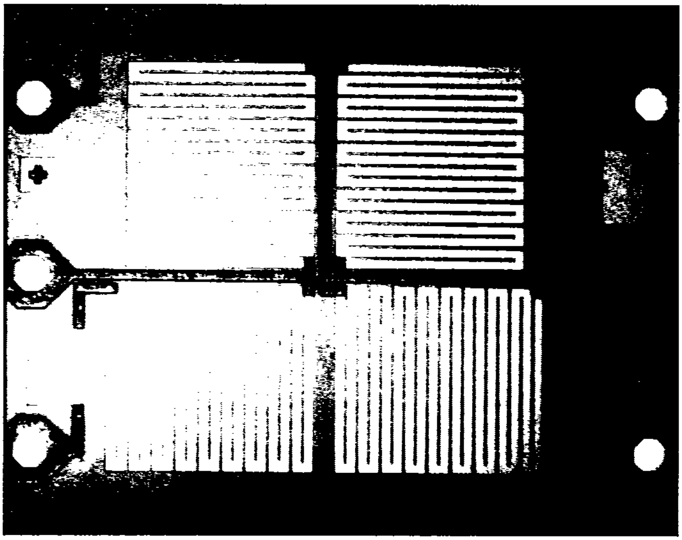
MAGNETIC FIELD SENSORS



DESCRIPTION

SSEC permalloy magnetic field sensors provide an unmatched ability to trade off size, power consumption, and sensitivity. They are fabricated by depositing a thin film of nickel-iron onto a silicon substrate which can have a simple dielectric layer or signal processing circuitry. Permalloy sensors can also be hybridized. Noise immunity and reliability are excellent.

FEATURES

- Low power consumption - as low as 0.1mW
- Sensitivity ranges from <.0001 Oe to >50 Oe (<.008 A/m to >4 kA/m)
- Temperature range: -55 to 200°C
- Frequency range: dc to hundreds of MHz

APPLICATIONS

- Solid state compassing: automotive, marine, aircraft, space craft
- Signature detection: traffic control, fusing, security, metal detection
- Position sensing: rotational, angular, linear, non-contact
- Anomaly detection: anomaly mapping, defense applications

Note: A/m = Ampere per meter, Oe = Oersted
79.58 Ampere per meter = 1 Oersted
1 Oersted is equivalent to 1 Gauss (in air)

MAGNETIC FIELD SENSORS

MAGNETIC FIELD SENSORS

SSEC began applied research to deposit thin nickel-iron films (permalloy) onto silicon under layers in the 1970s. These films are *magnetoresistive.* That is, their resistance changes as a function of an external magnetic field originating from a distant source, the earth's field, for example, or a nearby source, such as a current-carrying wire. The magnetic field rotates the internal magnetization vector in the film, and the varying angle of this vector with the current flow alters the resistance. Using Wheatstone bridges, unique layout techniques, and special signal conditioning, fields of less than 100 microgauss (.008 A/m) to over 50 gauss (4 kA/m) can be sensed. These magnetometers can be operated in either a saturated mode — typically used for applications such as gear tooth sensing — or an unsaturated mode. The following figures show a typical configuration of a permalloy sensing bridge and ΔV output versus input field.

This technology gives great flexibility in trading off high sensitivity, power consumption and physical size. For example, a NiFe bridge can be designed that consumes only .01mW. Further design flexibility is achieved by depositing permalloy films on bare silicon substrates or on ICs to create monolithically integrated sensors. Some applications for these devices are in magnetic compassing, magnetic signature and anomaly detection, noncontact battery charge monitoring, medical implant able devices and probes, and automotive systems such as anti lock brakes. A permalloy sensor used as the sensing element in an automotive compass is shown below. Tables 3 and 4 give parameters for typical permalloy magnetic field sensors.

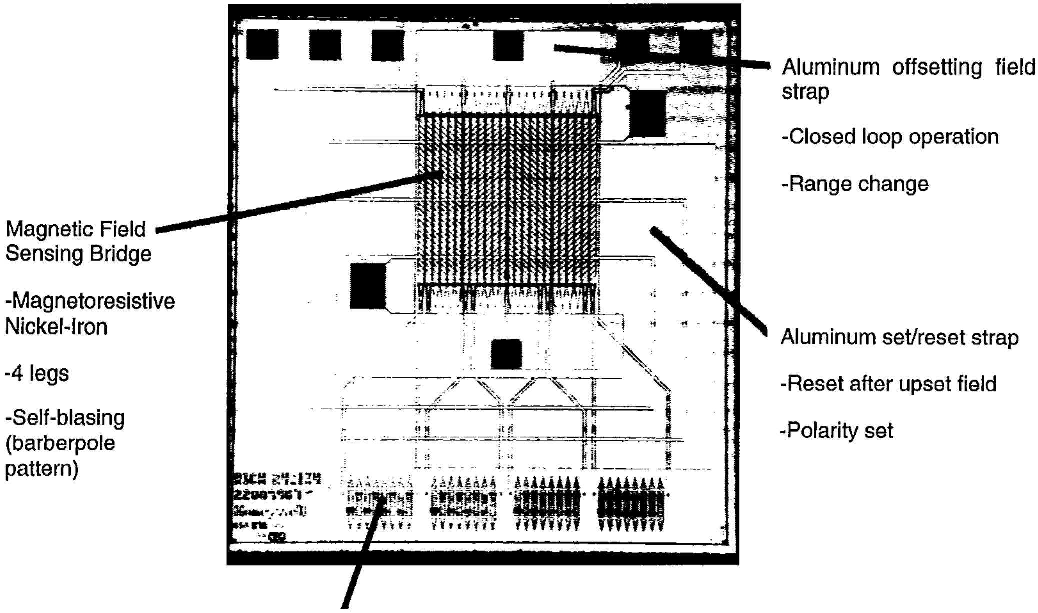


Figure 3. An SSEC Compass Magnetometer Chip Contains Unique Features

PERMALLOY BRIDGE

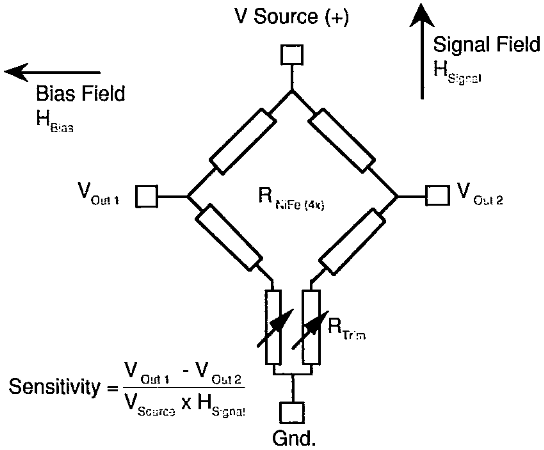


Figure 4. Permalloy Bridge Configuration

OUTPUT VERSUS SIGNAL FIELD

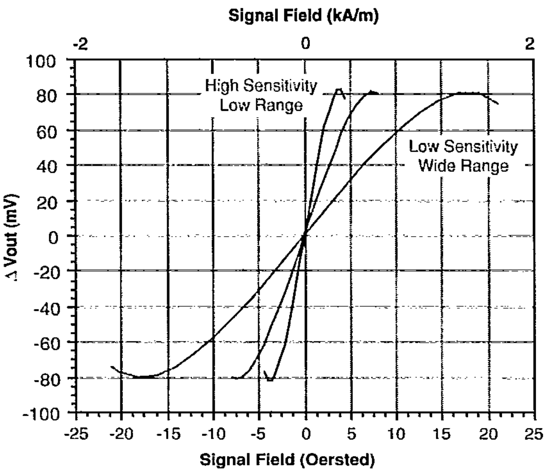


Figure 5. Permalloy Sensor Output versus Signal Field for Example Sensors

Note: A/m = Ampere per meter, Oe = Oersted
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MAGNETIC FIELD SENSORS

Table 3. SSEC Magnetic Field Sensor Characteristics (1)

CHARACTERISTIC	TYPICAL VALUES	UNITS
Operating Field Range (2)	.0001 to 50 (0.08 to 400 A/m)	Oe
Operating Temperature Range	55 to 200	°C
Sensitivity	2.5	mV/V/Oe
Bridge Resistance (3)	1 to 100	kΩ
Power	.1 to 25	mW
Linear Range	± 1 to ± 50 ± 80 to ± 400 A/m	Oe
Bridge Null Offset (4)	0 to 1	mV/V
Frequency Response	DC to 10^8	Hz

Table 4. Field Resolution and Range for Typical Magnetometer Applications

APPLICATION	FIELD RESOLUTION	FIELD RANGE
Proximity Sensor	Saturated Mode	4-80 kA/m 50-1000 Oe
Magnetic Control	1 A/m	0.4-1.6 kA/m 5-20 Oe
Compassing	0.05 A/m	0-0.24 kA/m 0-3 Oe

(1) These are typical characteristics of SSEC sensors developed for specific applications.
(2) These characteristics are for the unsaturated operating mode.
(3) Other resistance's are possible.
(4) Can be trimmed.

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ADVANCE INFORMATION

PERMALLOY MAGNETIC FIELD SENSORS

OVERVIEW

Magnetoresistive (MR) sensors provide an excellent means of measuring both linear and angular position and displacement. Honeywell magnetoresistive sensors consist of permalloy (NiFe) films deposited on a silicon substrate in various resistor bridge configurations to provide highly predictable outputs when subjected to magnetic fields. The low cost, small size, low noise, and high reliability of this solid state technology offers significant advantages over mechanical or other electrical alternatives.

These sensors are designed for use in a wide variety of applications, including navigation and compassing, earth's field measurement, magnetic anomaly detection, magnetic signature analysis, ferromagnetic metal detection and location, current measurement, position and proximity and sensing. They operate from dc to over 1 MHz.

Sensors are available with on-chip current straps that can be used to electrically "set" or "reset" the polarity of the output due to the sensed field by providing a momentary field orthogonal to the sensitive axis. This allows the user to program the output polarity of the device, and, by pulsing this current strap prior to each measurement, eliminates the traditional problem of magnetic upset common to other MR sensors.

This patented current strap arrangement can also be used to alternate the sensor output polarity for each measurement in a "flipping" technique. Although the polarity of the output due to the sensed field is switched, the offset associated with sensor and signal conditioning electronics is not, and can be synchronously filtered out, giving an output proportional to absolute field. Because offset of the signal conditioning circuitry as well as that of the sensor is eliminated, lower cost electronic components can be used, and trimming may be eliminated.

Devices HMR0015, HMR0040 and HMR0160 are direct replacements for KMZ10 series magnetic sensors, and offer improved noise performance. The HMR1015, HMR1040 and HMR1160 offer the improved noise performance plus the addition of a set/reset current strap for user convenience.

On the HMR2220 device, an additional current strap is fabricated on the chip to allow generation of an on-chip field to null the sensed field for closed loop operation. This mode gives the highest linearity and most sensitive output. This current strap may also be used to provide a calibration field or an offsetting field for linear operation in a larger field.

In addition to the standard MR sensor products, custom configurations can be designed to address specific system requirements such as lower power, higher sensitivity, or higher immunity to stray fields. Custom designs may be discrete, or may utilize on-chip amplification and signal conditioning.

PERMALLOY SENSORS

STANDARD MAGNETIC SENSOR PRODUCTS

SSEC Part#	Sensor Description	Sensitivity mV/V/kA/m
HMR0015P	Low Sensitivity Magnetic Sensor, Packaged	1.5
HMR0040P	Moderate Sensitivity Magnetic Sensor, Packaged	4
HMR0160P	High Sensitivity Universal Magnetic Sensor, Packaged	16
HMR1015P	Low Sensitivity Magnetic Sensor with Reset Current Strap,Packaged	1.5
HMR1040P	Moderate Sensitivity Magnetic Sensor with Reset Current Strap,Packaged	4
HMR1160P	High Sensitivity Magnetic Sensor with Reset Current Strap, Packaged	16
HMR2220P	Compassing Magnetic Sensor with Multiple Current Straps, Packaged	22
HMR0015D	Low Sensitivity Magnetic Sensor, Die Form	1.5
HMR0040D	Moderate Sensitivity Magnetic Sensor, Die Form	4
HMR0160D	High Sensitivity Magnetic Sensor, Die Form	16
HMR1015D	Low Sensitivity Magnetic Sensor with Reset Current Strap, Die Form	1.5
HMR1040D	Moderate Sensitivity Magnetic Sensor with Reset Current Strap, Die Form	4
HMR1160D	High Sensitivity Magnetic Sensor with Reset Current Strap, Die Form	16
HMR2220D	Compassing Magnetic Sensor with Multiple Current Straps, Die Form	22

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STANDARD DEVICE SPECIFICATIONS

Package Version:		HMR0015P	HMR0040P	HMR0160P	HMR1015P	HMR1040P	HMR1160P	HMR2220P
Die Version:		HMR0015D	HMR0040D	HMR0160D	HMR1015D	HMR1040D	HMR1160D	HMR2220D
Description	**Units**							
Operating Voltage	V	12V	14V	9V	12V	14V	9V	9V
Operating Temperature	°C	-55 -200°C	-55 - 200°C	-55 - 200°C	-55 - 200°C	-55 - 200°C	-55 - 200°C	-55 - 200°C
Storage Temperature	°C	-65 - 200°C	-65 - 200°C	-65 - 200°C	-65 - 200°C	-65 - 200°C	-65 - 200°C	-65 - 200°C
Operating Range	kA/m	±7.5	±2	±0.5	±7.5	±2	±0.5	±0.1
Sensitivity	mV/V/kA/m	1.5	4	16	1.5	4	16	22
Offset Voltage, untrimmed	mV/V	±8	±8	±8	±8	±8	±8	±8
Offset Voltage, trimmed	mV/V	1.5	1.5	1.5	1.5	1.5	1.5	N/A
Bridge Resistance, min	Ω	1000	1600	800	1000	1600	800	800
Bridge Resistance, max	Ω	1800	2600	1600	1800	2600	1600	1200
Temperature Coefficient of Resistance	%/°C	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Temperature Coefficient of Output	%/°C	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25	-0.25
Output Linearity at full scale	%FS	2.5	4	4	2.5	4	4	2
Output Voltage Hysteresis	%FS	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Operating Frequency	MHz	>1	>1	>1	>1	>1	>1	>1
Set/Reset Current Strap		No	No	No	Yes	Yes	Yes	Yes
Set/Reset Current Strap Resistance, max	Ω	N/A	N/A	N/A	2	2	2	2
Set/Reset Current Strap Current, max	Amps, peak	N/A	N/A	N/A	3	3	3	3
Feedback/Offset Current Strap		No	No	No	No	No	No	Yes
Feedback Current Strap Transfer Function	kA/m/A	N/A	N/A	N/A	N/A	N/A	N/A	1.15
Feedback Current Strap Resistance, max	Ω	N/A	N/A	N/A	N/A	N/A	N/A	3
Feedback Current Strap Current, max	Amps	N/A	N/A	N/A	N/A	N/A	N/A	0.1

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HOW PERMALLOY-BASED MAGNETIC SENSORS WORK

Magnetoresistive material is a material that changes resistance in the presence of a magnetic field. Almost every material exhibits some magnetoresistance. Aluminum, for example, has magnetoresistance. However, the magnetoresistive effect is particularly large in permalloy, a nickel-iron alloy, and other ferromagnetic materials.

A specimen of ferromagnetic material has a magnetization, or magnetic moment per unit volume. Magnetization is a vector quantity defined at each point in the material. A bar magnet, for example, has a net volume magnetization because the majority of the magnetic moments in the bar are aligned parallel to one another.

Assume a long, thin film of permalloy, with a current running along the length of the film. The magnetization of the film generally forms an angle with the current, and the film's resistance depends upon this angle. When the magnetization is parallel to the current, the resistance is at a maximum, and when it is perpendicular to the current, the resistance is at its minimum, or nominal, value. If the permalloy film is now subjected to an external magnetic field, the field acts on the magnetization, rotating it and thereby changing the film's resistance.

In permalloy, the maximum change in resistance due to rotation of the magnetic field is two to three percent of the nominal resistance.

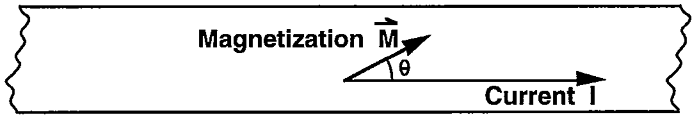

Figure 1. The resistance of permalloy varies with the direction of magnetization of the film. The resistance is highest when the magnetization is parallel to the current, and lowest when perpendicular to the current.

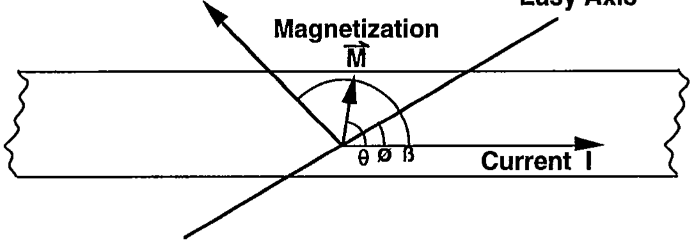

Figure 2. The magnetization rotates in the direction of an applied magnetic field, but it generally does not end up pointing in the same direction as the field because its direction is determined by several competing factors. One of these factors is the easy axis — the direction along which the magnetization in a film prefers to lie — which is determined by the magnetic field present during deposition of the film. Another factor is the shape of the film, which in the case of a long, thin film keeps the magnetization in the plane of the film and tends to make it point along the length of the film.

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PERMALLOY SENSORS

An alternate method of biasing in the linear region of the magnetoresistance curve is to rotate the current away from the magnetization by depositing strips of conductive material on top of the magnetoresistive films. The current takes the shortest path through the magnetoresistive film between the conductive strips. If the angle between the magnetization and the conductive strips is suitably defined, the device operates in the linear region of the magnetoresistance curve. This method is known as barberpole biasing, after the pattern the stripes form.

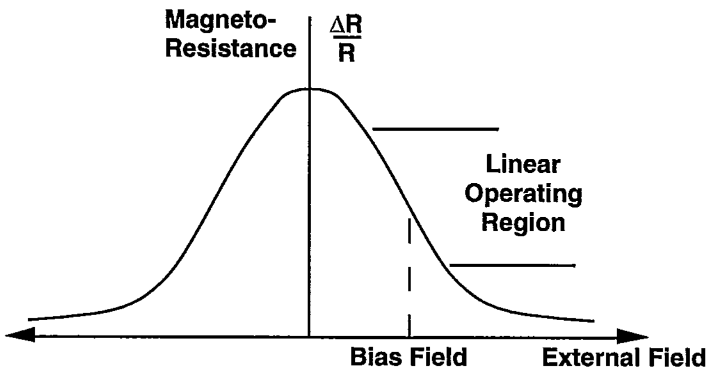

Figure 3. Magnetoresistance is expressed as the ratio of the change in total resistance of the film to its nominal resistance. To obtain a linear output, the film can be subjected to a bias field that places its output in the middle of the linear portion of the magnetoresistance curve. For the Honeywell standard barberpole magnetometer products, operation in this linear region is achieved by rotating the current through the device by using a special layout.

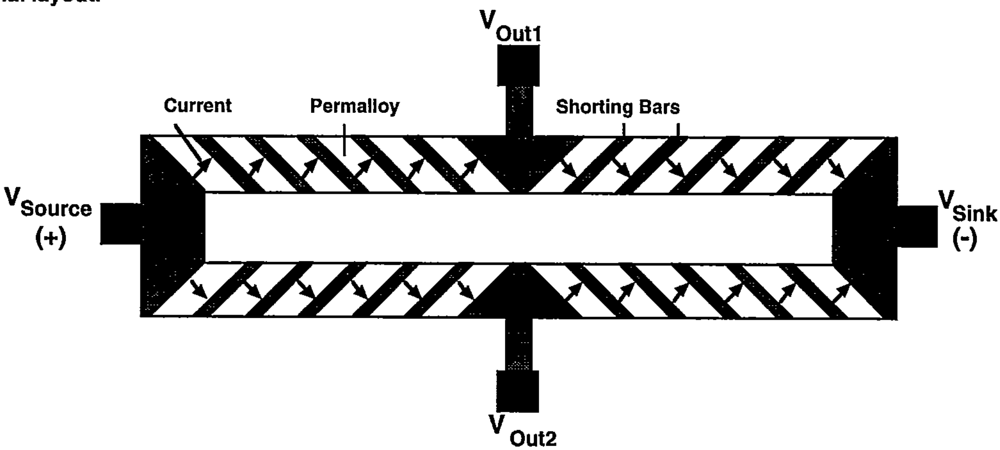

Figure 4. Barberpole biasing works by changing the direction of the current rather than the direction of the magnetization. Permalloy films are shorted by conducting strips (gray). The permalloy's magnetization is directed along the x axis. The current forms an angle with the magnetization of approximately 45°, which places the film's response in the linear portion of the magnetoresistance curve. The bridge illustrated here is sensitive to magnetic fields directed along the y axis.

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Due to the easy axis described earlier, the magnetization of the film has two stable states. Prior to use, the film must be set to one of these two states, and is done so during manufacture. The influence of a powerful magnetic field along the easy axis after manufacture, however, could upset or flip the polarity of this internal magnetization, changing the sensor characteristics. Following such an upset field, a strong restoring magnetic field must be applied momentarily to restore the sensor characteristics. This may be done with either a permanent magnet or an electromagnet. Polarity of the bridge output signal depends upon the direction of this internal polarization, and the output polarity may be selected by changing the direction of magnetization.

Honeywell has provided optional on-chip current straps for performing this magnetization / polarization electrically in the sensor application. This may be performed manually as required (such as following any accidental application of an upset field), or automatically at various time intervals depending upon the application. One option is to perform this polarization prior to each reading if the sensor is in a sampling (as opposed to real-time) system. A second option is to alternate the sensor output polarity for each measurement in a "flipping" technique. Although the polarity of the output due to the sensed field is switched, the offset associated with sensor and signal conditioning electronics is not, and may be synchronously filtered out, giving an output proportional to absolute field. Because offset of the signal conditioning circuitry is eliminated, lower cost electronic components can be used, and trimming may be eliminated.

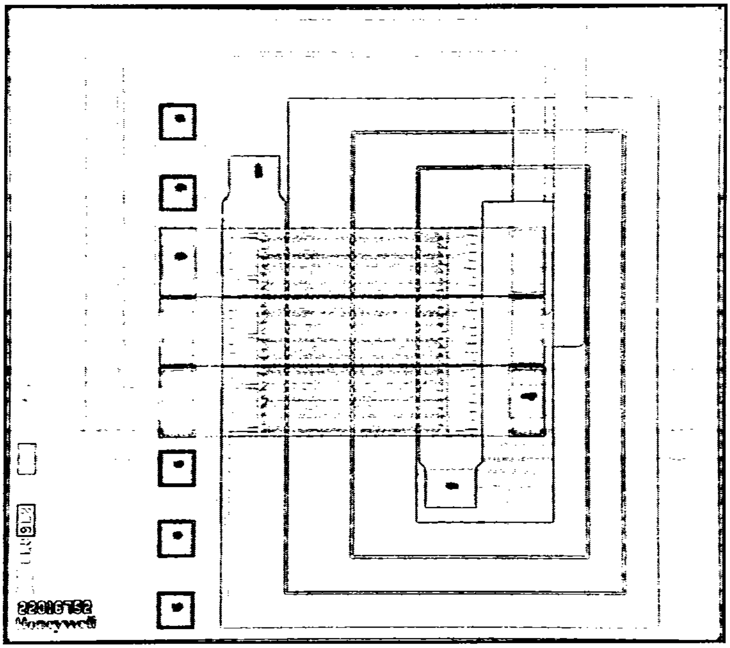
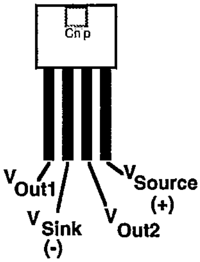


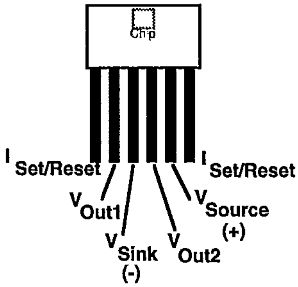
Illustration of the HMR2200P chip, showing the on-chip current straps (right and bottom) for setting and resetting the output polarity, as well as the current strap for closed loop feedback operation and calibration (left and top).

On the HMR2220 device, an additional current strap is fabricated on the chip to allow generation of an on-chip field to null the sensed field for closed loop operation. This mode gives the highest linearity and most sensitive output. This current strap can also be used to provide a calibration field or an offsetting field for linear operation in a larger field.

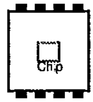
PACKAGE DRAWINGS



HMR0015P
HMR0040P
HMR0160P



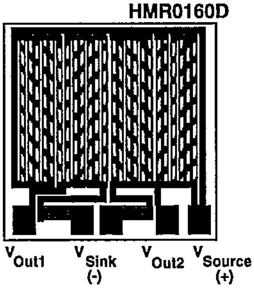
HMR1015P
HMR1040P
HMR1160P

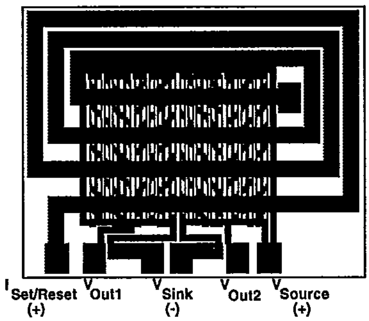


HMR2200P

DIE DRAWINGS

HMR0015D
HMR0040D
HMR0160D





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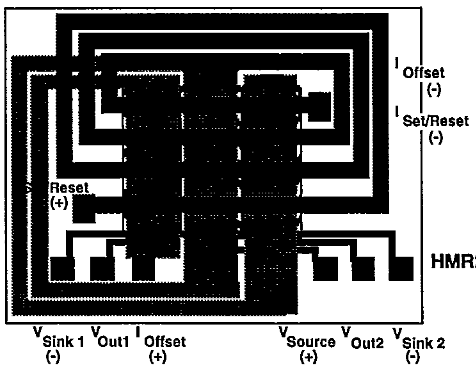

HMR2200D

PERMALLOY SENSORS

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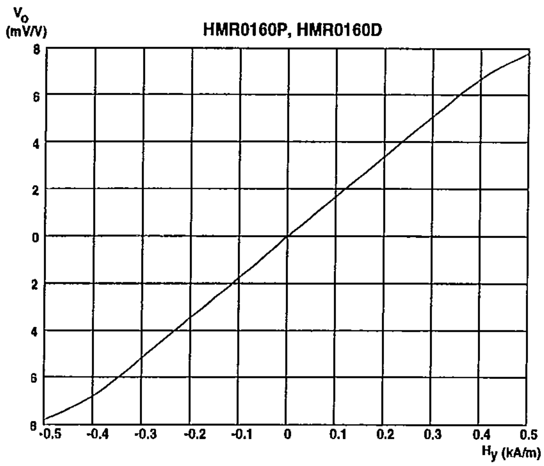
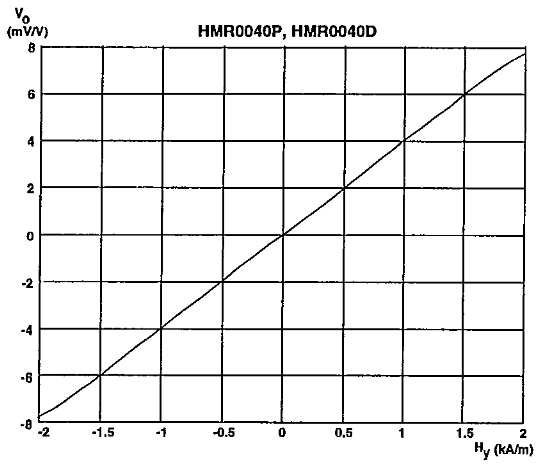
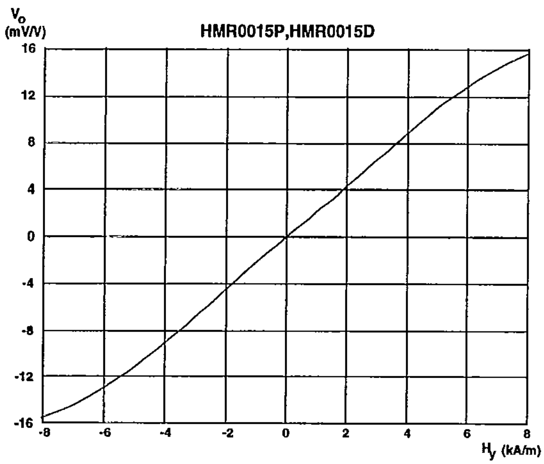
TRANSFER FUNCTIONS

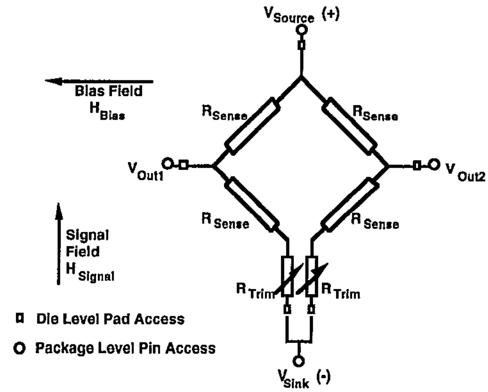




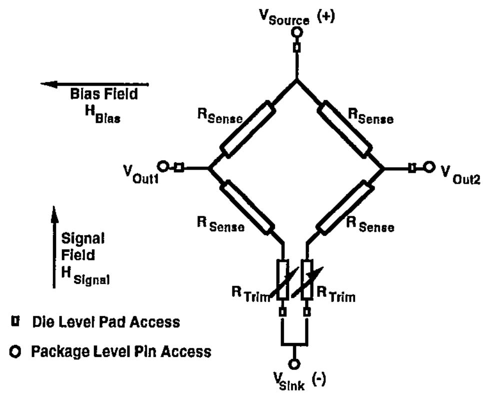


BRIDGE CIRCUITS

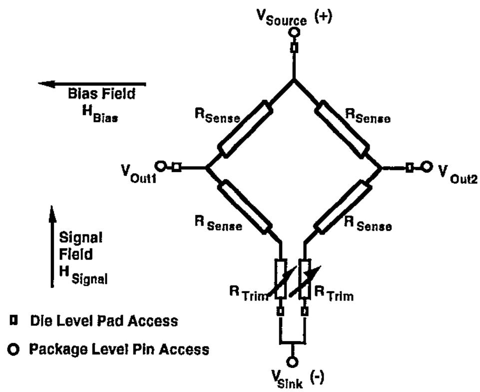
HMR0160



HMR0040

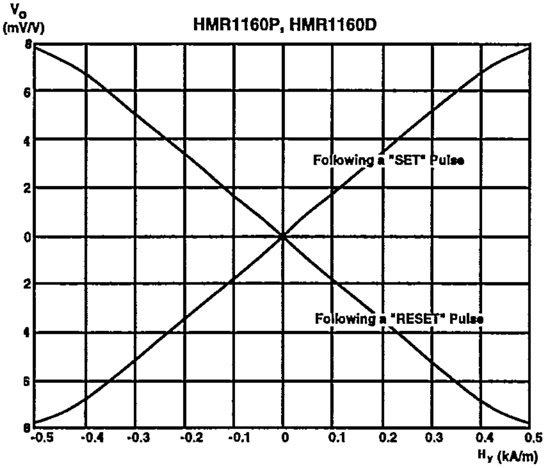


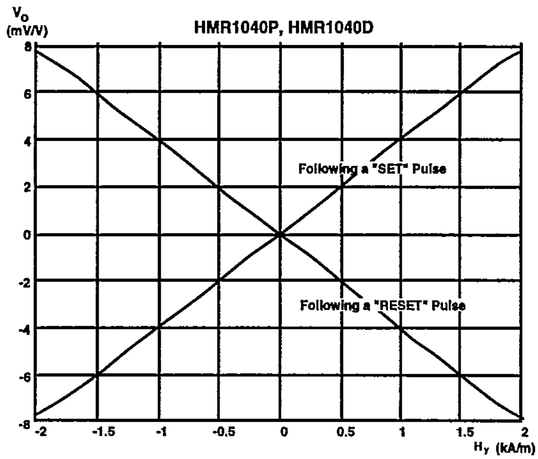
HMR0015

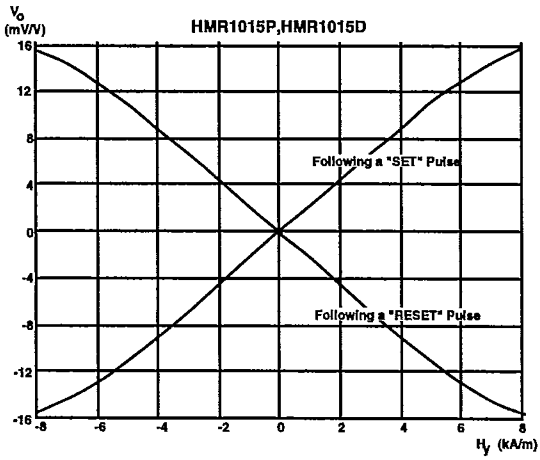


PERMALLOY SENSORS

TRANSFER FUNCTIONS

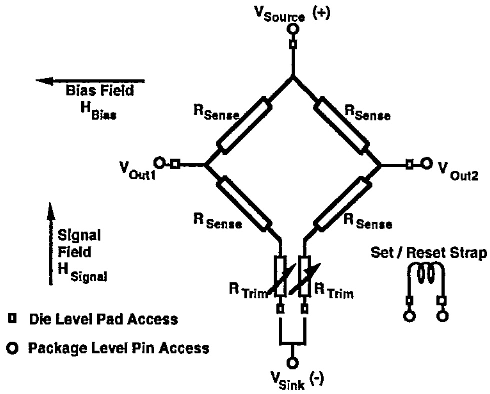




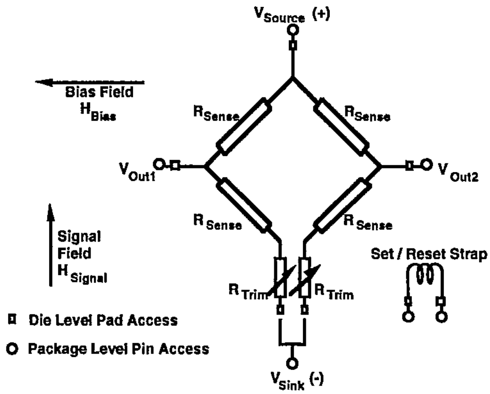


BRIDGE CIRCUITS

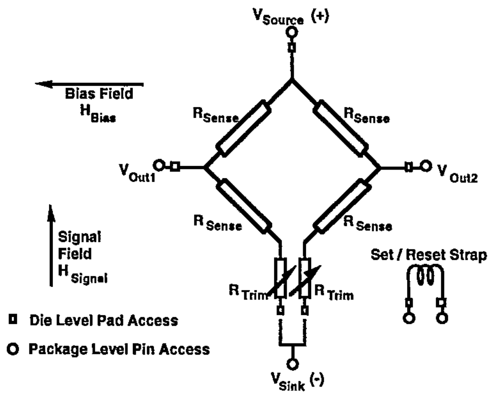
HMR1160



HMR1040

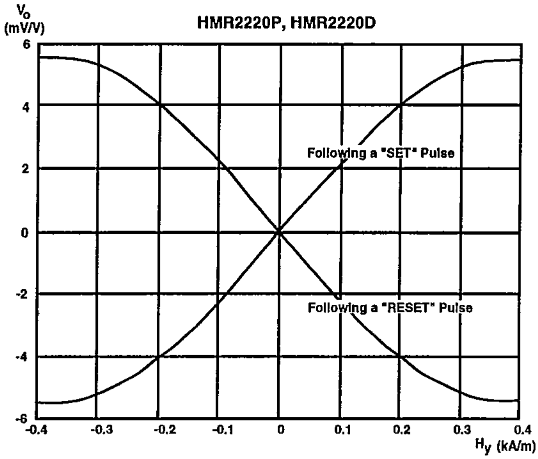


HMR1015

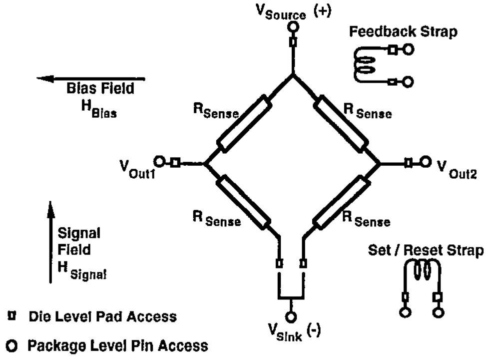


PERMALLOY SENSORS

TRANSFER FUNCTION



BRIDGE CIRCUIT



In addition to Honeywell's standard MR sensor products, custom configurations can be designed to address specific system requirements such as lower power, higher sensitivity, or higher immunity to stray fields. Honeywell's permalloy process is fully compatible with bipolar and CMOS integrated circuit processing. Custom designs may be discrete, or may utilize on-chip amplification and signal conditioning. Our semicustom analog array approach (the HBSA220) designed specifically for rapid prototyping of integrated sensors, is fully compatible with permalloy MR.

Certain restrictions may apply to the use of these sensors for compassing applications in automotive or marine pleasurecraft markets. Please consult Honeywell prior to designing any of these sensors into such applications.

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