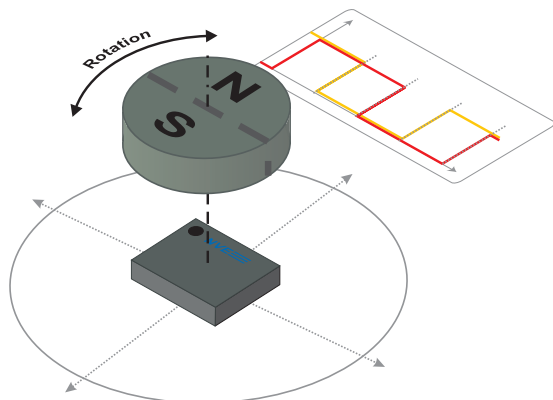


## ADT00X-10E Ultralow Power Rotation Sensors



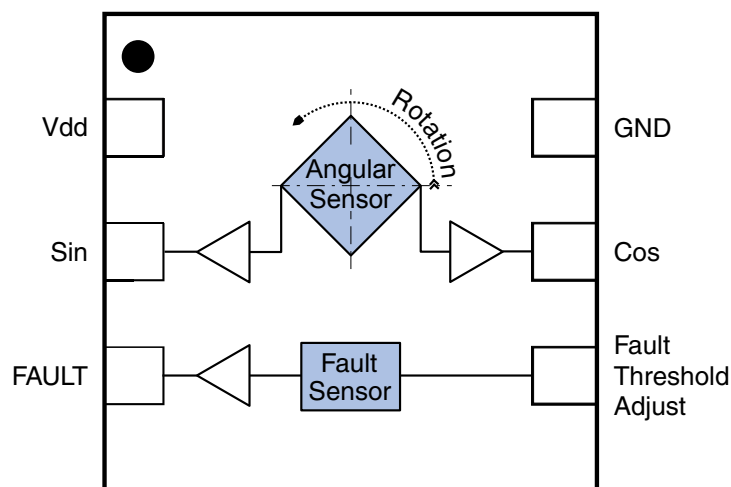
### Features

- Tunneling Magnetoresistance (TMR) technology
- Extremely low power (1.8  $\mu$ A typ. at 2.4 V)
- Precision digital quadrant outputs
- Wide airgap tolerance
- Operates with as little as 30 Oersteds of magnetic field
- Integrated fault detection
- 2.4 V to 5.5 V supply range
- $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  operating range
- Ultraminiature TDFN6 packages

### Applications

- Water meters
- Rotational speed sensors
- Rotational position sensors

### Functional Diagram and Pinout



### Description

The ADT001 and ADT002 rotation sensors are ultralow power, digital-output 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.

An additional output indicates a fault if the magnetic field is too high for accurate measurements.

The ADT001 is optimized for edge-sensitive applications and the ADT002 for absolute position. The ADT001 has high hysteresis for noise immunity in applications such as speed sensing and counting rotations. The ADT002 is low hysteresis 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.

### Truth Table

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

## 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

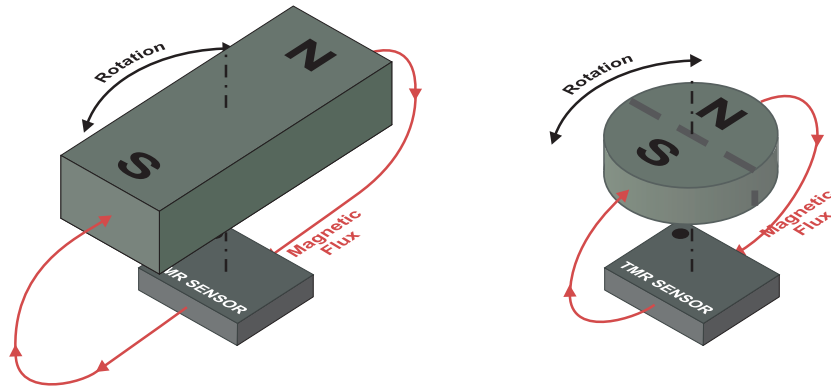
$T_{min}$ to $T_{max}$ ; 2.4 V < $V_{DD}$ < 5.5 V unless otherwise stated.						
Parameter	Symbol	Min.	Typ.	Max.	Units	Test Condition
Operating Temperature	$T_{min}; T_{max}$	-40		125	°C	
Supply Voltage	$V_{DD}$	2.4		5.5	V	
Supply Current	$I_{DDQ}$	0.55	1.8	3.1	$\mu A$	$V_{DD} = 2.4V$
			2.2			$V_{DD} = 3V$
		0.8	2.7	4.6		$3V < V_{DD} < 3.6V$
				6.95		$V_{DD} = 5.5V$
Applied Magnetic Field Strength		30		200	Oe	
Fault Output Field Strength Threshold		200	300	500	Oe	Pin 4 not connected; field in any direction
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				$\pm 1.5$	deg.	
Angular Hysteresis	$ \theta_H - \theta_L $	12	20	28	deg.	$V_{DD} = 3.6V; 25^\circ C$
ADT001		3	4	6		
ADT002						
Frequency Response	$f_{MAX}$	2			kHz	

## 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.

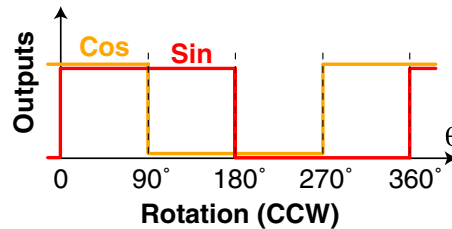
In a typical configuration, an external magnet provides a saturating magnetic field (30 to 200 Oe) in the plane of the sensor, as illustrated below for a bar magnet and a radially-magnetized disk magnet:



**Figure 1. Sensor operation.**

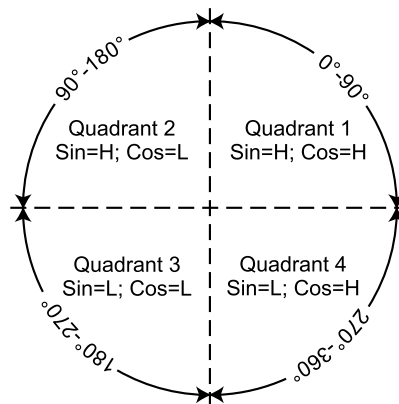
### Simple output encoding

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.,  $\text{sgn}(\sin\theta)$  and  $\text{sgn}(\cos\theta)$ , 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:



**Figure 3. Sensor outputs for each rotation quadrant.**

### **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.

When locating the magnet in relation to the sensor, note that the rotational center of the sensor is offset slightly from the package center (see Figure 11).

### **Absolute position**

Unlike some encoder types, ADT001/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 ADT00X 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.

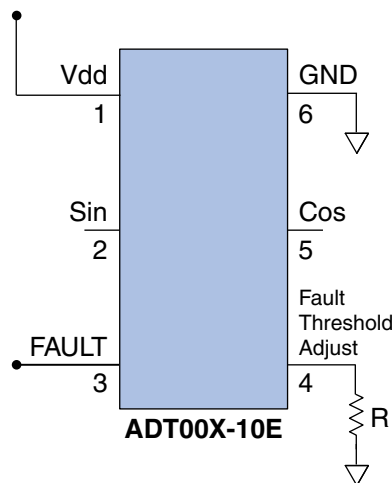
Because the sensor uses high-impedance circuitry and often operates in noisy environments, designers should consider filtering or debounce circuitry on the sensor outputs if possible, especially if the application relies on triggering or counting edges.

### **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.

The signal is intended for gross sensing since the exact threshold depends on the particular device, field orientation, and supply voltage, and can vary over temperature.

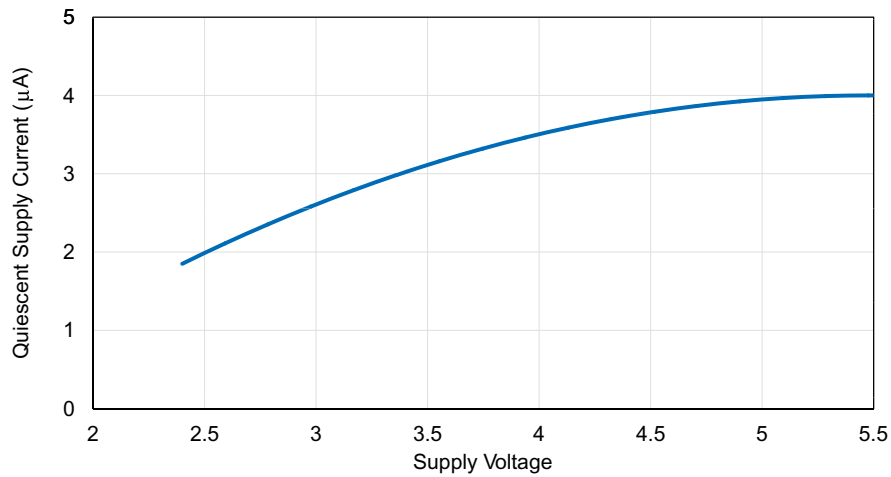
The fault detection threshold can be adjusted with an external resistor from pin 4 to ground, which increases the fault detection threshold field as shown in Figure 4:



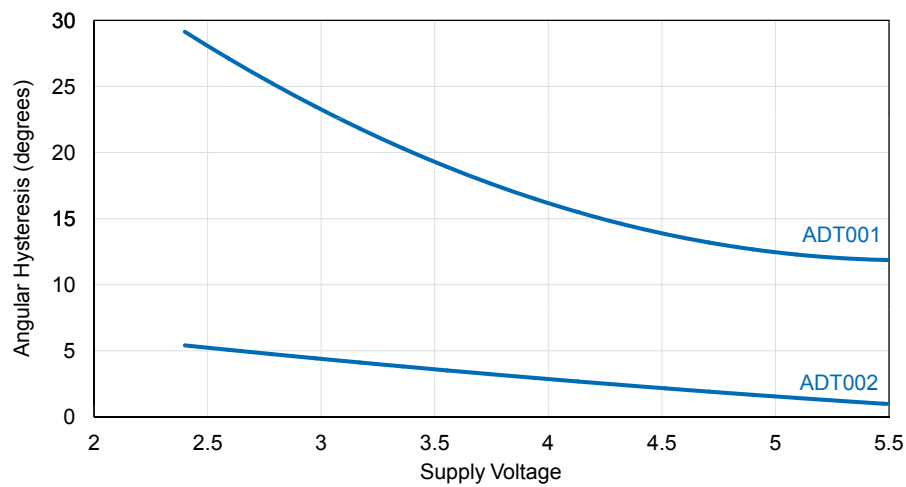
**Figure 4. Fault threshold adjustment test circuit.**

The typical effect of the external resistor value is shown in Figure 7.

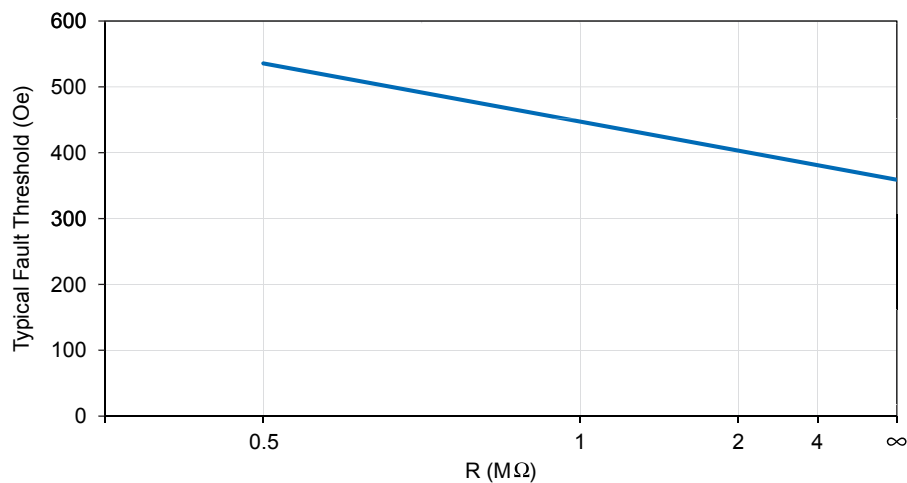
**Typical Performance Graphs**



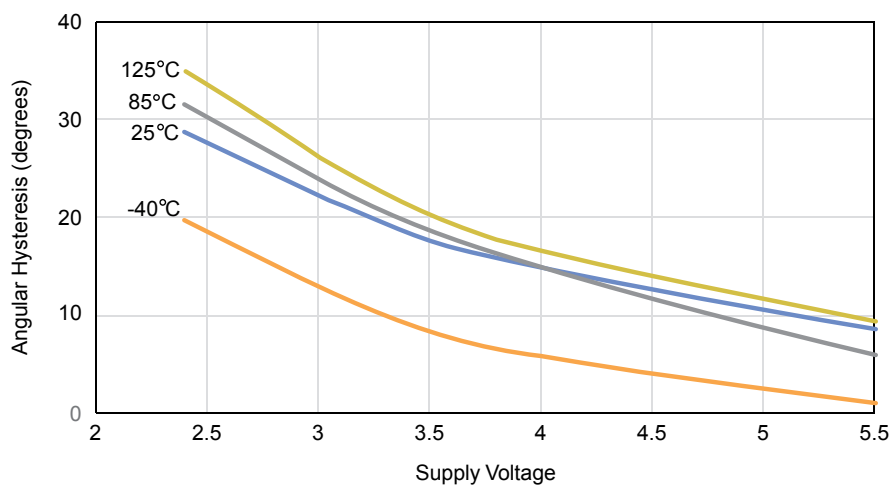
**Figure 5. Typical Quiescent Supply Current (25°C).**



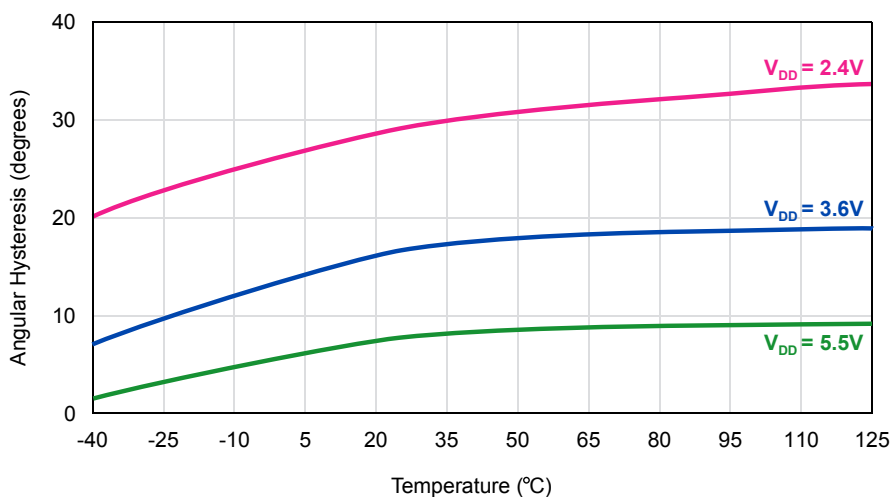
**Figure 6. Typical Angular Hysteresis vs. Supply Voltage (25°C).**



**Figure 7. Typical fault threshold vs. external threshold adjust resistor (Fig. 4 test circuit).**



**Figure 8. Typical angular hysteresis vs. supply voltage at various temperatures (ADT002).**



**Figure 9. Typical hysteresis vs. temperature at various supply voltages (ADT002).**

## Illustrative Application Circuits

### Quadrant detection

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

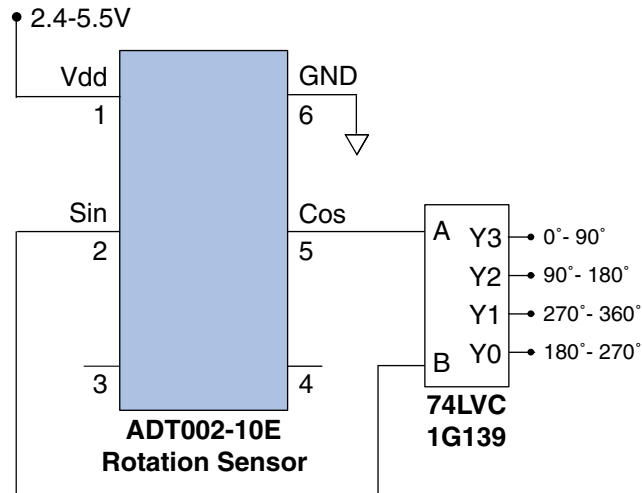


Figure 10. Quadrant detection.

### Direction detection

A “D” flip-flop can be used to create a direction output by detecting the phasing between the two outputs. In the circuit below, the direction signal is updated as the Sin output goes from low-to-high, which is at zero degrees for counterclockwise rotation and 180 degrees for clockwise rotation. The resistor and capacitor enhance noise immunity for harsh environments. The ADT001 is particularly well-suited for this type of application because its high hysteresis ensures clean transitions with no possibility of false triggering on the high-to-low transition to the flip-flop clock.

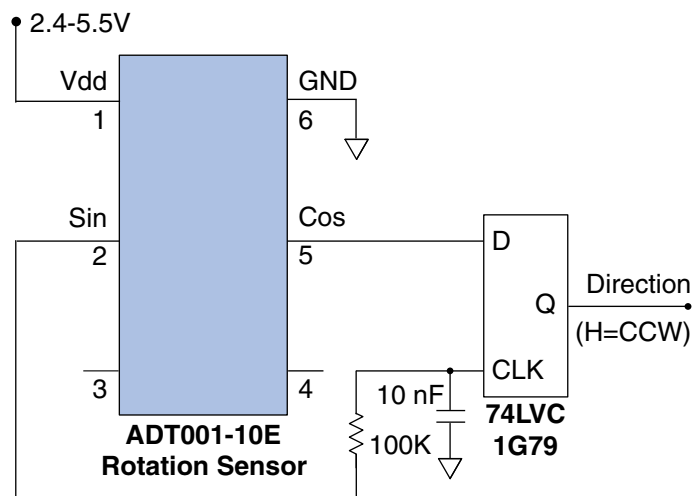
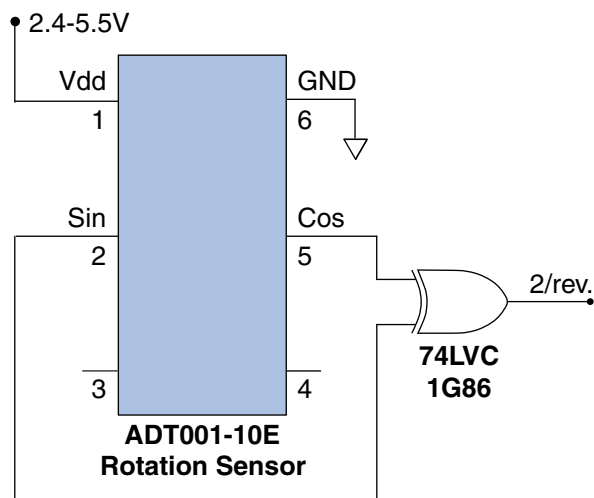


Figure 11. Direction detection.

***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 12. 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.



## Pinout

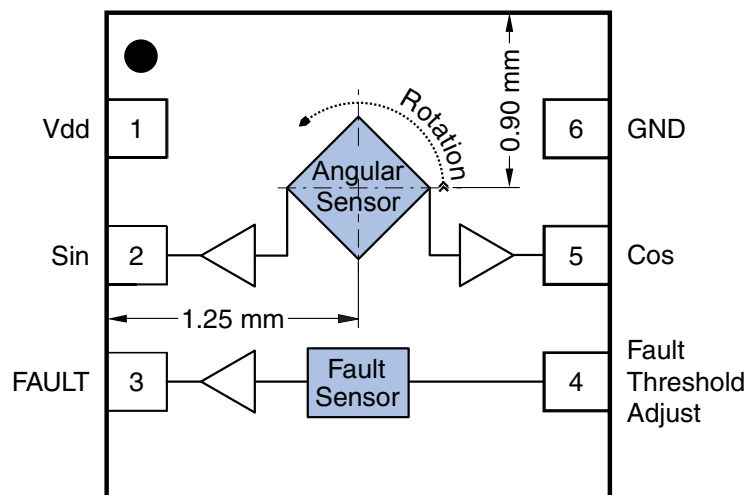


Figure 13. ADT00X-10E pinout and center of rotation.

Pin	Symbol	Description
1	V <sub>DD</sub>	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°).
3	FAULT	HIGH CMOS output indicates excess magnetic field and possible unreliable measurement.
4	Fault Threshold Adjust	Connection for an optional external resistor to GND to increase the fault detection threshold field for the FAULT output.
5	Cos	HIGH CMOS output when the cosine of the rotation angle is positive (0 – 90° or 270° – 360°).
6	GND	Ground.

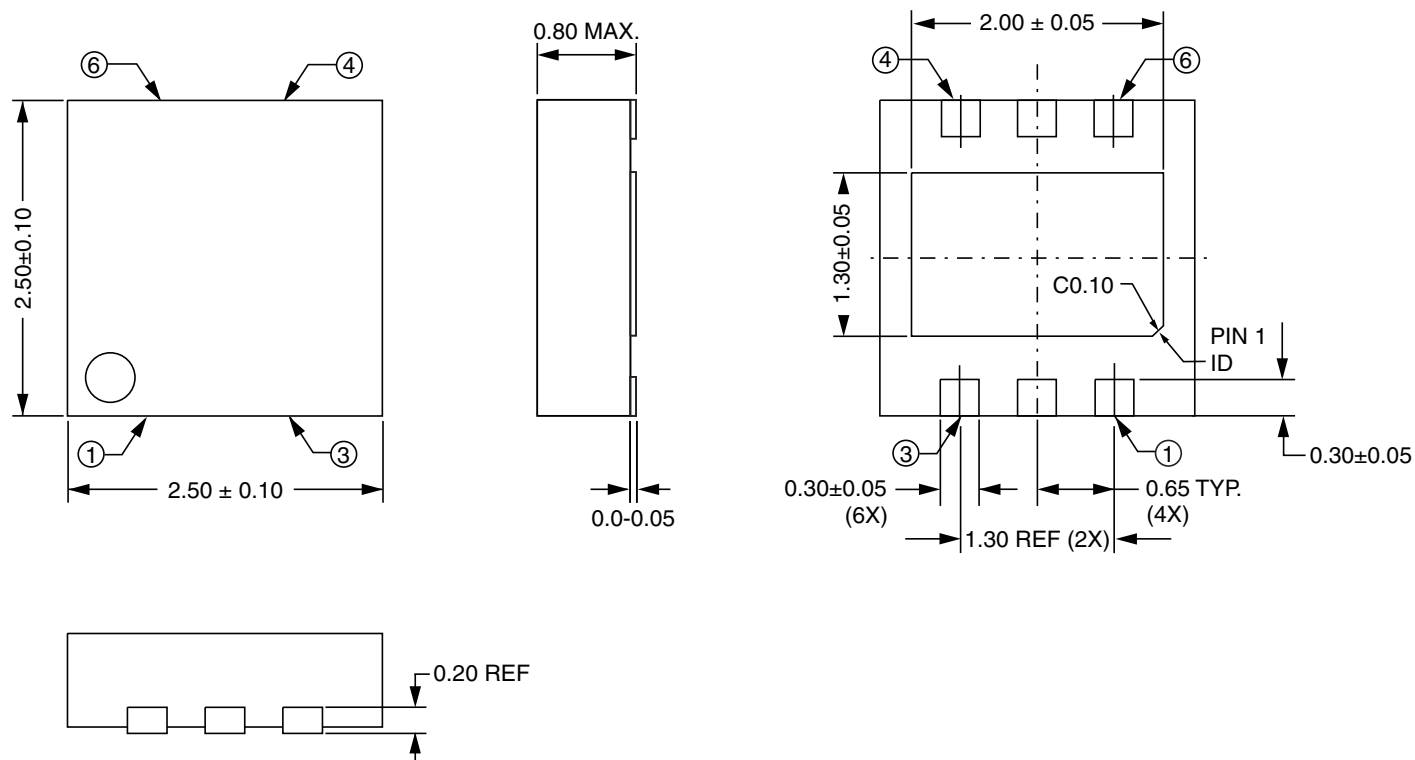
### Notes:

- 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
ADT001-10E	TDFN6	FDXe	High hysteresis, ultralow-power rotation sensor
ADT002-10E	TDFN6	FDYe	Low hysteresis, ultralow-power rotation sensor

**2.5 mm x 2.5 mm TDFN6 Package**



**Notes:**

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

**RoHS**  
COMPLIANT

**Revision History**

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**SB-00-048-B**

April 2017

**Change**

- 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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SB-00-048\_AD T00X-10E\_RevB

*April 2017*