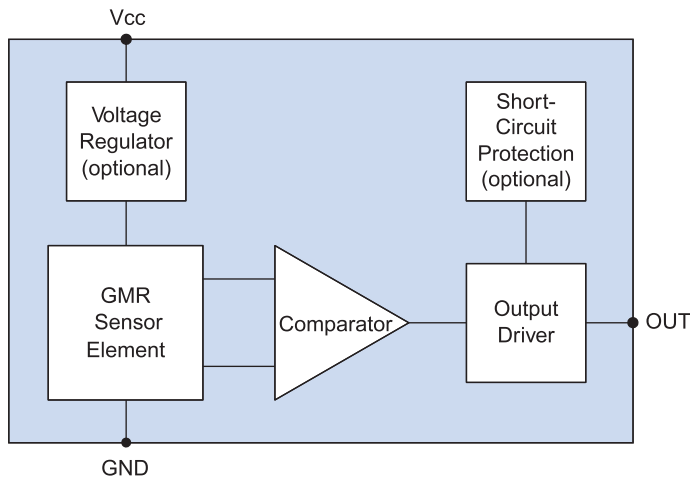


AD-Series GMR Switch™ Precision Digital Magnetic Sensors

Functional Diagram



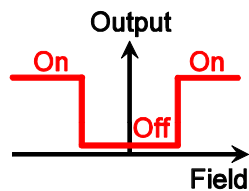
Features

- 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
- Models available with short-circuit protection
- Standard or cross-axis orientation
- Frequency response to 100 kHz
- Ultraminiature TDFN6 and MSOP8 packages

Applications

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

Idealized Transfer Function



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.

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 | |

Operating Specifications

| T _{min} to T _{max} ; 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 | B _{OP} | | | | mT* | |
| ADH025 | | 0.8 | 1 | 1.2 | | |
| AD004; AD021; AD621 | | 1.5 | 2 | 2.5 | | |
| AD024; AD084 | | 2.1 | 2.8 | 3.3 | | |
| AD005; AD022 | | 3 | 4 | 5 | | |
| AD006; AD023 | 6 | 8 | 10 | | | |
| Operate/release differential | B _{OP} -B _{REL} | | | | mT* | |
| ADH025 | | 0.2 | | 0.8 | | |
| AD004; AD021; AD621 | | 0.5 | | 1.4 | | |
| AD024; AD084 | | 0.5 | | 1.5 | | |
| AD005; AD022 | | 0.5 | | 2.5 | | |
| AD006; AD023 | 0.5 | | 5 | | | |
| Supply current | AD08x | | 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 | 20 | | | | |
| | AD8xx/AD9xx | 2 | | | | |
| Sinking output voltage | AD8xx/AD9xx | | | 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 _{CC} -2 | V | 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 | | 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 Oe = 0.1 mT in air.

Operation

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

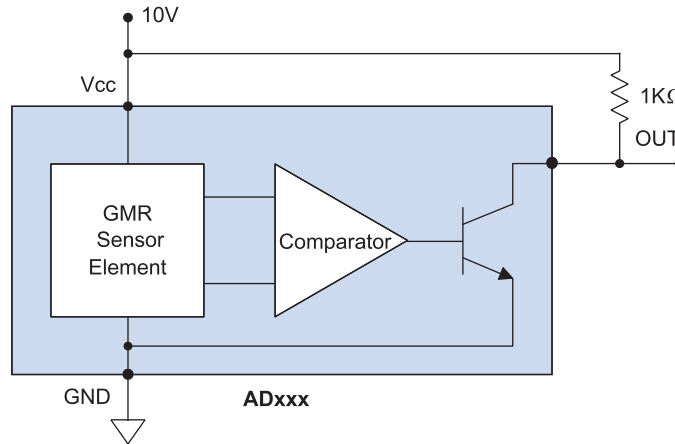


Figure 1. Typical connections.

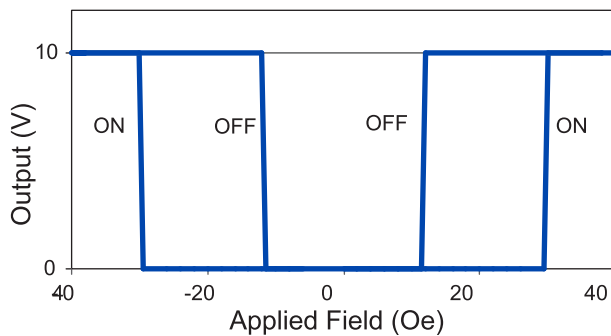


Figure 2a. Typical output vs. magnetic field
(AD024 with a 10 V supply and 1 KΩ pull-up resistor).

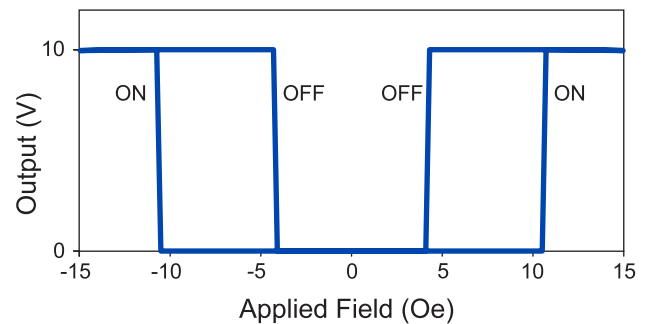


Figure 2b. Typical output vs. magnetic field
(ADH025 with a 10 V supply and 1 KΩ pull-up resistor).

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.

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:

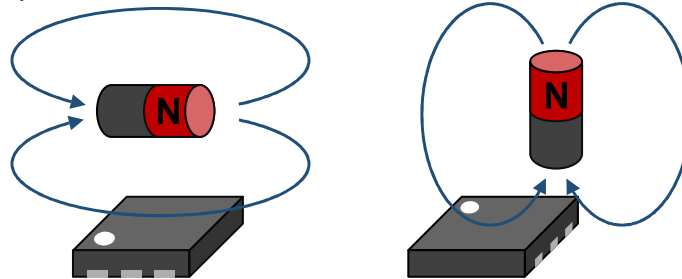
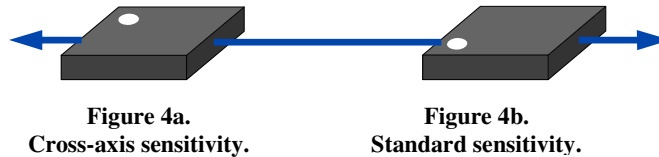


Figure 3. Planar magnetic sensitivity.

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):



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.

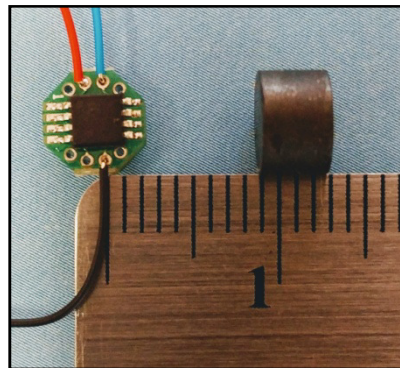


Figure 5. An AD022 sensor (pin 1 is upper left; the sensor has cross-axis sensitivity), on an AG015 circuit board with a 12031 8 mm dia. x 3 mm thick ferrite magnet. Sensor activates at approx. 9 mm distance. Red wire = V_{CC}; Blk = GND; Blue = OUT (Sink).

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

Illustrative Application Circuits

Integrated Short-Circuit Protection

AD8xx and AD9xx models include integrated Short Circuit Protection (“SCP”) circuitry. A detailed block diagram of such a device is shown below:

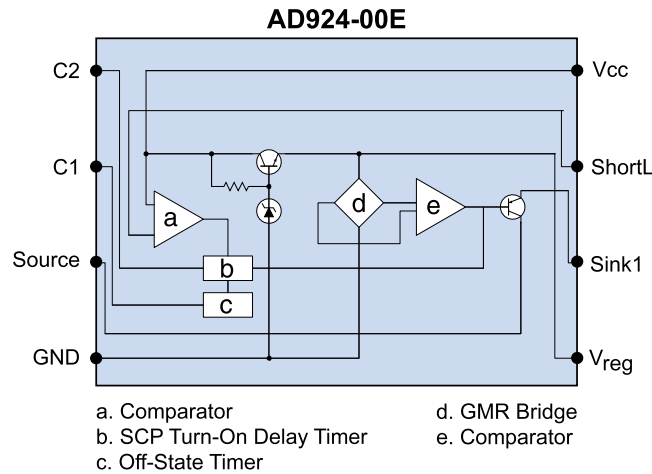


Figure 5. Detailed block-diagram of the AD924 sensor with short-circuit protection circuitry.

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

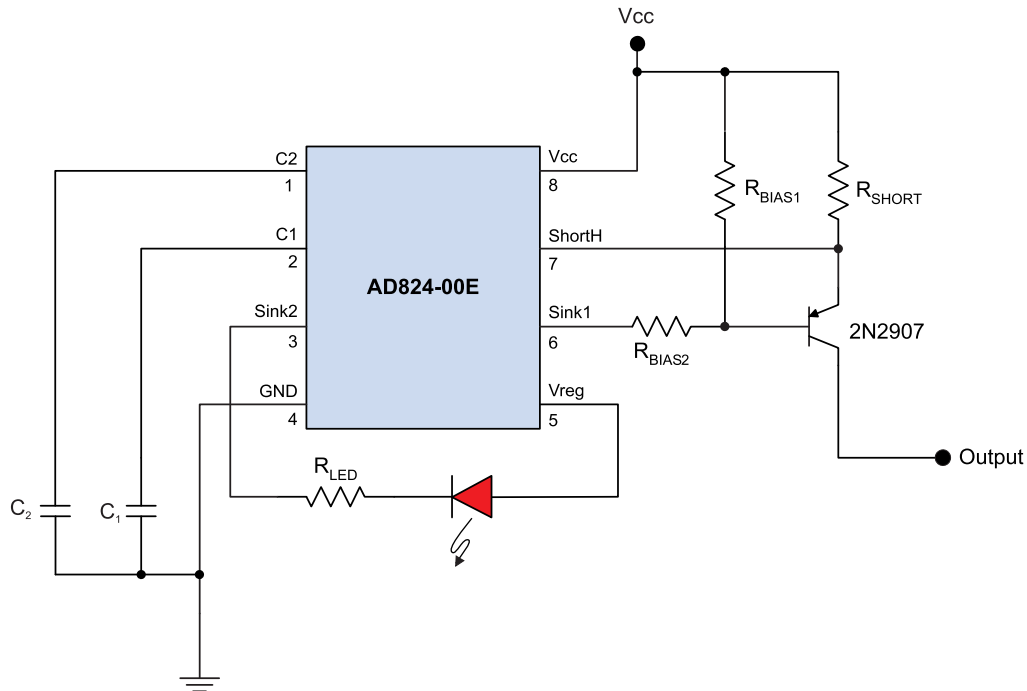


Figure 6. Short-circuit protection circuitry (sourcing output).

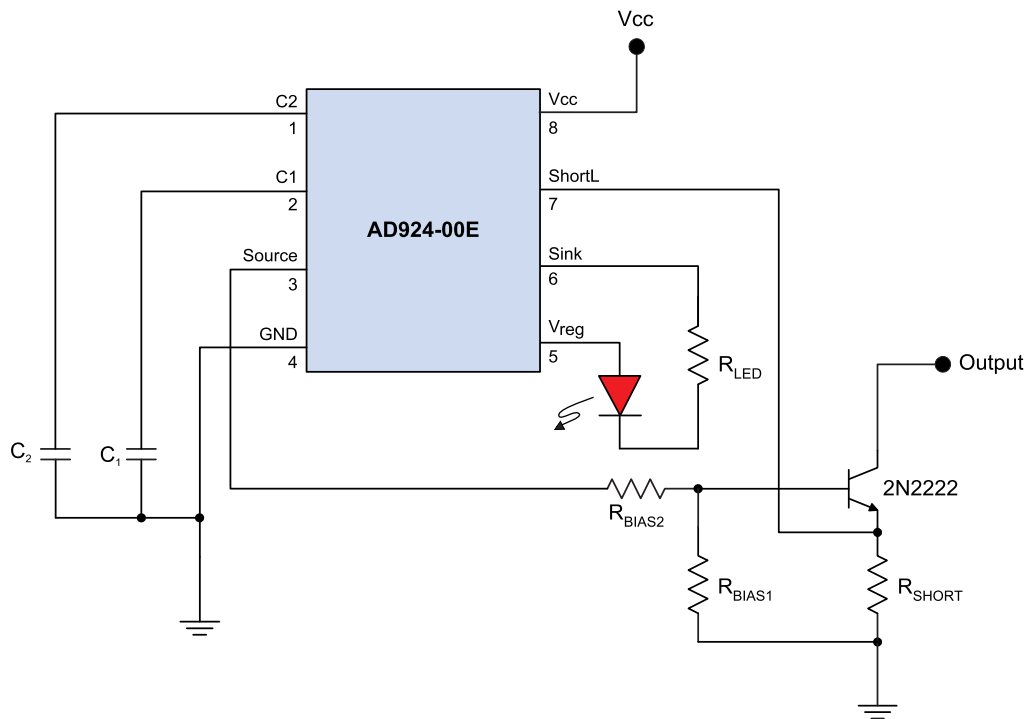


Figure 7. Short-circuit protection circuitry (sinking output).

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

Capacitor C_2 delays the shutdown so normal startup transients do not trigger the circuitry; a $0.001\ \mu\text{F}$ capacitor can be used for a typical $35\ \mu\text{s}$ delay (t_1). C_1 sets the SCP “OFF” time (t_2), which is typically $0.01\ \mu\text{F}$ for 15 ms OFF time.

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

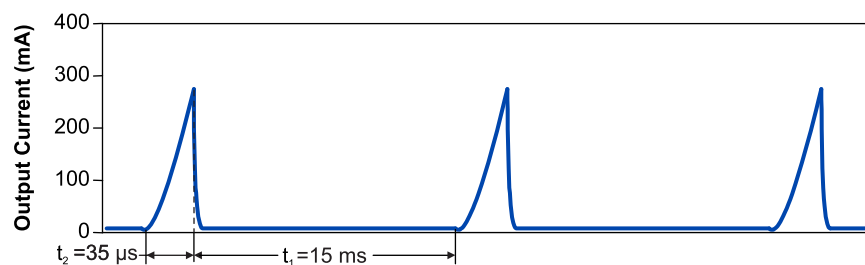


Figure 8. AD821 / AD921 output current with typical SCP components and output shorted (see Figures 5 and 6 for circuits).

R_{BIAS1} and R_{BIAS2} bias the output transistor. Typical values for are $16\ \text{K}\Omega$ for R_{BIAS1} and $3\ \text{K}\Omega$ 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:

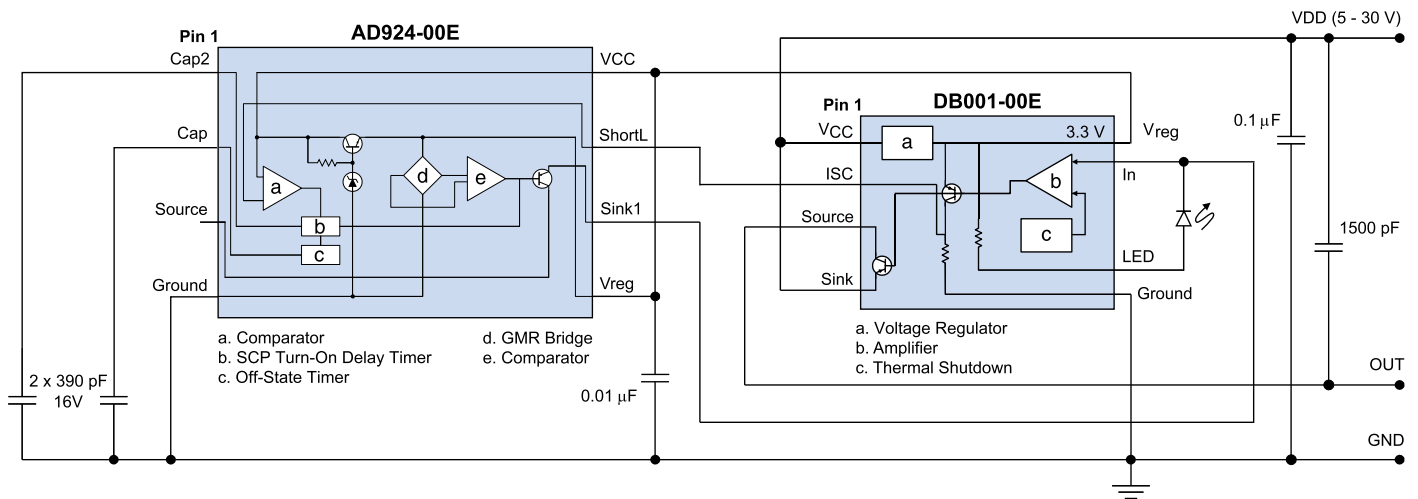


Figure 9. A GMR Switch with an external power switch IC for a high-power output, bullet-proof system.

Typical Performance Graphs

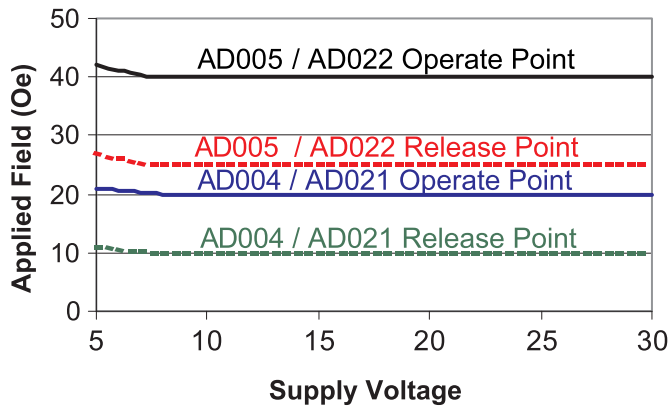


Figure 10. Typical Operate and Release Points vs. supply voltage (25°C).

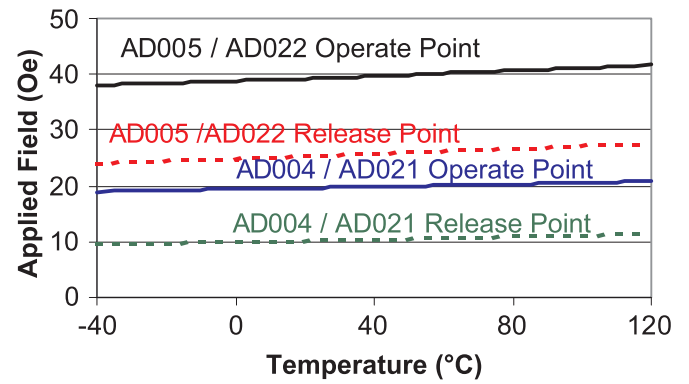


Figure 11. Typical Operate and Release Points vs. temperature (12 V).

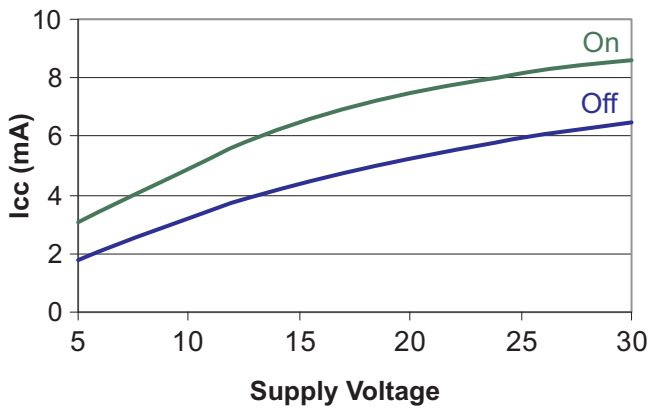


Figure 12. Typical AD0xx supply current vs. supply voltage.

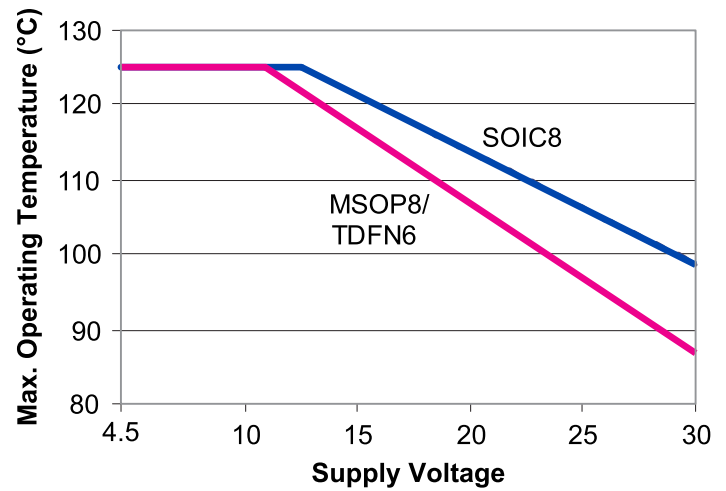


Figure 13. Operating temperature derating (free air).

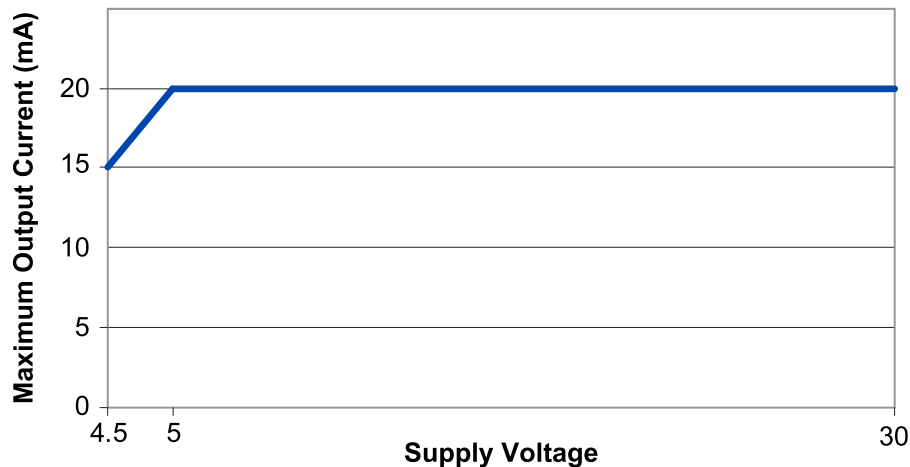
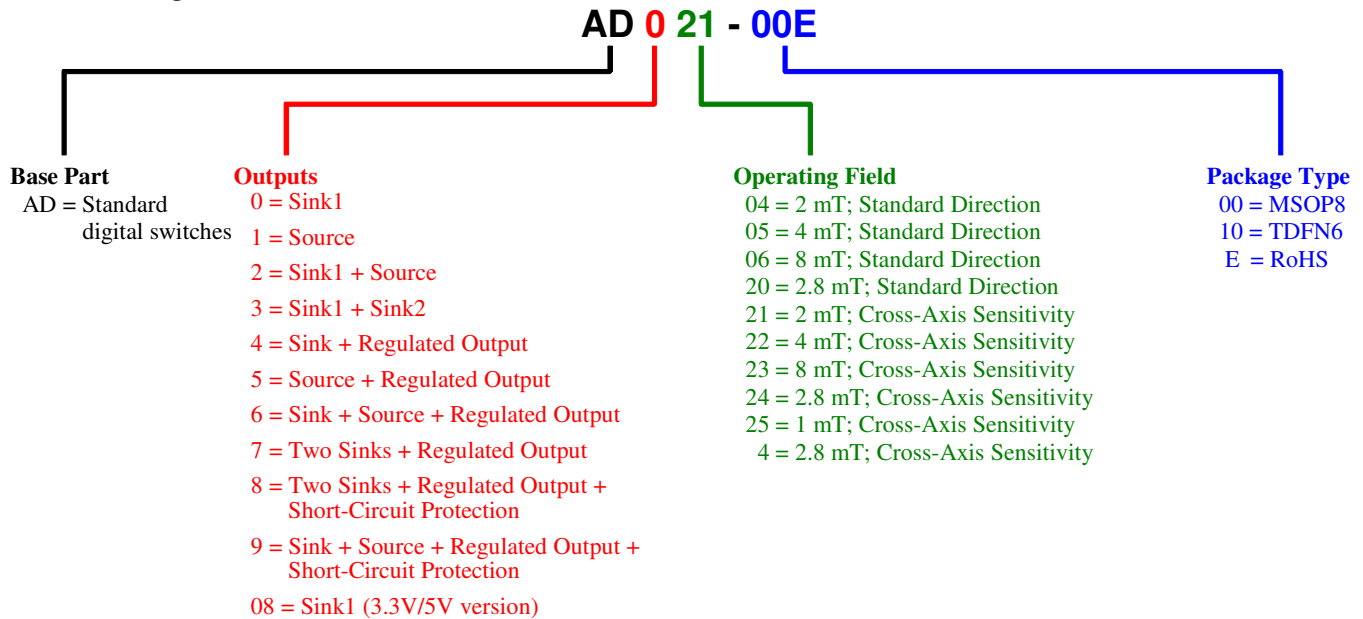


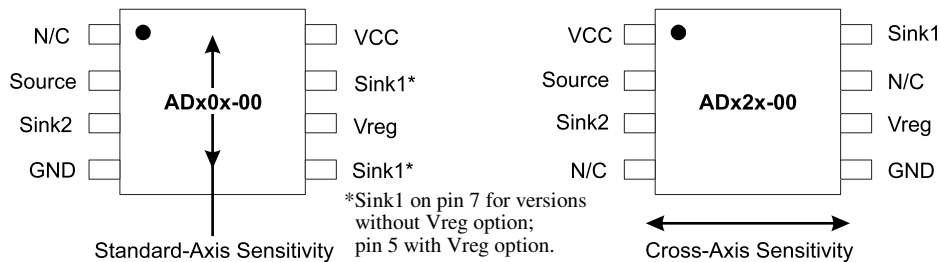
Figure 14. Output current vs. supply voltage.

Part Numbering

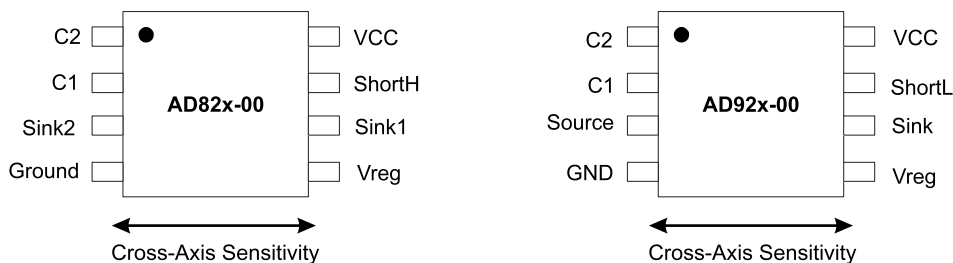


Pinouts

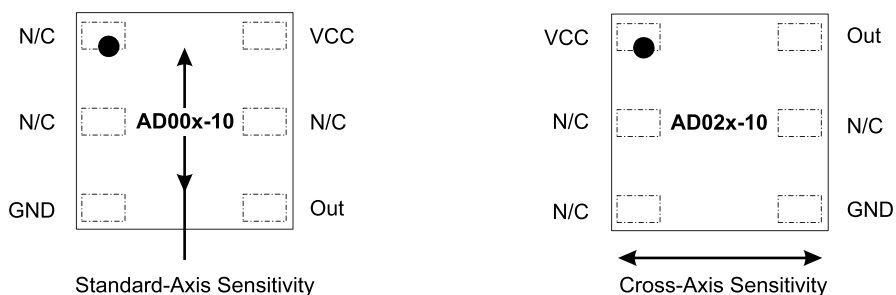
MSOP GMR Switches Without Short-Circuit Protection (AD0xx-00 – AD7xx-00; ADH0xx-00):



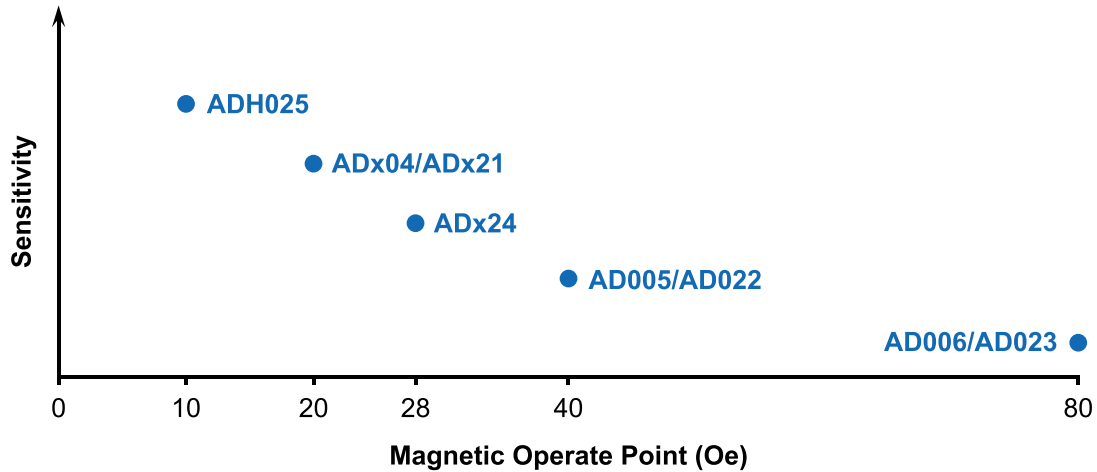
MSOP GMR Switches With Short-Circuit Protection (AD8xx-00 – AD9xx-00):



TDFN GMR Switches (AD0xx-10):



Operating Point Chart

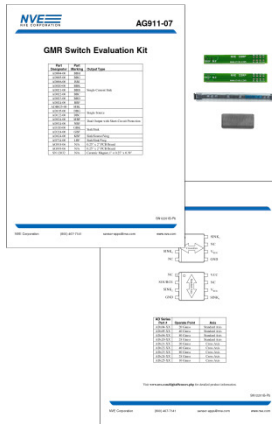


Stock Parts

| 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 | TDFN6 |
| 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 | 125 °C | MSOP8 |
| AD824-00E | 2.8 mT | 1.4 mT | Cross-axis | 2 Sinks + 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 |

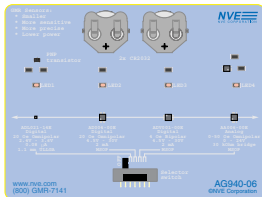
Evaluation Kits

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.

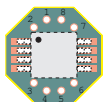


AG940-07E: Digital/Analog/Omnipolar/Bipolar Sensor Demo Board

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 specially designed 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



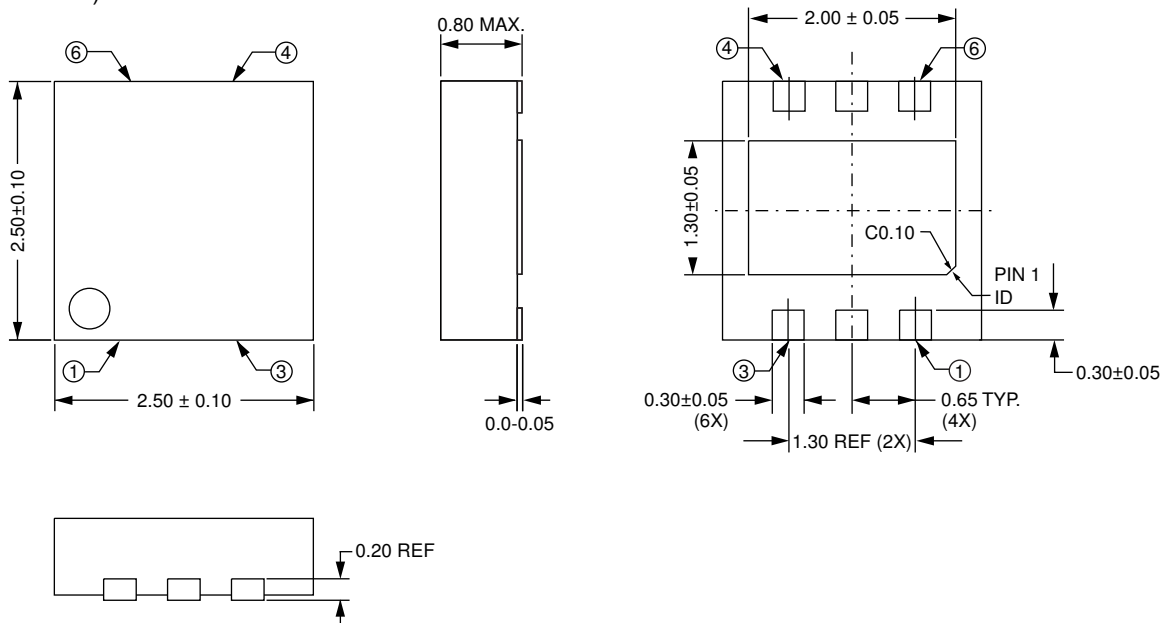
AG918-06 (standard) / **AG919-06** (cross-axis):
2" x 0.25" (50 mm x 6 mm) MSOP8



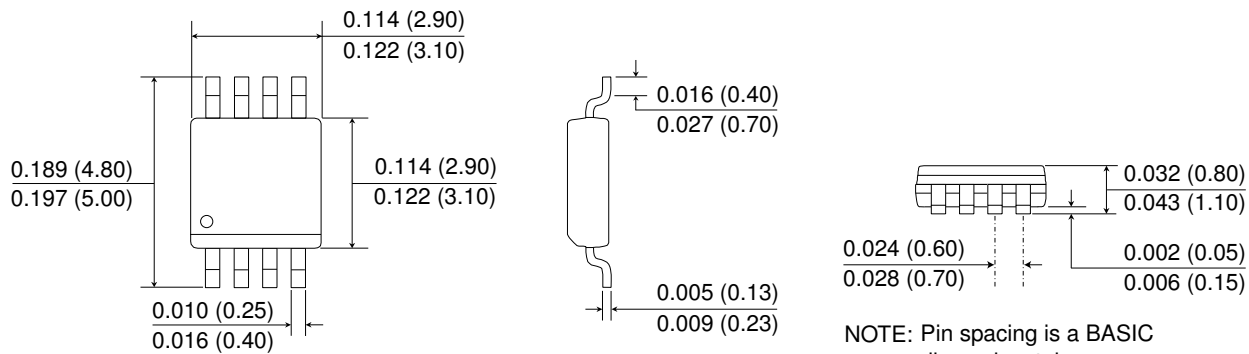
AG035-06:
1.57" x 0.25" (40 mm x 6 mm) TDFN6

Package Drawings

TDFN6 (-10 suffix)



MSOP8 (-00 suffix)



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

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



Revision History

SB-00-060-G

March 2020

Change

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

SB-00-060-F

November 2019

Change

- 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

Change

- 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

Change

- 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

Change

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

SB-00-060-B

August 2017

Change

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

SB-00-060-A

March 2017

Change

- Initial datasheet release superseding catalog.

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SB-00-060_RevG

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