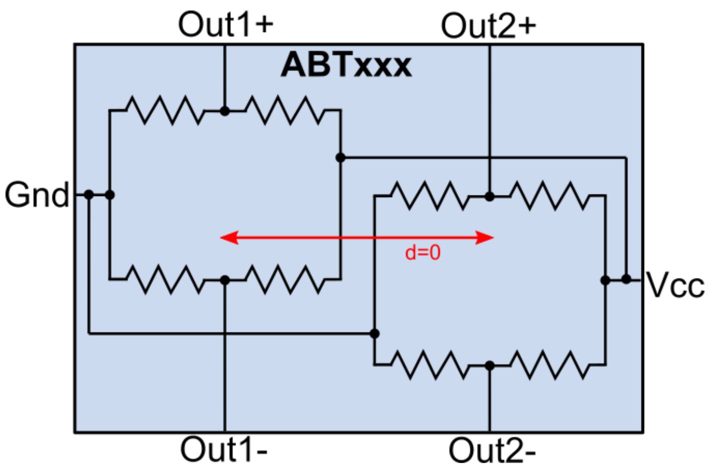
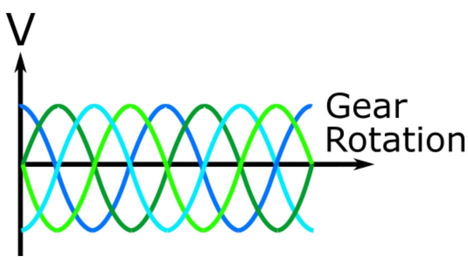
ABT-Series Dual-Channel TMR Gear-Tooth Sensors

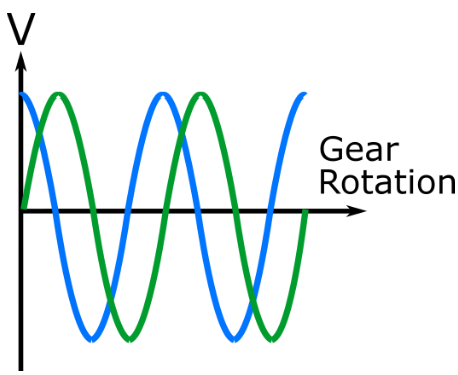
Block Diagram



Outputs



ABTxxx as single-ended half-bridge outputs



ABTxxx as differential full-bridge outputs

Features

- Excellent linearity, low distortion
- Large analog peak-to-peak signal
- Low hysteresis
- Operating frequency to 350 kHz
- 150°C maximum operating temperature
- Ultraminiature

Applications

- Motion, speed, and position sensing
- Linear and rotational encoders
- Closed-loop servo systems
- Machine tools
- Automotive sensors

Description

NVE's ABT-Series Gear-Tooth (GT) Sensors are versatile, linear analog sensors typically used with back-biasing magnets to encode the position of a ferrous gear track or wheel.

ABT-Series sensors are manufactured with NVE's state-of-the-art tunneling magnetoresistance (TMR) technology. They are dual-channel sensors consisting of four phase-shifted, half-bridge magnetometers. The sensor elements respond to the bipolar magnetic fields produced by a magnetic tooth structure with a bipolar transfer function.

ABT-Series sensors can be used in half-bridge or full-bridge mode depending on the application. Typically, an ABT-sensor is matched to the corresponding pitch teeth structure, and the half-bridge outputs are treated as differential.

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Absolute Maximum Ratings

ABT-Series TMR Gear-Tooth Sensors			
Parameter	**Min.**	**Max.**	**Units**
Supply voltage	-7	7	Volts
Storage temperature	−65	170	°C
ESD (Human Body Model)		2000	Volts
Applied magnetic field		Unlimited	mT

Operating Specifications

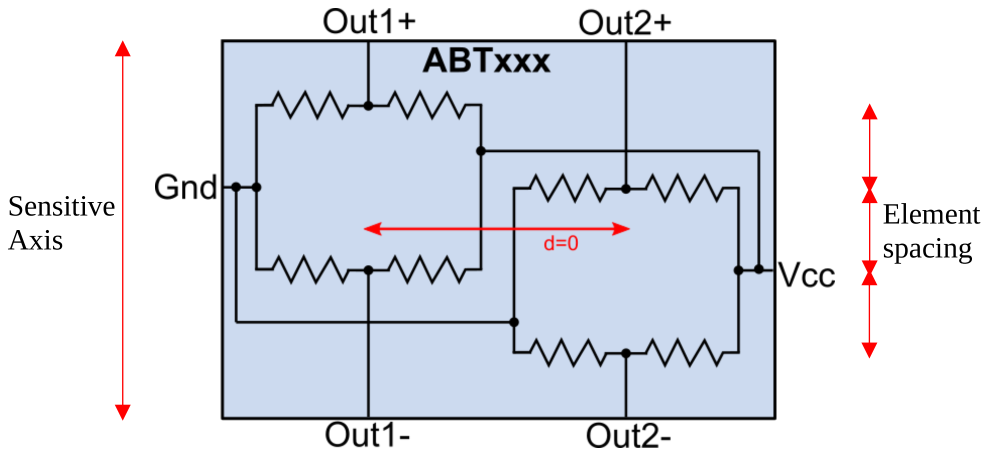
Parameter	Symbol	Min.	Typ.	Max.	Units
Operating temperature	T_{min}; T_{max}	−50		150	°C
Supply voltage	V_{CC}	0		5.5	V
Resistance		1	5	10	kΩ
Unbiased full-bridge offset voltage	V_O	−20		+20	mV/V
Sensor element linearity				3	%
Hysteresis				2	%
Sensor element linear range			±10		mT
Saturation of TMR sensor elements			±30		mT
Maximum output (half-bridges, zero airgap)		100	200	300	mVpp/V
Maximum output (full-bridges pitch matched to gear)		200	400	600	mVpp/V
Phase shift between half-bridges			$360 \cdot \left(\frac{Element\ Spacing}{Gear\ Pitch}\right)$		
Temperature coefficient of device resistance	TCR		-0.08		%/°C
Temperature coefficient of output	TCO	-0.1	0	0.1	%/°C
Sensor operating frequency*	f_{MAX}		350		kHz

*In the case of ferrous metal detection, the speed will be limited by the magnetic permeability of the magnetic target. For example, gear-tooth sensing is typically limited to around 20,000 teeth/second, depending on the size and shape of the gear.

Sensor Structure

TMR Element Layout

The ABT-Series Gear-Tooth Sensors consist of two Wheatstone bridges wired with common Vcc and GND. The structure is equivalent to four half-bridge magnetometers, equally spaced from the center of the package by a distance known as the 'element spacing'.



When a magnetic field gradient is swept along the sensor's sensitive axis, the four half-bridges produce identical, phase-shifted outputs corresponding to the pitch of the field gradient. In the case of a gear, the phase-shifted magnetic field is due to the gear-tooth pitch:

$$\text{Half-Bridge Phase Shift} = 360 \cdot \left(\frac{\text{Element Spacing}}{\text{Gear Pitch}}\right)$$

When the gear pitch is one-fourth the element spacing, the four half-bridge outputs are each 90 degrees out of phase. In this case, Out1 and Out2 are full differential Wheatstone bridge outputs, since the phase shift between Out1+, Out1- is 180 degrees (and likewise for Out2).

Operation Overview

Sensor Orientation

To detect passing gear teeth, the sensitive axis of an ABT-Series sensor is aligned parallel to passing gear teeth, as shown in Figure 1.

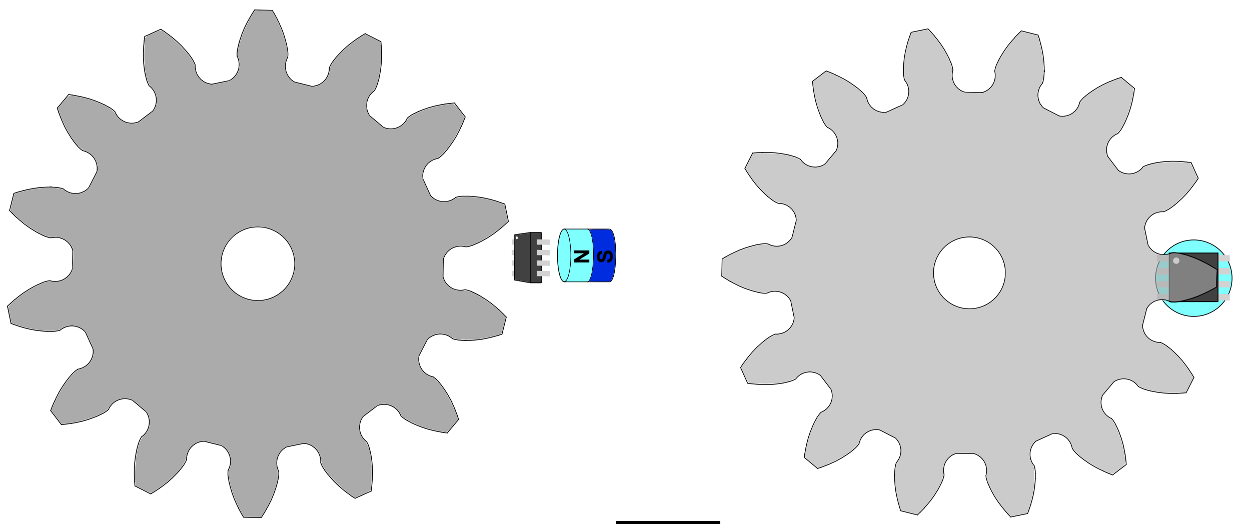


Figure 1: The two most common use configurations for ABT-Series TMR Gear-Tooth Sensors, showing the sensor and bias magnet orientation. The sensor is sensitive to gear motion along the length of the sensor package.

Magnetic Biasing

To sense ferromagnetic gears, ABT-Series sensors need to be back-biased with a permanent magnet. This is typically accomplished by fixing a magnet to the opposite side of a PCB, as in Figure 2. Table 1 has common bias magnets.

Here are some tips for biasing:

- Use ceramic magnets, grades C1, C5, C8 etc.
- The magnet needs to be at least 3 mm wide along the sensitive direction of the sensor
- The length of the magnet is not critical and can be chosen for convenience (if using a bar magnet)
- The thickness of the magnet should not exceed 4 mm
- Magnets should be placed on the opposite side of the PCB from the sensor. Use a 1.6 mm or thinner PCB

NVE Part Number	Width (mm)	Length (mm)	Thickness (mm)
12216	6	6	4
12217	3.5	3.5	4
12031	8	8	3

Table 1: Common bias magnet dimensions. Any disk magnet with diameter equal to the width in the above table will also work.

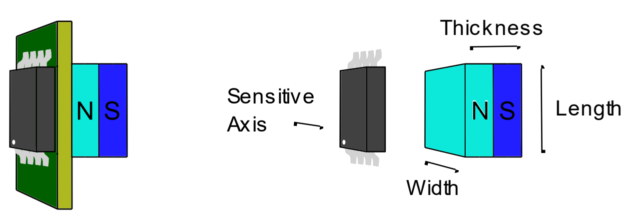


Figure 2 (Left): Back biasing an ABT-Series sensor. (Right): Magnet dimensions defined in relation to the sensor's orientation.

Sinusoidal Output with Rotation

The magnetic operation for the ABT-Series is shown below. The sensor output amplitude scales approximately linearly with airgap, reaching the maximum value when the sensor face is at the gear-tooth face. The sensor's sinusoidal analog output(s) scale ratiometrically with the supply voltage.

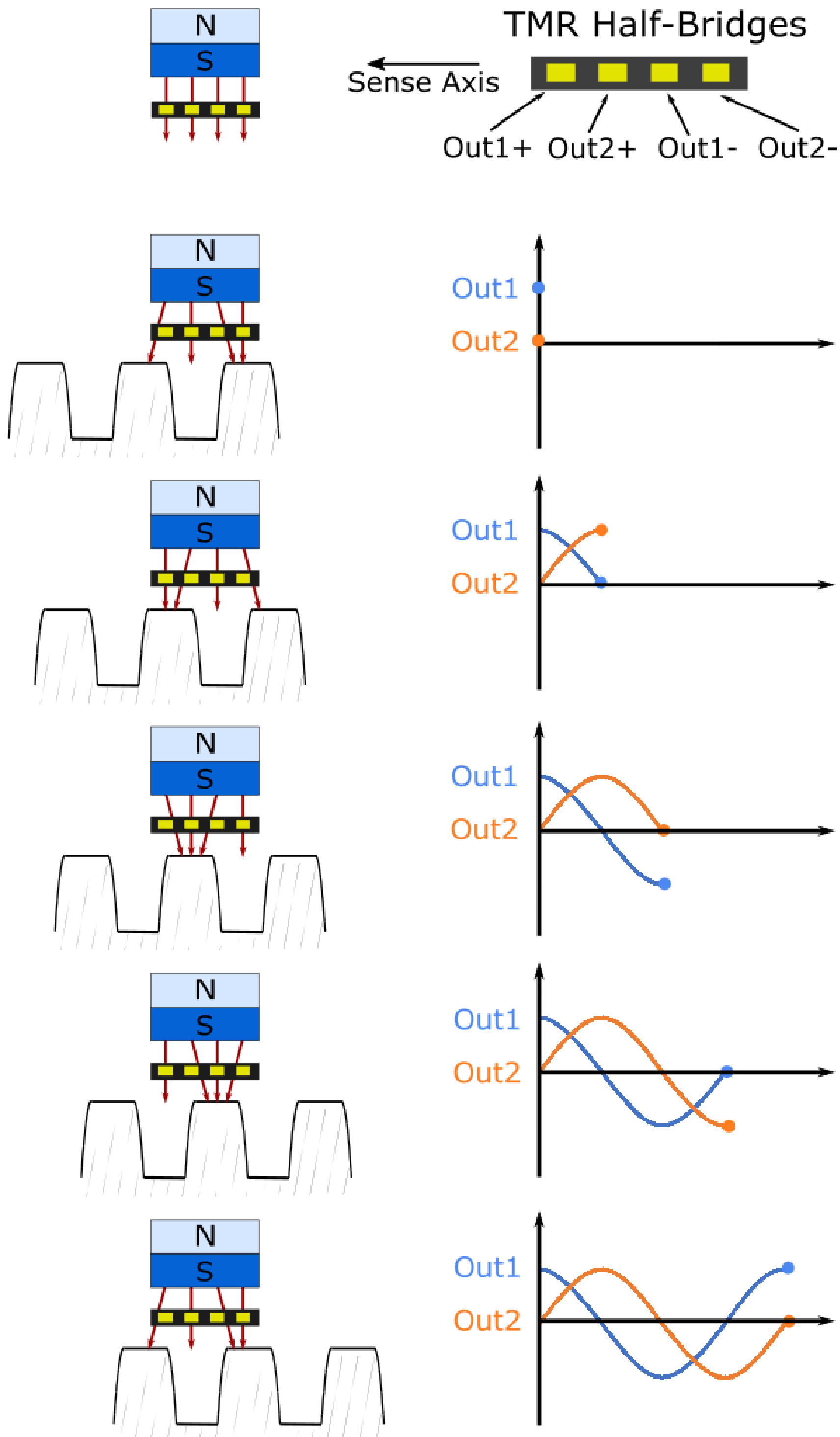


Figure 3. ABT-Series sensor output vs. gear rotation.

Detailed Operation

Back-Biasing TMR Elements

The bias magnet provides a magnetic field source the sensor can read. The magnetic field consists of a strong perpendicular-plane component and a weaker planar fringing field. This is shown in Figure 4 below.

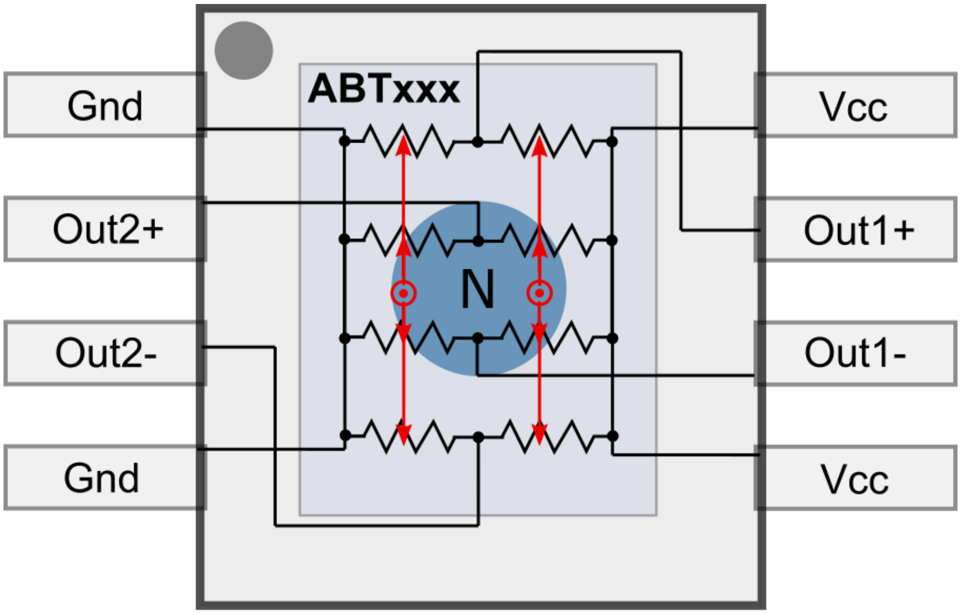


Figure 4. The planar fringing field generated from the predominately perpendicular bias magnetic field.

The planar fringing field introduces a DC offset in the half bridge outputs, as shown in the figures below.

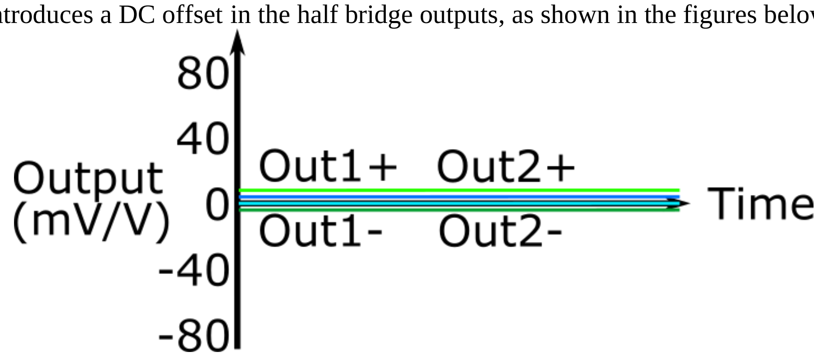


Figure 5. An ABT-Series sensor before applying the bias magnet

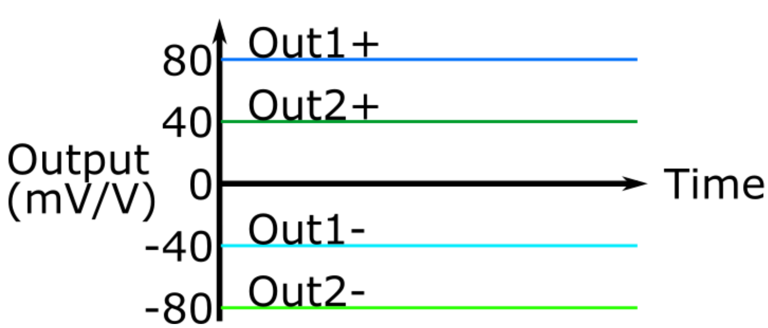


Figure 6. An ABT-Series sensor after applying the bias magnet

Operate region

Back-biased ABT-Series sensors need to be within their operate region to function properly. The operate point ranges from the face of the gear to a gear-dependent maximum operate point distance, as shown in Figure 7 below.

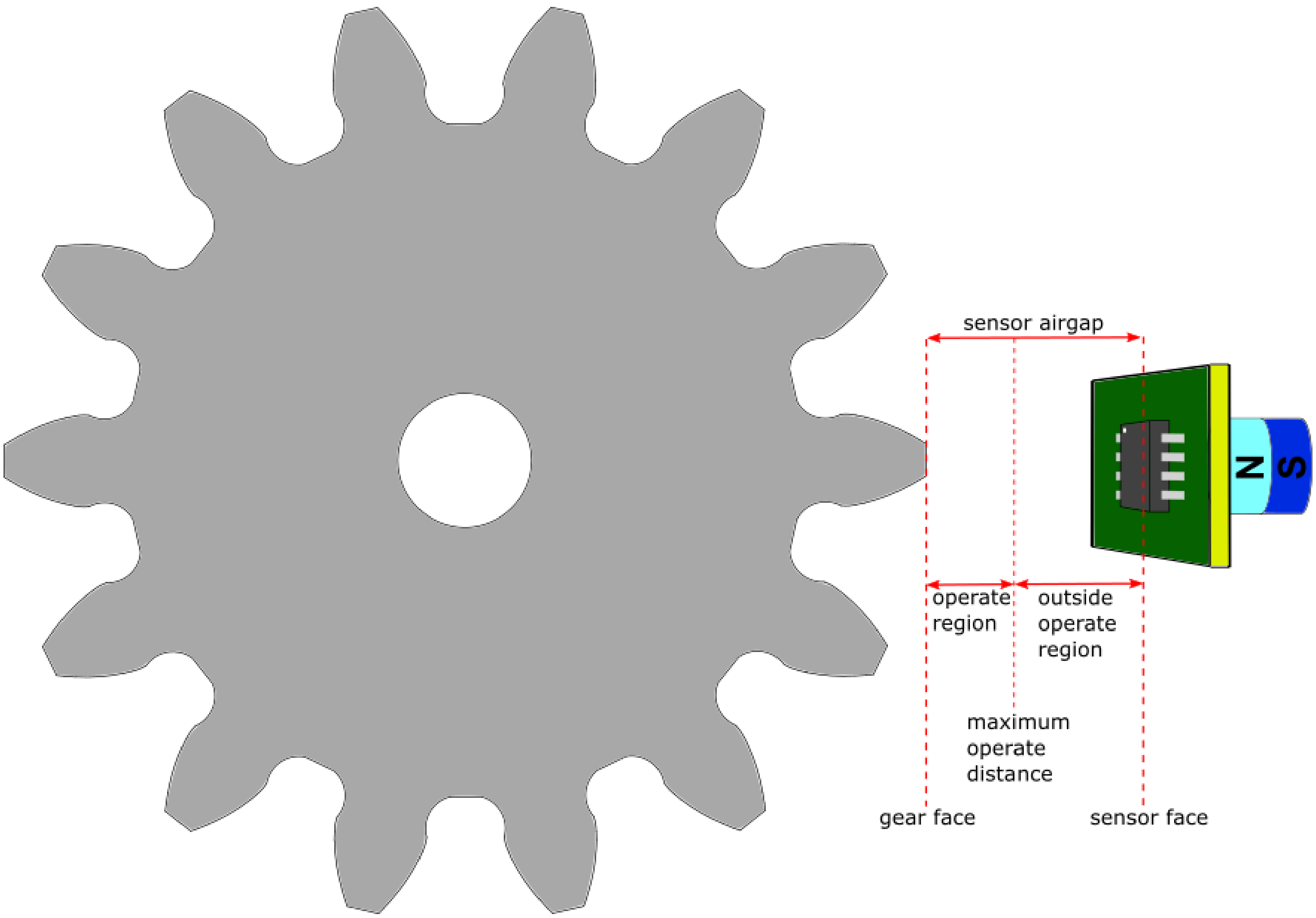


Figure 7. Definitions of ABT-Series sensor airgap and operate regions.

The sensor is in its operate region when the DC-offset on the half-bridge outputs vanish. The offset vanishes because the fringing magnetic fields causing the offset are redirected perpendicularly towards the gear, due to the closer proximity of the magnet to the gear in the operate range.

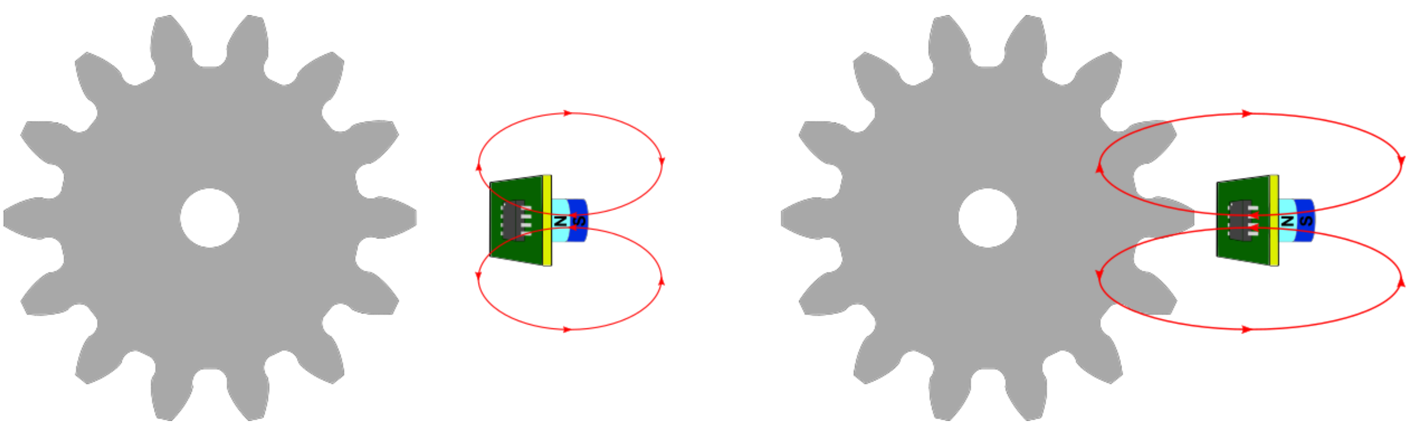


Figure 8. Close proximity to the gear pulls the bias magnet flux lines perpendicular to the sensor, removing the output offsets.

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The figures below show typical ABT600-00E performance with NVE part number 12217 bias magnet and a 32 pitch test gear.

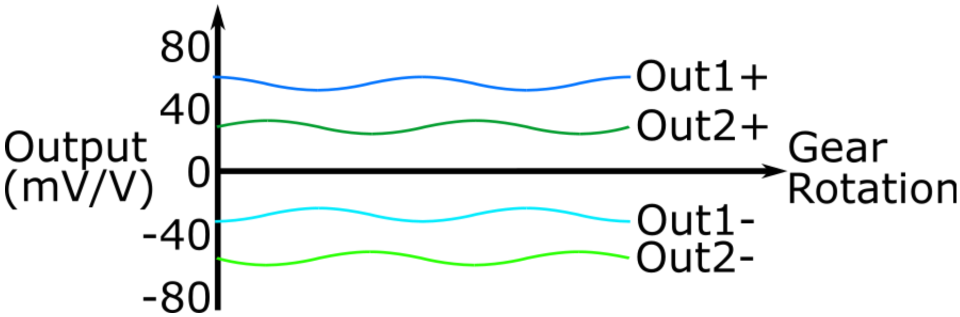


Figure 9. ABT600-00E outputs at an airgap of 4 mm. The sensor is outside its operate region.

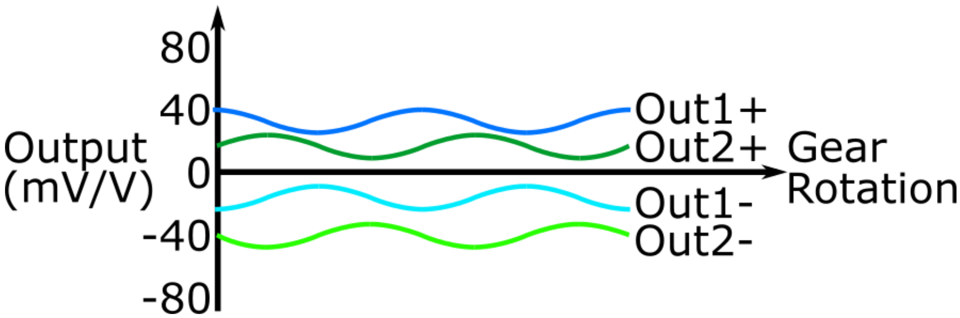


Figure 10. ABT600-00E outputs at an airgap of 2 mm. The sensor is outside its operate region.

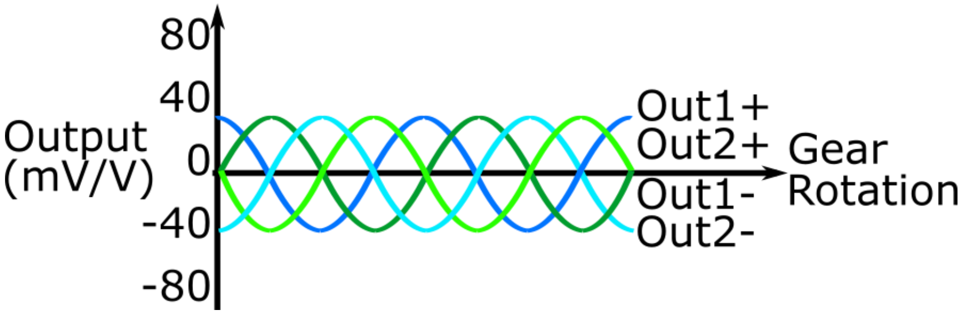


Figure 11. ABT600-00E outputs at an airgap of 1.5 mm. The sensor is in its operate region.

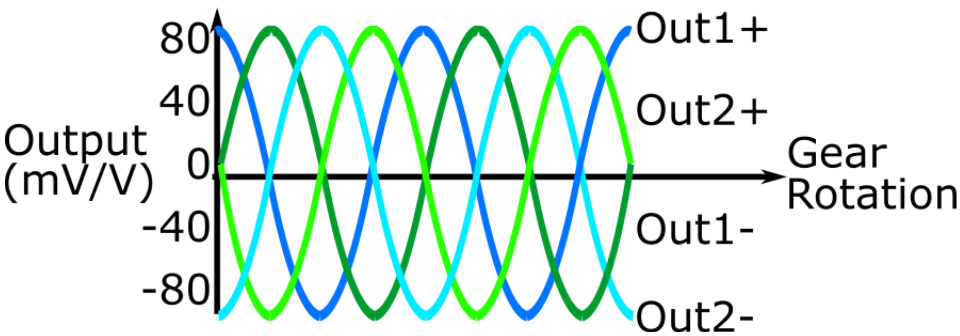


Figure 12. ABT600-00E outputs at an airgap under 0.3 mm. The sensor is in its operate region.

Illustrative Application Circuits

Direct interface

Due to its large output signal and low output impedance, an ABT-Series sensor can be interfaced directly to a standard microcontroller or ADC. Incremental position information can be obtained with an arctangent function.

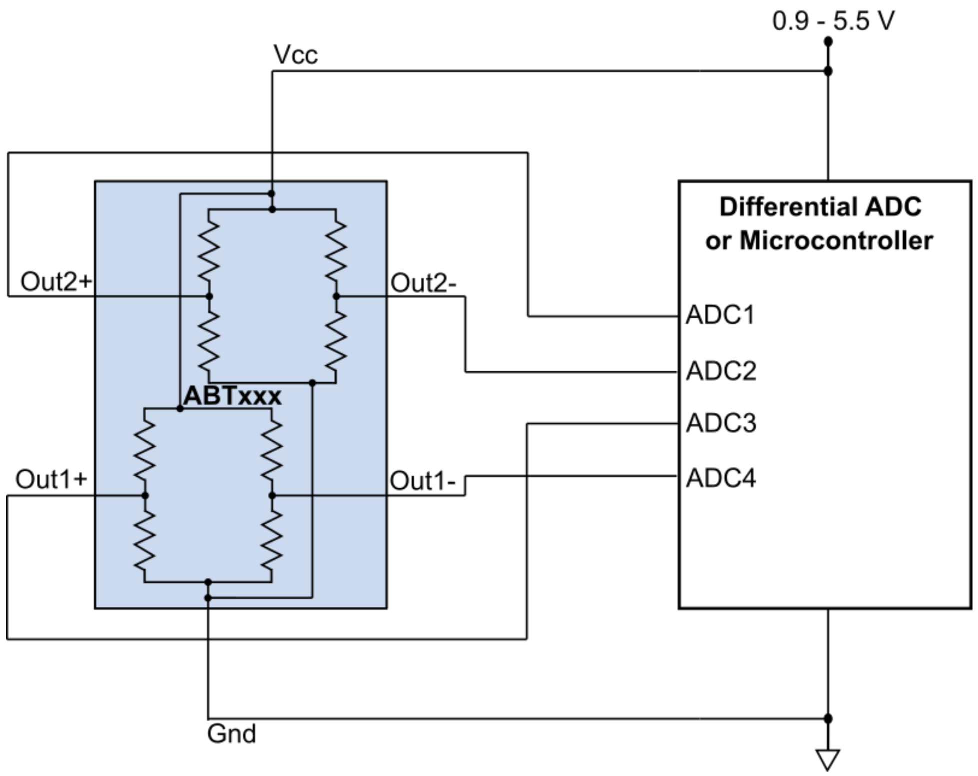


Figure 13. An ABT-Series sensor can be interfaced directly to an ADC or microcontroller for signal processing without any external conditioning.

Digital output from analog gear-tooth sensors

A comparator can be used with two of the ABT-Sensor outputs to provide a digital signal corresponding to each gear passing:

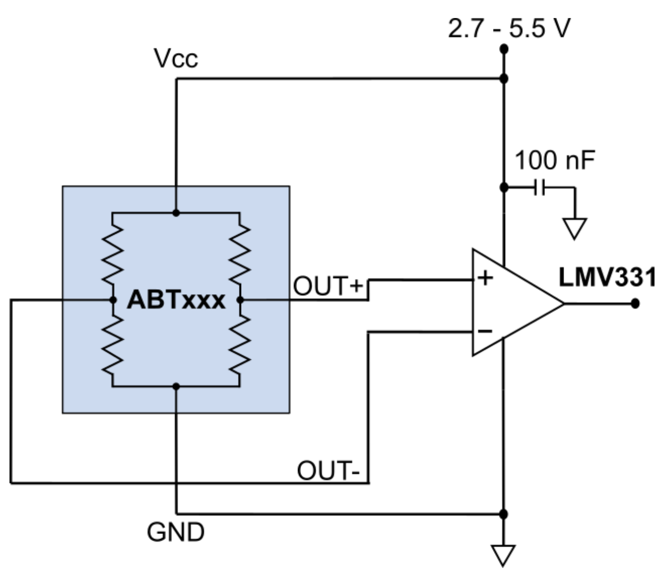


Figure 14. Digital output from an ABT-Series sensor, using a low-cost comparator.

Digital speed and direction signals

ABTxxx sensors have two outputs for direction information. A dual comparator and flip-flop can provide digital direction and speed outputs. Direction is determined by detecting the phasing between the two outputs. The “Speed” output is one cycle per tooth:

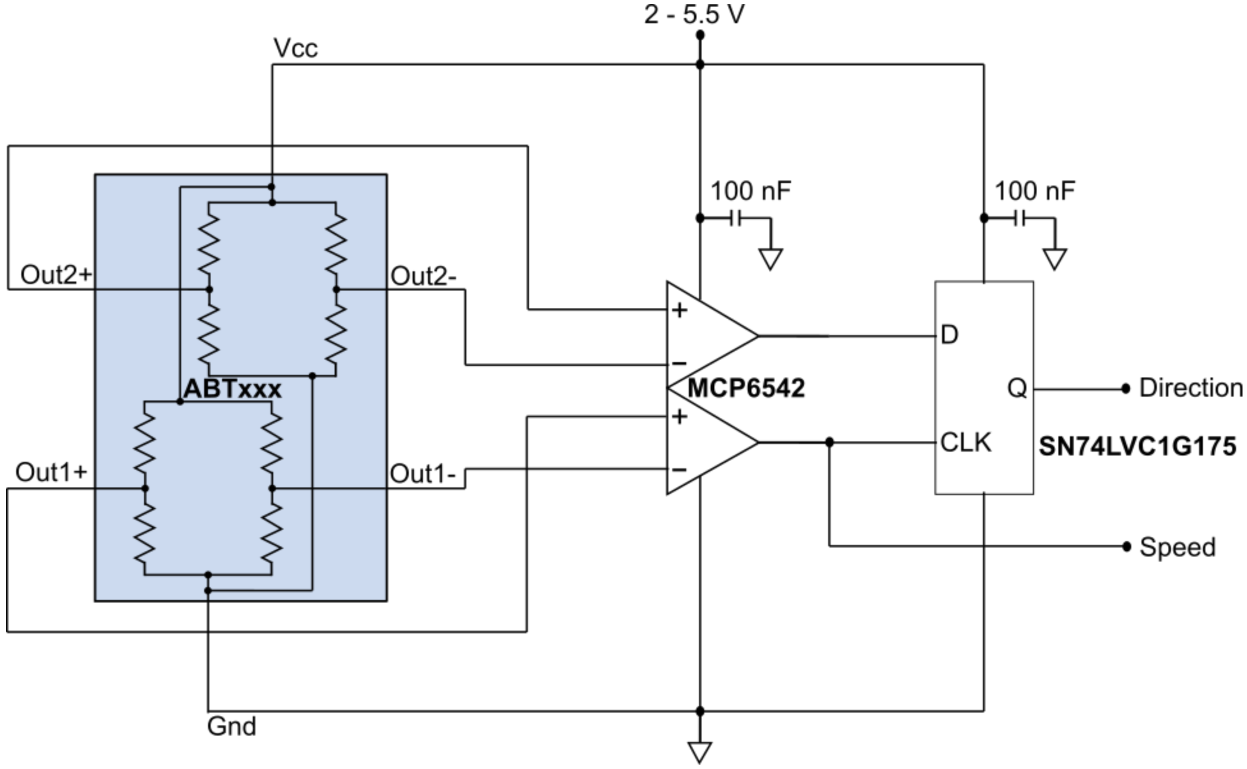


Figure 15. Digital speed and direction signals from an ABT-Series Gear-Tooth Sensor.

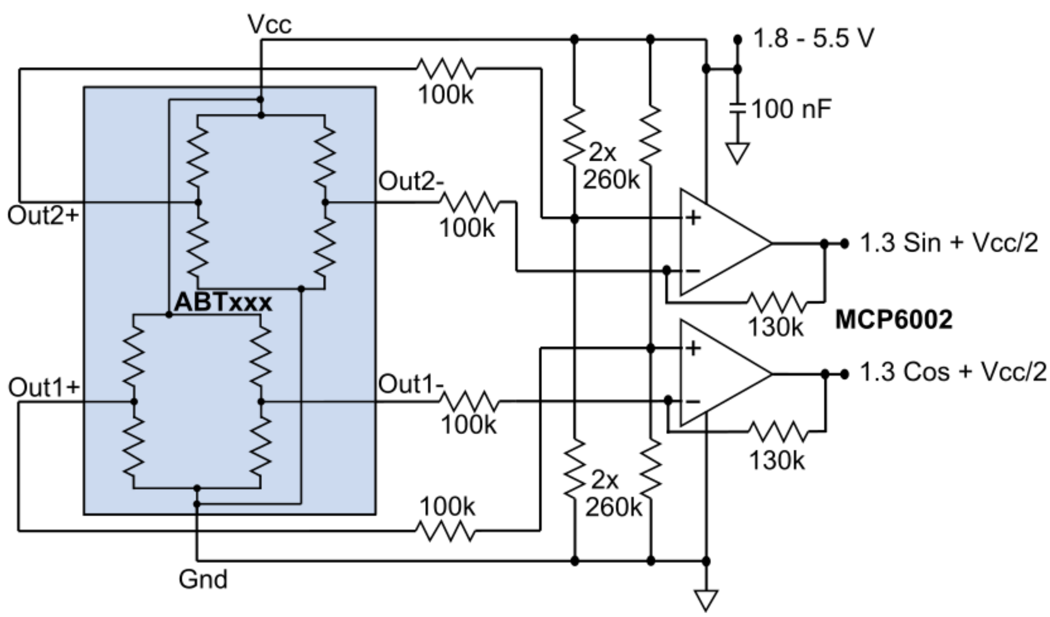
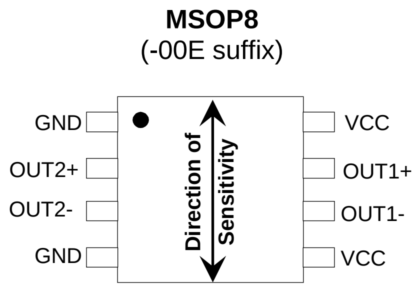


Figure 16. A simple differential amplifier boosts and buffers the signals of ABT-Series Gear-Tooth Sensors for encoder applications.

ABT-Series Sensor Pinout (top view)

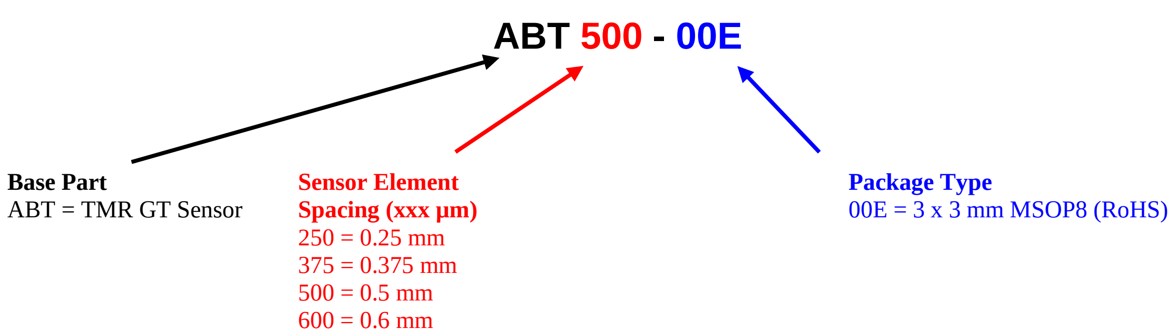


Pin	Symbol	Description
MSOP8 / SOIC8		
5	VCC	Bridge power supply*
8	VCC	Bridge power supply*
1	GND	Bridge ground*
4	GND	Bridge ground*
2	OUT2+	Differential output 2 (sine)
3	OUT2-	
6	OUT1+	Differential output 1 (cosine)
7	OUT1-	

*Pin 5 and pin 8 are connected internally, and Pin 1 and Pin 4 are connected internally.

Part Numbering

The following example shows the ABT-Series part-numbering system:



Available Parts

ABT-Series TMR Gear-Tooth Sensors						
Part No.	**Single or Dual Channel**	**Optimal Gear Pitch**	**Functional Gear Pitch**	**Maximum Airgap**	**Package**	**Package Marking Code**
ABT250-00E	Dual	1 mm	0.6 - 2 mm	0.5 mm	MSOP8	FTDe
ABT375-00E	Dual	1.5 mm	1 - 3 mm	0.75 mm	MSOP8	FTCe
ABT500-00E	Dual	2 mm	1.3 - 4 mm	1 mm	MSOP8	FTBe
ABT600-00E	Dual	2.4 mm	1.6 - 4.8 mm	1.2 mm	MSOP8	FTEe

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Evaluation Kits

A demonstration board is available for the ABT-Series sensors. NVE also sells circuit boards and bias magnets to use with the sensors.

AG972-07E ABT-Series Demonstration Board

The AG972-07E Demonstration Board showcases rotational encoding to one-thousandth of a degree of precision with an ABT375-00E sensor. The kit includes:

- A 3 x 5-inch (76 x 127 mm) PCB
- An ABT375-00E 0.375 mm element spacing gear tooth sensor
- A four digit rotational display
- Part #12216 ceramic bias magnet
- Powered by two AAA batteries (included)

Demonstration Videos

NVE uploads regular new product and application demonstrations to *Youtube*; check out our channel:

www.YouTube.com/NveCorporation

Detecting thousandths of a degree with ABT375-00E:

youtu.be/DERz2-UG3tM

Application Notes

Best practices and design support for NVE GT Sensors:

www.nve.com/SensorApps

Design Assistance Web-Application

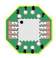
We have a free web-based application to provide design support for ABT Series GT Sensors, including bias magnet selection. Enter your gear's dimensions, then choose your sensor, bias magnet, and PCB thickness and view approximate sensor outputs for your system:

https://www.nve.com/spec/calculators.php#tabs-GT-Sensor-Output

Bare Circuit Boards and Magnets for Sensors

PCBs

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



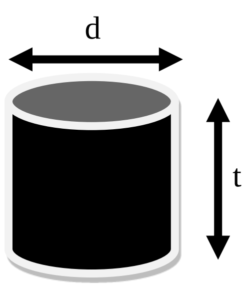
AG915-06:
0.25" (6 mm) octagonal
MSOP8

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

Magnets

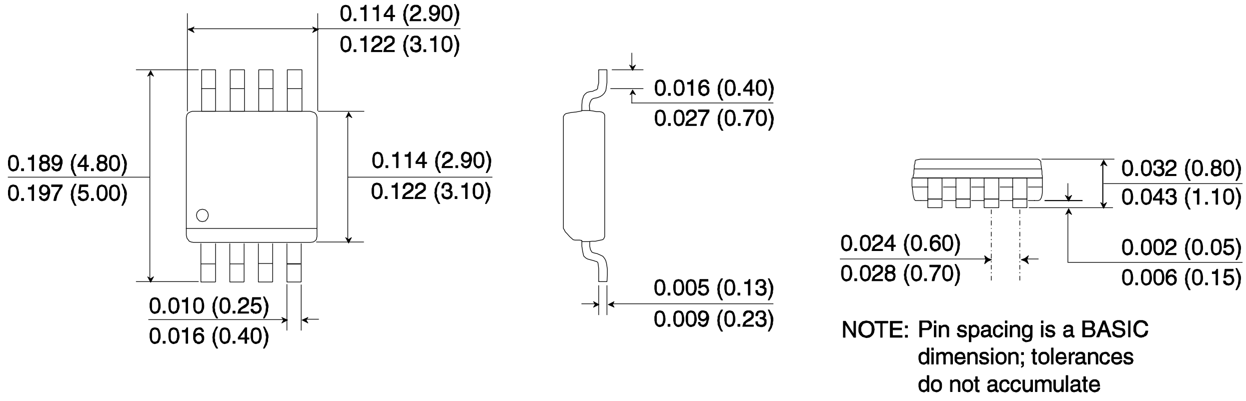
NVE offers three standard ferrite disk magnets for use with GT Sensors:



NVE Part #	Material	Diameter (d)	Thickness (t)
12031	C5/Y25	8 mm	3.2 mm
12216	C5/Y25	6 mm	4 mm
12217	C5/Y25	3.5 mm	4 mm

Package Drawing

MSOP8 (-00E suffix)



RoHS COMPLIANT

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

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Revision History

SB-00-121-A
August 2021

Change
- Initial datasheet release.

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