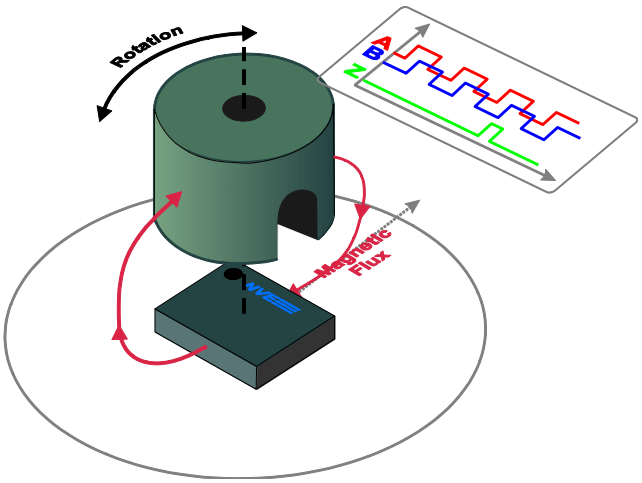
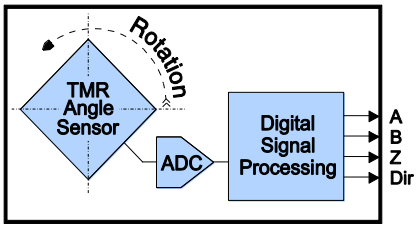
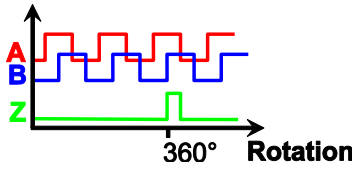
ASR022 TMR ABZ Noncontact Absolute Encoder Sensor



Block Diagram



Output



Features

- Rotational speeds to 15,000 RPM
- ABZ outputs
- Direction output
- 512 virtual lines (128 cycles) per revolution
- Robust airgap and misalignment tolerances
- Low power
- Factory calibrated
- Ultraminiature 2.5x 2.5x 0.8 mm TDFN6 package

Key Specifications

- Robust 6 to 20 mT field operating range
- Flexible 2.2 to 3.6 V supply range
- Low 4 mA typical supply current
- Full −40 °C to 125 °C operating range

Applications

- Motion control
- Robotics
- Automotive applications
- Internet of Things (IoT) end nodes

Description

ASR022 noncontact TMR encoder sensors provide precise pulses indicating angular motion, and is smaller, lower power, and more accurate than other magnetic encoders.

An industry-standard ABZ interface allows the ASR022 to replace legacy optical encoders and provide noncontact operation, wide mechanical tolerance, and inherent dust and contaminant immunity.

The sensor combines precise, low-power Tunneling Magnetoresistance (TMR) sensing elements with sophisticated digital signal processing.

The sensor is factory calibrated, with coefficients stored in an internal nonvolatile memory.

With its magnetic operation, ESD protection, and a full −40 °C to 125 °C operating temperature range, the ASR022 is ideal for harsh, contaminated environments.

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Boundary Ratings

Parameter	Min.	Max.	Units
Supply voltage	−12	4.2	Volts
Storage temperature	−55	150	°C
ESD (Human Body Model)		2000	Volts
Applied magnetic field		Unlimited	Tesla

Operating Specifications (T_{min} to T_{max}; $2.2 < V_{DD} < 3.6$ V unless otherwise stated)

Parameter	Symbol	Min.	Typ.	Max.	Units	Test Condition
Operating temperature	T_{min}; T_{max}	−40		125	°C	
Supply voltage	V_{DD}	2.2		3.6	V	
Supply current	I_{DD}		4	6	mA	Max. at V_{DD} = 3.6V
Power-on Reset supply voltage	V_{POR}		1.4		V	
Brown-out power supply voltage	V_{BOR}	0.75	1	1.36	V	
Start-up time	T_{STA}		15		ms	
Magnetics						
Applied magnetic field	B	6	12	20	mT	
Accuracy and Repeatability						
Angular segments			512			
Angular hysteresis (backlash)	∬			2	LSB	
Repeatability			±1			Fixed temperature and bias[1]
Absolute accuracy, fixed bias[1]	ε			±3 ±4		0 to 85°C −40 to 125°C
Absolute accuracy, variable bias[2]				±5		−40 to 125°C
Speed						
Update rate			10		kSps	
Package Thermal Characteristics						
Junction-to-ambient thermal resistance	θ_{JA}		320		°C/W	
Package power dissipation			500		mW	

Specification Notes:

1. "Fixed Bias" means a fixed airgap within between the bias magnet and sensor so the magnitude of the magnetic field at the sensor is constant within the specified field range of the parts. The highest accuracy is obtained using fields closest to the 17.5 mT factory calibration field.
2. "Variable Bias" means the magnitude of the magnetic field at the sensor can vary across the entire specification range.

ASR022 Overview

The heart of the ASR022 is a tunneling magnetoresistive (TMR) sensor. In a typical configuration, an external magnet provides a magnetic field of 6 to 20 mT (60 to 200 Oe) in the plane of the sensor, as illustrated below for a bar magnet and a diametrically-magnetized disk magnet. Factory-programmed signal conditioning is combined with a temperature sensor and digital linearization to produce speed, accuracy, and precision in a tiny 2.5 x 2.5 mm TDFN package.

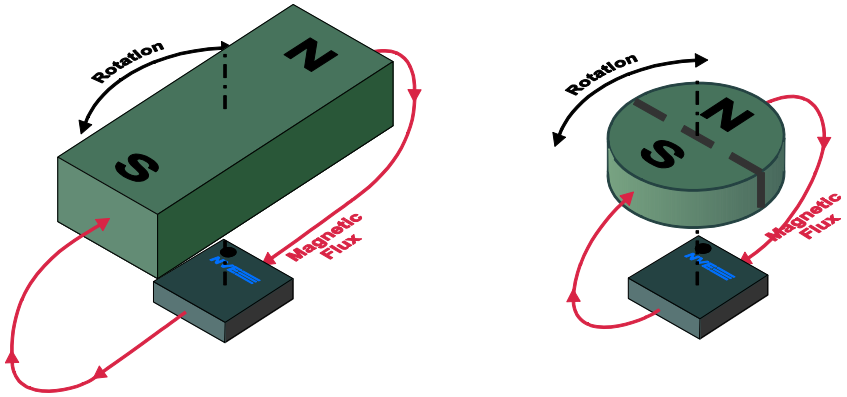

Figure 1. Magnetic operation.

ASR022 Operation

A detailed block diagram is shown below:

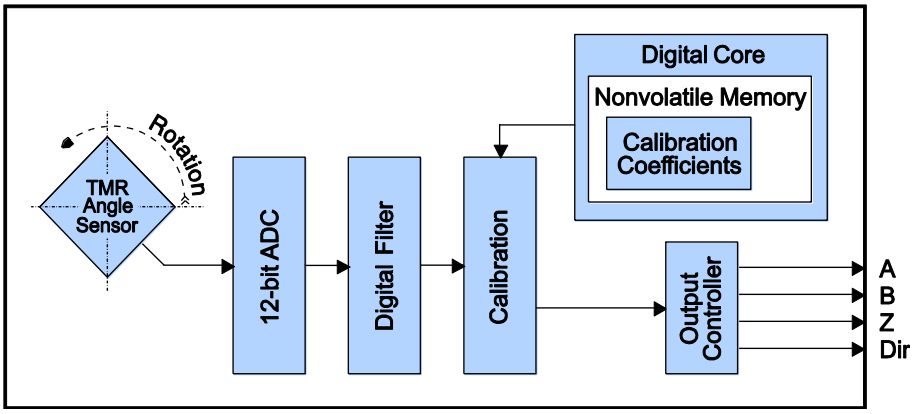

Figure 2. Detailed block diagram.

TMR Angle Sensor Element

ASR0x2 sensors use unique TMR sensor elements that are inherently high speed and low noise. The digital core calculates rotation from TMR sensor element.

ADC

The sensor output is digitized with a 12-bit ADC. The extra bits ensure precision and computational accuracy.

Orientation and Direction

The zero reference is shown in the figure below. Direction is defined looking at the top of the device, so clockwise is defined as a rotating field vector through pins 1-6-4-3 and counterclockwise is through pins 1-3-4-6.

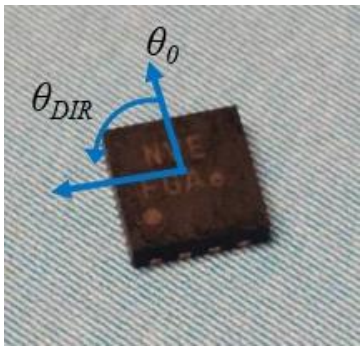

Figure 3. Zero-angle reference (θ_0) and counterclockwise rotation (θ_{DIR}).The rotational center of the sensor is the package center.

As shown in the timing diagram, below, output A leads B for clockwise magnet rotation, and B leads A for counterclockwise:

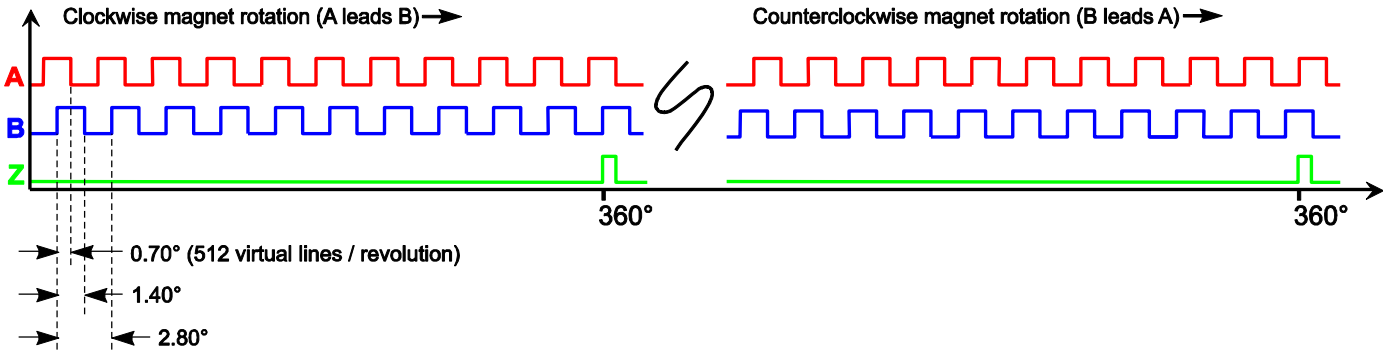

Figure 4. Timing diagram.

Minimizing Noise

Several steps can be taken to minimize noise:

- A 10 µF bypass capacitor is recommended as close as possible to the V_{DD} and GND pins. A 0.080 x 0.050 inch or smaller capacitor is recommended to minimize magnetic interference with the sensor.
- Use a circuit board ground plane.
- Grounding the sensor's center pad allows the leadframe to act as a shield.

Magnet Selection

The sensor's wide operating field range of 6 to 20 mT (60 to 200 Oe) allows inexpensive magnets and operation over a wide range of magnet spacing. The figures below show the magnetic field for various magnet geometries and distances for inexpensive C5/Y25 grade ferrite magnets:

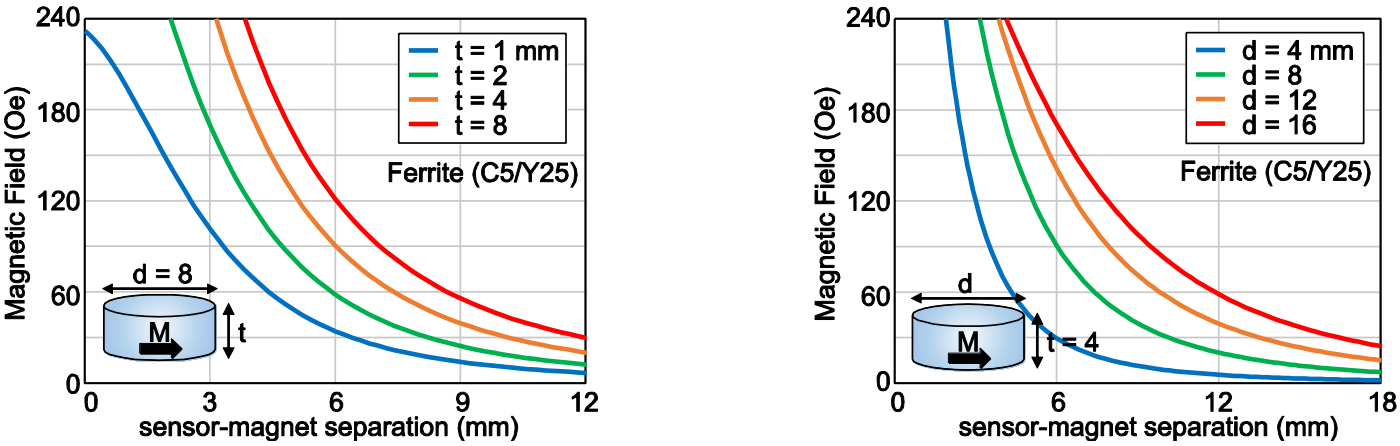

Figure 5. Magnetic fields for various geometries of C5/Y25 ferrite magnets plotted for the distance between the magnet and sensor. Eight-millimeter diameter magnets of various thicknesses are shown at left, and four-millimeter thick magnets of various diameters are shown at right.

Field varies less with distance for larger magnets, so maximizing magnet size within the mechanical constraints of the system maximizes accuracy.

Higher-grade magnets can be used for high-temperature applications or large magnet-sensor separations. The graph below shows field strengths with various materials:

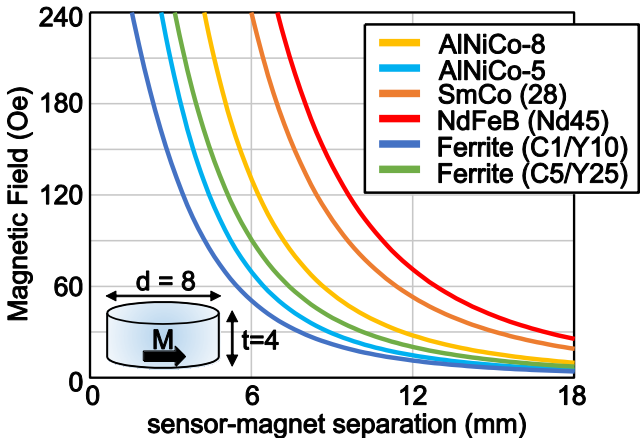

Figure 6. Magnetic fields from an 8 millimeter diameter, 4 millimeter thick magnet for increasing magnet-sensor separation. NdFeB materials produce the largest magnetic fields and separations. SmCo and AlNiCo materials offer the highest operating temperatures. Ferrite magnets are the most cost-effective.

Our free Web app can be used to determine optimum separations for various magnet sizes and materials:
https://www.nve.com/spec/calculators.php.

NVE's Online Store stocks popular magnets.

Application Circuits

Isolated Microcontroller Interface

Double isolation from human interface to line-voltage driven electrical circuitry is required in some safety intensive applications such as medical instruments. The mechanical gap between the magnet and the sensor can provide one level of isolation. Galvanic isolation from the sensor to the microcontroller provides a second isolation barrier. The IL715 isolator in the circuit above is rated at 2.5 kV isolation, is UL/VDE-compliant, and is available in an ultra-miniature QSOP package. The isolator can also level-shift between the 3.3-volt sensor and a five-volt microcontroller:

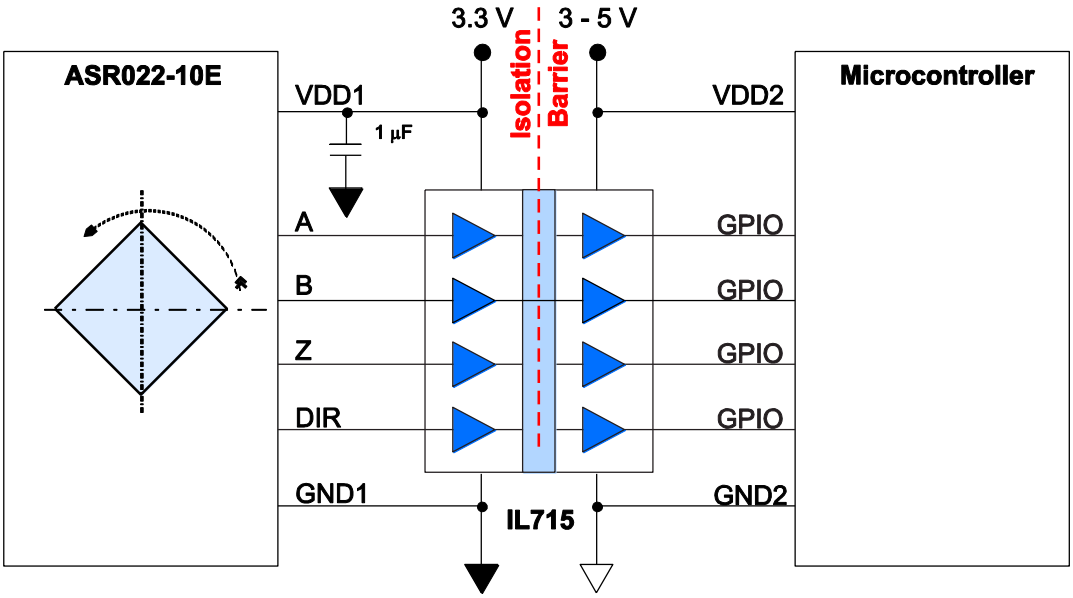

Figure 7. Isolated microcontroller interface.

Evaluation Support

Breakout Board

The breakout board provides easy connections to an ASR022-10E encoder sensor with a six pin header or a 1 mm edge connector. It also has a recommended 10 µF bypass capacitor:

Figure 8. ASR022-10E-EVB01 breakout board (actual size).
0.87" x 0.4" (21 mm x 10 mm)

Arduino Shield

The Arduino Shield connects via an edge connector to the breakout board above or other breakout boards. Sixty LEDs indicate the angle, and colors indicate direction of rotation. A diametrically-magnetized neodymium magnet is included, and a magnet fixture allows the magnet to be positioned on-axis or off axis. Arduino software is available via the NVE GitHub repository.

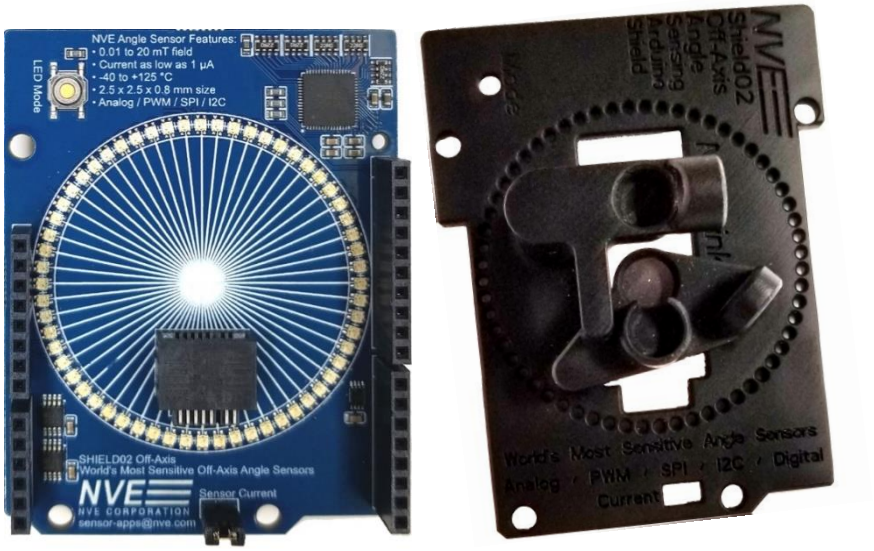

Figure 9. SHIELD02 Arduino Shield with magnet fixture (actual size).
2.7" x 2.1" (53 mm x 69 mm)

Evaluation Kit

This simple board includes a diametrically-magnetized cylindrical horseshoe magnet and fixturing. LEDs indicate the ASR022-10E outputs, and the position is shown on a three-digit seven-segment display:

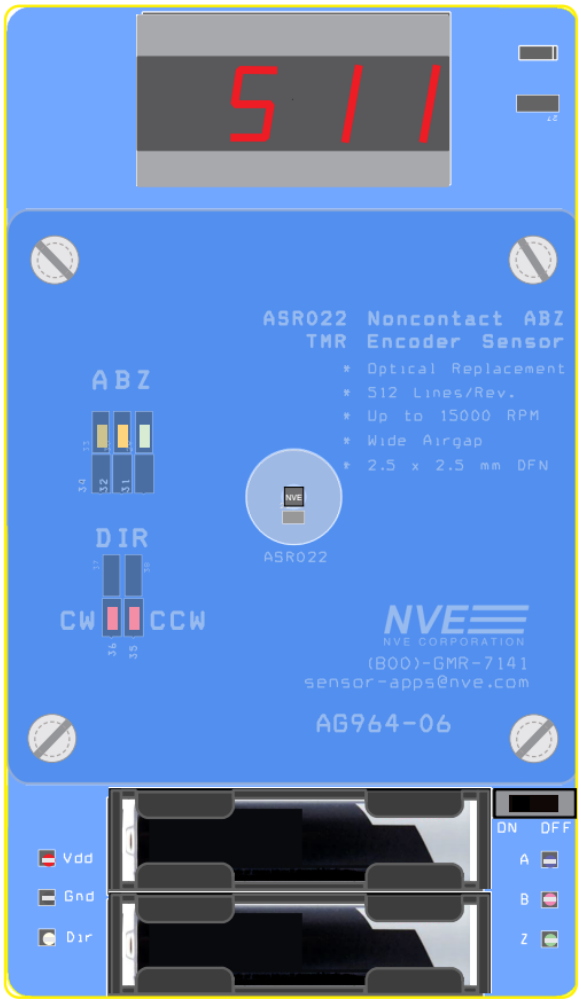

Figure 10. ASR022 TMR Encoder Sensor Evaluation Kit (AG964-07; actual size).
3" x 5.25" (76 mm x 133 mm)

Socket Board

The AG954-07E provides a TDFN6 socket for easy interface to sensors such as the ASR022-10E without soldering:

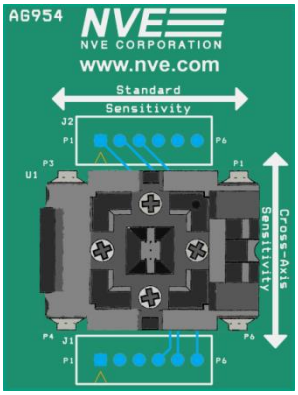

Figure 11. AG954-07E: TDFN socket board
1.5" x 2" (38 mm x 50 mm)(actual size)

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Magnets

NVE stocks five popular magnets for use with its angle and encoder sensors:

NVE Part Number	Compatible Magnet Holder	Diameter (mm)	Length (mm)	Typ. sensor distance (mm; 12 mT nom. field)	Material and Configuration
12526	4 mm	4	4	3	C5/Y25 ferrite disk magnets
12249	N/A	12.5	3.5	4	
12527	8 mm	8	4	5	
12528	8 mm	8	8	6	
12426*	N/A	11	11	8	Alnico-5 round horseshoe magnet with mounting hole

*Included in the Evaluation Kit for this encoder sensor.

Table 2. Popular encoder sensing magnets.

Magnet Holders

NVE offers two magnet holders for evaluation and prototyping. The holders are machined aluminum. Set screws secure the magnets in the holders and allow magnet position adjustments. There are threaded mounting holes for a thumbscrew to turn the magnet, or the hole can be used to attach the holder to a rotating shaft. A "clockhand" indicator helps track magnet rotation:

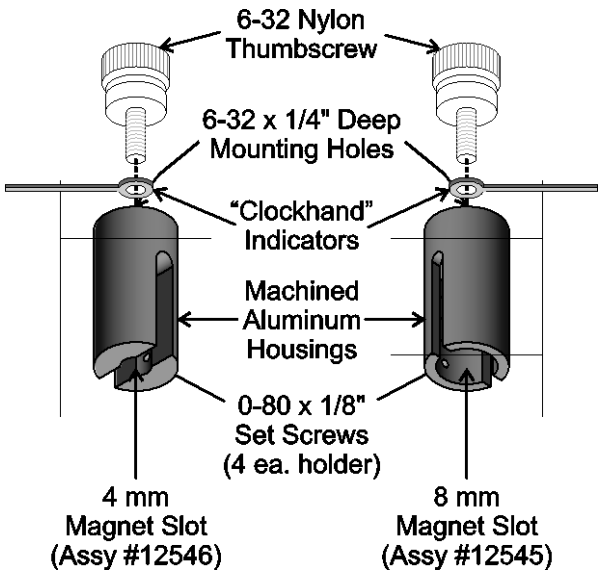


Figure 12. Four millimeter magnet holder (part #12546; left) and 8 mm magnet holder (part #12545; right).
0.44" dia. x 0.88" tall (11 mm x 22 mm) outside dimensions; actual size).

The holders are compatible with several popular diametrically-magnetized disk magnets and can be used with the Evaluation Kits:

Holder Part Number	Outside Dimensions	Compatible Magnets (NVE part #s)	Magnet Diameter (mm)	Max. Magnet Length (mm)
12546	11 mm dia. x 22 mm tall	12526	4	4
12545		12527; 12528	8	8

Table 3. Magnet holders.

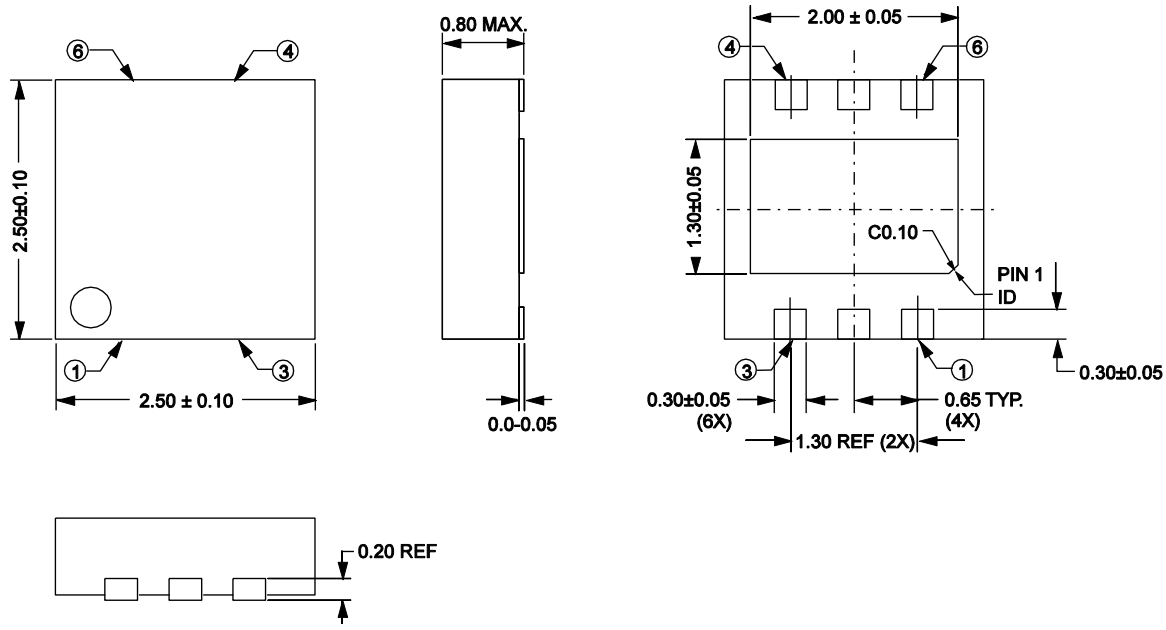
Illustrative Arduino Code

```
//Arduino interrupt-driven half-step or 2x decoding software.
//There can be up to four state changes per AB pulse;
//this code has two state changes per pulse
//because Arduinos only have two interrupts.
//One interrupt for A and one for Z.
//PINOUTS: A = 2; B = 4; Z = 3

byte counter = 0;  // Counter for AB cycles (0 to 255)
boolean A, B, lastA;  // Variables for reading the encoder signals
void setup() {
  Serial.begin(115200);
  lastA = digitalRead(2);  // Read the initial state of A
  attachInterrupt(digitalPinToInterrupt(2), updatePosition, CHANGE);  // A on interrupt
  attachInterrupt(digitalPinToInterrupt(3), resetPosition, RISING);   // Z on interrupt
}
void loop() {
  // Main loop does nothing, everything is handled by interrupts
}
void updatePosition() {
  A = digitalRead(2);  // Read current state of A
  B = digitalRead(4);  // Read current state of B

  if (A != lastA) {
    counter += (A == B) ? 1 : -1;
    lastA = A;
    }
    // Map counter to degrees (0-359) and print
    int angle = map(counter, 0, 255, 0, 359);
    Serial.println("Degrees: " + String(angle));
}
void resetPosition() {
  // Reset counter when Z pulse is detected
  counter = 0;
  Serial.println("Z pulse detected, degrees at 0");
}
```

2.5 x 2.5 mm TDFN6 Package



Pad	Symbol	Description
1	GND	Ground/V_{SS}
2	A	A Output
3	B	B Output
4	VDD	Power Supply (2.2 – 3.6 V; bypass with a 10 µF capacitor)
5	Z	Index output. HIGH indicates zero to 1 degree.
6	DIR	Direction output. Low is clockwise and HIGH is counterclockwise.
Center pad		Internal leadframe connection; connect to GND to minimize noise.

Notes:

- Dimensions in millimeters.
- Soldering profile per JEDEC J-STD-020C, MSL 1.

RoHS COMPLIANT

Ordering Information

ASR022 - 10E TR13

Product Family
ASR = Smart Angular Sensors

I/O Interface
002 = SPI
012 = I²C / PWM
022 = ABZ (Encoder)

Part Package
10E = RoHS-Compliant 2.5 x 2.5 mm TDFN6 Package

Bulk Packaging
TR13 = 13" Tape and Reel Package

Available Product Variants

Part Number	Breakout Board	Evaluation Kit	Repeat-ability	Resolution	Speed	Outputs
ASR002-10E	ASR002-10E-EVB01	AG956-07	0.2°	0.1°	12500 Sps	SPI
ASR012-10E	ASR012-10E-EVB01	AG963-07				I²C; PWM
ASR022-10E	ASR022-10E-EVB01	AG964-07		512 virtual lines (128 cycles) / rev.		ABZ; Dir

Revision History

SB-00-119-C Sept. 2024	**Changes** • Replaced AG-Series breakout board with ASR022-10E-EVB01 breakout board (p. 8). • Added Arduino Shield (p. 8). • Added illustrative Arduino code (p. 12). • Updated breakout board part numbers (p. 14).
SB-00-119-B Nov. 2020	**Changes** • Cosmetic changes.
SB-00-119-A April 2020	**Changes** • Added demonstration board. • Revised some graphics. • Initial release.
SB-00-119-PRELIM March 2020	**Change** • Preliminary release.

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