

ADT002-10E Low Hysteresis, Low Power Rotation Quadrant Sensors



Functional Diagram and Pinout



Truth Table

	Output		
Angle	Sin	Cos	
0°-90°	Н	Н	
90°-180°	Н	L	
180°-270°	L	L	
270°-360°	L	Н	

Features

- Tunneling Magnetoresistance (TMR) technology
- Extremely low power (1.8 μA typ. at 2.4 V)
- Precision digital quadrant outputs
- Wide airgap tolerance
- Operates with as little as 30 Oersteds of magnetic field
- 2.4 V to 5.5 V supply range
- -40°C to +125°C operating range
- Ultraminiature TDFN6 packages

Applications

- Water meters
- Rotational speed sensors
- Rotational position sensors

Description

ADT002 rotation sensors are ultralow power, digitaloutput magnetic rotation sensors. Tunneling Magnetoresistance (TMR) technology allows small size and low power, making the sensors ideal for battery operation.

The sensors have two digital, binary outputs. The two outputs are 90 degrees out of phase to provide directional information.

The ADT002 is optimized for absolute rotary position detection, with lower hysteresis than the ADT005 to provide accurate, absolute rotational quadrant information.

The parts are packaged in NVE's 2.5 mm x 2.5 mm x 0.8 mm TDFN6 surface-mount package.



Absolute Maximum Ratings

Parameter	Min.	Max.	Units
Supply Voltage	-0.5	7	Volts
Storage Temperature	-40	170	°C
ESD (Human Body Model)		2000	Volts
Applied Magnetic Field		Unlimited	Oe

Operating Specifications

T_{min} to T_{max} ; 2.4 V < V _{DD} < 5.5 V unless otherwise stated.						
Parameter	Symbol	Min.	Тур.	Max.	Units	Test Condition
Operating Temperature	T _{min} ; T _{max}	-40		125	°C	
Supply Voltage	V_{DD}	2.4		5.5	V	
		0.55	1.8	3.1		$V_{DD} = 2.4 V$
Supply Current	т		2.2		μА	$V_{\text{DD}} = 3V$
Suppry Current	I _{DDQ}	0.8	2.7	4.6	<i>p</i> 11 1	$3V < V_{\rm DD} < 3.6V$
				6.95		$V_{\text{DD}} = 5.5 V$
Applied Magnetic Field Strength		30		200	Oe	
Low-Level Output Voltage	V _{OL}	0		0.24	V	$I_L = -50 \ \mu A$
High-Level Output Voltage	V _{OH}	$V_{DD} - 0.25$		V_{DD}	V	$I_L = 50 \ \mu A$
Angular Precision/Repeatability				±1.5	deg.	
Angular Hysteresis	$ \theta_{\rm H} - \theta_{\rm L} $	3	4	8	deg.	$V_{DD} = 3.6V; 25^{\circ}C$
Frequency Response	f _{MAX}	2			kHz	



ADT002 Low Hysteresis Rotation Sensors

Operation

Overview

The heart of the unique sensor is an array of four Tunneling Magnetoresistance (TMR) elements, one in each quadrant. TMR technology enables low power and miniaturization, making the sensors ideal for battery operation.

In a typical configuration, an external magnet provides a saturating magnetic field (30 to 200 Oe) in the plane of the sensor, as illustrated below for a bar magnet and a radially-magnetized disk magnet:



Figure 1. Sensor operation.

Simple output encoding

The rotation is encoded in two quadrature outputs, 90 degrees out of phase. Mathematically, the outputs correspond to the sign of the sine and cosine of the rotation, i.e., $sgn(sin\theta)$ and $sgn(cos\theta)$, as shown below:



Figure 2. Sensor outputs (counterclockwise rotation viewed from the top of the sensor).

Thus the binary sensor outputs define the quadrant of rotation:







Wide range of magnets and magnet location

The sensor operates with as little as a 30 Oe magnetic field, and is accurate up to 200 Oe. This wide magnetic field range allows inexpensive magnets and operation over a wide range of magnet spacing. Larger or stronger magnets require more distance to avoid oversaturating the sensor; smaller or weaker magnets may require closer spacing. Low-cost, radially-magnetized ferrite disk magnets can be used with these sensors. Bar magnets can also be used in some configurations.

Absolute position

Unlike some encoder types, ADT002 sensors detect absolute position and maintain position information when the power is removed. The sensor immediately powers up indicating the correct position.

Power supply decoupling and noise filtering

Since ADT002 sensors are duty-cycled to reduce power consumption, a bypass capacitor should be used on V_{DD} if the sensor is powered by a power supply or a battery with long connections. 10 nF ceramic capacitors are typical.

Because the sensor uses high-impedance circuitry and often operates in noisy environments, designers should consider filtering or debounce circuitry on the sensor outputs if possible, especially if the application relies on triggering or counting edges.

Integrated fault detection

An additional output indicates a fault if the magnetic field is too high for accurate measurements. This can occur if the magnet is too close to the sensor, or due to interference from adjacent magnets. The signal can also be used to align assemblies.

Typical Performance Graphs







Illustrative Application Circuits

Quadrant detection

A 2-to-4 Line Decoder can provide digital signals indicating the quadrant of rotation:



Figure 5. Quadrant detection.

A two-cycle/revolution signal

An Exclusive-OR gate can be used to provide a digital signal with two cycles per revolution and transitions every 90 degrees:



Figure 6. Two-cycle per revolution signal.

Ultralow power external circuitry

Any of the application circuits described in this section can use 74AUP-series logic instead of 74LVC circuitry if lower power is required and five-volt operation is not needed.



Evaluation Support

Breakout Board

The breakout board provides easy connections to an ADT002-10E rotation sensor with a six-pin header or a 1 mm edge connector:



Figure 7. ADT002-10E-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 quadrant, 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 8. Shield02 Arduino Shield with magnet fixture(actual size). 2.7" x 2.1" (53 mm x 69 mm)



Illustrative Arduino Procedure

This procedure reads the two outputs of an ADT002 sensor and calculates the quadrant:

```
void setup() {
  Serial.begin(115200);
}
void loop() {
  // Call the calculateQuadrant function and print the result
  byte quadrant = calculateQuadrant();
  Serial.print("Quadrant: ");
  Serial.println(quadrant);
}
byte calculateQuadrant() {
  // Read the sine and cosine signals from pins 11 and 12
 byte Sin = digitalRead(11);
  byte Cos = digitalRead(12);
  // Return the calculated quadrant based on the signals
  return 3 + (Sin ^ Cos) - 2 * Sin;
}
```

The code uses bitwise operations and simple arithmetic to efficiently determine the quadrant. The expression $3 + Sin^{Cos} - 2*Sin$ maps the combinations of Sin and Cos to quadrants as follows:

Quadrant	Sin	Cos	Sin ^{Cos}	2*Sin	Calculation
1	1	1	0	2	3 + 0 - 2 = 1
2	1	0	1	2	3 + 1 - 2 = 2
3	0	0	0	0	3 + 0 - 0 = 3
4	0	1	1	0	3 + 1 - 0 = 4

The quadrant number can be used to determine the direction of rotation, since increasing quadrant numbers indicate counterclockwise rotation as shown in Fig. 3; decreasing quadrants indicate clockwise rotation.



Pinout



Figure 9. ADT002-10E pinout and center of rotation.

Pin	Symbol	Description
1	V_{DD}	Supply voltage (2.4 V to 5.5 V).
2	Sin	HIGH CMOS output when the sine of the rotation angle is positive $(0 - 180^{\circ})$.
3	DNC	Do not connect, leave floating (for test only).
4	DNC	Do not connect, leave floating (for test only).
5	Cos	HIGH CMOS output when the cosine of the rotation angle is positive $(0 - 90^{\circ} \text{ or } 270^{\circ} - 360^{\circ})$.
6	GND	Ground.

Notes:

- The package center pad may be left floating or connected to ground.
- This product has been tested for electrostatic sensitivity to the limits stated in the specifications. However, NVE recommends that all integrated circuits be handled with appropriate care to avoid damage. Damage caused by inappropriate handling or storage could range from performance degradation to complete failure.

Available Parts

Part No.	Package	Marking	Description
ADT002-10E	TDFN6	FDYe	Low hysteresis, ultralow-power rotation sensor



ADT002 Low Hysteresis Rotation Sensors

2.5 mm x 2.5 mm DFN6 Package







RoHS



Notes:

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

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ADT002 Low Hysteresis Rotation Sensors

Revision History

SB-00-048-D

SB-00-048-C

July 2022

Sept. 2024

Changes

- Added breakout board and Arduino Shield (p. 6).
- Added illustrative Arduino code (p. 7).

Changes

- Removed ADT001 for a standalone datasheet (see SB-00-155-A for ADT001 standalone datasheet).
- Removed FAULT sensor functionality. •
- Max. Angular Hysteresis specification increased from 6° to 8°.

SB-00-048-B

Changes

April 2017

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- Tightened supply current spec. based on more test data. Clarified repeatability vs. accuracy (p. 2). •
- Added performance graphs of angular hysteresis vs. temperature and supply voltage. •

SB-00-048-A Sept. 2016

Change

Initial release. •

SB-00-048-PRELIM

May 2016

- Change
- Preliminary release. •



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