# Noise in NVE TMR Magnetometers

### *Detecting Ultra-Low Magnetic Fields*

NVE's world class Tunneling Magnetoresistance (TMR) magnetometers have the important competitive advantage of low noise. With a wide linear range of ±10 mT and only 250 nT RMS noise in a 0.01 Hz – 300 kHz bandwidth, the NVE ALT0x5 TMR Magnetometer resolution is 12.5 ppm, which is equivalent to >16 bits of resolution.

### *Two Types of Sensor Noise*

Noise in TMR magnetometers consists of a low frequency 1/*f* flicker noise due to thermal resistance fluctuations and thermal magnetic fluctuations, and frequency invariant Johnson-Nyquist white noise, due to thermal electron motion. These effects result in a detectivity spectrum with 1/*f* frequency dependence at low frequency and constant white noise at high frequency. The noise density referred to the sensor input determines the minimum detectable field, and is called the *detectivity*.

### *High Resolution Low Field Sensors*

NVE's TMR Magnetometers have high sensitivity, high output, and low noise, allowing precision measurements over a wide field range. A typical noise spectrum for the ALT0x5 is shown in Figure 1 with a typical sensor output curve inset. The detectivity saturates at the white noise corner frequency near 50 kHz.

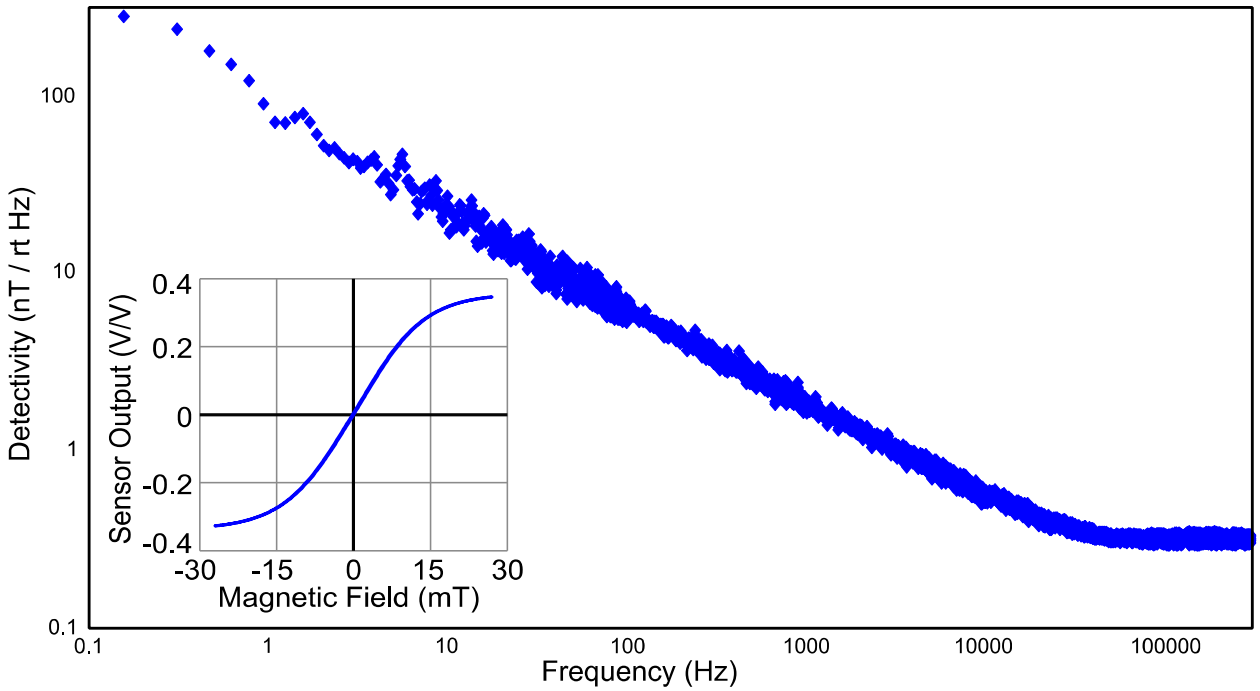


Figure 1: A typical detectivity spectrum for NVE's ALT005/ALT025 TMR magnetometer. Above 50 kHz, the noise spectrum is white, with a typical detectivity of 490 pT/ √Hz.

***Precision Linear Position Sensing***

With excellent linearity, high saturation field, and less than 1% hysteresis, the ALT005/ALT025 is a state-of-the-art linear position sensor. In typical applications, the sensor is used to detect the motion and absolute position of a magnet, such as the disk shown in Figure 2. The magnet produces a field that decreases with distance from the sensor. As an example, a four-mm thick, four-mm wide ferrite magnet, such as NVE part number 12217, will produce 15 mT at a nominal airgap of 5.5 mm. In a one-millimeter travel region about the center point, the field gradient is approximately 7.5 mT/mm.

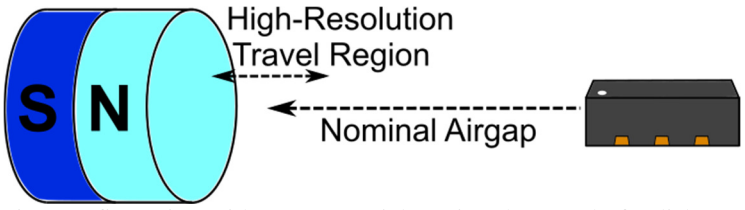


Figure 2: A typical sensing configuration with an ALT005 detecting the travel of a disk magnet. The magnet is set to a nominal airgap, and the motion of the magnet is detected with a sensitivity set by the magnet's field gradient and limited by the sensor's noise floor.

For a 0.1 – 10 Hz bandwidth, the ALT0x5 has just 0.15 µT (1.5 mOe) RMS field noise, which means the sensor can resolve displacements as small as 20 nm: smaller than the wavelength of visible light and 10,000 times smaller than the width of human hair. In this range, the sensor has a sensitivity of 20 mV/V/mT, translating to 150 mV/V/mm or 1.5 µV/V/nm. In the same frequency bandwidth, low-noise operational and instrumentational amplifiers, such as the OPA27 and INA163 have as low as 90 nVpp of input noise, making it possible to resolve tens of nanometers with a circuit such as the one shown in Figure 3.

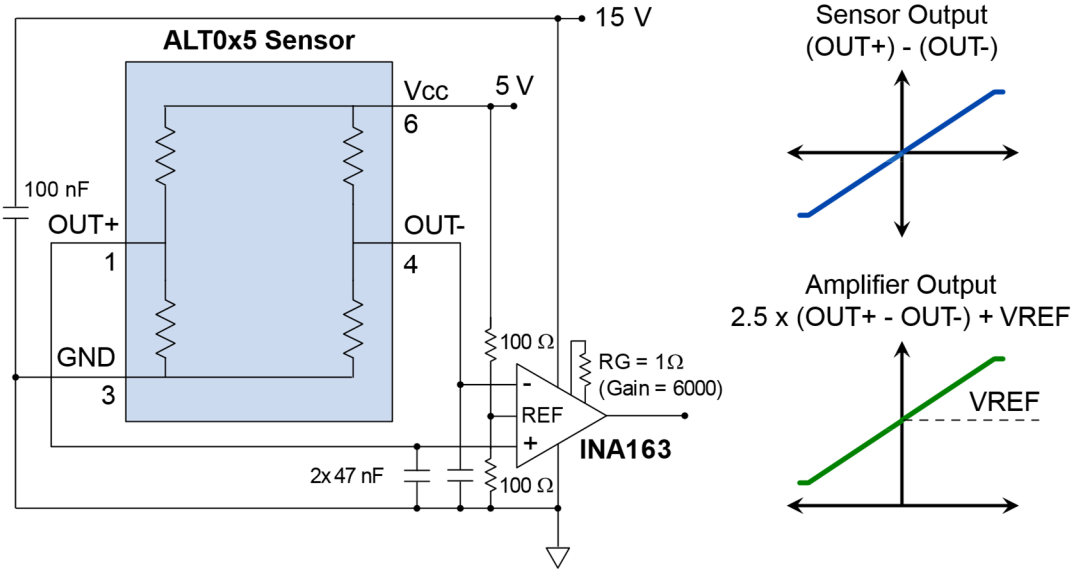


Figure 3: A precision nanometer detector circuit. With a 5V supply powering the sensor and a gain of 6000, this circuit has 45 mV / nm of signal, with a minimum detectable distance of 20 nm.



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When nanometer resolution is not required, the sensor has a huge dynamic range. The same magnet will hit the sensor's 30 mT saturation at an airgap of 2.5 mm, while at the sensor's 150 nT noise floor, the airgap reaches a staggering 250 mm.

***Current Sensing Use Case***

The cross-axis sensitive ALT025 TMR magnetometer is ideal for precision current sensing. With low hysteresis, wide linear range, high sensitivity, low power, and low noise, it is a versatile current-sensing solution. A typical configuration features the ALT025 mounted above a PCB trace with its output connected to the input of an inexpensive microcontroller/ADC. Figure 4 shows an example, with five turns directly beneath the ALT025 for high resolution. Conditioning circuitry is unnecessary due to the sensor's large signal and low output impedance.

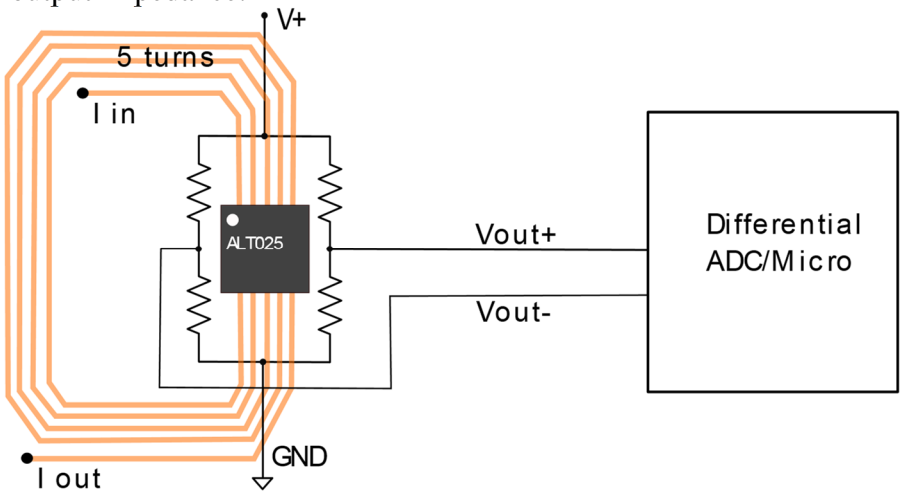


Figure 4: A typical high-resolution current sensing configuration, featuring the ALT025 above a five-turn trace for increased sensitivity. The sensor has a low 7.5 kΩ output impedance and high output amplitude, so it can be wired directly to an ADC without conditioning circuitry or buffers.

With a 3V supply, the 0.01 Hz – 300 kHz integrated RMS voltage noise of the ALT025 is 16.8 µV, and its sensitivity is 66 mV/mT. The resulting 250 nT integrated RMS field noise is the limit for detecting arbitrary AC signals in this frequency range. For the configuration in Figure 2, this corresponds to the detection of currents as low as 100 µA.

For higher currents, the full dynamic range of the ALT025 can be used. A thick 25 mm wide trace or busbar on the back of a PCB allows high current to be measured, as shown in Figure 5. The ALT025 has a noise floor of 10 mA in this configuration, while its linear range extends to more than 400 A. Since the sensor will not saturate up to 1300 A, the sensor can detect as much current as the copper can carry.



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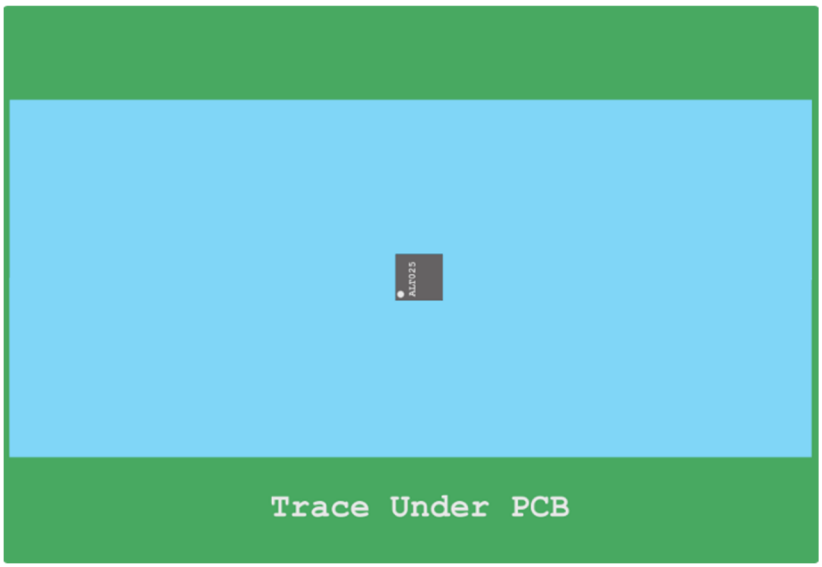


Figure 5: A high-current configuration with a 25 mm wide trace or busbar on the reverse side of a PCB. In this configuration, the ALT025 can detect as high as 1300 A with 10 mA resolution.

***Customer Support***

NVE engineers are experts in low noise, precision magnetic field sensing and are eager to help. For precision magnetometry, current detection, and other analog sensing inquiries, contact sensor-apps@nve.com.



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