Understanding GMR GT Sensors: Theory of Operation and Signal Optimization

World Class Gear Tooth Sensing

With wide airgap tolerance, large analog peak-to-peak signals and DC to 1 MHz operation, NVE's ABL-Series Gear Tooth (GT) sensors offer unmatched rotation-sensing performance. The ABL Series uses giant magnetoresistance (GMR) technology and has both single- and dual-channel versions. The dual-channel versions can determine direction as well as speed. This application note covers the basic theory of gear tooth sensing and rules of thumb for optimizing sensor outputs.

Theory of Operation

ABL-Series GT Sensors are gradiometers, which detect a magnetic field gradient across the sensor's sensitive axis. In gear-tooth sensing applications, this configuration maximizes signal amplitude and rejects external magnetic interference. The sensor operation is easy to understand, as shown in Figure 1:

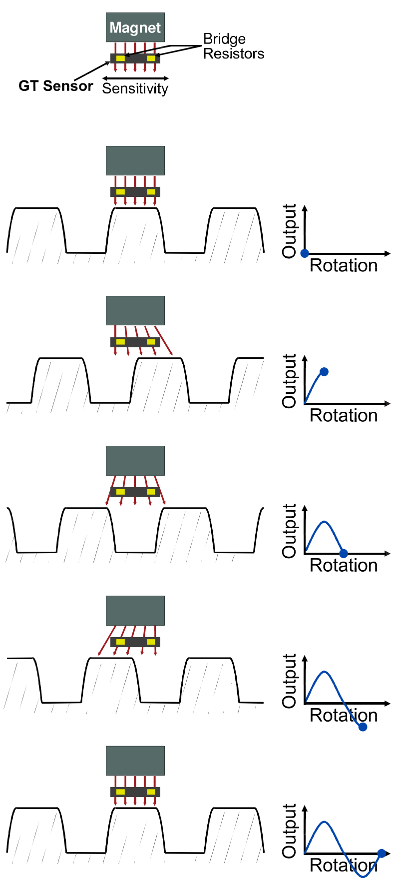

Figure 1: Gradiometer operation in gear tooth sensing applications. As ferromagnetic gear teeth pass the sensor's bridge resistors, the flux lines bend to unbalance the bridge, producing a sinusoidal output with one cycle per tooth.

The sensor is a Wheatstone bridge, with the bridge resistors spaced to detect the field gradients in the sensitive plane of the sensor. A bias magnet generates field to detect ferromagnetic gear teeth. When centered over a tooth, the bridge is balanced for zero output. As the gear turns, flux lines are deflected by the teeth along the axis of sensitivity, unbalancing the bridge. The output is sinusoidal with one cycle per gear tooth.

Choosing the Correct Sensor

Figure 1 makes it clear that the output signal can be optimized by using a sensor whose bridge resistors are placed optimally with respect to the gear pitch. Though this is the most important consideration, the best element spacing depends on several other factors and is a complex question. A sensor with an element spacing between one-fourth and one-half the gear pitch is recommended as a rule of thumb. NVE's ABL-Series has three spacing options and can be used with gear pitches from 0.5 mm to 10 mm.

Phase Shift in Dual Bridge Sensors

If sine and cosine outputs are required, the bridge phase shift should be one-fourth the gear pitch, and in general, the predicted phase shift can be approximated by

$$\text{Phase Shift } (°) = \frac{\text{Bridge Phase Shift}}{\text{Gear Pitch}} \cdot 360$$

This equation follows immediately from the fact that each dual bridge output is periodic, with 360° corresponding to the detection of a single gear tooth.

Magnetic Biasing

NVE GT Sensors are reliable and easy to use with proper magnetic biasing. Biasing provides a source of magnetic field to be measured, and it conditions the sensor to give an optimal transfer function. Typically, biasing is accomplished by fixing a disk magnet behind the sensor on a PCB. The magnetic flux produced by this configuration is shown in Figure 2.

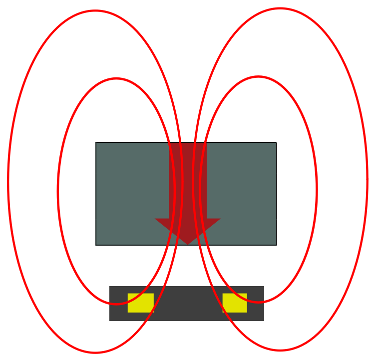

Figure 2: Biasing an ABL-Series GT Sensor with a disk magnet

Since the sensor is sensitive in-plane, the large field along the magnet's pole does not saturate the sensor. The relatively smaller in-plane component biases the sensor. GMR bridge resistors in NVE GT Sensors are omnipolar and detect magnetic fields along the sensitive axis, with a typical transfer function shown in Figure 3a. Key features of the transfer function are:

- impressive linearity and negligible hysteresis in the 1 to 180 Oe linear range
- an inflection point at zero field
- magnetic saturation at 200 Oe

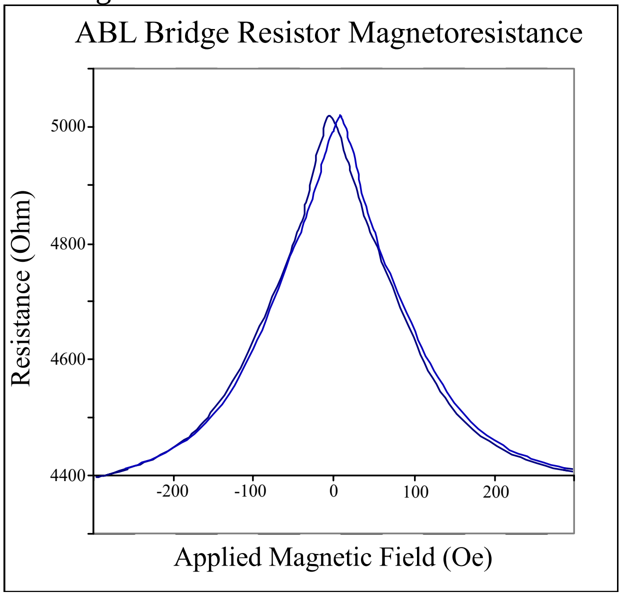

Figure 3a

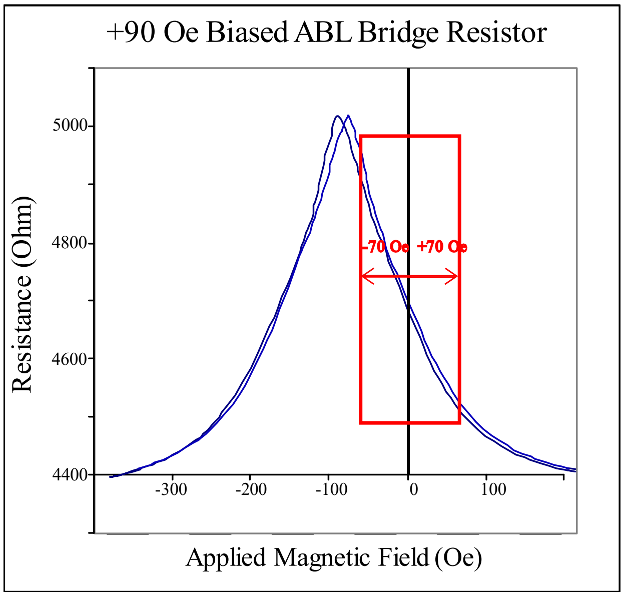

Figure 3b

For a perfect sine wave output, the bridge resistors must remain within their 1 to 180 Oe linear range through the full cycle. The effect of a 90 Oe bias is shown in Figure 3b, which results in a highly linear ±70 Oe range for gear tooth sensing.

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Avoiding magnetic saturation is the most important consideration for biasing a GT sensor; partial saturation causes sine wave distortions, and full saturations will cause significant signal loss. For this reason, we recommend small, inexpensive ferrite disk magnets such as NVE part numbers 12216 and 12217.

Sensor-to-Gear Airgap

In general, the maximum airgap is set by the shape and size of the gear, as well as the element spacing in relation to the gear pitch. As a rule of thumb, the maximum airgap will be roughly equal to the gear pitch, assuming the sensor has an element spacing of one-fourth to one-half the gear pitch. With simple amplification, the airgap can be increased further.

GT Sensor Design Support

We have a free web-based application to provide design support for ABL Series GT Sensors, including bias magnet selection. Enter your gear's dimensions, then choose your sensor, bias magnet, and PCB thickness and view approximate sensor outputs for your system: https://www.nve.com/spec/calculators.php#tabs-GT-Sensor-Output

To try NVE GT Sensors yourself, order our AG920-07 or AG921-07 evaluation kits:
https://www.nve.com/EvaluationKits.php

For live demonstrations of NVE GT sensors and other demonstrations, check out our YouTube channel:
http://www.youtube.com/NveCorporation
https://www.youtube.com/watch?v=brDLly1L6aE
https://www.youtube.com/watch?v=sAA3ILHs7h4
https://www.youtube.com/watch?v=7R3qPD5lW2w

Contact Us

NVE engineers are experts in gear tooth sensing and are eager to help. For design assistance and other inquiries, contact sensor-apps@nve.com.

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