Figure 6. Diodes (Sample 4)



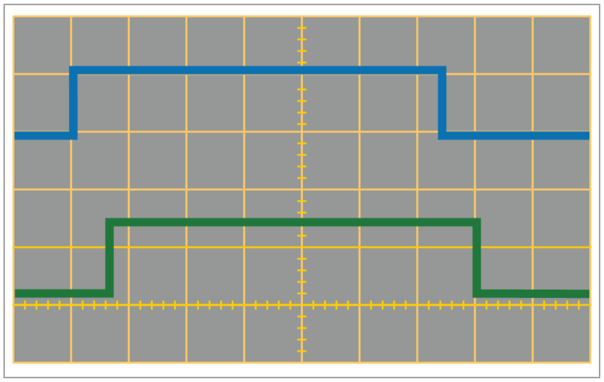
The Diodes part shows a 9 µs to 32 µs slower response time versus the Honeywell part. Testing also shows a variance in actuation of 15 µs.

Figure 7. Allegro (Sample 5)



The Allegro part shows a consistent 12 µs slower response time compared to the Honeywell part. The test does not indicate any variance in actuation time. One hypothesis for the higher repeatability is the higher frequency of the chopper stabilization compared to the other samples.

Figure 8. Infineon (Sample 6)



The Infineon part shows a consistent 14 µs slower response time compared to the Honeywell part. The test does not indicate any variance in actuation time. One hypothesis for the higher repeatability is the higher frequency of the chopper stabilization compared to the other samples.

Product Mounting Validation

A delay between triggers on two samples may be caused by a misaligned magnetic field. In the case noted above, a 10 µs delay at 5000 RPM and a target radius of 3 inches is equivalent to 0.0157 in ($10^{\wedge -6}$ s * 1m/60s * 5000 REV/m * 2π3"/REV). Therefore, to validate the test, the samples were reversed and then retested using the same method.

In all scope graphs below:

- Honeywell product is the top scope trace
- Competitor device is the lower trace
- 100 sweeps displayed
- Horizontal scale: 20 µs/grad
- Vcc = 24 Vdc
- 0.020 in air gap to target

Figure 9. Honeywell in the bottom nest, sample 5 in the top nest

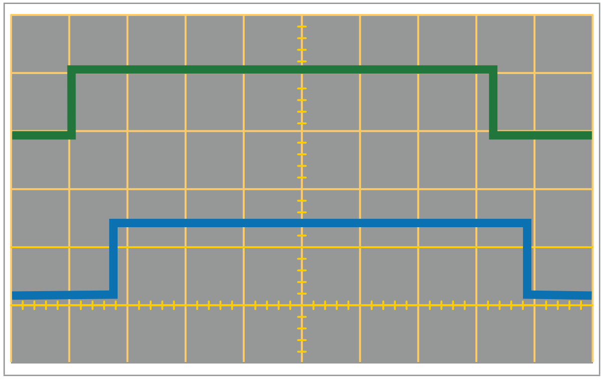
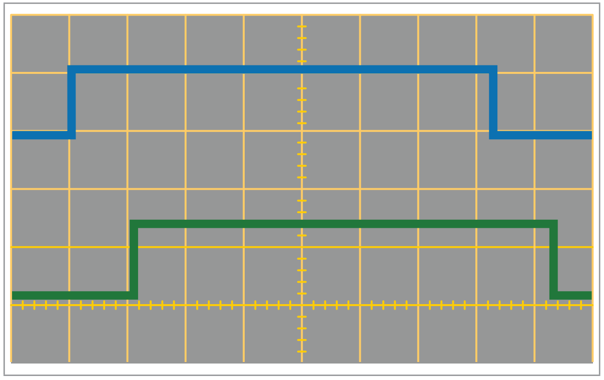


Figure 10. Honeywell in the top nest, sample 5 in the bottom nest



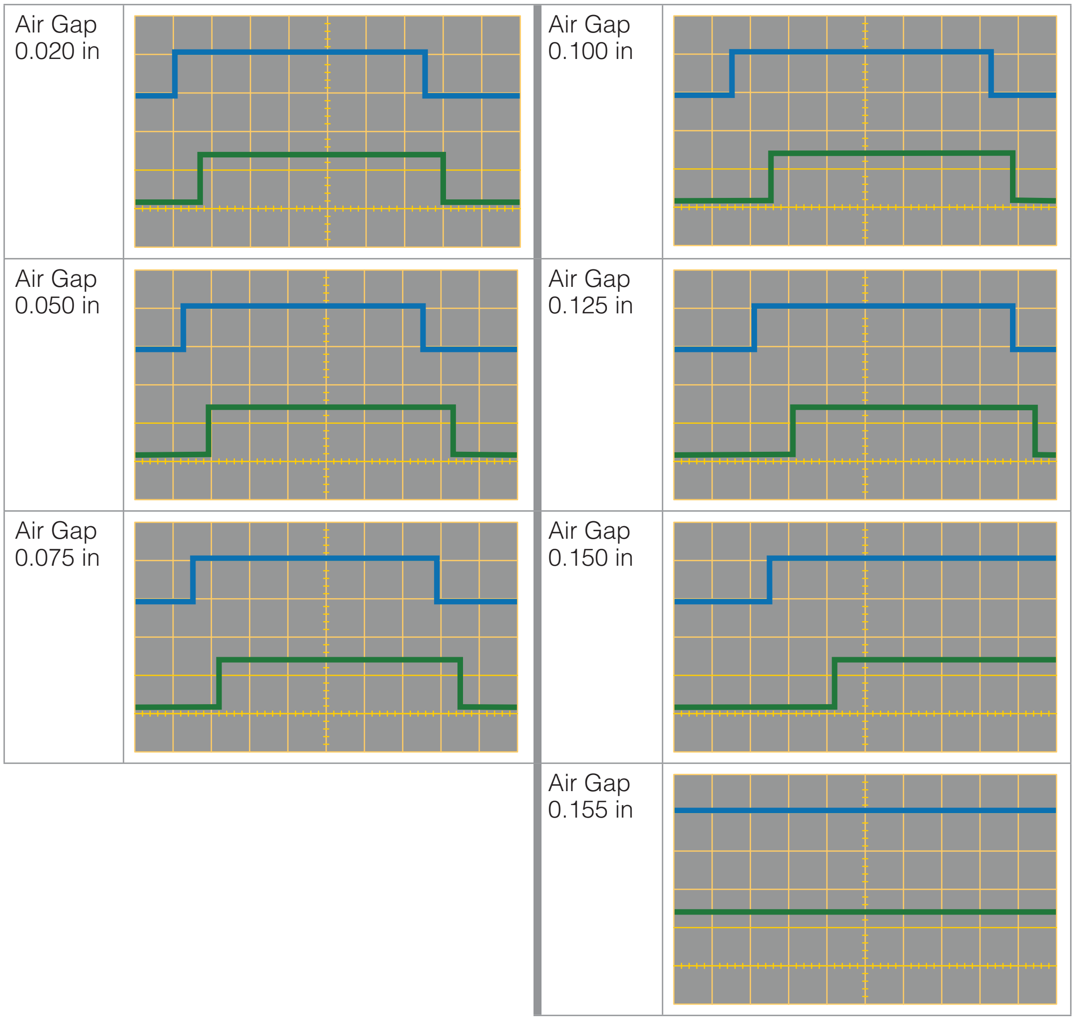
The results demonstrated a difference between nests. But regardless of the difference, the Honeywell sample responded more quickly to the magnetic field in both cases. The 10 µs additional delay on sample 5 equates to 0.0157 in and may be attributed to a small offset from the center of either sample or a small difference in magnetic field on the Z-axis.

Sensitivity to Air Gap

The air gap is believed to be a significant part of the sensor's total response time. To test the effect of the sensor versus air gap, the Honeywell sample (sensitivity equals 30 gauss typical) and the Allegro sample 5 (sensitivity equals 22 gauss typical*) were measured at various air gaps to see how response time changed.

*typical sensitivity information published in company's datasheet

Figure 11. Air Gap Effect Comparison



The SS460S sensor outperformed the Allegro sample (#5) at all air gap distances. The results indicate that no chopper stabilization is more important to response time than higher sensitivity.

As the air gap increased, the magnetic field latency increased, which led to a change in response from both sensors. Both sensors were tested up to an air gap of 0.150 in, but then failed to reach their threshold at 0.155 in. Because both sensors had a similar increase in response based on air gap, it can be concluded that the devices were equally placed in the magnetic field. Also, this test demonstrates that a change in 0.050 inch in air gap may be equivalent to a 10 µs response time delay.

Another test result showed that, given the same magnetic strength, there was a uniform change in response time by the Honeywell part. Based on the magnet used, the Honeywell part lost about 10 µs of response time for every 0.025 in.

Conclusion

Comparison testing for reliability and response time between the Honeywell SS460S bipolar latching Hall-effect sensor and five competitor samples shows that the Honeywell non-chopper-stabilized part has a repeatable output with a response time that is between 10 µs to 20 µs faster than competitive chopper-stabilized products, including high-sensitivity samples from Allegro and Infineon. In some cases, the competitor samples showed a varied response time of 10 µs to 30 µs. Testing indicates that chopper stabilization may cause repeatability issues due to variances in actuation. Higher frequency of the chopper stabilization may resolve this issue, as seen in the Allegro and Infineon parts. Even if the chopper-stabilized parts exhibit high sensitivity, they still show a slower response time.

Sensitivity level is based on the placement of the sensor relative to the magnet, the air gap, and magnet strength. As the magnet rotates past the sensor, a highly repeatable sensor changes state at the same angular position each time the magnet passes by, providing a consistent response time that will maintain all of the angular measurements very close to the same value. A delayed response to the target will have a negative effect on the efficiency of the motor commutation. Any error in the switching point of the Hall-effect sensor will reduce the torque of the motor, which results in lower motor efficiency.

In addition, testing for sensitivity to air gap shows that the Honeywell non-chopper-stabilized part outperformed the Allegro sample, and maintained a better response time as the air gap increased. Even though Honeywell's SS460S provides a magnetic sensitivity of 30 Gauss (G) typical (55 G maximum), which is less than the Allegro part, the SS460S outperformed Allegro's A1220EUA at all air gap distances.

A faster response time to a change in the magnetic field delivers greater efficiency in commutating a BLDC. If a sensor switches at a different magnetic field level than what is required due to slow response or delay, this could result in accuracy errors.

Honeywell's latching Hall-effect sensors offer repeatability and faster response time due to a non-chopper-stabilized design. This in turn contributes to higher motor efficiency in brushless dc motors.