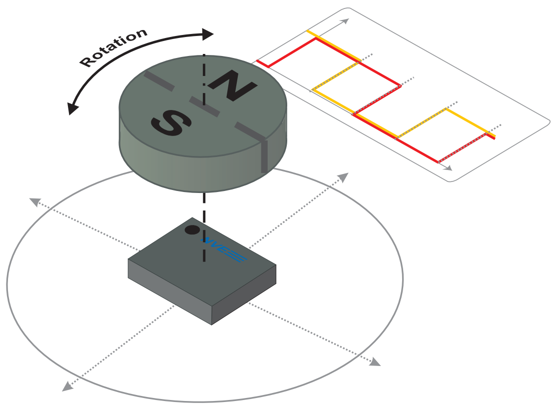
ADT001-10E Ultralow Power Rotation Sensor with Tamper Detection



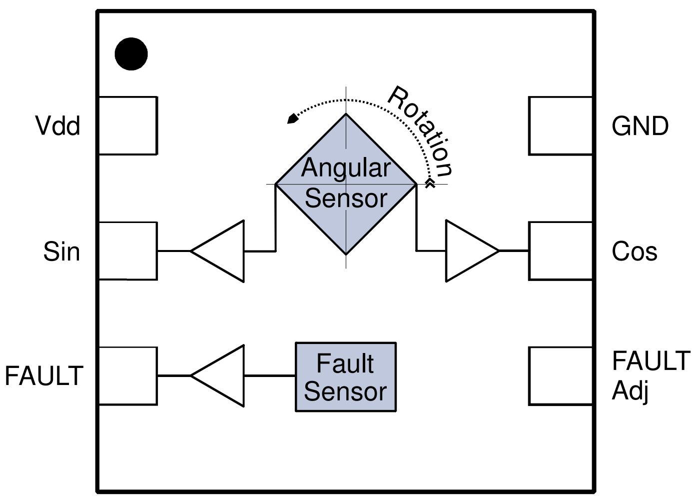
Features

- 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
- Integrated fault detection
- 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

Functional Diagram and Pinout



Description

ADT001 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, with high hysteresis for noise immunity in applications such as speed sensing and counting rotations.

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

Truth Table

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

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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	µA	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 µA
High-Level Output Voltage	V_{OH}	V_{DD} – 0.25		V_{DD}	V	I_L = 50 µA
Angular Precision/Repeatability				±1.5	deg.	
Angular Hysteresis	$\lvert\theta_H - \theta_L\rvert$	12	20	28	deg.	V_{DD} = 3.6V; 25°C
Frequency Response	f_{MAX}	2			kHz	

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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:

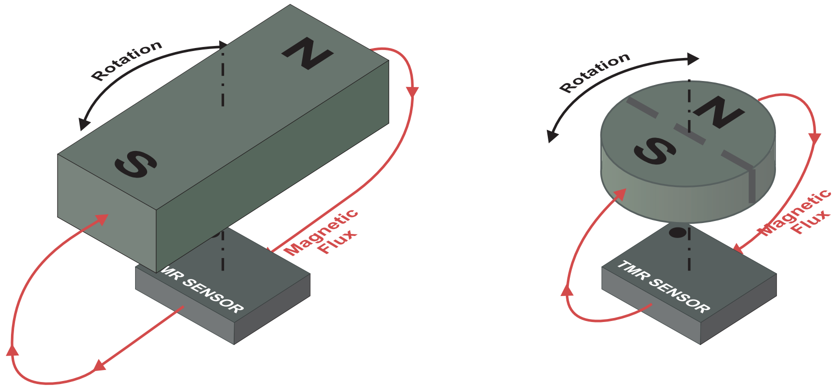

Figure 1. Sensor operation.

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(sinθ) and sgn(cosθ), as shown below:

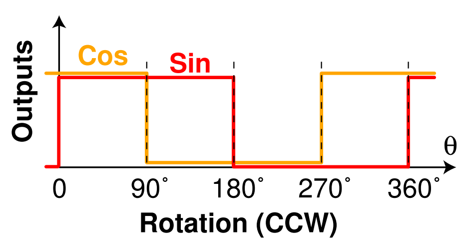

Figure 2. Sensor outputs
(counterclockwise rotation viewed from the top of the sensor).

Thus the binary sensor outputs define the quadrant of rotation:

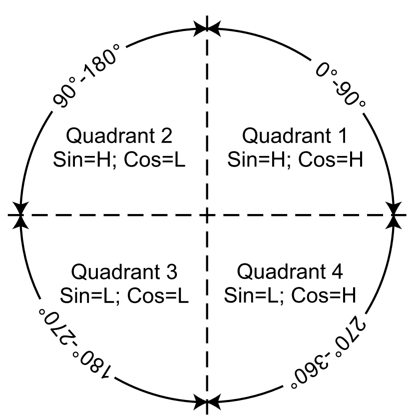

Figure 3. Sensor outputs for each rotation quadrant.

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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 13).

Absolute position

Unlike some encoder types, ADT001 sensors detect absolute position and maintain position information when the power is removed. The sensor immediately powers up indicating the correct position.

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:

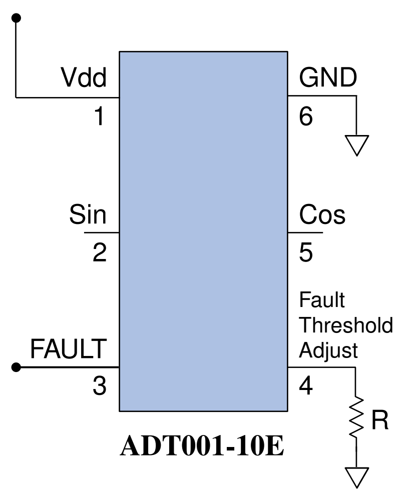

Figure 4. Fault threshold adjustment test circuit.

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

Typical Performance Graphs

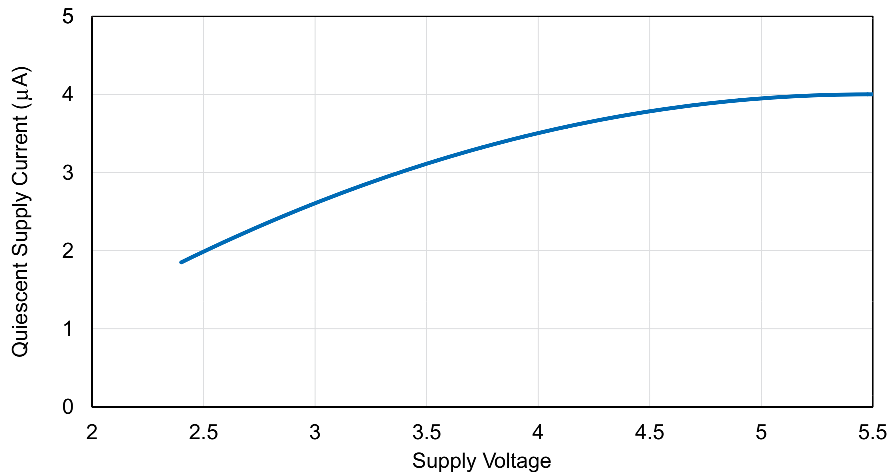

Figure 5. Typical Quiescent Supply Current (25°C).

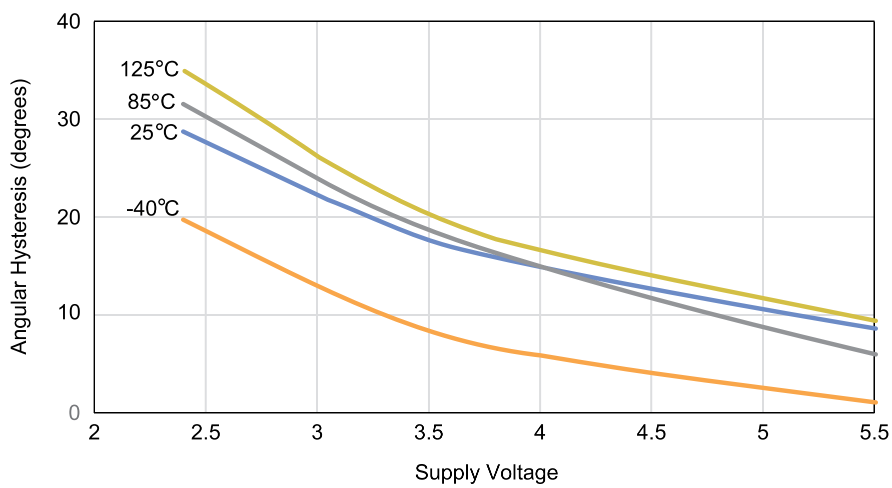

Figure 6. Typical Angular Hysteresis vs. Supply Voltage (25°C).

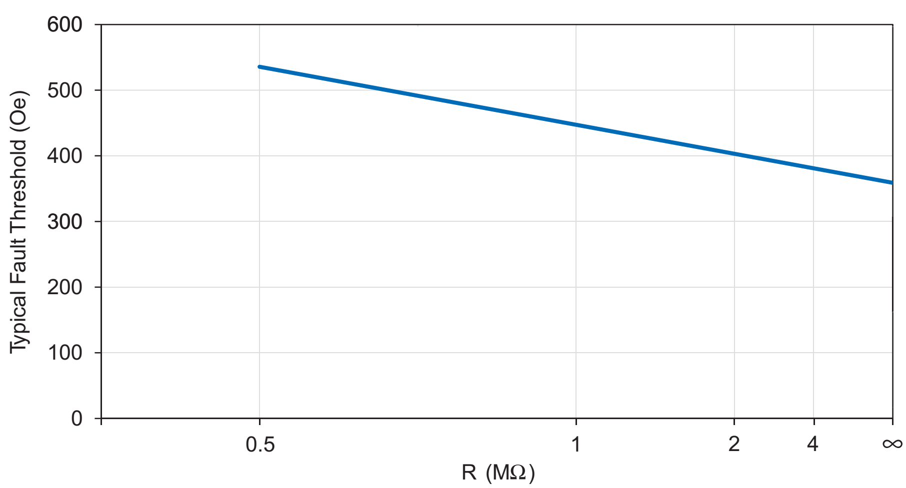

Figure 7. Typical fault threshold vs. external threshold adjust resistor (Fig. 4 test circuit).

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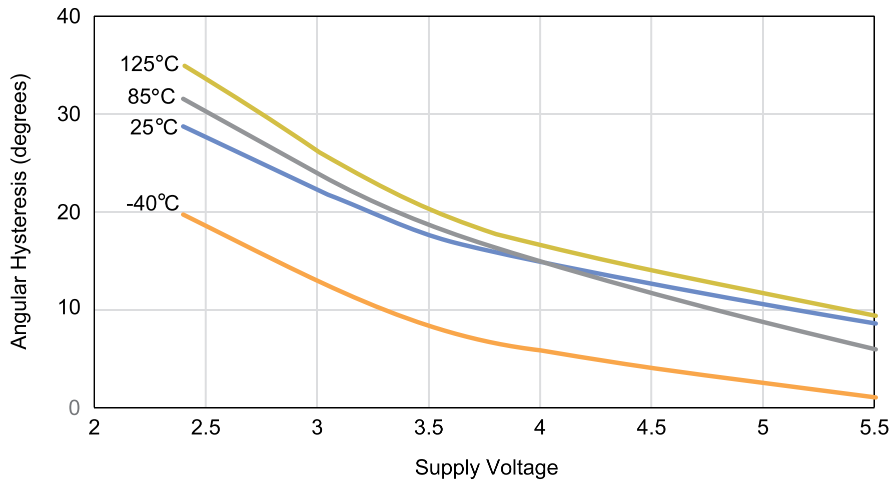

Figure 8. Typical angluar hysteresis vs. supply voltage at various temperatures.

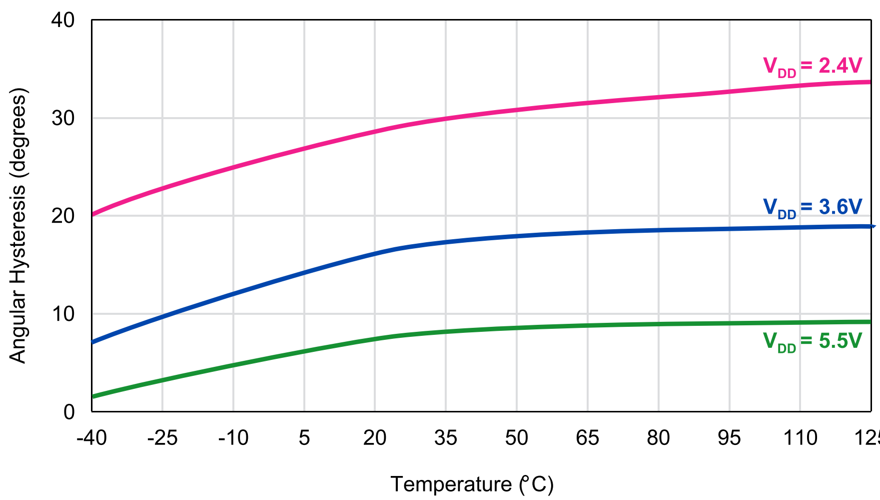

Figure 9. Typical hysteresis vs. temperature at various supply voltages.

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Illustrative Application Circuits

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

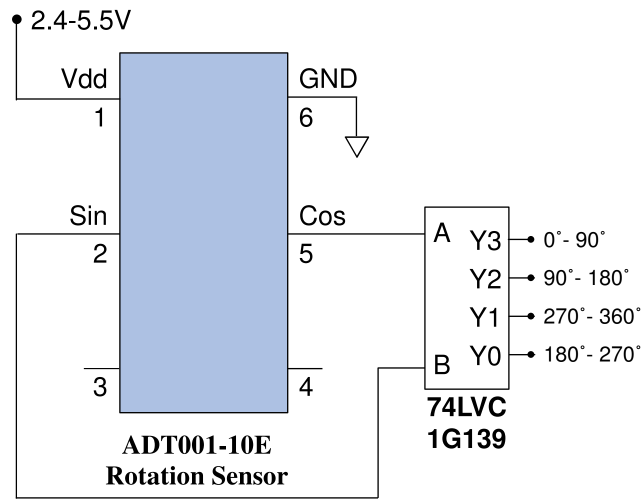

Figure 10. Quadrant detection.

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.

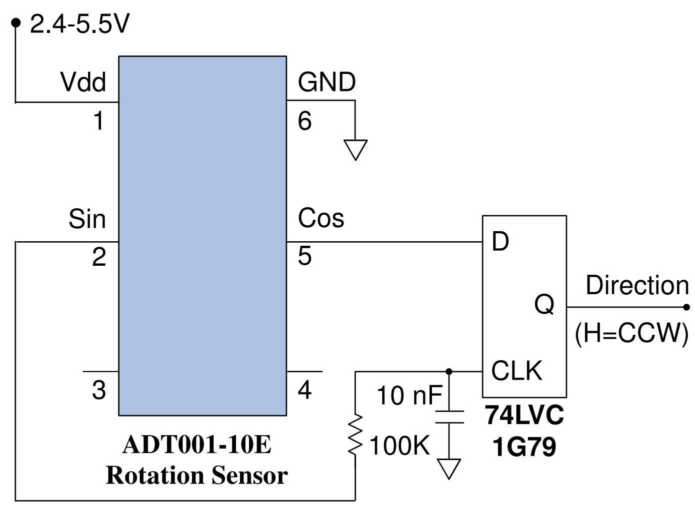

Figure 11. Direction detection.

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:

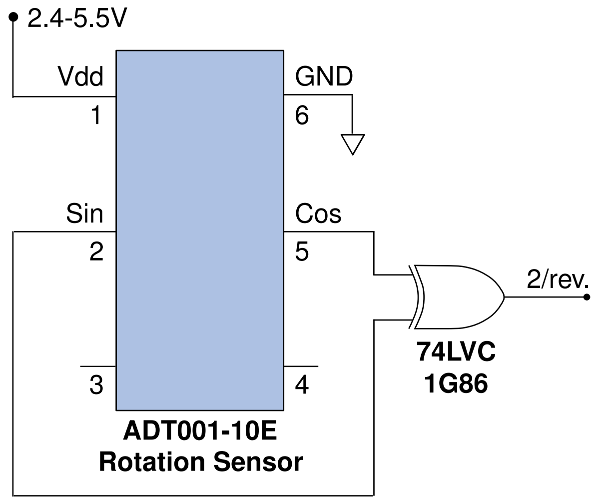

Figure 12. Two-cycle per revolution signal.

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.

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Pinout

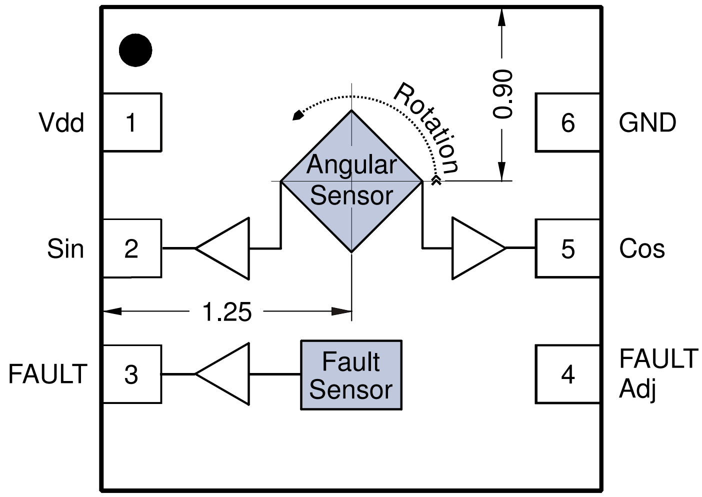

Figure 13. ADT00X-10E pinout and center of rotation.

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°).
3	FAULT	HIGH CMOS output indicates excess magnetic field and possible unreliable measurement.
4	FAULT Adj	FAULT Threshold Adjust.
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

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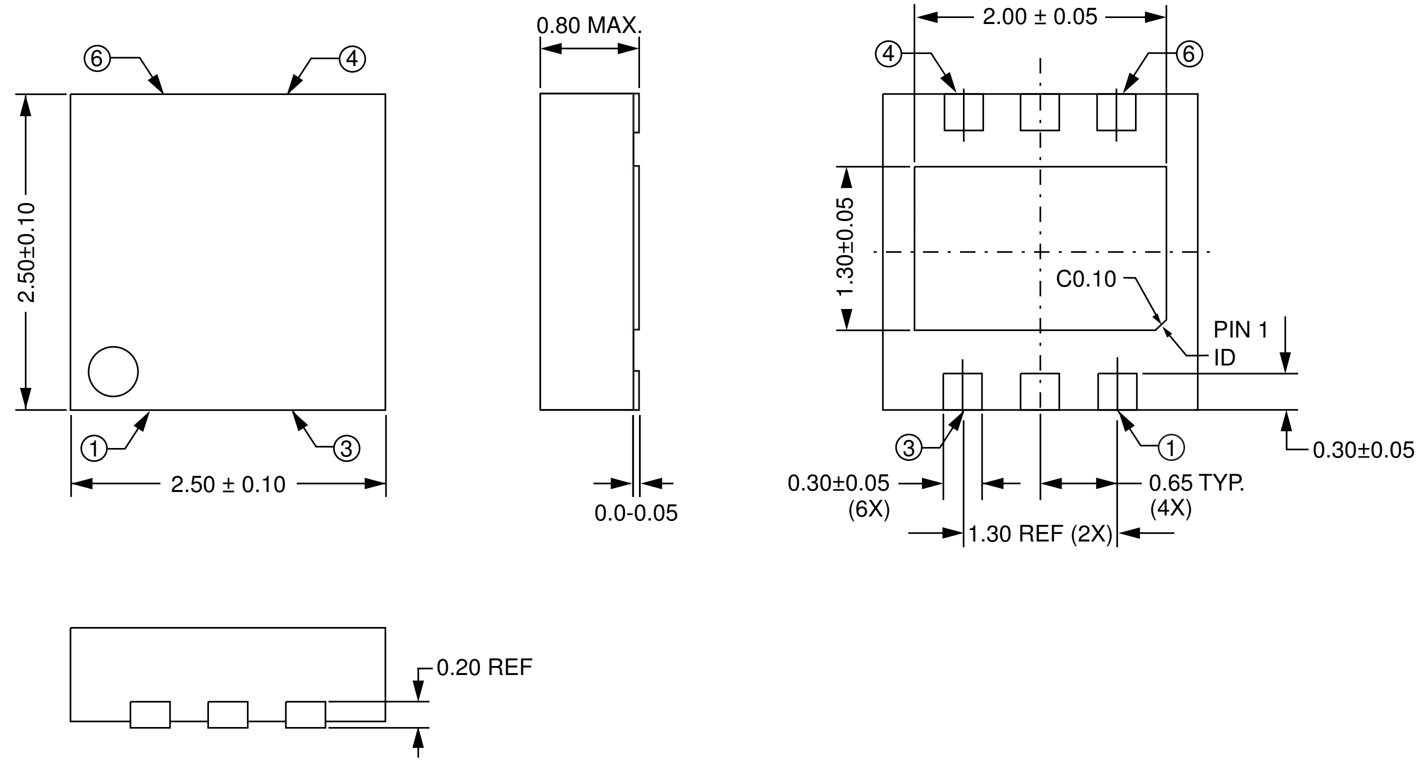
2.5 mm x 2.5 mm TDFN6 Package



RoHS COMPLIANT

Notes:

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

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Revision History

SB-00-155-A July 2022	**Change** • Split ADT001 from SB-00-048 to standalone datasheet number SB-00-155. • Updated diagrams to include the fault threshold adjustment pad.
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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NVE Corporation
11409 Valley View Road
Eden Prairie, MN 55344-3617 USA
Telephone: (952) 829-9217
Fax: (952) 829-9189
www.nve.com
e-mail: sensor-info@nve.com

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