Magnetoresistive Sensors

Application Note

## Industry: Position and Solid State Sensing

MAGNETORESISTIVITY

Magnetoresistivity is the ability of a material to change resistance under the influence of magnetic fields. There are several different magnetoresistive effects, but Honeywell sensors use the **A**nisotropic **M**agneto **R**esistive (AMR) effect which occurs in ferrous materials, including Permalloy. Permalloy is an alloy of nickel and iron and has been used as a sensing material since the early part of the 20th century in transformer designs. Low sensitivity to mechanical stress coupled with high sensitivity to magnetic fields provide sensors that vart from magnetometers to automotive engine applications.

MAGNETIC RESPONSE

Magnetic response for an individual magnetoresistor can be expressed as the ratio of the change in resistance (ΔR) over the nominal resistance (Ri) of the film. Figure 1 illustrates several properties of the AMR effect.

Figure 1. AMR effect
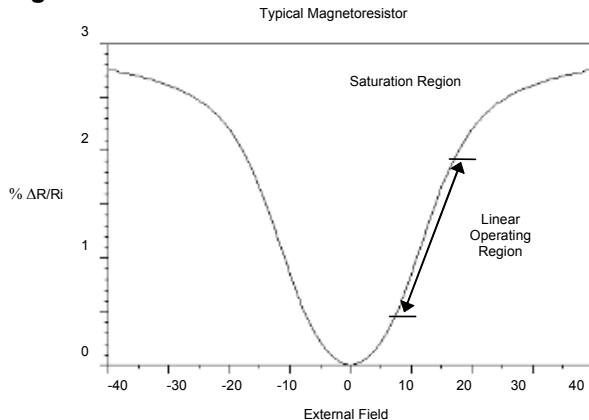
First, note that it is polarity insensitive, the response to a positive field is the same as the response to a negative field. Secondly, there is a region which is reasonably linear. However, this effect goes into saturation when the absolute value of the external field exceeds a particular value. Ferromagnetic materials, like Permalloy, have magnetization, or magnetic moment per unit volume, which is a vector quantity defined at each point in the material. It is the rotation of this magnetization vector from the direction of the current flow due to an external magnetic field which produces the change in resistance. This will be discussed in more detail. For polarity sensitive applications, the films can be biased into the linear region of the curve by either rotating the magnetization away from the current with an external magnetic field, or by rotating the current away from the magnetization in the sensor design.

PERMALLOY CHARACTERISTICS

Figure 2 represents a long, thin film of Permalloy with the current flowing along the length of the film.

Figure 2. Permalloy film with current flow
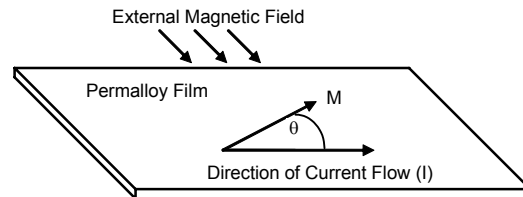
When a external magnetic field (B) is applied, the film's resistance changes proportional to the square of the sine of the angle θ (Theta in the XZ plane) between the magnetization vector (M) and current flow vector (I). The magnetization vector is the net summation of the film's internal fields and the applied external field. The internal fields arise from the film properties, layout geometry, and fabrication process. The films do exhibit some magnetic hysteresis (switch point variance) which can be minimized by operating in one magnetic quadrant (i.e. only presenting a single pole of the magnet) when possible in the application. The AMR effect responds to the in-plane (XZ plane) external magnetic field components BX and BZ as previously described (proportional to the square of the sine of the angle θ). Figure 3 illustrates a rotational misalignment in the YZ plane will reduce the change in resistance proportional to the cosine of α (Alpha in the YZ plane).

Figure 3. Rotational misalignment in the YZ plane
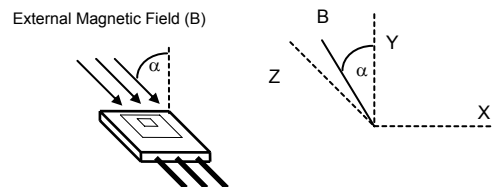
ACHIEVING MAXIMUM SENSITIVITY

Honeywell's 2SS52M/SS552MT Series Magnetoresistive position sensors are our new first level building blocks for low Gauss magnetic sensing applications. To maximize the sensitivity of the 2SS52M/SS552MT sensor, three main application characteristics should be met. First, the alignment of the sensor and the magnetic field should be in the same plane. Figure 4 illustrates the maximum sensitivity alignment position, either pole produces an equivalent result.

Figures 4 and 5. Sensitivity positioning


MR Bridge

     Figure 4   **Figure 5**
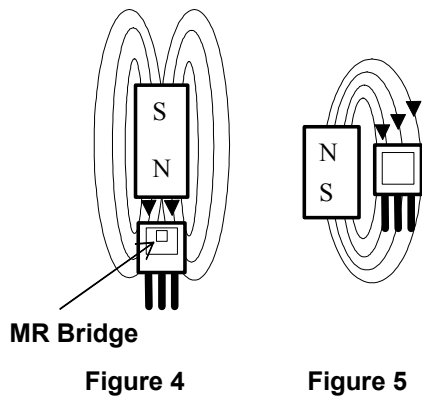
Second, the air gap between the sensor and magnetization must be minimized. The magnetoresistive bridge is located near the top center of the 2SS52M/SS552MT package for increased sensitivity. By minimizing the air gap the gauss level at the sensor is increased. Third, the strength of the magnetic field applied to the sensor should be maximized. Working in conjunction with proper alignment, the magnetic field placement and strength will effect the sensitivity of the sensor. Figure 5 depicts the maximum sensitivity position when this sensor is used in a slide by mode. As the sensor approaches either pole, the magnetic field changes direction resulting in decreased sensitivity. This will vary in each application based on the placement of the sensor and the type of the magnet.

MAGNETORESISTIVE EFFECT VS. HALL-EFFECT

The following compares the Hall-effect in silicon to the Magnetoresistive effect in a Permalloy thin film. Both technologies are compatible with integrated circuit processing and may be used to make totally integrated single-chip sensors. Both effects occur for time-invariant fields and may be used to construct zero-speed sensors. However, MR is roughly 100 times more sensitive than the Hall-effect in silicon. Furthermore, its sensitivity is adjustable through selection of film thickness and line width. Another advantage when replacing Hall-effect with MR sensors in applications that count revolutions using ring magnets is that the resolution doubles since MR sensors are omnipolar (operates with North or South pole). Although, Hall-effect has advantages as it is highly linear with no saturation effects out to extremely high fields. Hall-

effect films respond to fields perpendicular to the sensor, and AMR bridges respond to parallel fields, as illustrated in Figure 6. These are the main application differences between Hall-effect and Magnetoresistive sensors.

Figure 6. Hall-effect versus Magnetoresistive

Hall Effect Sensor   Magnetoresistive Sensor
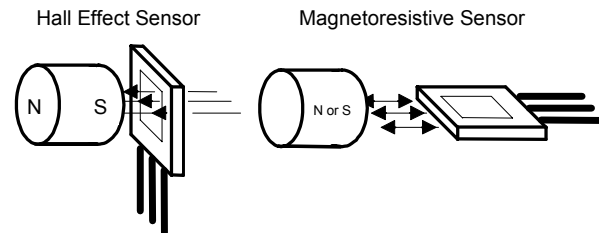
MAGNETORESISTIVE APPLICATIONS

Honeywell's small, highly sensitive omnipolar 2SS52M/SS552MT series magnetic sensors have become popular building block for cylinder position sensing. Many other applications can also benefit from the advantages of our AMR sensors: actuation by either pole, very high sensitivity, small size, wide voltage, and wide temperature operation. Since it has a longer sensing distance and lower Gauss operation than Hall-effect sensors, it can be used with lower cost magnets. The following are typical applications for the 2SS52M/SS552MT series:

- Cylinder position sensing in pneumatic cylinders
- Elevator sensor
- Lid sensor for laptop computers
- Digital current sensing for: overload circuit protection, traffic light burnout detection, motor overload sensor, power loss detection, and industrial process monitoring
- Position sensor for materials handling equipment (lift trucks)
- Geartooth sensor for industrial applications
- Handicapped lift for van / bus
- Low-cost industrial proximity sensors for ferromagnetic targets
- Blood analyzer
- Magnetic encoders

* Note: Figures are not drawn to scale. See 2SS52M & SS552MT Series M-drawing or Product sheet for actual dimensions.

While we provide application assistance personally, through our literature and the Honeywell web site, it is up to the customer to determine the suitability of the product in the application.
For application assistance, current specifications, or name of the nearest Authorized Distributor, contact a nearby sales office. Or call:
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