

# AN1189

## Dual Hall-Effect Latch with Speed and Direction Output

Aleck Jih, Analog, Diodes Incorporated

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 <sub>OP</sub> (Gauss)			Release Point B <sub>RP</sub> (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.

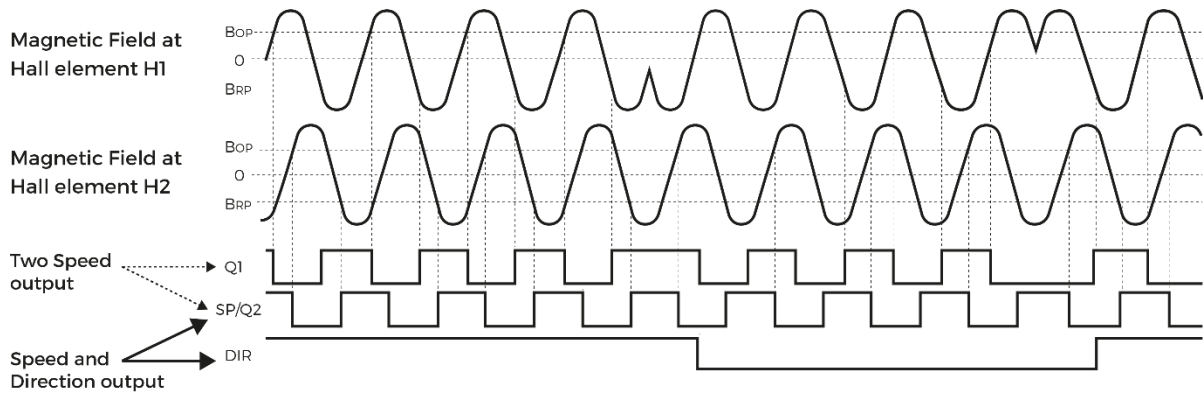


Figure 1. Timing diagrams of the speed and direction output of SP/DIR and dual SP output Q1/Q2

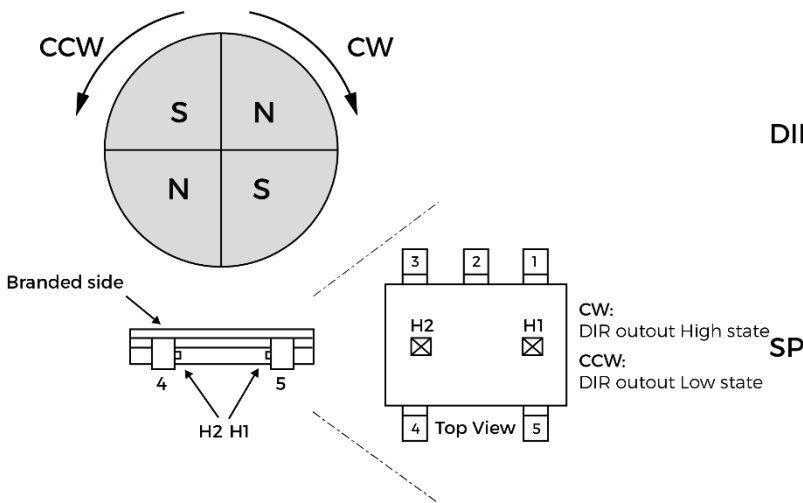


Figure 2. DIR output

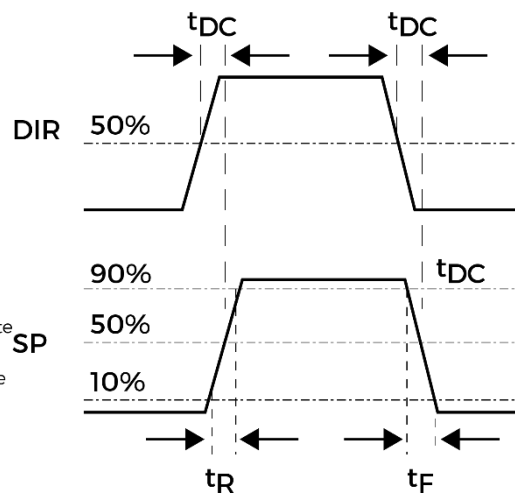


Figure 3. Updating DIR and SP

### 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.

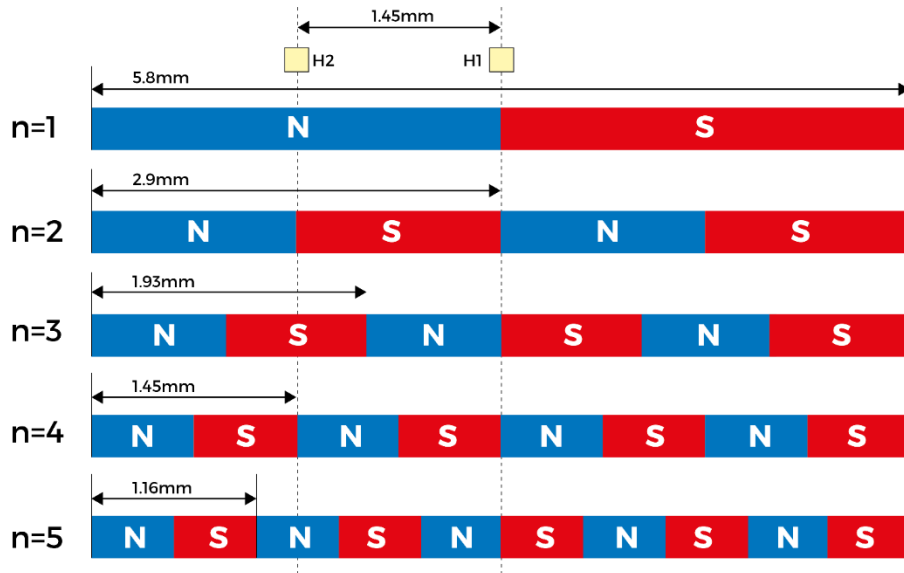


Figure 4. Pole-pair spacings for placement of the Hall element

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  $180^\circ$  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  $180^\circ$  out of phase of two Hall elements H1/H2, cause related circuits misjudgement, and then malfunction.

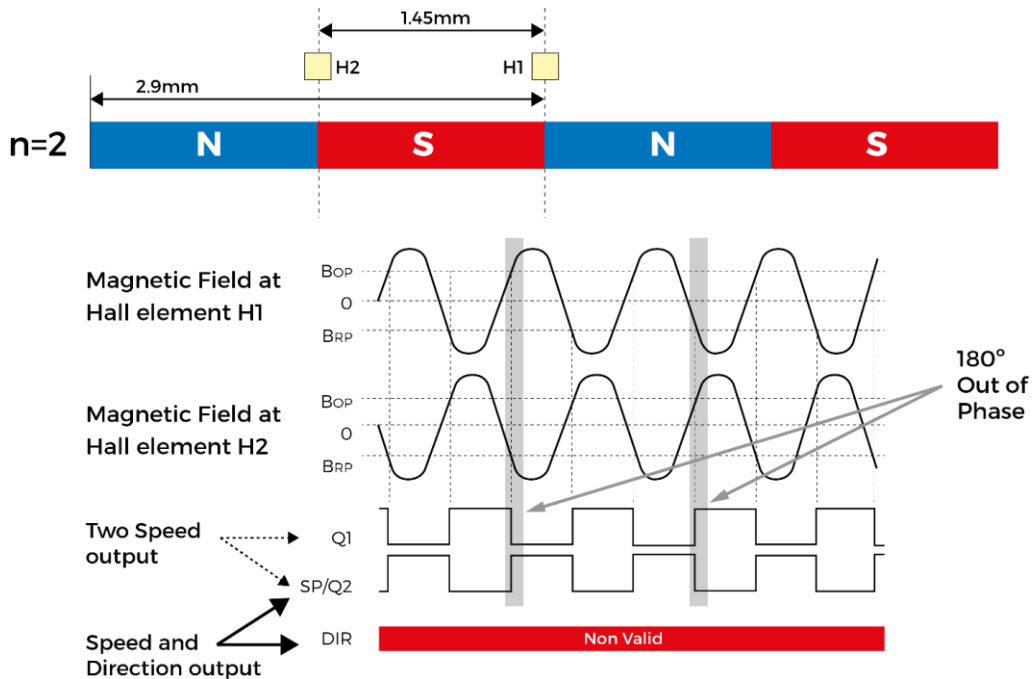
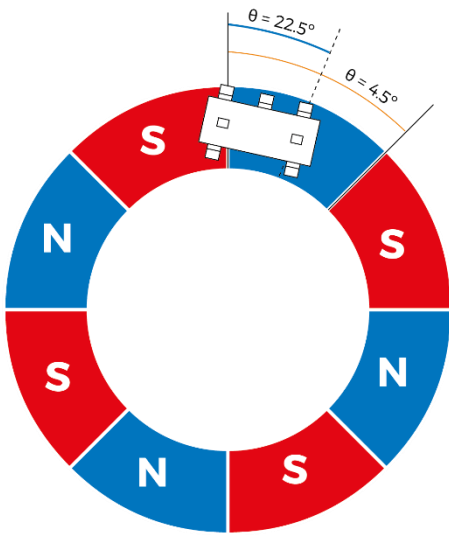


Figure 5. Why 'n' cannot be applied to any even integer

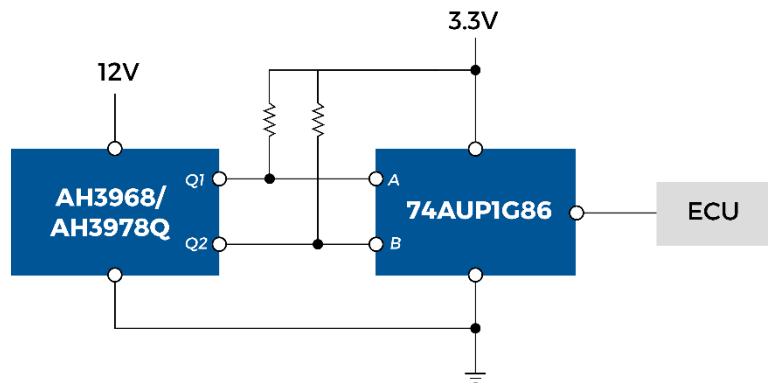
**Rotation of angle**

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  $nT/4 = 1.45\text{mm}$ , so that the Hall sensors are  $22.5^\circ$  apart. This configuration creates 2-bit states with an equal time duration of  $90^\circ$ , consisting of one north and one south magnetic pole.

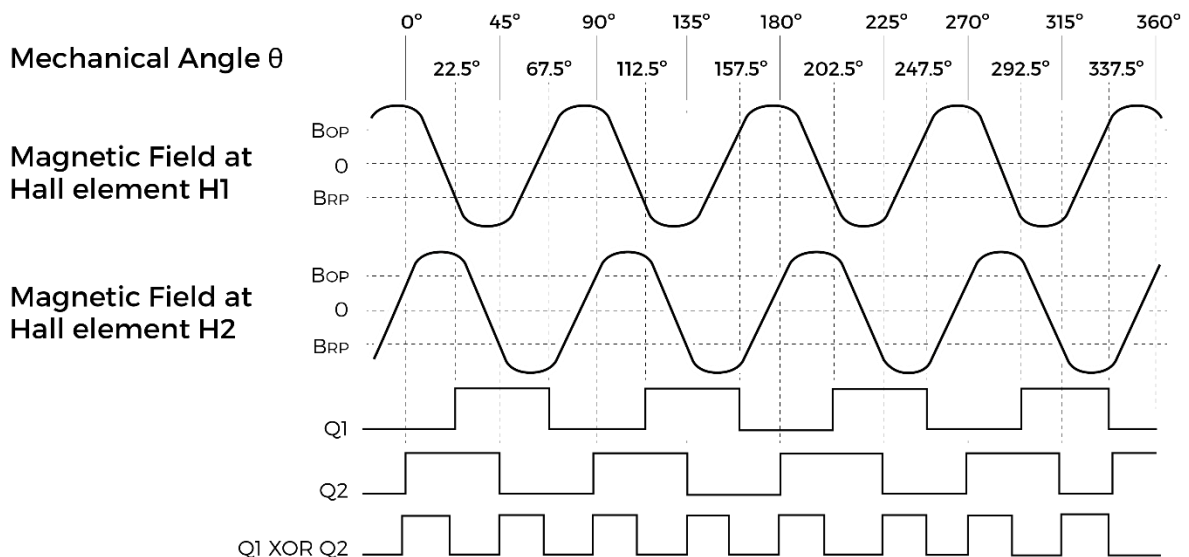
Two signals in quadrature provide H1 and H2 movement information, as shown in Figure 8. Generally, the AH3968x/AH3978Q can integrate with the 74AUP1G86 two-input EXCLUSIVE-OR gate IC applied to an ECU driven through an eight-pole ring magnet application, as shown in Figure 7.



**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  $nT/4 = 1.45\text{mm}$ , shown on page 2, and the arc formula equation  $2\pi r \times (\theta/360)$ , the diameter of the ring magnet can be calculated.

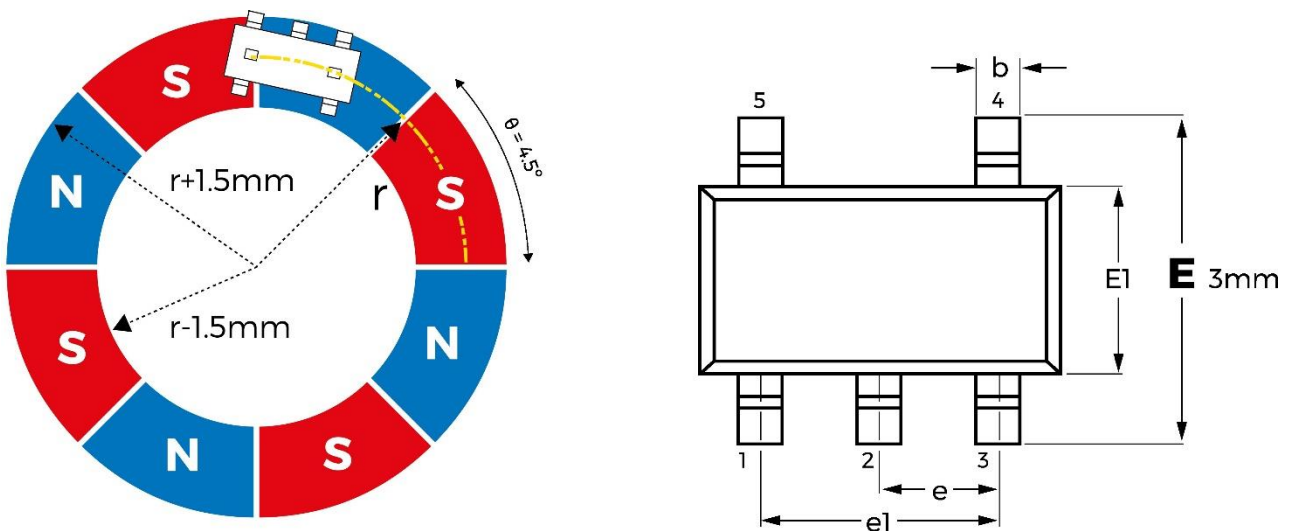
**Example:** Assuming  $n = 1$ , using the eight-pole ring magnet,  $\theta = 45^\circ$  per pole as shown in Figure 9, symbol  $r$  can be calculated by the following equation:

$$T = 1.45\text{mm} \times 4 \times 1 = 2\pi r \times (\theta \times M/360^\circ), M = 2 \text{ pole}$$

$$\Rightarrow r = 5.8\text{mm}/(2\pi \times (45^\circ \times 2/360^\circ))$$

$$\Rightarrow r = 3.69\text{mm}$$

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**

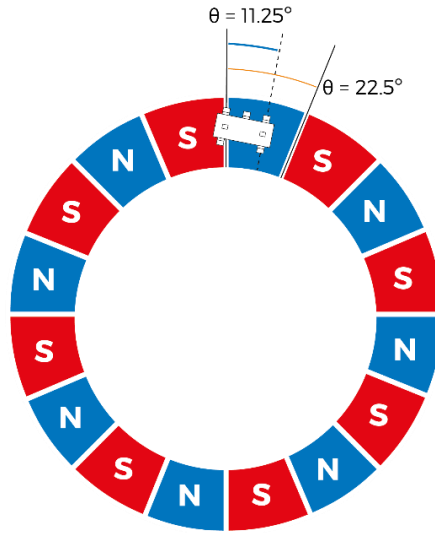
**Example:** Assuming  $n = 1$ , using a 16-pole ring magnet,  $\theta = 22.5^\circ$  per pole as shown in Figure 10, and symbol  $r$  can be calculated by the following equation:

$$T = 1.45\text{mm} \times 4/n = 2\pi r \times (\theta \times M/360^\circ), M = 2 \text{ pole}$$

$$\Rightarrow r = 5.8\text{mm}/(2\pi \times (22.5^\circ \times 2/360^\circ))$$

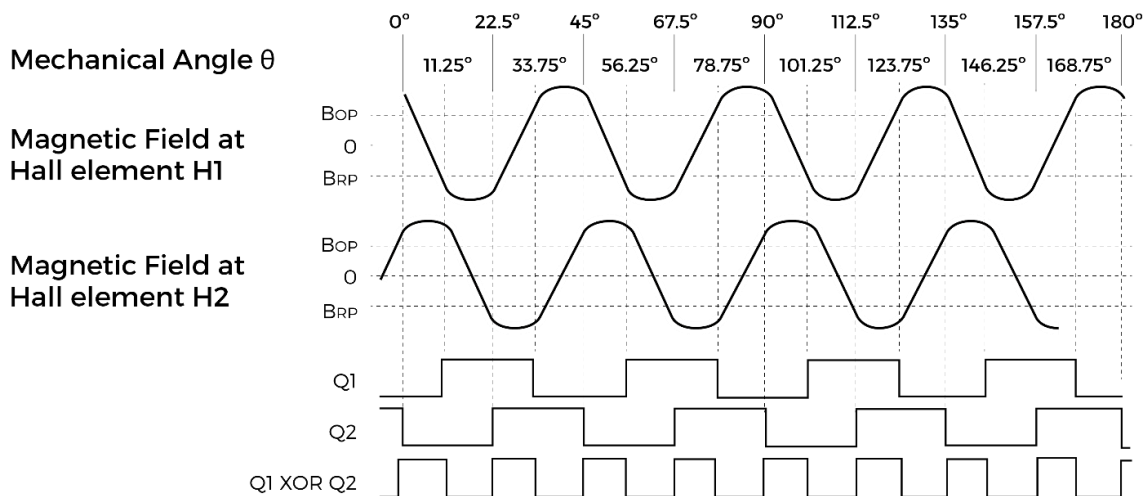
$$\Rightarrow r = 7.39\text{mm}$$

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  $11.25^\circ$  from the original  $22.5^\circ$  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,  $\theta = 22.5^\circ$  per pole as shown in Figure 12, symbol  $r$  can be calculated by the following equation:

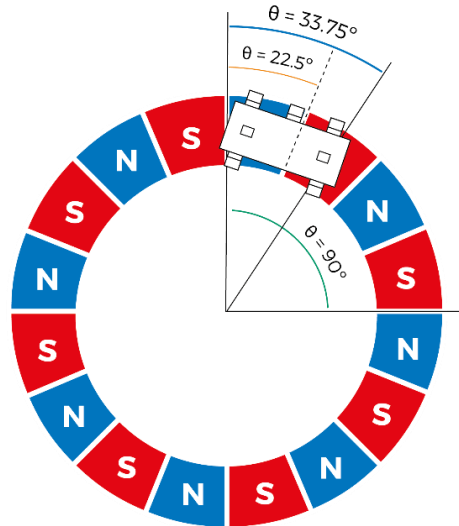
$$T = 1.45\text{mm} \times 4/n = 2\pi r \times (\theta \times M/360^\circ), M = 2 \text{ pole}$$

$$\Rightarrow T = 1.45\text{mm} \times 4/3 = 2\pi r \times (\theta \times M/360^\circ)$$

$$\Rightarrow r = 1.93\text{mm} / (2\pi \times (22.5^\circ \times 2/360^\circ))$$

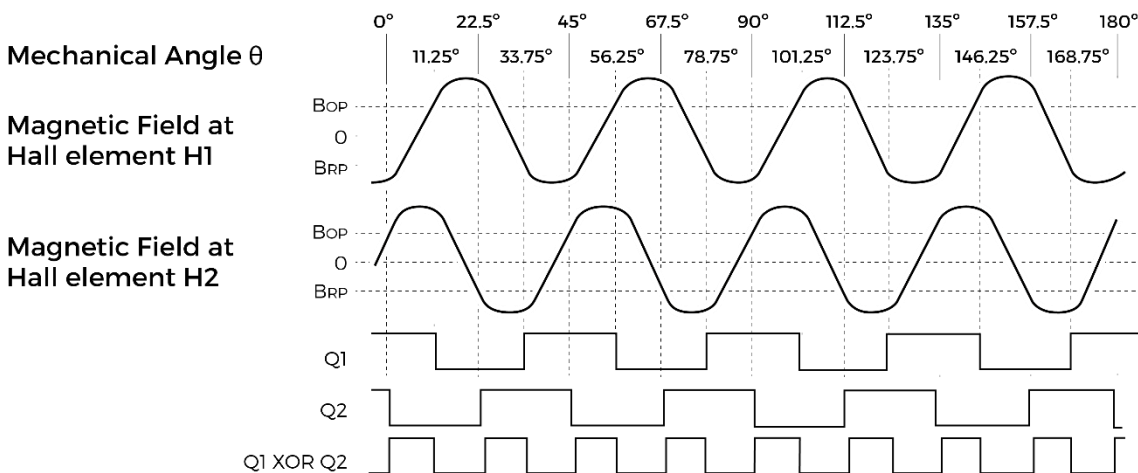
$$\Rightarrow r = 2.46\text{mm}$$

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 magnet, the angle resolution can be up to  $11.25^\circ$  from the original  $22.5^\circ$  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:**
  - $nT/4 = 1.45\text{mm}$ , where  $n$  is any odd integer
- ✓ **Ring magnet diameter design requirements and limitations:**
  - Based on the  $nT/4 = 1.45\text{mm}$  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](#).



**IMPORTANT NOTICE**

1. DIODES INCORPORATED (Diodes) AND ITS SUBSIDIARIES MAKE NO WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, WITH REGARDS TO ANY INFORMATION CONTAINED IN THIS DOCUMENT, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION).
2. The Information contained herein is for informational purpose only and is provided only to illustrate the operation of Diodes' products described herein and application examples. Diodes does not assume any liability arising out of the application or use of this document or any product described herein. This document is intended for skilled and technically trained engineering customers and users who design with Diodes' products. Diodes' products may be used to facilitate safety-related applications; however, in all instances customers and users are responsible for (a) selecting the appropriate Diodes products for their applications, (b) evaluating the suitability of Diodes' products for their intended applications, (c) ensuring their applications, which incorporate Diodes' products, comply the applicable legal and regulatory requirements as well as safety and functional-safety related standards, and (d) ensuring they design with appropriate safeguards (including testing, validation, quality control techniques, redundancy, malfunction prevention, and appropriate treatment for aging degradation) to minimize the risks associated with their applications.
3. Diodes assumes no liability for any application-related information, support, assistance or feedback that may be provided by Diodes from time to time. Any customer or user of this document or products described herein will assume all risks and liabilities associated with such use, and will hold Diodes and all companies whose products are represented herein or on Diodes' websites, harmless against all damages and liabilities.
4. Products described herein may be covered by one or more United States, international or foreign patents and pending patent applications. Product names and markings noted herein may also be covered by one or more United States, international or foreign trademarks and trademark applications. Diodes does not convey any license under any of its intellectual property rights or the rights of any third parties (including third parties whose products and services may be described in this document or on Diodes' website) under this document.
5. Diodes' products are provided subject to Diodes' Standard Terms and Conditions of Sale (<https://www.diodes.com/about/company/terms-and-conditions/terms-and-conditions-of-sales/>) or other applicable terms. This document does not alter or expand the applicable warranties provided by Diodes. Diodes does not warrant or accept any liability whatsoever in respect of any products purchased through unauthorized sales channel.
6. Diodes' products and technology may not be used for or incorporated into any products or systems whose manufacture, use or sale is prohibited under any applicable laws and regulations. Should customers or users use Diodes' products in contravention of any applicable laws or regulations, or for any unintended or unauthorized application, customers and users will (a) be solely responsible for any damages, losses or penalties arising in connection therewith or as a result thereof, and (b) indemnify and hold Diodes and its representatives and agents harmless against any and all claims, damages, expenses, and attorney fees arising out of, directly or indirectly, any claim relating to any noncompliance with the applicable laws and regulations, as well as any unintended or unauthorized application.
7. While efforts have been made to ensure the information contained in this document is accurate, complete and current, it may contain technical inaccuracies, omissions and typographical errors. Diodes does not warrant that information contained in this document is error-free and Diodes is under no obligation to update or otherwise correct this information. Notwithstanding the foregoing, Diodes reserves the right to make modifications, enhancements, improvements, corrections or other changes without further notice to this document and any product described herein. This document is written in English but may be translated into multiple languages for reference. Only the English version of this document is the final and determinative format released by Diodes.
8. Any unauthorized copying, modification, distribution, transmission, display or other use of this document (or any portion hereof) is prohibited. Diodes assumes no responsibility for any losses incurred by the customers or users or any third parties arising from any such unauthorized use.
9. This Notice may be periodically updated with the most recent version available at <https://www.diodes.com/about/company/terms-and-conditions/important-notice>

The Diodes logo is a registered trademark of Diodes Incorporated in the United States and other countries.  
All other trademarks are the property of their respective owners.  
© 2024 Diodes Incorporated. All Rights Reserved.

[www.diodes.com](http://www.diodes.com)