GT Sensors™

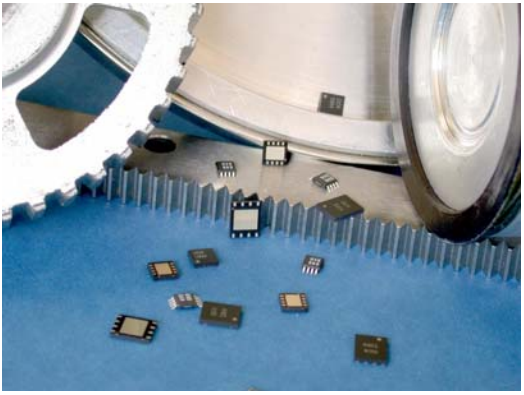
Precision Gear Tooth and Encoder Sensors

NVE's GT Sensor™ products are based on a Low Hysteresis GMR sensor material, and are designed for use in industrial speed applications where magnetic detection of gear teeth and magnetic encoder wheels is required.

GT Sensors with both analog and digital outputs are available. The analog parts feature the large signal and robust characteristics which NVE's GMR materials are known for (NVE's GMR sensors are not damaged by extremely large magnetic fields). The sensor elements themselves are designed to provide usable output with even the smallest gear teeth. Single and double output versions are available; the second output is phase shifted with respect to the first, to provide quadrature for determining direction.

The digital sensors take advantage of the high performance characteristics of GMR sensors to provide a 50% duty cycle output with a wide tolerance in airgap and temperature variations.

GT Sensors are available in low profile MSOP8, TDFN SO8, and TDFN6 packages, in order to fit into the tightest possible spaces. An evaluation kit is available, containing a selection of sensors, magnets, and PCBs, so that the user can test the parts in their application.



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11/15/02

ABL Sensors
Single/Double Bridge Gear Tooth And Encoder Sensors

Features:
⇒ Large Airgap
⇒ Direct Analog Output
⇒ DC (Zero Speed) Operation
⇒ Sine / Cosine Outputs
⇒ Precise Spacing and Phase Shifting Between Sensor Elements
⇒ Excellent Temperature and Voltage Performance
⇒ Small, Low Profile Surface Mount Packages

Applications:
⇒ Linear and Angular Speed Sensing
⇒ Linear and Angular Position Sensing
⇒ Direction Detection

Description:
The ABL Series GT Sensors are differential sensor elements that provide an analog sinusoidal output signal when used with a bias magnet and gear tooth or a magnetic encoder. These chips use NVE's proprietary GMR sensor elements, featuring an extremely large output signal from the raw sensor element, which is stable over the rated temperature and voltage range. As a result, ABL Series GT Sensors feature excellent airgap performance and an extremely stable operating envelope, as well as the robust reliability characteristics that NVE sensors are known for.

Two different standard spacings are available, for use with fine and coarse pitch encoders and gear teeth. Both single bridge and double bridge configurations are also available; double bridges are used to generate sine/cosine outputs. In addition to the standard spacings, NVE can provide custom spacings and multiple sensor elements tailored to the individual customer's application for a nominal design and tooling charge. Contact NVE for further details.

For digital output applications, these sensors can be used with NVE's DD001-12 signal processing IC, which converts their output into a 50% duty cycle modulated current signal. This IC allows placement of the ABL sensor in a very small housing, with wires running from the sensor to the signal processing IC in a remote location. In this fashion ABL series sensors can be used in M8 and smaller housings.

Specifications:

Property	Min	Typ	Max	Unit
Single Bridge Resistance	4K	5K	6K	Ohms
Input Voltage	<1[1]		30[1]	Volts
Operating Temperature Range	-50		+190	°C
Offset Voltage	-4		+4	mV/V
Linear Range	+/-5		+/-100	Oe
Linearity of Output	98			%[2]
Hysteresis			2	%[2]
Saturation of GMR Sensor Elements	-180		+180	Oe[3]
Single Resistor Sensitivity		.04		%ΔR/Oe[4]
Max Output		80		mV/V
Temperature Coefficient of Resistance		+0.3		%/°C
ESD		400		V[5]

Notes:

1. ABL Series sensors have a purely ratiometric output. They will operate with input voltages of 0.1V or lower. The output signal will scale proportionally with the input voltage. Maximum voltage will be limited by the power dissipation allowable in the package and user installation. See the package section for more details.

2. Linearity and Hysteresis measured across linear operating range, unipolar operation.

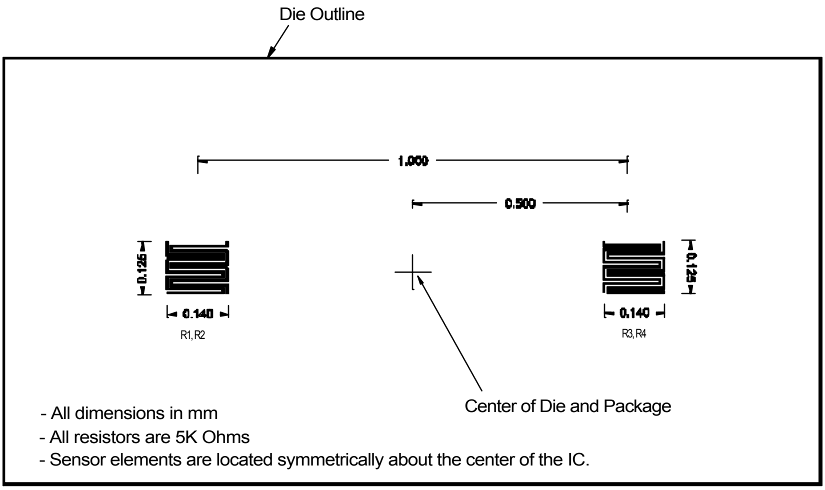
3. Application of a magnetic field in excess of this value will saturate the GMR sensor elements, and no further output will be obtained. No damage occurs to the sensor elements when saturated; *NVE GMR sensors will not be damaged by any large magnetic field.*

4. Percent change in resistance with application of 1 Oersted of magnetic field; corresponds to an 8% change in resistance with 200 Oersteds of applied magnetic field (1 Oersted = 1 Gauss in air, or 0.1 milli-Tesla).

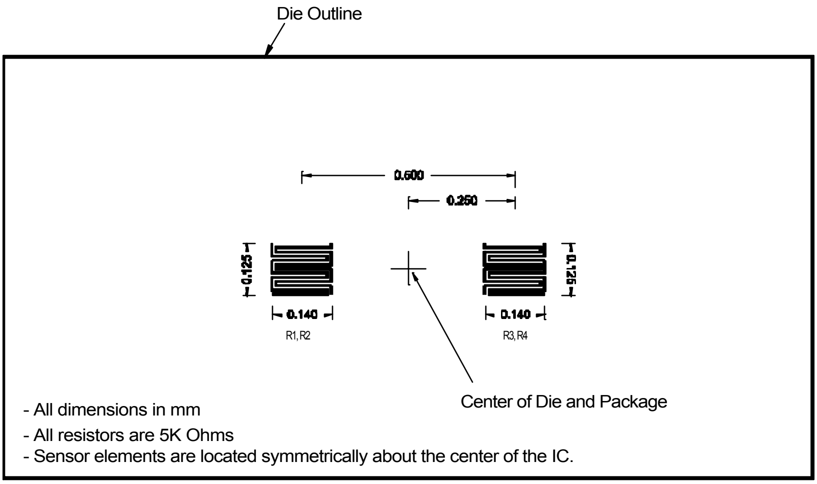
5. Pin to pin voltage, Human Body Model for ESD

IC Drawings:

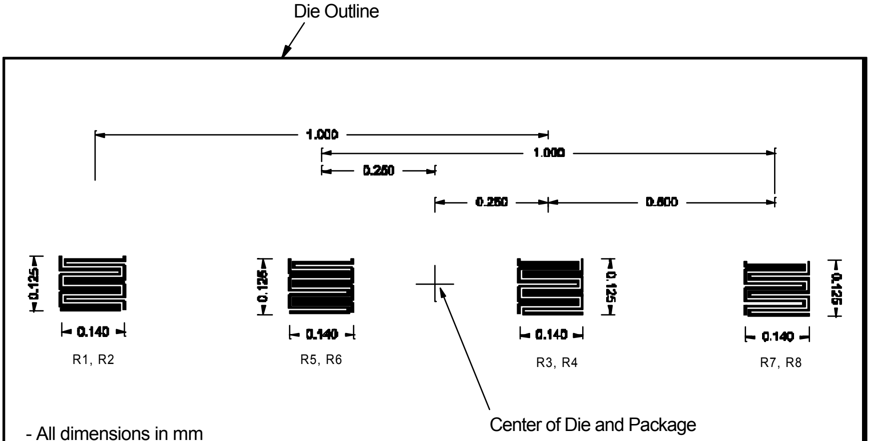
ABL004 Sensor Element Size and Spacing



ABL005 Sensor Element Size and Spacing

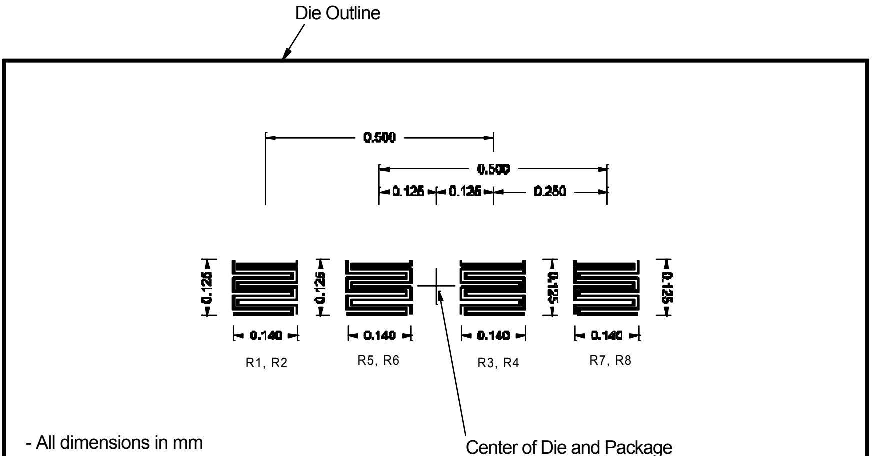


ABL014 Sensor Element Size and Spacing



- All dimensions in mm
- All resistors are 5K Ohms
- Sensor elements are located symmetrically about the center of the IC.

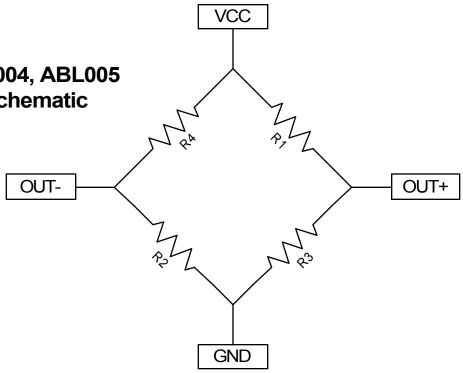
ABL015 Sensor Element Size and Spacing



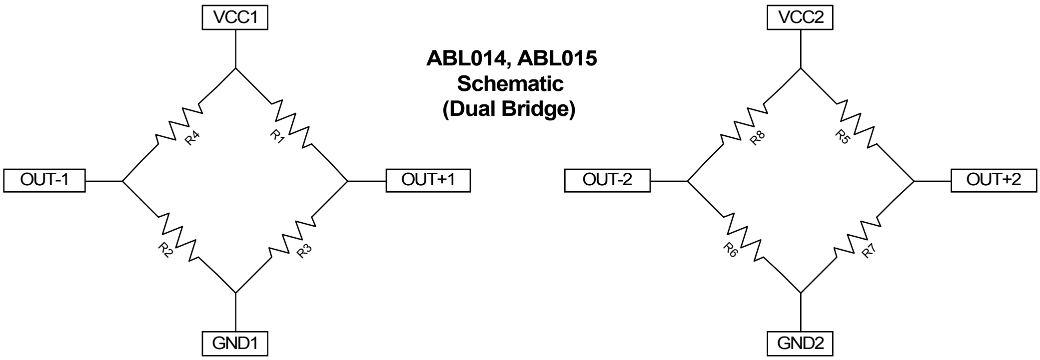
- All dimensions in mm
- All resistors are 5K Ohms
- Sensor elements are located symmetrically about the center of the IC.

Schematics:

ABL004, ABL005
Schematic



ABL014, ABL015
Schematic
(Dual Bridge)



Part Numbers and Configurations:

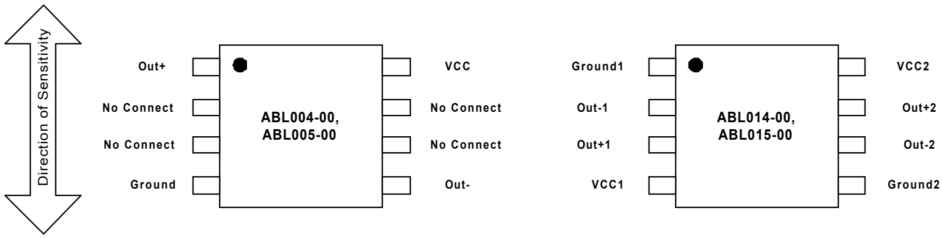
Part Number	Single or Dual Bridge	Element Spacing (Microns)	Phase Shift Between Bridges (Microns)	Package Marking
ABL004-00	Single	1000	NA	FDB
ABL005-00	Single	500	NA	FDC
ABL014-00	Dual	1000	500	FDD
ABL015-00	Dual	500	250	FDF
ABL004-10	Single	1000	NA	FDG
ABL005-10	Single	500	NA	FDH
ABL014-10	Dual	1000	500	FDJ
ABL015-10	Dual	500	250	FDK

Packages:

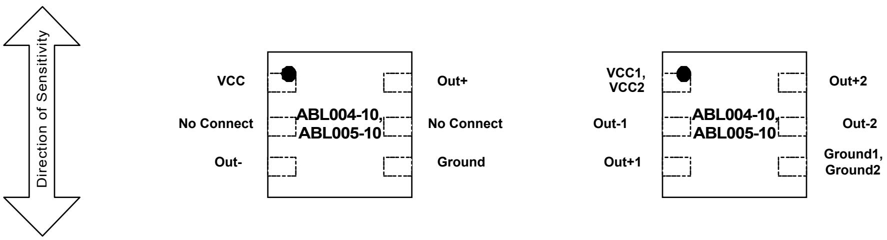
The ABL series parts are available in MSOP8 and TDFN6 packages. Please see the package drawing section in the Appendix for dimensions. Please note that for dual differential sensors in the TDFN package, the power and ground connections for both bridges are common.

Pin Configuration:

MSOP8 Package



TDFN6 Package



AKL Sensors
Digital Output Gear Tooth And Encoder Sensors

Features:

⇒ Large Airgap
⇒ 50% Duty Cycle
⇒ DC (Zero Speed) Operation
⇒ Precise Spacing Between Sensor Elements
⇒ Excellent Temperature and Voltage Performance
⇒ Small, Low Profile Surface Mount Package

Applications:

⇒ Anti-lock Brake System Sensors
⇒ Transmission Speed Sensors
⇒ Industrial Linear and Angular Speed Sensing
⇒ Linear and Angular Position Sensing

Description:

NVE offers these products specifically for use as sensors for gear tooth wheels or magnetic encoders with a digital output signal. The pulse output from the sensor corresponds with the gear teeth passing in front of it. When a gear tooth or magnetic pole is in front of the sensor, the sensor's output goes high; when the gear tooth or magnetic pole moves away, the output returns to low. This repeats at every tooth/pole, resulting in a pulse train output that provides speed information from the gear or encoder. Two part numbers are currently available: the AKL001-12 is designed for gear teeth or encoders with a pitch of 2.5 to 6mm, and the AKL002-12 is designed for a pitch of 1 to 2.5mm.

In order to minimize the number of wires leading to the sensor, the part is configured as a two wire device. The two output states are indicated with a change of current through the part. Therefore, when the part is in the digital low state, current is about 3mA. When the part is in the digital high state, the current increases to about 10mA. If necessary, the 2-wire output of the AKL series parts can be easily converted to a 3-wire current sinking output with the circuit shown in the GT Sensor applications section.

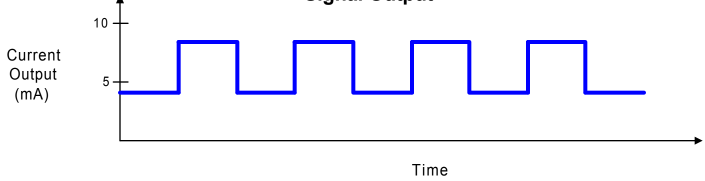
The parts are rated for the full automotive and industrial temperature range, -40°C to +150°C. They feature reverse battery protection, and have an operational voltage range of 4.5V to 48V. They operate from DC to 10 KHz. The parts are available in low profile, surface mount TDFN SO8 packages.

Specifications:

Property	Min	Typ	Max	Unit
Input Voltage	4.5		48	Volts[1]
Supply Current in Off State (Input Voltage=12V)	3.2	4.0	4.8	mA[2]
Supply Current in On State (Input Voltage=12V)	7.0	8.0	9.0	mA[2]
Output Duty Cycle	40	50	60	%
Operating Temperature Range	-40		+150	°C
AKL001-12 Airgap, Over Full Temperature and Voltage Range[4]	1.0		3.5	mm
AKL002-12 Airgap, Over Full Temperature and Voltage Range[4]	1.0		2.5	mm
Frequency of Operation	0		10K	Hz
ESD		2000		V[3]

Absolute Maximum Ratings	
Parameter	Limit
Supply Voltage	60V
Reverse Battery Voltage	-60V
Continuous Output Current	16mA
Junction Temperature Range	-40°C to +175°C
Storage Temperature Range	-65°C to +200°C

Signal Output



Notes:

1. The supply voltage must appear across the power and ground terminals of the part. Any additional voltage drop due to the presence of a series resistor is not included in this specification.

2. Supply currents can be factory programmed to different levels, for example 3mA and 6mA, or 7mA and 14mA; contact NVE for details.

3. Pin to pin voltage, Human Body Model for ESD

4. Airgap measured with standard ferrous gear tooth, contact NVE for details.

IC Drawings:

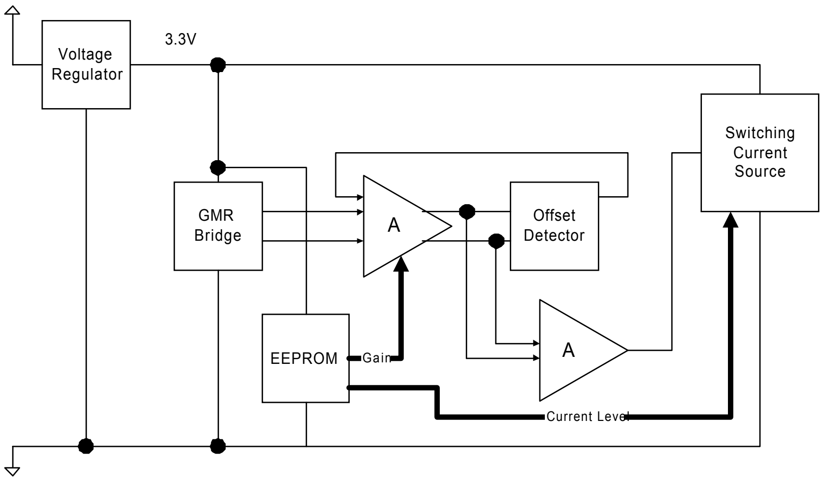
The AKL Series products use the ABL sensor elements described earlier in this section. The AKL001-12 part uses the ABL004 sensor element, and the AKL002-12 uses the ABL005 sensor element. Please see the IC drawings in the ABL series section for more information.

Part Numbers and Configurations:

Part Number	Single or Dual Bridge	Element Spacing (Microns)	Marking
AKL001-12	Single	1000	Part Number
AKL002-12	Single	500	Part Number

Schematic:

A block diagram of the AKL series parts is shown below:

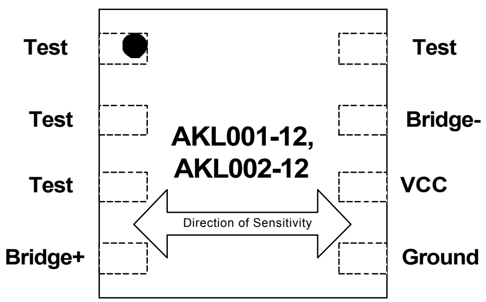


Packages:

The AKL series parts are available in the TDFN8 SO8 package. Please see the package drawing section in the Appendix for dimensions.

Pin Configuration:

TDFN8-SO8 Package

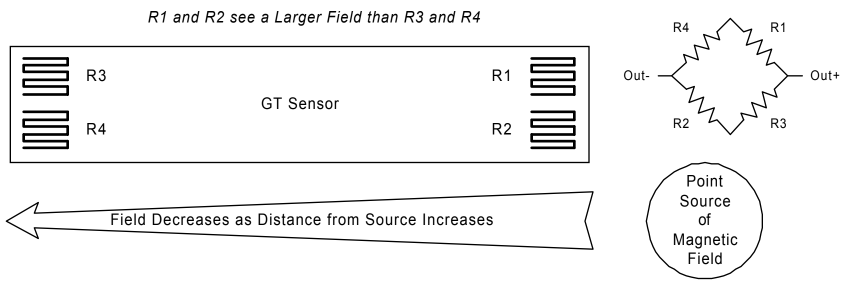


Note: Bridge + and Bridge – are provided for analysis purposes only. NVE does not recommend connecting these pins in a production product, for ESD and loading reasons. Also, all pins labeled 'Test' must be floating, *i.e.* not connected to each other, or any other circuit node.

Application Notes for GT Sensors

General Theory of Operation of Differential Sensors (Gradiometers)

Differential sensors, or gradiometers, provide an output signal by sensing the gradient of the magnetic field across the sensor IC. For example, a typical GMR sensor of this type will have four resistive sensor elements on the IC, two on the left side of the IC, and two on the right. These resistive sensor elements will be wired together in a Wheatstone bridge configuration. When a magnetic field approaches the sensor IC from the left, the left two resistive sensor elements will decrease in resistance before the elements on the right. This leads to an imbalance condition in the bridge, providing a signal output from the bridge terminals.



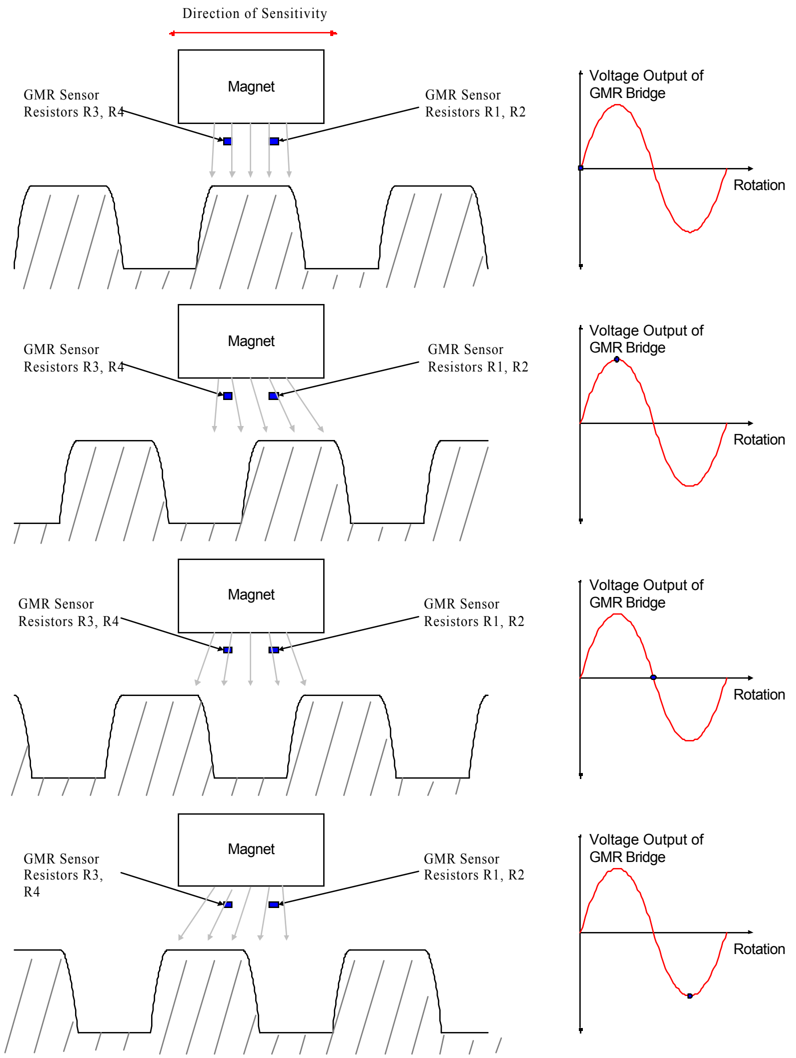
Note that if a uniform magnetic field is applied to the sensor IC, all the resistive sensor elements will change at the same time and the same amount, thus leading to no signal output from the bridge terminals. Therefore, a differential sensor cannot be used as a magnetometer, or an absolute field detector; it must be used to detect the presence of a magnetic gradient field.

Gradient fields are present at the edge of magnetic encoders and magnetically biased gear teeth. As a result, differential sensor elements are ideally suited for speed and position detection in these applications.

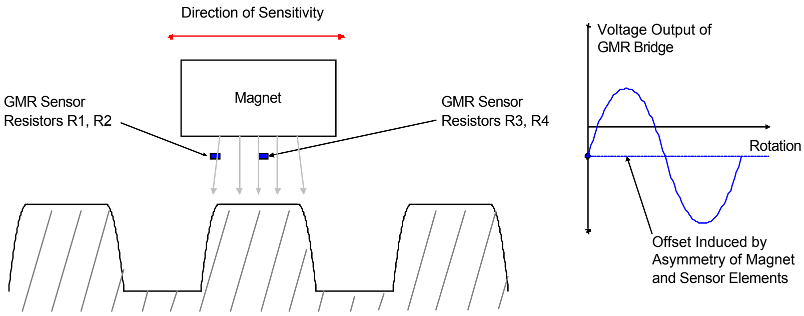
GT Sensor Operation with Permanent Magnet Bias

Magnetic encoders generate their own magnetic field, but a gear tooth wheel does not, so if a differential sensor is to be used to detect gear teeth, a permanent magnet of some sort must be used to generate a magnetic bias field. The differential magnetic sensor will then be used to detect variations in the field of the permanent magnet as the gear tooth passes by in close proximity.

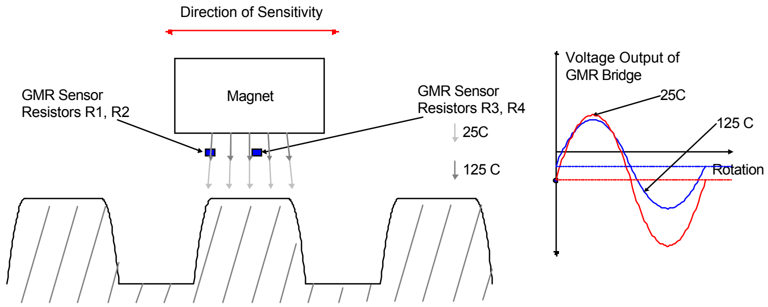
The following series of drawings shows a biased GT Sensor. The drawings show how the magnetic field generated by the bias magnet is influenced by the moving gear tooth, and what the output signal from the sensor looks like at four equally spaced positions, from one gear tooth to the next:



Despite the simple nature of the preceding drawings, magnetically biasing a gear tooth for a production product can be a complex and difficult task. Typically, the position of the sensor relative to the magnet is fixed, but there is a variation in the airgap between the sensor and the target (gear tooth). This arrangement leads to various magnetic conditions that can cause instability in the sensor output. For example, tolerances on the placement of the magnet relative to the sensor are not perfect, and any slight variation in the placement of the magnet can lead to offset problems; see the drawing below:



Generally the magnet is glued in place; this can lead to tilting of the magnet with respect to the sensor, introducing more variations in the field at the sensor, and more offset problems, not to mention potential glue joint problems. Further, the composition of most inexpensive magnets is not particularly uniform, and many have cracks or other mechanical imperfections on the surface, or internally, that will lead to a non-uniform magnetic field. Most permanent magnets have a temperature coefficient, and some can lose up to 50% of their strength from room temperature to 125°C. The following drawing shows the effects of temperature, added onto an imperfect bias. As can be seen, the offset of the sensor varies with temperature.



Finally, as the airgap changes, the magnetic field at the sensor also changes. So, the magnetic field at the sensor will vary from one installation to the next, and if the gear has runout, wobble, or expands with temperature, the output signal and offset of the sensor element will vary.

As a solution to these potential problems, NVE's AKL series GT Sensors offer internal signal processing which compensates for temperature variation, sensor output variation, and magnet/target variation. This results in a stable digital output signal with wide tolerance for magnet placement and quality. For analog applications, NVE offers the following guidelines for biasing GT Sensors with permanent magnets:

1. NVE recommends about 1.5mm distance from the back of the sensor to the face of the magnet, in order to keep the flux lines at the sensor element "flexible", and able to follow the gear teeth with relative freedom. This distance can be achieved by putting the sensor on one side of a circuit board, and the magnet on the other.

2. To fix the position of the magnet on the circuit board more precisely, the board can be made thicker, and a pocket can be machined into it to hold the magnet. This service is readily available from most circuit board manufacturers.

3. Various high temperature epoxies can be used to glue the magnet in position; NVE recommends 3M products for this purpose.

4. If zero speed operation is not required, AC coupling the sensor to any amplifier circuitry will remove the offset induced in the sensor by the magnet.

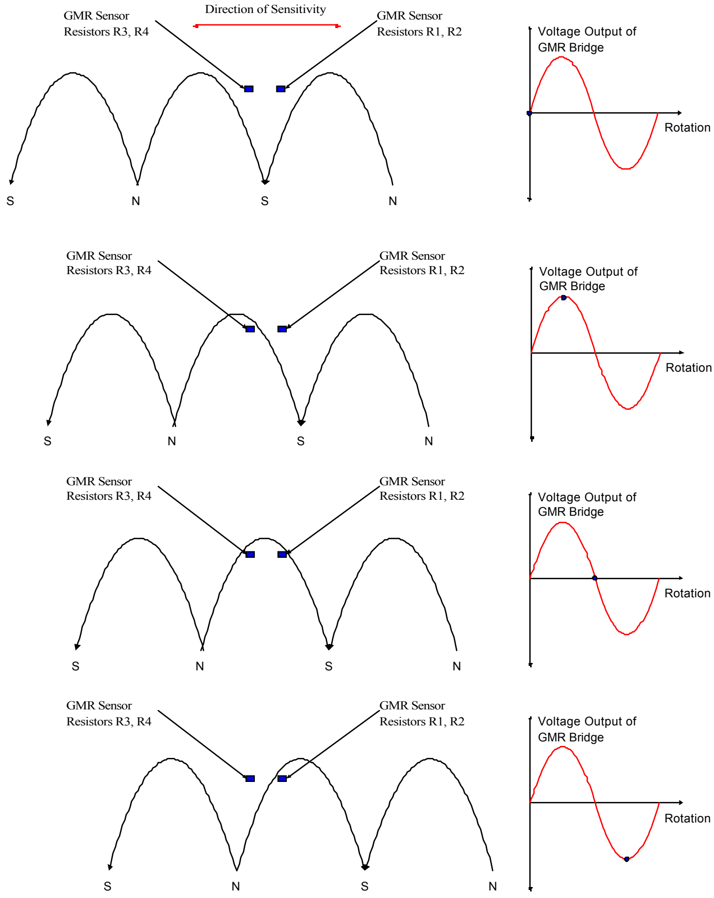
5. If zero speed operation is required, some method of zeroing the magnet-induced offset voltage from the sensor will be required for maximum airgap performance. NVE's AKL series sensors have this feature built in, and NVE's DD001-12 signal conditioning IC also includes this feature.

6. GT Sensor ICs are centered in the plastic package, so placement of the permanent magnet should be symmetrical with the package.

7. Ceramic 8 magnets are a popular choice in this application, and provide good field characteristics, and low cost. However, C8 magnets lose substantial magnetic strength at higher temperatures. For analog output applications where a consistent signal size over temperature is desirable, use of an Alnico 8 magnet (the most temperature stable magnet) is recommended. Samarium cobalt magnets and Neodymium-Iron-Boron magnets are not recommended, because they are so strong that they tend to saturate the GMR sensor element.

GT Sensor Operation with Magnetic Encoders

Magnetic encoders generate their own magnetic field; as a result, they are much easier to work with than gear tooth wheels. One reason is because no bias magnet is required for the sensor. Also, a magnetic encoder has alternating north and south magnetic poles on its face. Therefore the magnetic field is generated by the moving body, and sensor offset problems are greatly reduced. The following drawing shows a GT Sensor response to a magnetic encoder:



Note that in this case, as long as the sensor is positioned symmetrically with the encoder, offset is minimized. Also note that the GT Sensor provides one full sine wave output for each magnetic pole. This is double the frequency of a Hall effect sensor, which will provide one full sine wave output for each north-south pole pair. As a result, replacing a Hall sensor with a GT sensor will double the resolution of the output signal.

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NVE offers the following guidelines for using GT Sensors in magnetic encoder applications:

1. Position the sensor as symmetrically as possible with the encoder to minimize offset problems.

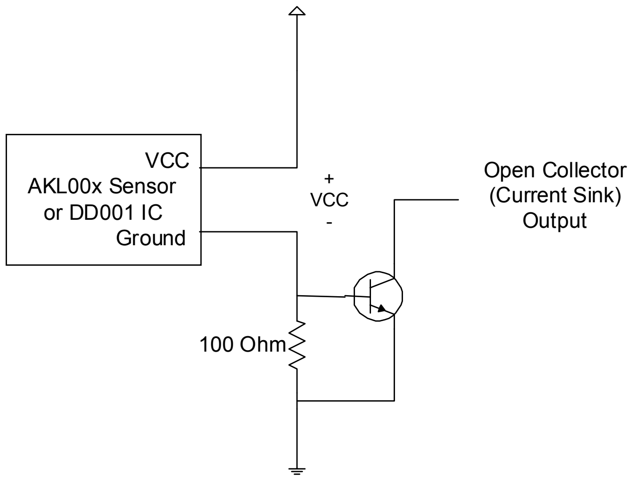
2. AC couple the sensor to an amplifier to eliminate any offset issues if zero speed operation is not required.

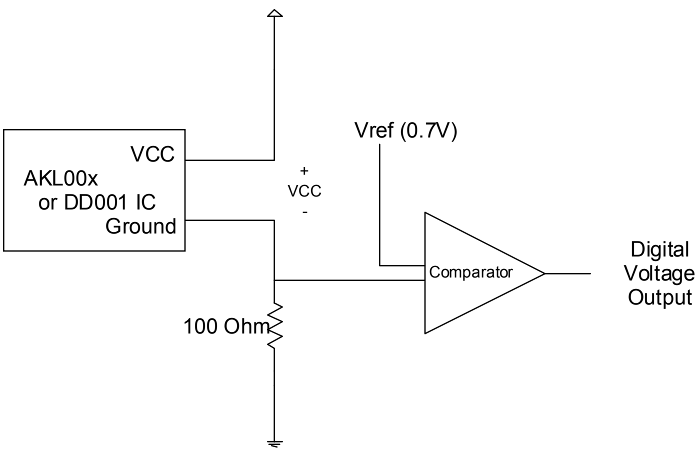
3. If zero speed operation is required, NVE's AKL series and DD series parts automatically compensate for offset variations, and provide a digital output signal.

Application Circuits

Signal processing circuitry for analog output sensors, such as NVE's ABL series products, varies widely in cost, complexity, and capability. Depending on user requirements, a single op amp design may be sufficient. For low signal level detection, a low noise instrumentation amp may be desirable. For complete control of all parameters, use of a complete signal processing IC which can tailor gain, offset calibration, and temperature compensation may be required. Please see NVE's Engineering and Application Notes bulletin for further details on the various approaches that are available.

For digital output applications, NVE's AKL series and DD series products provide the most cost effective approach. Both of these products provide 2 wire, or current modulated, output signals. For many applications, an open collector or digital voltage output signal is desirable. The following two circuits show how to convert a 2-wire current modulated signal into an open collector or digital voltage output signal:


VCC
AKL00x Sensor
or DD001 IC
Ground
+
VCC
-
Open Collector
(Current Sink)
Output
100 Ohm


VCC
AKL00x
or DD001 IC
Ground
+
VCC
-
Vref (0.7V)
Comparator
Digital
Voltage
Output
100 Ohm