DIODES INCORPORATED

AN1189

Dual Hall-Effect Latch with Speed and Direction Output

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The AH39xx series are high-voltage dual Hall-effect sensors designed for applications that require accurate speed and direction sensing. The AH39xx series includes three product families: the AH396x family (non-AEC-Q100 qualified), the AH396xQ family, and the AH397xQ family (AEC-Q100 qualified). The AH397xQ family is ISO 26262 qualified and these parts are deemed as Safety Element out of Context (SEooC) solutions.

To support a wide range of demanding applications, these designs are optimized to operate over the supply range of 2.7V to 27V. With chopper-stabilized architecture and an internal bandgap regulator to provide temperature-compensated supply for internal circuits, the AH39xx series provides two kinds of outputs: speed and direction outputs, and two independent outputs at Q1 and Q2.

Table 1. Product table with Gauss version and output type

Part Name	Operating Point B_{OP}(Gauss)			Release Point B_{RP} (Gauss)			Hysteresis BHYS (Gauss)			Output			
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	SPD	DIR	Q1	Q2
AH3965/65Q/75Q	-10	10	30	-30	-10	10	5	20	35	V	V		
AH3966/66Q/76Q	8	25	42	-42	-25	-8	32	50	68	V	V		
AH3967/67Q/77Q	50	75	100	-100	-75	-50	120	150	180	V	V		
AH3968/68Q/78Q	50	75	100	-100	-75	-50	120	150	180			V	V

Table 2. Alternate device recommendations

Part Name	AEC-Q100	ISO26262 Ready
AH396x	—	—
AH396xQ	◎	—
AH397xQ	◎	◎

Outputs

These devices provide up to two outputs: the H1 element output (Q1 pin) as the target direction (DIR pin), and the H2 element output (Q2 pin), as the target speed (SP pin). DIR provides the direction output of the device and is defined as off (high) for targets moving in the direction from H1 to H2, and on (low) for the direction H2 to H1, as shown in Figure 1 and Figure 2. Because of internal delays, DIR is always updated before SP and is updated by up-down counters without the loss of pulses, as shown in Figure 3.

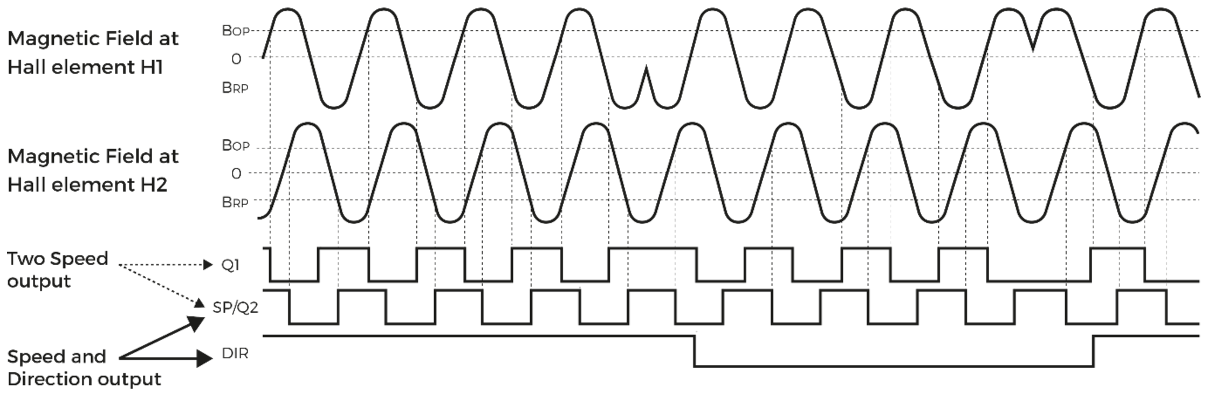

Figure 1. Timing diagrams of the speed and direction output of SP/DIR and dual SP output Q1/Q2

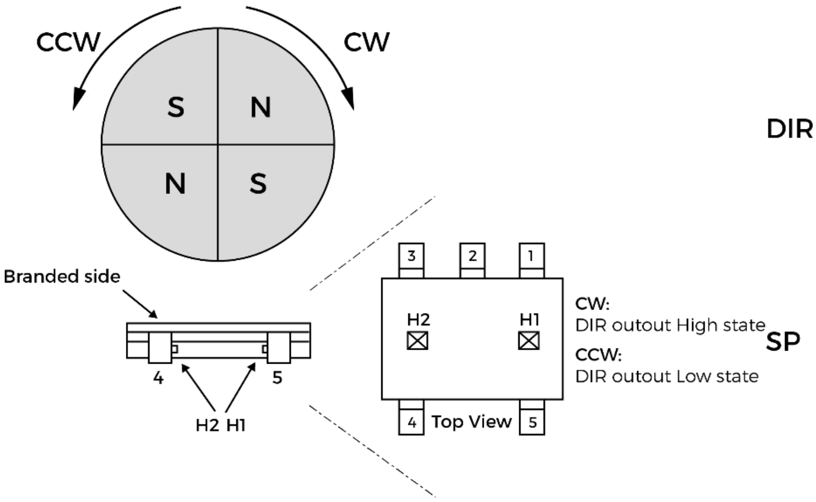

Figure 2. DIR output

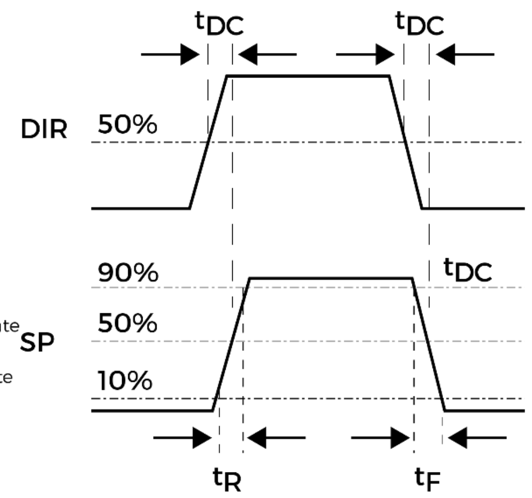

Figure 3. Updating DIR and SP

Selection of magnetic pole-pair spacing

Internal detection logic circuitry provides outputs representing the speed and direction of the magnetic field across the face of the package. For the direction signal to be appropriately updated, a quadrature relationship must be maintained between the target magnetic pole width, and the pitch between the two Hall elements (H1 and H2) in the device.

For optimal design, the device should be actuated by a ring magnet that presents a field with a pole width of two times the Hall element-to-element spacing, to the front of the device.

This will produce a sinusoidal magnetic field whose period (denoted as T) is then four times the element-to-element spacing. A quadrature relationship can also be maintained for a ring magnet with fields that have a period that satisfies the relationship:

$$nT/4 = 1.45\text{mm}$$

Where ‘n’ is any odd integer. Therefore, ring magnets with pole-pair spacing equal to 5.8mm (n = 1), 1.93mm (n = 3), 1.16mm (n = 5), and so on are permitted.

The two Hall elements of H1 and H2 will sense the simultaneous signal and cause misjudgement of the DIR pin in the device, when the number for ‘n’ is taken by any even integer.

Present the H2/H1 Hall element by placing it at different magnetic pole-pair spacings (n = 1 to n = 5), as shown in Figure 4.

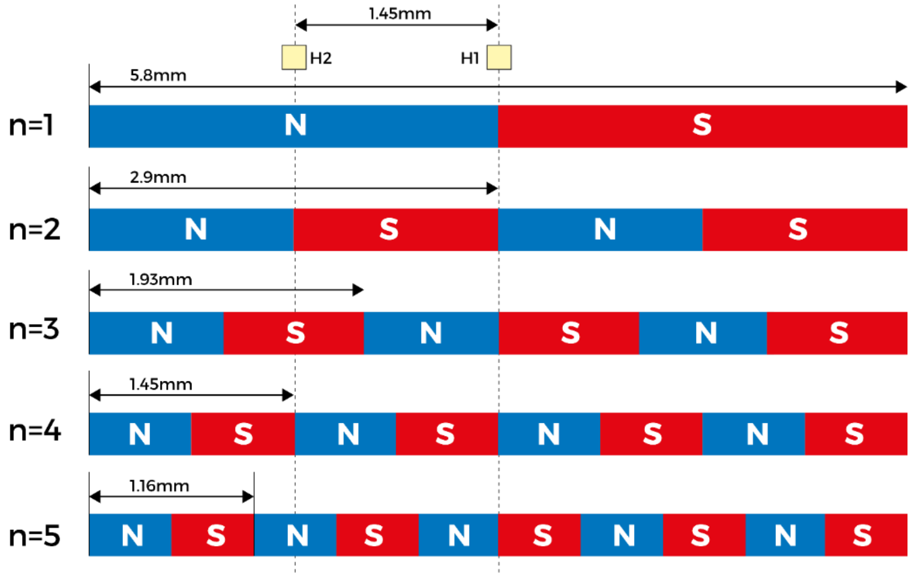

Figure 4. Pole-pair spacings for placement of the Hall element

Figure 5 shows why ‘n’ cannot be applied to any even integer; for example, if n = 2 the magnetic pole-pair spacing is twice the H2 to H1 Hall element spacing amount. Regardless of where H2 and H1 are placed, when the magnetic field passes through H2 and H1, synchronized pulses are 180° out of phase. The magnetic field changes in the case of n = 2, (or any even integer), whether clockwise or counterclockwise movement. The Q1/Q2 or SP output status changes once the magnetic field strength is higher or lower than the BOP/BRP threshold point. However, the directional function of the SP/DIR version or the function created by external components with two output versions (Q1/Q2) due to synchronized pulses 180° out of phase of two Hall elements H1/H2, cause related circuits misjudgement, and then malfunction.

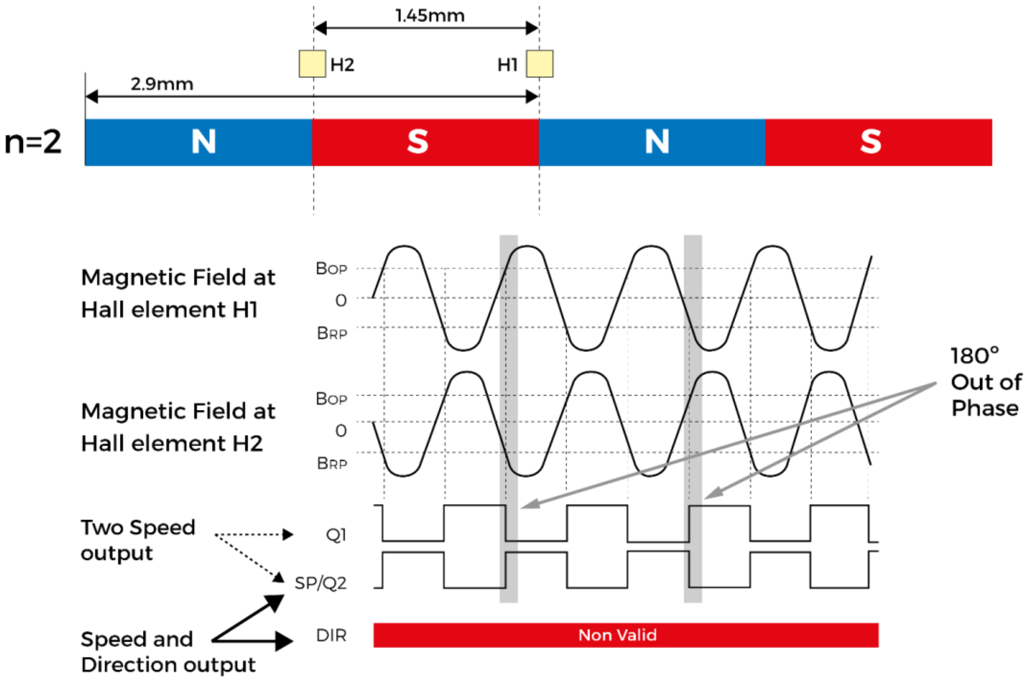

Figure 5. Why ‘n’ cannot be applied to any even integer

Rotation of angle

The AH39xx product family can also be applied in a rotating angle detection configuration with a ring magnet. For example, Figure 6 shows an eight-pole ring magnet with the magnetic pole-pair spacing equal to 5.8mm (n = 1) based on the equation nT/4 = 1.45mm, so that the Hall sensors are 22.5° apart. This configuration creates 2-bit states with an equal time duration of 90°, consisting of one north and one south magnetic pole.

Two signals in quadrature provide H1 and H2 movement information, as shown in Figure 8. Generally, the AH3968x/AH3978Q can integrate with the 74AUP1G86 two-input EXCLUSIVE-OR gate IC applied to an ECU driven through an eight-pole ring magnet application, as shown in Figure 7.

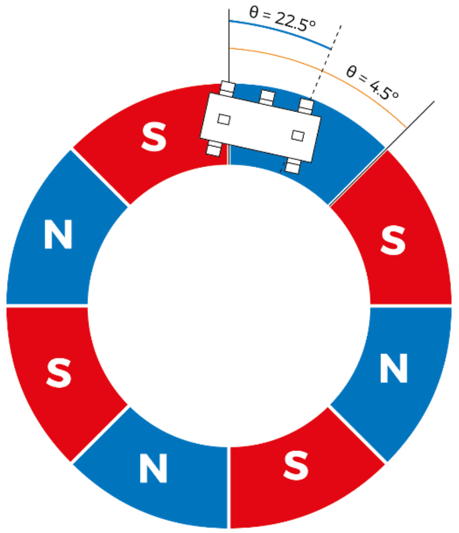

Figure 6. Eight-pole ring magnet

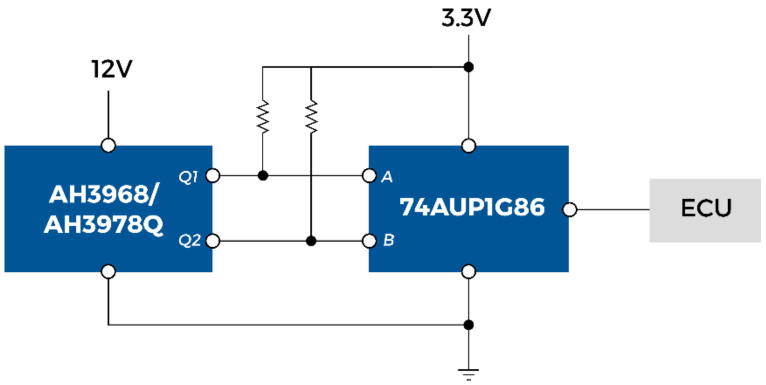

Figure 7. Integrating AH3968x/AH3978Q

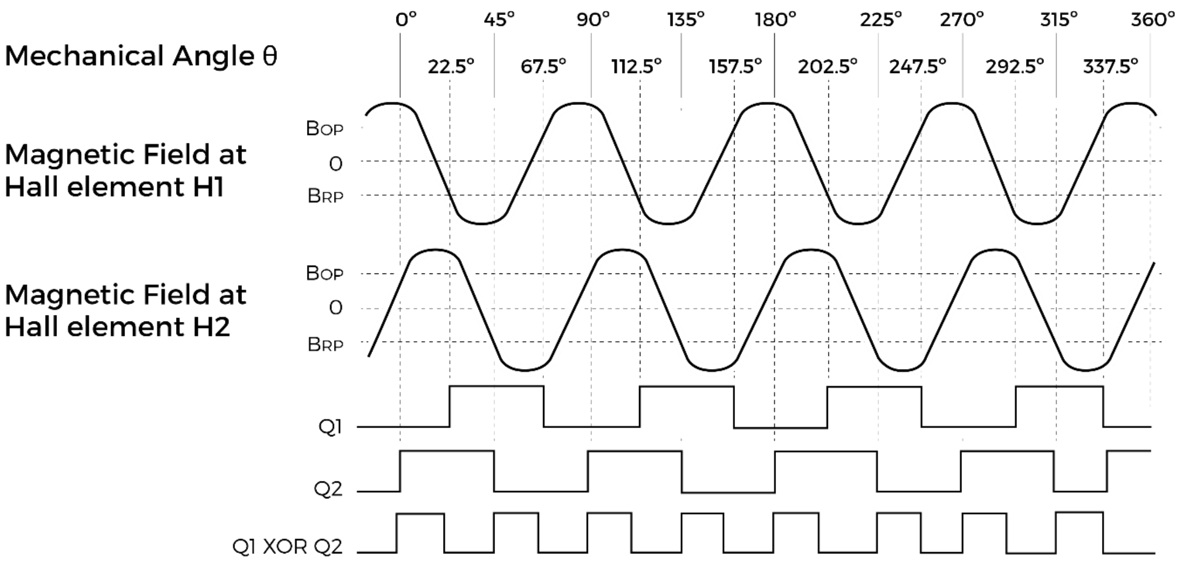

Figure 8. H1/H2 movement information

How to evaluate the diameter in a variety of ring magnet poles.

According to the equation nT/4 = 1.45mm, shown on page 2, and the arc formula equation 2πr x (θ/360), the diameter of the ring magnet can be calculated.

Example: Assuming n = 1, using the eight-pole ring magnet, θ = 45° per pole as shown in Figure 9, symbol r can be calculated by the following equation:

$$T = 1.45mm \times 4 \times 1 = 2\pi r \times (\theta \times M/360°),\ M = 2\ pole$$

⇨ $r = 5.8mm/(2\pi \times (45° \times 2/360°))$
⇨ $r = 3.69mm$

Therefore, based on the above calculated results for n = 1 using an eight-pole magnet, the outer/inner diameter difference must exceed or be equal to the AH39xx package E symbol dimension 3mm to avoid insufficient magnetic flux density due to AH39xx placement drift, so the ring magnet size outer diameter/inner diameter is 10.38mm/4.39mm and the dual Hall sensor detection diameter is 7.38mm.

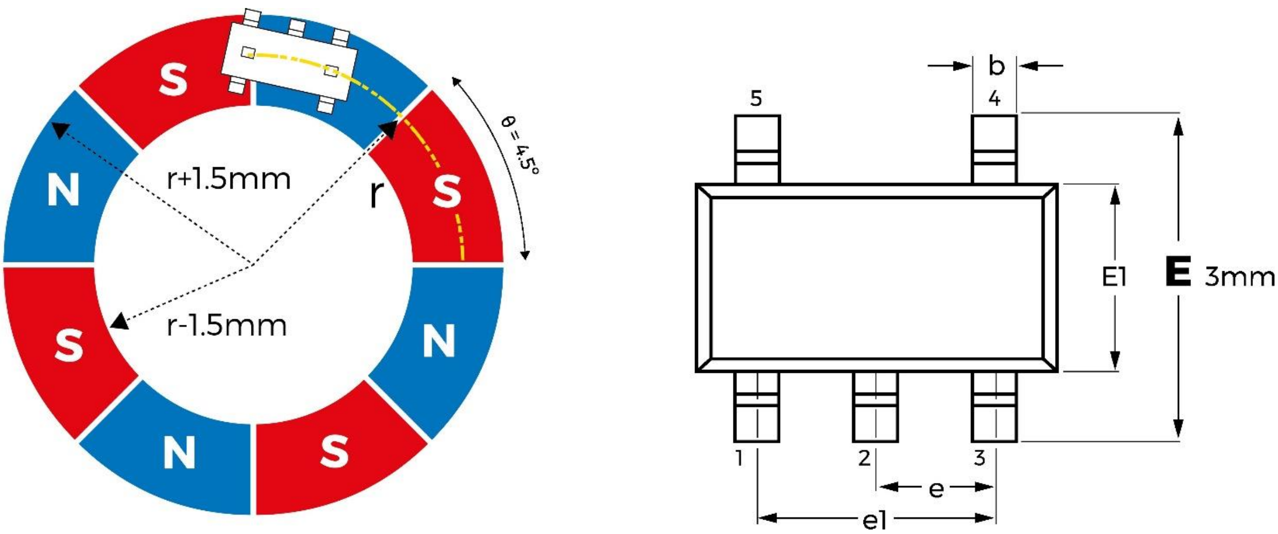

Figure 9. Eight-pole ring magnet

Example: Assuming n = 1, using a 16-pole ring magnet, θ = 22.5° per pole as shown in Figure 10, and symbol r can be calculated by the following equation:

T = 1.45mm x 4/n = 2πr x (θ x M/360°), M = 2 pole

⇨ r = 5.8mm/(2π x (22.5° x 2/360°))
⇨ r = 7.39mm

Therefore, based on the above calculated results for n = 1, using a 16-pole magnet, the ring magnet size outer diameter/inner diameter is 17.77mm/11.77mm and the dual Hall sensor detection diameter is 14.77mm.

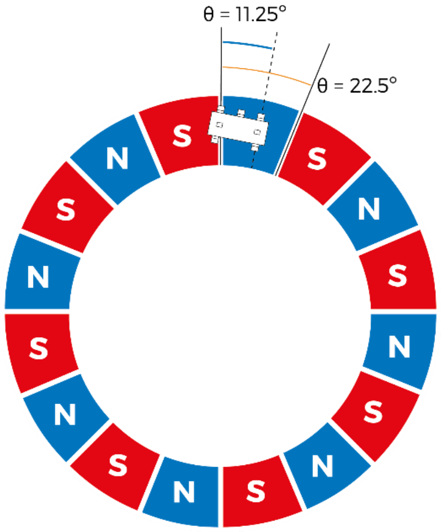

Figure 10. 16-pole ring magnet

Besides, n = 1, using a 16-pole ring magnet, the angle resolution can be up to 11.25° from the original 22.5° per pole by adding 74AUP1G86 XOR logic, as shown in Figure 11.

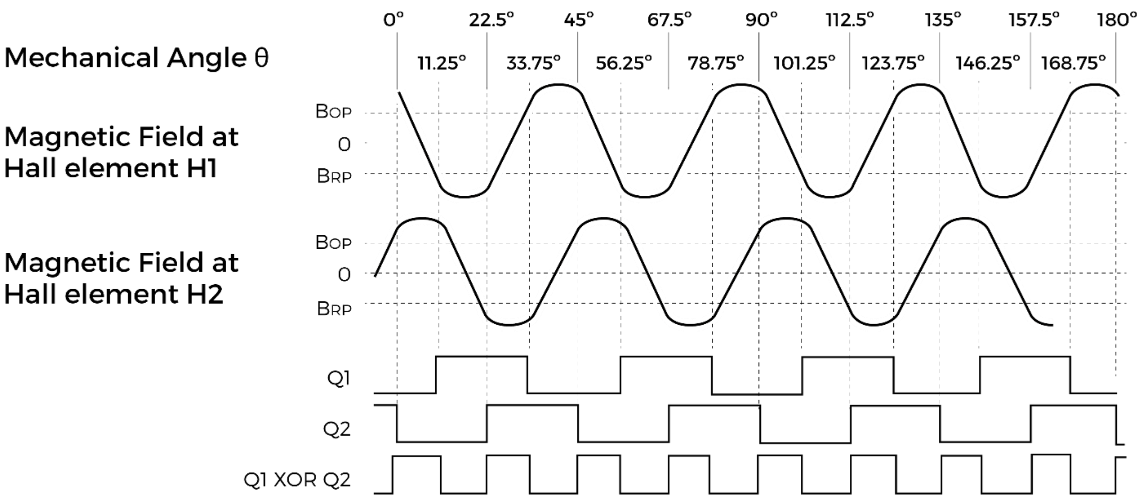

Figure 11. Adding 74AUP1G86 XOR logic

Example: Assuming n = 3, using a 16-pole ring magnet, θ = 22.5° per pole as shown in Figure 12, symbol r can be calculated by the following equation:

T = 1.45mm x 4/n = 2πr x (θ x M/360°), M = 2 pole

⇨ T = 1.45mm x 4/3 = 2πr x (θ x M/360°)
⇨ r = 1.93mm/ (2πx (22.5° x 2/360°))
⇨ r = 2.46mm

Therefore, based on the above calculated results for n = 1, using a 16-pole magnet, the ring magnet size outer diameter/inner diameter is 7.93mm/1.93mm and the dual Hall sensor detection diameter is 4.93mm.

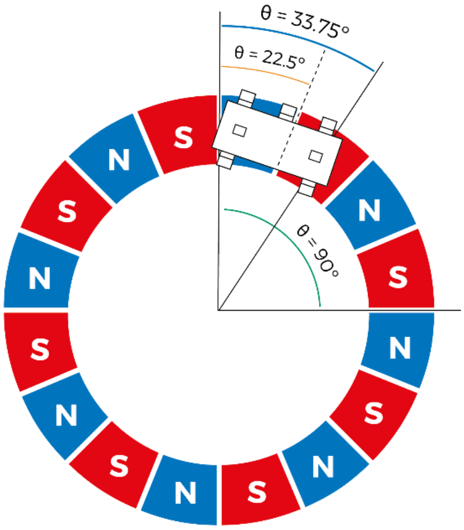

Figure 12. 16-pole ring magnet

Besides, n = 3, using a 16-pole ring magnet, the angle resolution can be up to 11.25° from the original 22.5° per pole by adding 74AUP1G86 XOR logic, as shown in Figure 13.

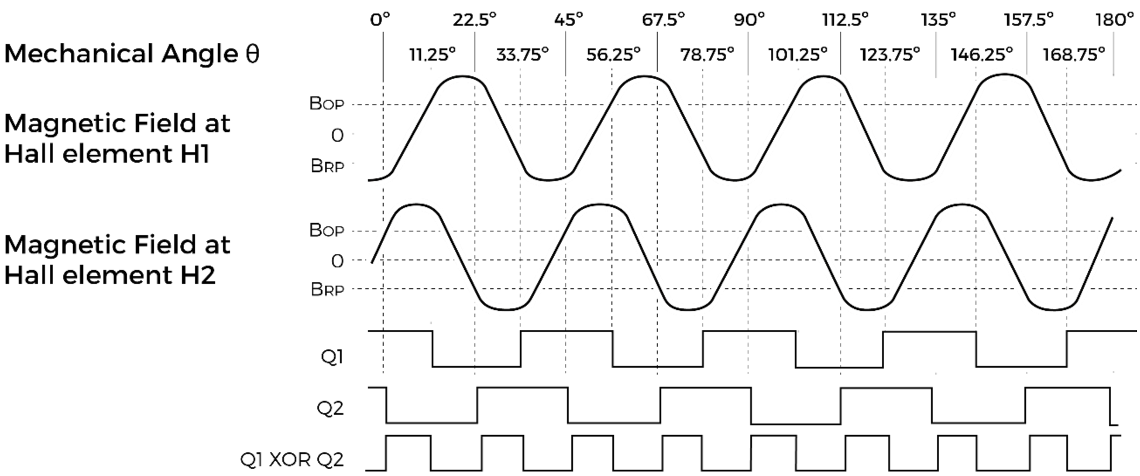

Figure 13. Adding 74AUP1G86 XOR logic

Conclusion

This application manual serves to advise customers on selecting from the AH39xx series (see Table 1). The use of the AH39xx IC is as described in the application note. Pay particular attention to the following:

- ✓ **Magnet pole-pair spacing:**
  - ➢ nT/4 = 1.45mm, where n is any odd integer
- ✓ **Ring magnet diameter design requirements and limitations:**
  - ➢ Based on the nT/4 = 1.45mm calculation and the arc formula equation
  - ➢ Size of package—the E symbol must be counted in the outer/inner diameter calculation

For more information about ring magnet evaluation, and AH39xx IC placement, design, and application inquiries, please contact **Diodes Technical Support**.