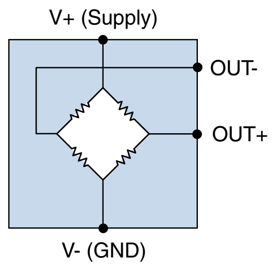
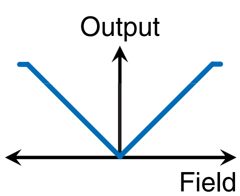
AA/AB-Series Analog Magnetic Sensors

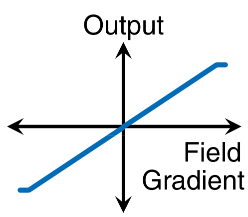
Equivalent Circuit



Idealized Transfer Functions



AA-Series
Magnetometer
Transfer Function



AB-Series
Gradiometer
Transfer Function

Features

- Magnetometer and gradiometer configurations
- Field ranges from <<0.1 mT to >45 mT
- Temperature coefficient as low as 0.05%/°C
- Ultrasensitive, high-field, and low-hysteresis versions
- Temperature-compensating analog bridge outputs
- Operation to near-zero supply voltage
- Up to 1 MHz bandwidth
- Up to 150°C operating temperature
- DFN6, MSOP8, and SOIC8 packages

Applications

- Motion, speed, and position control
- Low-field sensing
- Motor commutator sensors
- Noncontact current sensing

Description

NVE's analog GMR sensors have high sensitivity and excellent temperature stability. Their versatility and wide sensing range makes them an excellent choice for a variety of analog sensing applications including industrial and automotive position, speed, and current sensors.

The sensors are configured as inherently temperature-compensating Wheatstone bridges.

AA-Series sensors are magnetometers, which detect absolute magnetic field. AB-Series sensors are differential gradiometers, which detect field gradients.

Three magnetometer subtypes are available: the ultra-temperature-stable AA-Series, the ultrasensitive, high temperature "H" subtype, and the low-hysteresis "L" subtype.

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Absolute Maximum Ratings

Parameter		Symbol	Min.	Max.	Units
Supply voltage	AAxxx/ABxxx/AAL002	V_{CC}		24	Volts
	AAHxxx/ABHxxx/ AAL004/AAL024			12	
Operating temperature	AAxxx/ABxxx/AALxxx		−50	125	°C
	AAHxxx/ABHxxx			150	°C
Storage temperature	AAxxx/ABxxx/AALxxx		−65	135	°C
	AAHxxx/ABHxxx		−65	150	
ESD (Human Body Model)				400	Volts
Applied magnetic field		H		Unlimited	Tesla
Voltage from sensor connections to center pad (DFN6)				63	Volts DC

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Operating Specifications

Parameter		Symbol	Min.	Typ.	Max.	Units	Test Condition
Supply voltage	AAHxxx/ABHxxx/AAL004	V_{CC}	<1		12	Volts	Maximum limited by power dissipation
	AAxxx/ABxxx/AAL002				24		
Operating temperature	AAxxx/ABxxx/AALxxx	T_{MIN}; T_{MAX}	−50		125	°C	
	AAHxxx/ABHxxx				150		
Electrical offset	AAxxx/ AALxxx/ABxxx	V_O	−4		+4	mV/V	
	AAHxxx/ABHxxx		−5		+5		
Output at maximum field	AAxxx/ABxxx	$V_{OUT\text{-}MAX}$		60		mV/V	
	AAHxxx/ABHxxx			40			
	AALxxx			45			
Nonlinearity	AAxxx/ABxxx/AAL002				2	%	Unipolar field sweep
	AAHxxx/ABHxxx/AAL0x4			4			
Hysteresis	AAHxxx/ABHxxx			15		%	
	AAxxx/ABxxx				4		
	AALxxx				2		
Resistance tolerance			−20		+20	%	25°C
Resistance vs. temperature	AAxxx/ABxxx	TC_R		+0.14		%/°C	No applied field
	AAHxxx/AALxxx/ABHxxx			+0.11			
Output temperature coefficient	AAxxx/ABxxx	$TC_{O\text{-}I}$		N/A		%/°C	Constant-current supply
	AAHxxx/ABHxxx			−0.28			
	AALxxx			−0.28			
	AAxxx/ABxxx	$TC_{O\text{-}V}$		−0.05	−0.10	%/°C	Constant-voltage supply
	AAHxxx/ABHxxx			−0.4			
	AALxxx			−0.4			
Frequency bandwidth	AAxxx/AAHxxx	f_{MAX}	DC		75	kHz	−3 dB bandwidth
	AALxxx				500	kHz	
	ABxxx/ABHxxx				1	MHz	
Junction–Ambient thermal resistance	DFN4 (-14 suffix)	θ_{JA}		500		°C/W	Soldered to double-sided board; free air
	DFN6 (-10 suffix)			320			
	MSOP8 (-00 suffix)			320			
	SOIC8 (-02 suffix)			240			
Power Dissipation	DFN4 (-14 suffix)	P_D		100		mW	
	DFN6 (-10 suffix)			500			
	MSOP8 (-00 suffix)			500			
	SOIC8 (-02 suffix)			675			

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Operation

Sensor Subtypes

There are four AA/AB-Series subtypes, as summarized in the table below. "H" subtypes are designed for very high sensitivity and/or very high temperature, and "L" types offer low hysteresis.

Parameter	AAxxx/ ABxxx	AAHxxx/ ABHxxx	AALxxx
Field Sensitivity	High	Very High	High
Operating Field Range	High	Low	Medium
Hysteresis	Medium	High	Low
Temperature Coefficient	Very Low	Low	Low
Max. Temperature	High	Very High	High

Magnetometer Operation

AA-Series sensors are ***magnetometers***, which detect the absolute magnetic field.

Direction of Sensitivity

Unlike Hall effect or other sensors, the direction of sensitivity of GMR sensors is in the plane of the package, which more convenient for many applications. Two permanent magnet orientations that will activate the sensor are shown in Figure 1:

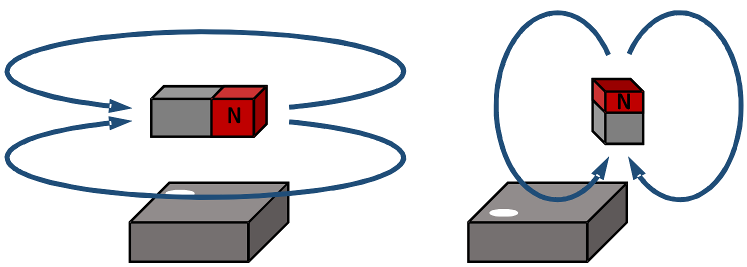

Figure 1. Planar magnetic sensitivity.

Omnipolar

AA-Series sensors are "omnipolar," meaning the output is equally sensitive to either magnetic field polarity and the output is always a positive voltage:

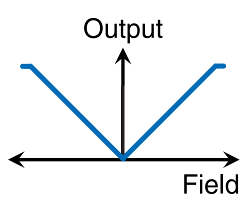

Figure 2. The omnipolar response of AA-Series sensors.

Standard and Cross-Axis Axis Directional Sensitivity

The standard axis of sensitivity is along the part axis, but there are some parts available with cross-axis sensitivity.

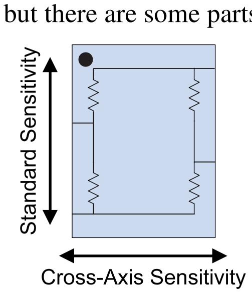

Figure 3. Standard versus cross-axis-sensitivity for AA-Series sensors.

Gradiometer Operation

AB-Series sensors are differential ***gradiometers*** that reject common mode magnetic fields, making them ideal for high magnetic noise environments such as near electric motors or current-carrying wires. The devices are sensitive to a field gradient along the part axis.

The figure below shows a typical gradiometer response:

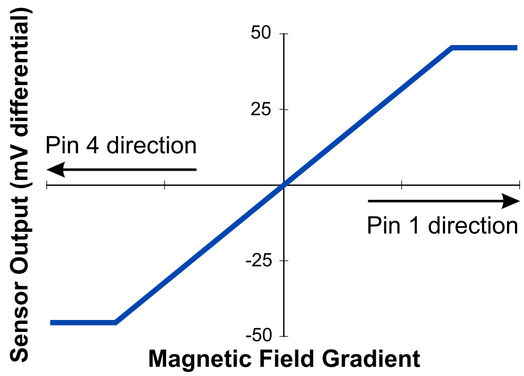

Figure 4. Typical AB-Series gradiometer response.

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Typical Performance Graphs

Figures 5 to 7 show the response of three types of high-sensitivity magnetometer models. All these sensors have low temperature coefficients over their linear ranges. Saturation fields decrease with increasing temperatures.

The flagship **AA00x** models have exceptional temperature stability. **AAH00x** parts have very high sensitivity and a maximum operating temperature of 150°C but more temperature dependence, and the **AAL00x** offers low hysteresis at the expense of slightly more temperature dependence. AAH00x and AAL00x temperature stability are enhanced with constant-current drive (see typical circuits in Figures 11a and 11b).

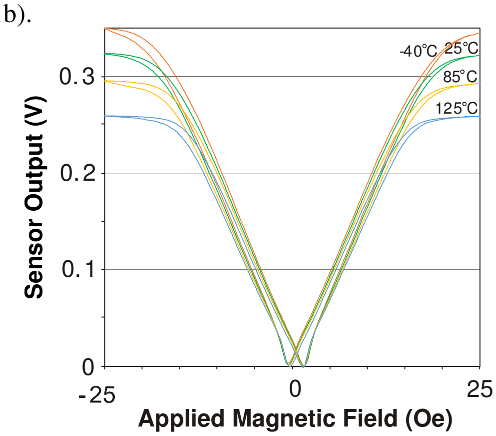

Figure 5. Typical AA002 output with a 5V supply.

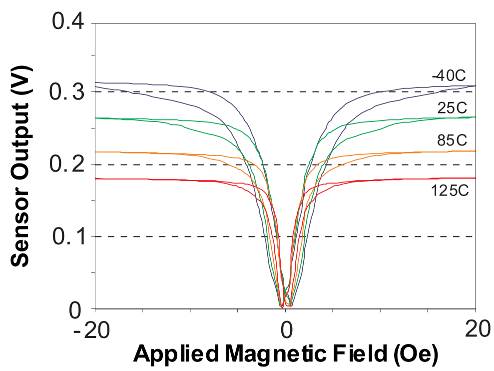

Figure 6a. Typical AAH002 output with 2.28 mA constant-current drive.

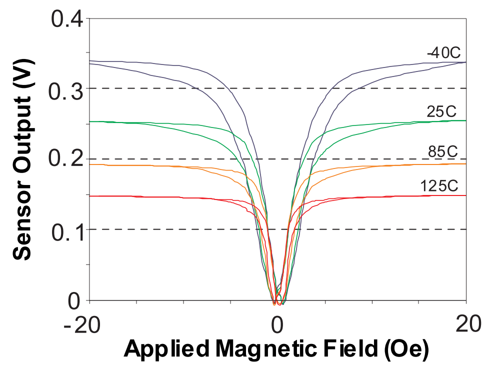

Figure 6b. Typical AAH002 output with a 5V supply.

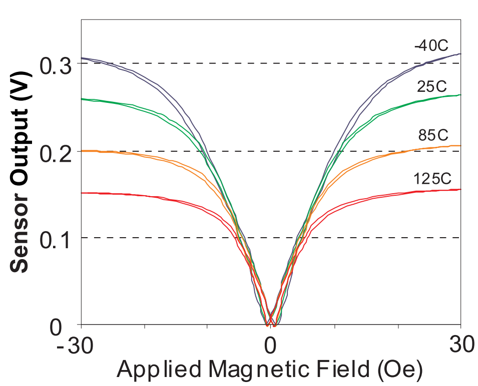

Figure 7a. Typical AAL002 output with 1 mA constant-current drive.

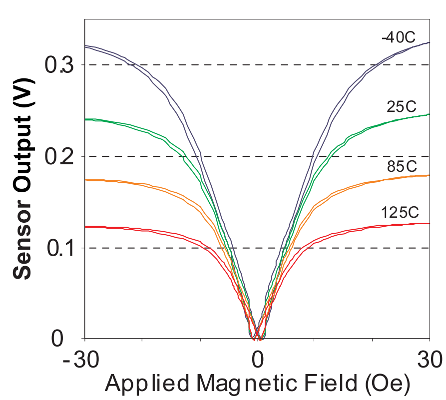

Figure 7b. Typical AAL002 output with a 5V supply.

Figure 8 shows AAxxx-Series sensitivity versus temperature. The temperature is especially stable at low temperature.

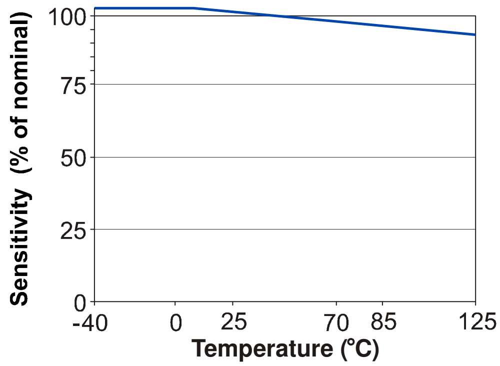

Figure 8. AA002 sensitivity versus temperature.

Illustrative Applications

Traditional Differential Amplifier

Traditional differential amplifiers use low-cost op-amps to provide a single-ended analog output. The circuit below has a gain of 20, which provides a full-scale output at slightly less than the sensor's saturation. A low-cost, low bias-current op amp allows large resistors to avoid loading the sensor bridge. The 500 kΩ input resistors are 100 times the 5 kΩ sensor output impedance to avoid significant loading.

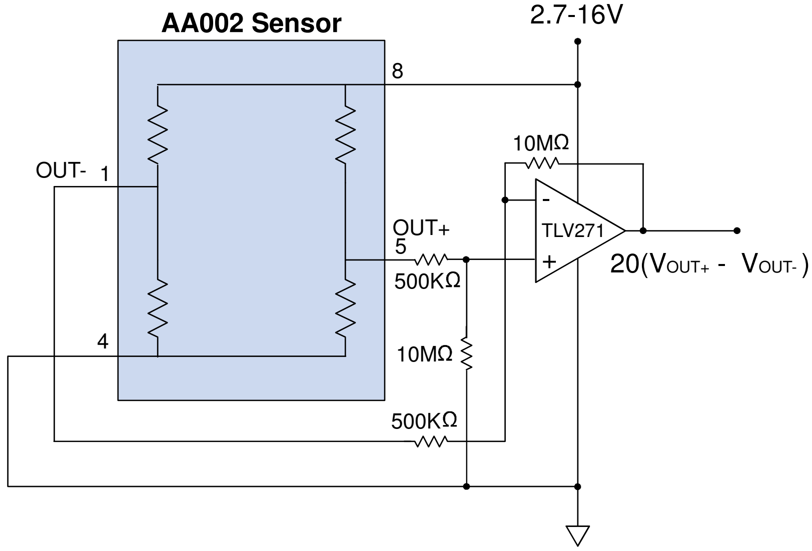

Figure 9. Traditional op-amp differential amplifier.

Sensor Instrumentation Amplifier

Instrumentation amplifiers such as the INA826 are popular bridge sensor preamplifiers because they have a low component count and have excellent common-mode rejection ratios without needing to match resistors. These amplifiers can run on single or dual supplies. AC coupling can be used for small, dynamic signals.

The circuit below has a gain of 20. The general equation for the output voltage is:

$$V_{OUT} = (1 + 49.4K / R_G)V_{IN} + V_{REF}\,; \quad V_{IN} = V_{OUT+} - V_{OUT-}$$

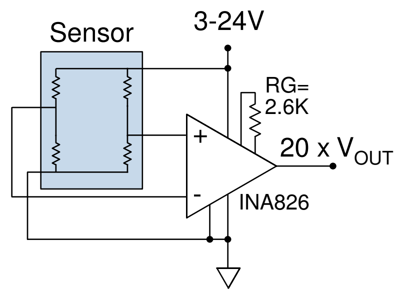

Figure 10. Single-ended analog sensor instrumentation amplifier.

Note that the instrumentation amplifier has a minimum output of 0.1 V, so to detect very low fields on a single supply, an offset can be provided by using a non-zero V_{REF}.

Constant-Current Sensor Drive

Using a constant current rather than conventional constant voltage sensor supply can improve temperature stability of some AAxxx/ABxxx sensors. AAH00x sensors, for example, have an output temperature coefficient ($TC_{O\text{-}I}$) of –0.28%/°C with constant current, versus –0.40%/°C with constant voltage ($TC_{O\text{-}V}$).

An op-amp constant-current supply is illustrated below:

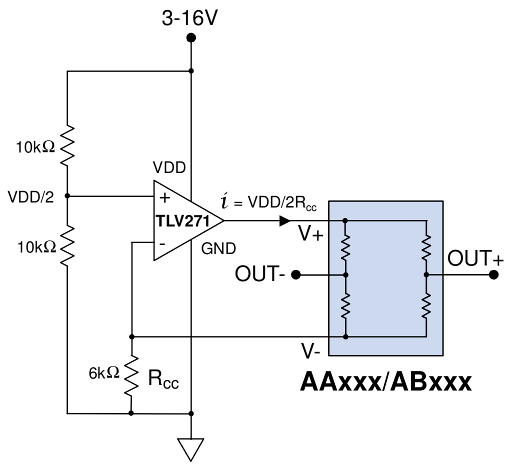

Figure 11a. Constant-current supply using an op-amp.

The supply current for the circuit above is V_{CC} / $2R_{CC}$. R_{CC} can be set to the maximum sensor bridge resistance (e.g., 6 kΩ for many sensors) to provide the highest possible output without saturating the op-amp. The sensor will be driven with 1 mA for a 12 V supply in the circuit above. The sensor supply voltage varies as the bridge resistance changes to provide constant current and compensate for bridge resistance changes with temperature. Op-amp or instrumentation amplifiers such as those illustrated in Figures 9 and 10 can be used with constant-current supplies to provide an amplified, single-ended output.

Alternatively, a voltage regulator and just one external resistor can be used as a constant current source:

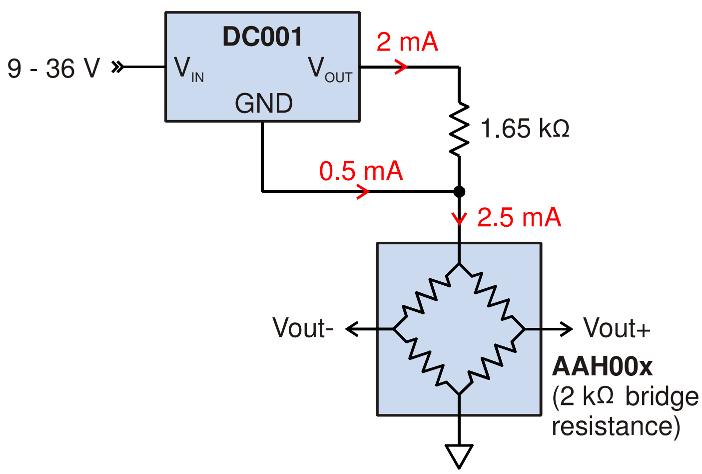

Figure 11b. Constant-current supply using a voltage regulator.

As shown in red in the example above, the current through the external resistor is the regulator output divided by the resistor value. The regulator's quiescent current (0.5 mA typical for the DC001) adds to the supply current. The total source current of 2.5 mA in this example provides approximately five volts to the 2 kΩ sensor.

Variable Threshold Magnetic Switch

NVE offers AD-Series factory-set GMR Switches, but AA-Series analog sensors can be used for special thresholds or hysteresis, or for variable thresholds. In this circuit, the threshold is varied by changing R_G, which sets the gain of the differential amplifier. The 1 MΩ resistor sets the threshold hysteresis:

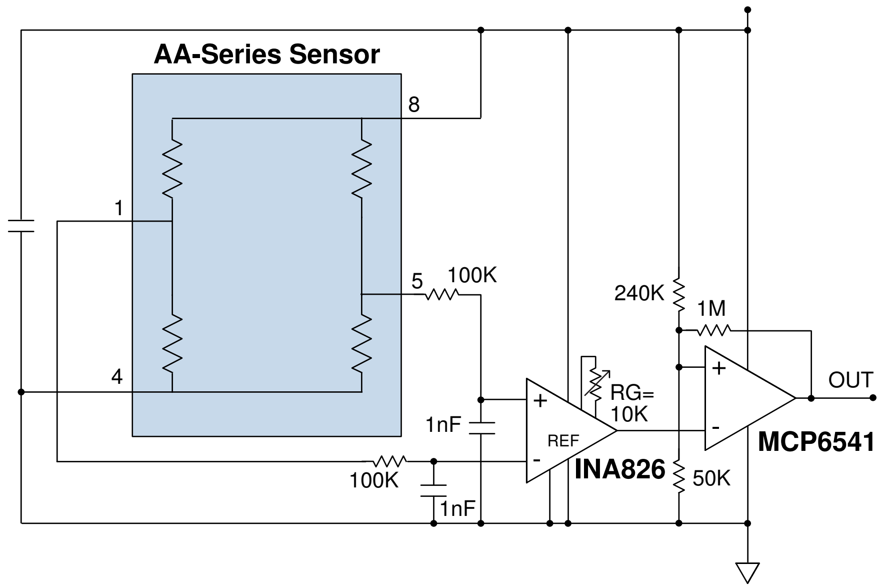

Figure 12. Variable threshold magnetic switch.

LED Field-Strength Indicator

The op-amp circuit in Figure 13 below can be used to change the brightness of an LED to indicate magnetic field strength at a glance:

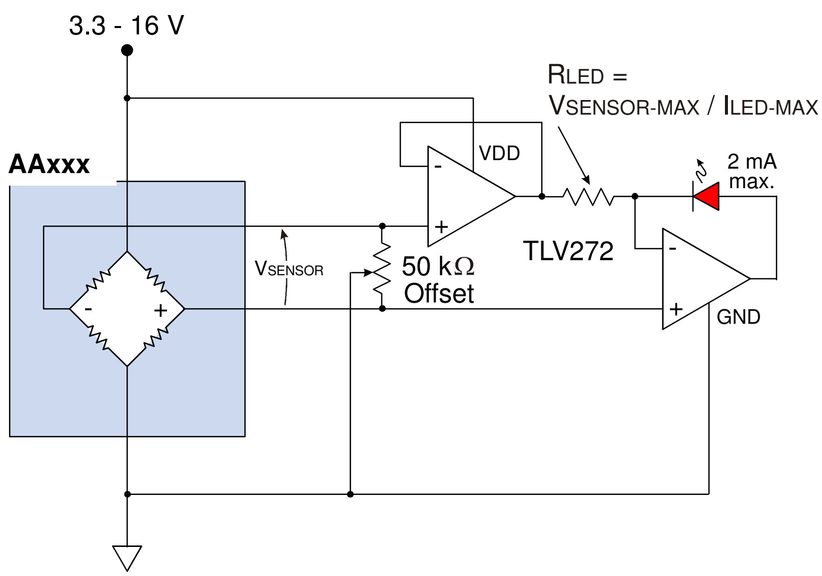

Figure 13. LED brightness indicates the magnetic field.

The LED current is proportional to the sensor output:

$$I_{LED} = (V_{OUT+} - V_{OUT-}) / R_{LED}$$

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The maximum LED current can be set to the maximum sensor output. For example, for an AAxxx, typical $V_{OUT-MAX}$ is 60 mV/V, so for a 3.3 V supply the maximum is approximately 200 mV. For a high-efficiency with a forward current of 2 mA, R_{LED} = 200 mV / 2 mA = 100Ω.

The 50 kΩ potentiometer is optional, to correct for sensor offset or set the minimum field to turn on the LED.
The 16-volt maximum supply voltage noted in Figure 13 is limited by the op-amp selected, but note that some sensors have a 12-volt maximum supply rating. The 3.3-volt minimum supply is required to turn on the LED; the sensors can operate on lower voltages.

Noncontact Current Sensing

AA-Series sensors are often used to measure the current over a circuit board trace. The sensor measures the current by detecting the magnetic field generated by the current through the trace.

The AAL024 is ideal for this application because its cross-axis sensitivity provides sensitivity to a current trace directly under the part, and its low hysteresis provides repeatability. The AA003-02 is popular for overcurrent protection where hysteresis is needed and high accuracy is not required.

Typical current sensing configurations are shown below:

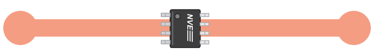

Figure 14a. 0.09" (2.3 mm) trace (0 – 10 A with an AA003 sensor)

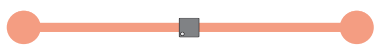

Figure 14b. 0.05" (1.3 mm) trace (0 – 5 A with an AAL024 sensor).

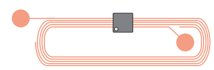

Figure 14c. Five turns of 0.0055" (0.14 mm) trace (0 – 1 A with an AAL024 sensor).

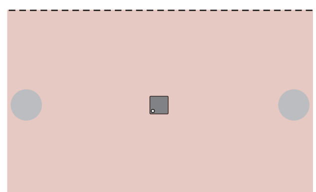

Figure 14d. 1" (25 mm) trace on the bottom side of the PCB (0 – 50 A with an AAL024 sensor).

For the geometry shown in Figure 15 and narrow traces with, the magnetic field generate can be approximated by Ampere's law:

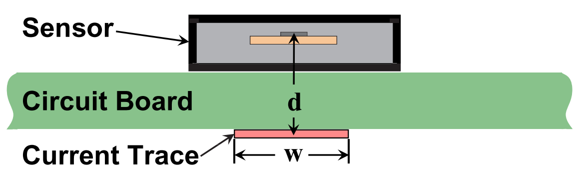

Figure 15. The geometry of current-sensing over a circuit board trace.

$$H = \frac{2I}{d}$$ ["H" in oersteds, "I" in amps, and "d" in millimeters]

The trace can also be run on the top side of the PCB for more current sensitivity.

More precise calculations can be made by breaking the trace into a finite element array of thin traces, and calculating the field from each array element. We have a free, Web-based application with a finite-element model to estimate magnetic fields and sensor outputs in this application:

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

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Part Numbering

AA H 002-02E

Base Part
AA = Analog Magnetometer Sensors
AB = Analog Gradiometers

Subtype
Blank = Standard
H = High sensitivity / High temperature
L = Low hysteresis

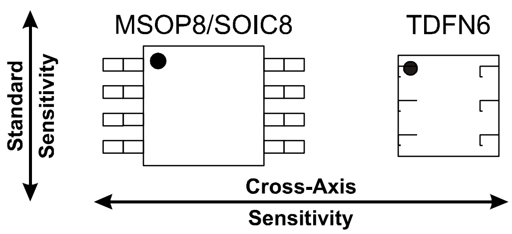
Sensitivity Direction
00 = Standard
02 = Cross-Axis

Sensitivity Code

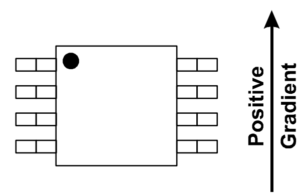
Package Type
00 = MSOP8
02 = SOIC8
10 = DFN6
E = RoHS

Direction of Sensitivity

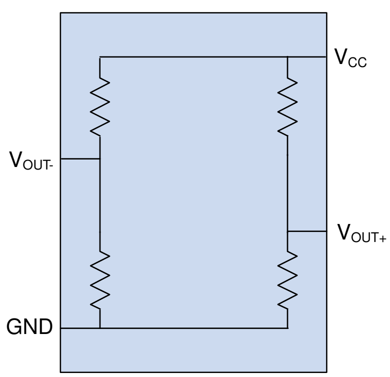
AA-Series (magnetometers)



AB-Series (gradiometers)



Pinouts



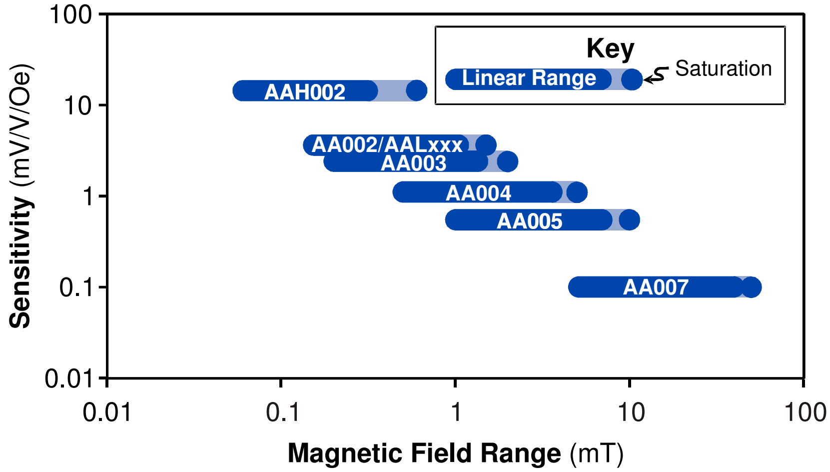
AA-Series Pinout

Sensitivity: Standard (AAx00x-xx) MSOP/SOIC	Standard (AAx00x-xx) DFN6	Cross-Axis (AAx02x-xx) MSOP/SOIC	Cross-Axis (AAx02x-xx) DFN6	Symbol	Description
1	1	5	4	V_{OUT-}	Negative bridge output (decreases with increasing field).
2	2	2	2	NC	No internal connection.
3		3			
4	3	4	3	V-/GND	Negative supply or ground.
5	4	1	1	V_{OUT+}	Positive bridge output (increases with field).
6	5	6	5	NC	No internal connection.
7		7			
8	6	8	6	V+	Positive supply voltage.
	Center Pad		Center Pad	DNC	Internally connected to leadframe (do not connect)

AB-Series Pinout

Pin	Symbol	Description
1	V_{OUT-}	Negative bridge output (decreases with gradient).
2	NC	No internal connection.
3		
4	V-/GND	Negative supply or ground.
5	V_{OUT+}	Positive bridge output (increases with gradient).
6	NC	No internal connection.
7		
8	V+	Positive supply.

AA-Series Sensor Selector Guides



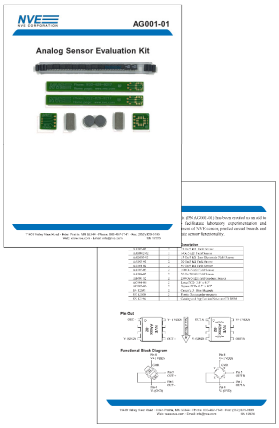
Available Parts

Magnetometers (AA-Series)										
Available Part	Linear Range (|Oe|) Min.	Linear Range (|Oe|) Max.	Saturation (|Oe|)	Sensitivity (mV/V-Oe) Min.	Sensitivity (mV/V-Oe) Max.	Max. Non-linearity (% Uni.)	Max. Hyst-eresis (% Uni.)	Max. Operating Temp.	Typ. Resist-ance	Package
AA002-02	1.5	10.5	15	3	5	2%	4%	125°C	5 kΩ	SOIC8
AA003-02	2	14	20	2	3.5	2%	4%	125°C	5 kΩ	SOIC8
AA004-00	5	35	50	0.9	1.3	2%	4%	125°C	5 kΩ	MSOP8
AA004-10	5	35	50	0.9	1.3	2%	4%	125°C	5 kΩ	DFN6
AA024-00	5	35	50	0.9	1.3	2%	4%	125°C	5 kΩ	MSOP8 (cross-axis)
AA004-02	5	35	50	0.9	1.3	2%	4%	125°C	5 kΩ	SOIC8
AA005-02	10	70	100	0.45	0.65	2%	4%	125°C	5 kΩ	SOIC8
AA005-00	10	70	100	0.45	0.65	2%	4%	125°C	5 kΩ	MSOP8
AA006-00	5	35	50	0.9	1.3	2%	4%	125°C	30 kΩ	MSOP8
AA006-02	5	35	50	0.9	1.3	2%	4%	125°C	30 kΩ	SOIC8
AA007-00	50	450	500	0.08	0.12	2%	4%	125°C	5 kΩ	MSOP8
AAH002-02	0.6	3	6	11	18	4%	15%	150°C	2 kΩ	SOIC8
AAH004-00	1.5	7.5	15	3.2	4.8	4%	15%	150°C	2 kΩ	MSOP8
AAL002-02	1.5	10.5	15	3	4.2	2%	2%	125°C	5.5 kΩ	SOIC8
AAL004-10	1.5	10.5	15	3	4.2	4%	2%	125°C	2.2 kΩ	DFN6
AAL024-10	1.5	10.5	15	3	4.2	4%	2%	125°C	2.2 kΩ	DFN6 (cross-axis)

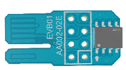
Gradiometers (AB-Series)										
Available Part	Linear Range (|Oe|) Min.	Linear Range (|Oe|) Max.	Saturation (|Oe|)	Sensitivity (%R/Oe) Min.	Sensitivity (%R/Oe) Max.	Max. Non-linearity (% Uni.)	Max. Hyst-eresis (% Uni.)	Max. Operating Temp.	Typ. Resist-ance	Package
AB001-02	10	175	250	0.02	0.03	2%	4%	125°C	2.5 kΩ	SOIC8
AB001-00	10	175	250	0.02	0.03	2%	4%	125°C	2.5 kΩ	MSOP8
ABH001-00	5	40	70	0.06	0.12	4%	15%	150°C	1.2 kΩ	MSOP8

Evaluation Kits and Breakout Boards

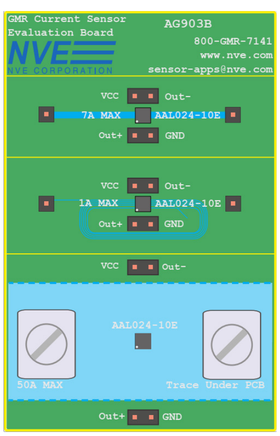
A number of evaluation kits and breakout boards are available for AA- and AB-Series sensors (visit https://www.nve.com/webstore/sensor-boards-and-eval-kits for details):



AG001-01: Analog Sensor Evaluation Kit
This kit features several types of NVE's AAxxx and ABxxx parts, a selection of ferrite magnets for activation or biasing, and circuit boards for testing.



AA00x-xx-EVB01: AA00x Breakout Boards
These 0.8 × 0.4 inch (21 × 10 mm) breakout boards include pre-soldered sensors, standard 0.1" (2.54 mm) header and a 1 mm pitch card-edge connector. Boards are available for most AAxxx sensors.

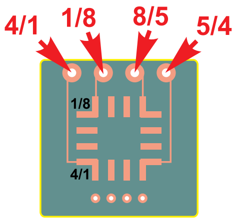


AG903B-07E: GMR Current Sensor Evaluation Kit
This board includes three AAL024-10E DFN current sensors on a PCB with three current-trace configurations, The board supports 0.75 amp, 5 amps, and 50 amp current ranges. The boards measure 1.565" × 2.915" (40 mm × 74 mm) and include sensor power and output connections, plus connections for the current to be measured.

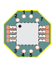
Bare Circuit Boards for Sensors

NVE offers several bare circuit boards specially designed for easy connections to surface-mount sensors. Popular PCBs are shown below (images are actual size):

AG004-06: 3" × 0.3" (75 × 8 mm) SOIC8 circuit board



AG005-06:
0.5" × 0.5" (13 mm x 13 mm)
SOIC8



AG915-06:
0.25" (6 mm) octagonal
MSOP8

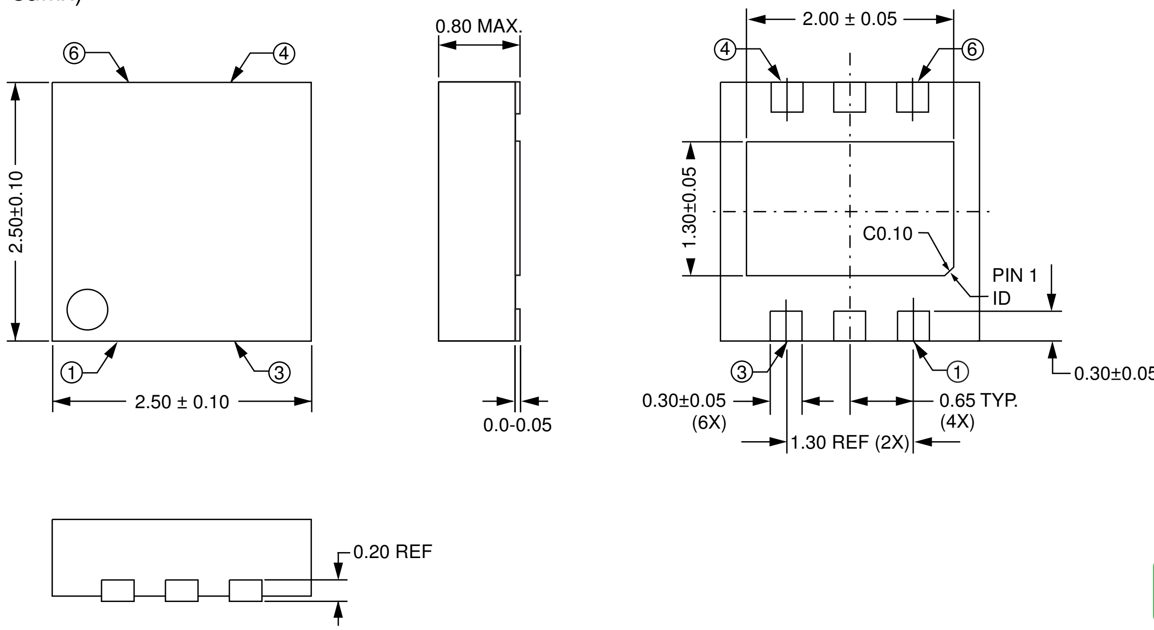
AG918-06 (standard) **/ AG919-06** (cross-axis):
2" × 0.25" (50 mm × 6 mm) MSOP8

AG035-06:
1.57" × 0.25" (40 mm × 6 mm) DFN6

NVE Corporation 11409 Valley View Road, Eden Prairie, MN 55344-3617 Phone: (952) 829-9217 sensor-apps@ nve.com www.nve.com

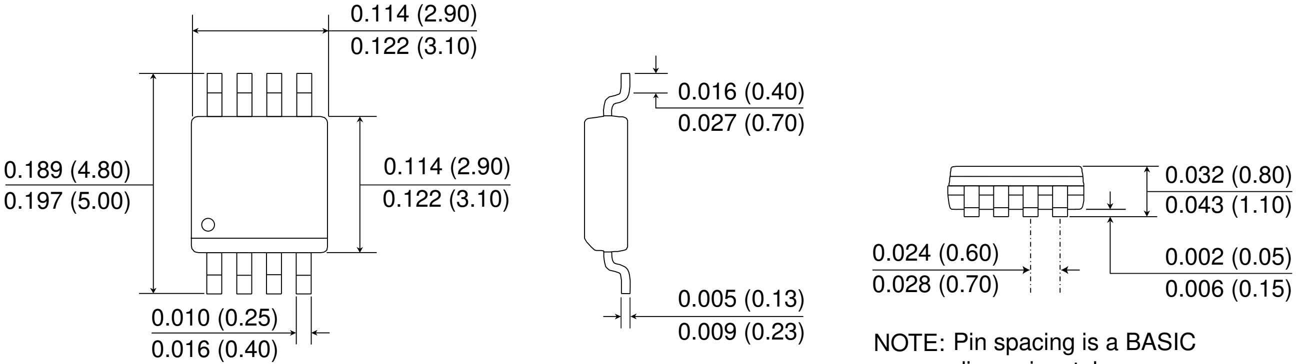
Package Drawings

DFN6 (-10 suffix)



RoHS COMPLIANT

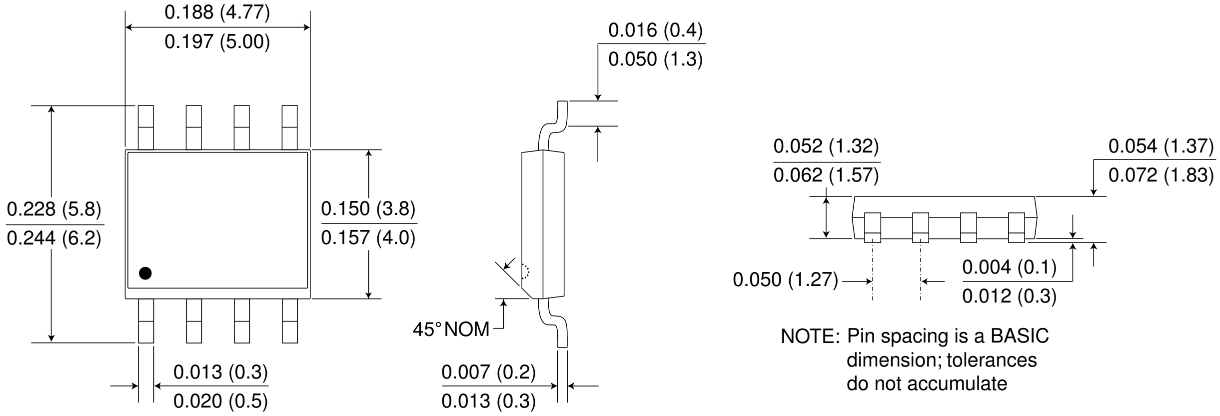
MSOP8 (-00 suffix)



NOTE: Pin spacing is a BASIC dimension; tolerances do not accumulate

RoHS COMPLIANT

SOIC8 (-02 suffix)



RoHS COMPLIANT

Soldering profiles per JEDEC J-STD-020C, MSL 1.

Revision History

SB-00-059-H
July 2025

Changes
- Improved AA00x/AB00x constant-voltage temperature coefficients from −0.10 to −0.05%/°C over full temperature range with new manufacturing process (p. 3).
- Eliminated AA00x/AB00x constant-current temperature coefficients (unnecessary with new process) (p. 3).
- Updated AA002 Typical Performance Graph for new manufacturing process (Fig. 5 on p. 6).
- Added graph of sensitivity vs. temperature (Fig. 8 on p. 7).
- Add a constant-current circuit using a voltage regulator (p. 9).
- Added AA004-10 and AA005-00; dropped obsolete AAK001.
- Added AA00x-xx-EVB01 breakout boards; deleted obsolete evaluation kits (p. 14).
- Standardized package names ("TDFN" and "ULLGA" replaced with DFN).

SB-00-059-G
July 2019

Changes
- Added SI units (mT) where appropriate.
- Added higher current-sensing trace illustration (p. 11).
- Revised AG903B-01 current sensor evaluation kit (p. 14).

SB-00-059-F
October 2018

Changes
- Improved AAL-Series bandwidth specification; specified −3 dB bandwidth (p. 3).
- Added AG903B high-current evaluation kit (p. 14).

SB-00-059-E
January 2018

Changes
- Added Absolute Maximum isolation specification for TDFN package (p. 2).
- Added TDFN Center Pad description (p. 12).
- Updated AAL004 and AAL024 linearity specification (p. 13).

SB-00-059-D
October 2017

Changes
- Added AAK001 ultrahigh-field model.
- Added LED field-strength indicator and current-sensing applications (p. 10).
- Added AA selector chart (p. 13).
- Added Evaluation Kits (p. 14) and bare circuit boards (p. 15).
- Misc. cosmetic changes and additional illustrations.

SB-00-059-C
September 2017

Change
- Added AA007-00E high-field model.

SB-00-059-B
August 2017

Change
- Added AA024-10E and AAL024-10E cross-axis versions.

SB-00-059-A
April 2017

Change
- Initial datasheet release superseding catalog.

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