ASR012 Smart I²C TMR Angle Sensor

Features
- Rotational speeds to 375,000 RPM
- 3.3 volt or 5 volt compatible I²C interface
- PWM output
- Robust airgap and misalignment tolerances
- Factory calibrated
- Ultraminiature 2.5 x 2.5 x 0.8 mm TDFN6 package

Key Specifications
- 0.1° resolution
- ±0.2° repeatability
- Robust 6 to 20 mT field operating range
- Fast 12.5 kSps sample rate
- Flexible 2.2 to 3.6 V supply range
- Low 4 mA typical supply current
- Full −40 °C to 125 °C operating range

Applications
- Rotary encoders
- Robotics
- Motor control
- Automotive applications
- Internet of Things (IoT) end nodes

Description
ASR012 TMR Smart Angle Sensors provide a precise digital angle measurement over a wide range of speeds.

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 internal memory.

An I²C interface provides angle data and allows setting device parameters. A PWM output also provides angle data.

The ASR012 is designed for harsh industrial or automotive environments with ESD protection, and full −40 °C to 125 °C operating temperature range.
## Boundary Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min.</th>
<th>Max.</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage</td>
<td>−12</td>
<td>4.2</td>
<td>Volts</td>
</tr>
<tr>
<td>Input and output voltages (SDA, SCL, PWM, and I2CADDR)</td>
<td>−0.5</td>
<td>$V_{cc} + 2.5$ up to 5.8</td>
<td>Volts</td>
</tr>
<tr>
<td>Input current</td>
<td>−100</td>
<td>+100</td>
<td>mA</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>−55</td>
<td>150</td>
<td>°C</td>
</tr>
<tr>
<td>ESD (Human Body Model)</td>
<td></td>
<td>2000</td>
<td>Volts</td>
</tr>
<tr>
<td>Applied magnetic field</td>
<td></td>
<td>Unlimited</td>
<td>Tesla</td>
</tr>
</tbody>
</table>
## Operating Specifications (T_{\text{min}} \text{ to } T_{\text{max}}; 2.2 < V_{\text{DD}} < 3.6 \text{ V unless otherwise stated})

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Units</th>
<th>Test Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating temperature</td>
<td>T_{\text{min}}; T_{\text{max}}</td>
<td>−40</td>
<td></td>
<td>125</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Supply voltage</td>
<td>V_{\text{DD}}</td>
<td>2.2</td>
<td></td>
<td>3.6</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Supply current</td>
<td>I_{\text{DD}}</td>
<td>4</td>
<td>6</td>
<td>15</td>
<td>mA</td>
<td>Max. at V_{\text{DD}} = 3.6V</td>
</tr>
<tr>
<td>Power-on Reset supply voltage</td>
<td>V_{\text{POR}}</td>
<td>1.4</td>
<td></td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Brown-out power supply voltage</td>
<td>V_{\text{BOR}}</td>
<td>0.75</td>
<td>1</td>
<td>1.36</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Start-up time</td>
<td>T_{\text{STA}}</td>
<td>15</td>
<td></td>
<td></td>
<td>ms</td>
<td></td>
</tr>
</tbody>
</table>

### Magnetics

- Applied magnetic field strength
  - H: 6, 12, 20 mT

### Accuracy and Repeatability

- Angular resolution
  - δ: 0.1

- Angular hysteresis
  - ±0.2

- Repeatability
  - ±0.2

- Angular accuracy, fixed bias
  - ±2
  - ±3

- Angular accuracy, variable bias
  - ±6

### Timing

- Sample rate
  - 12.5 kSps

- Parameter write time
  - t_{\text{NVM}}: 20 ms

- Parameter endurance
  - 10000 Cycles

- PWM frequency
  - 24 kHz

### I2C Interface

- Data transfer rate
  - DR

- Bus voltage
  - V_{\text{BUS}}: 2.2, 5.5 V

- Output response and transmission times
  - 20 μs

- Low level input threshold voltage
  - V_{\text{IL}}: 0.8 V

- High level input threshold voltage
  - V_{\text{IH}}: 2.2 V

- Low level output current
  - I_{\text{OL}}: 3 mA

- I/O capacitance
  - C_{\text{I/O}}: 10 pF

#### 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.
ASR012 Overview

The ASR012 is a non-contact angle sensor designed for high speed applications where size is limited. The heart of the ASR012 is a tunneling magneto-resistive (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 high speed, accuracy, and precision in a tiny 2.5 x 2.5 mm TDFN package.

Figure 1. Sensor operation.

ASR012 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 the angle from sensor element Sine and Cosine vectors, and the raw sensor data are available from separate memory locations.

ADC

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

Digital Filter

A first-order Infinite Impulse Response (IIR) digital filter with a programmable cutoff frequency can be used for ultralow noise if high-frequency operation is required. The factory default is the filter turned off.
Rotation Direction
The ASR012 can provide increasing angle values for either clockwise or counterclockwise field rotations. Counterclockwise is defined as a rotating field vector through pins 1-3-4-6, and clockwise through pins 1-6-4-3. The rotation direction can be programmed using the $\theta_{DIR}$ parameter.

![Image of sensor with $\theta_{DIR}$ and $\theta_0$ labels]

Figure 3. Zero-angle reference ($\theta_0$) and rotation direction ($\theta_{DIR}$). The rotational center of the sensor is the package center.

Zero-Angle Reference Point
A programmable parameter $\theta_0$ sets the zero-degree reference or angular offset. This is the angle of “discontinuity,” that is, where the angle output changes from 360° to 0°. The default $\theta_0$ value is zero for magnetic fields pointing from pin 1 to pin 6.

Direction and Hysteresis
The Direction output indicates direction of rotation. A hysteresis setting can be changed to prevent small changes from causing the Direction output to “chatter,” especially at low speed.

Digital Filter
The digital filter is an Infinite impulse response (IIR) weighted running average filter, which can reduce mechanical and electrical noise depending on the required speed.

The filtered output is calculated as follows:

$$\theta_n = \theta/m + [(m-1)/m] \theta_{n-1}$$

Where $\theta$ is the measured angle; $\theta_n$ is the filtered angle; $\theta_{n-1}$ is the previous value of the filtered angle; and $m$ is a constant that determines the cutoff frequency as follows:

$$f_{CUTOFF} = f_{SAMPLE} / (2\pi m)$$

Where $f_{CUTOFF}$ is the filter cutoff frequency and $f_{SAMPLE}$ is the sensor ADC sampling rate (approximately 12500/s). So for example, if $m = 10$, the cutoff frequency is approximately 200 Hz.

$m = 1$ disables filter so the output is simply updated with each sample.
I²C Interface

Changing the I²C Address in Nonvolatile Memory
The default I²C address is stored in nonvolatile memory, and can be changed like any other parameter. The I²C standard reserves certain addresses, so recommended I²C addresses are 16 to 238 (0x10 to 0xEE hex).

Note that if there are multiple ASR012’s on the same I²C bus there will be a collision before addresses can be changed. Therefore changing the address in this way may require a single-sensor programming setup.

Overriding the I²C Address with an External Jumper
Grounding the I²C address override pin (“I2CADDR”) changes the I²C address to 16 dec regardless of the programmed address. Leaving the pin open or tied HIGH invokes the I²C address in nonvolatile memory, which is 72 dec by default but can be reprogrammed by the user in memory location 0x44. The pin is checked only on power-up.

Eight-Bit I²C Address
In accordance with industry standards, ASR012 sensors have eight-bit I²C addresses (seven bits plus an R/W bit). Some I²C Master devices (such as Arduinos) send seven-bit addresses. In this case, the sensor address should be divided by two, so for example a default PC address of 36 rather than 72 would be used.

Reading and Writing the Sensor Memory
Data is read by first writing an address byte to the sensor (with the I²C Read/Write bit set to “Write”). Subsequent I²C read commands will return the data or parameter in the active address.

The default memory address is 0, which is the calibrated sensor output, so “out of the box” the sensor output can simply be retrieved with PC read commands.

Reading the Angle
To read the angle, the master simply writes zero for the “0” angle address, then reads the two-byte angle, which is expressed in tenths of degrees. The active address will remain the same until changes, so the angle can be read repeatedly without writing the address each time.

Reading and Writing Parameters
Reading and writing parameters are simple three-byte sequences. The master writes a byte for the parameter address, then reads or writes two bytes for the parameter value.

The number of bits in different parameters varies. Unused bits are sent as zeros by the sensor. Similarly, unused bits should be written as zeros to the sensor to avoid an out-of-range parameter that could be ignored.

Because of the slower speed of the sensor’s nonvolatile memory, allow 15 ms for parameter writes.

PWM Analog Output
The PWM output tracks the measured angle and can be externally filtered as an analog output. The output is ratiometric with the power supply, i.e., equal to \( V_{DD} \) at 360°, so the output is 9.2 mV per degree with a 3.3 V supply.
The ASR012 memory provides access to angle data and user-programmable parameters. The memory is accessed via I²C.

### Parameter Table

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Default</th>
<th>Read/Write</th>
<th>Range</th>
<th>Address</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>θ</td>
<td>N/A</td>
<td>R</td>
<td>0 – 3600</td>
<td>0x00</td>
<td>In tenths of a degree</td>
</tr>
<tr>
<td>Raw Sin Vector</td>
<td>Sinθ</td>
<td></td>
<td></td>
<td>Approx.</td>
<td>0x01</td>
<td>Raw outputs centered at approx. 2048 with peak-peak amplitudes of approx. 1000.</td>
</tr>
<tr>
<td>Raw Cos Vector</td>
<td>Cosθ</td>
<td></td>
<td></td>
<td>1500 – 2500</td>
<td>0x02</td>
<td></td>
</tr>
<tr>
<td>Direction</td>
<td>Dir</td>
<td></td>
<td></td>
<td>0 – 1</td>
<td>0x03</td>
<td>0 = decreasing angle</td>
</tr>
</tbody>
</table>

#### User-Programmable Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Default</th>
<th>Read/Write</th>
<th>Range</th>
<th>Address</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotation Direction</td>
<td>θDIR</td>
<td>0</td>
<td>R/W</td>
<td>0 – 1</td>
<td>0x40[bit 0]</td>
<td>0 → increasing CCW; 1 → increasing CW (see Fig. 3)</td>
</tr>
<tr>
<td>Angular Offset</td>
<td>θ₀</td>
<td>0</td>
<td>R/W</td>
<td>0 – 3600</td>
<td>0x41[bits 13:0]</td>
<td>Point at which angle is zero (see Fig. 3)</td>
</tr>
<tr>
<td>Digital Filter Constant</td>
<td>m</td>
<td>1</td>
<td>R/W</td>
<td>1 – 255</td>
<td>0x42</td>
<td>( f_{\text{CUTOFF}} = f_{\text{SAMPLE}}/(2\pi m) ); ( f_{\text{SAMPLE}} = \text{approx. } 12.5 \text{ kSps} ); m = 1 disables filter</td>
</tr>
<tr>
<td>Direction Hysteresis</td>
<td>δDIR</td>
<td>25</td>
<td>R/W</td>
<td>0 – 255</td>
<td>0x43</td>
<td>Hysteresis of the “Dir” output; in tenths of a degree</td>
</tr>
<tr>
<td>PC address</td>
<td>I2CADDR</td>
<td></td>
<td>R</td>
<td>16 to 238</td>
<td>0x44</td>
<td>I2CADDR with pin 1 floating or HIGH</td>
</tr>
</tbody>
</table>

#### Read-Only Memory

<table>
<thead>
<tr>
<th>Lot code</th>
<th>YYYY</th>
<th>WW</th>
<th>XX</th>
<th>(ASCII)</th>
<th>0x80</th>
<th>0x81</th>
<th>0x82</th>
<th>Description</th>
</tr>
</thead>
</table>

Table 1. ASR012 Memory Locations.
Power-Up and Initialization

**Absolute position**
Unlike some encoder types, ASR0x2 sensors detect absolute position and maintain position information when the power is removed. The sensor powers up indicating the correct position.

**Nonvolatile parameters**
All parameters are nonvolatile so they can be set once (via PC), and remain for the life of the product if desired.

Minimizing Noise

Several steps 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:

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:

![Graph showing 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.](image)

![Graph showing 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.](image)

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

NVE’s Online Store stocks popular magnets.
**Typical Microcontrollers Interface**

A typical microcontroller interface is shown below:

![Diagram of Smart TMR Angle Sensor with microcontroller interface](image)

**Figure 6. Typical microcontroller interface.**

The ASR012 is configured as a Slave and the microcontroller should be configured as the Master. The ASR012 I\(^2\)C interface is compatible with 3.3 or 5 volt microcontrollers.

The ASR012 SDA line is open-drain, so the microcontroller’s internal pull-up resistor should be activated in software. If an external pull-up is used with different power supplies, it should be connected to the lower supply voltage, which is generally the sensor supply.
**Double Isolation Circuit**

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 from a knob or other human interface. Galvanic isolation from the sensor to the microcontroller provides a second isolation barrier:

![Double-isolated microcontroller interface.](image-url)

Since it is single-channel and unidirectional, the PWM output can be easily isolated with just a single-channel digital isolator. The I²C interface is more complex and expensive to isolate since there are two bidirectional, open-drain lines.

The IsoLoop IL710V-1E isolator in the circuit above is a UL/VDE-compliant, ultra-miniature MSOP galvanic isolator with a 2.5 kV isolation rating. The isolator can also level-shift between the 3.3-volt sensor and a five-volt microcontroller.

The PWM signal can be decoded by the microcontroller using commonly-available routines.

There may be inaccuracies at angles close to zero if the PWM pulses are too narrow to be detected by the microcontroller.
Filtered PWM Read by an Analog Input
If speed is not critical, the isolated PWM signal can be filtered with a resistor and capacitor and connected to a microcontroller analog input. This provides accurate readings at all angles, including angles close to zero.

The 100 kΩ resistor avoids loading the isolator output while providing a low enough impedance for most microcontroller analog inputs. The 2 nF filter capacitor yields a 200 µs time constant, which is adequate to filter the sensor’s 24 kHz PWM output. The resultant cutoff frequency is approximately 31 kHz.
Illustrative Arduino Code for Continuously Reading Angles

```c
// Reads ASR012 angle via I2C via an Arduino Uno. SDA-->A4; A5-->SCL
#include <SPI.h>
int angle; // Sensor output (tenths of a degree)

void setup() {
   Wire.begin(); // Join I2C bus as Master
}
void loop() {
   Wire.requestFrom(36,2); // Request two bytes from sensor (I2C address 72/2=36)
   angle = Wire.read()<<8; // Read angle MSB
   angle |= Wire.read(); // Read angle LSB
   delay(200); // 5 samples per second
}"
Psuedo Code for I²C Reading and Writing

```c
uint16_t read_from_sensor(uint8_t ASR012_i2c_address, uint8_t read_location_address) {
    while (!i2c_start(ASR012_i2c_address)) i2c_stop(); //spins till bus is available to start
    i2c_write(read_location_address);
    i2c_stop();
    while (!i2c_rep_start((ASR012_i2c_address) | 0x01)); // write the address of the sensor with the read bit set
    uint8_t MSB = i2c_read(0); //MSB read from bus, no ack
    uint8_t LSB = i2c_read(1); //LSB read from bus, ack to notify sensor that transfer is done
    i2c_stop(); //read is complete
    return (MSB << 8) | LSB;
}

void write_to_sensor(uint8_t ASR012_i2c_address, uint8_t write_location_address, uint8_t MSB, uint8_t LSB) {
    while (!i2c_start(ASR012_i2c_address)) i2c_stop(); //spins till bus is available to start
    i2c_write(write_location_address); //sensor write location is written to the bus
    i2c_write(MSB); //MSB first
    i2c_write(LSB); //LSB second
    i2c_stop(); //write is complete
    delay(15); //15 ms delay after write to nonvolatile memory
}
```
Evaluation Support

Breakout Board
The AG966-07E breakout board provides easy connections to an ASR012-10E angle sensor with a six pin connector. It also has a recommended 10 µF bypass capacitor:

![AG966-07E breakout board](image)

**Figure 9. AG966-07E breakout board (actual size)**
0.5” x 0.6” (12 mm x 15 mm)

Smart Angle Sensor Evaluation Kit
This simple board includes an ASR012-10E Smart Angle Sensor, a microcontroller that interfaces to the Sensor via PC, and to a PC via USB. The kit includes a diametrically-magnetized cylindrical horseshoe magnet and fixturing. A PC-based user interface provides two-way communication with the sensor to display the sensor outputs and change the sensor’s parameters:

![ASR012 Smart Angle Sensor Evaluation Kit](image)

**Figure 10. ASR012 Smart Angle Sensor Evaluation Kit.**

Socket Board
The AG954-07E provides a TDFN6 socket for easy interface to sensors such as the ASR012-10E without soldering:
Figure 11. AG954-07E: TDFN socket board
1.5" x 2" (38 mm x 50 mm)(actual size)
Magnets
NVE stocks five popular magnets for use with its angle sensors:

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

*Included in the Smart Angle Sensor Evaluation Kits.

Table 2. Popular magnets for angle sensing.

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 “clock hand” 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 in Smart Angle Sensor Evaluation Kits:

<table>
<thead>
<tr>
<th>Holder Part Number</th>
<th>Outside Dimensions</th>
<th>Compatible Magnets (NVE part #s)</th>
<th>Magnet Diameter (mm)</th>
<th>Max. Magnet Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12546</td>
<td>11 mm dia. x</td>
<td>12526</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>12545</td>
<td>22 mm tall</td>
<td>12527; 12528</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 3. Magnet holders.
**Smart TMR Angle Sensor**

**2.5 x 2.5 mm TDFN6 Package**

<table>
<thead>
<tr>
<th>Pad</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND</td>
<td>Ground/V&lt;sub&gt;SS&lt;/sub&gt;</td>
</tr>
<tr>
<td>2</td>
<td>SDA</td>
<td>PC Data (bidirectional; open drain)</td>
</tr>
<tr>
<td>3</td>
<td>SCL</td>
<td>PC Clock (input)</td>
</tr>
<tr>
<td>4</td>
<td>VDD</td>
<td>Power Supply (bypass with a 10 µF capacitor)</td>
</tr>
<tr>
<td>5</td>
<td>PWM</td>
<td>PWM Output</td>
</tr>
<tr>
<td>6</td>
<td>I2CADDR</td>
<td>PC address override (LOW-true input; read on power-up). Grounding this pin changes the PC address to 16 dec regardless of the programmed address. Open or HIGH invokes the PC address in nonvolatile memory.</td>
</tr>
</tbody>
</table>

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

ASR012 - 10E TR13

Product Family
ASR = Smart Angle Sensors

I/O
00 = SPI
01 = I²C / PWM
02 = ABZ (encoder)

Sensor Element
2 = High speed, medium accuracy

Field Range Identifier
Blank = General Purpose (6 to 20 mT / 60 to 200 Oe)

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

Bulk Packaging
TR13 = 13” Tape and Reel Package

Available Product Variants

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Breakout Board</th>
<th>Evaluation Kit</th>
<th>Repeatability</th>
<th>Resolution</th>
<th>Speed</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASR002-10E</td>
<td>AG956-07</td>
<td>AG956-07</td>
<td>0.2°</td>
<td>0.1°</td>
<td>12500 Sps</td>
<td>SPI</td>
</tr>
<tr>
<td>ASR012-10E</td>
<td>AG966-07</td>
<td>AG963-07</td>
<td></td>
<td></td>
<td></td>
<td>I²C; PWM</td>
</tr>
<tr>
<td>ASR022-10E</td>
<td>AG967-07</td>
<td>AG964-07</td>
<td></td>
<td>512 virtual lines (128 cycles) / rev.</td>
<td></td>
<td>ABZ; Dir</td>
</tr>
</tbody>
</table>
# Revision History

## SB-00-081-RevB
**January 2021**

**Changes**
- Revised timing parameters.
- Renumbered figures.

## SB-00-081-RevA
**January 2020**

**Changes**
- Added application diagrams.
- Added illustrative Arduino code and PC pseudocode.
- Moved I2CADDR parameter memory address.
- Initial release.

## SB-00-081-PRELIM
**December 2019**

**Change**
- Preliminary release.
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Smart TMR Angle Sensor

An ISO 9001 Certified Company

NVE Corporation
11409 Valley View Road
Eden Prairie, MN 55344-3617 USA
Telephone: (952) 829-9217
www.nve.com
e-mail: sensor-info@nve.com

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