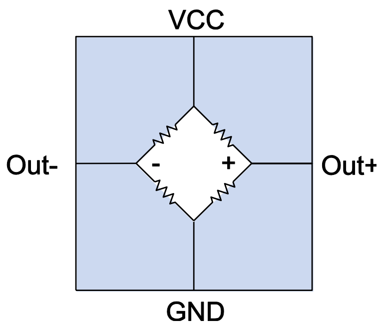
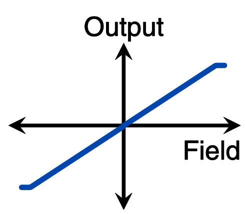
ALT-Series TMR Analog Magnetometer Sensors

Equivalent Circuit



Transfer Function



ALT-Series Transfer Function.

Features

- Tunneling Magnetoresistive (TMR) technology
- High sensitivity (up to 500 mV/V/mT)
- Large signals (up to 200 mV/V typ. full scale)
- ±0.25 mT, ±1 mT, ±2 mT, ±10 mT, and ±20 mT versions
- Highly linear output (<1 % of full scale)
- Low temperature coefficient of output (0.1 %/°C)
- Up to 350 kHz frequency bandwidth
- 20 kΩ typ. device resistance for low power
- Operation to near-zero supply voltage
- Up to 125 °C operating temperature
- 2.5 x 2.5 mm DFN6 and 1.1 x 1.1 DFN4 packages

Applications

- Proximity sensing
- Motion, speed, and position control
- Ferromagnetic material detection
- Nondestructive testing
- Flow sensing
- Geomagnetic navigation
- Noncontact current sensing
- Wearables
- Mechatronics and robotics

Description

ALT-Series sensors are Tunneling Magnetoresistance (TMR) analog bridge sensors with an extraordinary amount of signal, wide linear range, and ultraminiature packages.

The differential bridge output is bipolar, meaning it is positive for a positive field and negative for an opposite field polarity.

The Wheatstone bridge configuration allows the sensors to be pure ratiometric devices. They can operate at extremely low supply voltages and the output signal is proportional to the supply.

The output is stable over the operating temperature range of −40 to 125 °C.

Absolute Maximum Ratings

Parameter	Symbol	Min.	Typical	Max.	Units
Supply voltage	V_{CC}	0		14	Volts
Operating temperature	T_{min}, T_{max}		−40	125	°C
Storage temperature			−65	150	°C
ESD (Human Body Model)[1]				2000	Volts
Applied magnetic field[2]	H			Unlimited	Tesla
Voltage from sensor connections to center pad				63	Volts DC

General Operating Specifications

Parameter	Symbol	Min.	Typical	Max.	Units
Operating temperature	T	−40		125	°C
Supply voltage	V_{cc}	0		10	Volts
Offset voltage ALT025-14E All other part types	V_{offset}	 −40 −20		 +40 +20	mV/V
Device resistance	R	8	20	55	kΩ
Frequency bandwidth[3]	f	DC		350	kHz
Output at maximum operating field	V_{max}		200	700	mV/V
Temperature coefficient of device resistance[6]	TCR		−0.08		%/°C
Temperature coefficient of output[6]	TCO	0	0.1	0.25	%/°C
Off-axis characteristic[7]			Cos(θ)		

Part-Specific Operating Specifications

Parameter	Symbol	Min.	Typical	Max.	Units
Operating field linear range[2]	H				mT
ALT021, ALT002		−0.25		0.25	
ALT023		−1		1	
ALT024		−2		2	
ALT025		−10		10	
ALT026		−20		20	
Saturation field[2]	H_{sat}				mT
ALT021, ALT002			0.5		
ALT023			1.5		
ALT024			3		
ALT025			30		
ALT026			35		
Sensitivity[2]	Sen				mV/V/mT
ALT021-10E		400	500	600	
ALT002-14E		100	200	300	
ALT023-10E		150	200	250	
ALT024-10E		90	120	150	
ALT025-10E		6	8	10	
ALT025-14E		15	22.5	30	
ALT026-10E		3	4.5	6	
Field Detectivity[2]	H_{min}				nT/√Hz
ALT021					
1 Hz			4		
5 kHz			0.07		
ALT002, ALT023, ALT024					
1 Hz			10		
5 kHz			0.2		
ALT025					
1 Hz			130		
5 kHz			2		
ALT026					
1 Hz			200		
5 kHz			4		
Hysteresis[4]	H_c				%F.S.
ALT021-10E, ALT002-14E				10	
ALT023-10E; ALT024-10E				5	
ALT025-10E				1	
ALT025-14E				15	
ALT026-10E				1	
Linearity[4,5]	Lin				%F.S.
ALT021-10E, ALT002-14E			2	3	
ALT023-10E, ALT024-10E. ALT025-10E, and ALT026-10E					
±20% of linear range, −40 to 85 °C			0.1	0.2	
±50% of linear range, −40 to 85 °C			0.2	0.4	
±20% of linear range, −40 to 125 °C			0.2	0.5	
±50% of linear range, −40 to 125 °C			0.5	1	
ALT025-14E			10	15	
Over linear range, −40 to 125 °C					

Thermal Specifications

Parameter	Symbol	Min.	Typical	Max.	Units
Junction–ambient thermal resistance[8] ALT0xx-14E (DFN4) ALT0xx-10E (DFN6)	θja		 500 320		°C/W
Power dissipation ALT0xx-14E (DFN4) ALT0xx-10E (DFN6)	Pd		 100 500		mW

Notes to all specifications:

1. Human Body Model (HBM) per JESD22-A114.
2. 1 millitesla (mT) = 10^6 nanotesla (nT) = 10 Gauss (G) = 10 Oersted (Oe) in air.
3. Specified for amplitude reduction of −3 dB.
4. Full scale is defined as the operating field range.
5. Maximum deviation from best linear fit. Excludes contributions from hysteresis.
6. TCR is the device resistance change with temperature in constant applied field. TCO is the output change with temperature using either a constant current or constant voltage source to power the sensor.
7. Theta (θ) is the angle between the positive sensitive direction and the applied field.
8. Measured per JESD51 with ground pad not connected to circuit board.

Typical Performance Graphs

Figures 1 shows the typical response of ALT0xx TMR sensors.

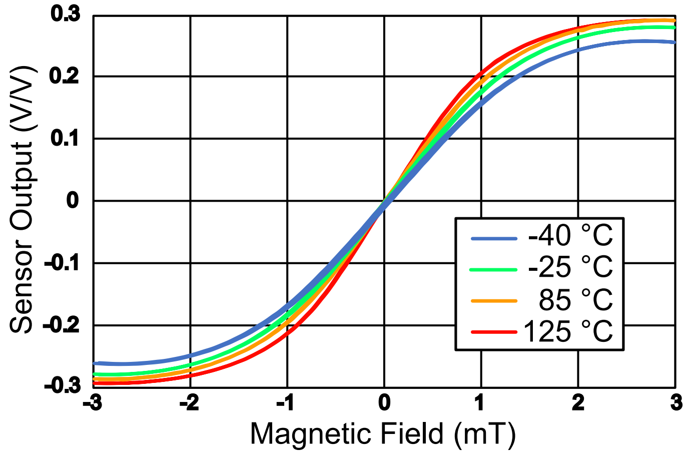


Figure 1. Typical ALT023-10E output at various temperatures.

Single-Axis, Bipolar Directional Sensitivity

The ALT0xx sensors have single-axis sensitivity to magnetic fields within the operating field linear range. Positive-polarity magnetic field is defined with the same convention as the magnetic field produced by a current loop (sometimes called the “right hand rule”).

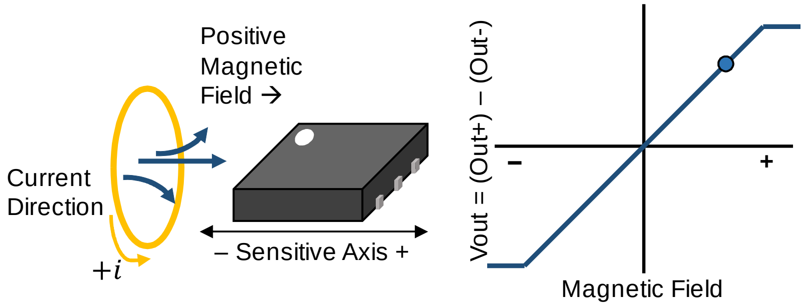


Figure 2. Definition of positive magnetic field direction and ALT02x polarity.

Following the same convention, the north pole of a permanent magnet creates a positive full-bridge output Vout = (Out+) – (Out-).

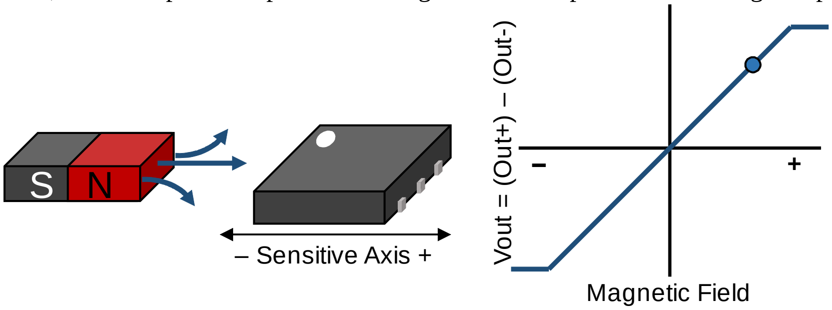


Figure 3. Alternate definition of positive magnetic field direction and ALT02x polarity.

The sensitivity direction of each sensor is clarified with the package outline drawings on page 14. As shown in Figure 2 and Figure 3, ALT0xx sensors have bipolar voltage outputs. The sensor output changes sign with the magnetic field direction. This is ideal for AC current sensing and certain proximity-sensing applications. The sensor can only measure magnetic field along the sensitive axis. Only the vector component of magnetic field along the sensitive axis will generate a voltage output; magnetic fields applied at an angle θ from the sensor’s positive sensitive direction will reduce the voltage output by a factor of $Cos\ (\theta)$.

In-Plane Sensitivity

Unlike Hall Effect or other sensors, the direction of sensitivity of ALT-Series sensors is in the plane of the package, which is more convenient for many applications.

Standard-Axis and Cross-Axis sensitivity

ALT-Series sensors are available in two sensitivity directions. The definitions are shown in Figure 4.

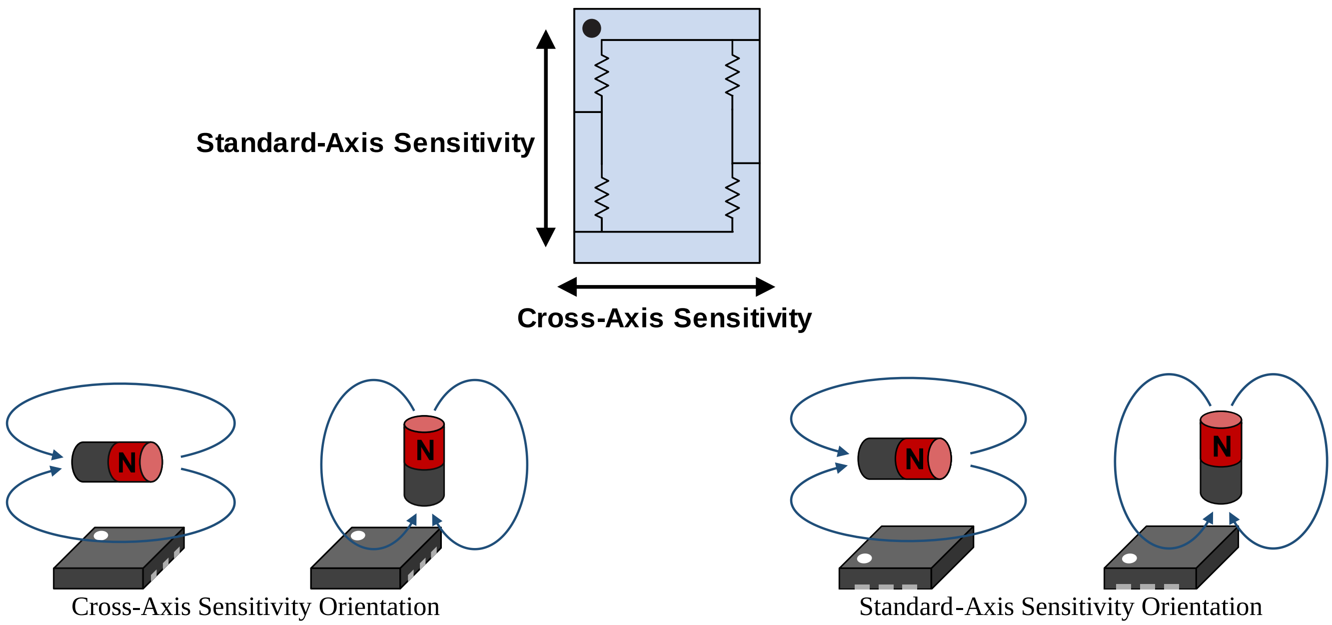


Figure 4. Standard-Axis and Cross-Axis Sensitivity directions.

Minimum Magnetic Field Detectivity

ALT-Series TMR sensors have a remarkably high sensitivity and low noise. These parameters define the sensor's minimum detectable field. The noise spectrum of ALT-Series sensors follows a classical 1/f noise profile at low frequency and is white noise at high frequency. Therefore, the detectivity varies with frequency. For more information, see NVE's TMR magnetometer noise application note, SB-00-101.

Illustrative Applications

Dual-Supply Differential Amplifier

The ALT0xx sensor's bipolar output is ideal for applications requiring positive and negative output voltages. The circuit below converts the output from differential to a single-ended positive or negative voltage. A low-cost, low bias-current op amp allows large resistors to avoid loading the sensor bridge. The 1 MΩ input resistors are 100 times the 10 kΩ sensor output impedance to avoid loading. The amplifies in the example has a gain of five:

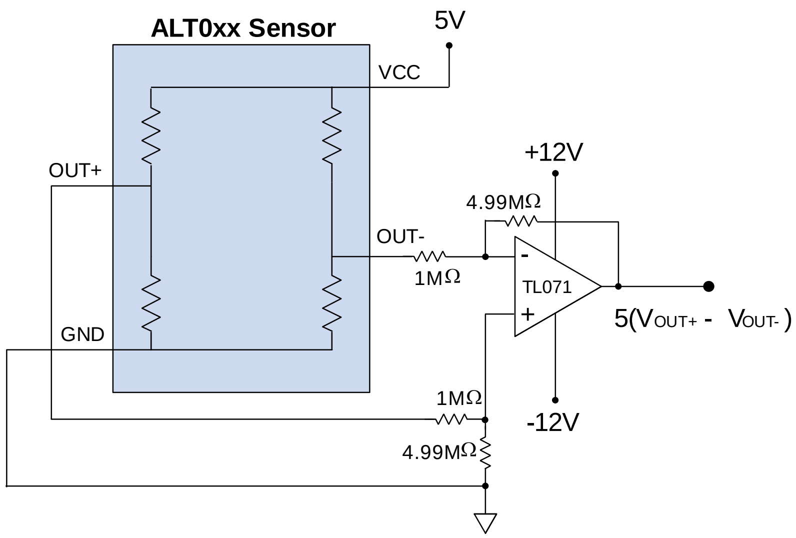


Figure 5. Dual-supply differential amplifier.

Single-Supply Differential Amplifier

The circuit below uses a single-supply op amp. The NCV2001 op amp has a wide bandwidth and can run on as low as a 0.8-volt supply, allowing operation on a 1.5-volt battery:

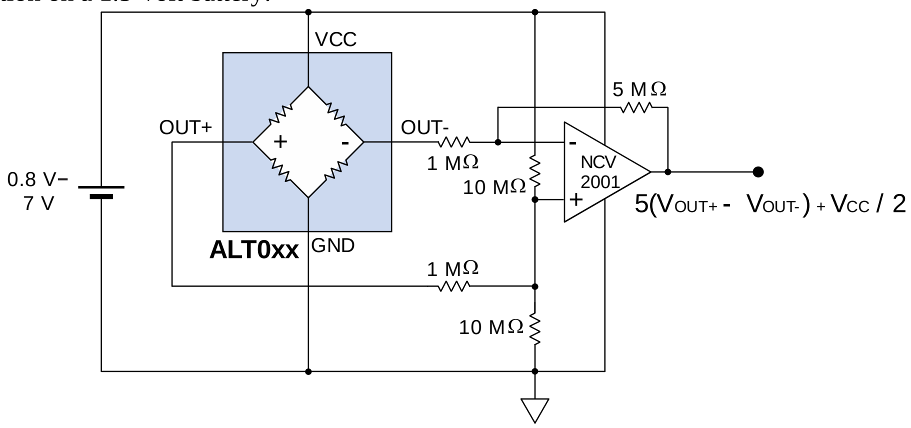


Figure 6. Single-supply differential amplifier.

A nanopower op amp such as an MCP6441 can be used for low-power applications. In addition to low power, the MCP6441 has a low gain-bandwidth product, which could eliminate the need for low-pass filtering in some applications.

Single-Ended Instrumentation Amplifier

A circuit like the one below can be used to generated a positive, single-ended output. A voltage divider provides a 2.5 V reference voltage to center the amplifier output with zero field. Without the gain resistor, the gain is one and the output is 80% of rail-to-rail at the ±400 mV/V maximum output. A gain resistor can be added to increase the output, although this could narrow the usable field range.

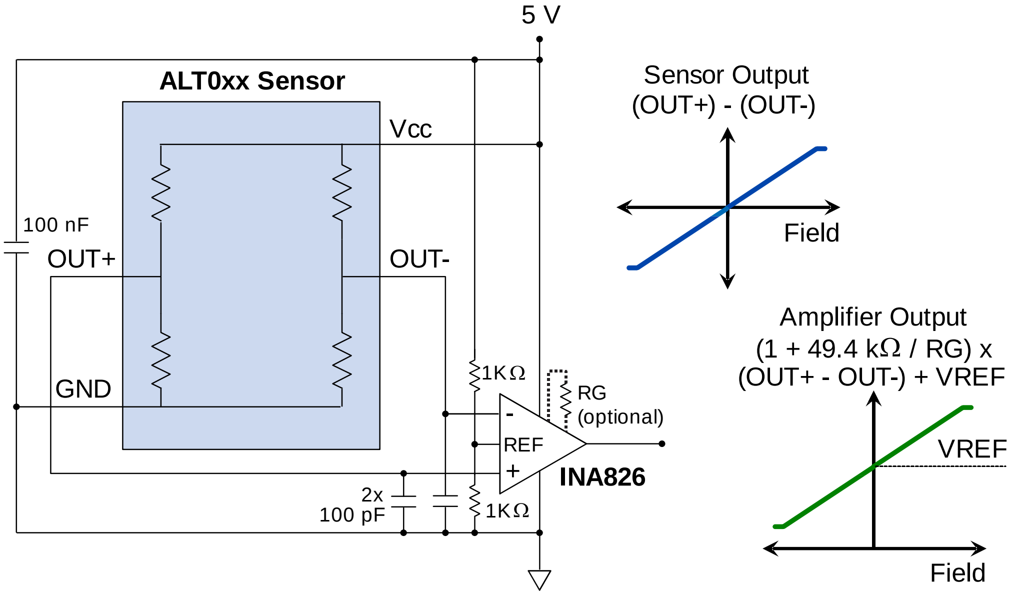


Figure 7. Single-ended analog sensor instrumentation amplifier.

Simple Direct Microcontroller Interfaces

With their large output signals, ALT0xx sensors can often interface directly to microcontrollers, even the simple 10-bit ADCs built into inexpensive microcontrollers such as Atmel AVRs®. Such microcontrollers are common in Arduino and other sensor interface boards. The ALT0xx's 20 kΩ typical device resistance provides 10 kΩ output impedances, ideal for direct interface to many microcontrollers:

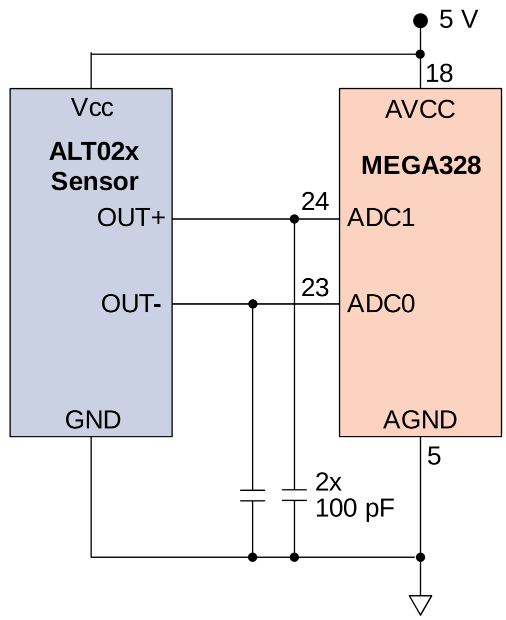


Figure 8. Typical direct microcontroller interface.

Here is an illustrative Arduino sketch:

```
/*****************************************************************
Reads an analog magnetometer with an Arduino Uno.
Arduino-Sensor connections: A0 = sensor OUT-; A1 = OUT+; 5V = Vcc
www.nve.com * www.YouTube.com/NveCorporation * sensor-apps@nve.com
******************************************************************/
const float sens = 0.008; //Sensitivity in V/V/mT (ALT025 = 8 mV/V/mT)
const int offset = 3; //Sensor offset (bits)
void setup() {
Serial.begin(57600); //Initialize the serial port
}
void loop() { //Read, scale, & print sensor output.
Serial.print(float(analogRead(A1)-analogRead(A0)-offset)/1024/sens);
Serial.print(" mT  \r" );
delay(100); //10 samples per second
}
```

High-Resolution ADC Interface

A separate ADC can be used for higher resolution or higher speed than a typical direct microcontroller interface. The following circuit uses a 24-bit ADC that can be clocked at up to 20 MHz, and uses the ADC's two-wire interface mode for simple wiring:

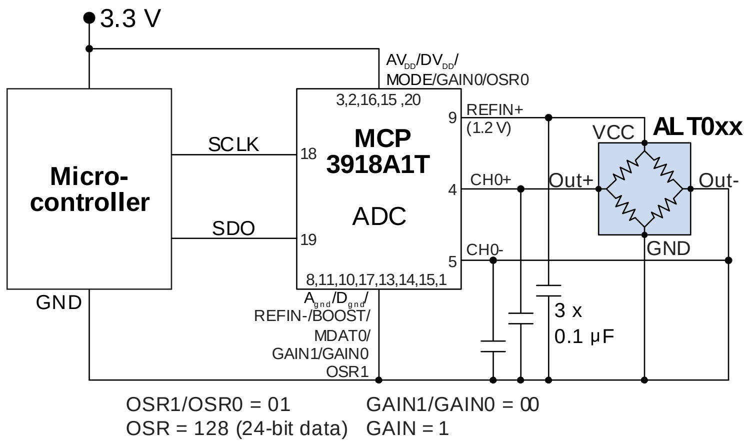


Figure 9. Typical high-resolution ADC interface.

The sensor is low power and has no minimum supply voltage, so it can be powered by the 1.2-volt ADC reference. Since sensor is ratiometric, reference variations and noise cancel. Additionally, the sensor output is differential, which further increases the Common-Mode Rejection Ratio.

Magnetic Switch Using a Comparator

ALT0xx sensors can be combined with simple comparators to form magnetic switches. Like ALT0xx sensors, the NCS2200 comparator is low voltage (as low as 0.8 volts) and low power. With no active elements, the sensors have no minimum supply voltages, and because they are ratiometric, power supply variations cancel. This makes the sensors ideal for battery-powered applications:

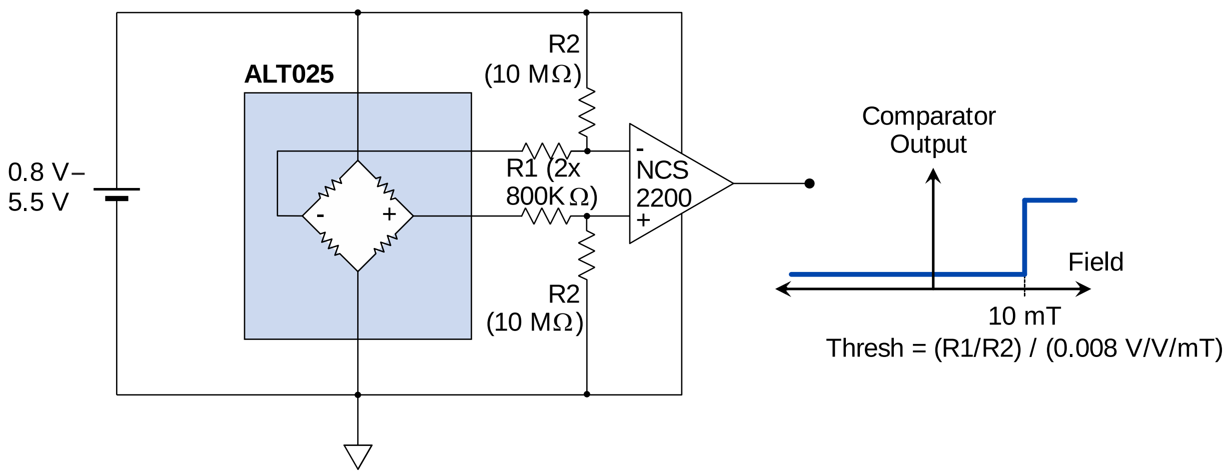


Figure 10. An adjustable magnetic switch using an ALT0xx and a comparator.

The matched resistors in the circuit above preserve the sensor bridge's inherent cancelation of temperature and power supply variations. The switching threshold is set by the R1/R2 ratio (1/5 in the example above), combined with the sensor's sensitivity. The relatively large resistors avoid loading the bridge. Since the sensor has a bipolar magnetic response, the comparator only switches with a large enough field of the correct polarity.

The circuit above has only the small amount of hysteresis provided by the comparator, so the comparator output could "chatter" around the switching point in some applications. Hysteresis can be added in the following circuit.

Adding Comparator Hysteresis

A positive feedback resistor on the comparator adds hysteresis:

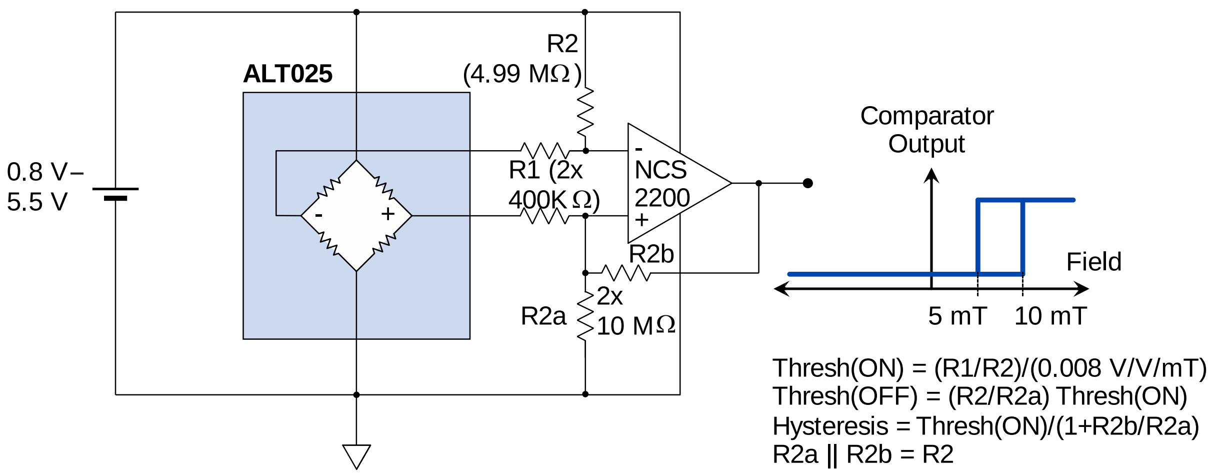


Figure 11. Magnetic switch with added hysteresis.

LED Field-Strength Indicator

The ALT0xx's true bipolar output allows detection of field polarity. The op-amp circuit below detects the polarity of the magnetic field and change brightness to show field strength at a glance:

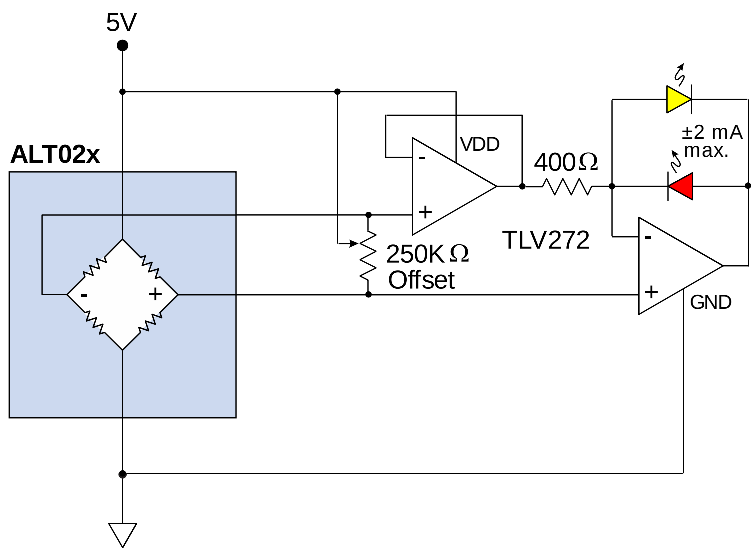


Figure 12. LED brightness indicates the magnetic field and color indicates polarity.

A positive field turns on the red LED and a negative field turns on the yellow LED. The 250 kΩ potentiometer is optional to adjust for sensor offset.

Noncontact Current Sensing

With low hysteresis, high linearity at low fields, and high speed, ALT0xx sensors are ideal for noncontact current detection or overcurrent protection. Due to their convenient in-plane sensitivity, they can be mounted directly over PCB traces. The sensor measures the current by detecting the magnetic field generated by the current through the trace.

These sensors feature cross-axis sensitivity, so they are able to detect current traces directly beneath the part for maximum accuracy. These sensors have a wide linear range, so they can detect a wide range of currents. By tailoring the PCB trace to the application, they can detect currents from 0.1 mA to 250 A.

Two typical high-resolution current sensing configurations are shown below. The current trace runs directly under the sensor on a single side of the PCB.

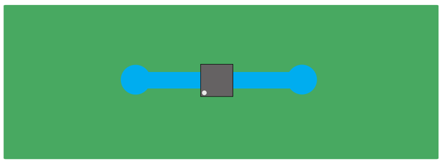


Figure 13a. 0.05" (1.3 mm) trace for currents 0 – 5 A.

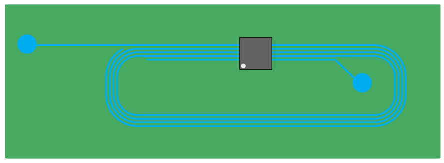


Figure 13b. Five turns of 0.0055" (0.14 mm) trace for currents 0 – 1 A.

The generated magnetic field is easily calculated with Ampere's Law:

H = 5nI   ["H" in oersteds and "I" in amps. "n" is the number of turns.]

For high current sensing, larger traces are required. The sensor is typically mounted opposite a high current trace on a standard PCB, as shown in Figure 1. In this case, the width of the trace is significant, and a formula can be obtained by breaking the trace into a finite element array of thin traces, and calculating the field from each array element.

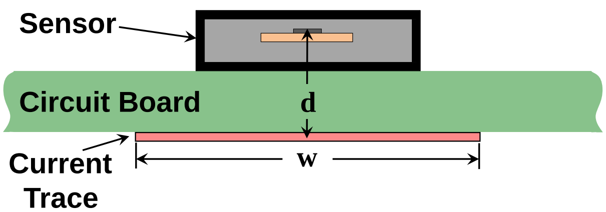


Figure 14. The geometry of current sensing over a circuit board trace. Depending on the trace's width and thickness, currents up to 250 A can be measured.

$$H = \frac{4I}{w} \cdot arcTan\left[\frac{w}{2d}\right]$$

["H" in oersteds, "I" in amps, "d" in millimeters includes half of the package thickness, and "w" in millimeters.]

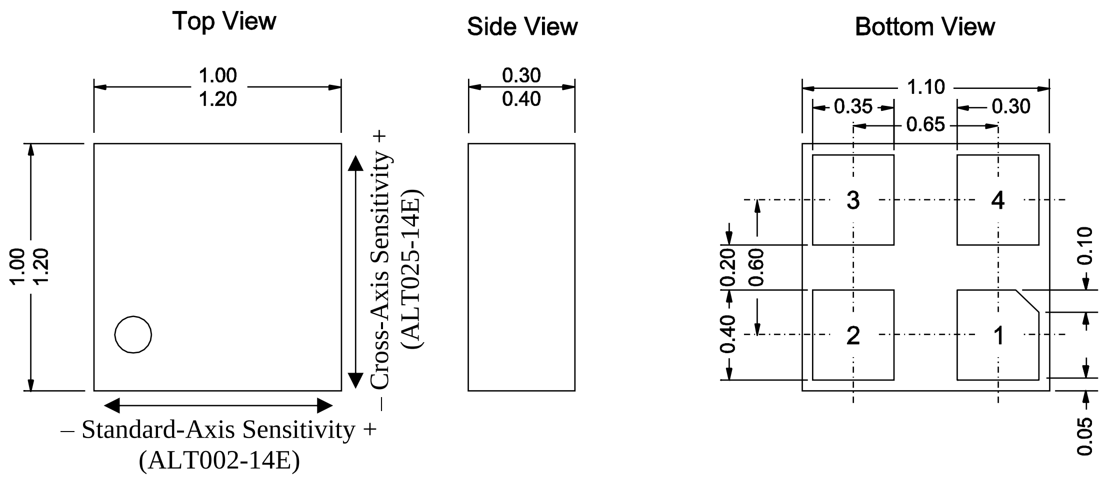
To simplify these calculations, we have a free, Web-based application with these formulas to calculate magnetic fields and sensor outputs in current-sensing applications:

www.nve.com/spec/calculators.php#tabs-Current-Sensing

To help with the design of high current traces for current sensing applications, see our application note, which provides a comprehensive guide.

www.nve.com/Downloads/SB-00-083_Precision_High_Current_Sensing_Over_PCB_Traces.pdf

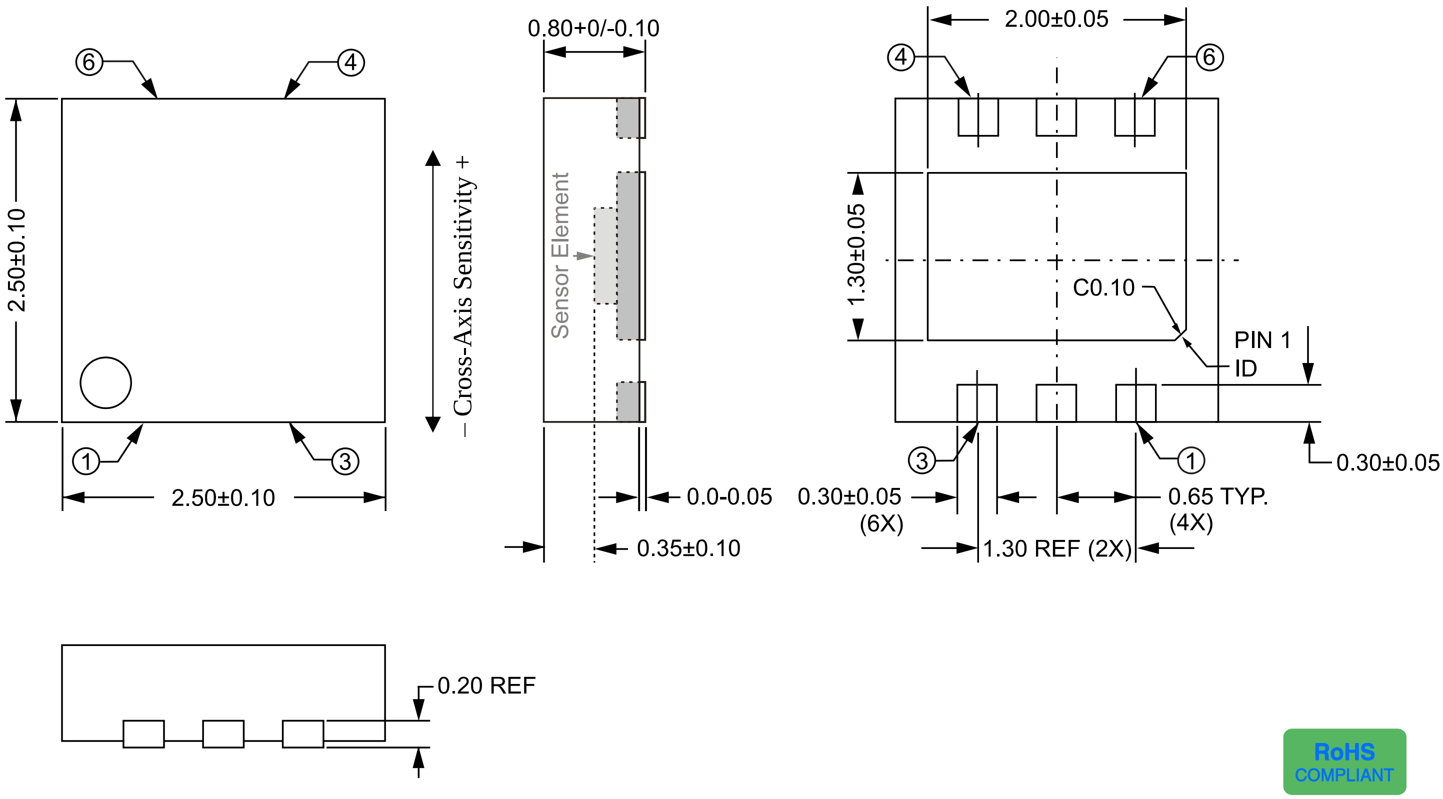
1.1 mm x 1.1 mm DFN4 Package (-14 suffix)



Dimensions in mm; ±0.10 mm unless otherwise noted.

RoHS COMPLIANT

2.5 mm x 2.5 mm DFN6 Package (-10 suffix)

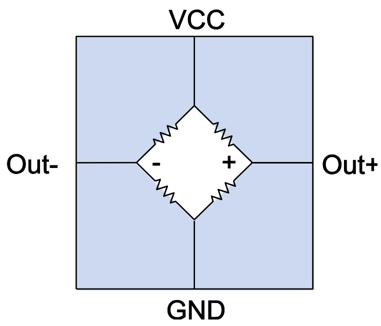


RoHS COMPLIANT

Notes:

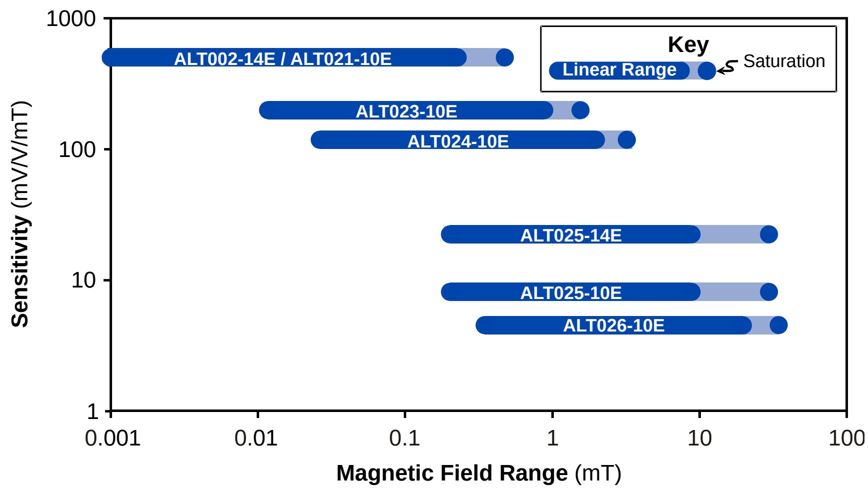
- Dimensions in millimeters.
- Soldering profile per JEDEC J-STD-020C, MSL 1.

Functional Diagram and Pinout



Symbol	Description	Pad # ALT0xx-14E (DFN4)	Pad # ALT0xx-10E (DFN6)
V_{cc}	Positive bridge supply.	2	6
GND	Negative bridge supply or ground.	4	3
Out+	Positive bridge output.	1	1
Out-	Negative bridge output.	3	4
NC	No internal connection.		2, 5
-	Internally connected to leadframe	N/A	Center Pad

Field Ranges



Part Numbering

ALT025-10E

Base Part
ALT = Analog TMR Magnetometer Sensors

Sensitivity Direction
00 = Standard-Axis
02 = Cross-Axis

Linear Range
1, 2 = ±0.25 mT
3 = ±1 mT
4 = ±2 mT
5 = ±10 mT
6 = ±20 mT

Package Type
14 = 1.1 x 1.1 mm DFN4
10 = 2.5 x 2.5 mm DFN6
E = RoHS

Available Parts

Part Number	Linear Range	Package	Package Marking
ALT021-10E	±0.25 mT	2.5 x 2.5 mm DFN6	FHF
ALT023-10E	±1 mT		FGH
ALT024-10E	±2 mT		FGH
ALT025-10E	±10 mT		FHC
ALT026-10E	±20 mT		FHC
ALT002-14E	±0.25 mT	1.1 x 1.1 mm DFN4	x
ALT025-14E	±10 mT		x

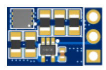
Breakout Boards

Breakout boards are available for evaluating each ALT-series sensor:

Part numbers ALT0xx-1xE-EVB01
(0.8" x 0.4" / 21 mm x 10 mm; actual size).

Ultrasensitive Evaluation Board with Amplifier

We offer a small board with a differential amplifier to demonstrate the ALT021-10E sensor:



Part numbers ALT021-10E-EVB02
(0.8" x 0.4" / 21 mm x 10 mm; actual size).

Bare Circuit Boards

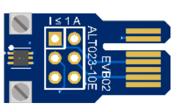
NVE offers bare circuit boards for easy connections to DFN4 and DFN6 sensors such as the ALT0xx series:

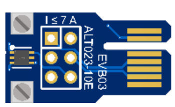
AG904-06: DFN4 connection board for -14E suffix sensors.
(1.2" x 0.25" /30 mm x 6 mm; actual size).

AG035-06: DFN6 connection board for -10E suffix sensors.
(1.57" x 0.25" /40 mm x 6 mm; actual size).

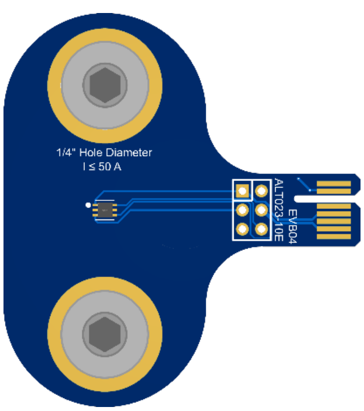
Current Sensor Evaluation Boards

These evaluation boards make it simple to evaluate ALT023 for different current sensing requirements:



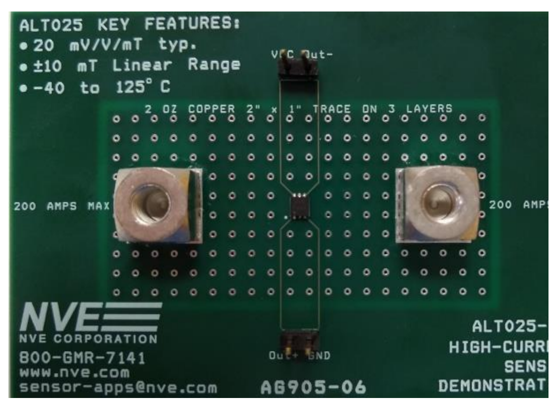


ALT023-10E-EVB02 **ALT023-10E-EVB03**
(0.87" x 0.47" / 22 mm x 12 mm; actual size).



ALT023-10E-EVB04
(2.0" x 1.9" / 52 mm x 48 mm; actual size).

This evaluation board shows the ALT025's remarkable linear range and accuracy for up to ±200 A noncontact current measurement:



AG905-07E: ALT025-10E High-Current Sensing Evaluation Board.
(3" x 2.065" / 76 mm x 52 mm; actual size).

Revision History

SB-00-102 – Rev. M
July 2024

Change
- Added ALT024-10E version.

SB-00-102 – Rev. L
July 2024

Changes
- Added ALT002-14E version.
- Added ALT023 current sensor evaluation boards.
- Updated Figures 2 through 4 and package outline drawings to clarify sensitivity direction.

SB-00-102 – Rev. K
May 2024

Changes
- Added ALT026-10E version.
- Corrected ALT025 noise detectivity specification.
- Added single-supply differential amplifier application circuit (p. 8, Fig. 6).
- Added breakout boards and ultrasensitive evaluation board with amplifier (p. 16).

SB-00-102 – Rev. J
February 2023

Changes
- Corrected ALT025-14E offset and sensitivity specifications.
- Clarified sensitivity directions on page 12.
- Tightened ALT021-10E offset specification.

SB-00-102 – Rev. I
December 2022

Changes
- Added ultrahigh sensitivity version (ALT021-10E).
- Increased max. operating supply voltage to 10 V (p. 3).
- Maximum sensitivity operating specifications (p. 3).
- Dimensions for sensing die location in package (p. 12).
- Chart of field ranges (p. 13).
- Tightened various specification tolerances.

SB-00-102 – Rev. H
June 2022

Change
- Added DFN4 version (ALT025-14E).

SB-00-102 – Rev. G
December 2021

Changes
- Finalized specs for high-sensitivity version (ALT023-10E).
- Dropped DFN4 version.

SB-00-102 – Rev. F
July 2021

Changes
- Added high-sensitivity version (ALT023-10E).
- Added DFN4 version (ALT025-14E).
- Dropped “standard-axis” version (ALT005).
- Added instrumentation amplifier gain equation (Fig. 6).
- Added illustrative Arduino program.
- 24-bit ADC application circuit (Fig. 8).
- Comparator application circuits (Figs. 9 and 10).

SB-00-102 – Rev. E
April 2020

Change
- Increased maximum resistance rating for lower power.

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