Honeywell

Magnetic Products

ONE AND TWO AXIS MAGNETIC SENSORS

HMC1001
HMC1002

FEATURES

- Measures strength and direction of magnetic fields
- Detects change in magnetic field due to presence of ferromagnetic objects
- Field resolution less than 30 µgauss
- No external coils required
- Low hysteresis and high linearity
- Magnetic signal bandwidth of 5MHz

APPLICATIONS

- Compassing
- Traffic Detection
- Navigation Systems
- Virtual Reality
- Laboratory Instruments
- Underground Boring
- Medical Instruments
- Mineral Prospecting
- Food Processing
- Agricultural Equipment
- Position Sensing
- Environmental Monitoring

GENERAL DESCRIPTION

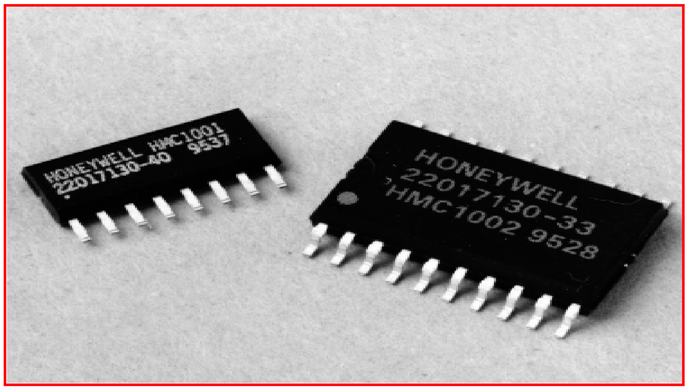
Honeywell's HMC1001 and HMC1002, one and two-axis magnetoresistive (MR) microcircuits, provide extremely sensitive magnetic sensors in small package outlines. These sensors offer low cost and small size for high volume OEM applications. The sensitivity of these sensors is unsurpassed for their size and offer versatility in applications. These are designed to work together to provide full three-axis (x, y, z) capability or alone for one and two-axis sensing.

The HMC1001 (one-axis) and HMC1002 (two-axis) convert magnetic fields—well within the earth's range of 0.6 gauss—to a differential output voltage. The voltage indicates both field magnitude and direction. Magnetic fields as low as 27 microgauss can be detected. There are no flux concentrators used in this design that can lead to hysteresis and non-repeatability. These devices come in a 8-pin SIP and a 20-pin SOIC packages.

The HMC1001/2 provide the basic MR bridge circuit(s) that convert magnetic fields to a differential output voltage. The voltage output is in the ± 15mV range for a 1 gauss applied field. In addition to the MR bridge, there are two "straps", OFFSET and Set/Reset, that can be electrically driven to couple a magnetic field onto the sensor bridge. These straps are patented by Honeywell and eliminate the need for external coils as required for other MR sensors.

The transducer is configured as a magnetoresistive Wheatstone bridge. That is, all four legs of the bridge change resistance proportional to an applied magnetic field. This produces an output voltage of ±16 mV that is linear within ±0.5%FS within the earth's magnetic field. The low hysteresis and high repeatability make these sensors ideal for precision measurement of magnetic fields.

Honeywell's magnetoresistive microcircuits provide an excellent means of measuring both linear and angular position and displacement. The HMC products offer low cost, high sensitivity, small size (no coils), and high reliability over other magnetic sensor alternatives. With its high sensitivity within the earth's magnetic field, these sensors solve a variety of problems in custom applications.



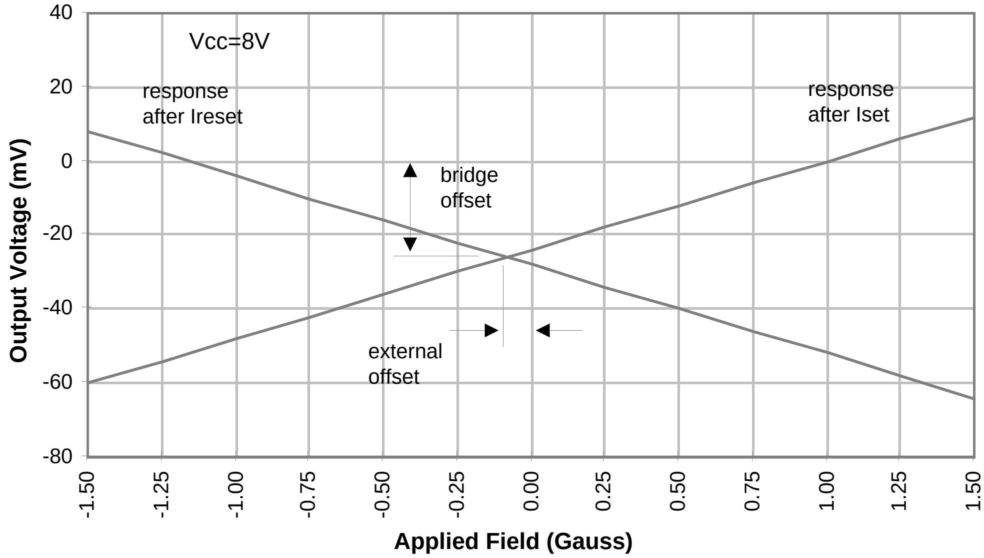


Figure 1—Output Voltage vs. Applied Magnetic Field

Basic HMC1001/2 Device Operation

The HMC1001/2 sensors are simple resistive bridge devices that only require a supply voltage to measure magnetic fields. When a voltage from 0 to 10 volts is connected to Vbridge, the sensor begins measuring any ambient, or applied, magnetic field in the sensitive axis. For Vbridge=5V, the outputs, OUT+ and OUT-, will typically range from ±16 mV around the 2.5V level for a ±1 gauss ambient field. This output swing is derived from the sensitivity number by multiplying the bridge supply voltage by the nominal sensitivity of 3.2 mV/V/gauss. For a bridge supply of 5V, this results in 16 mV/gauss output sensitivity. If the bridge outputs are amplified by a gain of 62, then the total output sensitivity would be about 1V/gauss (=62 x 16 mV/gauss). If a full scale range of ±2 gauss is desired, this implies a 4 volt output swing centered around the 2.5V bridge center value—or a span of 0.5V to 4.5V. This signal level is suitable for most A/D converters.

In addition to the bridge circuit, the transducer has two on-chip magnetically coupled straps—the OFFSET strap and the Set/Reset strap. These straps are patented by Honeywell and eliminate the need for external coils around the devices.

The OFFSET strap allows for several modes of operation when a dc current is driven through it.

- An unwanted magnetic field can be subtracted out
- The bridge offset can be set to zero
- The bridge output can drive the OFFSET strap to cancel out the field being measured in a closed loop configuration
- The bridge gain can be auto-calibrated in the system on command.

The Set/Reset (S/R) strap can be pulsed with a high current to:

- Force the sensor to operate in the high sensitivity mode
- Flip the polarity of the output response curve
- Be cycled during normal operation to improve linearity and reduce cross-axis effects and temperature effects.

The output response curves shown in Figure 1 illustrate the effects of the S/R pulse. When a SET current pulse (Iset) is driven into the SR+ pin, the output response follow the curve with the positive slope. When a RESET current pulse (Ireset) is driven into the SR- pin, the output response follow the curve with the negative slope. These curves are mirror images about the origin except for two offset effects.

In the vertical direction, the bridge offset for these curves is around -25mV. This is due to the resistor mismatch during the manufacture process. This offset can be trimmed to zero by one of several techniques. The most straight forward technique is to add a shunt (parallel) resistor across one leg of the bridge to force both outputs to the same voltage. This must be done in a zero magnetic field environment, usually in a zero gauss chamber.

The offset of Figure 1 in the horizontal direction is referred to here as the external offset. This may be due to a nearby ferrous object or an unwanted magnetic field that is interfering with the applied field being measured. A dc current in the OFFSET strap can adjust this offset to zero. Other methods such as shielding the unwanted field can also be used to zero the externaloffset. It is important to note that the output response curves due to the SET and RESET pulses are reflected about these two offsets.

Simple Circuit Application

The circuit in Figure 2 shows a simple magnetic sensor. This circuit acts as a proximity sensor and will turn on the LED when a magnet is brought within 0.25 to 0.5 inch of the sensor. The amplifier acts as a simple comparator and switches low when the HMC1001 bridge output exceeds 30mV. The magnet must be strong (200 gauss) and have one of its magnetic poles point along the sensitive direction of the sensor. This circuit can be used to detect a door open/closed status or the presence or absence of an item. Figures 5, 6, and 7 show other circuit examples.

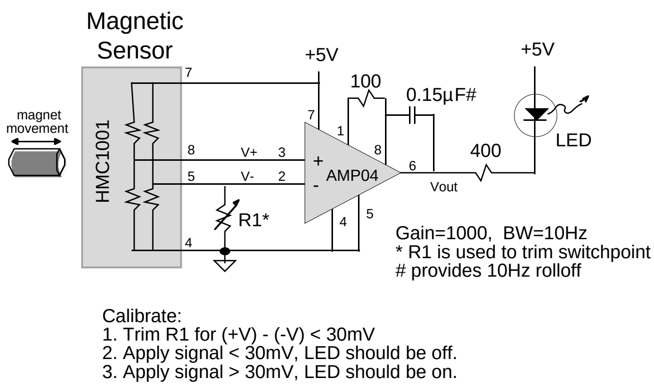


Figure 2—Magnetic Proximity Switch

What is the Set/Reset strap?

Most low field magnetic sensors will be affected by large magnetic disturbing fields (>4 gauss) that may lead to output signal degradation. In order to reduce this effect, and maximize the signal output, a magnetic switching technique can be applied to the MR bridge that eliminates the effect of past magnetic history. The purpose of the Set/Reset (S/R) strap is to restore the MR sensor to its high sensitivity state for measuring magnetic fields. This is done by pulsing a large current through the S/R strap. The Set/Reset (S/R) strap looks like as a nominal 1.6 ohm resistance between the SR+ and SR- pins. This strap differs from the OFFSET strap in that it is magnetically coupled to the MR sensor in the cross-axis, or insensitive, direction. Once the sensor is set (or reset), low noise and high sensitivity field measurement can occur. In the discussion that follows, the term "set" refers to either a set or reset current.

The on-chip S/R should be pulsed at a nominal 3.5 Amps to realign, or "flip", the magnetic domains in the transducer. This effect is illustrated in Figure 1. This pulse can be as short as two microsecond and on average consumes less than 1 mA dc when pulsing continuously. The duty cycle can be selected for a 2 µsec pulse every 50 msec, or longer, to conserve power. The only requirement is that each pulse only drive in one direction. That is, if a +3.5 amp pulse is used to "set" the sensor, the pulse decay should not drop below zero current. Any undershoot of the current pulse will tend to "un-set" the sensor and the sensitivity will not be optimum.

Using the S/R strap, many effects can be eliminated or reduced that include: temperature drift, non-linearity errors, cross-axis effects, and loss of signal output due to the presence of a high magnetic fields. This can be accomplished by the following process:

- A current pulse, Iset, can be driven from the S/R+ to the S/R- pins to perform a "SET" condition. The bridge output can then be measured and stored as Vout(set).
- Another pulse of equal and opposite current should be driven through the S/R pins to perform a "RESET" condition. The bridge output can then be measured and stored as Vout(reset).
- The bridge output, Vout, can be expressed as: Vout = [Vout(set) - Vout(reset)]/2. This technique cancels out offset and temperature effects introduced by the electronics as well as the bridge temperature drift.

The magnitude of the S/R current pulse depends on the magnetic noise sensitivity of the application. If the minimum detectable field for a given application is roughly 500 µgauss, then a 2.5 amp pulse (min) is adequate. If the minimum detectable field is less than 100 µgauss, then a 3.5 amp pulse (min) is required. The circuit that generates the S/R pulse should be located close to the MR sensor and have good power and ground connections.

There are many ways to design the set/reset pulsing circuit, though, budgets and ultimate field resolution will determine which approach will be best for a given application. A simple set/reset circuit is shown in Figure 3. Other set/reset circuits can be found in Honeywell's application note AN-201. To receive a copy, visit our web site or contact the Honeywell Customer Service Representative listed on the back of this data sheet.

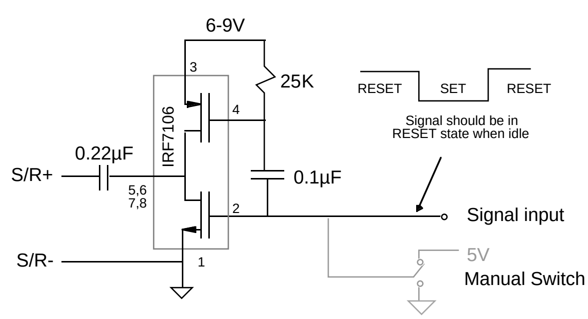


Figure 3—Single-Axis Set/Reset Pulse Circuit

What is the OFFSET strap?

Any ambient magnetic field can be canceled by driving a defined current through the OFFSET strap. This is useful for eliminating the effects of stray hard iron distortion of the earth's magnetic field. For example, reducing the effects of a car body on the earth's magnetic field in an automotive compass application. If the MR sensor has a fixed position within the automobile, the effect of the car on the earth's magnetic field can be approximated as a shift, or offset, in this field. If this shift in the earth's field can be determined, then it can be compensated for by applying an equal and opposite field using the OFFSET strap. Another use for the OFFSET strap would be to drive a current through the strap that will exactly cancel out the field being measured. This is called a closed loop configuration where the current feedback signal is a direct measure of the applied field.

The field offset strap (OFFSET+ and OFFSET-) will generate a magnetic field in the same direction as the applied field being measured. This strap provides a 1 Oersted (Oe) field per 50 mA of current through it. (Note: 1 gauss=1 Oersted in air). That is, if 25 mA were driven from the OFFSET+ pin to the OFFSET- pin, a field of 0.5 gauss would be added to any ambient field being measured. Also, a current of -25 mA would subtract 0.5 gauss from the ambient field. The OFFSET strap looks like as a nominal 2.5 ohm resistance between the OFFSET+ and OFFSET- pins.

The OFFSET strap can be used as a feedback element in a closed loop circuit. Using the OFFSET strap in a current feedback loop can produce desirable results for measuring magnetic fields. To do this, connect the output of the bridge amplifier to a current source that drives the OFFSET strap. Using high gain and negative feedback in the loop, this will drive the MR bridge output to zero, (OUT+) = (OUT-). This method gives extremely good linearity and temperature characteristics. The idea here is to always operate the MR bridge in the balanced resistance mode. That is, no matter what magnetic field is being measured, the current through the OFFSET strap will cancel it out. The bridge always "sees" a zero field condition. The resultant current used to cancel the applied field is a direct measure of that field strength and can be translated into the field value.

The OFFSET strap can also be used to auto-calibrate the MR bridge while in the application during normal operation. This is useful for occasionally checking the bridge gain for that axis or to make adjustments over a large temperature swing. This can be done during power-up or anytime during normal operation. The concept is simple; take two point along a line and determine the slope of that line—the gain. When the bridge is measuring a steady applied magnetic field the output will remain constant. Record the reading for the steady field and call it H1. Now apply a known current through the OFFSET strap and record that reading as H2. The current through the OFFSET strap will cause a change in field the MR sensor measures—call that the delta applied field (ΔHa). The MR sensor gain is then computed as:

$$MRgain = (H2-H1) / \Delta Ha$$

There are many other uses for the OFFSET strap than those described here. The key point is that ambient field and the OFFSET field simply add to one another and are measured by the MR sensor as a single field.

Noise Characteristics

The noise density curve for a typical MR sensor is shown in Figure 4. The 1/f slope has a corner frequency near 10 Hz and flattens out to 3.8 nV/√Hz. This is approximately equivalent to the Johnson noise (or white noise) for an 850Ω resistor—the typical bridge resistance. To relate the noise density voltage in Figure 4 to the magnetic fields, use the following expressions:

For Vsupply=5V and Sensitivity=3.2mV/V/gauss,
Bridge output response = 16 mV/gauss
or 16 nV/μgauss

The noise density at 1Hz ≈ 30nV/√Hz
and corresponds to 1.8 μgauss/√Hz

For the noise components, use the following expressions:

1/f noise(0.1-10Hz) = $30 * \sqrt{(\ln(10/.1))}$ nV
64 nV (rms)
4 μgauss (rms)
27 μgauss (p-p)

white noise (BW=1KHz) = $3.8 * \sqrt{BW}$ nV
120 nV (rms)
50 μgauss (p-p)

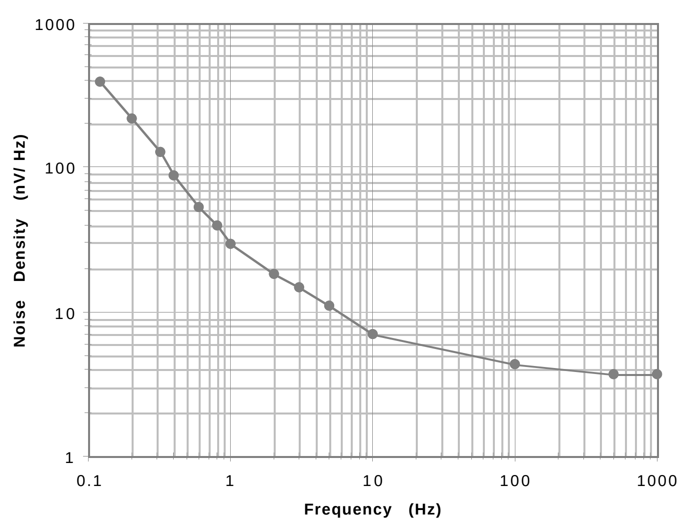


Figure 4—Typical Noise Density Curve

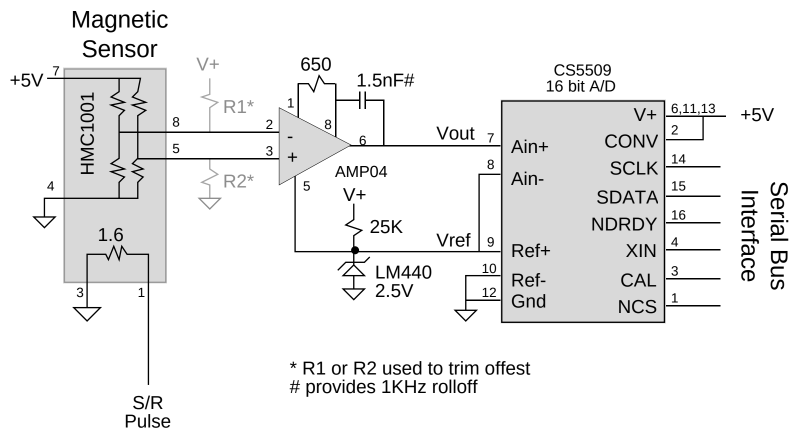


Figure 5—One-Axis Sensor With Digital Interface

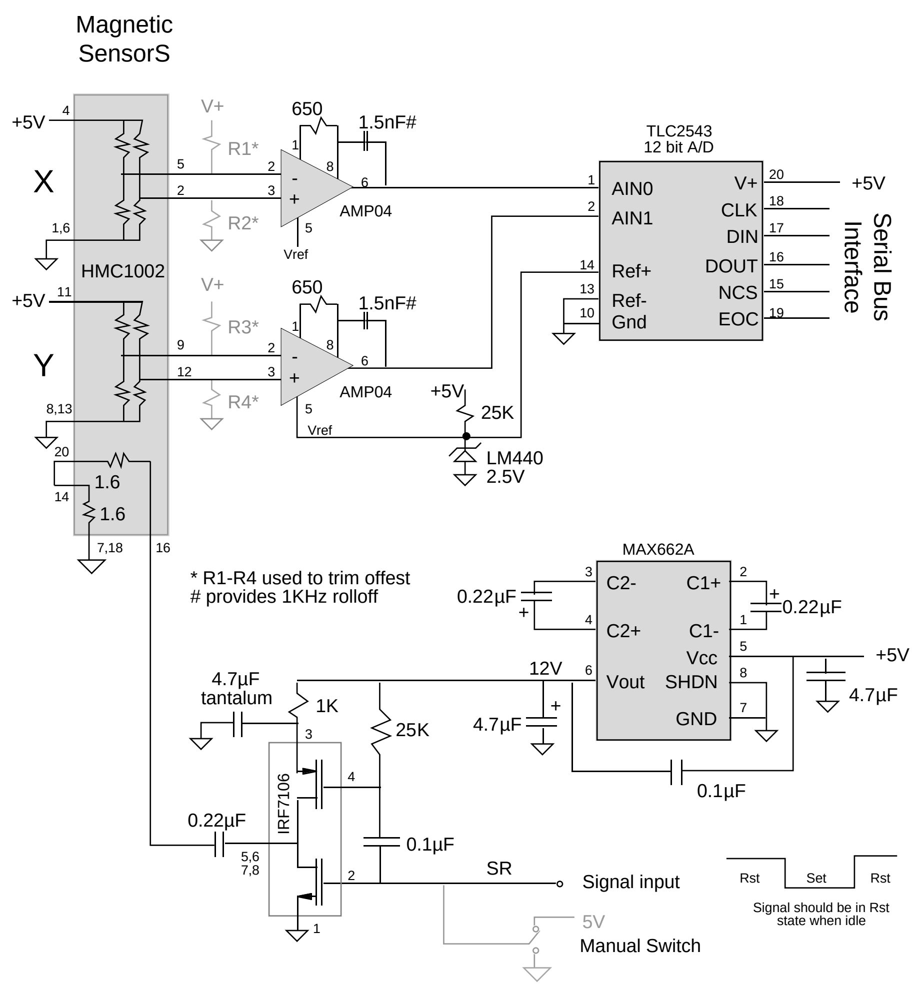


Figure 6—Two-Axis Sensor With Set/Reset Circuit and Digital Interface

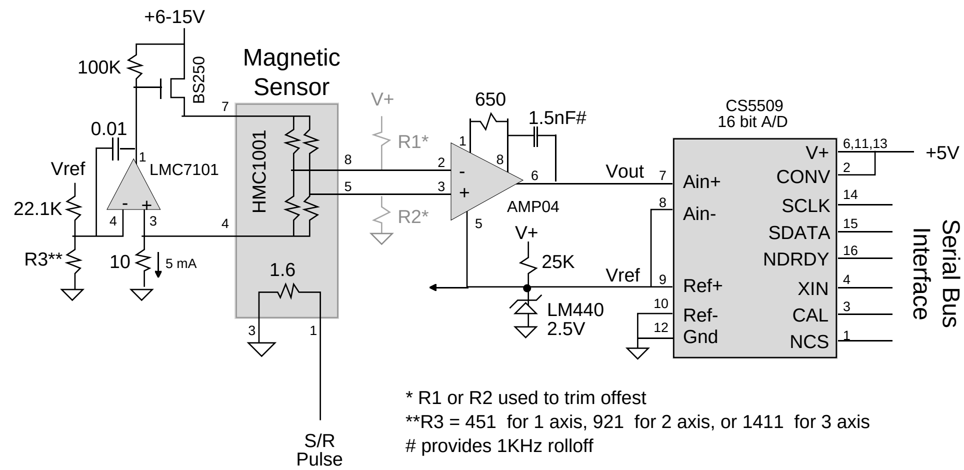
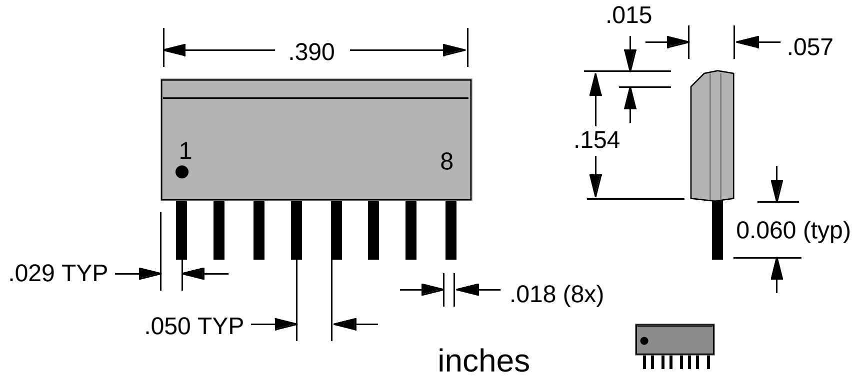
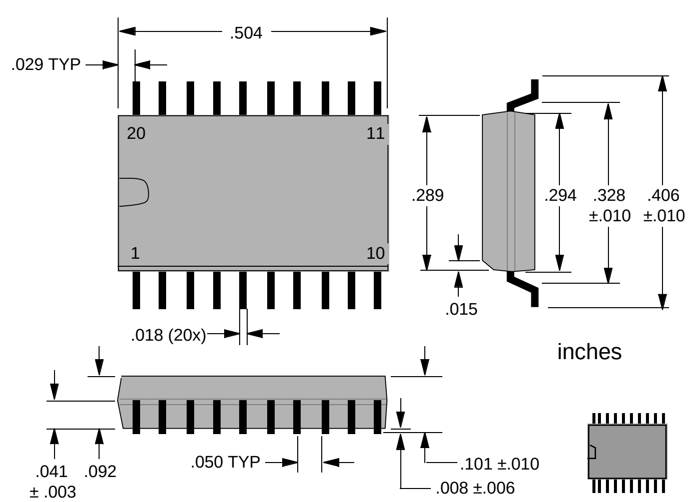


Figure 7—One-Axis Sensor With Constant Bridge Current and Digital Interface

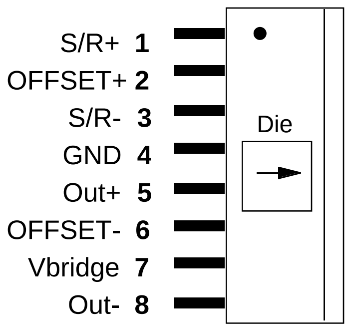
HMC1001—Package Outline



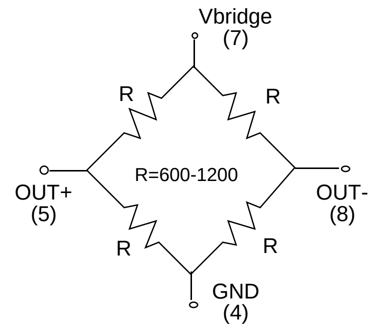
HMC1002—Package Outline

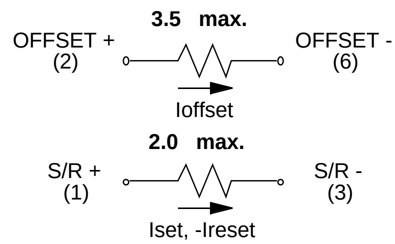


HMC1001 - One Axis MR Microcircuit



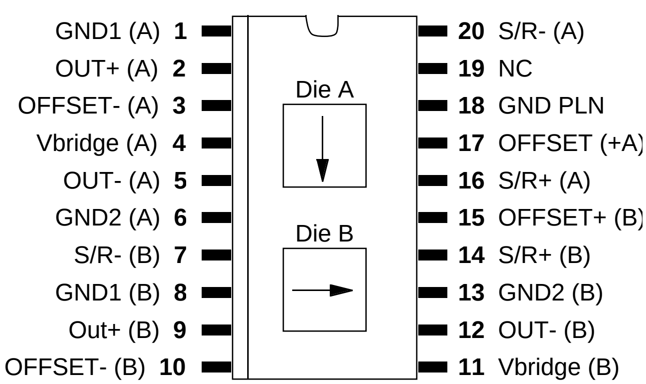
Arrow indicates direction of applied field that generates a positive output voltage after a SET pulse.

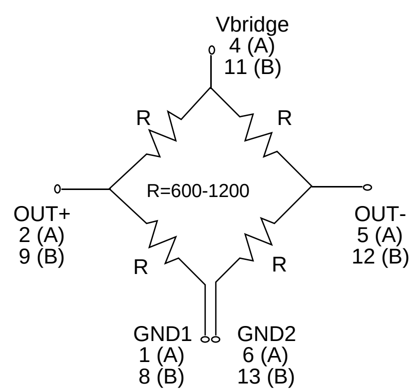




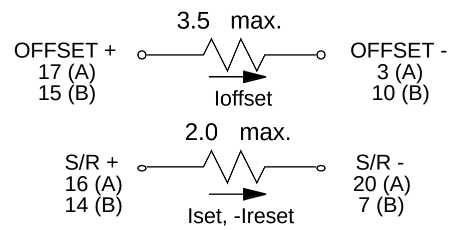
Iset and Ireset must be 2 Amp
see Appl. Note AN-201 for circuits

HMC1002—Two-Axis MR Microcircuit





Arrow indicates direction of applied field that generates a positive output voltage after a SET pulse.



Iset and Ireset must be 2 Amp
see Appl. Note AN-201 for circuits

Characteristic	Conditions	Min	Typ	Max	Unit
Bridge Supply (4)	Vbridge referenced to GND		5	10	Volts
Bridge Resistance	Bridge current = 10mA	600	850	1200	
Operating Temperature (4)	Ambient	-40		85	° C
Storage Temperature (4)	Ambient, unbiased	-55		125	° C
Field Range (1) (2) (4)	Full scale (FS), total applied field	-2		+2	gauss
Linearity Error (1) (2) (4)	Best fit straight line ±1 gauss (at 25° C) ±2 gauss		0.1 1	0.5 2	%FS
Hysteresis Error (1) (2) (4)	3 sweeps across ±2 gauss @ 25° C		0.05	0.10	%FS
Repeatability Error (1) (2) (4)	3 sweeps across ±2 gauss @ 25° C		0.05	0.10	%FS
S/R Repeatability (1) S/R Repeatability (2)	Output variation after alternate S/R pulses		2	10 100	µV
Bridge Offset	Offset = (OUT+) - (OUT-), Field=0 gauss after Set pulse, Vbridge=8V	-60	-15	30	mV
Sensitivity (1) (2)	At I_{OFFSET} = ±50mA, Vbridge=8V	2.5	3.2	4.0	mV/V/gauss
Noise Density	Noise at 1Hz, Vbridge=5V		29		nV/√ Hz
Resolution	Bandwidth=10Hz, Vbridge=5V		27		µgauss
Bandwidth	Magnetic signal (lower limit = DC)		5		MHz
OFFSET Strap	Measured from OFFSET+ to OFFSET-		2.5	3.5	
OFFSET Current (4)	Current at 0.1% duty cycle, or less		2	10	µV
OFFSET Field (4)	Field applied in sensitive direction	46	51	56	mA/gauss
Set/Reset Strap	Measured from S/R+ to S/R-		1.5	1.8	
Set/Reset Current (2) (3) (4)	Current at 0.1% duty cycle, or less		3.2	5	Amp
Disturbing Field (4)	Sensitivity starts to degrade. Use S/R pulse to restore sensitivity.	3			gauss
Sensitivity Tempco	T_A=-40 to 85° C Vbridge=8V Ibridge=5mA		-3000 -600		ppm/° C
Bridge Offset Tempco	T_A=-40 to 85° C no Set/Reset Ibridge=5mA with Set/Reset		±300 ±10		ppm/° C
Resistance Tempco	Vbridge=8V, -40 to 85° C		2500		ppm/° C
Cross-Axis Effect	Cross field=1gauss no Set/Reset (see AN-205) with Set/Reset		±3 +0.5		%FS
Max. Exposed Field (4)	No perming effect on zero reading			100	gauss
Weight			0.14 0.53		gram

(1) V_{Bridge} = 4.3V, $I_{S/R}$ = 3.2A, T = 25°C. $V_{OUT} = V_{SET} - V_{RESET}$
(2) If V_{Bridge} = 8.0V, $I_{S/R}$ = 2.0A, T = 25°C, lower S/R current leads to greater output variation.
(3) Effective current from power supply is less that 1mA.
(4) Not tested, guaranteed by characterization.

Units: 1 gauss (g) = 1 Oersted (in air), = 79.58 A/m, 1G = 10E-4 Tesla, 1G = 10E5 gamma.

Additional Product Details:
Customer Service Representative
(612) 954-2888 fax: (612) 954-2582
E-Mail: clr@mn14.ssec.honeywell.com