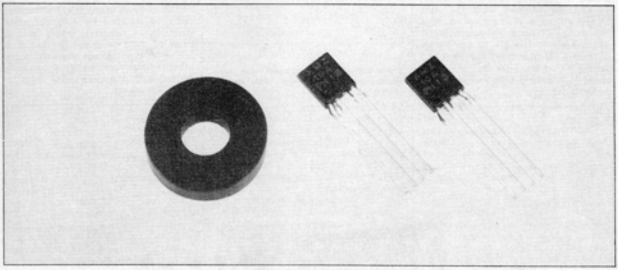
MAGNETIC-FIELD SENSORS



Announced as being more sensitive than Hall-effect elements, magnetoresistive sensors (MRS) have recently been introduced by leading manufacturers of electronic components. This introductory article examines their fundamental characteristics and possible applications.

The physical operation of magnetic sensitive resistors is based on the Gauss-effect, which may be summarized as follows: a magnetic field with lines of force perpendicular to a current carrying conductor forces charge carriers to travel along the surface of that conductor; the magnetic field 'pushes' the current into a thin layer, which results in a diminished cross-sectional area for the current to pass along, or, in other words, an increased resistivity of the conductive material. Figure 1 illustrates this effect which has been known for quite some time, but has re-

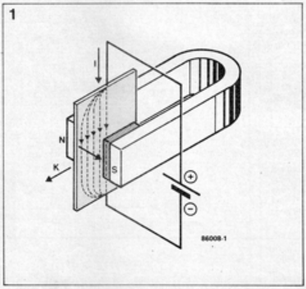


Fig. 1 The magnet pushes the electric current out of the area with maximum magnetic field strength.

Fig. 2 A sufficiently high total resistance can only be obtained by means of a long conductor path.

Fig. 3 Gold stripes have been applied to the resistor track, which make it look like a barber's pole.

Fig. 4 The four resistive elements in a Wheastone bridge configuration.

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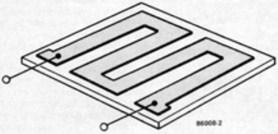

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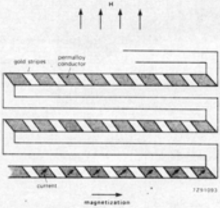

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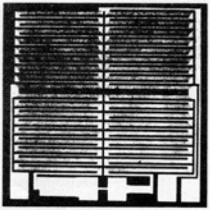

mained disregarded by the electronics industry until quite recently, when suitable alloys were developed to put the effect to practical use.
The increase in resistivity caused by the Gauss-effect is minimal with pure metal conductors, with the exception of bismuth (Bi), which is a so-called diamagnetic metal with poor conductivity. However, certain alloys have been developed which are more sensitive to the presence of a magnetic field.
Siemens, for instance, use a semiconductor with antimony (Sb) based alloys, such as indiumantimonid-nickelantimonid (InSb-NiSb). This material has semiconductor properties and may be glued onto a permeron, ferrite, ceramic or plastic substrate. The magnetic sensitive resistor is usually realized in the form of a meander path as shown in the sketch of Fig. 2; this is done to achieve a maximum-length current track within the encapsulation.
While Siemens manufacture single, flat type resistive elements, Philips have developed complete Wheatstone bridges in a standard transistor case. These devices are made from a thin permalloy layer on a silicon substrate. Permalloy is a 20% iron, 80% nickel ferromagnetic alloy without semiconductor properties. The resistivity of a polycrystalline alloy such as permalloy varies in direct proportion to the angle between magnetic field lines and the direction of the current in the conductor. In order to obtain a maximum operational linearity for these devices, Philips have come up with a special arrangement for the permalloy track: a regular pattern of gold stripes is applied onto the conductive track, at an angle of 45° with respect to the current flow direction. For reasons made clear by Fig. 3, this layout is referred to as a 'barber's pole'. Since gold has a much higher conductivity than permalloy, the gold stripes effect a net current turn of 45° with respect to the conductor axis; this causes the current to travel zigzag through the flat, conductive track.
A complete sensor device of this type contains two resistive elements that feature an increase in resistance with an increase in magnetic field strength, and another two elements with precisely the inverse property: their resistance decreases in a stronger magnetic field. These four resistors have been connected in a Wheatstone bridge setup, with the same resistor types arranged diagonally, as illustrated by Fig. 4. The diagonal configuration offers a high element sensitivity while minimizing bridge unbalancing by changes in ambient temperature.

One of the most important advantages of magnetic sensitive resistors is the ease of device sensitivity definition by means of the manufacturing process. The new Philips magnetic sensitive Wheatstone bridge devices come in a TO92 style case with four leads: two for the bridge supply voltage and two for the bridge output voltage. Applications are found in any electronic field involving magnetic force detection or measurement. A revolution counter, for instance, may be constructed by mounting a MRS device between a permanent magnet and a cogwheel, driven by the engine; every passing cog will unbalance the Wheatstone bridge and cause an output voltage which may be applied to equipment for further signal processing. Similarly, these devices may be used to determine the angular position of a spindle. If placed close to a current carrying conductor, a magnetic sensor may even perform the function of current transformer.

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