Current Measurement Using GMR Sensors

By measuring the magnetic field from a circuit board trace, NVE AA- or AAH-Series GMR magnetometers can determine DC current accurately enough for overcurrent protection.

For example, to measure an overcurrent of 10 A, we calculate the magnetic field strength at the sensor element inside the IC package from a PCB trace with the 10 A.

First, we sum the distances between the center of the current-carrying conductor and the sensor element as shown in Figure 1:

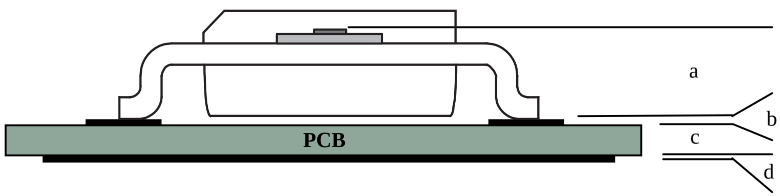

Figure 1. Distance from the sensor element to the center of the trace.

Dimension	Distance in mm	Notes
a		Distance between bottom of leads and the 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 (r)		**Distance of the center of the trace to the sensor element.**

For NVE MSOPs, a = 0.89 mm; for SOIC packages, a = 1.15 mm. The larger SOIC package dimensions make the design less sensitive to mechanical tolerances, so we will use a SOIC package for this example.

With 3 oz copper and a 0.1-inch wide trace, 10 A will cause a 10ºC temperature rise, so we will use 3 oz copper in this example. For standard PCBs, copper thickness is 35 µm per ounce plus approximately 20 µm of plating, so b = 125 µm for 3 oz plated copper. The distance to the center of the conductor is half the trace thickness, so d = 62 µm. Trace thickness is usually negligible for 1 oz copper.

We will assume a standard 1.6 mm thick PCB, so:

$r = a + b + c + d$

$= 1.15\ \text{mm} + 0.125\ \text{mm} + 1.6\ \text{mm} + 0.062\ \text{mm} = 2.94\ \text{mm}.$

The tolerance in PCB thickness (typically ±10%) will cause an increase or decrease in calculated field strength at the sensor. This variation will be extremely small, and, if necessary, could be corrected in the electronics in the same way as gain is adjusted for component tolerances.

The axis of magnetic sensitivity is *along* the package. Therefore, the current-carrying conductor must run perpendicular to this axis for maximum sensitivity as shown in Figure 2:

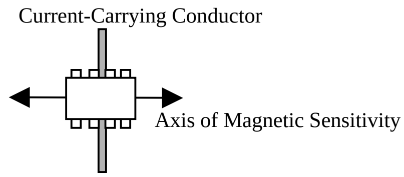

Figure 2. Axis of Magnetic Sensitivity

To calculate the field strength we need to know the length of the current-carrying PCB track perpendicular to the package, and the angles shown in Figure 3:

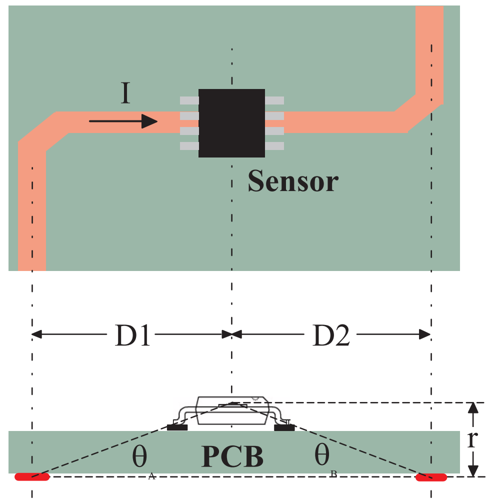

Figure 3. PCB track layout

D_1 and distance D_2 need not be equal. If they are not the same, however, the field strength at the sensor will not be uniform along the same axis.

Using the Biot-Savart Law, the magnetic field at the sensor element is approximated as:

$$H = \frac{I\,(\cos\theta_A + \cos\theta_B)}{4\,\pi\,r}$$

Where I is the current in conductor in amperes, r is the distance of the sensor from the center of the conductor in meters, and H is the magnetic field at the sensor element in A/m using SI units (1 A/m = 0.0126 Oe in air).

Calculating the magnetic field strength H for our example, where:

- $I = 10$ A;
- $r = 2.94$ mm (0.00294 meters); and
- $D_1 = D_2 = 10$ mm

$\theta_A = \theta_B = \tan^{-1}(2.94 / 10) = 16.4°$

Therefore,

$$H = \frac{10\,(\cos 16.4° + \cos 16.4°)}{4\,\pi \times 0.00294}$$

$= 519$ A/m
$= 6.54$ Oe

To simplify these calculations and help select the correct sensor, an Excel spreadsheet is available on the NVE web site at *http://www.nve.com/technicalTools.htm*. This Field Current Calculator also shows the output voltage of various sensors for the desired supply voltage.

Typical Circuit

Figure 4 illustrates a 10 A overload detection circuit using an AA002-2 GMR magnetic sensor with the PCB configuration previously discussed.

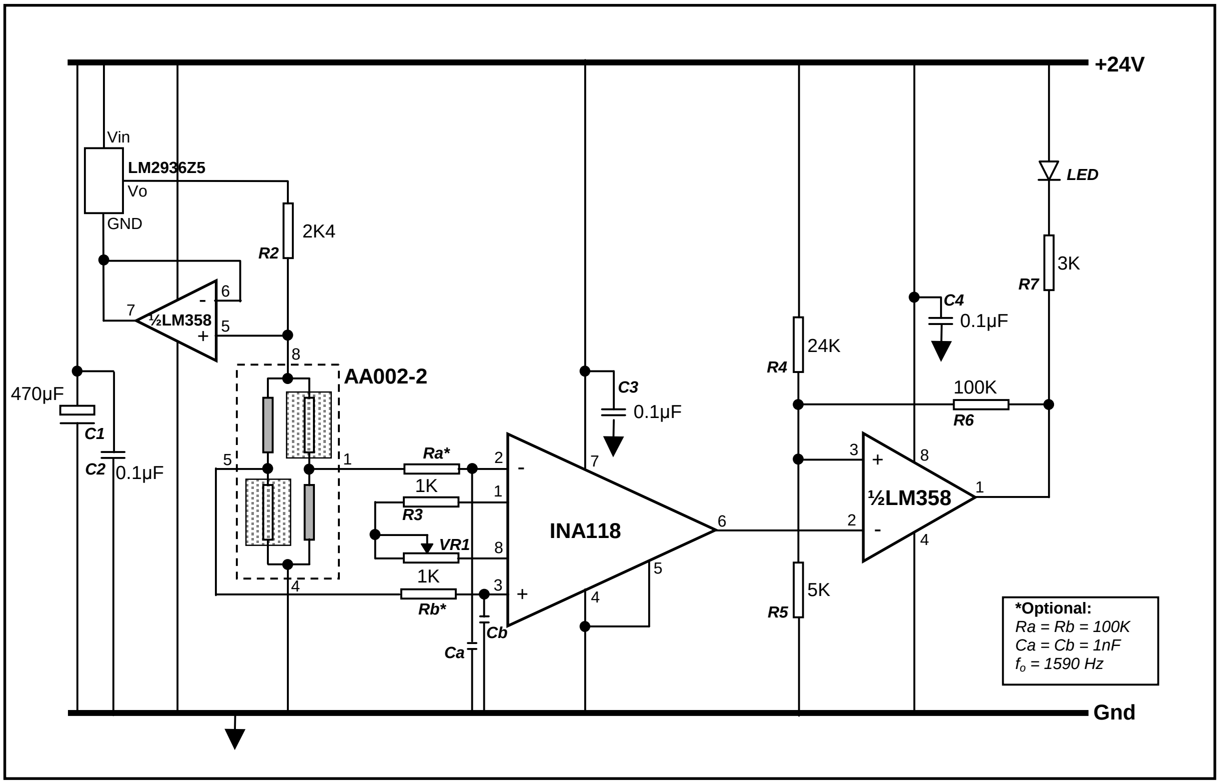

Figure 4. 10 A Overload Detection Circuit Using AA002-2.

The constant current source created by half of an LM358 dual op-amp, an LM2936 5 V regulator, and R2 delivers 2 mA into the AA002-2 sensor bridge. At 10 A, the sensor field is 6.54 Oe and the bridge output is approximately 240 mV. The bridge output is amplified by the INA118 to provide a 5 V output. A gain of 20 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, so the LED turns off at approximately 4 V, corresponding to 8 A sensed current.

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.