Current Measurement Using GMR Sensors

NVE's AA or AAH-Series GMR sensors can be use to measure the current in a conductor. Since the GMR sensor is a magnetic device, this is done by measuring the magnetic field created by the current-carrying conductor at a known distance from the conductor center and translating this as a voltage or current. Since the relationship between the current in the conductor and the magnetic field that it creates is nonlinear due to sensor position and the length of the current-carrying conductor, a rule-of-thumb equation is not possible. All GMR sensors are characterized by their sensitivity to magnetic field strength H. NVE sensors are specified in Oersted (Oe, where 1 Oe = 79.6 A/m in air).

The best way to proceed is with an example of this application. All measurements are in SI units.

<u>Requirement:</u> To measure a current of 10 A in a PCB trace. Thereafter, we can design a trip circuit for over-current if necessary.

The axis of magnetic sensitivity is *along* the package. Therefore, the current-carrying conductor must run at 90° to this axis for maximum sensitivity.

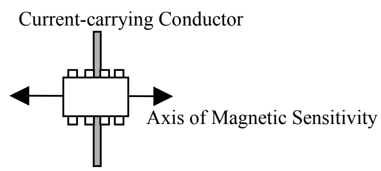
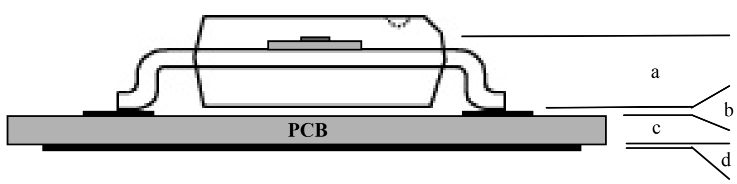


Figure 1. Axis of Magnetic Sensitivity

We must calculate the magnetic field strength H due to the 10 A, which will appear at the sensor element inside the IC package. First, we must sum the distances between the center of the current-carrying conductor and the sensor element.



Dimension	Distance in mm	Notes
a	1.15	Distance between bottom of leads and sensor element (specified by NVE).
b		Distance between bottom of package leads and top of PCB.
c		PCB thickness.
d		Distance between bottom of PCB and *half* trace thickness.
Total		

For standard PCBs the copper thickness is 35 µm per ounce, plus approximately 20 µm of plating. However, PCB thickness has a tolerance of approximately ±10%, which will swamp these measurements. For a 1.6 mm thick PCB the tolerance would be ±160 µm. It is important to be aware that the critical distance is from the sensor element to the center of the conductor. In practical terms the critical measurements, due to the tolerance of the PCB, are distances a + c. Therefore, for a standard 1.6 mm thick PCB with 1 oz copper, the distance from the center of the conductor to the sensor is

2.75 mm (1.6 mm + 1.15 mm). The variation in PCB thickness will show as an increase or decrease in calculated field strength at the sensor. This will be extremely small, and if necessary, could be corrected in the electronics in the same way as gain is adjusted for component tolerances.

To calculate the field strength it is now necessary to know the PCB track length (current carrying conductor) that creates the magnetic field.

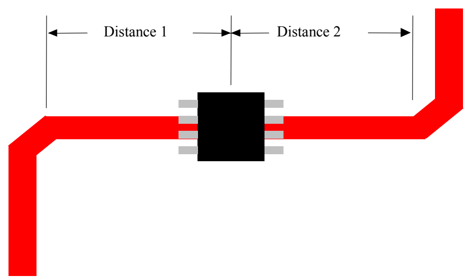


Figure 2. PCB track layout

Note: Distance 1 and distance 2 need not be the same. If they are not the same, however, the resulting field strength at the sensor will not be uniform along the same axis. Figure 3 shows the angles needed to calculate the correct field strength at the sensor position in the magnetic field.

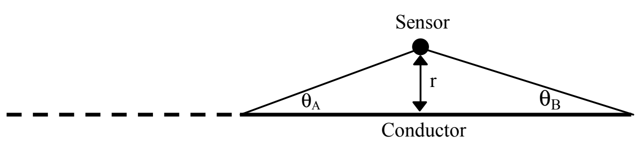


Figure 3. Angle Relationship for Calculating Magnetic Field

The formula for calculating the magnetic field at a point due to a current in a conductor is given by:

$$H = \frac{I\,(\cos\theta_B + \cos\theta_A)}{4\Pi r} \quad \text{A/m}$$

where I is the current in conductor and r is the distance of the sensor from the center of the conductor.

To simplify this procedure and help select the correct sensor, an Excel spreadsheet is provided on the NVE web site at *http://www.nve.com/technicalTools.htm*.

For the following values we can calculate the magnetic field strength H:

1. I = 10 A;
2. r = (a+b) = 2.75 mm;
3. assume distance 1 = distance 2 = 10 mm.

$\theta_A = \tan^{-1}(2.75 / 10) = 15.4°$ $\qquad$ $\theta_B = \tan^{-1}(2.75 / 10) = 15.4°$

Therefore,

$$H = \frac{10\,(\cos 15.4 + \cos 15.4)}{4\Pi \times 0.00275}$$

$$= 557 \text{ A/m}$$
$$= 7.00 \text{ Oe}$$

Using the Field Current Calculator on NVE's Website will also show the output voltage of various sensors for the desired supply voltage.

Application:

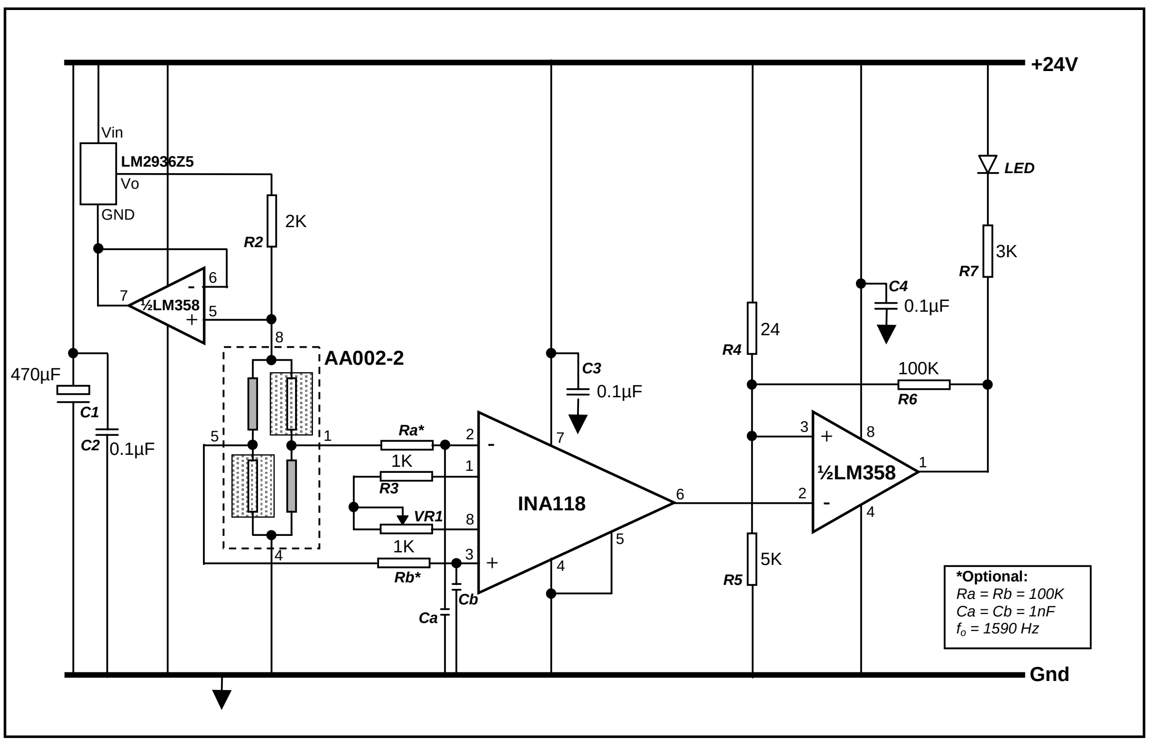


Figure 4. Using AA002-2 in a 10 A Overload Detection Circuit

Circuit Description:

The constant current source created by the LM2936 5 V regulator and R2 delivers 2 mA into the bridge of the AA002-2 GMR sensor. At 10 A, the bridge output is approximately 200 mV. This is amplified by the INA118 to provide a 5 V output. A gain of 25 is set by R3 and VR1. The other half of the LM358 forms a comparator that switches at 5 V and turns on an LED. The comparator hysteresis is approximately 1 V. *Ra, Rb, Ca,* and *Cb* are optional, providing a simple low pass filter to reduce input noise susceptibility in industrial environments. Using the values shown gives a –3 dB point of 1590 Hz. The PCB is constructed with a 3-oz copper layer. The 0.1-inch wide current-carrying conductor under the sensor will cause a 10ºC temperature rise with the 10 A current flow.