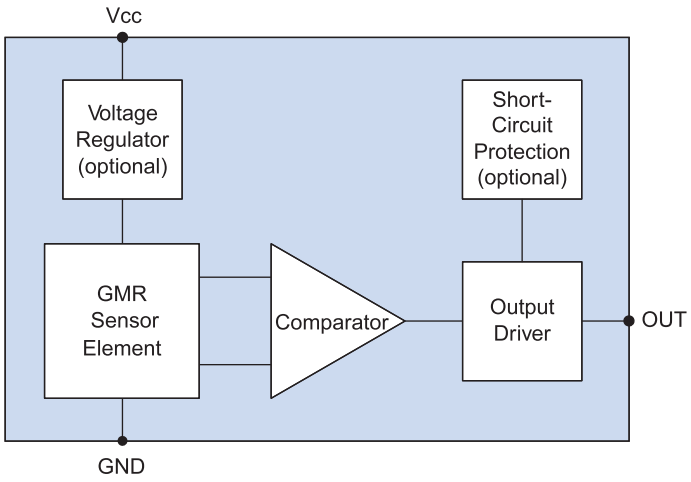
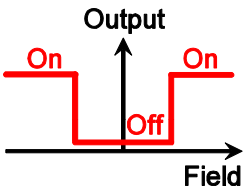
AD-Series GMR Switch™ Precision Digital Magnetic Sensors

Functional Diagram



Idealized Transfer Function



Features

- Digital outputs
- Precision operate points from 1 – 8 mT (10 – 80 Oe)
- 3 V – 6 V and 4.5 V – 30 V versions
- 20 mA output drive
- Temperature and voltage stability
- Available with short-circuit protection
- Standard or cross-axis orientation
- Frequency response to 100 kHz
- Ultraminiature DFN6 and MSOP8 packages

Applications

- Motion, speed, and position control
- Pneumatic cylinder position sensing
- Speed sensing

Description

AD-Series GMR Switches are the industry standard for sensitivity and precision.

GMR Switches integrate GMR sensor elements with digital signal processing electronics. These sensors are more precise than other magnetic sensors, and magnetic field operate points are stable over voltage and temperature extremes.

AD-Series models available in a wide variety of magnetic operate points and output configurations. Versions are available with short-circuit protection circuitry and with integrated voltage regulators.

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Absolute Maximum Ratings

Parameter		Symbol	Min.	Max.	Units	Test Conditions
Supply voltage	AD08x		−0.5	7	Volts	
	AD8xx/AD9xx		−0.5	33		
	All others	V_{CC}	−33	33		
Output voltage			−0.5	33	Volts	
Continuous output current				24	mA	
Operating temperature			−40	125	°C	
Storage temperature			−65	150	°C	
ESD				2000	Volts	Human Body Model
Applied magnetic field		B		Unlimited	tesla	

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Operating Specifications

Tmin to Tmax; 4.5 V < V_{CC} < 30 V unless otherwise stated.							
Parameter		**Symbol**	**Min.**	**Typ.**	**Max.**	**Units**	**Test Conditions**
Supply voltage		V_{CC}					
AD084			3		6	Volts	
All others			4.5		30		
Operating temperature		T_{MIN}; T_{MAX}	–40		125	°C	
Magnetic operate point							
ADH025		B_{OP}	0.8	1	1.2	mT*	
AD004; AD021; AD621			1.5	2	2.5		
AD024; AD084; AD824; AD924			2.1	2.8	3.3		
AD005; AD022			3	4	5		
AD913			5	6	7		
AD006; AD023			6	8	10		
Operate/release differential							
ADH025		B_{OP}–B_{REL}	0.2		0.8	mT*	
AD004; AD021; AD621			0.5		1.4		
AD024; AD084; AD824; AD924			0.5		1.5		
AD005; AD022			0.5		2.5		
AD913			0.5		2.2		
AD006; AD023			0.5		5		
Supply current	AD08x	I_{CC}		0.7	1.2	mA	V_{CC} = 5 V; Output Off
	AD0xx–AD7xx (except AD08x)			1.8			V_{CC} = 5 V; Output Off
				3			V_{CC} = 5 V; Output On
				2.5	4.5		V_{CC} = 12 V; Output Off
				4	6.5		V_{CC} = 12 V; Output On
				5.5			V_{CC} = 24 V; Output Off
				7.5			V_{CC} = 24 V; Output On
				6.3			V_{CC} = 30 V; Output Off
				8.3			V_{CC} = 30 V; Output On
	AD8xx/AD9xx			1.75	3.5		V_{CC} = 12 V; Output Off
				3	5.5		V_{CC} = 12 V; Output On
Output current	AD0xx–AD7xx	I_{O-ON}	20			mA	
	AD8xx/AD9xx		2				
Sinking output voltage	AD8xx/AD9xx	V_{OL}			0.4	V	V_{CC} = 12 V; I_O = 2 mA
	AD0xx–AD7xx				0.2		V_{CC} = 12 V; I_O = 20 mA
Sourcing output voltage	AD8xx/AD9xx	V_{OH}			V_{CC}–2		V_{CC} = 12 V
	AD0xx–AD7xx				V_{CC}–2.5		
Output leakage current (output Off)		I_{O-OFF}			10	µA	V_{CC} = 12 V
Short-circuit voltage (AD8xx/AD9xx only)		V_{Short}	0.12		0.17	V	Output On
Regulator output	AD4xx – AD7xx	V_{REG}		5.8	6.2	V	V_{CC} >6.6V; 0< I_{REG} <20 mA
			3.5	V_{CC} – 0.9			V_{CC} < 6.6 V
	AD8xx/AD9xx			5.8	6	V	V_{CC} >6.6V; 0< I_{REG} <20 mA
			3.5	V_{CC} – 0.9			V_{CC} < 6.6 V
Regulator output (AD4xx – AD9xx)		I_{REG}	3			mA	
Frequency response		f_{MAX}	100			kHz	
Junction–Ambient Thermal Resistance		θ_{JA}		320		°C/W	Double-sided PCB; free air

*1 mT = 10 Oe in air.

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Operation

Typical connections with an external pull-up resistor are shown below:

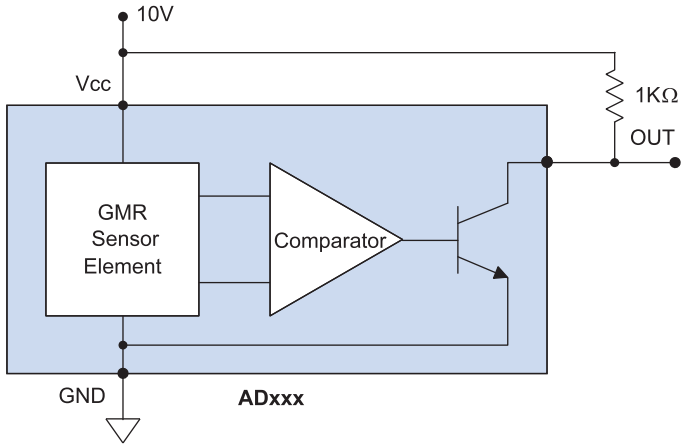

Figure 1. Typical connections.

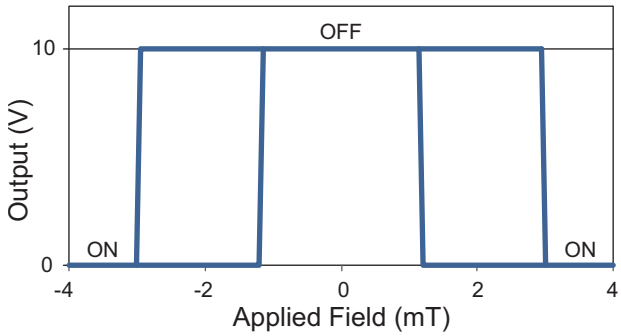

Figure 2a. Typical output vs. magnetic field
(**AD024** with a 10 V supply and 1 kΩ pull-up resistor).

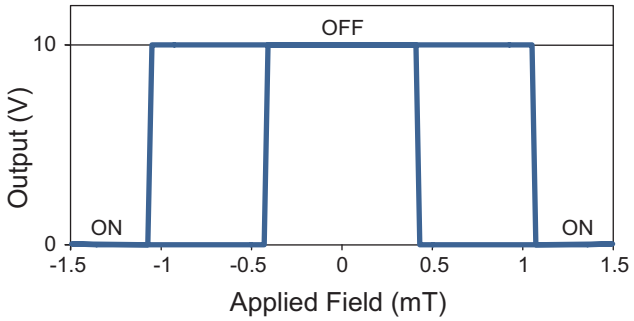

Figure 2b. Typical output vs. magnetic field
(**ADH025** with a 10 V supply and 1 kΩ pull-up resistor).

ON / OFF Behavior
AD-Series sensor outputs turn ON when the field exceeds the magnetic operate point, and OFF when the field drops below the operate point minus the release differential.

External Pull-Up Resistors
Outputs are open collector, with PNP output transistors for sourcing versions and NPN transistors for sinking versions. Outputs should have external pull-up or pull-down resistors. For microcontroller interfaces, the microcontroller's input pull-up resistors can be activated.

Omnipolar
GMR Switches are "omnipolar," which means the outputs turn ON when a magnetic field of either magnetic polarity is applied.

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In-Plane Magnetic Sensitivity

As the field varies in intensity, the digital output will turn on and off. Unlike Hall-effect or other sensors, the direction of sensitivity is in the plane of the package. The diagrams below show two permanent magnet orientations that will activate the sensor in the direction of sensitivity:

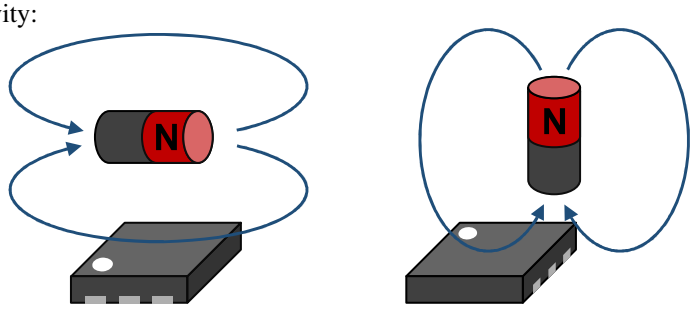

Figure 3. Planar magnetic sensitivity.

Standard and Cross-Axis Sensitivity

Standard AD-Series sensors are sensitive along the part axis as shown in Figure 4b, but a number of versions are available with cross-axis sensitivity (see Figure 4a):

Figure 4a.
Cross-axis sensitivity.

Figure 4b.
Standard sensitivity.

Typical Operation

A typical proximity sensor using an AD022 cross-axis sensor and magnet is shown in the figures below. This sensor has a 40 Oe typical operate point, and actuates with the magnet approximately 0.375 inches (9 mm) from the center of the sensor. Because the sensor is omnipolar, it will operate with either a north or south magnet face.

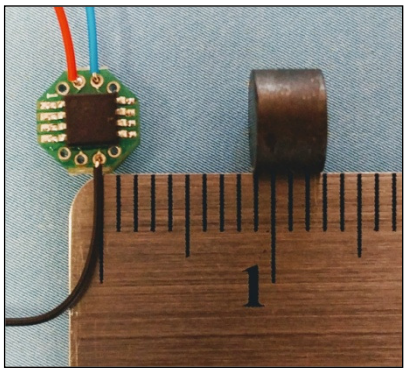

Figure 5. An AD022 sensor (pin 1 is upper left; the sensor has cross-axis sensitivity), on an AG015 circuit board with a 12031 8 mm dia. x 3 mm thick ferrite magnet. Sensor activates at approx. 9 mm distance. Red wire = V_{CC}; Blk = GND; Blue = OUT (Sink).

More sensitive sensors with lower magnetic operate points (such as the 1 mT ADH025-00E) operate with the magnet farther away. Stronger or larger magnets will also increase the operate distance. Our most sensitive digital sensor (the AFL006; see AFL-Series sensor datasheet) has been demonstrated to operate with a rare-earth magnet at an air gap of two inches (50 mm) or more.

We have a free, Web-based application that provides fields and operate distances for various sensor and magnet types:

www.nve.com/spec/calculators.php

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Illustrative Application Circuits

Integrated Short-Circuit Protection

AD8xx and AD9xx models include integrated Short Circuit Protection ("SCP") circuitry. A detailed block diagram of these devices is shown below:

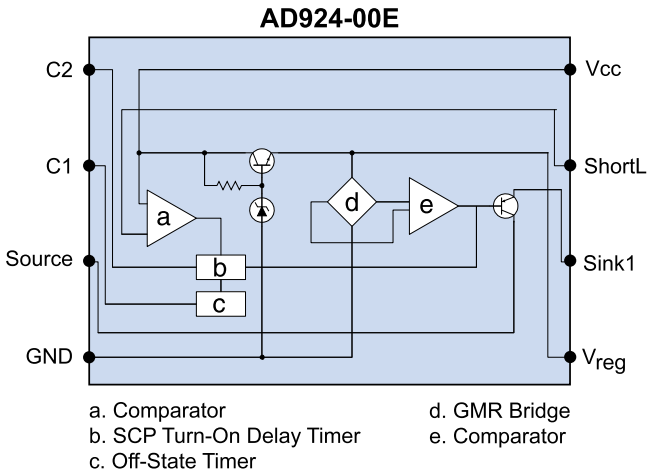


Figure 6. Detailed block-diagram of the AD924 sensor with short-circuit protection circuitry.

Typical SCP external circuitry for sourcing and sinking SCP versions are shown in the following schematics:

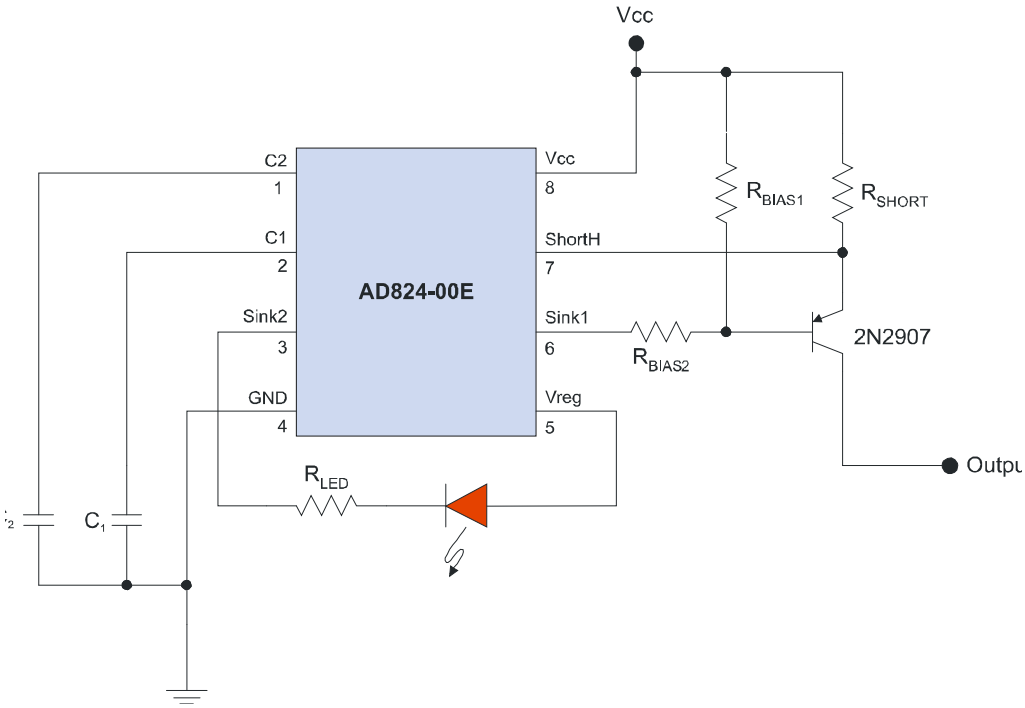


Figure 7. Short-circuit protection circuitry (sourcing output).

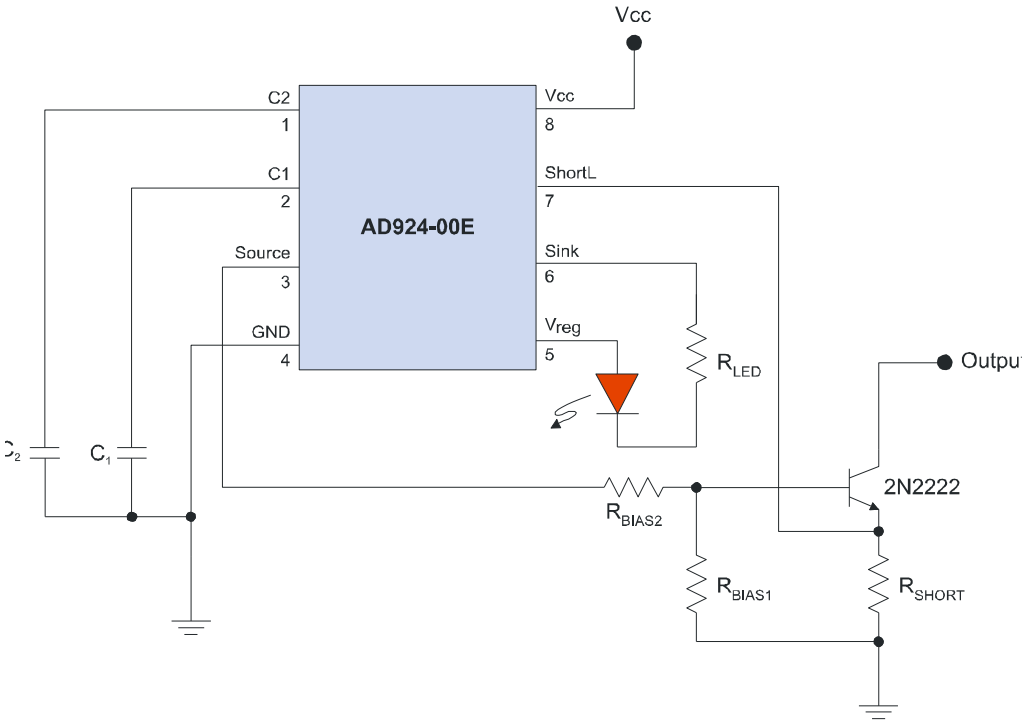


Figure 8. Short-circuit protection circuitry (sinking output).

If the voltage across R_{SHORT} exceeds 145 mV (typical), the SCP circuitry is activated. An R_{SHORT} of 0.47Ω provides a protection threshold of approximately 300 mA.

Capacitor C_2 delays the shutdown so normal startup transients do not trigger the circuitry; a 0.001 µF capacitor can be used for a typical 35 µs delay (t_1). C_1 sets the SCP "OFF" time (t_2), which is typically 0.01 µF for 15 ms OFF time.

The short-circuit output current using these typical component values is shown below:

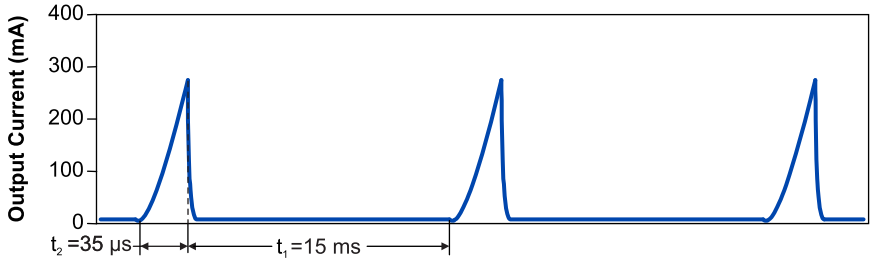


Figure 9. AD821 / AD921 output current with typical SCP components and output shorted (see Figures 7 and 8 for circuits).

R_{BIAS1} and R_{BIAS2} bias the output transistor. Typical values for are 16 KΩ for R_{BIAS1} and 3 KΩ for R_{BIAS2}, which provides 1 mA of transistor base current. R_{LED} sets the LED current up to a maximum of 3 mA.

External Short-Circuit Protection

NVE offers a separate Power Switch IC, the DB001-00, for sensor Short Circuit Protection of sensors that do not have SCP support. The DB001 also provides a high-current output, reverse battery protection, and transient protection.

A typical circuit is as follows:

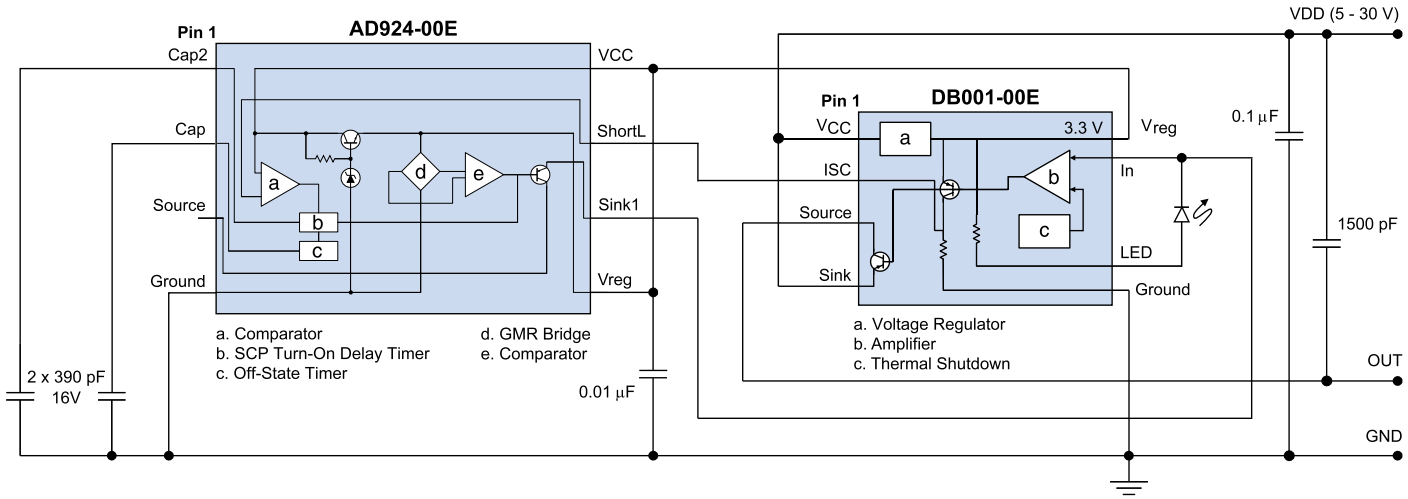


Figure 10. A GMR Switch with an external power switch IC for a high-power output, bullet-proof system.

Typical Performance Graphs

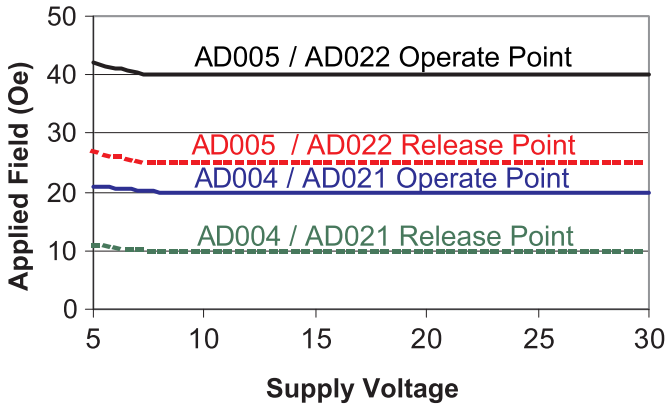


Figure 11. Typical Operate and Release Points vs. supply voltage (25°C).

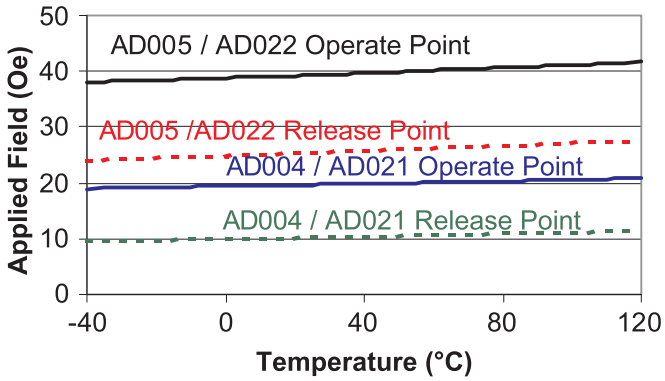


Figure 12. Typical Operate and Release Points vs. temperature (12 V).

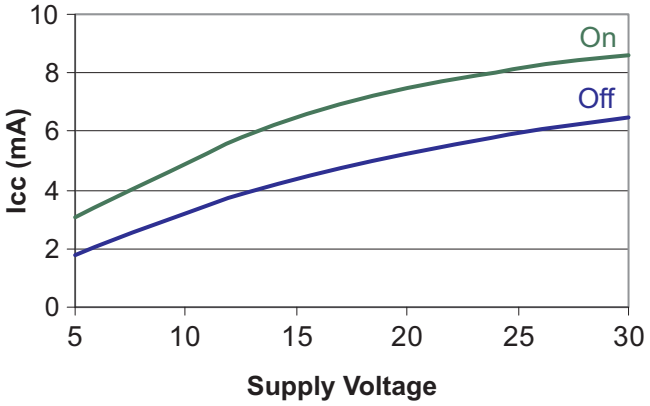


Figure 13. Typical AD0xx supply current vs. supply voltage.

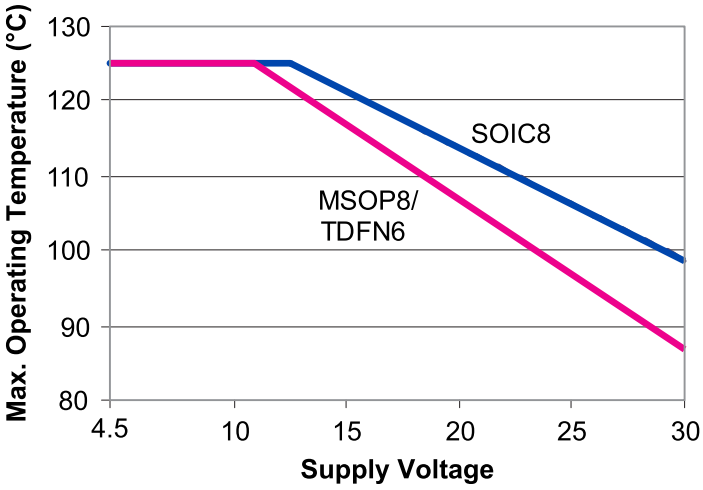


Figure 14. Operating temperature derating (free air).

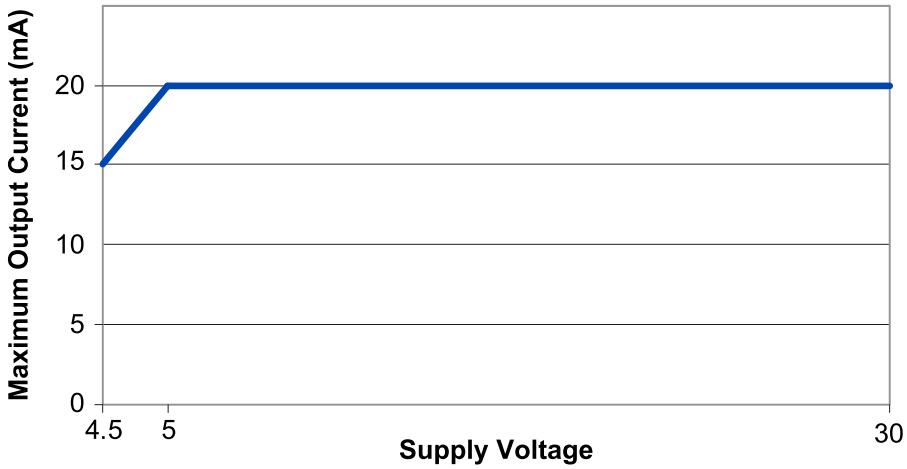


Figure 15. Output current vs. supply voltage.

Part Numbering

AD 0 21 - 00E

Base Part
AD = Standard digital switches

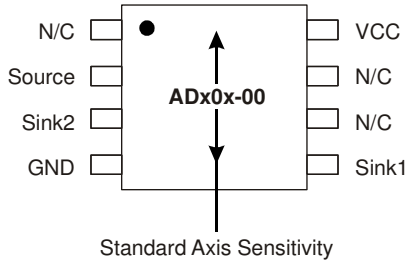
Outputs
0 = Sink1
1 = Source
2 = Sink1 + Source
3 = Sink1 + Sink2
4 = Sink + Regulated Output
5 = Source + Regulated Output
6 = Sink + Source + Regulated Output
7 = Two Sinks + Regulated Output
8 = Two Sinks + Regulated Output + Short-Circuit Protection
9 = Sink + Source + Regulated Output + Short-Circuit Protection
08 = Sink1 (3.3V/5V version)

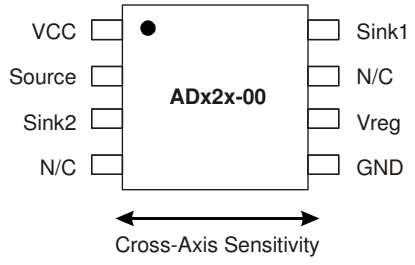
Operating Field
04 = 2 mT; Standard Direction
05 = 4 mT; Standard Direction
06 = 8 mT; Standard Direction
21 = 2 mT; Cross-Axis Sensitivity
22 = 4 mT; Cross-Axis Sensitivity
23 = 8 mT; Cross-Axis Sensitivity
24 = 2.8 mT; Cross-Axis Sensitivity
25 = 1 mT; Cross-Axis Sensitivity

Package Type
00 = MSOP8
10 = DFN6
E = RoHS

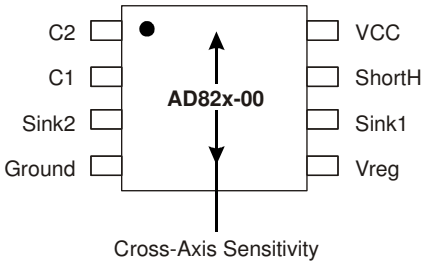
Pinouts

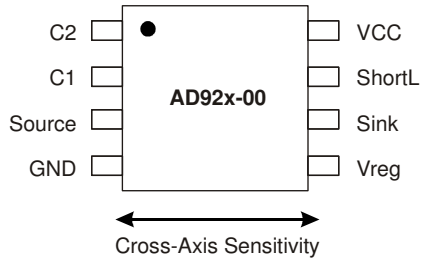
MSOP GMR Switches Without Short-Circuit Protection (AD0xx-00 – AD7xx-00; ADH0xx-00):



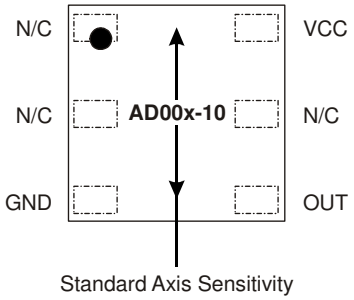


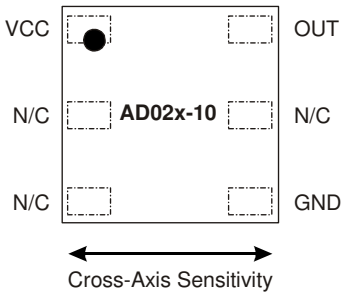
MSOP GMR Switches with Short-Circuit Protection (AD8xx-00 – AD9xx-00):





DFN GMR Switches (AD0xx-10):





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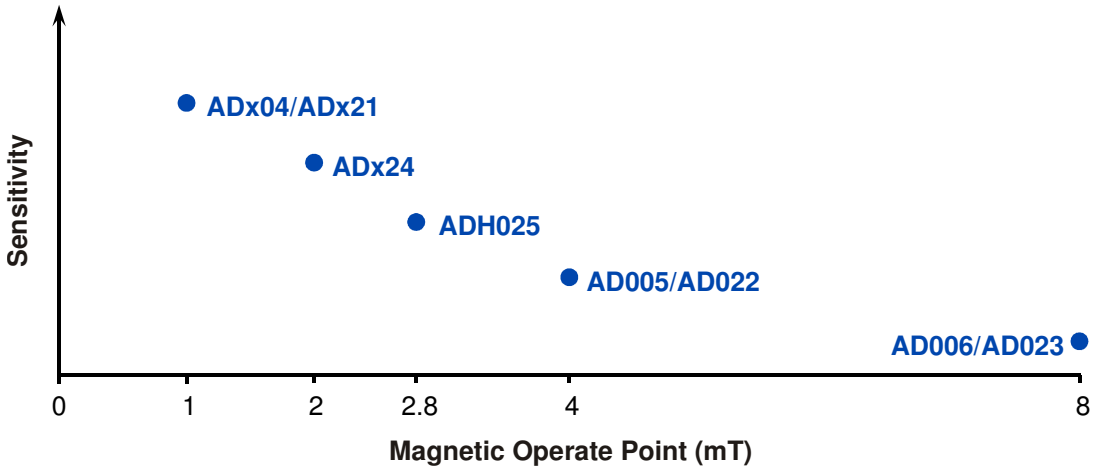
Operating Point Chart



Available Parts

Available Part	Operate Point (typ.)	Release Point (typ.)	Magnetic Orientation	Output; Features	Max. Operating Temperature	Package
AD004-00E	2 mT	1 mT	Standard	Sink	125 °C	MSOP8
AD005-00E	4 mT	2.5 mT	Standard	Sink	125 °C	MSOP8
AD006-00E	8 mT	5 mT	Standard	Sink	125 °C	MSOP8
AD021-00E	2 mT	1 mT	Cross-axis	Sink	125 °C	MSOP8
AD022-00E	4 mT	2.5 mT	Cross-axis	Sink	125 °C	MSOP8
AD024-00E	2.8 mT	1.4 mT	Cross-axis	Sink	125 °C	MSOP8
AD024-10E	2.8 mT	1.4 mT	Cross-axis	Sink	125 °C	DFN6
AD023-00E	8 mT	5 mT	Cross-axis	Sink	125 °C	MSOP8
AD084-00E	2.8 mT	1.4 mT	Cross-axis	Sink; 3 to 6 V operation	125 °C	MSOP8
AD621-00E	2 mT	1 mT	Cross-axis	Sink+Source+Regulator	125 °C	MSOP8
AD624-00E	2.8 mT	1.4 mT	Cross-axis	Sink+Source+Regulator	125 °C	MSOP8
AD622-00E	4 mT	2.5 mT	Cross-axis	Sink+Source+Regulator	125 °C	MSOP8
AD623-00E	8 mT	5 mT	Cross-axis	Sink+Source+Regulator	125 °C	MSOP8
AD721-00E	2 mT	1 mT	Cross-axis	Two Sinks + Regulator	125 °C	MSOP8
AD724-00E	2.8 mT	1.4 mT	Cross-axis	Two Sinks + Regulator	125 °C	MSOP8
AD722-00E	4 mT	2.5 mT	Cross-axis	Two Sinks + Regulator	125 °C	MSOP8
AD723-00E	8 mT	5 mT	Cross-axis	Two Sinks + Regulator	125 °C	MSOP8
AD824-00E	2.8 mT	1.4 mT	Cross-axis	Two Sinks + Short-Circuit Protection	125 °C	MSOP8
AD913-00E	6 mT	3.5 mT	Cross-axis	Sink+Source + Short-Circuit Protection	125 °C	MSOP8
AD924-00E	2.8 mT	1.4 mT	Cross-axis	Sink+Source + Short-Circuit Protection	125 °C	MSOP8
ADH025-00E	1 mT	0.5 mT	Cross-axis	Sink	150 °C	MSOP8

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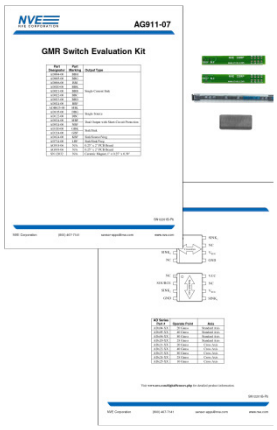
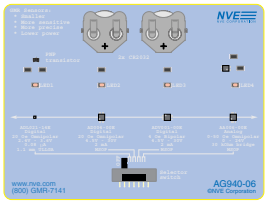
Evaluation Kits

Two inexpensive evaluation kits including AD-Series GMR switches are available:



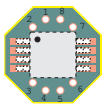
AG910-07/AG911-07—GMR Switch Evaluation Kits
Several GMR Switches with different magnetic operate points and different output options such as current sink and current source. Magnets and circuit boards for mounting the parts are also included. The AG910-07 kit also includes a zero insertion force (ZIF) socket for easy testing of the MSOP-packaged sensors.



AG940-07E: Digital/Analog/Omnipolar/Bipolar Sensor Demo Board
The kit includes a demo board with our most popular digital, analog, omnipolar, and bipolar sensors, including an AD004-00 digital sensor. Each sensor drives an indicator LED. A bar magnet is included so you can see for yourself how the sensors work. The evaluation boards are 3.75 by 5 inches (95 mm by 127 mm), and are powered by two coin cells (included).

Bare Circuit Boards for Sensors

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



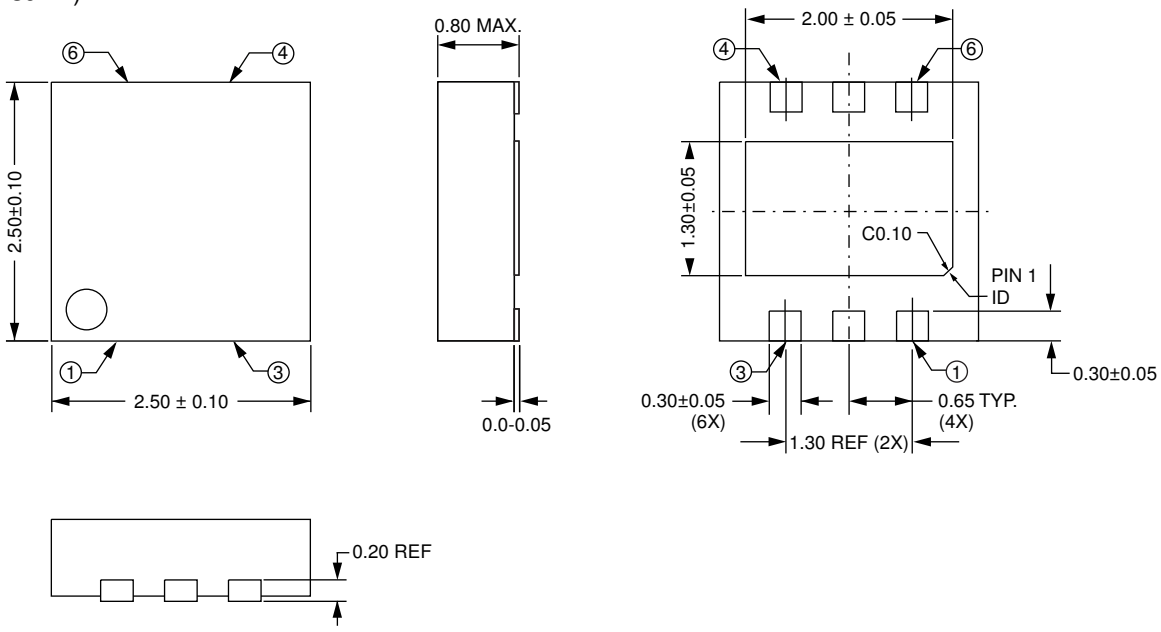
AG915-06:
0.25" (6 mm) octagonal
MSOP8

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

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

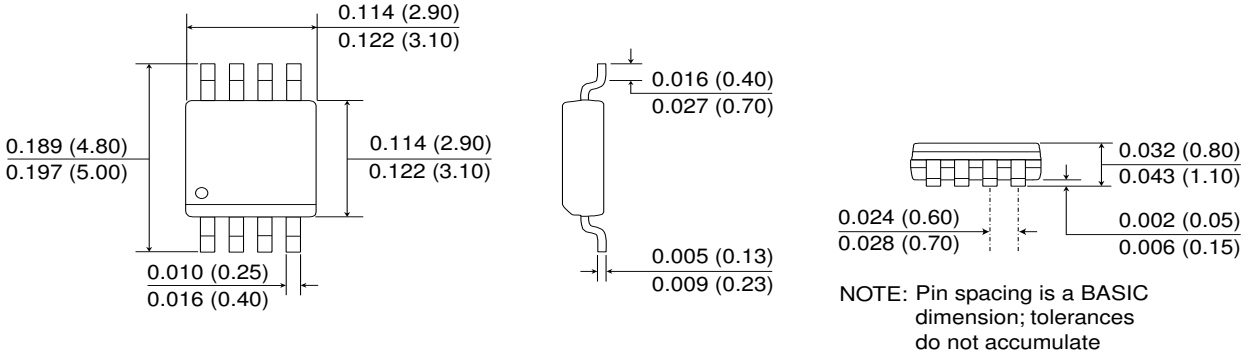
Package Drawings

DFN6 (-10 suffix)



MSOP8 (-00 suffix)

Dimensions in inches (mm); scale = approx. 5X



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

Soldering profiles per JEDEC J-STD-020C, MSL1

RoHS COMPLIANT

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

Revision History

SB-00-060-I
April 2024

Changes
- Corrected MSOP standard-axis pinout (p. 10).
- Additional AD62x-00E and AD72x-00E available parts (p. 11).
- Misc. cosmetic changes.

SB-00-060-H
July 2021

Change
- Added AD913-00E.

SB-00-060-G
March 2020

Changes
- Added 3 V to 6 V version (AD084-00E).
- Added supply current specifications with output on and at various supply voltages (p. 3).
- Clarified Figs. 2a and 2b (p. 4).
- Added graph of typical AD0xx supply current vs. supply voltage (p. 9).

SB-00-060-F
November 2019

Changes
- Changed Figure 7 from AD921-00 to AD924-00E (p. 6).
- Added cross-axis versions to Figures 10 and 11 graphs (p. 8).
- Corrected TDFN standard-axis and cross-axis diagrams (p. 9).
- Added AD924-00E to “Stock Parts” (p. 10).

SB-00-060-E
October 2019

Changes
- Added AD023-00E (8 mT cross-axis GMR Switch).
- Added “Magnetic Orientation” (standard or cross-axis) to “Stock Parts” list (p. 10).
- SI units (mT) in addition to oersteds.
- Improved Figs. 3 and 4 (p. 4).

SB-00-060-D
October 2017

Changes
- Added description and image for “Typical Operation” (p. 4).
- Changed pin 5 of AD00x-10 drawing to “NC” instead of “Test” (p. 9).
- Added Operating Point Chart (p. 10).
- Added Evaluation Kits and bare circuit boards (p. 11).

SB-00-060-C
September 2017

Changes
- Added AD006-00E (80 Oe GMR Switch).
- Misc. cosmetic changes.

SB-00-060-B
August 2017

Changes
- Eliminated SOIC package option.
- Misc. cosmetic changes.

SB-00-060-A
March 2017

Change
- Initial datasheet release superseding catalog.

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NVE Corporation
11409 Valley View Road
Eden Prairie, MN 55344-3617 USA
Telephone: (952) 829-9217
www.nve.com
www.youtube.com/NveCorporation

e-mail: sensor-info@nve.com

SB-00-060_RevI

April 2024