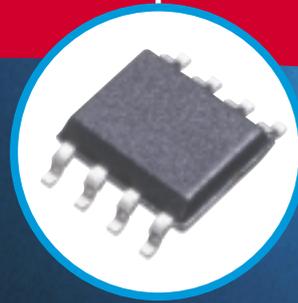


Philips Semiconductors

Earth field sensors

A world of sensing possibilities

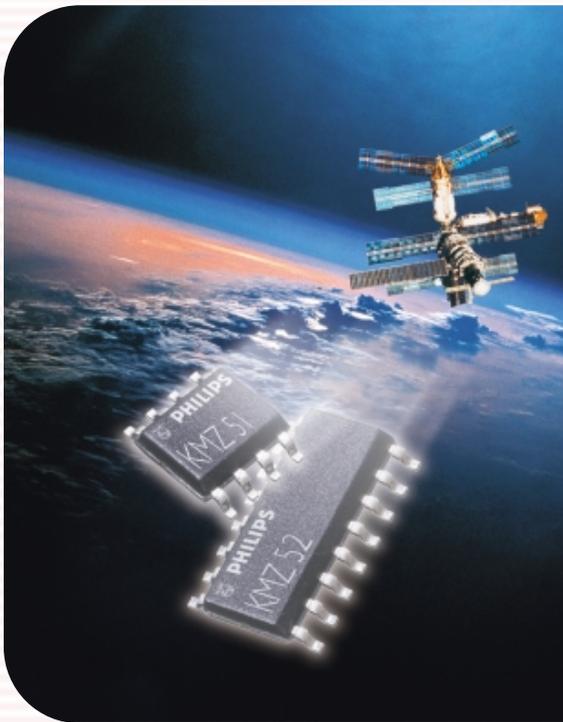


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Earth magnetic field sensing: a Philips strength

Within its extensive range, Philips Semiconductors has a number of magnetoresistive sensors ideal for applications requiring the sensing of the Earth's magnetic field and other weak fields, such as electronic compasses, Earth magnetic field compensation, traffic detection and so on. They offer all the inherent advantages of magnetoresistive technology, with none of the trade-offs between precision and sensitivity, frequency limitations, temperature restrictions and other drawbacks found with many other sensing techniques.



Philips' MR sensors for Earth field sensing

Magnetoresistance: the natural choice for weak field sensing

A magnetoresistive sensor uses a current-carrying magnetic material which changes its resistivity in the presence of an external magnetic field. As an external field is applied, the internal magnetization vector will rotate by an angle α , changing the resistance R of the material according to the relationship $R \propto \sin 2\alpha$. By depositing aluminium strips in a so-called 'Barber pole' arrangement at an angle on the material, the effect can be linearized and the processing electronics can be simpler.

Philips' MR sensors consist of four magnetically sensitive permalloy resistors arranged in a Wheatstone bridge configuration. This maximizes sensitivity and minimizes temperature influences, so Philips' sensors offer:

- high sensitivity and high reliability
- low offset voltage
- contactless and therefore wear-free measurement/detection
- a wide operating frequency range (0 Hz to 1 MHz)
- high operating temperatures (up to 125 °C peak)
- long operating life, high stability and ruggedness

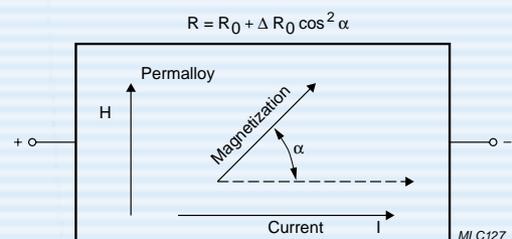


Figure 1. The magnetoresistive effect in permalloy

Compensation: the key to weak field sensing

Despite electrical trimming and their inherent high sensitivity, as with any weak field sensor MR devices can have an offset value larger than a typical target weak field, such as the Earth's geomagnetic field. Also, their sensitivity decreases as temperature increases but fortunately, both these effects can easily be compensated, allowing the high sensitivity and reliability of magnetoresistive sensors to be exploited in weak field measurement.

Compensation uses two coils wrapped around the sensor which, in Philips' KMZ51 and KMZ52, are already integrated into the housing for easy design-in. The 'flipping' coil both stabilizes the sensor and eliminates offset effects; the other provides electromagnetic feedback so the sensor can be operated at its zero-point, where offset and sensitivity are unaffected by temperature.

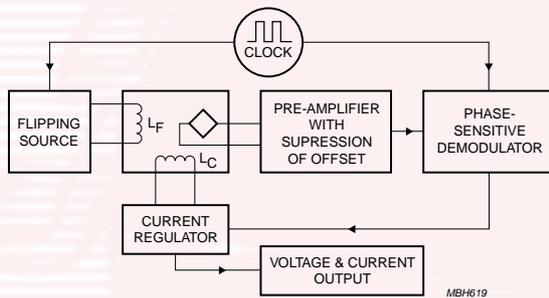


Figure 2. Compensation circuit

Figure 2 shows a typical compensation circuit. This can be greatly simplified if a microprocessor is available within the system to drive the flipping and compensation coils: for a typical example, see page 5.

Offset compensation

All magnetoresistive sensors have two stable output characteristics. Using a reversible, pulsed external magnetic field of very short duration, produced using the first current carrying coil wrapped around the sensor, the output is periodically switched or

'flipped' between the two states. Thus the unknown field is measured in one direction in one half of the cycle, while in the second half it is measured in the opposite direction. The two different outputs are symmetrically positioned around the offset value, so simple high pass filtering and rectification produces a single continuous, offset-free output.

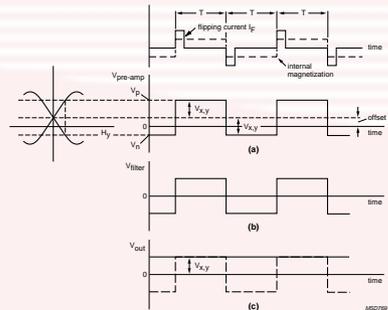


Figure 3. Timing diagram for flipping circuit

Temperature compensation

By using a principle called current compensation in an electromagnetic feedback set-up, the MR sensor can always be operated at its null-point, where compensation is independent of the sensor's actual sensitivity or its drift with temperature (see figure 4). This is easily achieved with a second compensation coil wrapped around the sensor, perpendicular to the flipping coil. Variations in the sensor's output are converted to a current and fed back through the compensation coil to produce an equal and opposite field, exactly compensating the change in output signal, regardless of its actual, temperature-dependent value. The value of the target field is then easily derived from the current fed to this coil.

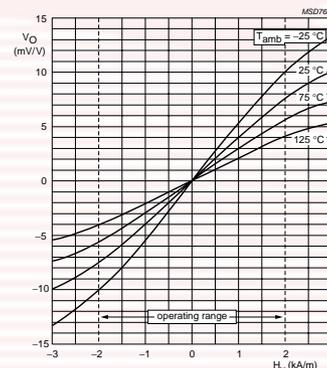
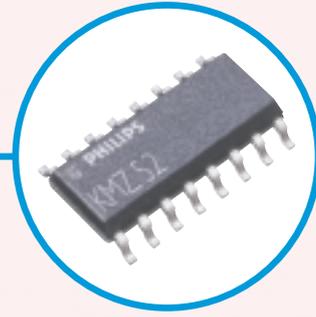


Figure 4. Sensor sensitivity or drift at four different temperatures

Pointing the way



Probably the most common weak field application for magnetoresistive sensors is in electronic compasses. These use two sensors, aligned in the same plane but at 90° to one another, to measure the x- and y-components of the horizontal Earth field (figure 5). From the two sensor signals, the direction heading can be determined.

The KMZ52 is the optimum choice for realizing a two-sensor-element, as it integrates the required sensor configuration within one package. An analog signal conditioning circuit is needed for amplification and offset compensation, and optionally for temperature compensation (see page 3).

Magnetoresistive-based compasses offer basic set-up simplicity, as well as design flexibility to allow tailoring of compass performance to the application. Depending on the level of accuracy required and expected environmental influences, various levels of complexity can be incorporated into the compass circuit, to make systems ranging from a simple 8-segment compass to high-precision set-ups including a microcontroller. It is also possible to design tilt-compensated systems which use a three dimensional sensor arrangement and gravity sensors, to eliminate compass sensitivity to the angle with respect to the Earth's surface.

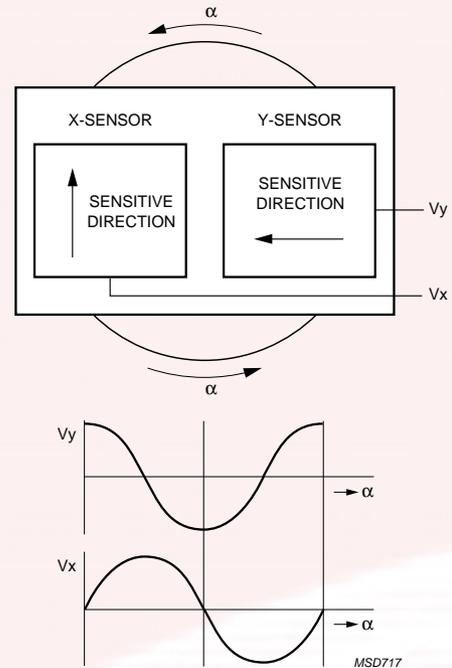


Figure 5. Operating principles of an electronic compass

Support material

Technical support is crucial to reduce time-to-market for new designs. For its range of magnetoresistive sensors, Philips Semiconductors provides comprehensive support including samples, demonstration boards and application reports, to help you evaluate the KMZ range and speed up the design-in process.

Contact your local sales person for more information or check out our website: <http://www.semiconductors.philips.com/discretes/products/> and the 'Give range to your ideas' brochure (12NC order number: 9397 750 07392).

Simple 8-segment compass

Simple compass applications give an approximate indication of direction, displaying only the eight major compass directions (N, NE, E, etc.). This basic functionality is typically found in simple navigation aids where, for example, car drivers need to know their rough orientation but do not need an accurate indication of their direction. In such a system, output signals from the two magnetoresistive sensors can be compared with each other and with reference signals to provide the 8-segment directional information (figure 6). For realization, only comparators and basic logic gates are required, as shown in figure 7: in this case, the signals V_x and V_y would be the amplified and offset compensated outputs of a KMZ52.

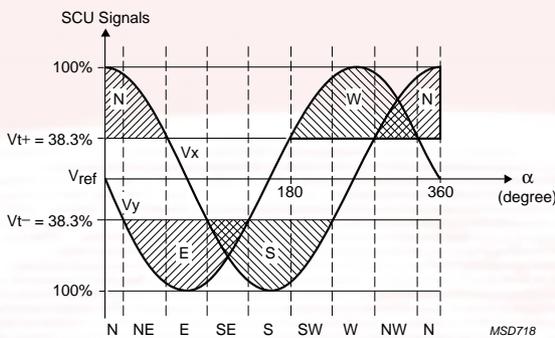


Figure 6. Direction determination for an 8-segment compass

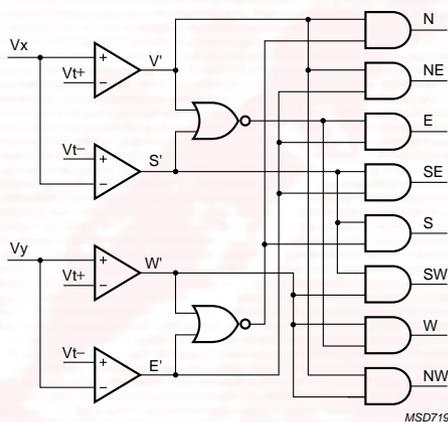


Figure 7. Circuit for 8-segment compass

Compass with microcontroller

Using a microcontroller to calculate heading direction from two sensor signals increases compass resolution from the basic eight directions (figure 8), with compass resolution then depending mainly on the resolution of the A/D converter used. A microcontroller also enables additional functionality to be included, increasing accuracy under practical conditions. Two examples are:

- **Calibration against magnetic field interference**, e.g. from the compass housing. The components of the interference field are measured using a dedicated software routine and, if stored in non-volatile memory, can be applied during normal operation to compensate for interference effects. Such calibration can also be performed automatically by algorithms, which use data measured in normal compass operation.
- **True north correction**. This enables the compass to display the heading direction with respect to true, or geographic, north, instead of magnetic north.

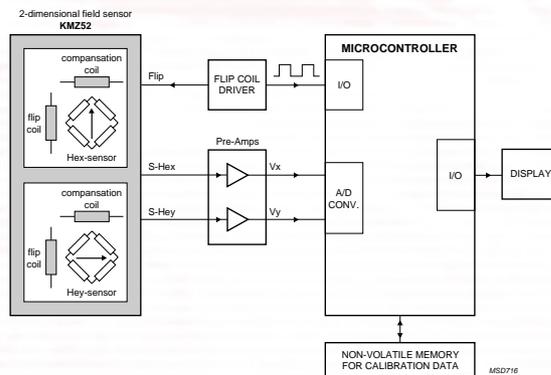
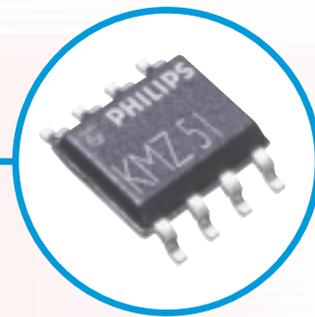


Figure 8. Compass with microcontroller

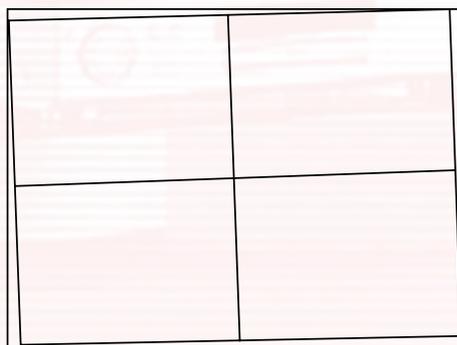


Squaring the picture



The Earth's geomagnetic field is strong enough to cause problems for TV and monitor manufacturers. It influences the trajectory of electrons in a CRT tube, producing a horizontal tilt in the geometry and convergence error shifts, creating unacceptable picture distortion which is especially noticeable with increasingly popular 16:9 aspect ratios. The solution is straightforward and, if a magnetoresistive weak field sensor is incorporated into the system, can be made fully automatic.

A DC-current carrying coil is wrapped around the neck of the CRT and generates a magnetic field that opposes the Earth's field, cancelling the twist in the electron's path and reducing the number of convergence errors. This coil also compensates for any other extraneous electromagnetic field sources emanating from the TV such as the loudspeakers. Residual picture twist and North/South trapezoid errors can be eliminated with a simple shift in the compensation current.



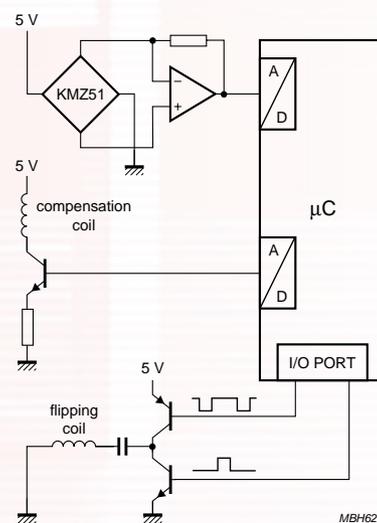
MBH627

Figure 9. Geometry error - horizontal picture tilt

Automatic adjustment

Although highly effective, this method still requires manual adjustment of the coil drive currents to meet the varying geomagnetic fields around the world. Here, magnetoresistive sensors come into their own - they detect the magnitude of the Earth's field and sensor output can be used to drive the compensation field accordingly. This makes adjustment fully automatic and the same compensation circuitry will deliver the same high quality picture geometries anywhere in the world.

For all but low-end monitors and TVs, there is always a microcontroller or microprocessor in the system, which can then be used to drive the flipping and compensation coils. This greatly simplifies design of the sensor circuitry (see figure 10) and in principle, this is true for any application which uses a microcontroller.



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Figure 10. Weak-field measurement compensation circuit using a microcontroller

Handling traffic flows

As the number of vehicles using already congested roads steadily increases, traffic control systems are a powerful tool in avoiding time consuming traffic jams. By monitoring traffic flow, average speed and traffic density they allow optimal control of electronic road signs, regulating traffic flow and speed at known trouble spots. They can also indicate possible incidents points, where traffic speeds fall significantly below average and, with simple modifications, are effective in improving safety and monitoring ground traffic at airports. Another possible application is active parking lot steering where, by detecting occupied bays, cars can be directed automatically to empty parking spaces.

A traffic system is only as accurate and reliable as its inputs and systems based on magnetoresistive technology have none of the drawbacks of existing inductive systems. They can be easily and quickly installed in any stretch of road, or even by the side of the road, if necessary, due to their small size and simple placement. Combined with almost negligible power consumption, this makes magnetoresistive control systems inexpensive and highly efficient. They meet all functional requirements and environmental conditions, such as large temperature ranges, insensitivity to climatic changes, low power consumption and, most of all, low cost, high reliability and ruggedness.

More than just detection

Every vehicle manufactured contains some ferromagnetic components, which in turn produce a measurable magnetic field specific to an individual model. Even with the greater use of aluminium in manufacture and if the vehicle has been demagnetized, Philips' high sensitivity weak field MR sensors can still detect a measurable change in geomagnetic field strength and flux density created by the vehicle (figure 11). Moreover, unlike other methods, magnetoresistive measuring provides information on vehicle type and can even detect and distinguish motorbikes (even with engine, frame and wheels being made of aluminium) (figure 12).

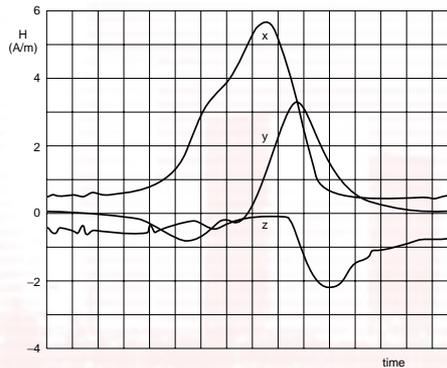


Figure 11. Spectra for a motorbike

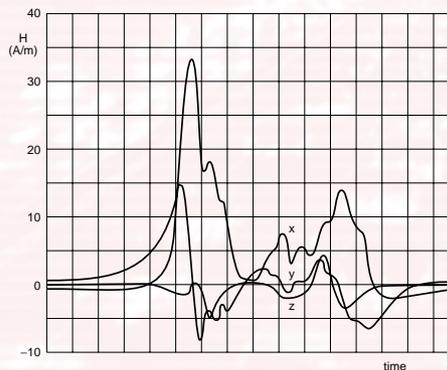
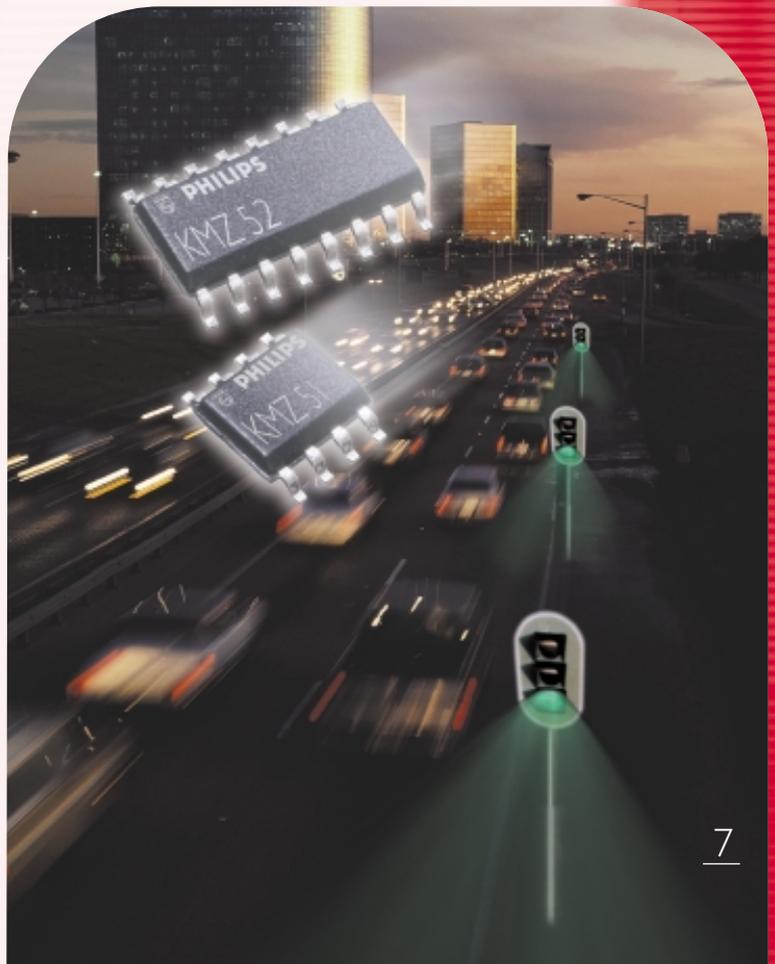
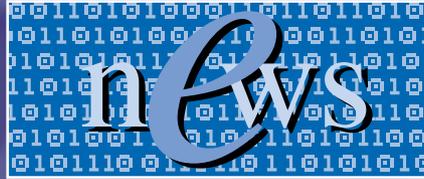


Figure 12. Spectra for an Opel Kadett from ground sensor





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