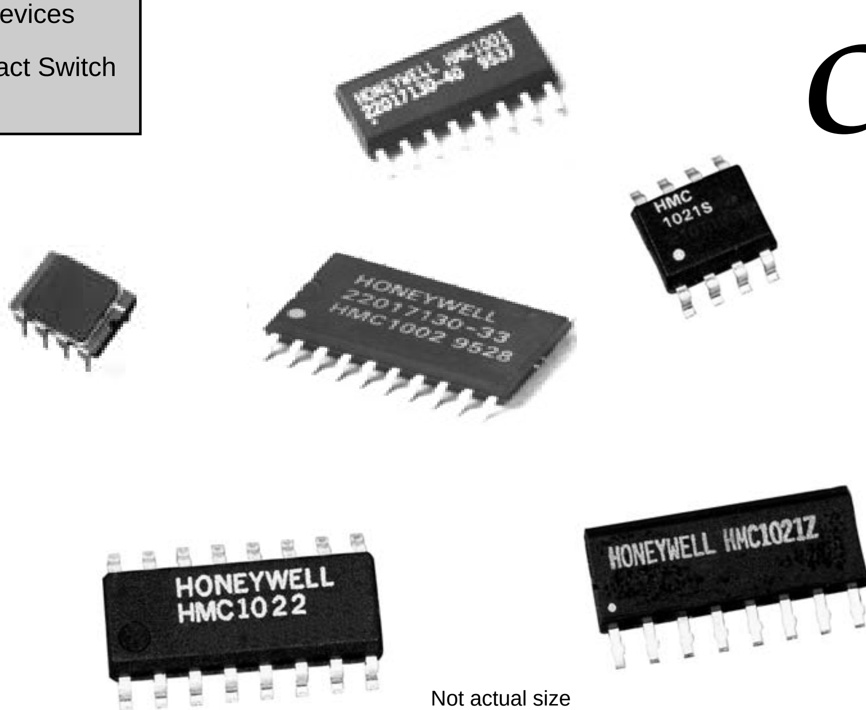
1- and 2-Axis Magnetic Sensors

HMC1001 / 1002
HMC1021 / 1022

APPLICATIONS

- Compassing
- Navigation Systems
- Attitude Reference
- Traffic Detection
- Medical Devices
- Non-Contact Switch



Not actual size

Configured as a 4-element wheatstone bridge, these magnetoresistive sensors convert magnetic fields to a differential output voltage, capable of sensing magnetic fields as low as 30 µgauss. These MRs offer a small, low cost, high sensitivity and high reliability solution for low field magnetic sensing.

FEATURES AND BENEFITS

Wide Field Range	Field range up to ±6 gauss, (earth's field = 0.5 gauss)
Small Package	• Designed for 1- and 2-axis to work together to provide 3-axis (x, y, z) sensing • 1-axis part in an 8-pin SIP or an 8-pin SOIC or a ceramic 8-pin DIP package • 2-axis part in a 16-pin or 20-pin SOIC package
Solid State	These small devices reduce board assembly costs, improve reliability and ruggedness compared to mechanical fluxgates.
On-Chip Coils	Patented on-chip set/reset straps to reduce effects of temperature drift, non-linearity errors and loss of signal output due to the presence of high magnetic fields Patented on-chip offset straps for elimination of the effects of hard iron distortion
Cost Effective	The sensors were specifically designed to be affordable for high volume OEM applications.

HMC1001/1002 SPECIFICATIONS

Characteristics	Conditions*	Min	Typ	Max	Unit
Bridge Supply	Vbridge referenced to GND		5	12	Volts
Bridge Resistance	Bridge current = 10mA	600	850	1200	ohm
Operating Temperature (4)		-55		150	°C
Storage Temperature (4)	Unbiased	-55		175	°C
Field Range (4)	Full scale (FS), total applied field	-2		+2	gauss
Linearity Error (4)	Best fit straight line ±1 gauss ±2 gauss		0.1 1	0.5 2	%FS
Hysteresis Error (4)	3 sweeps across ±2 gauss		0.05	0.10	%FS
Repeatability Error (4)	3 sweeps across ±2 gauss		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	S/R Current = 3A	2.5	3.2	4.0	mV/V/gauss
Noise Density (4)	Noise at 1 Hz, Vbridge=5V		29		nV/ Hz
Resolution (4)	Bandwidth=10Hz, Vbridge=5V		27		µgauss
Bandwidth (4)	Magnetic signal (lower limit = DC)		5		MHz
OFFSET Strap	Measured from OFFSET+ to OFFSET-		2.5	3.5	ohm
OFFSET Strap Ω Tempco (4)	T_A = -40 to 125° C		0.39		%/° C
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	ohm
Set/Reset Current (2) (3) (4)	2 µs current pulse, 1% duty cycle	3.0	3.2	5	Amp
Set/Reset Ω Tempco (4)	T_A = -40 to 125° C		0.37		%/° C
Disturbing Field (4)	Sensitivity starts to degrade. Use S/R pulse to restore sensitivity.	3			gauss
Sensitivity Tempco (4)	T_A = -40 to 125° C Vbridge=8V Ibridge=5mA	-0.32	-0.3 -0.06	-0.28	%/° C
Bridge Offset Tempco (4)	T_A = -40 to 125° C no Set/Reset Vbridge=5V with Set/Reset		±0.03 ±0.001		%/° C
Resistance Tempco (4)	T_A = -40 to 125° C		0.25		%/° C
Cross-Axis Effect (4)	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			10000	gauss
Weight	HMC1001 HMC1002		0.14 0.53	gram	

(1) V_{Bridge} = 4.3V, $I_{S/R}$ = 3.2A, $V_{OUT} = V_{SET} - V_{RESET}$
(2) If V_{Bridge} = 8.0V, $I_{S/R}$ = 2.0A, lower S/R current leads to greater output variation.
(3) Effective current from power supply is less than 1mA.
(4) Not tested in production, guaranteed by characterization.
(*) Tested at 25° C except otherwise stated.
Units: 1 gauss (g) = 1 Oersted (in air), = 79.58 A/m, 1G = 10E-4 Tesla, 1G = 10E5 gamma.

HMC1021/1022 SPECIFICATIONS

Characteristic	Conditions**	Min	Typ	Max	Unit
Bridge Supply	Vbridge referenced to GND		5	25	Volts
Bridge Resistance	Bridge current = 5mA	800	1100	1300	Ω
Operating Temperature (1)	HMC1021S, 1021Z, 1022 HMC1021D*	-55 - 55		150 300*	°C
Storage Temperature (1)	Unbiased	-55		175	°C
Field Range (1)	Full scale (FS), — total applied field	-6		+6	gauss
Linearity Error (1)	Best fit straight line ±1 gauss ±3 gauss ±6 gauss		0.05 0.4 1.6		%FS
Hysteresis Error (1)	3 sweeps across ±3 gauss		0.08		%FS
Repeatability Error (1)	3 sweeps across ±3 gauss		0.08		%FS
Bridge Offset	Offset = (OUT+) – (OUT-), Field = 0 gauss After Set pulse, Vbridge=5V	-10	±2.5	11.25	mV
Sensitivity	S/R Current = 0.5A	0.8	1.0	1.25	mV/V/gauss
Noise Density (1)	Noise at 1Hz, Vbridge=5V		48		nV/√Hz
Resolution (1)	Bandwidth=10Hz, Vbridge=5V		85		µgauss
Bandwidth (1)	Magnetic signal (lower limit = DC)		5		MHz
OFFSET Strap	Measured from OFFSET+ to OFFSET-	38	50	60	Ω
OFFSET Strap Ω Tempco (1)	T_A = -40 to 125° C		0.39		%/° C
OFFSET Field (1)	Field applied in sensitive direction	4.0	4.6	6.0	mA/gauss
Set/Reset Strap	Measured from S/R+ to S/R-	5.5	7.7	9	Ω
Set/Reset Current	2µs current pulse, 1% duty cycle	0.5	0.5	4.0	Amp
Set/Reset Ω Tempco (1)	T_A = -40 to 125° C		0.37		%/° C
Disturbing Field (1)	Sensitivity starts to degrade. Use S/R pulse to restore sensitivity.	20			gauss
Sensitivity Tempco (1)	T_A = -40 to 125° C Vbridge=5V Ibridge=5mA	-0.32	-0.3 -0.06	-0.28	%/° C
Bridge Offset Tempco (1)	T_A = -40 to 125° C no Set/Reset Vbridge=5V with Set/Reset		±0.05 ±0.001		%/° C
Resistance Tempco (1)	Vbridge=5V, T_A = –40 to 125° C		0.25		%/° C
Cross-Axis Effect (1)	Cross field=1 gauss (see AN-205) Happlied=±1 gauss		+0.3		%FS
Max. Exposed Field (1)	No perming effect on zero reading			10000	gauss
Set/Reset (1)	S/R current ≥ 0.5 Amps			30	µV

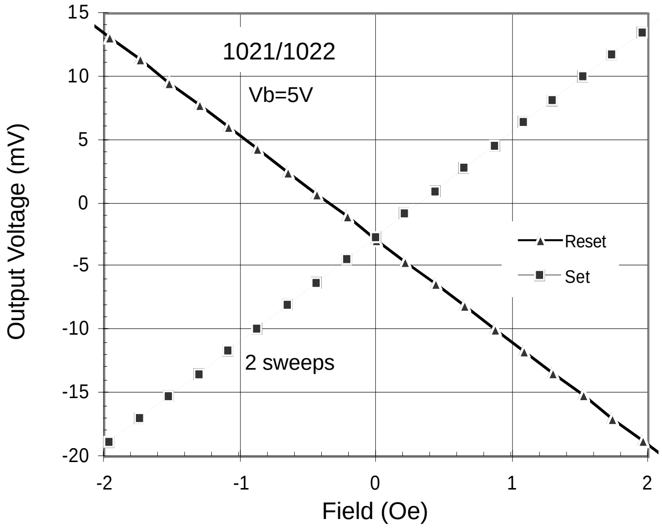
*Please reference data sheet, HTMC1021D for specifications.
(1) Not tested in production, guaranteed by characterization.

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

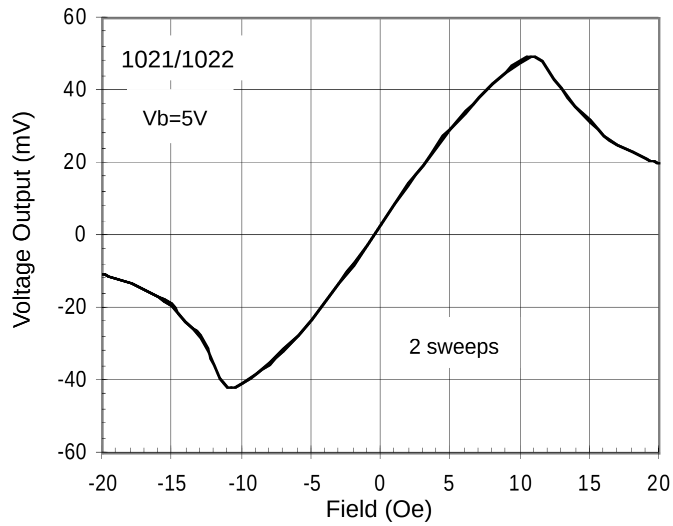
**Tested at 25° C except otherwise stated.

KEY PERFORMANCE DATA

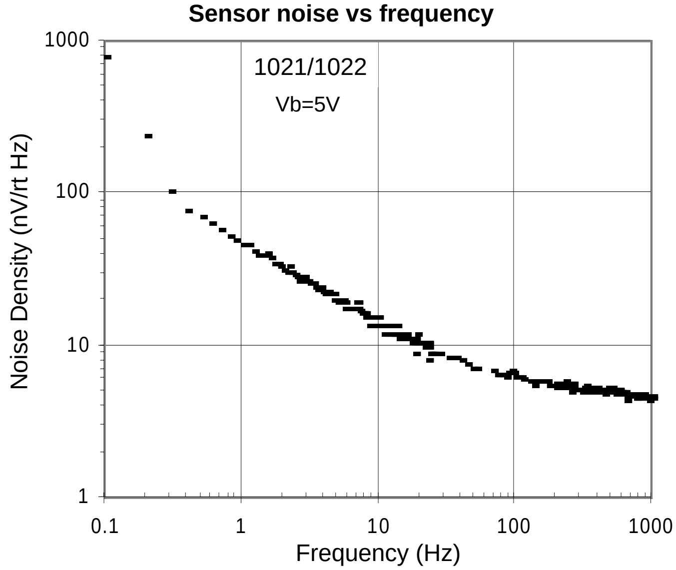
Sensor output vs magnetic field after being set or reset



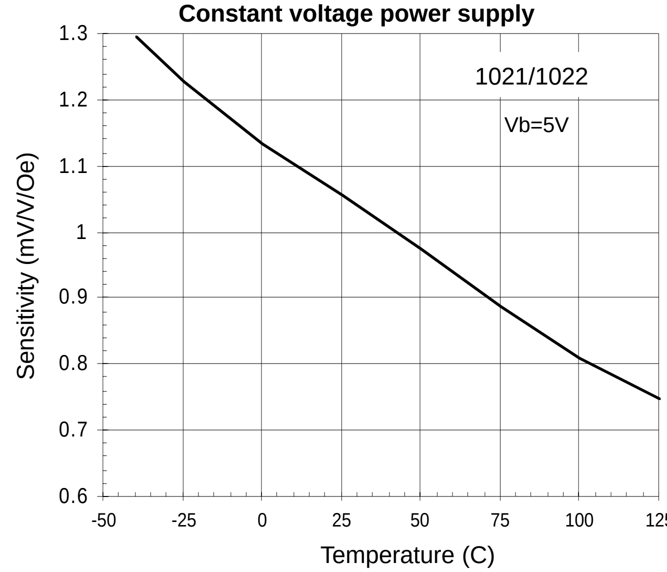
Sensor output vs magnetic field Output is repeatable in field range ±20 Oe



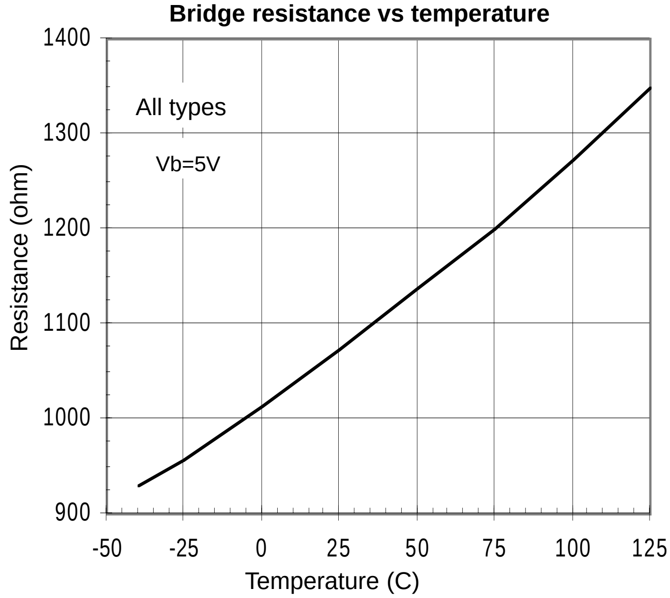
Sensor noise vs frequency



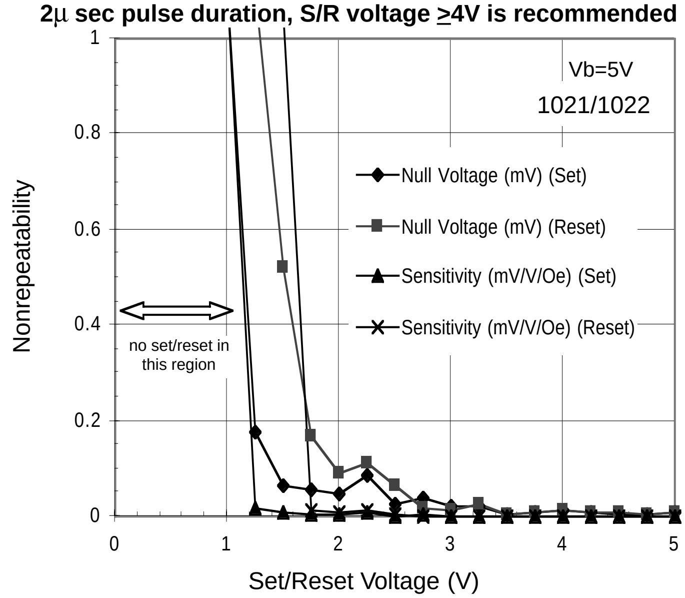
Sensitivity vs temperature Constant voltage power supply



Bridge resistance vs temperature

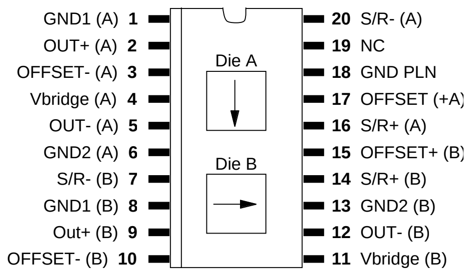


Effects of set/reset pulse variation 2µ sec pulse duration, S/R voltage ≥4V is recommended

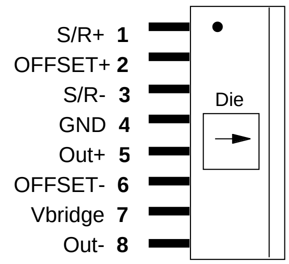


PACKAGE / PINOUT SPECIFICATIONS

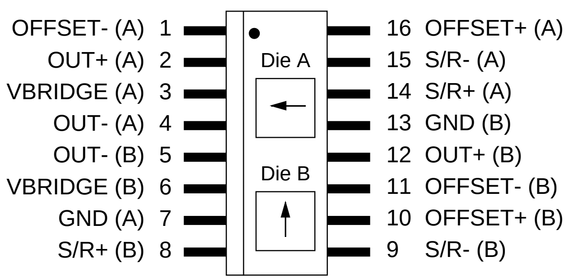
HMC1002—Two-Axis MR Microcircuit



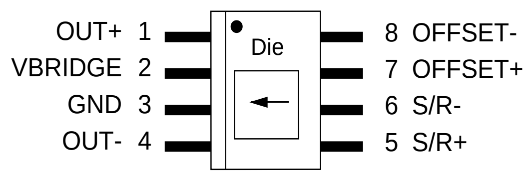
HMC1001—One Axis MR Microcircuit



HMC1022—Two-Axis MR Circuit

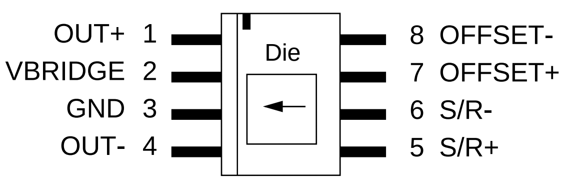


HMC1021S—One-Axis MR Circuit

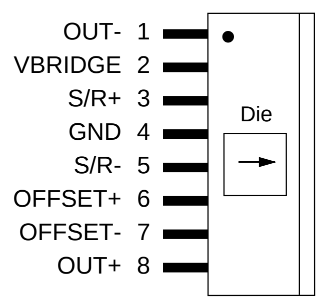


HMC1021S

HMC1021D—One-Axis MR Circuit



HMC1021Z—One-Axis MR Circuit



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

BASIC DEVICE OPERATION

Honeywell magnetoresistive sensors are simple resistive bridge devices (Figure 1) 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. In addition to the bridge circuit, the sensor 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.

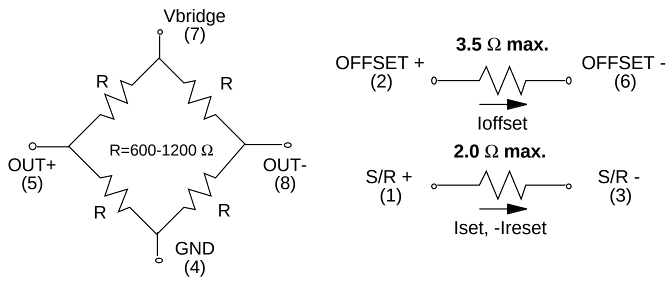


Figure 1—On-Chip components (HMC1001)

Magnetoresistive sensors are made of a nickel-iron (Permalloy) thin film deposited on a silicon wafer and patterned as a resistive strip. In the presence of an applied magnetic field, a change in the bridge resistance causes a corresponding change in voltage output.

An external magnetic field applied normal to the side of the film causes the magnetization vector to rotate and change angle. This in turn will cause the resistance value to vary ($\Delta R/R$) and produce a voltage output change in the Wheatstone bridge. This change in the Permalloy resistance is termed the *magnetoresistive effect* and is directly related to the angle of the current flow and the magnetization vector.

During manufacture, the easy axis (preferred direction of magnetic field) is set to one direction along the length of the film. This allows the maximum change in resistance for an applied field within the permalloy film. However, the influence of a strong magnetic field (more than 10 gauss) along the easy axis could upset, or flip, the polarity of film magnetization, thus changing the sensor characteristics. Following such an upset field, a strong restoring magnetic field must be applied momentarily to restore, or set, the sensor characteristics. This effect will be referred to as applying a set pulse or reset pulse. Polarity of the bridge output signal depends upon the direction of this internal film magnetization and is symmetric about the zero field output.

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 2 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 shown in Figure 2, 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 2 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 external offset. The output response curves due to the SET and RESET pulses are reflected about these two offsets.

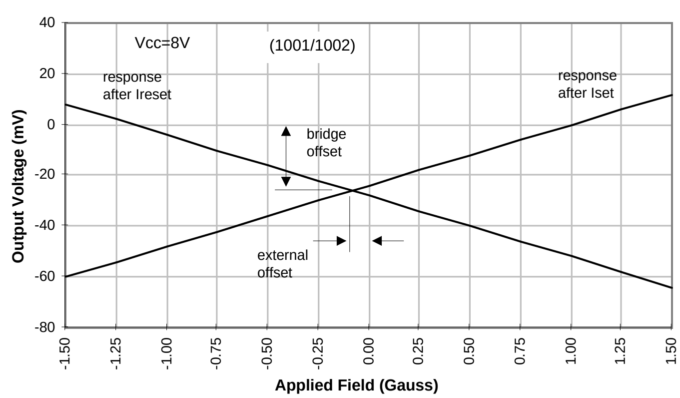


Figure 2—Output Voltage vs. Applied Magnetic Field

NOISE CHARACTERISTICS

The noise density curve for a typical MR sensor is shown in Figure 3. 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 3 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 * √(ln(10/.1)) nV
64 nV (rms)
4 μgauss (rms)
27 μgauss (p-p)

white noise (BW=1KHz) = 3.8 * √BW nV
120 nV (rms)
50 μgauss (p-p)

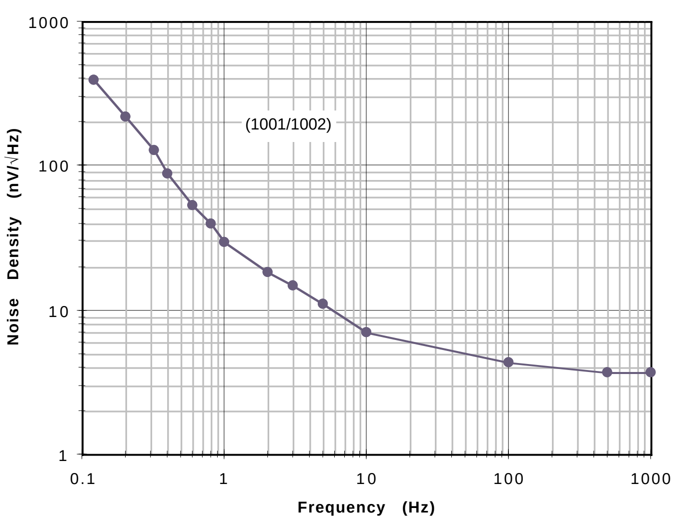


Figure 3—Typical Noise Density Curve

WHAT IS *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 in HMC1001/2 and 1 Oe/5mA in HMC1021/2. (Note: 1 gauss=1 Oersted in air). For example, if 25 mA were driven from the OFFSET+ pin to the OFFSET- pin in HMC1001/2, 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 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 the field the MR sensor measures—call that 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.

WHAT IS *SET/RESET* STRAP?

Most low field magnetic sensors will be affected by large magnetic disturbing fields (>4 - 20 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 a 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.

When MR sensors exposed to a magnetic disturbing field, the sensor elements are broken up into ramdonly oriented magnetic domains (Figure 4A) that leads to sensitivity degrading. A current pulse (set) with a peak current above minimum current in spec through the Set/Reset strap will generate a strong magnetic field that realigns the magnetic domains in one direction (Figure 4B). This will ensure a high sensitivity and repeatable reading. A negative pulse (Reset) will rotate the magnetic domain orientation in the opposite direction (Figure 4C), and change the polarity of the sensor outputs. The state of these magnetic domains can retain for years as long as there is no magnetic disturbing field present.

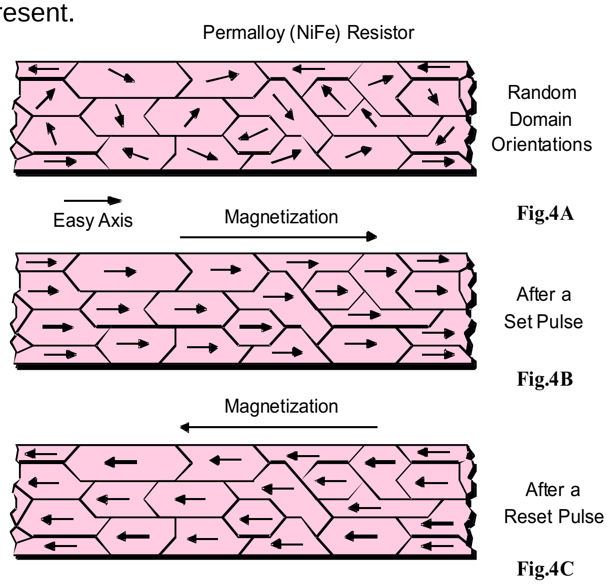


Figure 4—

The on-chip S/R should be pulsed with a current to realign, or "flip", the magnetic domains in the sensor. 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.

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 5.

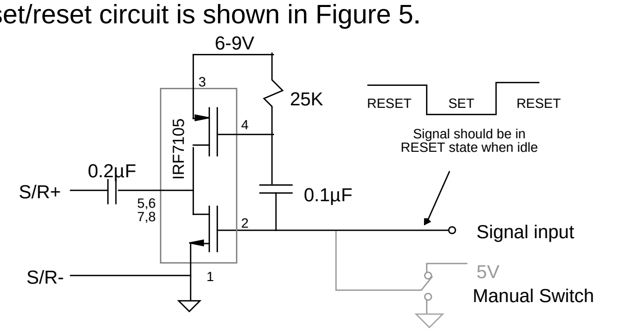


Figure 5—Single-Axis Set/Reset Pulse Circuit (1001)

The magnitude of the set/reset current pulse depends on the magnetic noise sensitivity of the system. If the minimum detectable field for a given application is roughly 500 µgauss in HMC1001/2, then a 3 amp pulse (min) is adequate. If the minimum detectable field is less than 100 µgauss, then a 4 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.

The set/reset straps on the Honeywell magnetic sensors are labeled S/R+ and S/R-. There is no polarity implied since this is simply a metal strap resistance.

Single Clock Circuitry—Some form of clock is needed to trigger the set and reset pulses (Figure 6) to create the switching signal. The circuit shown in Figure 8 can be used to create a strong (>4Amp) pulse. The diodes, resistors, capacitors and inverters basically create the TRS and the TSR delays. Now a single signal (Clock) can trigger a set or reset pulse. The minimum timing between the rising and falling edges of Clock are determined by the 25KΩ and 1nF time constant. That is, the minimum high and low time for Clock is ≈25 µs.

Micro Processor—The circuit in Figure 9 generates a strong set/reset pulse (>4 Amp) under microprocessor control. The SET and RESET signals are generated from a microprocessor and control the P and N channel HEXFET drivers (IRF7105). The purpose of creating the TRS and the TSR delays are to make sure that one HEXFET is off before the other one turns on. Basically, a break-before-make switching pattern. The current pulse is drawn from the 4.7 µF capacitor. If the 5V to 20V converter is used as shown in Figure 7, then the resultant noise and droop on the 16-20V supply is not an issue. But if the 16-20V supply is used elsewhere in the system, then a series dropping resistor (≈500Ω) should be placed between the 4.7µF capacitor and the supply.

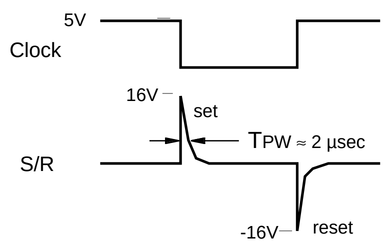


Figure 6—Single Clock Set/Reset Timing

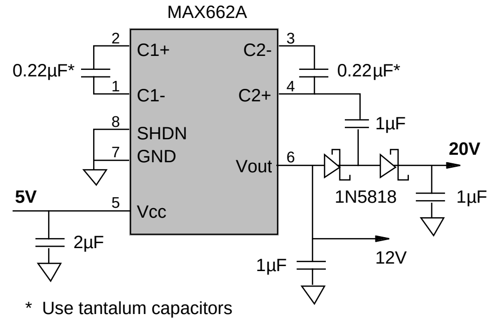


Figure 7—5V to 20V Converter

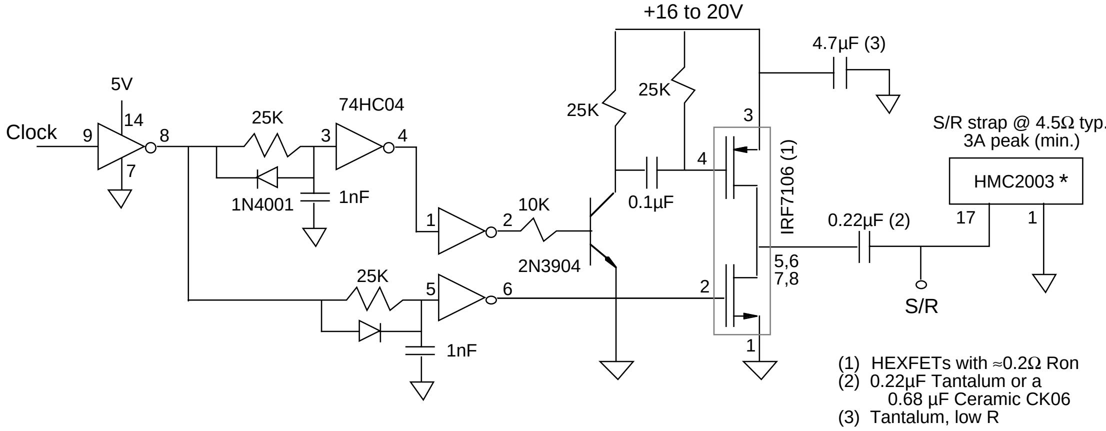
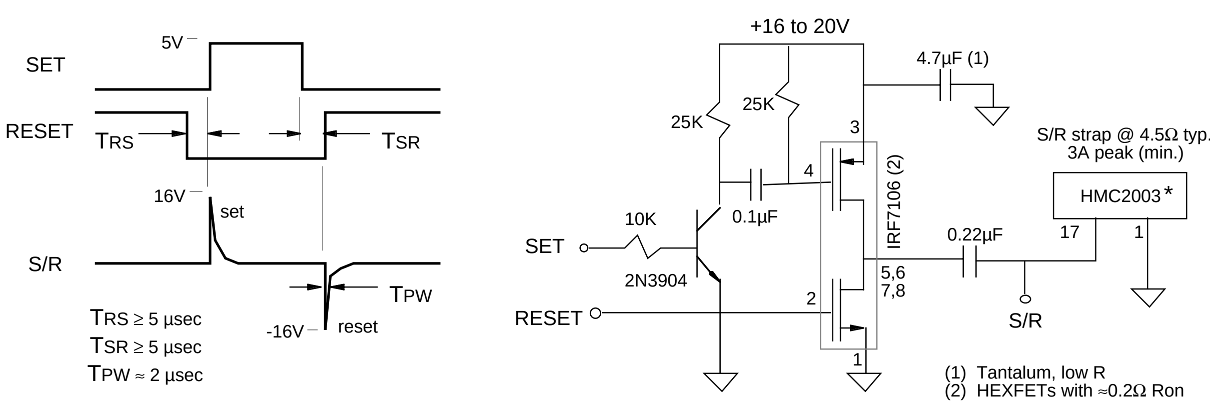


Figure 8—Single Clock Set/Reset Pulse Circuit (1001/1002)



•HMC2003 contains one HMC1001 and one HMC1002; together they make the 3-axis sensor. Three S/R straps are in serial, the total resistance is ~4.5Ω.

Figure 9—Set/Reset Circuit With Microprocessor Control (1001/1002)

Low Field Measurements—When measuring 100 µgauss resolution or less, the permalloy film must be completely set, or reset, to insure low noise and repeatable measurements. A current pulse of 4 amps, or more, for just a couple microseconds will ensure this. The circuits in Figures 8 and 9 are recommended for applications of HMC1001/2 that require low noise and high sensitivity magnetic readings.

Low Cost—For minimum field measurements above 500 µgauss, a less elaborate pulsing circuit can be used. In both Figures 10 and 11, the pulse signal is switched using lower cost Darlington transistors and fewer components. This circuit may have a more limited temperature range depending on the quality of transistors selected. If accuracy is not an issue and cost is, then the reset only circuit in Figure 11 will work.

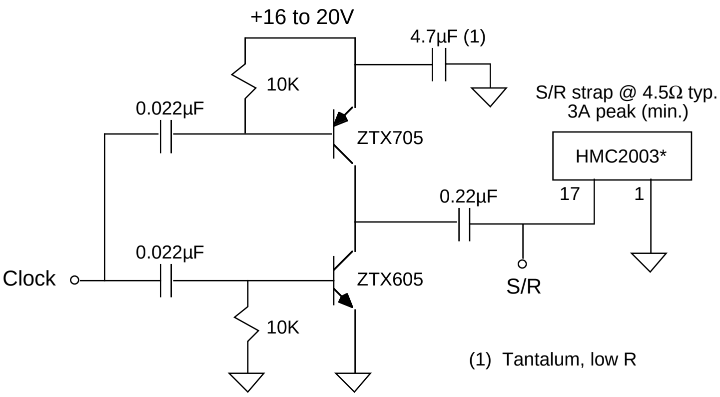
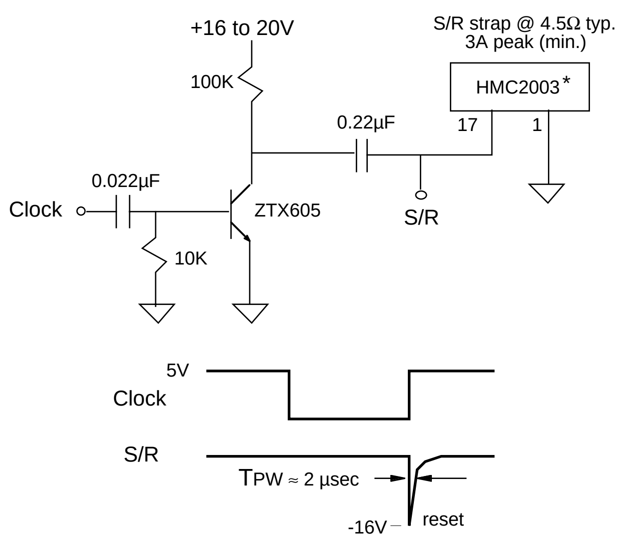


Figure 10—Single Clock Set/Reset Circuit (1001/1002)



*The HMC2003 has 3-axis S/R straps in series.
These are the HMC1001 and HMC1002 sensors.

Figure 11—Single Clock Reset Only Circuit (1001/1002)

For any magnetic sensor application, if temperature drift is not an issue, then the reset pulse need only be occasionally applied. This will save power and enable the use of digital filtering techniques as shown in Figure 12. Circumstances for a reset pulse would be 1) power on or, 2) field over/under range condition. Any other time the sensor should perform normally.

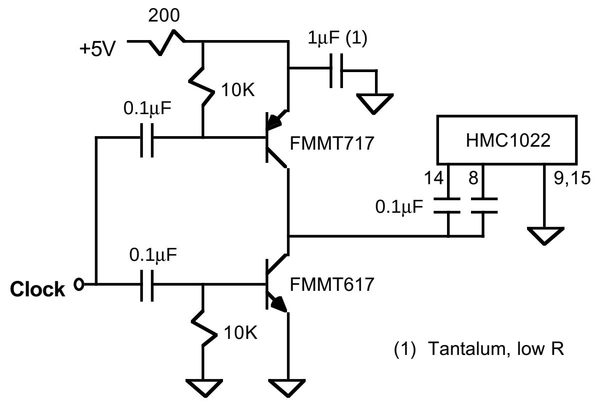


Figure 12—5V Circuit for SET/RESET (1021/1022)

The circuit in Figure 13 generates a strong set/reset pulse under a microprocessor clock driven control. A free running 555 timer can also be used to clock the circuit. The SET current pulse is drawn from the 1 µF capacitor and a 200 ohm dropping resistor should be placed in series with the supply to reduce noise.

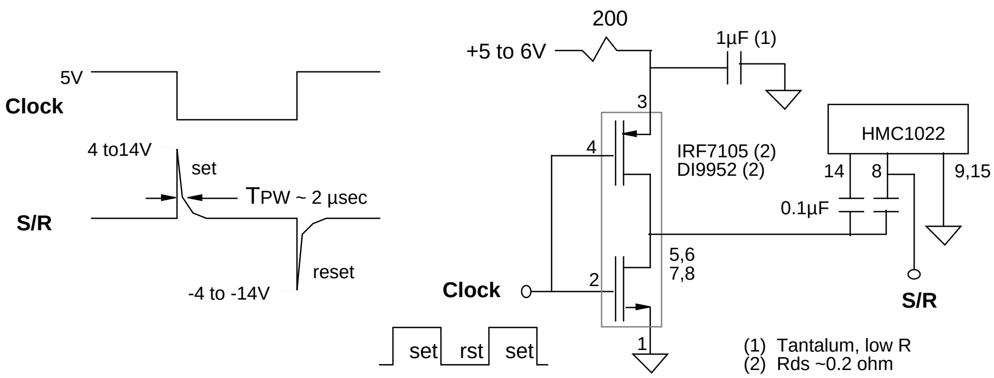


Figure 13—Set/Reset Pulse With Clock Control (1021/1022)

Low Power—For low power application, down to 3.3 volt supply, the circuit shown in Figure 15 can be used. These low threshold FETs provide low on-resistance (0.3Ω) at V_{GS}=2.7V. The set/reset pulsing does not need to be continuous. To save power, the SET pulse can be initially applied followed by a single RESET pulse. The offset (OS) can be calculated as:

$$OS = (Vset + Vrst)/2$$

This offset term will contain the DC offset of both the sensor bridge and interface electronics, as well as the temperature drift of the bridge and interface electronics. Store this value and subtract it from all future bridge output readings. Once the bridge is RESET, it will remain in that state for years—or until a disturbing field (>20 gauss) is applied. A timer can be set, say every 10 minutes, to periodically update the offset term. A flow chart is shown in Figure 14 along with a timing diagram in Figure 15 to illustrate this process.

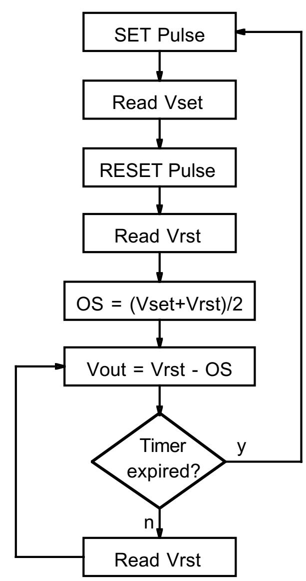


Figure 14—Low Power Set/Rst Flowchart

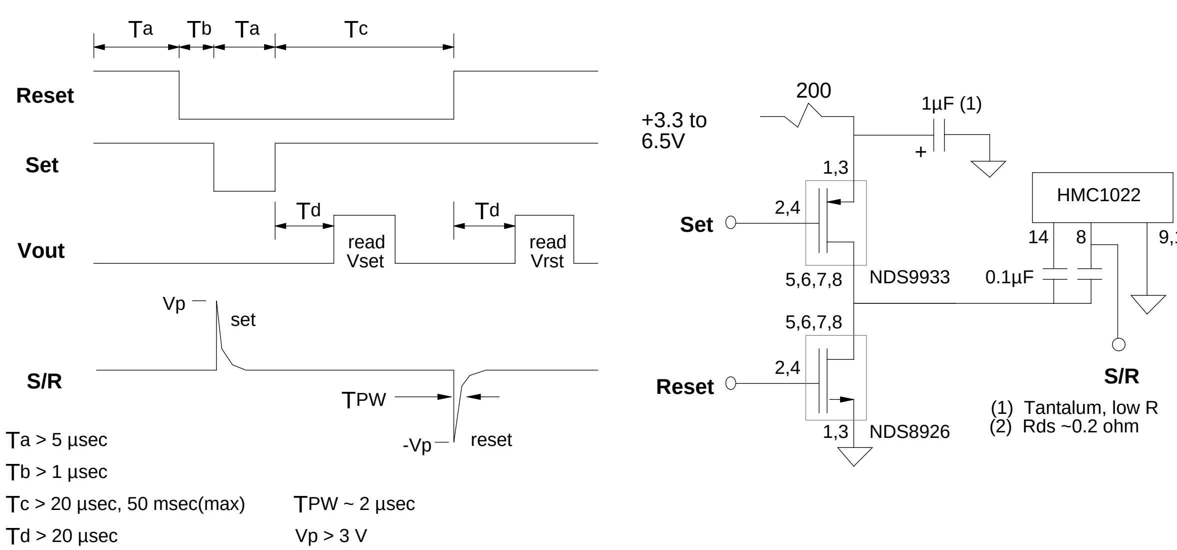


Figure 15—Single Clock Set/Reset Pulse Circuit (1021/1022)

Simple Circuit Application

The circuit in Figure 16 shows a simple application of a 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 17, 18, 19, 20 and 21 show other circuit examples.

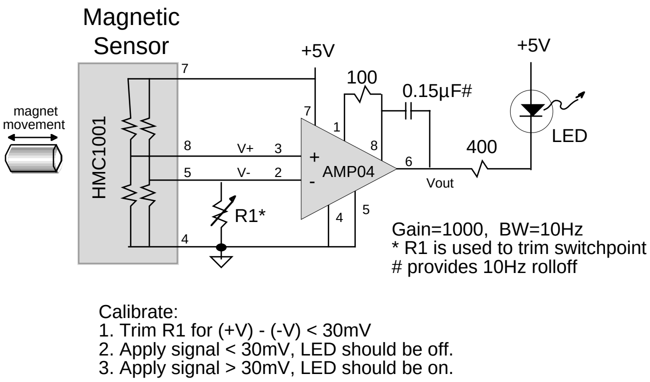


Figure 16—Magnetic Proximity Switch

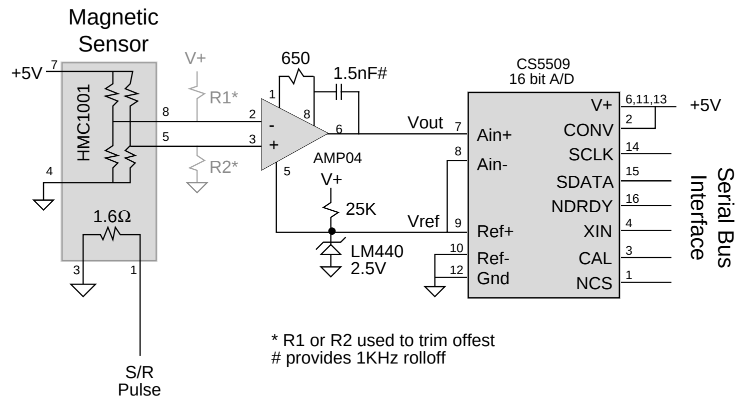


Figure 17—One-Axis Sensor With Digital Interface

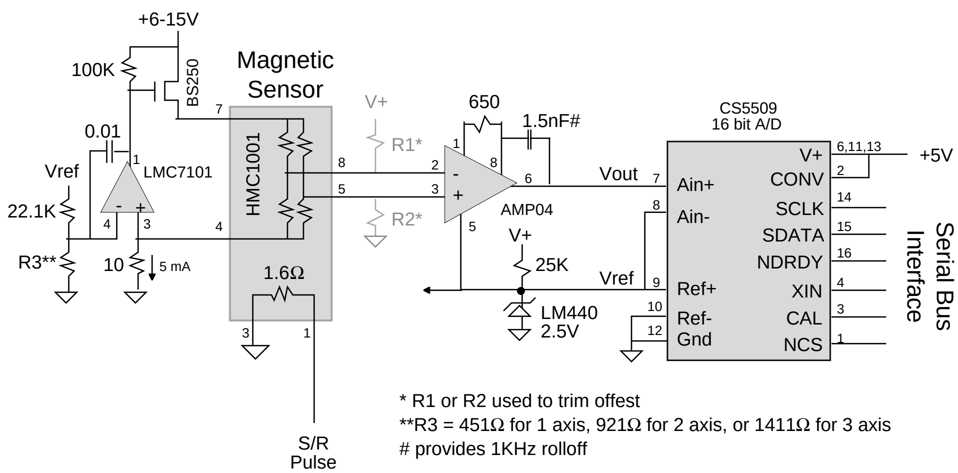
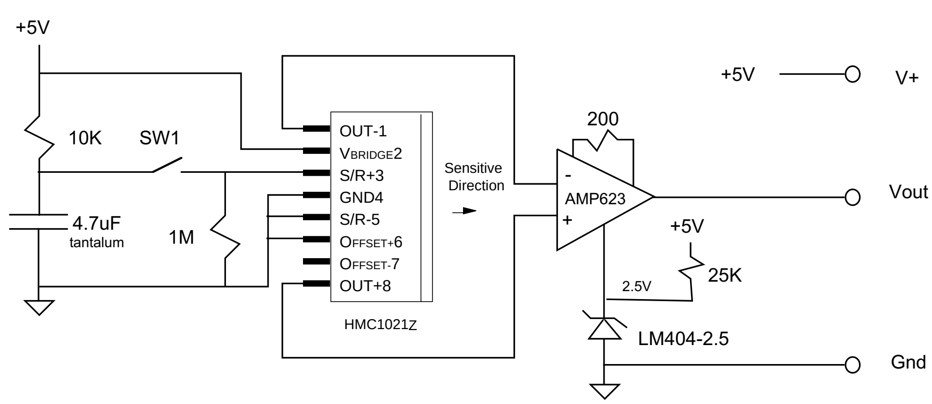


Figure 18—One-Axis Sensor With Constant Bridge Current and Digital Interface



(1) Momentarily close switch SW1. This creates a SET pulse. (2) Measure bridge output (OUT+) - (OUT-) **NOTE:** Bridge output signal will be 5mV/gauss (3) Measure Vout after AD623 amplifier (G~500) **NOTE:** Vout signal will be 2.5V/gauss

Figure 19—One-Axis Low Cost Sensor

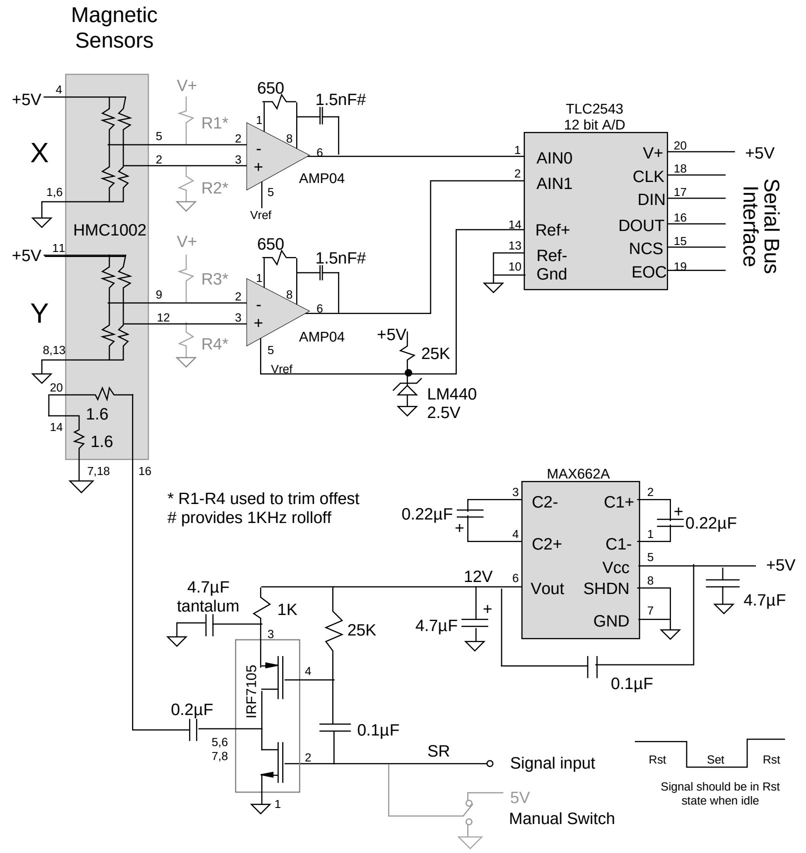


Figure 20—Two-Axis Sensor With Set/Reset Circuit and Digital Interface

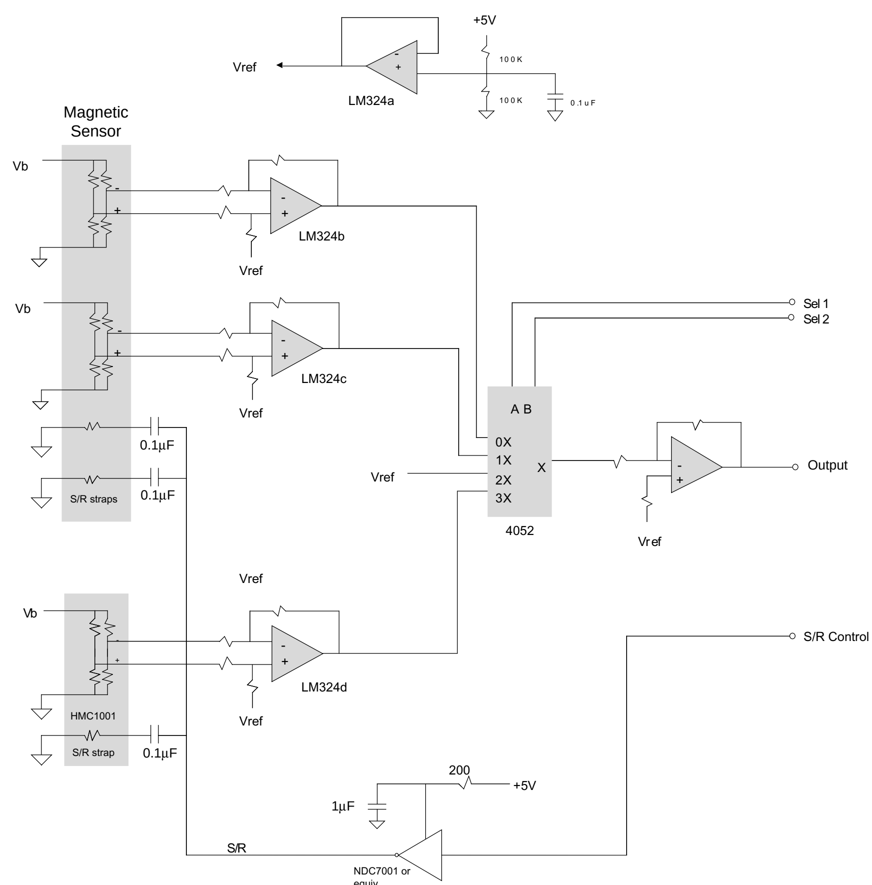
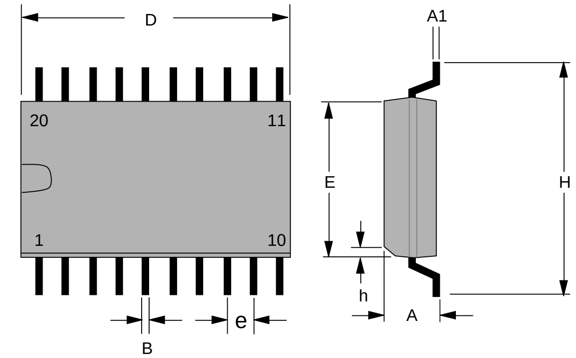


Figure 21—Three-Axis Low Cost Magnetic Sensor

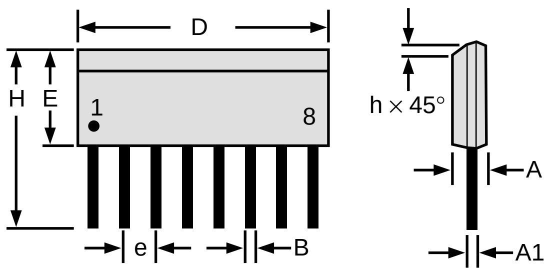
PACKAGE OUTLINES

HMC1002—Package Outline



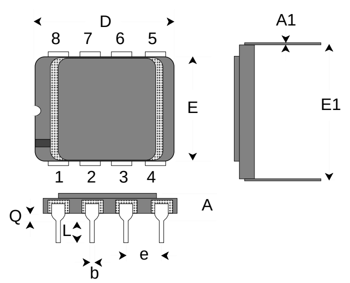
Symbol	Millimeters		Inches	
	Min	Max	Min	Max
A	2.489	2.642	.098	.104
A1	0.127	0.279	.005	.011
B	0.457	0.483	.014	.019
D	12.675	12.929	.499	.509
E	7.264	7.417	.286	.292
e	1.270 ref		.050 ref	
H	1.270	10.566	.396	.416
h	0.381	ref	.015	.030

HMC1001—8-Pin SIP and HMC1021Z—8-Pin SIP



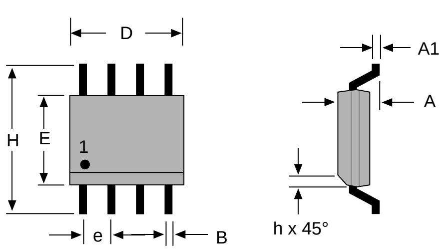
Symbol	Millimeters		Inches	
	Min	Max	Min	Max
A	1.371	1.728	.054	.068
A1	0.101	0.249	.004	.010
B	0.355	0.483	.014	.019
D	9.829	11.253	.387	.443
E	3.810	3.988	.150	.157
e	1.270 ref		.050 ref	
H	6.850	7.300	0.270	0.287
h	0.381	0.762	.015	.030

HMC1021D—8-Pin Ceramic DIP



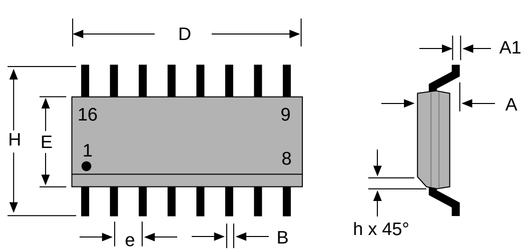
Symbol	Millimeters		Inches	
	Min	Max	Min	Max
A	2.718 ref		0.107 ref	
A1	0.229	0.305	0.009	0.012
b	0.406	0.508	0.016	0.020
D	—	10.287	—	0.405
E	7.163	7.569	0.282	0.298
E1	7.366	7.874	0.290	0.310
e	2.54 ref		0.100 ref	
Q	0.381	1.524	0.015	0.060
L	3.175	4.445	0.125	0.175

HMC1021S—8-Pin SOIC



Symbol	Millimeters		Inches	
	Min	Max	Min	Max
A	1.371	1.728	.054	.068
A1	0.101	0.249	.004	.010
B	0.355	0.483	.014	.019
D	4.800	4.979	.189	.196
E	3.810	3.988	.150	.157
e	1.270 ref		.050 ref	
H	5.816	6.198	.229	.244
h	0.381	0.762	.015	.030

HMC1022—16-Pin SOIC



Symbol	Millimeters		Inches	
	Min	Max	Min	Max
A	1.371	1.728	.054	.068
A1	0.101	0.249	.004	.010
B	0.355	0.483	.014	.019
D	9.829	11.253	.387	.443
E	3.810	3.988	.150	.157
e	1.270 ref		.050 ref	
H	5.816	6.198	.229	.244
h	0.381	0.762	.015	.030

DESIGN / PACKAGE OPTIONS

Honeywell offers a range of magnetic microcircuit products. Two different sensor designs and five package configurations are available:

- **HMC1001/1002** series offers a higher sensitivity and lower field resolution.
- **HMC1021/1022** series offers a wider field range, lower set/reset current and has a lower cost for higher volume applications.

Two-axis parts contain two sensors for the x- and y- field measurements. Single-axis variations include a SIP package for mounting through the circuit board to create a 3-axis solution, a SOIC for direct surface mount, and a ceramic DIP for high performance military and high temperature applications.

	HMC1001/02	HMC1021/22	Units
Sensitivity	3.1	1.0	mV/V/G
Resolution	27	85	µgauss
Range	± 2	± 6	gauss
Set/Rst Current	3.0	0.5	Amps
Cost		Lower in high volume	

ORDERING INFORMATION

Part Number	Axis Number	Sensitivity	Package Style
HMC1001	Single	3mV/V/G	8-Pin SIP
HMC1002	Two	3mV/V/G	20-Pin SOIC
HMC1021D	Single	1mV/V/G	8-Pin Ceramic DIP
HMC1021Z	Single	1mV/V/G	8-Pin SIP
HMC1021S	Single	1mV/V/G	8-Pin SOIC
HMC1022	Two	1mV/V/G	16-Pin SOIC

Solid State Electronics Center • 12001 State Highway 55, Plymouth, MN 55441 • (800) 323-8295 • www.magneticsensors.com

Additional Product Details:
Customer Service Representative
(612) 954-2888 fax: (612) 954-2257
E-Mail: clr@mn14.ssec.honeywell.com

Honeywell

900248 Rev. B
4-00

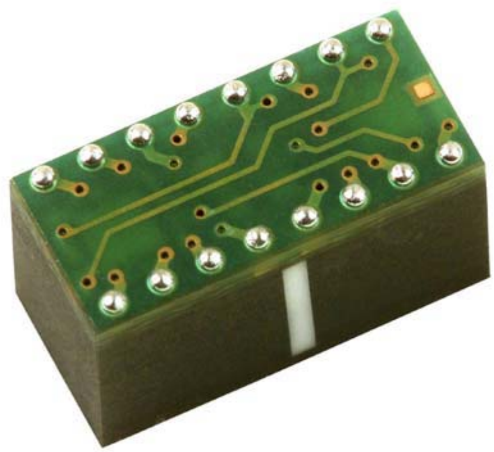
Honeywell

SENSOR PRODUCTS

3-AXIS MAGNETIC SENSOR

Features

- Ball Grid Array (BGA) Surface-Mount Package
- Three Orthogonal Magneto-Resistive Sensors
- Wide Field Range of ± 6 Gauss
- 1.0 mV/V/gauss Sensitivity
- Minimum Detectable Field to 85μgauss
- Patented On-Chip Set/Reset and Offset Straps



Product Description

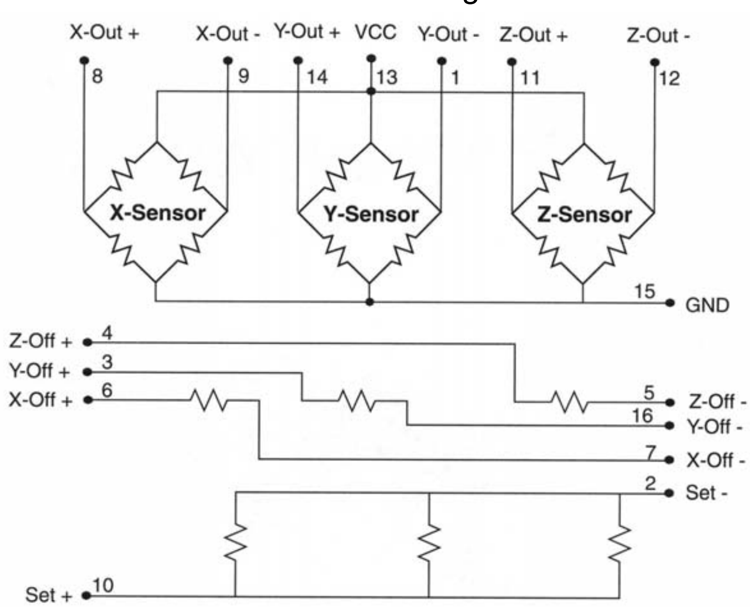
The Honeywell HMC1023 is a high performance three-axis magneto-resistive sensor design in a single package. The advantages of the HMC1023 include orthogonal three-axis sensing, small size and a 16-contact BGA surface mount package.

Each of the magneto-resistive sensors are configured as 4-element Wheatstone bridges to convert magnetic fields to differential output voltages. Capable of sensing fields down to 85 micro-gauss, these sensors offer a compact, high sensitivity and highly reliable solution for low field magnetic sensing.

APPLICATIONS

- **Compassing**
- **Navigation Systems**
- **Attitude Reference**
- **Traffic Detection**
- **Medical Devices**

HMC1023 Circuit Diagram



SPECIFICATIONS

Characteristics	Conditions*	Min	Typ	Max	Units
Bridge Elements					
Supply	Vbridge referenced to GND	1.8	5.0	12	Volts
Resistance	Bridge current = 5mA, VCC to GND	250	350	450	ohms
Operating Temperature	Ambient	-40		125	°C
Storage Temperature	Ambient, unbiased	-55		125	°C
Humidity	Tested at 121°C			100	%
Field Range	Full scale (FS) – total applied field	-6		+6	gauss
Linearity Error	Best fit straight line ± 1 gauss ± 3 gauss ± 6 gauss		 0.05 0.4 1.6		%FS
Hysteresis Error	3 sweeps across ±3 gauss		0.08		%FS
Repeatability Error	3 sweeps across ±3 gauss		0.08		%FS
Bridge Offset	Offset = (OUT+) – (OUT-) Field = 0 gauss after Set pulse, VCC = 5V	-10	±2.5	+10	mV
Sensitivity	Set/Reset Current = 2.0A	0.8	1.0	1.2	mV/V/gauss
Noise Density	@ 1kHz, VCC=5V		48		nV/sqrt Hz
Resolution	50Hz Bandwidth, VCC=5V		85		μgauss
Bandwidth	Magnetic signal (lower limit = DC)		5		MHz
Disturbing Field	Sensitivity starts to degrade. Use S/R pulse to restore sensitivity.	20			gauss
Sensitivity Tempco	T_A= -40 to 125°C, VCC=5V T_A= -40 to 125°C, ICC=5mA	-2800	-3000 -600	-3200	ppm/°C
Bridge Offset Tempco	T_A= -40 to 125°C, No Set/Reset T_A= -40 to 125°C, With Set/Reset		±500 ±10		ppm/°C
Bridge Ohmic Tempco	VCC=5V, T_A= -40 to 125°C	2100	2500	2900	ppm/°C
Cross-Axis Effect	Cross field = 1 gauss, Happlied = ±1 gauss		+0.3		%FS
Max. Exposed Field	No perming effect on zero reading			200	gauss
Sensitivity Ratio of X,Y,Z Sensors	T_A= -40 to 125°C		100±5		%
X,Y, Z sensor Orthogonality	Sensitive direction in X, Y and Z sensors			1.0	degree

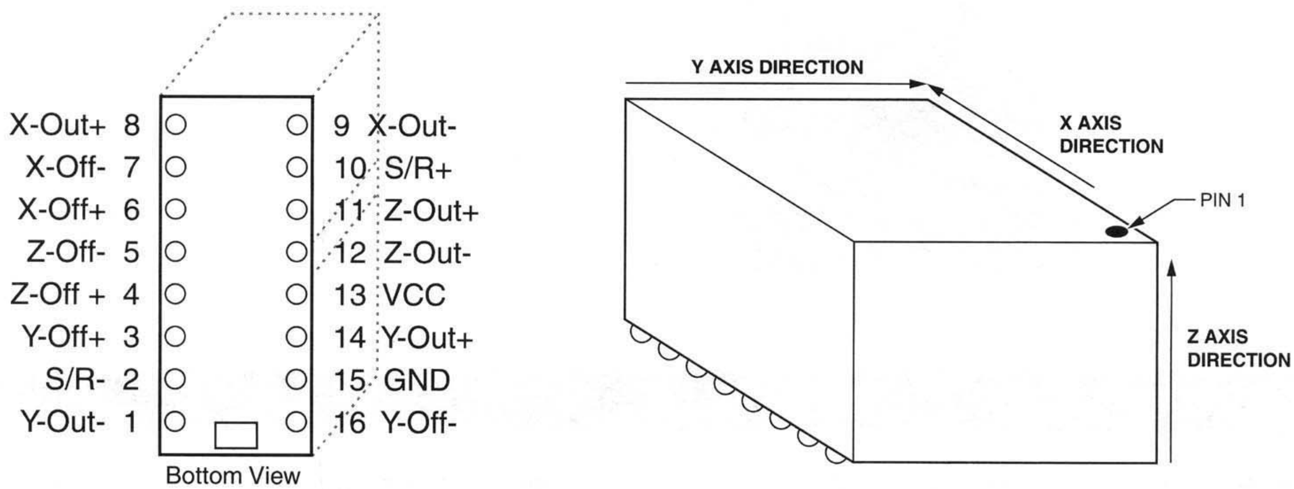
* Tested at 25°C except stated otherwise.

SPECIFICATIONS

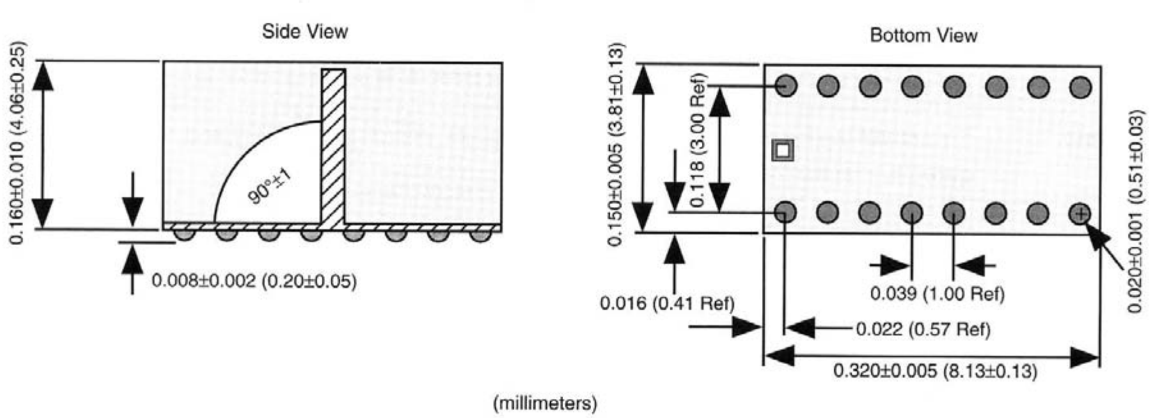
Characteristics	Conditions*	Min	Typ	Max	Units
Set/Reset Strap					
Resistance	Measured from S/R+ to S/R-	2.0	3.0	4.0	ohms
Current	0.1% duty cycle, or less, 2μsec current pulse	1.5	2.0	4.0	Amp
Resistance Tempco	T_A= -40 to 125°C	3300	3700	4100	ppm/°C
Offset Straps					
Resistance	Measured from OFFSET+ to OFFSET-	40	50	60	ohms
Offset Constant	DC Current Field applied in sensitive direction	4.0	4.6	6.0	mA/gauss
Resistance Tempco	T_A= -40 to 125°C	3500	3900	4300	ppm/°C

* Tested at 25°C except stated otherwise.

Pin Configuration (Arrows indicate direction of applied field that generates a positive output voltage after a SET pulse.)



Package Outline

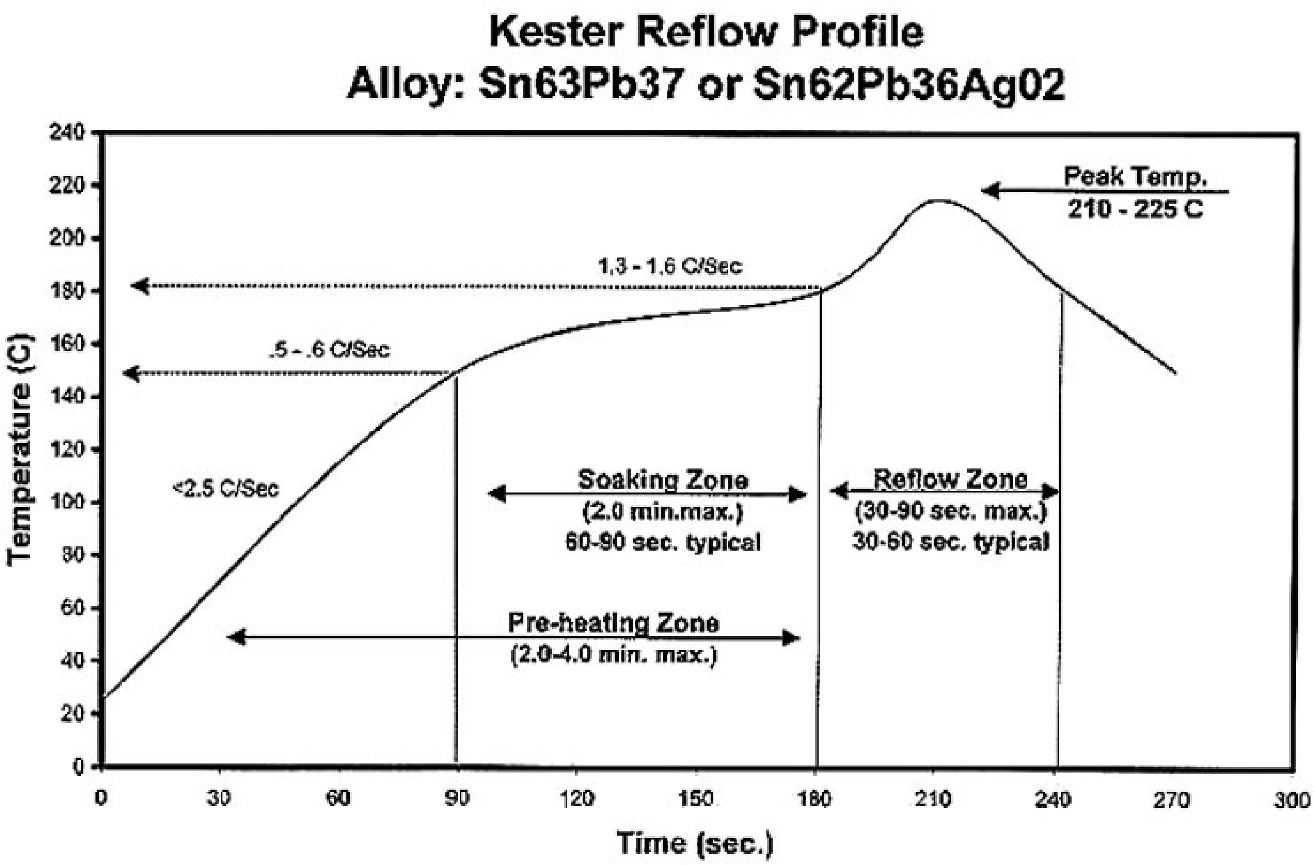


Mounting Considerations

When mounting the Honeywell HMC1023 on a circuit board, please consider the following advice for ball grid array component attachment.

Ball Grid Array attachment/removal to printed circuit boards is precisely controlled thermal solder reflow process. To prevent internal electrical damage and package cracking, do not use conventional soldering iron/solder station tools. If you do not have experience and the reflow oven, please have a qualified BGA rework technician do the work for you.

The reflow profile show below is the recommended profile for HMC1023 package attachment.



Melting temperature for the HMC1023 balls is at 180°C. The recommended rise and fall temperatures should be no greater than 3°C/sec to prevent mechnical stresses or "popcorning". Peak external temperature the part should be exposed to is between 200 to 210°C. When exposed a high temperature, such as the solder reflow process, the internal connections in the package could sustain permanent damage, leaving open connections. 225°C is the melting point of solder inside the HMC1023 Ball Grid Array package. Do not expose the part to this level of temperature.

If using solder paste, we recommend Kester SN62 solder paste with water soluble flux R560. This has a melting point around 180°C. Kester recommends a pre-heating zone from ambient temperature to 180°C for 2 to 4 minutes maximum. The first part of this pre-heating zone ramps up from ambient to 150°C in 90 seconds with a ramp rate of less than 2.5 degrees C per second. The soak zone should last from 60 to 90 seconds (2 minutes maximum) and ramp up in temperature from 150 to 180°C at 0.5 to 0.6 °C/ sec. The reflow zone should last for 30 to 90 seconds maximum (40 to 60 seconds is ideal) and peak in temperature between 200 and 210°C with a ramp of 1.3 to 1.6°C/sec.

The reflow parameters can vary significantly and excellent reflow results can still be achieved. A thin layer of paste flux or a 2 to 3 mil layer of solder paste applied to the mother-board prior to placing the HMC1023 is helpful. The profile can be verified by placing a thermocouple between the HMC1023 and motherboard.

Basic Device Operation

The Honeywell HMC1023 magneto-resistive sensor is composed of three Wheatstone bridge elements to measure magnetic fields for both field strength and direction. With power applied to the bridges, the sensors elements convert any incident magnetic field in each element's sensitive axis direction to a differential voltage output. In addition to the bridge elements, these sensors have two types of on-chip magnetically coupled straps; the offset straps and the set/reset strap. These straps are Honeywell patented features for incident field adjustment and magnetic domain alignment; and eliminate the need for external coils positioned around the sensors.

The magnetoresistive sensors are made of a nickel-iron (Permalloy) thin-film deposited on a silicon wafer and patterned as a resistive strip element. In the presence of a magnetic field, a change in the bridge resistive elements causes a corresponding change in voltage across the bridge outputs.

These resistive elements are aligned together to have a common sensitive axis (indicated by arrows on the pinouts) that will provide positive voltage change with magnetic fields increasing in the sensitive direction. Because the output only is in proportion to the one-dimensional axis (the principle of anisotropy) and its magnitude, additional sensor bridges placed at orthogonal directions permit accurate measurement of arbitrary field direction. The combination of sensor bridges in this three orthogonal axis configuration permit applications such as compassing and magnetometry.

The individual sensor offset straps allow for several modes of operation when a direct current is driven through it. These modes are: 1) Subtraction (bucking) of an unwanted external magnetic field, 2) null-ing of the bridge offset voltage, 3) Closed loop field cancellation, and 4) Auto-calibration of bridge gain.

The set/reset strap can be pulsed with high currents for the following benefits: 1) Enable the sensor to perform high sensitivity measurements, 2) Flip the polarity of the bridge output voltage, and 3) Periodically used to improve linearity, lower cross-axis effects, and temperature effects.

Noise Characteristics

The noise density for the HMR1023 series is around 50nV/sqrt Hz at the 1 Hz corner, and drops below 10nV/sqrt Hz at 20Hz and begins to fit the Johnson Noise value at around 5nV/sqrt Hz beyond 100Hz. The 10Hz noise voltage averages around 0.58 micro-volts with a 0.16 micro-volts standard deviation. These values are provided with a 5-volt supply.

Offset Strap

The offset strap is a spiral of metalization that couples in the sensor element's sensitive axis. In the HMC1023 design, there is one strap per bridge with both ends brought out externally. Each offset strap measures nominally 50 ohms, and requires about 4.6mA for each gauss of induced field. The straps will easily handle currents to buck or boost fields through the ±6 gauss linear measurement range, but designers should note the extreme thermal heating on the sensor die when doing so.

With most applications, the offset strap is not utilized and can be ignored. Designers can leave one or both strap connections (Off- and Off+) open circuited, or ground one connection node. Do not tie positive and negative strap connections together of the same strap to avoid shorted turn magnetic circuits.

Set/Reset Strap

The set/reset strap is another spiral of metalization that couples to the sensor elements easy axis (perpendicular to the sensitive axis on the sensor die). The HMC1023 set/reset strap circuit has three straps (one per sensor) paralleled together for operation at low voltages. The set/reset strap connections have a nominal resistance of 3.0 ohms with a minimum required peak current of 1.5A for reset or set pulses. With rare exception, the set/reset strap must be used to periodically condition the magnetic domains of the magneto-resistive elements for best and reliable performance.

A set pulse is defined as a positive pulse current entering the S/R+ strap connection. The successful result would be the magnetic domains aligned in a forward easy-axis direction so that the sensor bridge's polarity is a positive slope with positive fields on the sensitive axis result in positive voltages across the bridge output connections.

A reset pulse is defined as a negative pulse current entering the S/R+ strap connection. The successful result would be the magnetic domains aligned in a reverse easy-axis direction so that sensor bridge's polarity is a negative slope with positive fields on the sensitive axis result in negative voltages across the bridge output connections.

Typically a reset pulse is sent first, followed by a set pulse a few milliseconds later. By shoving the magnetic domains in completely opposite directions, any prior magnetic disturbances are likely to be completely erased by the duet of pulses. For simpler circuits with less critical requirements for noise and accuracy, a single polarity pulse circuit may be employed (all sets or all resets). With these uni-polar pulses, several pulses together become close in performance to a set/reset pulse circuit. Figure 1 shows a quick and dirty manual pulse circuit for uni-polar application of pulses to the set/reset strap.

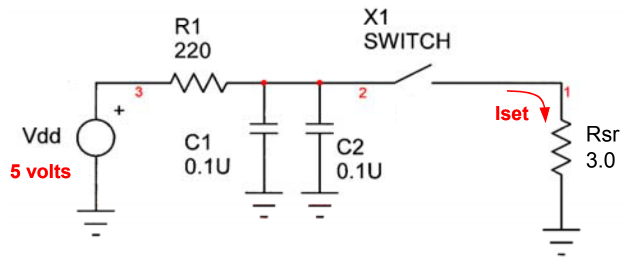


Figure 1
Set Pulse Circuit

Application Notes

Three Axis Compassing with Tilt Compensation

For full three-axis compassing, the circuit depicted in Figure 2 shows HMC1023 used for sensing the magnetic field in three axes. A two-axis accelerometer with digital (PWM) outputs is also shown to provide pitch and roll (tilt) sensing, to correct the three-axis magnetic sensors outputs into to the tilt-compensated two-axis heading. The accelerometer can be substituted with a fluidic 2-axis tilt sensor if desired. For lower voltage operation with Lithium battery supplies (2.5 to 3.6Vdc), the Set/Reset circuit should be upgraded from a single IRF7509 to the dual IRF7509 implementation (H-bridge) to permit a minimum 1.5-ampere pulse (500mA per set/reset strap resistance) to the sensors.

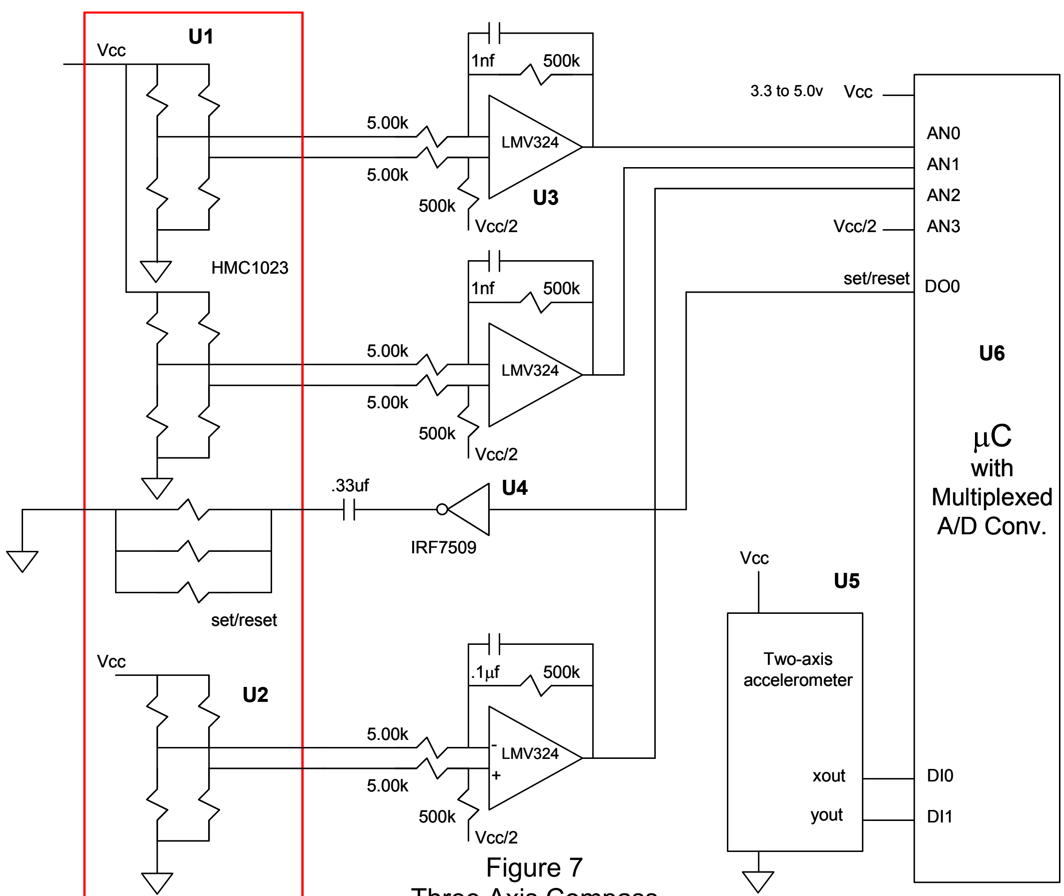


Figure 7
Three Axis Compass

Duty Cycling for Lower Energy Consumption

For battery powered and other applications needing limited energy consumption, the sensor bridge and support electronics can be switched "off" between magnetic field measurements. The HMC1023 sensors are very low capacitance (Bandwidth > 5MHz) sensor bridges and can stabilize quickly, typically before the support electronics can. Other energy saving ideas would be to minimize the quantity of set/reset pulses which saves energy over the battery life. Figure 3 shows a simple supply switching circuit that can be microprocessor controlled to duty cycle (toggle) the electronics in moderate current (<25mA) applications.

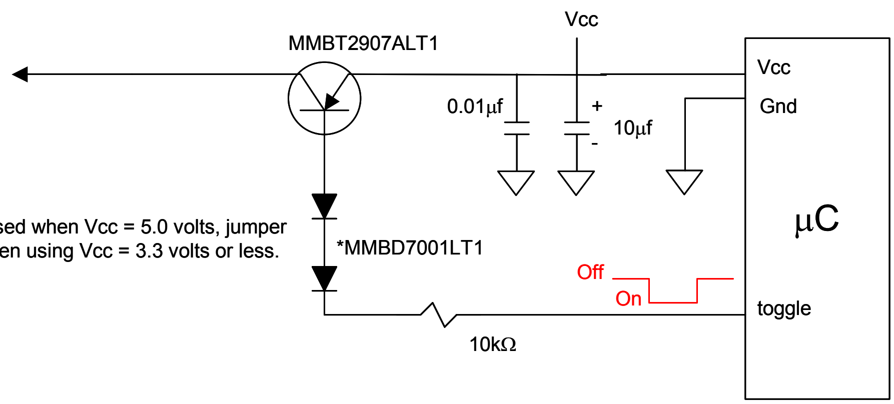


Figure 3
Duty Cycling

ORDERING INFORMATION

Part Number	Package Style
HMC1023	Three Axis Magnetic Sensor
HMC1023PCB	Three Axis Magnetic Sensor – 16-Pin DIP Demo

The application circuits herein constitute typical usage and interface of Honeywell product. Honeywell does not warrant or assume liability for customer-designed circuits derived from this description or depiction.

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This product may be covered by one or more of the following U.S. Patents: 4569742 4681812 4847584 4857418 4945397 5019461 5247278 5820924 5952825 and 6529114.

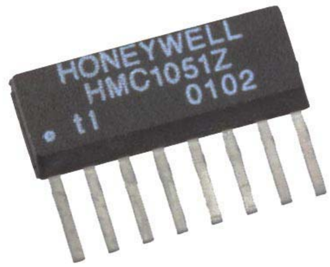
900252 10-03 Rev. B

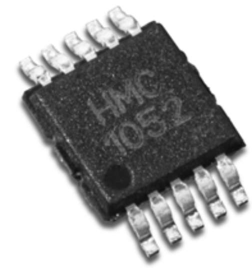
Honeywell
SENSOR PRODUCTS

1, 2 AND 3-AXIS MAGNETIC SENSORS

Features

- Miniature Surface-Mount Packages
- Wide Field Range of ± 6 Gauss
- 1.0 mV/V/gauss Sensitivity
- Low Power Operation Down to 1.8V
- Patented On-chip Set/Reset and Offset Straps

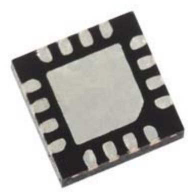


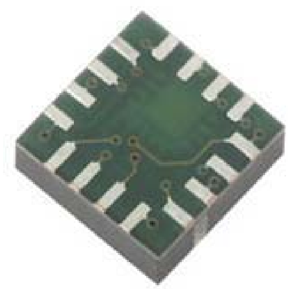


Product Description

The Honeywell HMC1051, HMC1052 and HMC1053 are high performance magnetoresistive sensor designs on a single chip (HMC1051, HMC1052) or two chips (HMC1053). The advantages of these patented chips include orthogonal two-axis sensing (HMC1052), ultra small size and low cost in miniature surface mount packages.

Each of the magneto-resistive sensors are configured as a 4-element wheatstone bridge to convert magnetic fields to differential output voltages. Capable of sensing fields down to 120 micro-gauss, these sensors offer a compact, high sensitivity and highly reliable solution for low field magnetic sensing.

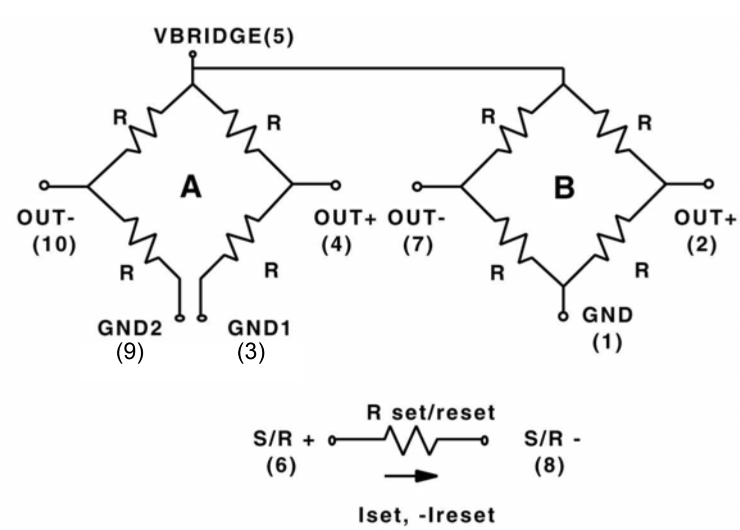




APPLICATIONS

- **Compassing**
- **Navigation Systems**
- **Attitude Reference**
- **Traffic Detection**
- **Medical Devices**
- **Position Sensing**

HMC1052 Circuit Diagram



SPECIFICATIONS

Characteristics	Conditions*	Min	Typ	Max	Units
Bridge Elements					
Supply	Vbridge referenced to GND	1.8	3.0	20	Volts
Resistance	Bridge current = 10mA	800	1000	1500	ohms
Operating Temperature	Ambient	-40		125	°C
Storage Temperature	Ambient, unbiased	-55		150	°C
Humidity	Tested at 85°C			85	%
Field Range	Full scale (FS) – total applied field	-6		+6	gauss
Linearity Error	Best fit straight line ± 1 gauss ± 3 gauss ± 6 gauss		 0.1 0.5 1.8		%FS
Hysteresis Error	3 sweeps across ±3 gauss		0.06		%FS
Repeatability Error	3 sweeps across ±3 gauss		0.1		%FS
Bridge Offset	Offset = (OUT+) – (OUT-) Field = 0 gauss after Set pulse	-1.25	±0.5	+1.25	mV/V
Sensitivity	Set/Reset Current = 0.5A	0.8	1.0	1.2	mV/V/gauss
Noise Density	@ 1kHz, Vbridge=5V		50		nV/sqrt Hz
Resolution	50Hz Bandwidth, Vbridge=5V		120		μgauss
Bandwidth	Magnetic signal (lower limit = DC)		5		MHz
Disturbing Field	Sensitivity starts to degrade. Use S/R pulse to restore sensitivity.	20			gauss
Sensitivity Tempco	T_A= -40 to 125°C, Vbridge=5V T_A= -40 to 125°C, Ibridge=5mA	-3000	-2700 -600	-2400	ppm/°C
Bridge Offset Tempco	T_A= -40 to 125°C, No Set/Reset T_A= -40 to 125°C, With Set/Reset		±500 ±10		ppm/°C
Bridge Ohmic Tempco	Vbridge=5V, T_A= -40 to 125°C	2100	2500	2900	ppm/°C
Cross-Axis Effect	Cross field = 1 gauss, Happlied = ±1 gauss		±3		%FS
Max. Exposed Field	No perming effect on zero reading			10000	gauss
Sensitivity Ratio of X,Y Sensors (HMC1052 Only)	T_A= -40 to 125°C	95	100	105	%
X,Y sensor Orthogonality (HMC1052)	Sensitive direction in X and Y sensors			0.01	degree

* Tested at 25°C except stated otherwise.

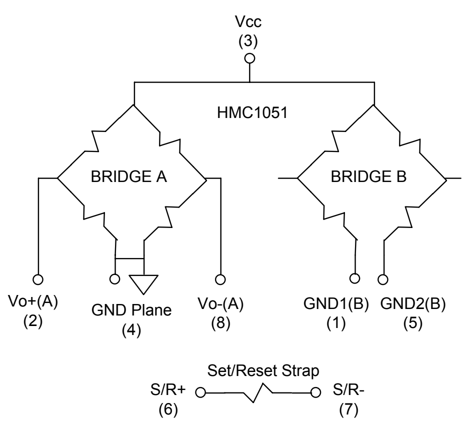
SPECIFICATIONS

Characteristics	Conditions*	Min	Typ	Max	Units
Set/Reset Strap					
Resistance	Measured from S/R+ to S/R-	3	4.5	6	ohms
Current	0.1% duty cycle, or less, 2μsec current pulse	0.4	0.5	4	Amp
Resistance Tempco	T_A= -40 to 125°C	3300	3700	4100	ppm/°C
Offset Straps					
Resistance	Measured from OFFSET+ to OFFSET-	12	15	18	ohms
Offset Constant	DC Current Field applied in sensitive direction		10		mA/gauss
Resistance Tempco	T_A= -40 to 125°C	3500	3900	4300	ppm/°C

* Tested at 25°C except stated otherwise.

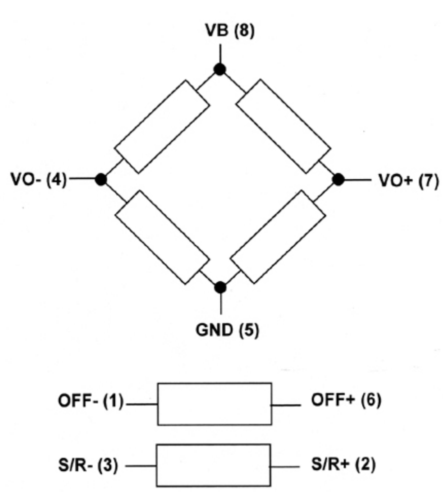
PIN CONFIGURATIONS (Arrow indicates direction of applied field that generates a positive output voltage after a SET pulse.)

HMC1051

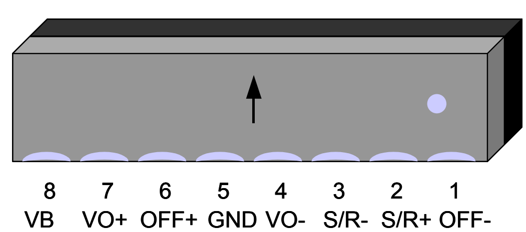


HMC1051Z Pinout

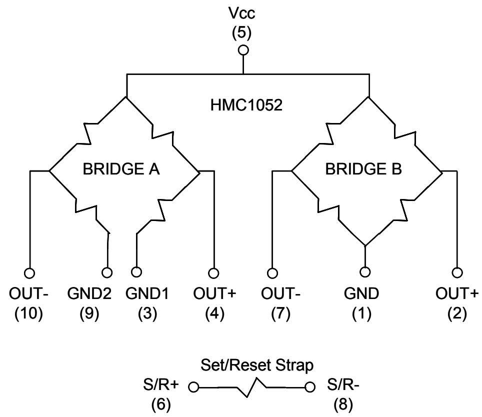
HMC1051ZL



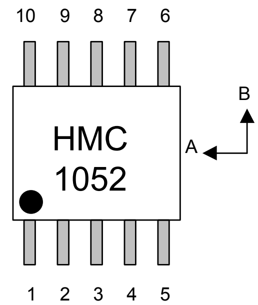
HMC1051ZL Pinout



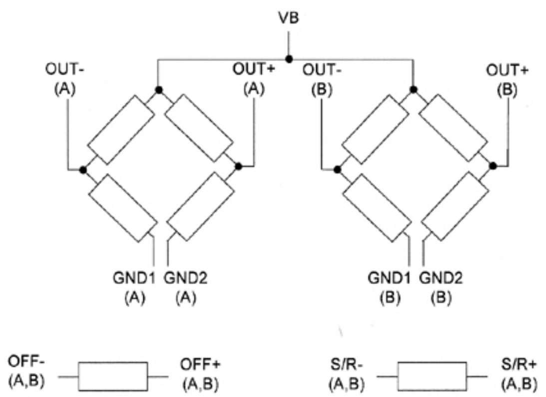
HMC1052



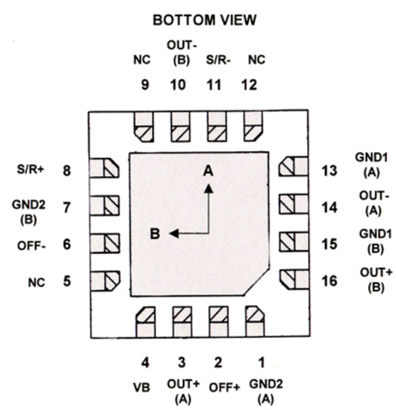
HMC1052 Pinout



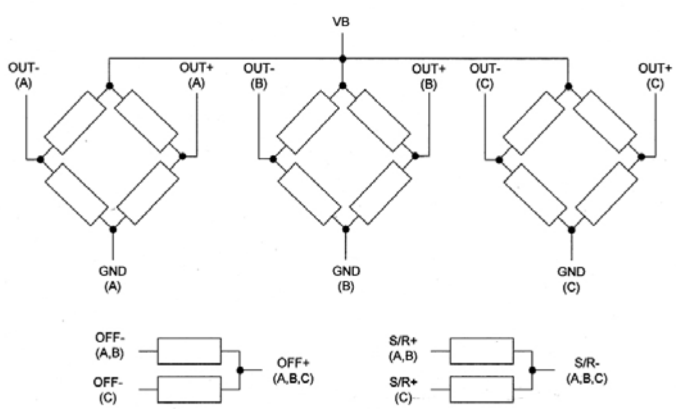
HMC1052L



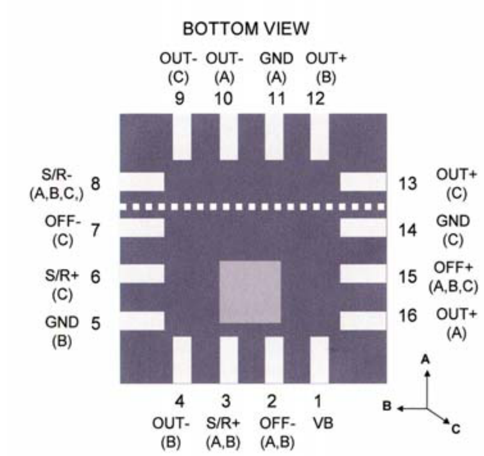
HMC1052L Pinout



HMC1053

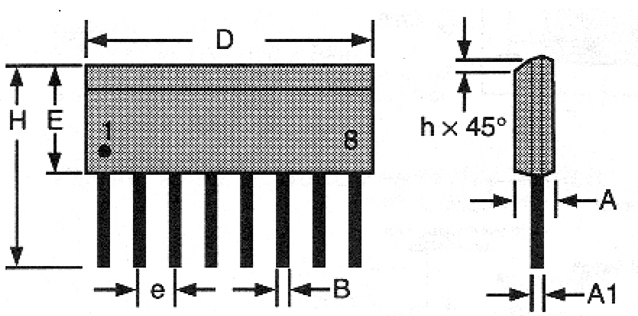


HMC1053 Pinout



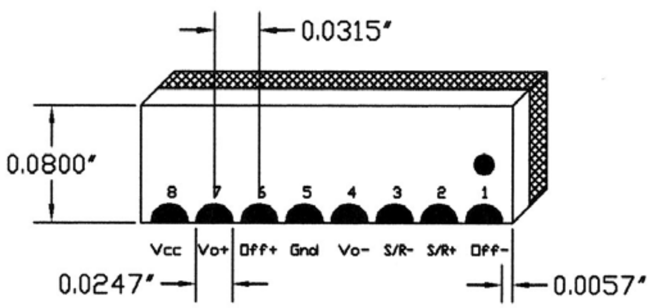
PACKAGE OUTLINES

PACKAGE DRAWING HMC1051Z (8-PIN SIP)

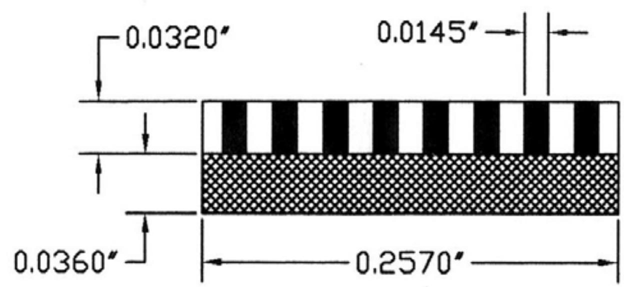


Symbol	Millimeters		Inches x 10E-3	
	Min	Max	Min	Max
A	1.371	1.728	54	68
A1	0.101	0.249	4	10
B	0.355	0.483	14	19
D	9.829	11.253	387	443
E	3.810	3.988	150	157
e	1.270 ref		50 ref	
H	6.850	7.300	270	287
h	0.381	0.762	15	30

PACKAGE DRAWING HMC1051ZL (8-PIN IN-LINE LCC)

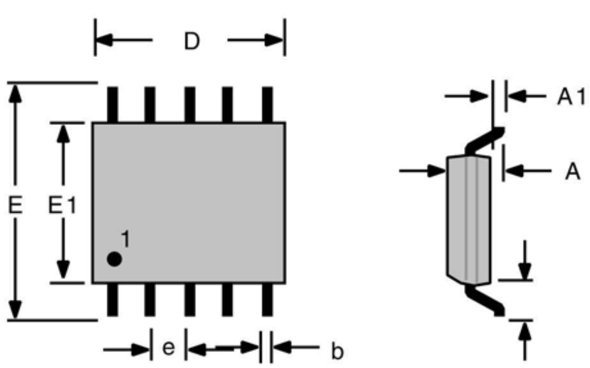


SIDE VIEW



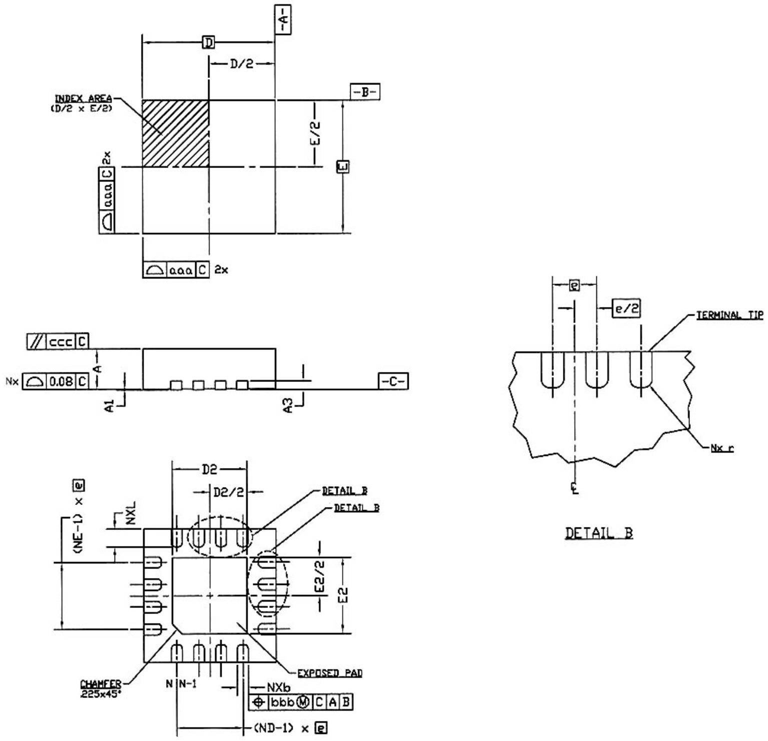
BOTTOM VIEW

PACKAGE DRAWING HMC1052 (10-PIN MSOP)



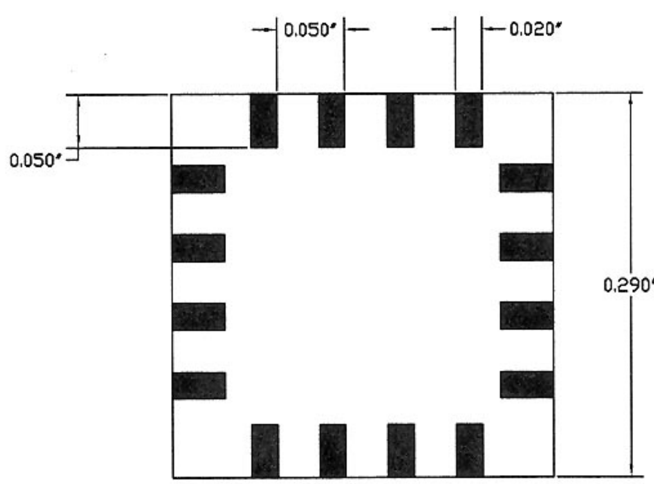
Symbol	Millimeters		Inches x 10E-3	
	Min	Max	Min	Max
A	-	1.10	-	43
A1	0.05	0.15	2.0	5.9
B	0.15	0.30	5.9	11.8
D	2.90	3.10	114	122
E1	2.90	3.10	114	122
e	0.50 BSC		2.0 BSC	
E	4.75	5.05	187	199
L1	0.95 BSC		37.4	

PACKAGE DRAWING HMC1052L (16-PIN LCC)

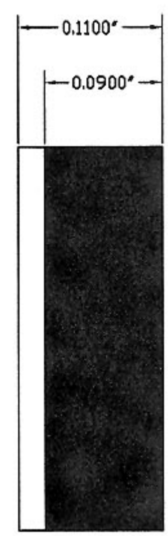


Symbol	Millimeters	
	min	max
A	0.80	1.00
A1	0	0.05
A3	0.20 REF	
b	0.18	0.30
D	3.00 BSC	
D2	1.55	1.80
E	3.00 BSC	
E2	1.55	1.80
e	0.50 BSC	
L	0.30	0.50
N	16	
ND	4	
NE	4	
r	B(min)/2	
aaa	0.15	
bbb	0.10	
ccc	0.10	

PACKAGE DRAWING HMC1053 (16-PIN LCC)



BOTTOM VIEW



SIDE VIEW

Basic Device Operation

The Honeywell HMC105X family of magnetoresistive sensors are Wheatstone bridge devices to measure magnetic fields. With power supply applied to a bridge, the sensor converts any incident magnetic field in the sensitive axis direction to a differential voltage output. In addition to the bridge circuit, the sensor has two on-chip magnetically coupled straps; the offset strap and the set/reset strap. These straps are Honeywell patented features for incident field adjustment and magnetic domain alignment; and eliminate the need for external coils positioned around the sensors.

The magnetoresistive sensors are made of a nickel-iron (Permalloy) thin-film deposited on a silicon wafer and patterned as a resistive strip element. In the presence of a magnetic field, a change in the bridge resistive elements causes a corresponding change in voltage across the bridge outputs.

These resistive elements are aligned together to have a common sensitive axis (indicated by arrows on the pinouts) that will provide positive voltage change with magnetic fields increasing in the sensitive direction. Because the output only is in proportion to the one-dimensional axis (the principle of anisotropy) and its magnitude, additional sensor bridges placed at orthogonal directions permit accurate measurement of arbitrary field direction. The combination of sensor bridges in two and three orthogonal axis permit applications such as compassing and magnetometry.

The offset strap allows for several modes of operation when a direct current is driven through it. These modes are: 1) Subtraction (bucking) of an unwanted external magnetic field, 2) null-ing of the bridge offset voltage, 3) Closed loop field cancellation, and 4) Auto-calibration of bridge gain.

The set/reset strap can be pulsed with high currents for the following benefits: 1) Enable the sensor to perform high sensitivity measurements, 2) Flip the polarity of the bridge output voltage, and 3) Periodically used to improve linearity, lower cross-axis effects, and temperature effects.

Noise Characteristics

The noise density for the HMR105X series is around 50nV/sqrt Hz at the 1 Hz corner, and quickly drops below 10nV/sqrt Hz at 5Hz and begins to fit the Johnson Noise value at just below 5nV/sqrt Hz beyond 50Hz. The 10Hz noise voltage averages around 1.4 micro-volts with a 0.8 micro-volts standard deviation.

Cross-Axis Effect

Cross-Axis effect for the HMR105X series is typically specified at ±3% of full scale to 1 gauss. See application note AN215 regarding this effect and methods for nulling.

Offset Strap

The offset strap is a spiral of metalization that couples in the sensor element's sensitive axis. In two-axis designs, the strap is common to both bridges and must be multiplexed if each bridge requires a different strap current. In three-axis designs, the A and B bridges are together with the C bridge sharing a common node for series driving all three bridges' offset straps. Each offset strap measures nominally 15 ohms, and requires 10mA for each gauss of induced field. The straps will easily handle currents to buck or boost fields through the ±6 gauss linear measurement range, but designers should note the extreme thermal heating on the die when doing so.

With most applications, the offset strap is not utilized and can be ignored. Designers can leave one or both strap connections (Off- and Off+) open circuited, or ground one connection node. Do not tie both strap connections together to avoid shorted turn magnetic circuits.

Set/Reset Strap

The set/reset strap is another spiral of metalization that couples to the sensor elements easy axis (perpendicular to the sensitive axis on the sensor die). Like the offset strap, the set/reset strap runs through a pair of bridge elements to keep the overall die size compact. Each set/reset strap has a nominal resistance of 3 to 6 ohms with a minimum required peak current of 400mA for reset or set pulses. With rare exception, the set/reset strap must be used to periodically condition the magnetic domains of the magneto-resistive elements for best and reliable performance.

A set pulse is defined as a positive pulse current entering the S/R+ strap connection. The successful result would be the magnetic domains aligned in a forward easy-axis direction so that the sensor bridge's polarity is a positive slope with positive fields on the sensitive axis result in positive voltages across the bridge output connections.

A reset pulse is defined as a negative pulse current entering the S/R+ strap connection. The successful result would be the magnetic domains aligned in a reverse easy-axis direction so that sensor bridge's polarity is a negative slope with positive fields on the sensitive axis result in negative voltages across the bridge output connections.

Typically a reset pulse is sent first, followed by a set pulse a few milliseconds later. By shoving the magnetic domains in completely opposite directions, any prior magnetic disturbances are likely to be completely erased by the duet of pulses. For simpler circuits with less critical requirements for noise and accuracy, a single polarity pulse circuit may be employed (all sets or all resets). With these uni-polar pulses, several pulses together become close in performance to a set/reset pulse circuit. Figure 1 shows a quick and dirty manual pulse circuit for uni-polar application of pulses to the set/reset strap.

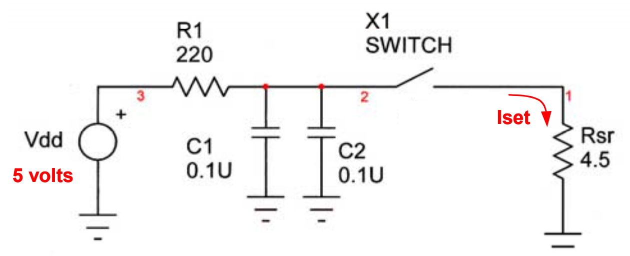


Figure 1
Set Pulse Circuit

Application Notes

Low Cost 2-Axis Compass

Very high precision measurements can be made using the HMC105X family of sensors when interfaced with low noise amplifiers and 12 to 16-bit Analog-to-Digital (A/D) converters. For lower resolution (3° accuracy or more) or low cost compass applications, 8 or 10-bit A/D converters may be used with general purpose operational amplifiers. Figure 2 shows a typical 2-axis compassing application using readily available off-the-shelf components.

The basic principle of two-axis compassing is to orient the two sensor bridge elements horizontal to the ground (perpendicular to the gravitational field) and to measure the resulting X and Y analog output voltages. With the amplified sensor bridge voltages near-simultaneously converted (measured) to their digital equivalents, the arc-tangent Y/X can be computed to derive the heading information relative to the X-axis sensitive direction. See the application notes on compassing at Honeywell Magnetic Sensors website (www.magneticsensors.com) for basic principles and detailed application information.

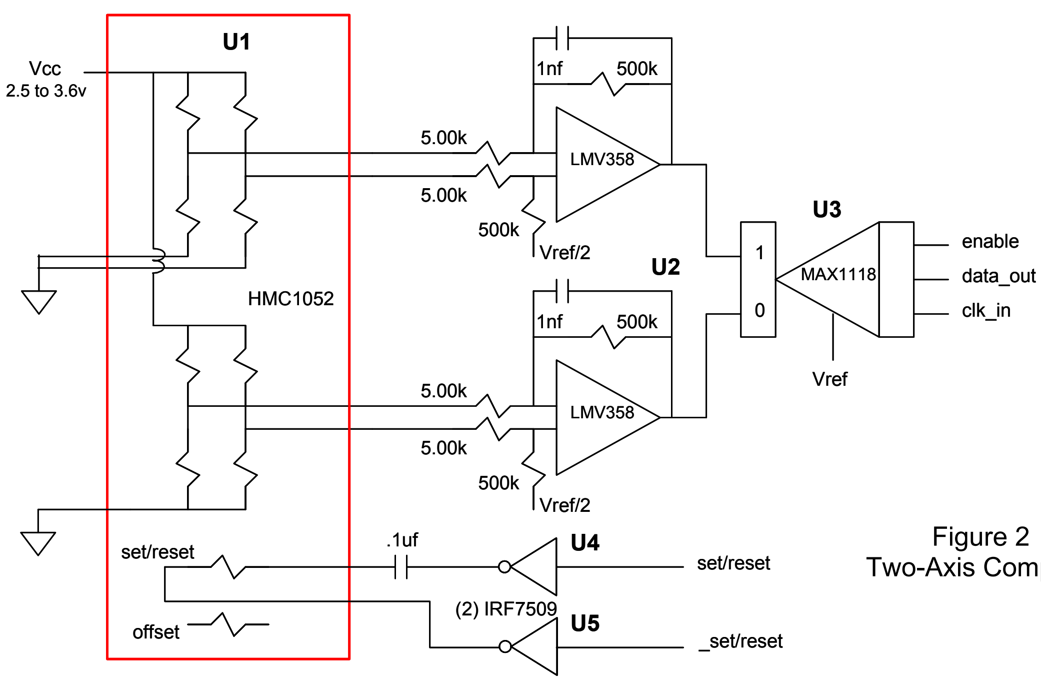


Figure 2
Two-Axis Compass

Set/Reset Circuit Notes

The above set/reset circuit in Figure 1using the IRF7507 dual complementary MOSFETs is shown in detail by Figure 2 in its H-bridge driven configuration. This configuration is used primarily in battery operated applications were the 500mA nominal set/reset pulsed currents can be best obtained under low voltage conditions.

The 200-ohm resistor trickle charges the 1uf supply reservoir capacitor to the Vcc level, and isolates the battery from the high current action of the capacitors and MOSFET switches. Under conventional logic states one totem pole switch holds one node of the 0.1uf capacitor low, while the other switch charges Vcc into the capacitors opposite node. At the first logic change, the capacitor exhibits almost a twice Vcc flip of polarity, giving the series set/reset strap load plenty of pulse current. A restoring logic state flip uses the 0.1uf capacitors stored energy to create a second nearly equal but opposite polarity current pulse through the set/reset strap.

For operation at normal 3.3 or 5-volt logic levels, a single complementary MOSFET pair can be used in a single ended circuit shown in Figure 4. Other complementary MOSFET pairs can be used with the caution that the chosen devices should have less than 0.5 ohms ON resistance and be able to handle the needed supply voltages and set/reset currents. Note that even a 1Hz rate of set/reset function draws an average current of less than 2 microamperes.

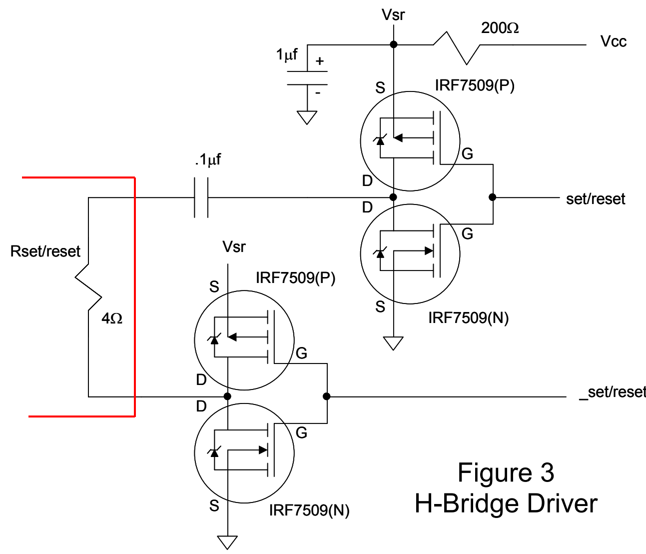


Figure 3
H-Bridge Driver

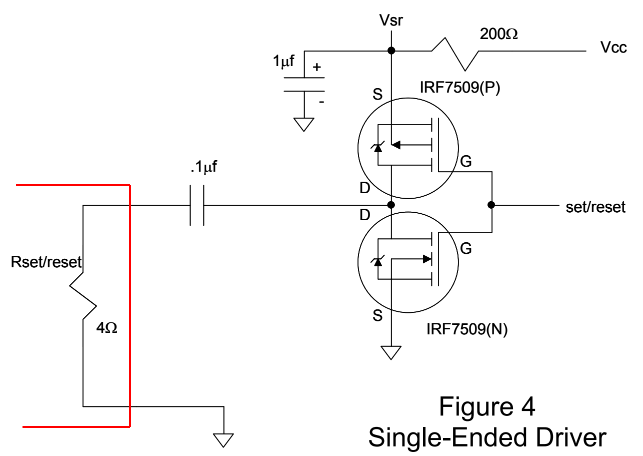


Figure 4
Single-Ended Driver

Magnetic Field Detection

For simple magnetic field sensing applications such Magnetic Anomaly Detectors (MADs) and Magnetometers, a similar circuit to the compass application can be implemented using one, two, or three magnetic sensors. In the example circuit in Figure 5, a HMC1051Z sensor bridge is used with a low voltage capable dual op-amp to detect sufficient intensity of a magnetic field in a single direction. Uses of the circuit include ferrous object detection such as vehicle detection, a “sniffer” for currents in nearby conductors, and magnetic proximity switching. By using two or three sensor circuits with HMC1051, HMC1052, or HMC1053 parts, a more omni-directional sensing pattern can be implemented. There is nothing special in choosing the resistors for the differential op-amp gain stages other than having like values (e.g. the two 5kΩ and the 500kΩ resistors) matched at 1% tolerance or better to reject common-mode interference signals (EMI, RFI). The ratio of the 500kΩ/5kΩ resistors sets the stage gain and can be optimized for a specific purpose. Typical gain ratios for compass and magnetometer circuits using the HMC105X family, range from 50 to 500. The choice of the 5kΩ value sets impedance loading seen by the sensor bridge network and should be about 4 kilo-ohms or higher for best voltage transfer or matching. Note that Figure 5 also shows an alternative set/reset strap driver circuit using two darlington complentary paired BJTs as electronic switches.

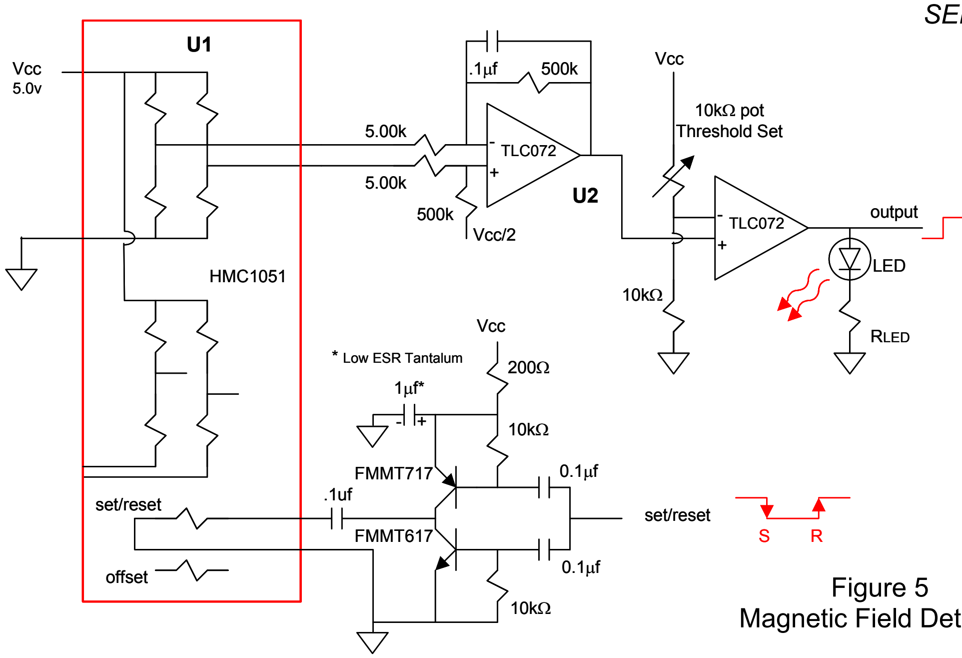


Figure 5
Magnetic Field Detector

Alternating or Direct Current Sensing

The HMC105X family sensors can be utilized in a novel way for moderate to high current sensing applications using a nearby external conductor providing the sensed magnetic field to the bridge. Figure 6 shows a HMC1051Z used as a current sensor with thermistor element performing a temperature compensation function for greater accuracy over a wide range of operational temperatures. Selection of the temperature compensation (tempco) resistors used depends on the thermistor chosen and is dependant on the thermistor's %/°C shift of resistance. For best op-amp compatibility, the thermistor resistance should be above about 1000 ohms. The use of a 9-volt alkaline battery supply is not critical to this application, but permits fairly common operational amplifiers such as the 4558 types to be used. Note that the circuit must be calibrated based on the final displacement of the sensed conductor to the measuring bridge. Typically, an optimally oriented measurement conductor can be placed about one centimeter away from the bridge and have reasonable capability of measuring from tens of milliamperes to beyond 20 amperes of alternating or direct currents. See application note AN-209 for the basic principles of current sensing using AMR bridges.

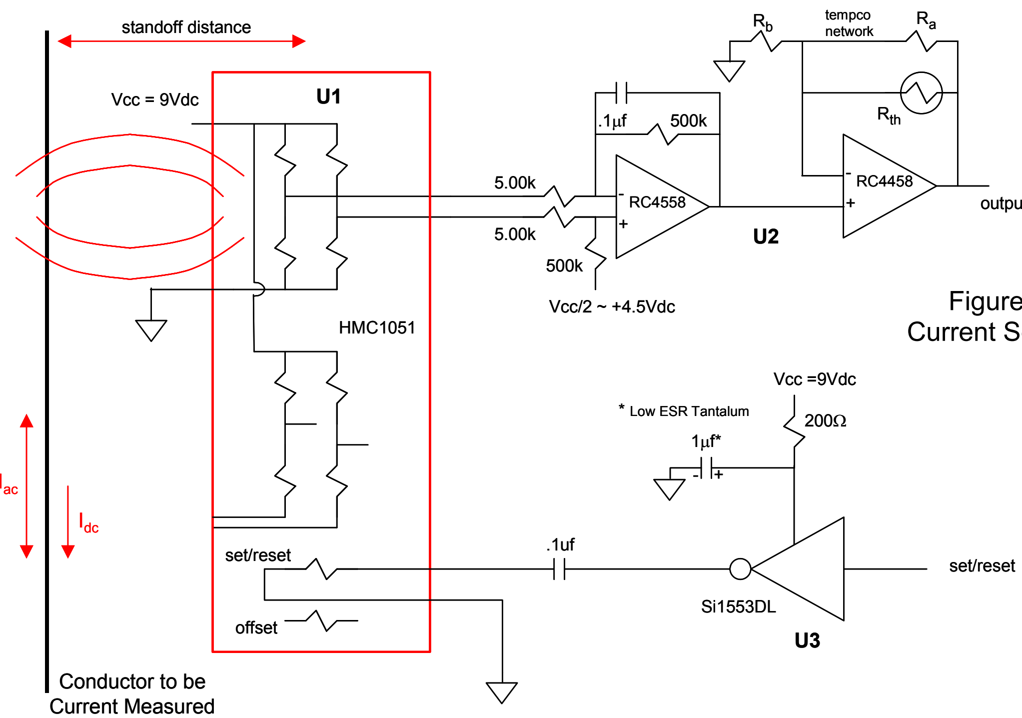


Figure 6
Current Sensor

Three Axis Compassing with Tilt Compensation

For full three-axis compassing, the circuit depicted in Figure 7 shows both a HMC1051 and a HMC1052 used for sensing the magnetic field in three axes. Alternatively a single HMC1053 could be used for a single sensor package design. A two-axis accelerometer with digital (PWM) outputs is also shown to provide pitch and roll (tilt) sensing, to correct the three-axis magnetic sensors outputs into to the tilt-compensated two-axis heading. The accelerometer can be substituted with a fluidic 2-axis tilt sensor if desired. For lower voltage operation with Lithium battery supplies (2.5 to 3.6Vdc), the Set/Reset circuit should be upgraded from a single IRF7507 to the dual IRF7507 implementation (per Figure 2) to permit a minimum 1-ampere pulse (500mA per set/reset strap resistance) to both the HMC1052 and HMC1051 sensors.

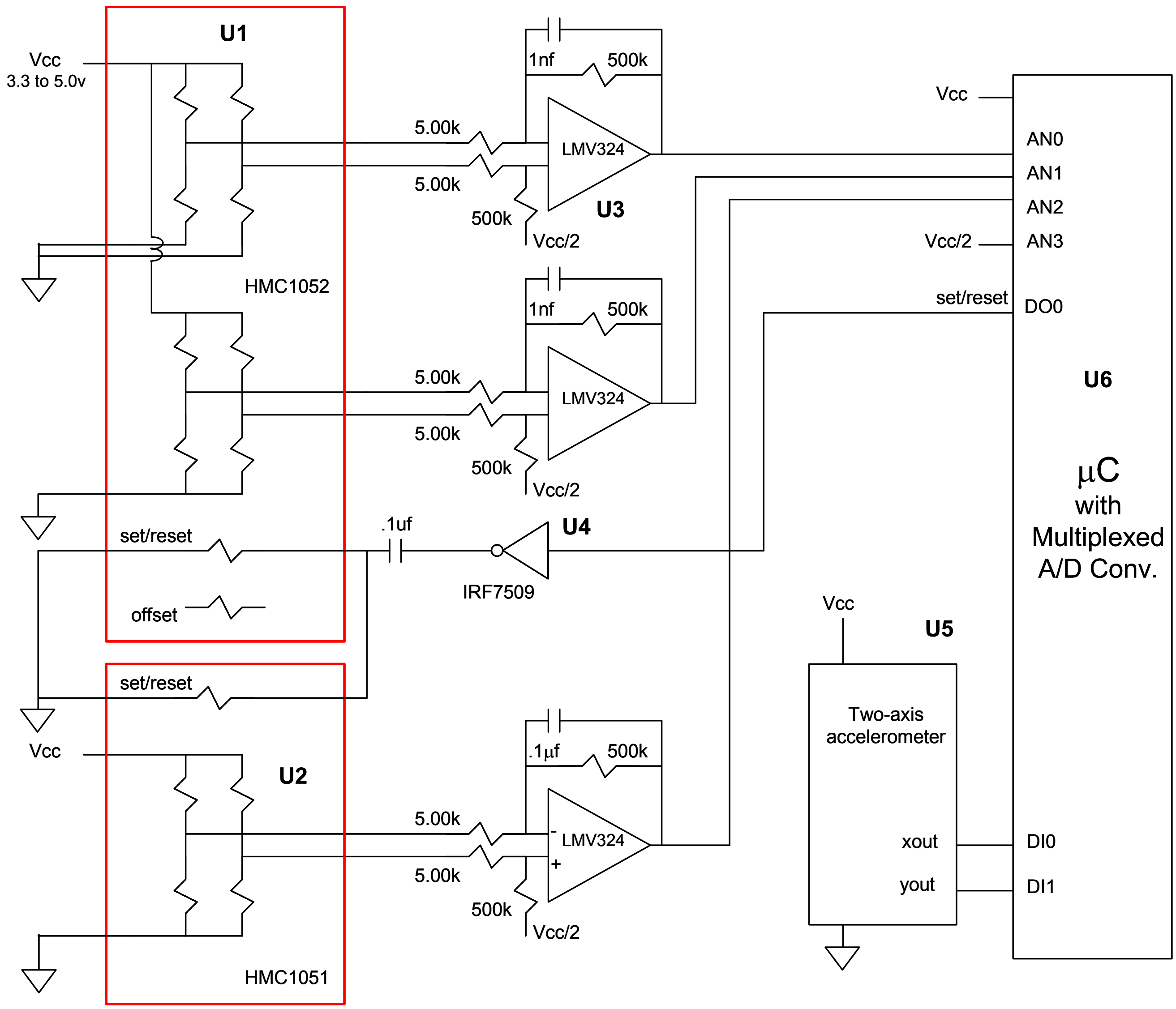


Figure 7
Three Axis Compass

Duty Cycling for Lower Energy Consumption

For battery powered and other applications needing limited energy consumption, the sensor bridge and support electronics can be switched "off" between magnetic field measurements. The HMC105X family of magnetic sensors are very low capacitance (Bandwidth > 5MHz) sensor bridges and can stabilize quickly, typically before the support electronics can. Other energy saving ideas would be to minimize the quantity of set/reset pulses which saves energy over the battery life. Figure 8 shows a simple supply switching circuit that can be microprocessor controlled to duty cycle (toggle) the electronics in moderate current (<25mA) applications.

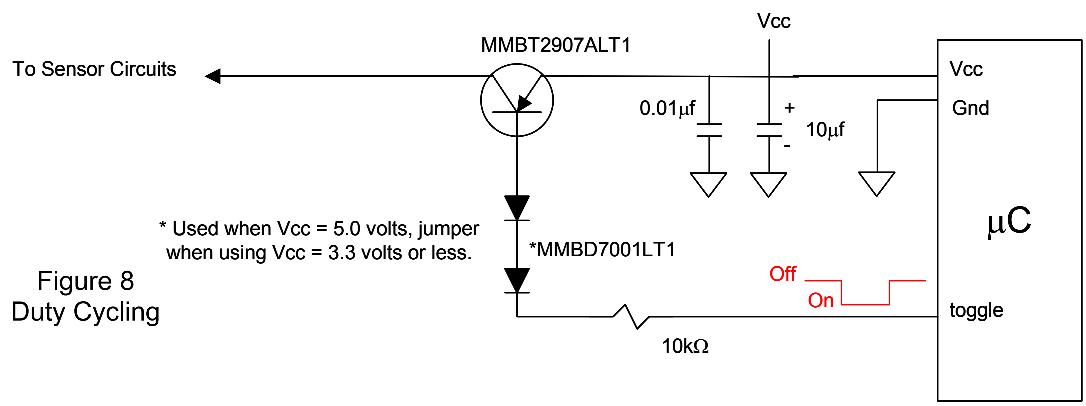


Figure 8
Duty Cycling

ORDERING INFORMATION

Part Number	Package Style
HMC1051Z	One Axis Magnetic Sensor – SIP8
HMC1051ZL	One Axis Magnetic Sensor – 8-PIN IN-LINE LCC
HMC1052	Two Axis Magnetic Sensors – MSOP10
HMC1052L	Two Axis Magnetic Sensors – 16-PIN LCC
HMC1053	Three Axis Magnetic Sensors – 16-PIN LCC

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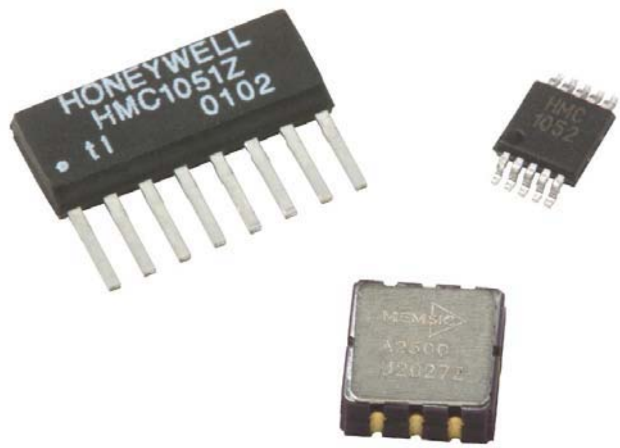
900308 10-03 Rev. -

Honeywell
SENSOR PRODUCTS

3-AXIS COMPASS SENSOR SET

Features

- 3 Precision Sensor Components
- 2-Axis Magnetoresistive Sensor for X-Y Axis Earth's Field Detection
- 1-Axis Magnetoresistive Sensor for Z-Axis Earth's Field Detection
- 2-Axis Accelerometer for 60° Tilt Compensation
- 2.7 to 5.5 volt Supply Range
- 3-Axis Compass Reference Design Included



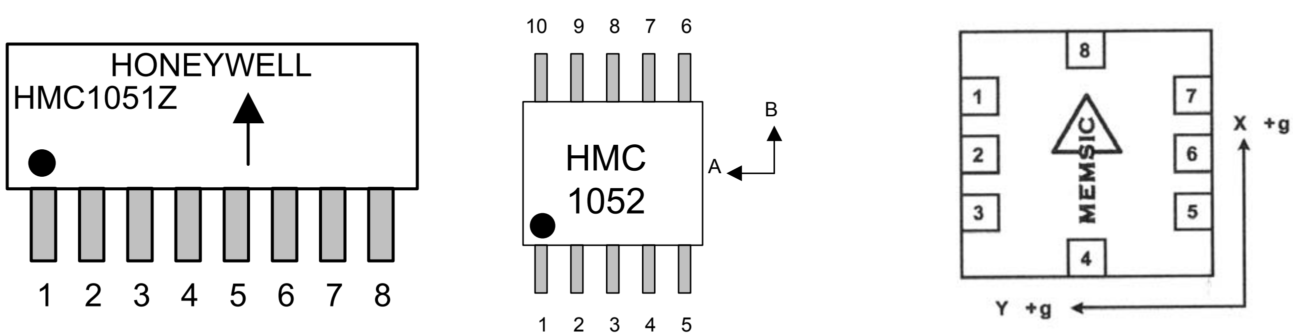
Product Description

The Honeywell HMC1055 3-Axis Compass Sensor Set combines the popular HMC1051Z one-axis and the HMC1052 two-axis magneto-resistive sensors plus a 2-axis MEMSIC MXS3334UL accelerometer in a single kit. By combining these three sensor packages, OEM compass system designers will have the building blocks needed to create their own tilt compensated compass designs using these proven components.

The HMC1055 chip set includes the three sensor integrated circuits and an application note describing sensor function, a reference design, and design tips for integrating the compass feature into other product platforms.

DIAGRAMS

Pinouts (top view)



SPECIFICATIONS – MAGNETIC SENSORS HMC1051Z, HMC1052

Characteristics	Conditions*	Min	Typ	Max	Units
Bridge Elements					
Supply	Vbridge referenced to GND	1.8	2.5	20	Volts
Resistance	Bridge current = 1mA	800	1000	1500	ohms
Field Range	Full scale (FS) – total applied field	-6		+6	gauss
Sensitivity	Set/Reset Current = 0.5A	0.8	1.0	1.2	mV/V/gauss
Bridge Offset	Offset = (OUT+) – (OUT-) Field = 0 gauss after Set pulse	-1.25	±0.5	+1.25	mV/V
Bandwidth	Magnetic signal (lower limit = DC)		5		MHz
Noise Density	@ 1kHz, Vbridge=5V		50		nV/sqrt Hz
Resolution	50Hz Bandwidth, Vbridge=5V		120		μgauss
Disturbing Field	Sensitivity starts to degrade. Use S/R pulse to restore sensitivity.	20			gauss
Max. Exposed Field	No perming effect on zero reading			10000	gauss
Operating Temperature	Ambient	-40		125	°C
Storage Temperature	Ambient, unbiased	-55		150	°C
Sensitivity Tempco	T_A=-40 to 125°C, Vbridge=5V T_A=-40 to 125°C, Ibridge=5mA	-3000	-2700 -600	-2400	ppm/°C
Bridge Offset Tempco	T_A=-40 to 125°C, No Set/Reset T_A=-40 to 125°C, With Set/Reset		±500 ±10		ppm/°C
Bridge Ohmic Tempco	Vbridge=5V, T_A=-40 to 125°C	2100	2500	2900	ppm/°C
Sensitivity Ratio of X,Y Sensors (HMC1052 Only)	T_A=-40 to 125°C	95	101	105	%
X,Y sensor Orthogonality (HMC1052)	Sensitive direction in X and Y sensors			0.01	degree
Linearity Error	Best fit straight line ± 1 gauss ± 3 gauss ± 6 gauss		 0.1 0.5 1.8		%FS
Hysteresis Error	3 sweeps across ±3 gauss		0.06		%FS
Repeatability Error	3 sweeps across ±3 gauss		0.1		%FS

* Tested at 25°C except stated otherwise.

SPECIFICATIONS – MAGNETIC SENSORS HMC1051Z, HMC1052

Characteristics	Conditions*	Min	Typ	Max	Units
Set/Reset Strap					
Resistance	Measured from S/R+ to S/R-	3	4	5	ohms
Current	0.1% duty cycle, or less, 2μsec current pulse	0.4	0.5	4	Amp
Resistance Tempco	T_A= -40 to 125°C		3700		ppm/°C
Offset Straps	*(available on die)*				
Resistance	Measured from OFFSET+ to OFFSET-	12	15	18	ohms
Offset Constant	DC Current Field applied in sensitive direction		10		mA/gauss
Resistance Tempco	T_A= -40 to 125°C		3900		ppm/°C

* Tested at 25°C except stated otherwise.

SPECIFICATIONS – ACCELEROMETER MXS3334UL

Characteristics	Conditions*	Min	Typ	Max	Units
Sensor Input					
Range		±1			g
Non-Linearity	Best fit straight line		0.5	1.0	% of FS
Alignement Error			±1.0		degree
Transverse Sensitivity			±2.0		%
Sensitivity	*(Each Axis)*				
Digital Outputs	Vdd = 5.0 volts	19.00	20.00	21.00	%Duty Cycle/g
Change Over Temperature	-40°C, Uncompensated +105°C, Uncompensated Compensated (-40°C to +105°C) Δ from 25°C	 -50	 < 3.0	+100	%
Resistance	T_A= -40 to 125°C		3900		ppm/°C
Zero g Bias Level	*(Each Axis)*				
0 g Offset		-0.1	0.00	+0.1	g
0 g Duty Cycle		48	50	52	% Duty Cycle
0 g Offset Over Temperature	Δ from 25°C Δ from 25°C, based on 20%/g		±0.75 ±0.015		mg/°C %/°C
Performance					
Noise Density	rms		0.2	0.4	mg/sqrt-Hz
Frequency Response	3dB Bandwidth		25		Hz

Tested at 25°C except stated otherwise.

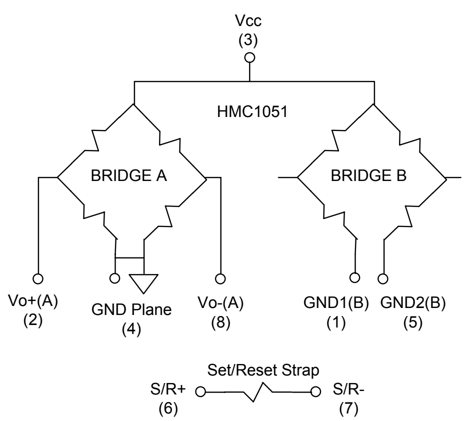
MXS3334UL SPECIFICATIONS

Characteristics	Conditions*	Min	Typ	Max	Units
Voltage Reference					
Vref	Vdd = 2.7 to 5.0	2.4	2.5	2.65	volts
Change Over Temperature			0.1		mV/°C
Current Drive Capability	Source			100	μA
Self Test					
Continuous Voltage Under Failure	Vdd = 5.0 volts, D_{OUTX} and D_{OUTY} Vdd = 2.7 volts, D_{OUTX} and D_{OUTY}		5.0 2.7		volts
Digital Outputs	*(D_{OUTX} and D_{OUTY})*				
Normal Range	Vdd = 5.00 volts Vdd = 2.7 volts	0.1 0.1		4.9 2.6	volts
Current	Source or Sink (Vdd =2.7 to 5.0v)		100		μA
Rise/Fall Time	Vdd = 2.7 to 5.0 volts	90	100	110	ηsec
Turn-On Time	Vdd = 5.0 volts Vdd = 2.7 volts		100 40		msec
Power Supply					
Operating Voltage Range		2.7		5.25	volts
Supply Current	Vdd = 5.0 volts Vdd = 2.7 volts	3.0 4.0	3.6 4.9	4.2 5.8	mA
Temperature					
Operating Range		-40		+105	°C
Storage Range		-65		+150	°C

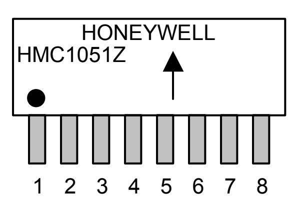
Tested at 25°C except stated otherwise.

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

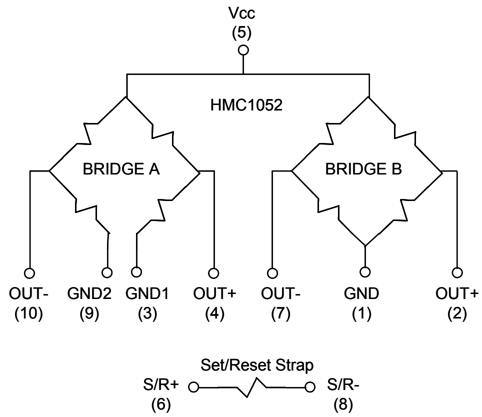
HMC1051



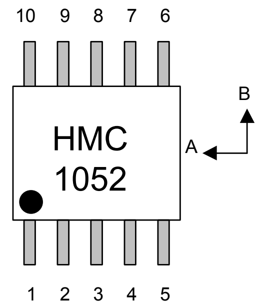
HMC1051Z Pinout



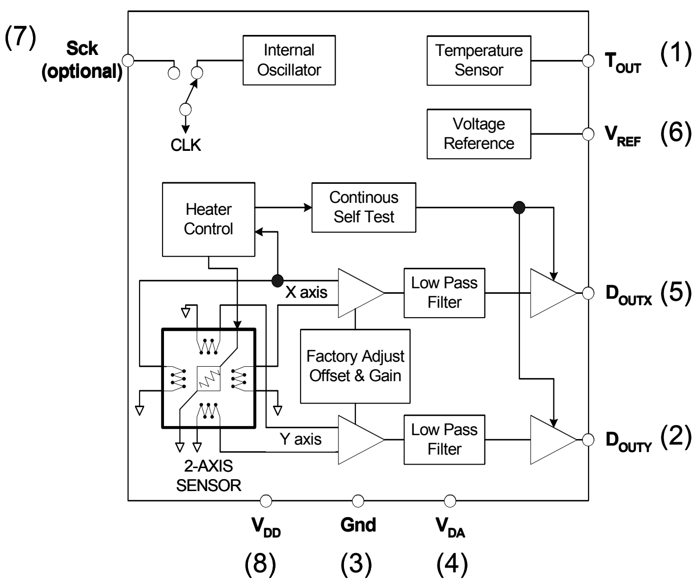
HMC1052

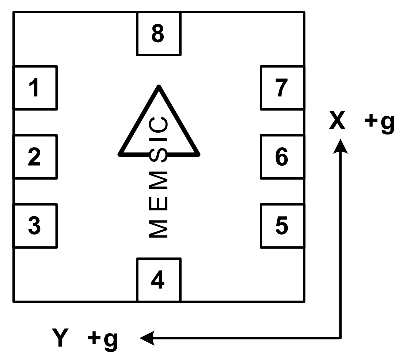


HMC1052 Pinout



MXD3334UL





Top View

Pin Descriptions

HMC1051Z

Pin	Name	Description
1	GND1(B)	Bridge B Ground 1 (normally left open)
2	Vo+(A)	Bridge Output Positive
3	Vcc	Bridge Positive Supply
4	GND Plane	Bridge Ground (substrate)
5	GND2(B)	Bridge B Ground 2 (normally left open)
6	S/R+	Set/Reset Strap Positive
7	S/R-	Set/Reset Strap Negative
8	Vo-(A)	Bridge Output Negative

HMC1052

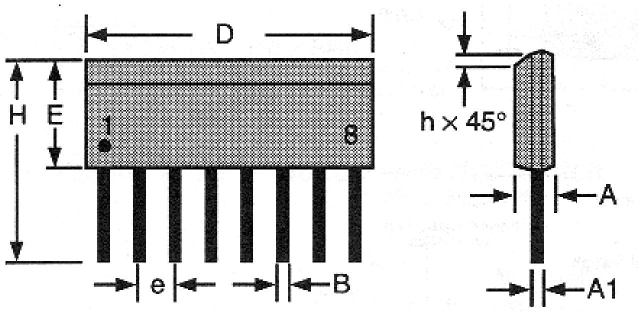
Pin	Name	Description
1	GND	Bridge B Ground
2	OUT+	Bridge B Output Positive
3	GND1	Bridge A Ground 1
4	OUT+	Bridge B Output Positive
5	Vcc	Bridge Positive Supply
6	S/R+	Set/Reset Strap Positive
7	OUT-	Bridge B Output Negative
8	S/R-	Set/Reset Strap Negative
9	GND2	Bridge A Ground 2
10	OUT-	Bridge A Output Negative

MXD3334UL

Pin	Name	Description
1	T_{OUT}	Temperature (Analog Voltage)
2	D_{OUTY}	Y-Axis Acceleration Digital Signal
3	Gnd	Ground
4	V_{DA}	Analog Supply Voltage
5	D_{OUTX}	X-Axis Acceleration Digital Signal
6	V_{ref}	2.5V Reference
7	Sck	Optional External Clock
8	V_{DD}	Digital Supply Voltage

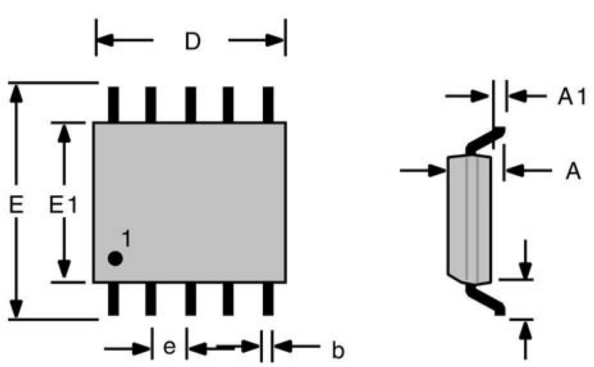
Package Dimensions

HMC1051Z

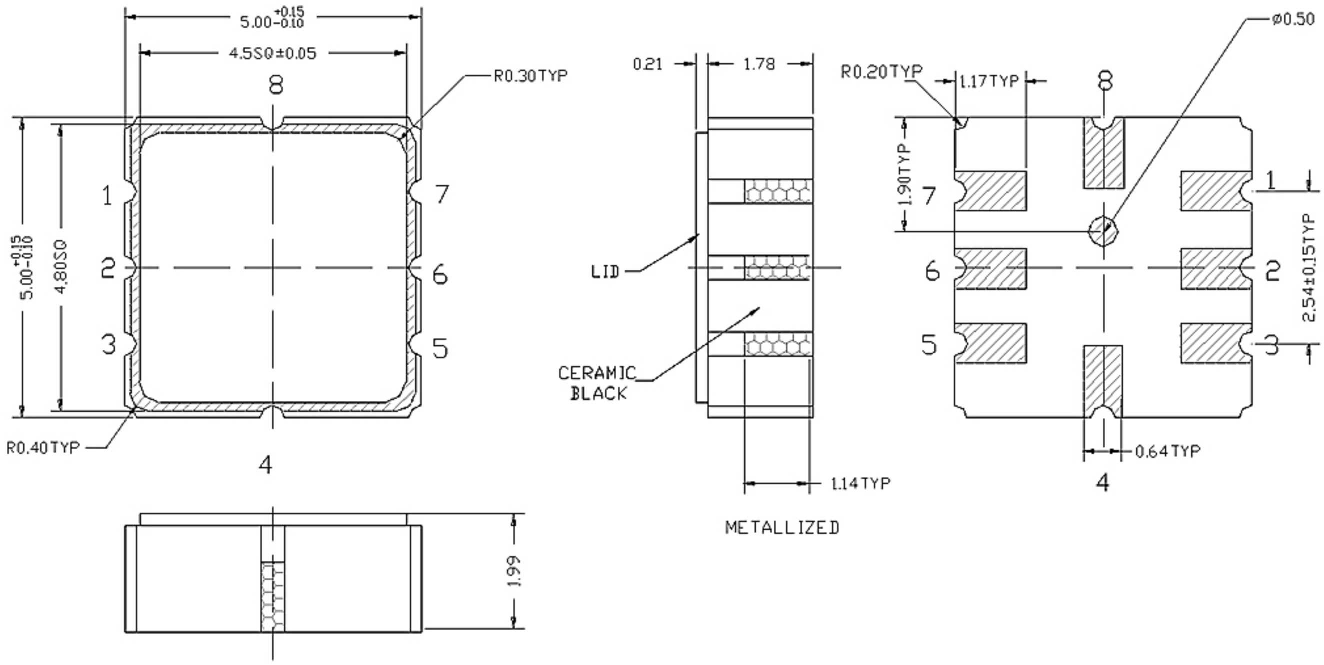


Symbol	Millimeters		Inches x 10E-3	
	Min	Max	Min	Max
A	1.371	1.728	54	68
A1	0.101	0.249	4	10
B	0.355	0.483	14	19
D	9.829	11.253	387	443
E	3.810	3.988	150	157
e	1.270 ref		50 ref	
H	6.850	7.300	270	287
h	0.381	0.762	15	30

HMC1052



Symbol	Millimeters		Inches x 10E-3	
	Min	Max	Min	Max
A	-	1.10	-	43
A1	0.05	0.15	2.0	5.9
B	0.15	0.30	5.9	11.8
D	2.90	3.10	114	122
E1	2.90	3.10	114	122
e	0.50 BSC		2.0 BSC	
E	4.75	5.05	187	199
L1	0.95 BSC		37.4	



Application Notes

The HMC1055 Chipset is composed of three sensors packaged as integrated circuits for tilt compensated electronic compass development. These three sensors are composed of a Honeywell HMC1052 two-axis magnetic field sensor, a Honeywell HMC1051Z one-axis magnetic sensor, and the Memsic MXS3334UL two-axis accelerometer. Traditionally, compassing is done with a two-axis magnetic sensor held level (perpendicular to the gravitational axis) to sense the horizontal vector components of the earth's magnetic field from the south pole to the north pole. By incorporating a third axis magnetic sensor and the two-axis accelerometer to measure pitch and roll (tilt), the compass is able to be electronically "gimbaled" and can point to the north pole regardless of level.

The HMC1052 two-axis magnetic sensor contains two Anisotropic Magneto-Resistive (AMR) sensor elements in a single MSOP-10 package. Each element is a full wheatstone bridge sensor that varies the resistance of the bridge magneto-resistors in proportion to the vector magnetic field component on its sensitive axis. The two bridges on the HMC1052 are orientated orthogonal to each other so that a two-dimensional representation of an magnetic field can be measured. The bridges have a common positive bridge power supply connection (Vb); and with all the bridge ground connections tied together, form the complete two-axis magnetic sensor. Each bridge has about an 1100-ohm load resistance, so each bridge will draw several milli-amperes of current from typical digital power supplies. The bridge output pins will present a differential output voltage in proportion to the exposed magnetic field strength and the amount of voltage supply across the bridge. Because the total earth's magnetic field strength is very small (~0.6 gauss), each bridge's vector component of the earth's field will even be smaller and yield only a couple milli-volts with nominal bridge supply values. An instrumentation amplifier circuit; to interface with the differential bridge outputs, and to amplify the sensor signal by hundreds of times, will then follow each bridge voltage output.

The HMC1051Z is an additional magnetic sensor in an 8-pin SIP package to place the sensor silicon die in a vertical orientation relative to a Printed Circuit Board (PCB) position. By having the HMC1052 placed flat (horizontal) on the PCB and the HMC1051Z vertical, all three vector components of the earth's magnetic field (X, Y, and Z) are sensed. By having the Z-axis component of the field, the electronic compass can be oriented arbitrarily; and with a tilt sensor, perform tilt-compensated compass heading measurements as if the PCB where perfectly level.

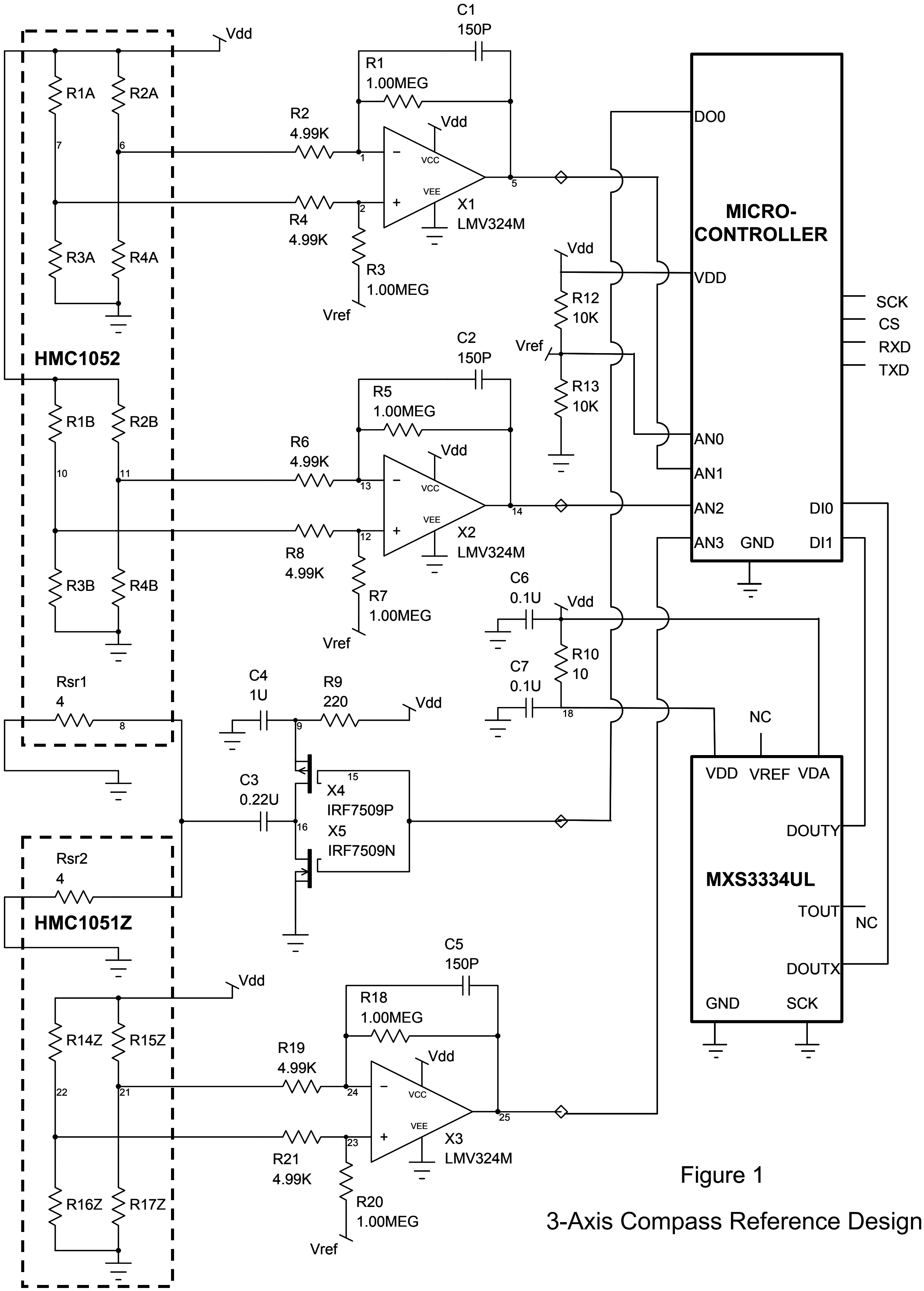


Figure 1

3-Axis Compass Reference Design

The MXS3334UL is a two-axis accelerometer in an 8-pin LCC package that provides a digital representation of the earth's gravitational field. When the MXS3334UL is held level and placed horizontally on a PCB, both digital outputs provide a 100 Hz Pulse Width Modulated (PWM) square wave with a 50 percent duty cycle. As the accelerometer is pitched or rolled from horizontal to vertical, the Doutx and Douty duty cycles will shift plus or minus 20% of its duty from the 50% center point.

The reference design in Figure 1 shows a reference design incorporating all three sensor elements of the HMC1055 chipset for a tilt compensated electronic compass operating from a 5.0 volt regulated power supply described as Vdd. The HMC1052 sensor bridge elements A and B are called out as R1A, R2A, R3A, R4A, and R1B, R2B, R3B, R4B respectively; and create a voltage dividing networks that place nominally 2.5 volts into the succeeding amplifier stages. The HMC1051Z sensor bridge elements R14Z, R15Z, R16Z, and R17Z also do a similar voltage dividing method to its amplifier stage.

In this design each amplifier stage uses a single operational amplifier (op-amp) from a common LMV324M quad op-amp Integrated Circuit (IC). For example, resistors R1, R2, R3, and R4 plus capacitor C1 configure op-amp X1 into an instrumentation amplifier with a voltage gain of about 200. These instrumentation amplifier circuits take the voltage differences in the sensor bridges, and amplify the signals for presentation at the micro-controller Analog to Digital Converter (ADC) inputs, denoted as AN1, AN2, and AN3. Because the zero magnetic field reference level is at 2.5 volts, each instrumentation amplifier circuit receives a 2.5 volt reference voltage (Vref) from a resistor divider circuit composed of R12 and R13.

For example, a +500 milli-gauss earth's field on bridge A of the HMC1052 will create a 2.5 milli-volt difference voltage at the sensor bridge output pins (0.5 gauss multiplied by the 1.0mV/V/gauss sensitivity rating). This 2.5mV then is multiplied by 200 for 0.5 volt offset that is referenced to the 2.5 volt Vref for a total of +3.0 volts at AN1. Likewise any positive and or negative magnetic field vectors from bridge B and the HMC1051Z bridge are converted to voltage representations at AN2 and AN3.

The micro-controller also receives the sensor inputs from the MXS3334UL accelerometer directly from Doutx and Douty into two digital inputs denoted as DI0 and DI1. Optionally, the MXS3334UL temperature output pin (Tout) can routed to another microcontroller ADC input for further temperature compensation of sensor inputs. Power is supplied to the MXS3334UL from the 5.0 volt Vdd source directly to the accelerometer VDA pin and on to the VDD pin via a ten ohm resistor (R10) for modest digital noise decoupling. Capacitors C6 and C7 provide noise filtering locally at the accelerometer and throughout the compass circuit.

The set/reset circuit for this electronic compass is composed of MOSFETs X4 and X5, capacitors C3 and C4, and resistor R9. The purpose of the set/reset circuit is to re-align the magnetic moments in the magnetic sensor bridges when they exposed to intense magnetic fields such as speaker magnets, magnetized hand tools, or high current conductors such as welding cables or power service feeders. The set/reset circuit is toggled by the microcontroller and each logic state transition creates a high current pulse in the set/reset straps for both HMC1052 and the HMC1051Z.

Operational Details

With the compass circuitry fully powered up, sensor bridge A creates a voltage difference across OUTA- and OUTA+ that is then amplified 200 times and presented to microcontroller analog input AN1. Similarly, bridges B and C create a voltage difference that is amplified 200 times and presented to microcontroller analog inputs AN2 and AN3. These analog voltages at AN1 and AN2 can be thought of as "X" and "Y" vector representations of the magnetic field. The third analog voltage (AN3) plus the tilt information from accelerometer, is added to the X and Y values to create tilt compensated X and Y values, sometimes designated X' and Y'.

To get these X, Y, and Z values extracted, the voltages at AN1 through AN3 are to be digitized by the microcontroller's onboard Analog-to-Digital Converter (ADC). Depending on the resolution of the ADC, the resolution of the Compass is set. Typically compasses with one degree increment displays will have 10-bit or greater ADCs, with 8-bit ADCs more appropriate for basic 8-cardinal point (North, South, East, West, and the diagonal points) compassing. Individual microcontroller choices have a great amount of differing ADC implementations, and there may be instances where the ADC reference voltage and the compass reference voltage can be shared. The point to remember is that the analog voltage outputs are referenced to half the supplied bridge voltage and amplified with a similar reference.

The most often asked question on AMR compass circuits is how frequent the set/reset strap must be pulsed. The answer for most low cost compasses is fairly infrequently; from a range of once per second, to once per compass menu selection by the user. While the set circuit draws little energy on a per pulse basis, a constant one pulse per second rate could draw down a fresh watch battery in less than a year. In the other extreme of one "set" pulse upon the user manually requesting a compass heading, negligible battery life impact could be expected. From a common sense standpoint, the set pulse interval should be chosen as the shortest time a user could withstand an inaccurate compass heading after exposing the compass circuit to nearby large magnetic sources. Typical automatic set intervals for low cost compasses could be once per 10 seconds to one per hour depending on battery energy capacity. Provision for a user commanded "set" function may be a handy alternative to periodic or automatic set routines.

In portable consumer electronic applications like compass-watches, PDAs, and wireless phones; choosing the appropriate compass heading data flow has a large impact on circuit energy consumption. For example, a one heading per second update rate on a sport watch could permit the compass circuit to remain off to nearly 99 percent of the life of the watch, with just 10 millisecond measurement snapshots per second and a one per minute set pulses for perming correction. The HMC1052 and HMC1051Z sensors have a 5 MHz bandwidth in magnetic field sensing, so the minimum snapshot measurement time is derived principally by the settling time of the op-amps plus the sample-and-hold time of the microcontroller's ADCs.

In some "gaming" applications in wireless phones and PDAs, more frequent heading updates permits virtual reality sensor inputs for software reaction. Typically these update rates follow the precedent set more than a century ago by the motion picture industry ("Movies") at 20 updates or more per second. While there is still some value in creating off periods in between these frequent updates, some users may choose to only switch power on the sensor bridges exclusively and optimize the remainder of the circuitry for low power consumption.

Compass Firmware Development

To implement an electronic compass with tilt compensation, the microcontroller firmware must be developed to gather the sensor inputs and to interpret them into meaningful data to the end user system. Typically the firmware can be broken into logical routines such as initialization, sensor output collection and raw data manipulation, heading computation, calibration routines, and output formatting.

For the sensor output data collection, the analog voltages at microcontroller inputs AN0 through AN3 are digitized and a "count" number representing the measured voltage is the result. For compassing, the absolute meaning of the ADC counts scaled back to the sensor's milli-gauss measurement is not necessary, however it is important to reference the zero-gauss ADC count level. For example, an 8-bit ADC has 512 counts (0 to 511 binary), then count 255 would be the zero offset and zero-gauss value.

In reality errors will creep in due to the tolerances of the sensor bridge (bridge offset voltage), multiplied by the amplifier gain stages plus any offset errors the amplifiers contribute; and magnetic errors from hard iron effects (nearby magnetized materials). Usually a factory or user calibration routine in a clean magnetic environment will obtain a correction value of counts from mid ADC scale. Further tweaking of the correction value for each magnetic sensor axis once the compass assembly is in its final user location, is highly desired to remove the magnetic environment offsets.

For example, the result of measuring AN0 (Vref) is about count 255, and the measuring of AN1, AN2, and AN3 results in 331, 262, and 205 counts respectively. Next calibration values of 31, -5, and 20 counts would be subtracted to result in corrected values of 301, 267, and 205 respectively. If the pitch and roll were known to be zero; then the AN3 (Z-axis output) value could be ignored and the tilt corrected X and Y-axis values would be the corrected values of AN1 and AN2 minus the voltage reference value of AN0. Doing the math yields arctan [y/x] or arctan [(267-255)/(301-255)] or 14.6 degrees east of magnetic north.

Heading Computation

Once the magnetic sensor axis outputs are gathered and the calibration corrections subtracted, the next step toward heading computation is to gather the pitch and roll (tilt) data from the MEMSIC MXS3334UL accelerometer outputs. The MXS3334UL in perfectly horizontal (zero tilt) condition produces a 100Hz, 50 percent duty cycle Pulse Width Modulated (PWM) digital waveform from its Doutx and Douty pins corresponding to the X and Y sensitive axis. These output pins will change their duty cycle from 30% to 70% when tilted fully in each axis (±1g). The scaling of the PWM outputs is strictly gravitational, so that a 45 degree tilt results in 707 milli-g's or a slew of ±14.1% from the 50% center point duty cycle.

With the MXS3334UL's positive X-axis direction oriented towards the front of the user's platform, a pitch downward will result in a reduced PWM duty cycle, with a pitch upward increasing in duty cycle. Likewise, the Y-axis arrow is 90 degrees counter-clockwise which results in a roll left corresponding to a decreasing duty cycle, and roll right to an increasing duty cycle.

Measuring the pitch and roll data for a microcontroller is reasonably simple in that the Doutx and Douty logic signals can be sent to microcontroller digital input pins for duty cycle measurement. At firmware development or factory calibration, the total microcontroller clock cycles between Doutx or Douty rising edges should be accrued using an interrupt or watchdog timer feature to scale the 100Hz (10 millisecond) edges. Then measuring the Doutx and Douty falling edges from the rising edge (duty cycle computation) should be a process of clock cycle counting. For example, a 1MHz clocked microcontroller should count about 10,000 cycles per rising edge, and 5,000 cycle counts from rising to falling edge would represent a 50% duty cycle or zero degree pitch or roll.

Once the duty cycle is measured for each axis output and mathematically converted to a gravitational value, these values can be compared to a memory mapped table, if the user desires the true pitch and roll angles. For example, if the pitch and roll data is to be known in one degree increments, a 91-point map can be created to match up gravitational values (sign independent) with corresponding degree indications. Because tilt-compensated compassing requires sine and cosine of the pitch and roll angles, the gravitational data is already formatted between zero and one and does not require further memory maps of trigonometric functions. The gravity angles for pitch and roll already fit the sine of the angles, and the cosines are just one minus the sine values (cosine = 1 – sine).

The equations:

$$X' = X * \cos(\phi) + Y * \sin(\theta) * \sin(\phi) - Z * \cos(\theta) * \sin(\phi)$$

$$Y' = Y * \cos(\theta) + Z * \sin(\theta)$$

Create tilt compensated X and Y magnetic vectors (X', Y') from the raw X, Y, and Y magnetic sensor inputs plus the pitch (ϕ) and roll (θ) angles. Once X' and Y' are computed, the compass heading can be computed by equation:

Azimuth (Heading) = arctan (Y' / X')

To perform the arc-tangent trigonometric function, a memory map needs to be implemented. Thankfully the pattern repeats in each 90° quadrant, so with a one-degree compass resolution requirement, 90 mapped quotients of the arc-tangent function can be used. If 0.1° resolution is needed then 900 locations are needed and only 180 locations with 0.5° resolution. Also, special case quotient detections are needed for the zero and inifinity situations at 0°, 90, 180°, and 270° prior to the quotient computation.

After the heading is computed, two heading correction factors may be added to handle declination angle and platform angle error. Declination angle is the difference between the magnetic north pole and the geometric north pole, and varies depending on the latitude and longitude (global location) of the user compass platform. If you have access to Global Positioning Satellite (GPS) information resulting in a latitude and longitude computation, then the declination angle can be computed or memory mapped for heading correction. Platform angle error may occur if the sensors are not aligned perfectly with the mechanical characteristics of the user platform. These angular errors can be inserted in firmware development and or in factory calibration.

COMPASS CALIBRATION

In the paragraphs describing raw magnetic sensor data, the count values of X, Y, and Z are found from inputs AN0 to AN3. A firmware calibration routine will create Xoff, Yoff and Xsf, and Ysf for calibration factors for "hard-iron" distortions of the earth's magnetic field at the sensors. Typically these distortions come from nearby magnetized components. Soft-iron distortions are more complex to factor out of heading values and are generally left out for low cost compassing applications. Soft-iron distortion arises from magnetic fields bent by un-magnetized ferrous materials either very close to the sensors or large in size. Locating the compass away from ferrous materials provides the best error reduction. The amount of benefit is dependant on the amount of ferrous material and its proximity to the compass platform.

To derive the calibration factors, the sensor assembly (platform) and its affixed end-platform (e.g. watch/human, boat, auto, etc.) are turned at least one complete rotation as the compass electronics collects many continuous readings. The speed and rate of turn are based on how quickly the microcontroller can collect and process X, Y, and Z data during the calibration routine. A good rule of thumb is to collect readings every few degrees by either asking the user to make a couple rotations or by keeping in the rotation(s) slow enough to collect readings of the correct rate of turn.

The Xh and Yh readings during calibration are done with Xoff and Yoff at zero values, and axis scale factors (Xsf and Ysf) at unity values. The collected calibration X and Y values are then tabulated to find the min and max of both X and Y. At the end of the calibration session, the Xmax, Ymax, Xmin, and Ymin values are converted to the following:

Xsf = 1 or (Ymax –Ymin) / (Xmax – Xmin) , whichever is greater

Ysf = 1 or (Xmax –Xmin) / (Ymax – Ymin) , whichever is greater

Xoff = [(Xmax – Xmin)/2 – Xmax] * Xsf

Yoff = [(Ymax –Ymin)/2 –Ymax] * Ysf

Z-axis data is generally not corrected if the end-platform can not turned upside-down. In portable or hand-held applications, then the compass assembly can be tipped upside down and Zoff can be computed like Xoff and Yoff, but with only two reference points (upright and upside down). Factory values for Zoff maybe the only values possible. Creating corrected X, Y, and Z count values are done as previously mentioned by subtracting the offsets. The scale factor values are used only after the Vref counts are subtracted form the offset corrected axis counts. For more details on calibration for iron effects, see the white paper "Applications of Magnetoresistive Sensors in Navigation Systems" located on the magneticsensors.com website.

Offsets due to sensor bridge offset voltage of each sensor axis are part of the Xoff, Yoff, and Zoff computation. These offsets are present even with no magnetic field disturbances. To find their true values, the set and reset drive circuits can be toggled while taking measurements shortly after each transition. After a reset pulse, the magnetic field portion of the sensor bridge will have flipped polarity while the offset remains the same. Thus two measurements, after a reset and a set pulse can be summed together. The magnetic portions of the sum will cancel, leaving just a double value of the offset. The result can then be divide by two to derive the bridge offset.

The reason for knowing the bridge offset, is that the offset will drift with temperature. Should the user desire the best accuracy in heading, a new calibration should be performed with each encounter with a new temperature environment. See application notes AN-212, AN-213, and AN-214 for further compass design considerations.

Ordering Information

Ordering Number	Product
HMC1055	3-Axis Compass Sensor Set

900302 12-02 Rev –

Linear / Angular / Rotary Displacement Sensors

HMC1501 / HMC1512

APPLICATIONS

- Linear Displacement
- Angular Displacement
- Motor Control
- Valve Position
- Proximity Detection
- Current Spike Detection

Not actual size

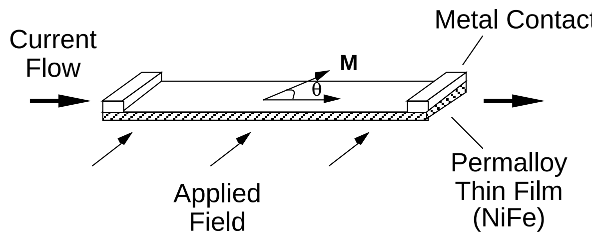
High resolution, low power MR sensor capable of measuring the angle direction of a magnetic field from a magnet with <0.07° resolution. Advantages of measuring field direction versus field strength include: insensitivity to the tempco of the magnet, less sensitivity to shock and vibration, and the ability to withstand large variations in the gap between the sensor and magnet. These sensors may be operated on 3 volts with bandwidth response of 0-5 MHz. Output is typical Wheatstone bridge.

FEATURES AND BENEFITS

No Rare Earth Magnets	Unlike Hall effect devices which may require samarium cobalt or similar “rare earth” magnets, the HMC1501 and HMC1512 can function with Alnico or ceramic type magnets.
Wide Angular Range	HMC1501—Angular range of ±45° with <0.07° resolution. HMC1512—Angular range of ±90° with <0.05° resolution.
Effective Linear Range	Linear range of 8mm with two sensors mounted on two ends; range may be increased through multiple sensor arrays operating together.
Absolute Sensing	Unlike incremental “encoding” devices, sensors know the exact position and require no indexing for proper positional output.
Non-Contact Sensing	No moving parts to wear out; no dropped signals from worn tracks as in conventional contact based rotary sensors.
Small Package	Available in an 8-pin surface mount package with case dimensions (exclusive of pins), of 5mm x 4mm x 1.2mm total mounting envelope, with pins of less than 6mm square.
Large Signal Output	Full Scale output range of 120mV with 5V of power supply.

PRINCIPLES OF OPERATION

Anisotropic magnetoresistance (AMR) occurs in ferrous materials. It is a change in resistance when a magnetic field is applied in a thin strip of ferrous material. The magnetoresistance is a function of $\cos^2\theta$ where θ is the angle between magnetization M and current flow in the thin strip. When an applied magnetic field is larger than 80 Oe, the magnetization aligns in the same direction of the applied field; this is called saturation mode. In this mode, θ is the angle between the direction of applied field and the current flow; the MR sensor is only sensitive to the direction of applied field.



The sensor is in the form of a Wheatstone bridge (Figure 1). The resistance R of all four resistors is the same. The bridge power supply V_S causes current to flow through the resistors, the direction as indicated in the figure for each resistor.

Both HMC1501 and HMC1512 are designed to be used in saturation mode. HMC1501 contains one MR bridge and HMC1512 has two identical MR bridges, coexisting on a single die. Bridge B physically rotates 45° from bridge A. The HMC1501 has sensor output $\Delta V=-V_S S \sin(2\theta)$ and the HMC1512 has sensor output $\Delta V=V_S S \sin(2\theta)$ for sensor A and sensor B output $\Delta V_S=-V_S S \cos(2\theta)$, where V_S is supply voltage, S is a constant, determined by materials. For Honeywell sensors, S is typically 12mV/V.

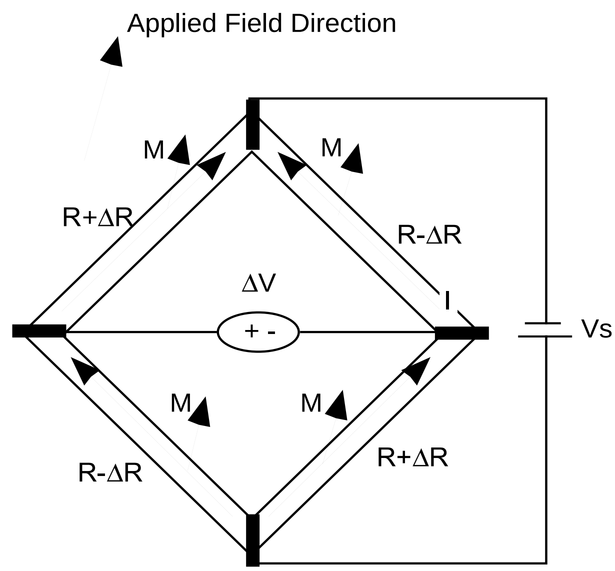
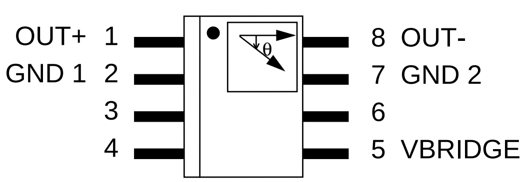
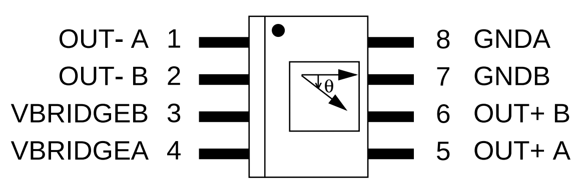


Figure 1

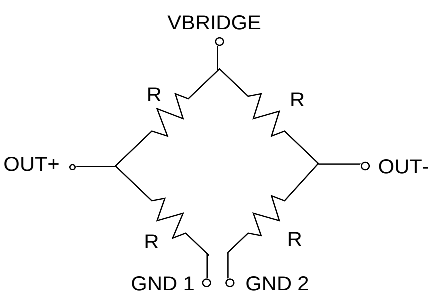
PINOUT DRAWINGS

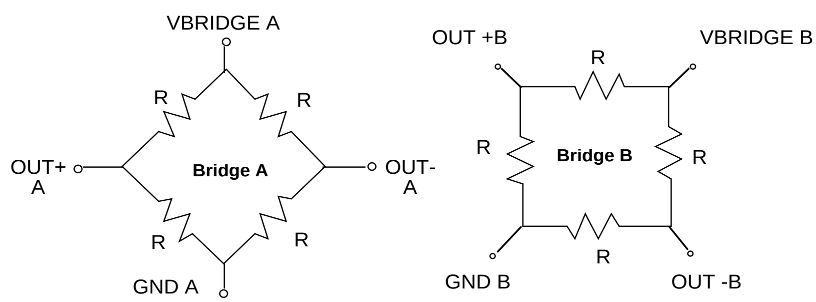




Caution: Do not connect GND or Power to Pin 3,4 &6.

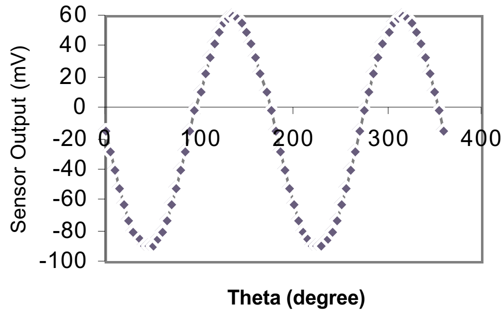
MR SENSOR CIRCUITS



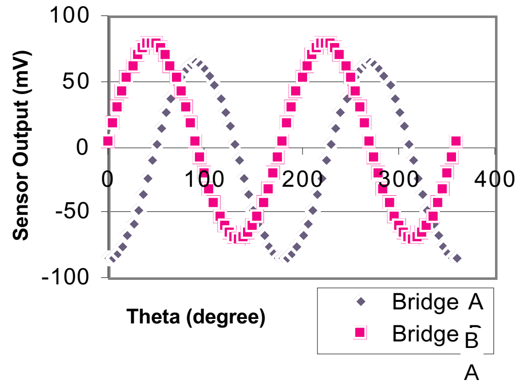


TYPICAL SENSOR OUTPUT

HMC1501 output voltage vs. magnetic field angle

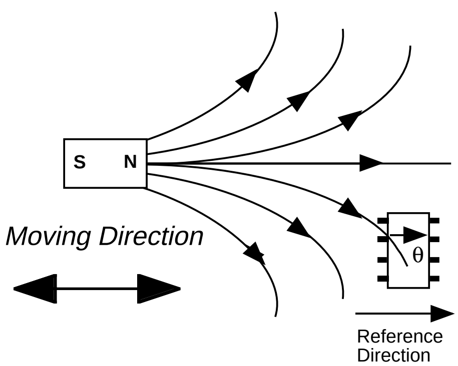


HMC1512 output voltage vs. magnetic field angle

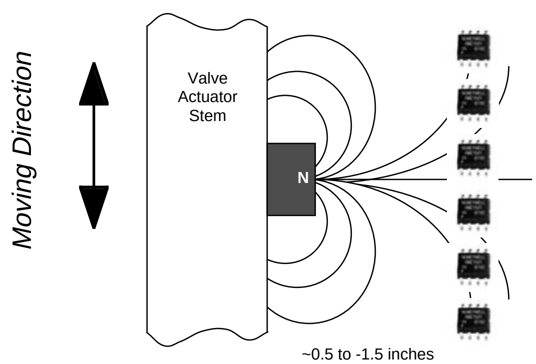


APPLICATION CONFIGURATION

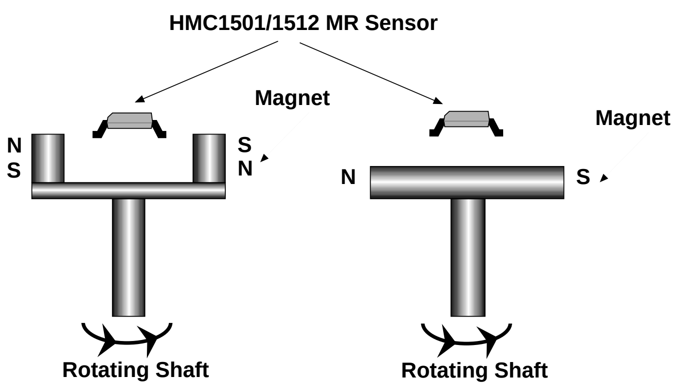
Proximity Position



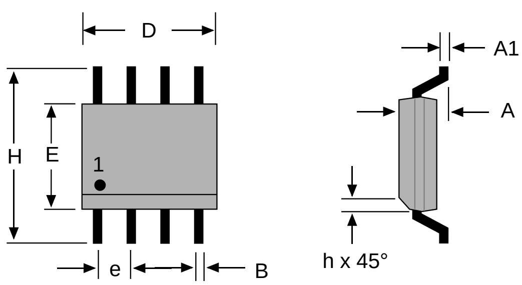
Linear Position



Rotary Position



PACKAGE DRAWING 8-Pin SOIC



Symbol	Millimeters Min	Millimeters Max	Inches Min	Inches Max
A	1.371	1.728	.054	.068
A1	0.101	0.249	.004	.010
B	0.355	0.483	.014	.019
D	4.800	4.979	.189	.196
E	3.810	3.988	.150	.157
e	1.270 ref		.050 ref	
H	5.816	6.198	.229	.244
h	0.381	0.762	.015	.030

SPECIFICATIONS

Characteristics	Conditions*	HMC1501			HMC1512			Units
		Min	Typ	Max	Min	Typ	Max	
Bridge supply	Vbridge referenced to GND	1	5	25	1	5	25	V
Bridge resistance	Bridge current—1 mA	4	5	6.5	2.0	2.1	2.8	KΩ
Angle range	≥ Saturation field	-45		+45	-90		+90	deg
Sensitivity	Vbridge = 5V, field 80 Oe, (1) @ zero crossing (2) @ Zero crossing, averaged in the range of 45°		2.1 1.8			2.1 1.8		mV/°
Peak -to-peak Voltage	Vbridge = 5V, field = 80 Oe	100	120	140	100	120	140	mV
Bridge offset	Field 80 Oe, θ =0° Bridge A Bridge B	-7	3	7	0 -4	2.5 0	5 1	mV/V
Saturation field	Repeatability <0.03% FS	80			80			G
Bandwidth	Magnetic signal	0		5	0		5	MHz
Resolution	Bandwidth =10Hz,Vbridge =5V		0.07			0.05		°
Hysteresis error	Magnetic field ≥saturation field, Vbridge = 5V		30 $1.7x10^{-2}$			30 $1.7x10^{-2}$		µV deg
Bridge Ω tempco	T_A = -40° C to +125° C		0.28			0.28		%/° C
Sensitivity tempco	T_A = -40° C to +125° C Vbridge = 5V		-0.32			-0.32		%/° C
Bridge offset tempco	T_A = -40° C to +125° C		-0.01			-0.01		%/° C, FS
Noise Density	Noise at 1Hz, Vbridge = 5V		100			70		nV Hz
Power Consumption	Vbridge = 5V		5			23		mW

*Tested at 25°C except stated otherwise.

Sensitivity tempco $C_s = \frac{S_t - S_o}{S_o * t} = -0.32\%/°C$

Where S_o = sensitivity at zero temperature
t = temperature in the range -40°C to 125°C
S_t = sensitivity at temperature t

Power consumption $P = \frac{V^2}{R}$

Where V = Bridge supply voltage
R = Bridge resistance

Offset tempco $C_o = \frac{V_o(t) - V_o(o)}{V_{P-P} * t} = -0.01\%/°C$

Where $V_o(o)$ = bridge offset at zero temperature
V_{P-P} = peak-to-peak voltage
t = temperature in the range -40°C to 125°C
$V_o(t)$ = offset at temperature t

1 KA/m = 12.5 Gauss
1 Tesla = 10^4 Gauss

Honeywell

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900246 8-00 Rev. B

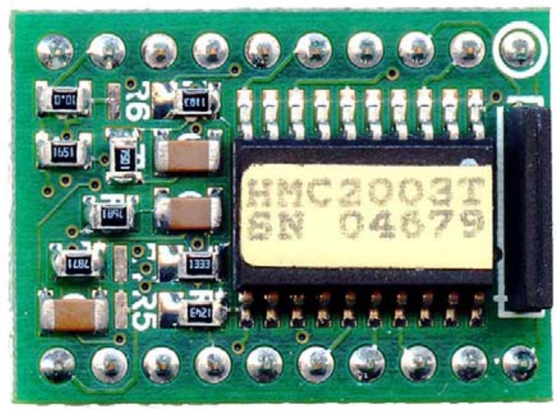
Honeywell

SENSOR PRODUCTS

THREE-AXIS MAGNETIC SENSOR HYBRID

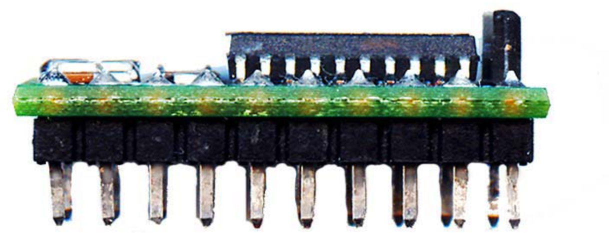
Features

- 20-pin Wide DIP Footprint (1” by 0.75”)
- Precision 3-axis Capability
- Factory Calibrated Analog Outputs
- 40 micro-gauss to ±2 gauss Dynamic Range
- Analog Output at 1 Volt/gauss (2.5V @ 0 gauss)
- Onboard +2.5 Volt Reference
- +6 to +15 Volt DC Single Supply Operation
- Very Low Magnetic Material Content
- -40° to 85°C Operating Temperature Range



General Description

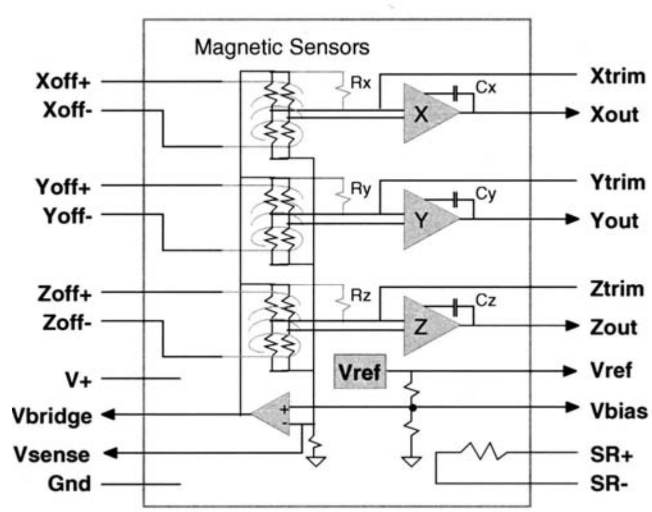
The Honeywell HMC2003 is a high sensitivity, three-axis magnetic sensor hybrid assembly used to measure low magnetic field strengths. Honeywell’s most sensitive magneto-resistive sensors (HMC1001 and HMC1002) are utilized to provide the reliability and precision of this magnetometer design. The HMC2003 interface is all analog with critical nodes brought out to the pin interfaces for maximum user flexibility. The internal excitation current source and selected gain and offset resistors, reduces temperature errors plus gain and offset drift. Three precision low-noise instrumentation amplifiers with 1kHz low pass filters provide accurate measurements while rejecting unwanted noise.



APPLICATIONS

- Precision Compassing
- Navigation Systems
- Attitude Reference
- Traffic Detection
- Proximity Detection
- Medical Devices

BLOCK DIAGRAM



SPECIFICATIONS

Characteristics	Conditions[1]	Min	Typ	Max	Units[2]
Magnetic Field					
Sensitivity		0.98	1	1.02	V/gauss
Null Field Output		2.3	2.5	2.7	V
Resolution			40		μgauss
Field Range	Maximum Magnetic Flux Density	-2		2	gauss
Output Voltage	Each Magnetometer Axis Output	0.5		4.5	
Bandwidth			1		kHz
Errors					
Linearity Error	±1 gauss Applied Field Sweep ±2 gauss Applied Field Sweep		0.5 1	2 2	%FS
Hysteresis Error	3 Sweeps across ±2 gauss		0.05	0.1	%FS
Repeatability Error	3 Sweeps across ±2 gauss		0.05	0.1	%FS
Power Supply Effect	PS Varied from 6 to 15V With ±1 gauss Applied Field Sweep			0.1	%FS
Offset Strap					
Resistance				10.5	ohms
Sensitivity		46.5	47.5	48.5	mA/gauss
Current				200	mA
Set/Reset Strap					
Resistance			4.5	6	ohms
Current	2msec pulse, 1% duty cycle	3.0	3.2	5	amps
Tempcos					
Field Sensitivity			-600		ppm/°C
Null Field	Set/Reset Not Used Set/Reset Used		±400 ±100		ppm/°C
Environments					
Temperature	Operating Storage	-40 -55	- -	+85 +125	°C °C
Shock			100		g
Vibration			2.2		g rms
Electrical					
Supply Voltage[3]		6		15	VDC
Supply Current				20	mA

(1) Unless otherwise stated, test conditions are as follows: Power Supply = 12VDC, Ambient Temp = 25°C, Set/Reset switching is active

(2) Units: 1 gauss = 1 Oersted (in air) = 79.58 A/m = 10E5 gamma

(3) Transient protection circuitry should be added across V+ and Gnd if an unregulated power supply is used.

Honeywell
SENSOR PRODUCTS

General Description

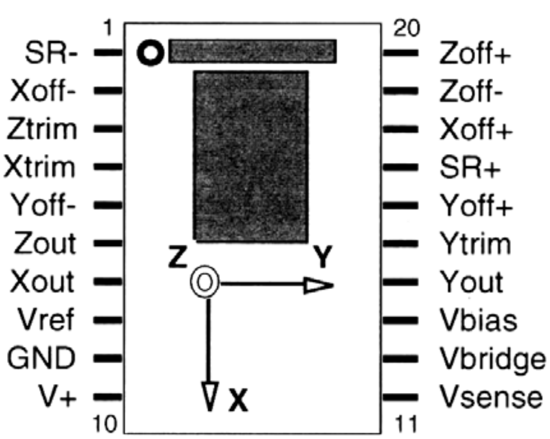
Honeywell's three axis magnetic sensor hybrid uses three permalloy magneto-resistive sensors and custom interface electronics to measure the strength and direction of an incident magnetic field. These sensors are sensitive to magnetic fields along the length, width, and height (X, Y, Z axis) of the 20-pin dual-in-line hybrid. Fields can be detected less than 40 microgauss and up to ±2 gauss. Analog outputs are available for each X, Y and Z axis from the hybrid. With the sensitivity and linearity of this hybrid, changes can be detected in the earth's magnetic field to provide compass headings or attitude sensing. The high bandwidth of this hybrid allows for anomaly detection of vehicles, planes, and other ferrous objects at high speeds.

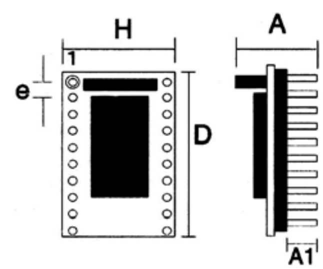
The hybrid is packaged on a small printed circuit board (1" by 0.75") and has an on-chip +2.5 voltage reference that operates from a single 6 to 15V supply. The hybrid is ideal for applications that require two- or three-axis magnetic sensing and have size constraints and need a magnetic transducer (magnetometer) front-end. Note that the hybrid's resistor values will vary, or an abscense of some resistor components, is likely due to individual factory calibration.

Integrated with the sensor elements composed of wheatstone bridge circuits, are magnetically coupled straps that replace the need for external field coils and provide various modes of operation. The Honeywell patented integrated field offset straps (Xoff+ and Xoff-, etc.) can be used electrically to apply local magnetic fields to the bridges to buck, or offset an applied incident field. This technique can be used to cancel unwanted ambient magnetic fields (e.g. hard-iron magnetism) or in a closed loop field nulling measurement circuit. The offset straps nominally provide 1 gauss fields along the sensitive axis per 48mA of offset current through each strap.

The HMC2003's magnetic sensors can be affected by high momentary magnetic fields that may lead to output signal degradation. In order to eliminate this effect, and maximize the signal output, a magnetic switching technique can be applied to the bridge using set/reset pins (SR+ and SR-) that eliminates the effect of past magnetic history. Refer to the application notes that provide information on set/reset circuits and operation.

Pinout Diagram and Package Drawing

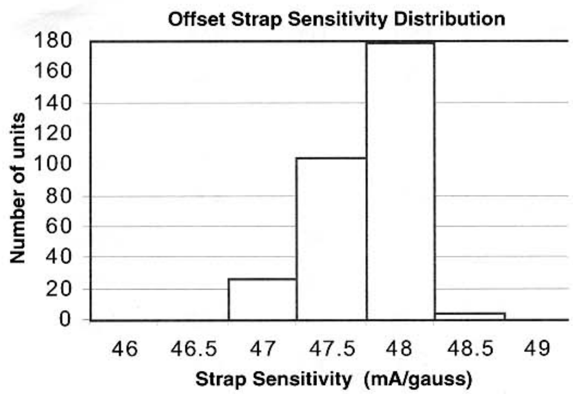


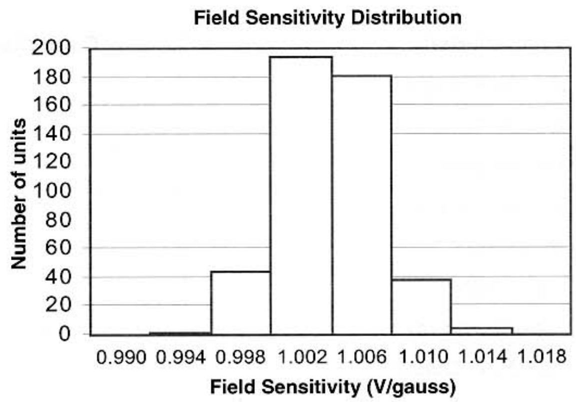


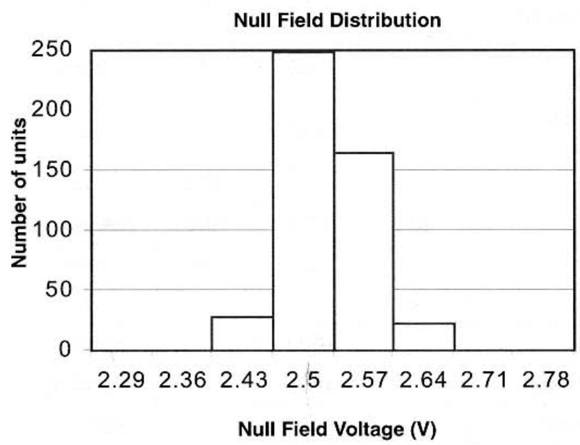
Symbol	Millimeters		Inches	
	Min	Max	Min	Max
A	10.92	11.94	0.43	0.47
A1	2.92	3.42	0.115	0.135
D	25.91	27.30	1.02	1.075
e	2.41	2.67	0.095	0.105
H	18.03	19.69	0.71	0.775

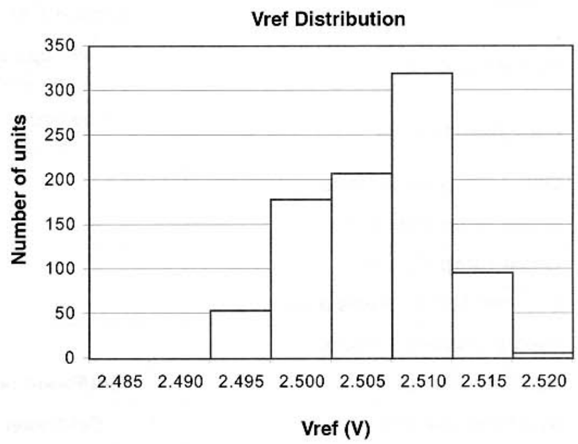
Ordering Information

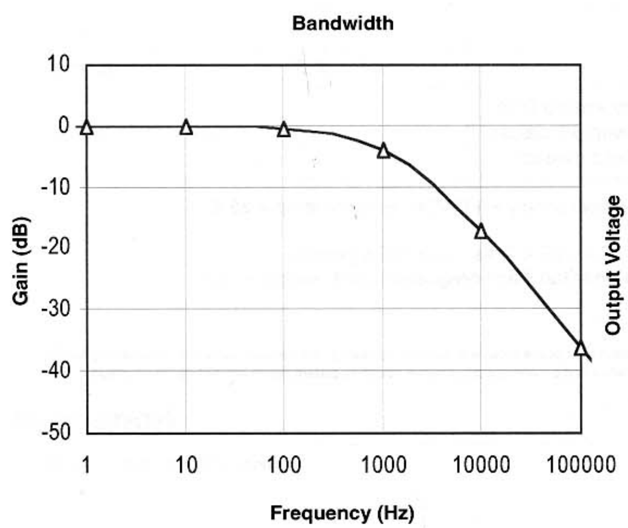
Ordering Number	Product
HMC2003	Three-Axis Magnetic Sensor Hybrid

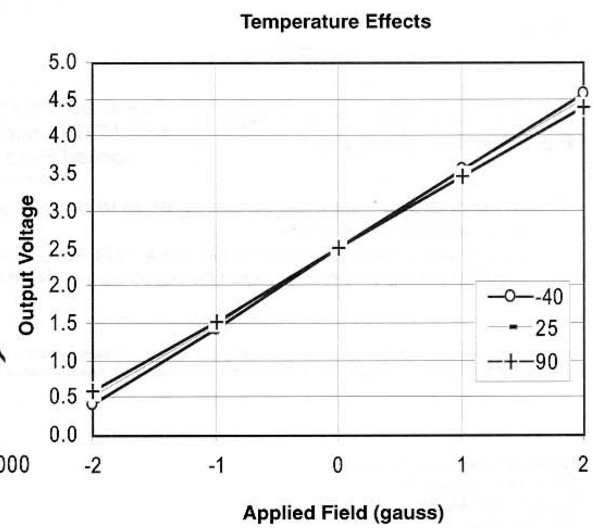












Honeywell reserves the right to make changes to improve reliability, function or design. Honeywell does not assume any liability arising out of the application or use of any product or circuit described herein; neither does it convey any license under its patent rights nor the rights of others.

900151 02-04 Rev. E

Honeywell
SENSOR PRODUCTS

DIGITAL COMPASS SOLUTION

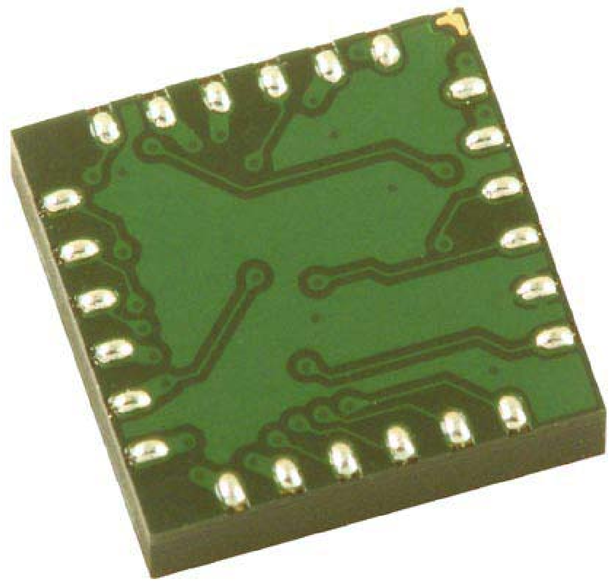
Features

- Fully Integrated Compass Module
- 2-Axis Magnetic Sensors with Electronics
- Miniature (6.5 by 6.5 by 1.5mm) 24-Pin LCC Package
- 2.7 to 5.2 volt Supply Range
- Accurate Compassing Capability
- I^2C Digital Interface
- User Selectable Slave Address

Product Description

The Honeywell HMC6352 2-Axis Digital Integrated Compass Solution combines a two-axis MR magnetic field sensor design with the required analog and digital support circuits for heading computation.

By combining the sensor elements and all the processing electronics into a 6.5mm square LCC package, designers will have the simplest solution to integrate low cost and space efficient electronic compasses for wireless phones, consumer electronics, vehicle compassing, and antenna positioning.

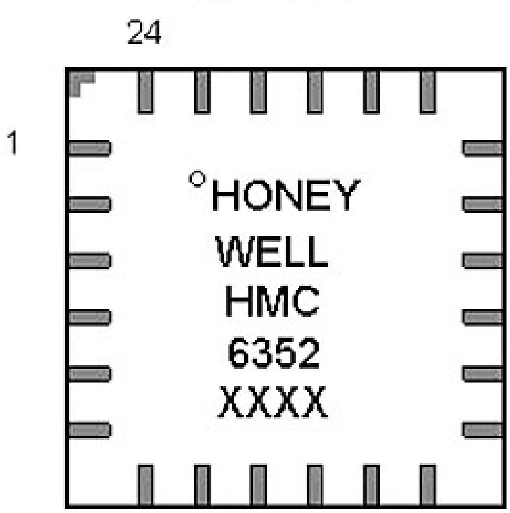


BOTTOM VIEW

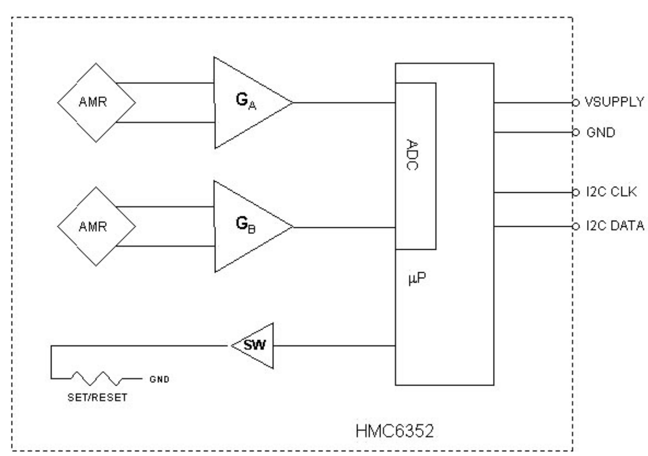
DIAGRAMS

PINOUT

TOP VIEW



BLOCK DIAGRAM

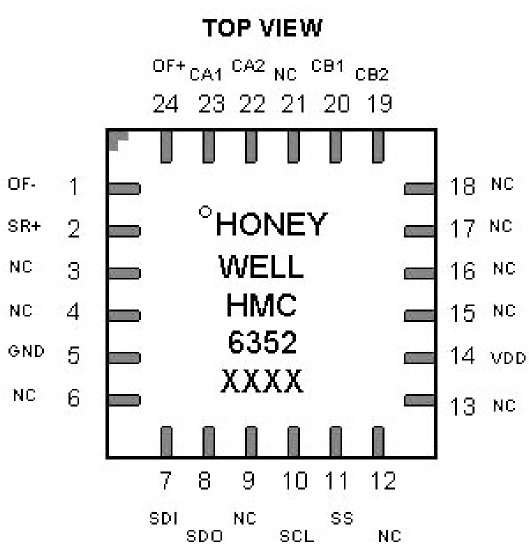


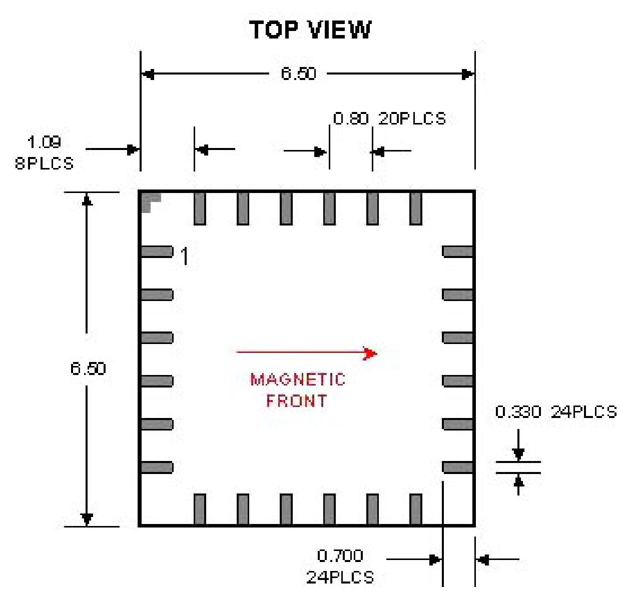
HMC6352 SPECIFICATIONS

Characteristics	Conditions [1]	Min	Typ	Max	Units
Supply Voltage	Vsupply to GND	2.7	3.0	5.2	Volts
Supply Current	Vsupply to GND Steady State (Vsupply = 3.0V) Steady State (Vsupply = 5.0V) Dynamic Peaks		 1 2 	 10	 mA mA mA
Field Range [2]	Total applied field	0.10	-	0.75	gauss
Heading Accuracy	HMC6352		6		degRMS
Heading Resolution			0.5		deg
Heading Repeatability			1.0		deg
Disturbing Field	Sensitivity starts to degrade. Enable set/reset function to restore sensitivity.	20			gauss
Max. Exposed Field	No permanent damage and set/reset function restores performance.			10000	gauss
Operating Temperature	Ambient	-20		70	°C
Storage Temperature	Ambient	-55		125	°C
Reflow Temperature	Per JEDEC J-STD-020B			225	°C
Output	Heading, Mag X, Mag Y				
Size	6.5 x 6.5 x 1.5				mm
Weight			0.14		grams

(1) Tested at 25°C except stated otherwise.
(2) Field upper limit can be extended by using external resistors across CA1/CA2 and CB1/CB2.

Pin Configuration/Package Dimensions





Pin Descriptions

HMC6352

Pin	Name	Description
1	OF-	No User Connection (Offset Strap Negative)
2	SR+	No User Connection (Set/Reset Strap Positive)
3	NC	No User Connection
4	NC	No User Connection
5	GND	Supply/System Ground
6	NC	No User Connection
7	SDI	I2C Data Output (SPI Data In)
8	SDO	No User Connection (SPI Data Out)
9	PGM	No User Connection (Program Enable)
10	SCL	I2C Clock (SPI Clock)
11	SS	No User Connection (Slave Select)
12	NC	No User Connection
13	NC	No User Connection
14	VDD	Supply Voltage Positive Input (+2.7VDC to +5.0VDC)
15	NC	No User Connection
16	NC	No User Connection
17	NC	No User Connection
18	NC	No User Connection
19	CB2	Amplifier B Filter Capacitor Connection
20	CB1	Amplifier B Filter Capacitor Connection
21	NC	No User Connection
22	CA2	Amplifier A Filter Capacitor Connection
23	CA1	Amplifier A Filter Capacitor Connection
24	OF+	No User Connection (Offset Strap Positive)

I^2C Communication Protocol

The HMC6352 communicates via a two-wire I^2C bus system as a slave device. The HMC6352 uses a layered protocol with the interface protocol defined by the I^2C bus specification, and the lower command protocol defined by Honeywell. The data rate is the standard-mode 100kbps rate as defined in the I^2C Bus Specification 2.1. The bus bit format is an 8-bit Data/Address send and a 1-bit acknowledge bit. The format of the data bytes (payload) shall be case sensitive ASCII characters or binary data to the HMC6352 slave, and binary data returned. Negative binary values will be in two's complement form. The default (factory) HMC6352 7-bit slave address is 42(hex) for write operations, or 43(hex) for read operations.

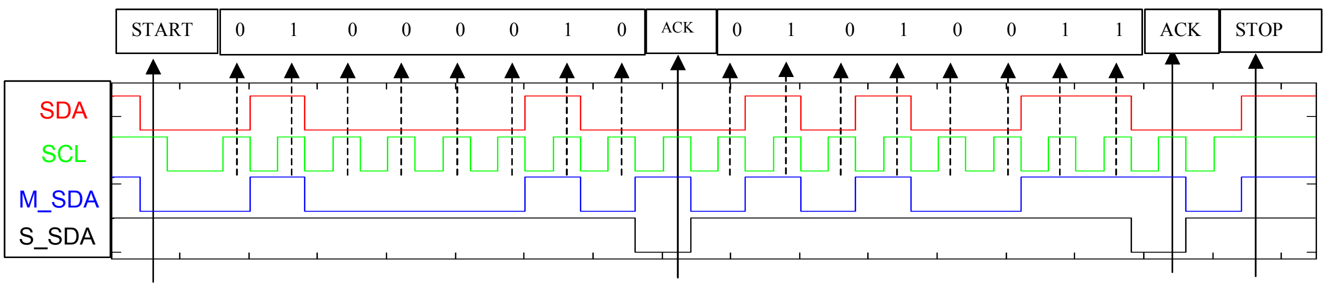
The HMC6352 Serial Clock (SCL) and Serial Data (SDA) lines do not have internal pull-up resistors, and require resistive pull-ups (Rp) between the master device (usually a host microprocessor) and the HMC6352. Pull-up resistance values of about 10k ohms are recommended with a nominal 3.0-volt supply voltage. Other values may be used as defined in the I^2C Bus Specification 2.1.

The SCL and SDA lines in this bus specification can be connected to a host of devices. The bus can be a single master to multiple slaves, or it can be a multiple master configuration. All data transfers are initiated by the master device which is responsible for generating the clock signal, and the data transfers are 8 bit long. All devices are addressed by I^2C's unique 7 bit address. After each 8-bit transfer, the master device generates a 9th clock pulse, and releases the SDA line. The receiving device (addressed slave) will pull the SDA line low to acknowledge (ACK) the successful transfer or leave the SDA high to negative acknowledge (NACK).

Per the I^2C spec, all transitions in the SDA line must occur when SCL is low. This requirement leads to two unique conditions on the bus associated with the SDA transitions when SCL is high. Master device pulling the SDA line low while the SCL line is high indicates the Start (S) condition, and the Stop (P) condition is when the SDA line is pulled high while the SCL line is high. The I^2C protocol also allows for the Restart condition in which the master device issues a second start condition without issuing a stop.

All bus transactions begin with the master device issuing the start sequence followed by the slave address byte. The address byte contains the slave address; the upper 7 bits (bits7-1), and the Least Significant bit (LSb). The LSb of the address byte designates if the operation is a read (LSb=1) or a write (LSb=0). At the 9 th clock pulse, the recieving slave device will issue the ACK (or NACK). Following these bus events, the master will send data bytes for a write operation, or the slave will transmit back data for a read operation. All bus transactions are terminated with the master issuing a stop sequence.

The following timing diagram shows an example of a master commanding a HMC6352 (slave) into sleep mode by sending the "S" command. The bottom two traces show which device is pulling the SDA line low.



I^2C bus control can be implemented with either hardware logic or in software. Typical hardware designs will release the SDA and SCL lines as appropriate to allow the slave device to manipulate these lines. In a software implementation, care must be taken to perform these tasks in code.

Command Protocol

The command protocol defines the content of the data (payload) bytes of I^2C protocol sent by the master, and the slave device (HMC6352).

After the master device sends the 7-bit slave address, the 1-bit Read/Write, and gets the 1-bit slave device acknowledge bit returned; the next one to three sent data bytes are defined as the input command and argument bytes. To conserve data traffic, all response data (Reads) will be context sensitive to the last command (Write) sent. All write commands shall have the address byte least significant bit cleared (factory default 42(hex)). These commands then follow with the ASCII command byte and command specific binary formatted argument bytes in the general form of:

(Command ASCII Byte) (Argument Binary MS Byte) (Argument Binary LS Byte)

The slave (HMC6352) shall provide the acknowledge bits between each data byte per the I^2C protocol. Response byte reads are done by sending the address byte (factory default 43(hex)) with the least significant bit set, and then clocking back one or two response bytes, last command dependant. For example, an "A" command prompts the HMC6352 to make a sensor measurement and to route all reads for a two byte compass heading or magnetometer data response. Then all successive reads shall clock out two response bytes after sending the slave address byte. Table 1 shows the HMC6352 command and response data flow.

Table 1 – HMC6352 Interface Commands/Responses

Command Byte ASCII (hex)	Argument 1 Byte (Binary)	Argument 2 Byte (Binary)	Response 1 Byte (Binary)	Response 2 Byte (Binary)	Description
w (77)	EEPROM Address	Data			Write to EEPROM
r (72)	EEPROM Address		Data		Read from EEPROM
G (47)	RAM Address	Data			Write to RAM Register
g (67)	RAM Address		Data		Read from RAM Register
S (53)					Enter Sleep Mode (Sleep)
W (57)					Exit Sleep Mode (Wakeup)
O (4F)					Update Bridge Offsets (S/R Now)
C (43)					Enter User Calibration Mode
E (45)					Exit User Calibration Mode
L (4C)					Save Op Mode to EEPROM
A (41)			MSB Data	LSB Data	Get Data. Compensate and Calculate New Heading

Operational Controls

HMC6352 has two parameters; *Operational Mode* and *Output Mode*, which control its operation. The Operational Mode control byte is located at RAM register byte 74(hex) and is shadowed in EEPROM location 08(hex). This byte can be used to control the continuous measurement rate, set/reset function, and to command the HMC6352 into the three allowed operating modes; Standby, Query, and Continuous.

The Output Mode control byte is located at RAM register byte 4E(hex) and is not shadowed in the EEPROM, and upon power up the device is in the Heading output mode. This byte can be changed to get magnetometer data if necessary but is typically left in a default heading data mode.

Non-Volatile Memory

The HMC6352 contains non-volatile memory capability in the form of EEPROM that retains key operational parameters and settings for electronic compassing. Table 2 shows the balance of the EEPROM locations that the user can read and write to. Details on the features of these location bytes will be discussed in the following paragraphs.

Table 2 – HMC6352 EEPROM Contents

EE Address (hex)	Byte Description	Factory Default
00	I^2C Slave Address	42(hex)
01	Magnetometer X Offset MSB	factory test value
02	Magnetometer X Offset LSB	factory test value
03	Magnetometer Y Offset MSB	factory test value
04	Magnetometer Y Offset LSB	factory test value
05	Time Delay (0 – 255 ms)	01(hex)
06	Number of Summed measurements(1-16)	04(hex)
07	Software Version Number	> 01(hex)
08	Operation Mode Byte	50(hex)

Operational Modes

The HMC6352 has three operational modes plus the ability to enter/exit the non-operational (sleep) mode by command. Sleep mode sends the internal microprocessor into clock shutdown to save power, and can be brought back by the "W" command (wake). The "S" command returns the processor to sleep mode. The three operational modes are defined by two bits in the internal HMC6352 Operation Mode register. If the master device sends the "L" command, the current operational mode control byte in the RAM register is loaded into the internal EEPROM register and becomes the default operational mode on the next power-up. The application environment of the HMC6352 will dictate the most suitable operational mode.

Standby Mode: (Operational Mode=0) This is the factory default mode. The HMC6352 waits for master device commands or change in operational mode. Receiving an "A" command (get data) will make the HMC6352 perform a measurement of sensors (magnetometers), compute the compensated magnetometer and heading data, and wait for the next read or command. No new measurements are done until another "A" command is sent. This mode is useful to get data on demand or at random intervals as long as the application can withstand the time delay in getting the data.

Query Mode: (Operational Mode=1) In this mode the internal processor waits for "A" commands (get data), makes the measurements and computations, and waits for the next read command to output the data. After each read command, the HMC6352 automatically performs another get data routine and updates the data registers. This mode is designed to get data on demand without repeating "A" commands, and with the master device controlling the timing and data throughput. The tradeoff in this mode is the previous query latency for the advantage of an immediate read of data.

The above two modes are the most power conserving readout modes.

Continuous Mode: (Operational Mode=2) The HMC6352 performs continuous sensor measurements and data computations at selectable rates of 1Hz, 5Hz, 10Hz, or 20Hz, and updates the output data bytes. Subsequent "A" commands are un-necessary unless re-synchronization to the command is desired. Data reads automatically get the most recent updates. This mode is useful for data demanding applications.

The continuous mode measurement rate is selected by two bits in the operational mode selection byte, along with the mode selection and the periodic Set/Reset bit. The periodic Set/Reset function performs a re-alignment of the sensors magnetic domains in case of sensor perming (magnetic upset event), operating temperature shifts, and normal thermal agitation of the domains. Exposure of the HMC6352 to magnetic fields above 20 gauss (disturbing field threshold) leads to possible measurement inaccuracy or "stuck" sensor readings until the set/reset function is performed. With the periodic Set/Reset bit set, the set/reset function occurs every few minutes.

Operational Mode Control Byte Syntax

As described above, the HMC6352 operation mode, measurement rate, and periodic set/reset are selected and stored both in a processor RAM register and in EEPROM. Upon power-up the EEPROM will transfer the saved operational mode control byte into register address 74(hex). The following is the byte format:

Bit 7 =0

Bits 6 and 5 (Continuous Mode Measurement Rate)

Bit 6	Bit 5	Description
0	0	1 Hz Measurement Rate
0	1	5 Hz Measurement Rate
1	0	10 Hz Measurement Rate
1	1	20 Hz Measurement Rate

Bit 4 (Periodic Set/Reset), 0 = Off, 1 = On

Bit 3 = 0

Bit 2 = 0

Bits 1 and 0 (Operational Mode Value)

Bit 1	Bit 0	Description
0	0	Standby Mode
0	1	Query Mode
1	0	Continuous Mode
1	1	Not Allowed

The total bit format for the Operational Mode Byte is shown below:

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
0	M. Rate_H	M. Rate_L	Per. S/R	0	0	Op Mode_H	Op Mode_L

Output Data Modes

The read response bytes after an “A” command, will cause the HMC6352 will return two bytes with binary formatted data. Either heading or magnetometer data can be retrieved depending on the output data selection byte value. Negative signed magnetometer data will be returned in two’s complement form. This output data control byte is located in RAM register location 4E(hex) and defaults to value zero (heading) at power up.

The following is the byte format:

Bits 7 through 3 = 0

Bits 0, 1, 2 (Output Mode Value)

Bit 2	Bit 1	Bit 0	Description
0	0	0	Heading Mode
0	0	1	Raw Magnetometer X Mode
0	1	0	Raw Magnetometer Y Mode
0	1	1	Magnetometer X Mode
1	0	0	Magnetometer Y Mode

The total bit format for the Output Mode Byte is shown below:

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
0	0	0	0	0	Mode	Mode	Mode

Heading Mode: The heading output data will be the value in tenths of degrees from zero to 3599 and provided in binary format over the two bytes.

Raw Magnetometer Modes: These X and Y raw magnetometer data readings are the internal sensor values measured at the output of amplifiers A and B respectively and are 10-bit 2’s complement binary ADC counts of the analog voltages at pins CA1 and CB1. The leading 6-bits on the MSB are zero filled or complemented for negative values. The zero count value will be about half of the supply voltage. If measurement averaging is implemented, the most significant bits may contain values of the summed readings.

Magnetometer Modes: These X and Y magnetometer data readings are the raw magnetometer readings plus offset and scaling factors applied. The data format is the same as the raw magnetometer data. These compensated data values come from the calibration routine factors plus additional offset factors provided by the set/reset routine.

User Calibration

The HMC6352 provides a user calibration routine with the “C” command permitting entry into the calibration mode and the “E” command to exit the calibration mode. Once in calibration mode, the user is requested to rotate the compass on a flat surface at least one full circular rotation while the HMC6352 collects several readings per second at various headings with the emphasis on rotation smoothness to gather uniformly spaced readings. Optimally two rotations over 20 seconds duration would provide an accurate calibration. The calibration time window is recommended to be from 6 seconds up to 3 minutes depending on the end user’s platform.

The calibration routine collects these readings to correct for hard-iron distortions of the earth’s magnetic field. These hard-iron effects are due to magnetized materials nearby the HMC6352 part that in a fixed position with respect to the end user platform. An example would be the magnetized chassis or engine block of a vehicle in which the compass is mounted onto. Upon exiting the calibration mode, the resulting magnetometer offsets and scaling factors are updated

I^{2}C Slave Address

The I^{2}C slave address byte consists of the 7 most significant bits with the least siginificant bit zero filled. A described earlier, the default (factory) value is 42(hex) and the legal I^{2}C bounded values are between 10(hex) and F6(hex). This slave address is written into EEPROM address 00(hex) and changed on the power up.

Magnetometer Offsets

The Magnetometer Offset bytes are the values stored after the completion of the last factory or user calibration routine. Additional value changes are possible, but will be overwritten when the next calibration routine is completed. Note that these offset values are added to the sensor offset values computed by the set/reset routine to convert the raw magnetometer data to the compensated magnetometer data. These values are written into EEPROM addresses 01(hex) to 04 (hex) and loaded to RAM on the power up. These offsets are in ADC counts applied to the 10-bit ADC raw magnetometer data. Most offset MSB values will likely be zero filled or complemented.

Time Delay

The EEPROM time delay byte is the binary value of the number of milliseconds from the time a measurement request was commanded and the time the actual measurements are made. The default value is 01(hex) for no delay. Extra measurement delays maybe desired to allow for amplifier stabilization from immediate HMC6352 power-up or for external filter capacitor selection that limits the bandwidth and time response of the amplifier stages. This value is written into EEPROM address 05(hex) and loaded to RAM on the power up.

Measurement Summing

This EEPROM summed measurement byte permits designers/users to back average or data smooth the output data (heading, magnetometer values) to reduce the amount of jitter in the data presentation. The default value is 04(hex) which is four measurements summed. A value of 00(hex) would be no summing. Up to 16 sets of magnetometer data may be selected for averaging. This slave address is written into EEPROM address 06(hex) and loaded to RAM on the power up.

Software Version

This EEPROM software version number byte contains the binary value of the programmed software. Values of 01(hex) and beyond are considered production software.

Timing Requirements

Table 3 contains the time delays required by HMC6352 upon receipt of the command to either perform the commanded task or to have the response available on the I^2C bus.

Table 3 – Interface Command Delays

Command Byte ASCII (hex)	Description	Time Delay (μsec)
w (77)	Write to EEPROM	70
r (72)	Read from EEPROM	70
G (47)	Write to RAM Register	70
g (67)	Read from RAM Register	70
S (53)	Enter Sleep Mode (Sleep)	10
W (57)	Exit Sleep Mode (Wakeup)	100
O (4F)	Update Bridge Offsets (S/R Now)	6000
C (43)	Enter User Calibration Mode	10
E (45)	Exit User Calibration Mode	14000
L (4C)	Save Op Mode to EEPROM	125
A (41)	Get Data. Compensate and Calculate New Heading	6000

Command and Operation Mode Interactions

All commands are accepted in the standby mode. Honeywell strongly recommends using this mode during the initial setup stage. Setting up of the HMC6352 operation mode and its slave address are typical set up examples. Although execution of all commands in the Query and Continuous Modes is acceptable, the completion outcome is not guaranteed.

Q: How to Read Data from HMC6352?

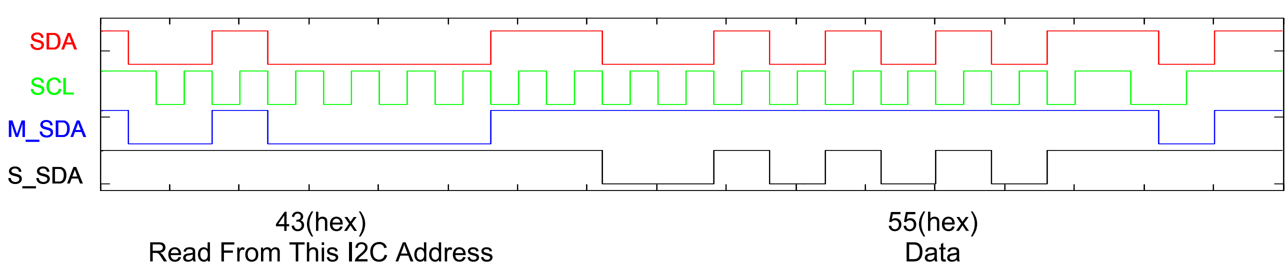
A: In Standby Mode - Use “A” command.

In Query Mode - Send 43(hex) slave address to read data and clock out the two register data bytes for heading. An initial “A” command is needed to update the heading after each read.

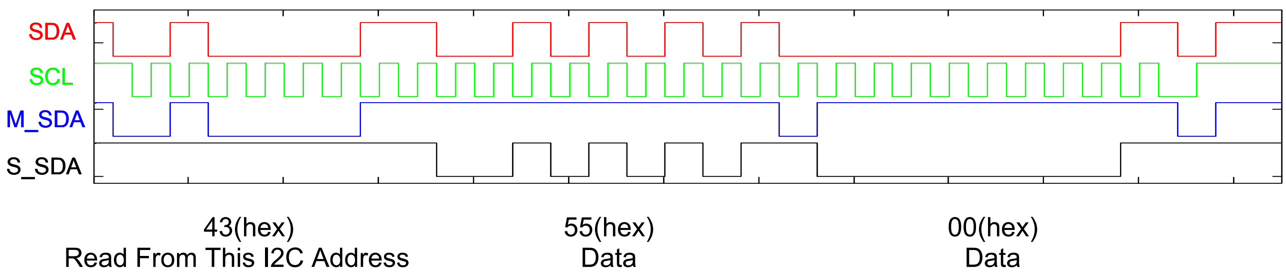
In Continuous Mode - Send 43(hex) slave address to read data and clock out the register data bytes for heading. The “A” command is not allowed or required.

Waveform Examples

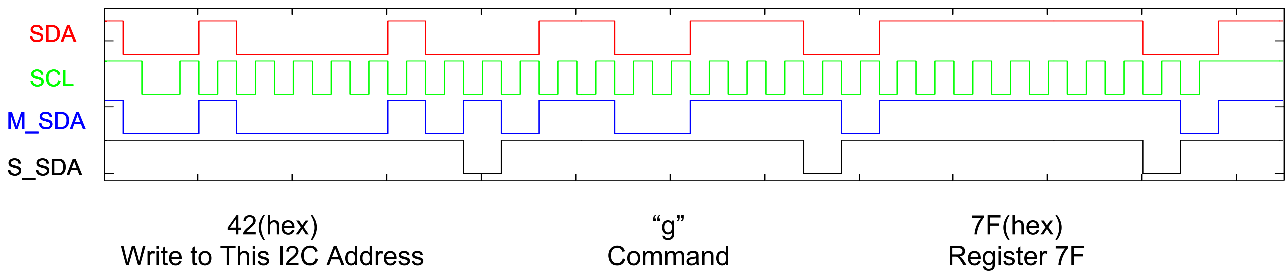
Example 1: This example shows how to read a single byte from the HMC6352. The Slave (HMC6352) continues to hold the SDA line low after the acknowledge (ACK) bit because the first bit of the data byte is a zero. Remember that the data read is last command sensitive.



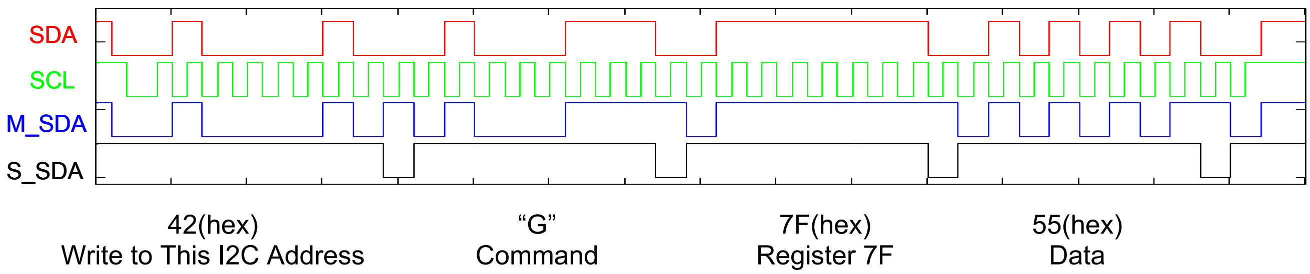
Example 2: This example shows how to read two bytes from the HMC6352 (slave). The slave continues to hold the SDA line low after the acknowledge bit because the first bit of the data bytes is zero.



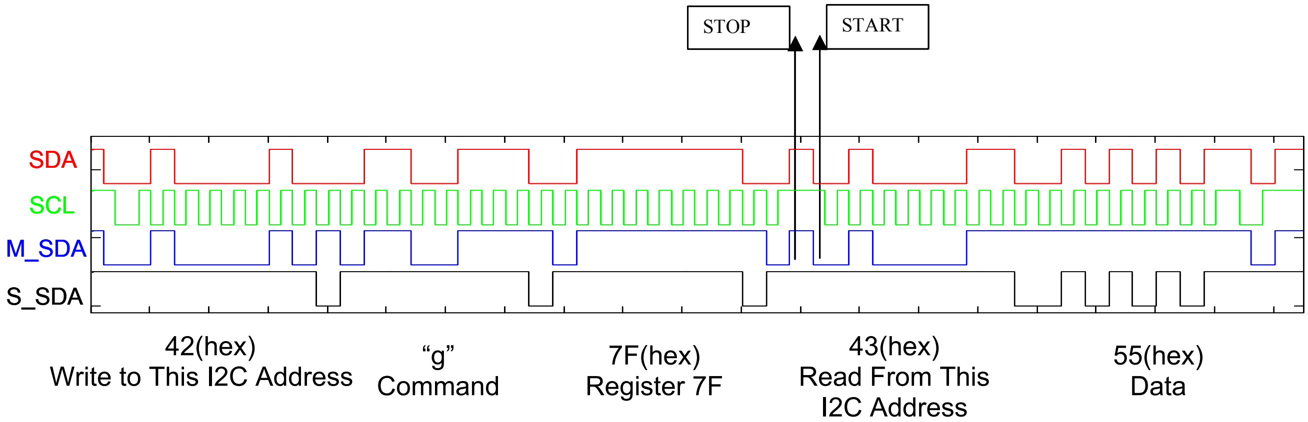
Example 3: This example shows how to command HMC6352 to read a RAM register by sending the "g" command and the register address 7F(hex). Note that this example does not show the process of reading the answer. See example 1 for reading a byte.



Example 4: This example shows how to write to a RAM register in the HMC6352 by sending the "G" command, the register address 7F(hex), and the data byte 55(hex) to the HMC6352 slave.



Example 5: The final example shows how to read RAM register 7F(hex). First perform a write operation to command the HMC6352 to read a RAM register and define which register to read (Example 3). The sensor puts the answer in the data buffer. Then perform a read operation to clock out the answer (Example 1). There is a Stop/Start event in between the write operation and the read operation. This example is just a combination of Examples 3 and 1, but it is provided to show that reading a register involves both a write and a read operation.



Application Notes

The HMC6352 Integrated Compass Sensor circuit is composed of two magneto-resistive (MR) sensors with orthogonal orientation for sensing the horizontal components of the earth's magnetic field (0 to 630 milli-gauss), plus two amplifiers, a set/reset drive circuit, and a microprocessor (μP). Best accuracy is obtained in clean magnetic environments (free air) and held level, or perpendicular to the gravitational direction. At worst case, each degree of tilt from a level orientation could add two degrees of compass heading error. Magnetic errors can be introduced if operated near strong magnetic sources such as microphone or speaker magnets, transformers in test equipment, and CRT deflection yokes in video displays/monitors. These magnetic errors can typically be reduced or eliminated by performing the calibration routine.

When locating the HMC6352 in dense printed circuit board designs, take precautions in location of this magnetic field sensing device for soft-iron effects that bend the earth's magnetic field. These soft-iron effects are from ferrous materials without residual magnetization and tend to be items like nickel-plating on SMT component contacts and RFI/EMI shielding materials. The amount of stand-off of the HMC6352 from these soft-irons is heuristic and dependant on the amount of material, material shape, and proximity.

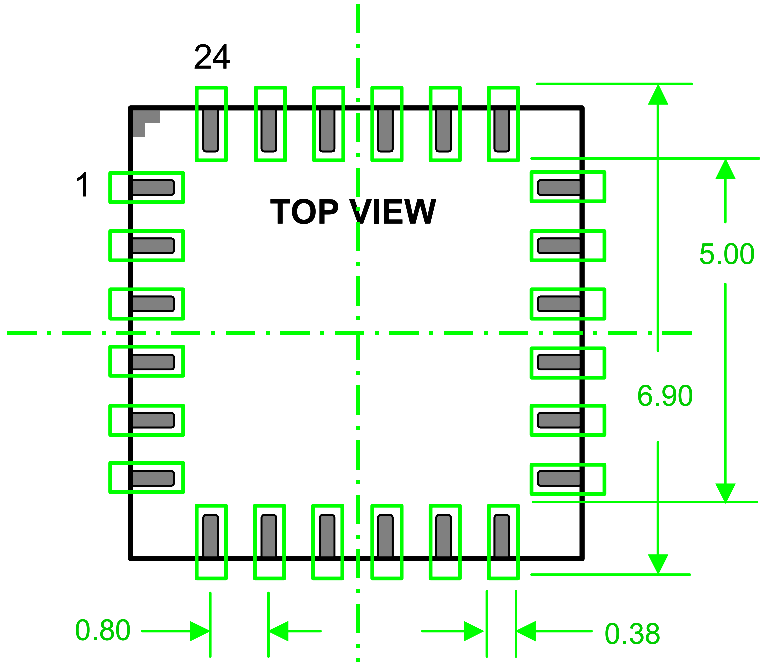
A user calibration mode is available in the HMC6352 to diminish hard-iron effects of the end-user's (customer's) location of the product. Hard-iron effects come from nearby ferrous materials with residual magnetism that buck or boost the intensity of the earth's magnetic field, leading to heading errors. Such hard-iron effects come from vehicle chassis, speaker magnets, and high current conductors or circuit traces.

PCB Pad Definition

(Dimensions in Millimeters)

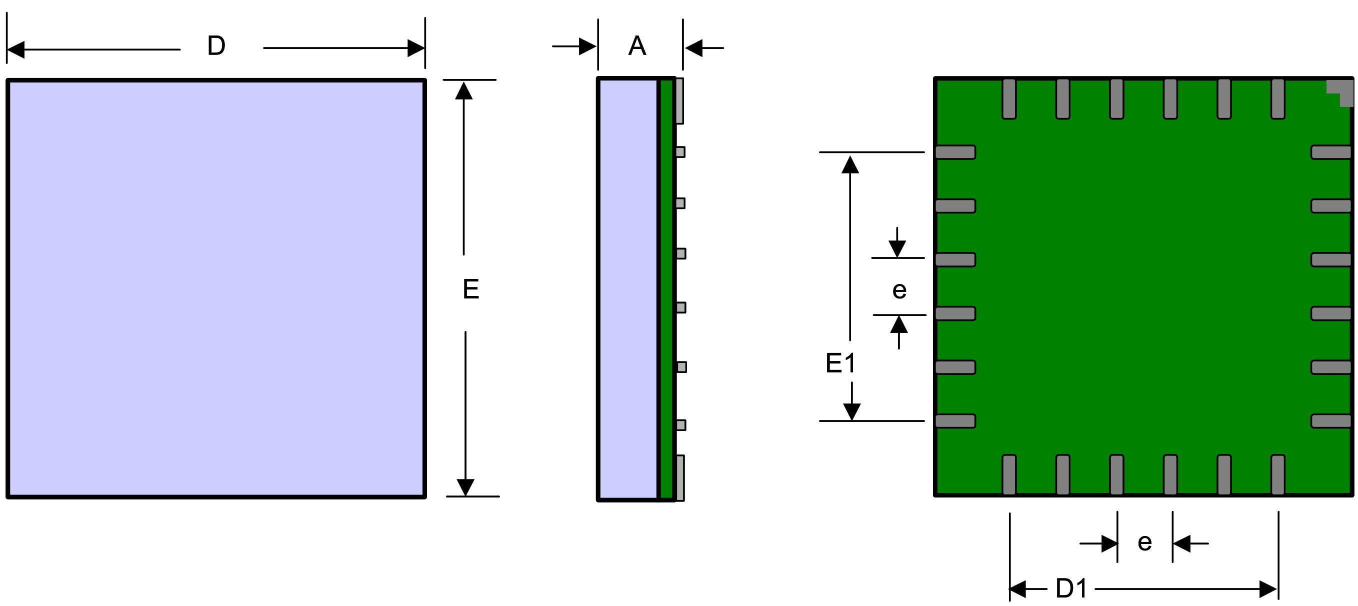
The HMC6352 is a fine pitch LCC package with a 0.80mm pin pitch (spacing), with the pin pads defined as 0.70mm by 0.33mm in size. PCB pads are recommended to be oversized by 0.025mm from each pad for a short dimension oversize of 0.05mm. The interior PCB pad is recommended to be 0.05mm oversized per pin with an exterior oversize of 0.20mm for proper package centering and to permit test probing.

Soldering attachment shall be done by SMT reflow methods with preheating, soaking, reflow, and cooling profiles as described in JEDEC J-STD-020B for large body parts. Both lead eutectic and lead-free profiles may be used. Caution, excessive temperature exposure beyond the profiles may result in internal damage to the HMC6352 circuits.



MECHANICAL DIMENSIONS

(In millimeters)



Dimension	Minimum	Nominal	Maximum
D	-	6.50 BSC	-
D1	-	4.00 BSC	-
E	-	6.50 BSC	-
E1	-	4.00 BSC	-
e	-	0.8 Basic	-
A	1.37	1.52	1.67

SOLDERING GUIDELINES

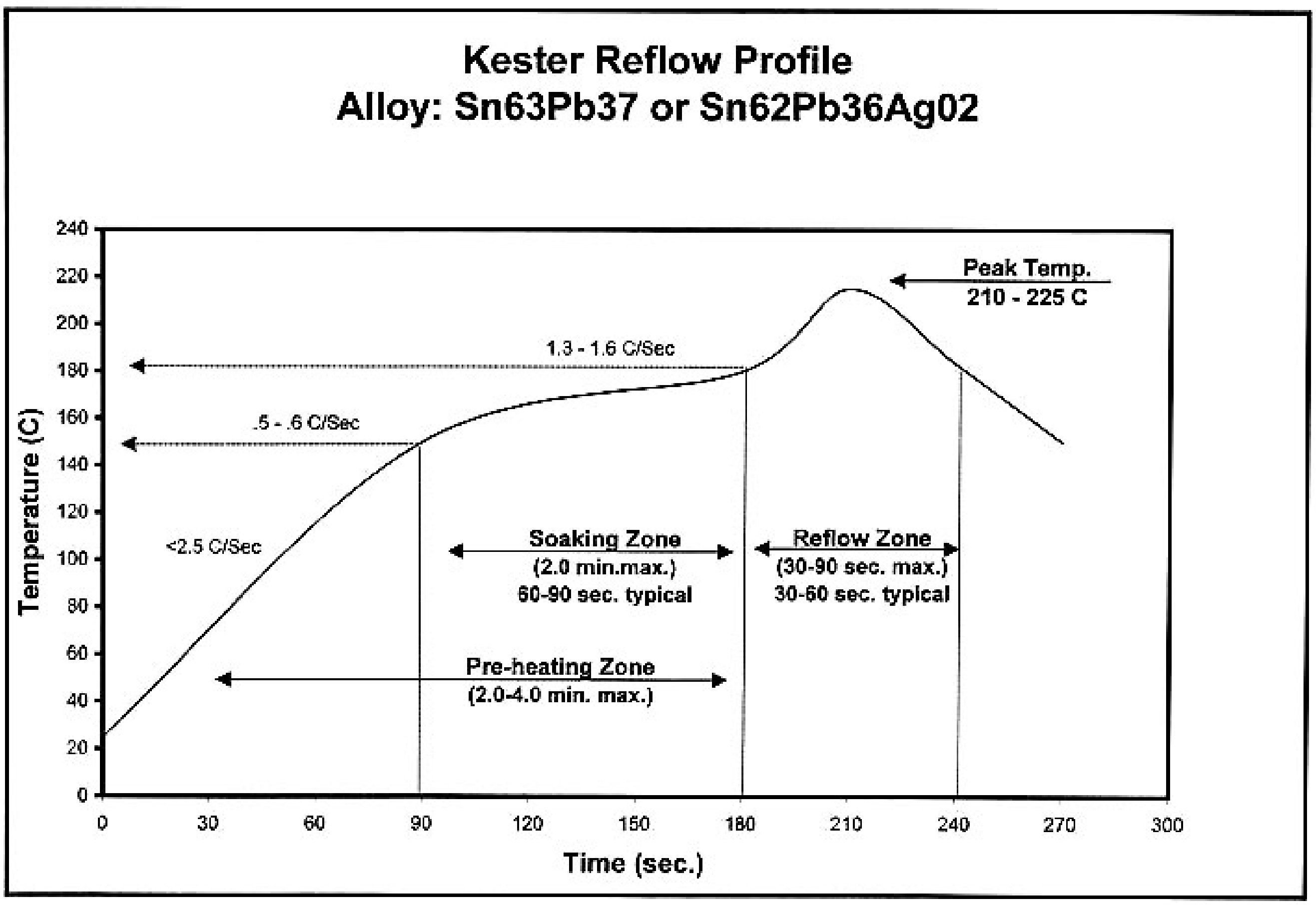
The HMC6352 shall follow the guidelines set by JEDEC J-STD-020B for handling and solder reflow for this surface mount device. It is recommended to follow the guidelines for Sn-Pb Eutectic, Large Body profile parts.

Most LCC packages have no special requirements beyond normal procedures for attaching SMT components to printed circuit boards. The exception to this process is the Honeywell HMC6352 that has a FR4 substrate package with epoxy top encapsulation. This package design use two solder types with differing reflow temperatures. Inside this package, a high-temp reflow solder is used that reflows at 225°C and above to make internal circuit connections. On the package outside, low-temp solder is recommended with a reflow temp range from 180 to 210°C.

Three heating zones are defined in SMT reflow soldering process; the preheating zone, the soaking zone, and the reflow zone. The preheating zone includes the soaking zone, and nominally ranges from 2 to 4 minutes depending on temperature rise to arrive in the 160°C to 180°C soaking plateau to active the flux and remove any remaining moisture in the assembly. Preheat rise times must not exceed 3°C per second to avoid moisture and mechanical stresses that result in “popcorning” the package encapsulation.

The soaking zone is a one to two minute temperature stabilization time to bring the all the PCB assembly to an even temperature. Typically this zone has a 0.5 to 0.6°C rise in temperature heading towards the main reflow heating elements. The reflow zone is 30 to 90 second bump in temperature over the 180°C point to reflow the screened solder paste before a gradual cooling. The peak temperature is typically in the 210°C to 225°C range. In dual temp solder parts, it is recommended that peak temperatures remain at least 5°C below the internal reflow solder temperature (i.e. 220°C). The figure below shows a typical reflow profile.

It should be noted that lead-free solders tend to require higher peak reflow temperatures and longer reflow times. Cooling zone temperature fall should decrease not more than 6°C per second to avoid mechanical stresses in the PCB assembly.



REFERENCE DESIGN

The schematic diagram in Figure 1 shows the basic HMC6352 application circuit with a minimum of external components.

From Figure 1, the host microprocessor (μP) controls the HMC6352 via I^2C serial data interface lines for data (SDA) and clock (SCL). Two external 10k-ohm pull-up resistors to the nominal +3 volt DC supply create normally high logic states when the interface lines are not in use. The host initiates use of the interface by creating the 100kHz clock and pulling low the data line to indicate the start condition. The data line logic state transitions are only allowed during the clock low states and require the data line to be stable in the high states, with the exception of the start and stop conditions.

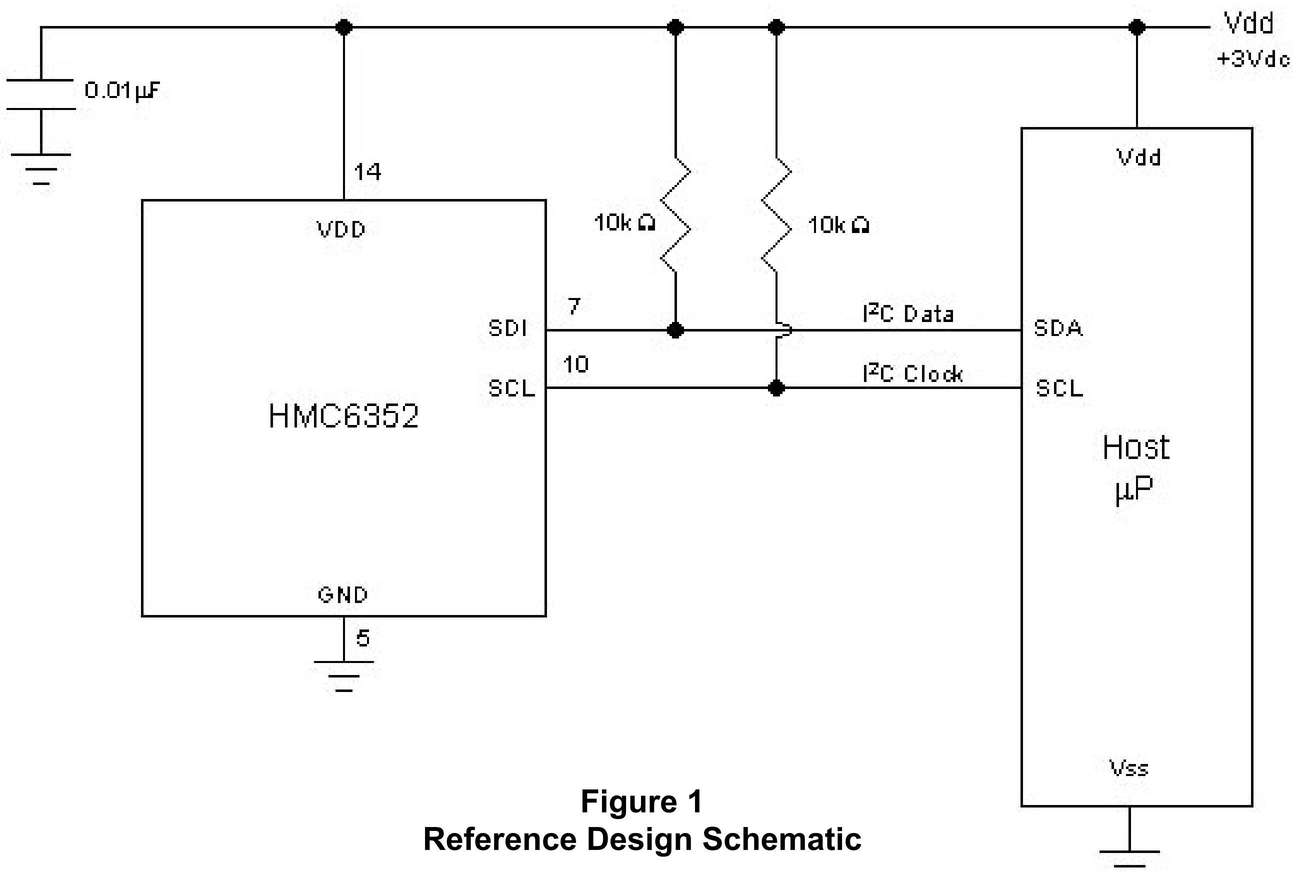


Figure 1
Reference Design Schematic

The 0.01μF supply decoupling capacitor in this reference can be omitted if another supply filter capacitor is already included in the overall circuit design. If the supply traces extend beyond a couple inches to the HMC6352, it is advisable to add a local supply decoupling capacitor near the HMC6352 to retain optimum circuit stability.

Additional masters and slaves can be added to the I^2C bus traces without interface trouble to the HMC6352. There are no periodic maintenance commands required, and even HMC6352 sleep mode or power shutdown can be accomplished without harm to the data or clock lines.

Amplifier Filter Connections

The HMC6352 design has provisions for the feedback loop of each amplifier stage to be accessible via the CA1, CA2, CB1, and CB2 pin contacts. Across the contacts and internal to the HMC6352 is the amplifier section plus a 1200k-ohm feedback resistance to set the voltage gain. By placing small value ceramic capacitors across CA1 to CA2 (or CB1 to CB2), the designer can set the –3dB bandwidth of the amplified magnetometer signals to drop spurious magnetic interference in the system. For example a 120 pico-Farad capacitor (Cext) in the amplifier feedback loop would limit the bandwidth to about 1kHz. Be aware that larger values of capacitance begin to slow the amplifier response to where the measurement delay time EEPROM byte may have to be increased in value to let the signal settle before making a measurement. Figure 2 shows the partial schematic of the amplifier feedback loop.

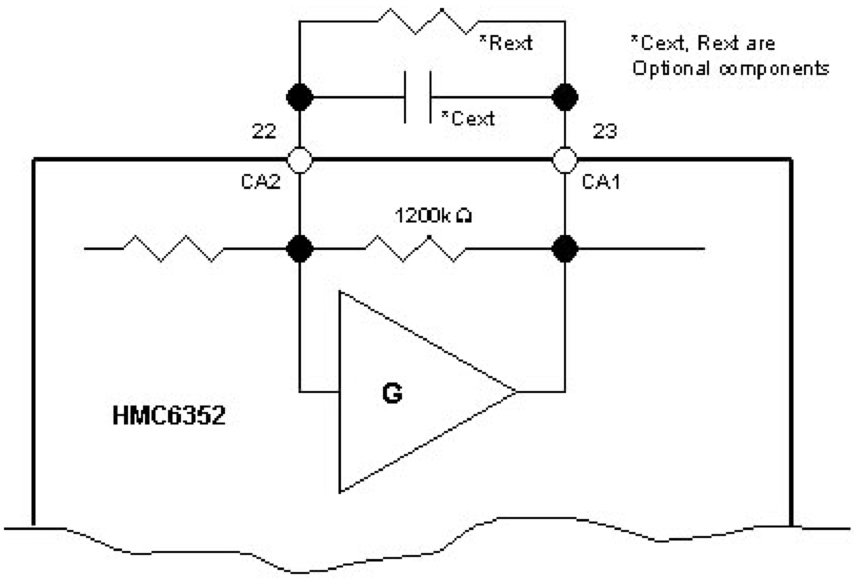


Figure 2
Amplifier Filter Connections

An optional gain reducing resistor (Rext) could also place across the feedback loop of the amplifier stages. With the amplifier set with the internal 1200 k-ohm feedback for ±750 milli-gauss maximum magnetic field flux density, a second 1200k-ohm external resistor would halve the gain and permit ±1.5 gauss capability if desired. Gain can be reduced for up to ±6 gauss capability for magnetometry-only applications or compassing with significant magnetic stray fields nearby.

ORDERING INFORMATION

Ordering Number	Product
HMC6352	Digital Compass Solution, I2C

Honeywell reserves the right to make changes to improve reliability, function or design. Honeywell does not assume any liability arising out of the application or use of any product or circuit described herein; neither does it convey any license under its patent rights nor the rights of others.

U.S. Patents 4,441,072 4,533,872 4,569,742 4,681,812 4,847,584 6,529,114 and patents pending apply to the technology described herein.

900307 07-04 Rev A

Device Operational Overview HMC6352

HMC6352 has two parameters; *Operational Mode* and *Output Mode*, which control its operation.
The Operational Mode is a RAM byte (0x74) and is shadowed in EEPROM location 0x08. This byte can be used to control the Measurement rate, Set/reset function, and to command the device into the three allowed operating modes; Standby, Query, and Continuous. The current *Op Mode* RAM value can be saved in the EEPROM using the "L" command, and will become the default mode on subsequent power up. Also, HMC6352 can be put in to Sleep mode for the lowest power consumption.

The Output Mode Byte is located in RAM 0x4E and is not shadowed in the EEPROM, and upon power up the device is in the Heading output mode. This byte can be changed to get magnetometer data if necessary.

The application environment of the HMC6352 will dictate the most suitable operational mode.
In the Standby Mode the HMC6352 is not performing measurements and is waiting for a command, and can be commanded in to making a heading measurement by issuing the "A" command. This mode is useful to get data on demand or at random intervals as long as the application can withstand the time delay in getting the data.

With the Query Mode, the HMC6352 will make a fresh measurement after it is read by the host processor. In this mode the data are available for immediate read.

The above two modes are the most power efficient readout modes.

In the Continuous Mode the user can choose 1,5,10,or 20 Hz output rate and the HMC6352 will make continuous measurements and update the output registers. This mode is useful for data demanding applications. In this mode the output can be read by writing 0x43 to the HMC6352 I2C bus.

I^2C Bus Overview

HMC6352 employs the 2-wire I^2C bus protocol (http://www.semiconductors.philips.com/acrobat/literature/9398/39340011.pdf) in the 100 Kb/s data rate, 7 bit addressing mode.

There is a clock line (SCL) and a data SDA line in this bus specification and a host of devices can be connected. The bus can be a single Master – multi Slave or it can be a Multi-Master configuration. All data transfers are initiated by the Master device which is responsible for generating the clock signal, and the transfers are 8 bit long. All devices are addressed by its unique 7 bit **Address**. After each 8-bit transfer, the Master generates a 9 th clock pulse, and the transmitting device releases the SDA line. The receiving device will pull the SDA line low to acknowledge (**ACK**) the successful transfer or leave the SDA high to **NACK**.

All transitions in the SDA line must occur when SCL is low. This requirement leads to two unique conditions on the bus associated with the SDA transitions when SCL is high. Master device pulling the SDA low while SCL high is the **Start (S)** condition, and the **Stop(P)** condition when the SDA is pulled high while SCL is high. The I^2C protocol also allows for the **Restart** condition in which the master device issues a second Start condition without issuing a Stop.

All bus transactions begin with the Master issuing the Start sequence followed by the slave **address-byte**. The address-byte contains the slave address; the upper 7 bits (bits7-1), and the LSb. The LSb of the address-byte designates if the operation is read (LSb=1) or write (LSb=0). At the 9 th clock pulse, the transmitting device will issue the ACK (or NACK). Following these bus events, the master will send data bytes for a write operation, and the slave will transmit data for a read operation. All bus transactions are terminated with the Master issuing a Stop sequence.

I²C Implementation

I2C bus can be implemented with either a hardware module or in software. Typical hardware modules will release the SDA and SCL lines as appropriate to allow the slave device to manipulate these lines. In software implementation care must be taken to perform these tasks in software.

HMC6352 Interface Commands (Table 1)

Command	Argument1	Argument2	Response1	Response2	Description
(0x77) w	EEPROM Address	Data			Write to EEPROM.
(0x72) r	EEPROM Address		Data		Read from EEPROM.
(0x47) G	RAM Address	Data			Write to Register.
(0x67) g	RAM Address		Data		Read from Register.
(0x53) S					Sleep.
(0x57) W					Wake Up.
(0x4F) O					Update the Bridge Offset.
(0x43) C					Enter the User Calibration Mode.
(0x45) E					Exit the User Calibration Mode.
(0x4C) L					Save the current MODE into EEPROM
(0x41) A			MSByte	LSByte	Get Data. Compensate and Calculate Heading

EEPROM Content

EE Address (hex)	Byte Description	Factory Default
00	I2C Slave Address	0x42
01	Magnetometer X Offset MSB	**
02	Magnetometer X Offset LSB	**
03	Magnetometer Y Offset MSB	**
04	Magnetometer Y Offset LSB	**
05	Time Delay (0 – 255 ms)	0x01
06	Number of Summed measurements(1-16)	0x04
07	Software Version Number	> 0x01
08	Operation Mode Byte	0x50

Timing Requirements

Below are the time delays required by HMC6352 upon receipt of the command to either perform the commanded task or to have the response available on the I2C bus

Command	Description	Time Delay
(0x77) w	Write to EEPROM.	70 uS
(0x72) r	Read from EEPROM.	70 uS
(0x47) G	Write to Register.	70 uS
(0x67) g	Read from Register.	70 uS
(0x53) S	Sleep.	10 uS
(0x57) W	Wake Up.	100 uS
(0x4F) O	Update the Bridge Offset.	6 mS
(0x43) C	Enter the User Calibration Mode.	10 uS
(0x45) E	Exit the User Calibration Mode.	14 mS
(0x4C) L	Save the current MODE into EEPROM	125 uS
(0x41) A	Get Data. Compensate and Calculate Heading	6 mS

Command and Operation Mode Interactions

All commands are acceptable in the Standby Mode. Honeywell strongly recommends using this mode during initial setup stage. Setting up of the HMC6352 operation mode and its slave address are set up examples. Although execution of all commands in the Query and Continuous Modes is acceptable, the outcome is not guaranteed.

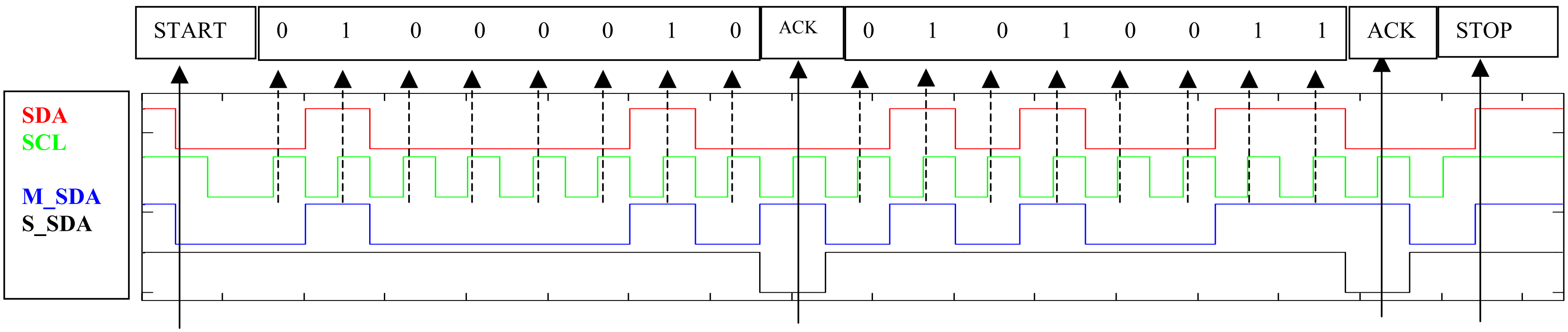
How to Read Data from HMC6352

1) In Standby Mode
   Use "A" command
2) In Query Mode
   Send 0x43 and clock out data (See Example 5)
3) In Continuous Mode
   Send 0x43 and clock out data (See Example 5)
   A is not allowed

Waveform Examples

Red: This is what actually happens on the SDA line.
Green: This is what actually happens on the SCL line.
Blue: This is what the Master tries to make happen on the SDA line.
Black: This is what the senso (Slave) tries to make happen on the SDA line.

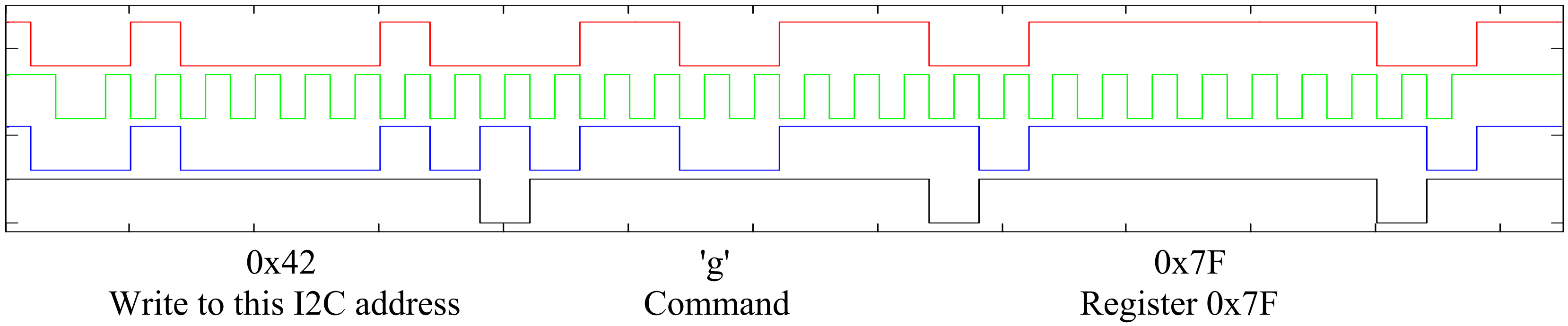
Example 1: This example shows how to command the HMC6352 in to Sleep mode by writing the 'S' command to the slave.



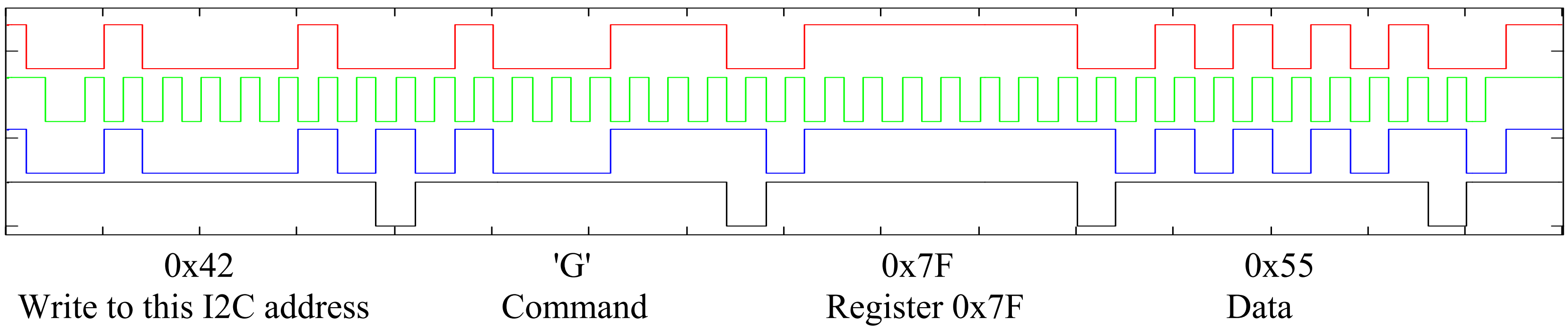
0x42
Write to this I2C address

'S'
Command

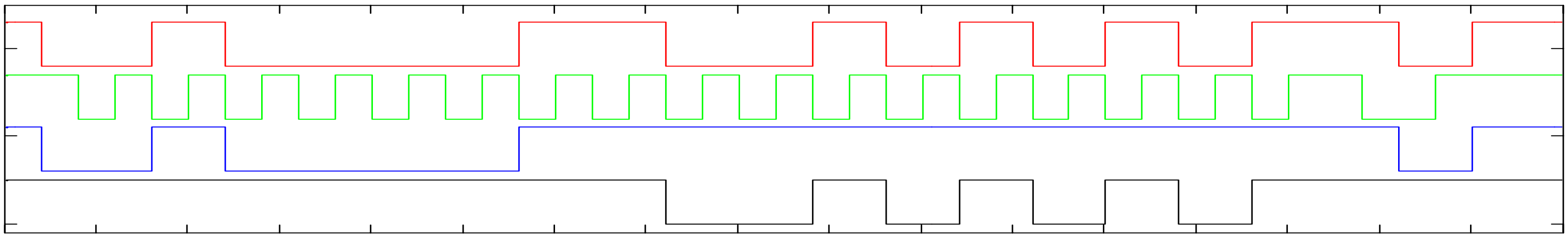
Example 2: This example shows how to command HMC6352 to read a RAM register by sending the 'g' command and the register address (0x7F). Note that this example does not show the process of reading the answer. See below for reading.



Example 3: This example shows how to write to a RAM register in the HMC6352 by sending the 'G' command, the register address (0x7F), and the data byte (0x55) to the sensor.



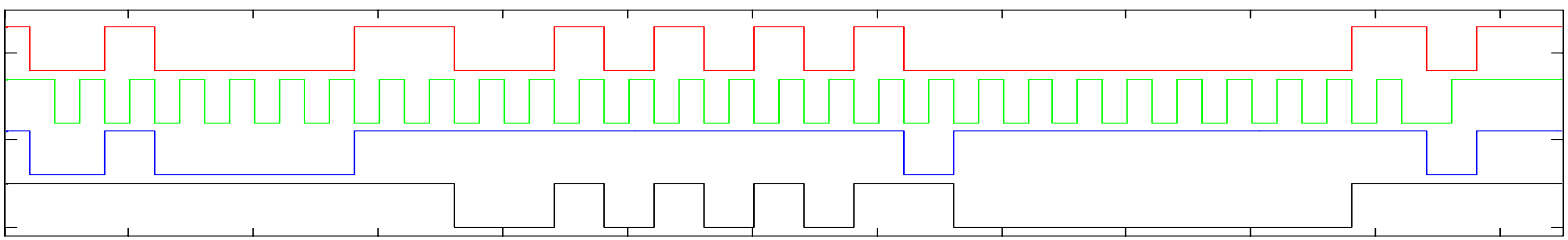
Example 4: This example shows how to read a single byte from the HMC6352. The Slave(HMC6352) continues to hold the SDA line low after the acknowledge (ACK) because the first bit of the data byte is a zero.



0x43
Read from this I2C address

0x55
Data

Example 5: This example shows how to read two bytes from HMC6352 (slave). The slave continues to hold the SDA line low after the acknowledge because the first bit of the data byte is a zero.

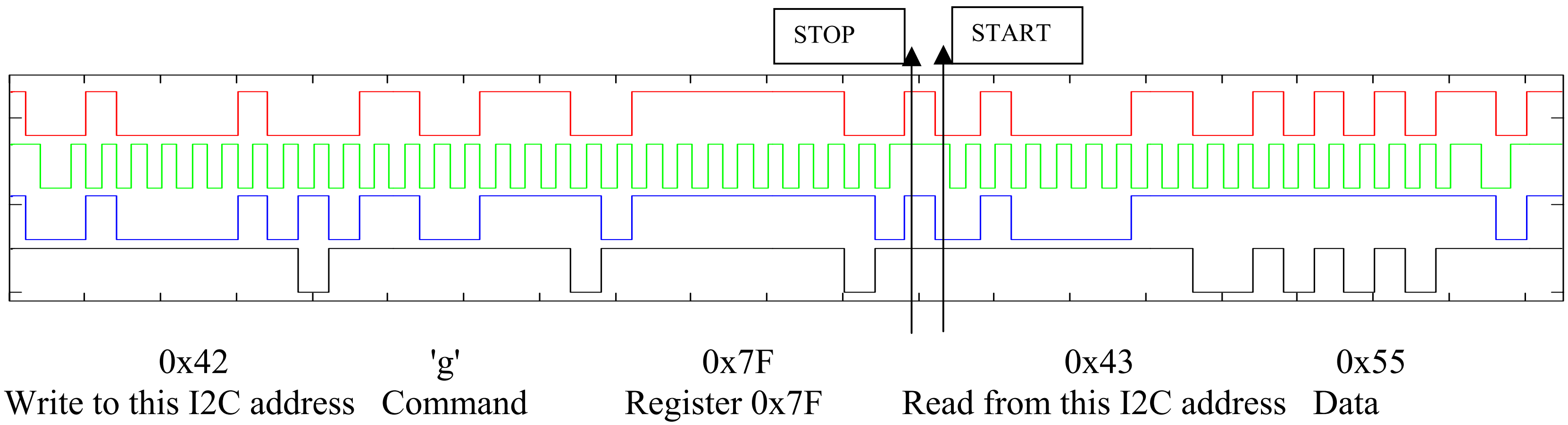


0x43
Read from this I2C address

0x55
Data

0x00
Data

Example 6: The final example shows how to read RAM register 0x7F. First perform a write operation to command the HMC6352 to read a RAM register and define which register to read (Example 2). The sensor puts the answer in the data buffer. Then perform a read operation to clock out the answer (Example 4). There is a Stop / Start event in between the write operation and the read operation. This example is just a combination of Examples 2 and 4, but it is provided to show that reading a register involves both a write and a read operation.

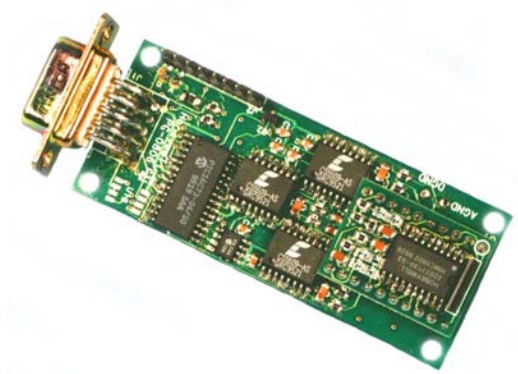


SENSOR PRODUCTS

SMART DIGITAL MAGNETOMETER

Features

- High Accuracy Over ±1 gauss, <0.5% Full Scale
- Range of ±2 gauss, <70 μgauss Resolution
- Three Axis (X, Y, Z) Digital Outputs
- 10 to 154 Samples Per Second, Selectable
- RS-232 or RS-485 Serial Data Interfaces
- PCB or Aluminum Enclosure Options
- 6-15 volt DC Unregulated Power Supply Interface



General Description

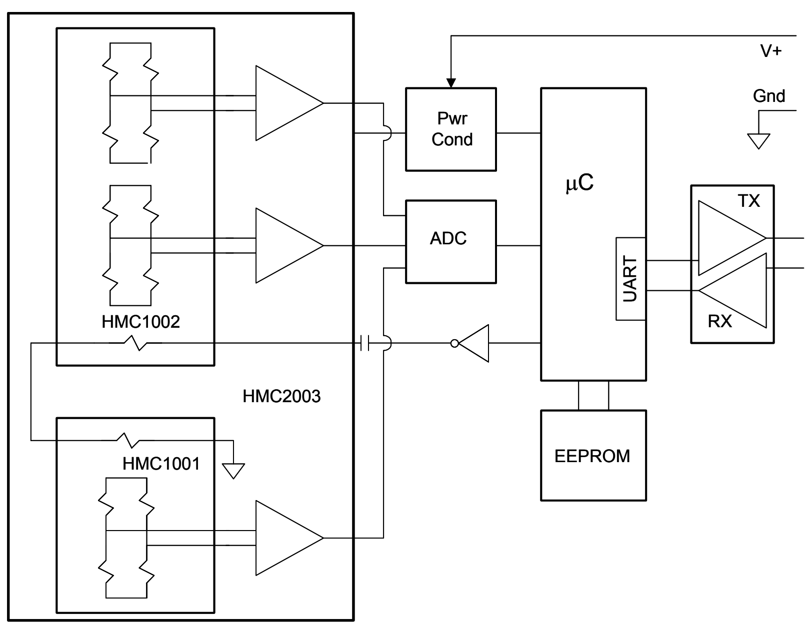
The Honeywell HMR2300 is a three-axis smart digital magnetometer to detect the strength and direction of an incident magnetic field. The three of Honeywell's magneto-resistive sensors are oriented in orthogonal directions to measure the X, Y and Z vector components of a magnetic field. These sensor outputs are converted to 16-bit digital values using an internal delta-sigma A/D converter. An onboard EEPROM stores the magnetometer's configuration for consistent operation. The data output is serial full-duplex RS-232 or half-duplex RS-485 with 9600 or 19,200 data rates.

A RS-232 development kit version is available that includes a windows compatible demo program, interface cable, AC adapter, and carrying case.

APPLICATIONS

- Attitude Reference
- Compassing & Navigation
- Traffic and Vehicle Detection
- Anomaly Detection
- Laboratory Instrumentation
- Security Systems

Block Diagram

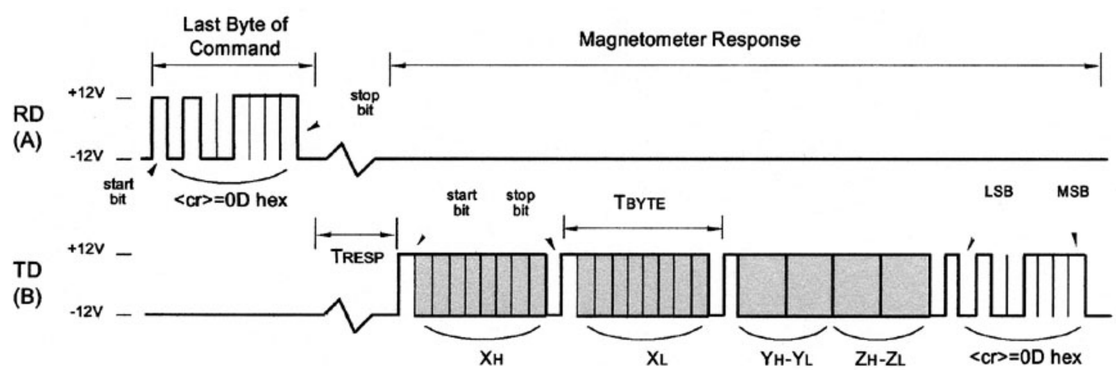


SPECIFICATIONS

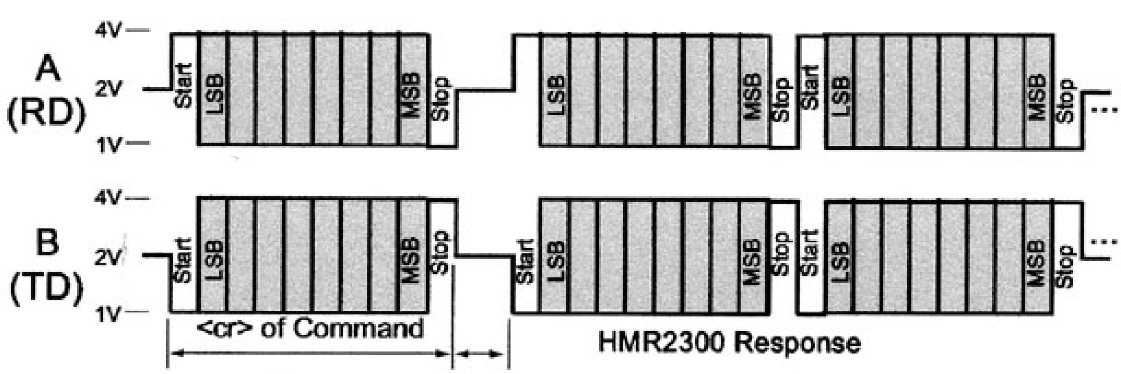
Characteristics	Conditions	Min	Typ	Max	Units
Power Supply					
Supply Voltage	Pin 9 referenced to Pin 5 (Ground)	6.5		15	Volts
Supply Current	Vsupply = 15V, with S/R = On		27	35	mA
Temperature					
Operating	Ambient	-40		+85	°C
Storage	Ambient, Unbiased	-55		125	°C
Magnetic Field					
Range	Full Scale (FS), Total Field Applied	-2		+2	gauss
Resolution	Applied Field to Change Output	67			micro-gauss
Accuracy	RSS of All Errors @+25°C ± 1 gauss ± 2 gauss		 0.01 1	 0.52 2	 %FS %FS
Linearity Error	Best Fit Straight Line @+25°C ± 1 gauss ± 2 gauss		 0.1 1	 0.5 2	 %FS %FS
Hysterisis Error	3 Sweeps Across ± 2 gauss @+25°C		0.01	0.02	%FS
Repeatability Error	3 Sweeps Across ± 2 gauss @+25°C		0.05	0.10	%FS
Gain Error	Applied Field for Zero Reading		0.05	0.10	%FS
Offset Error	Applied Field for Zero Reading		0.01	0.03	%FS
Temperature Effect	Coefficient of Gain		-600 ±114		ppm/°C
Power Supply Effect	From +6 to +15V with 1 gauss Applied Field		150		ppm/V
Mechanical					
Weight	PCB Only PCB and Non-Flanged Enclosure PCB and Flanged Enclosure		28 94 98		grams
Vibration	Operating, 5 to 10Hz for 2 Hours 10Hz to 2kHz for 30 Minutes		 10 2.0		 mm g

Characteristics	Conditions	Min	Typ	Max	Units
Digital I/O Timing	(See Timing Diagrams)				
T_{RESP}	*dd Commands (dd = Device ID)	1.9	2	2.2	msec
	*ddP		3	3.2	
	*ddR, *ddS, *ddT		6	6.2	
	*ddC		40	60	
	*ddQ		2+(ddx80)	2+Typ	
	*99 Commands		2+(ddx40)	2+Typ	
	*99Q		2+(ddx120)	2+Typ	
T_{DELAY}	*dd Commands (dd = Device ID)	39	40	41	msec
	*99 Commands		ddx40	2+Typ	
T_{BYTE}	9600		1.04		msec
	19,200		0.52		
$T_{STARTUP}$	Power Applied to End of Start-Up Message		50	80	msec

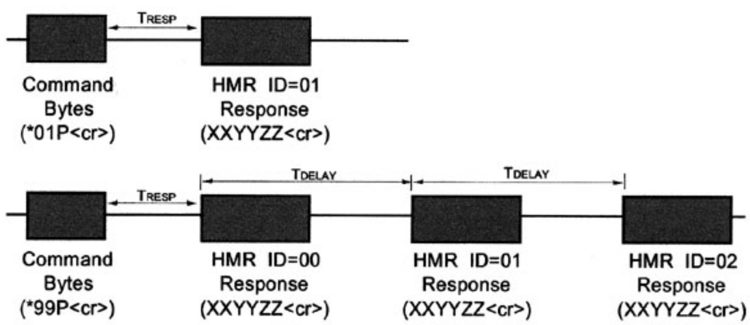
RS-232 COMMUNICATIONS – Figure1 (Timing is Not to Scale)



RS-485 COMMUNICATIONS – Figure 2 (Timing is Not to Scale)



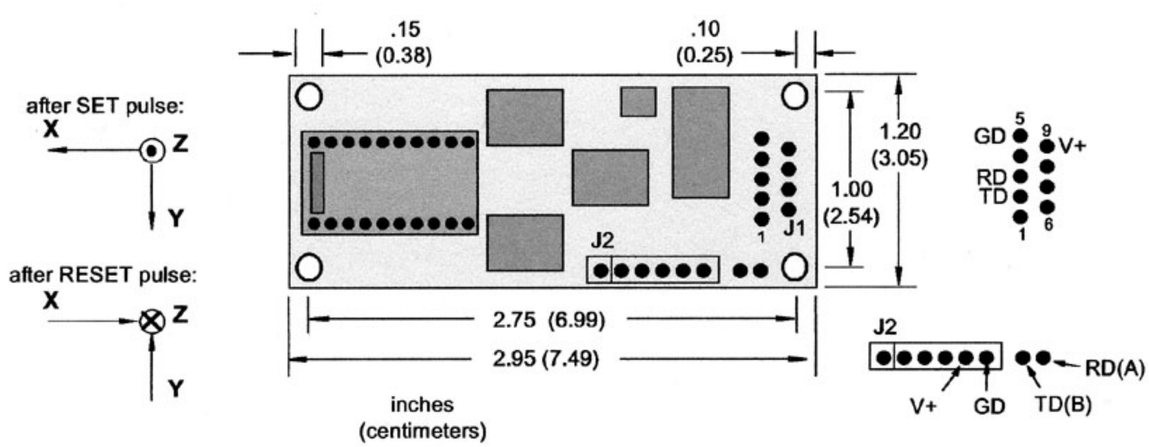
GLOBAL ADDRESS (*99) DELAY – Figure 3 (Timing is Not to Scale)



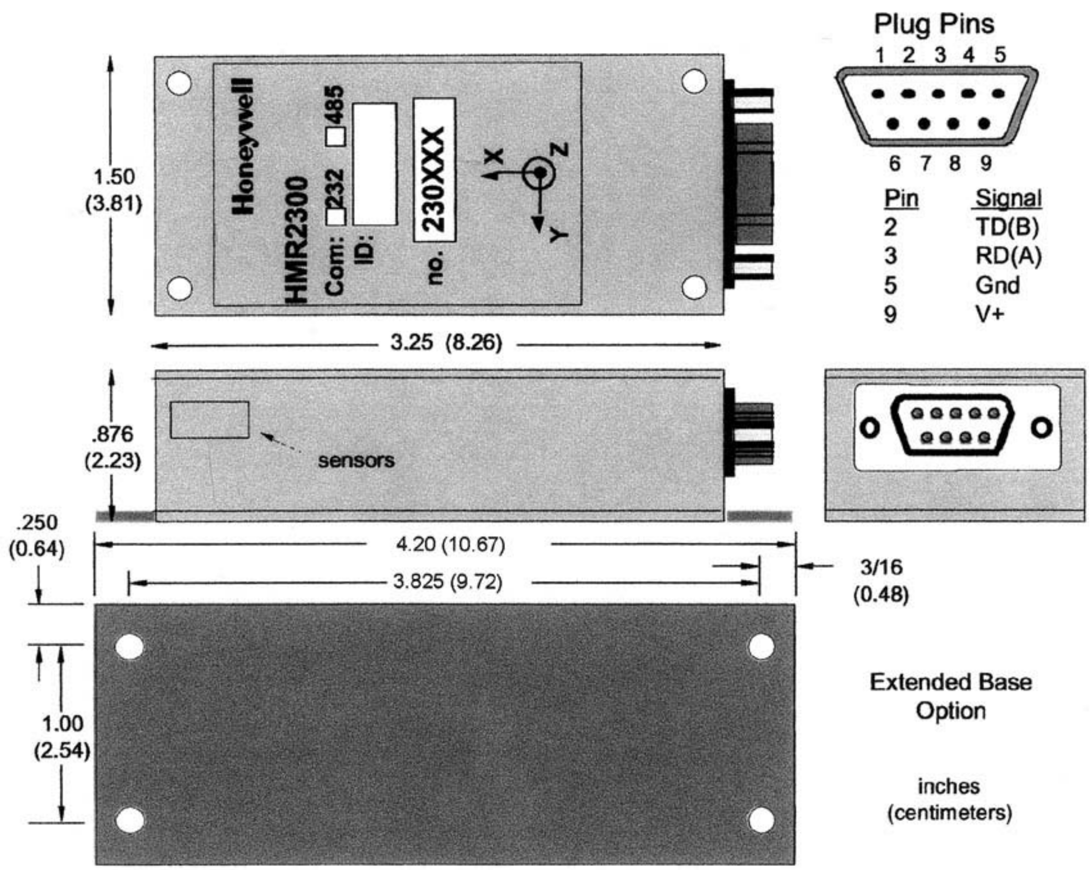
PIN CONFIGURATION

Pin Number	Pin Name	Description
1	NC	No Connection
2	TD	Transmit Data, RS-485 (B+)
3	RD	Receive Data, RS-485 (A-)
4	NC	No Connection
5	GND	Power and Signal Ground
6	NC	No User Connection (factory X offset strap +)
7	NC	No User Connection (factory Y offset strap +)
8	NC	No User Connection (factory Z offset strap +)
9	V+	Unregulated Power Input (+6 to +15 VDC)

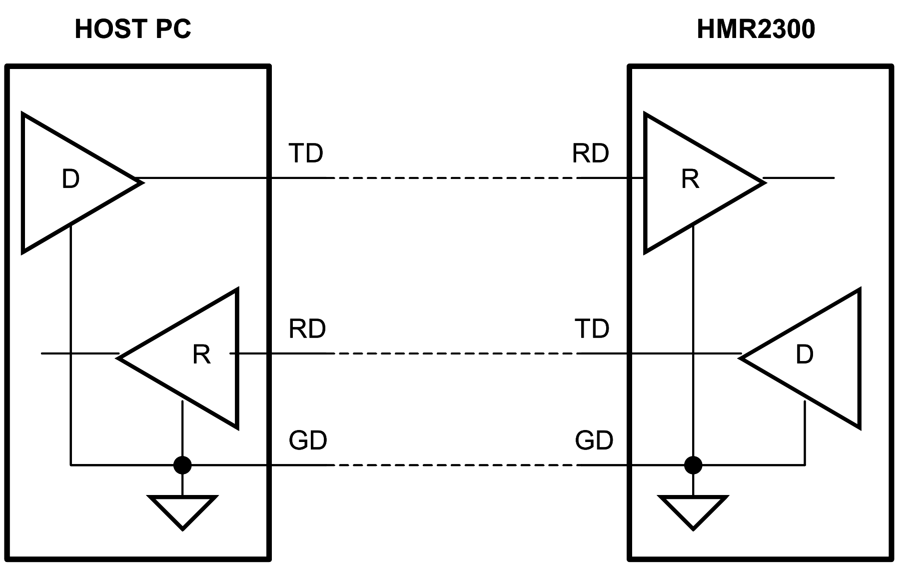
PCB DIMENSIONS AND PINOUT – Figure 4 (Connector Not Shown for Clarity)



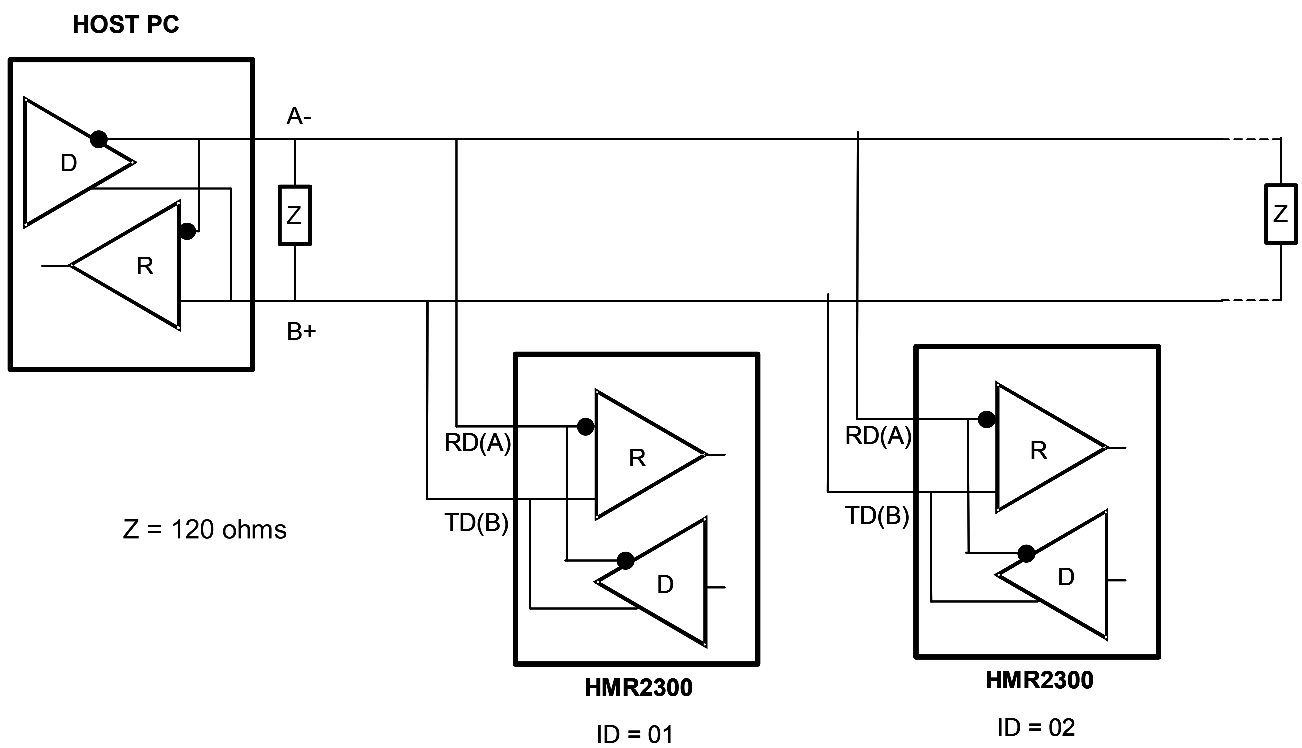
CASE DIMENSIONS – Figure 5



RS-232 UNBALANCED I/O INTERCONNECTS – Figure 6



RS-485 BALANCED I/O INTERCONNECTS – Figure 7



DATA COMMUNICATIONS

The RS-232 signals are single-ended undirectional levels that are sent received simultaneously (full duplex). One signal is from the host personal computer (PC) transmit (TD) to the HMR2300 receive (RD) data line, and the other is from the HMR2300 TD to the PC RD data line. When a logic one is sent, either the TD or RD line will drive to about +6 Volts referenced to ground. For a logic zero, the TD or RD line will drive to about –6 Volts below ground. Since the signals are transmitted and dependent on an absolute voltage level, this limits the distance of transmission due to line noise and signal to about 60 feet.

When using RS-485, the signals are balanced differential transmissions sharing the same lines (half-duplex). This means that logic one the transmitting end will drive the B line at least 1.5 Volts higher than the A line. For a logic zero, the transmitting end will drive the B line at least 1.5 Volts lower than the A line. Since the signals are transmitted as difference voltage level, these signals can withstand high noise environments or over very long distances where line loss may be a problem; up to 4000 feet. Note that long RS-485 lines should be terminated at both ends with 120-ohm resistors.

Another precaution on RS-485 operation is that when the HMR2300 is in a continuous output mode of operation, the host PC may have to send repeated escape and carriage return bytes to stop the stream of output data. If the host can detect a recieved carriage return byte (0D hex), and immediately send the escape-carriage return bytes; then a systematic stop of continuous output is likely. If manually sent, beware that the half-duplex nature of the interface corrupt the HMR2300 outbound data while attempting to get the stop command interleaved between the data.

As noted by the Digital I/O timing specification and Figure 3, the HMR2300 has a delayed response feature based on the programmed device ID in response to global address commands (*99….<cr>). Each HMR2300 will take its turn responding so that units do not transmit simultaneously (no contension). These delays also apply to the RS-232 interface versions of the HMR2300.

COMMAND INPUTS

A simple command set is used to communicate with the HMR2300. These commands can be automated; or typed in real-time while running communication software programs, such a windows hyperterminal.

Command	Inputs(1)	Response(2)	Bytes(3)	Description
Format	*ddWE *ddA *ddWE *ddB	ASCII_ON¬ BINARY_ON¬	9 10	ASCII – Output Readings in BCD ASCII Format (Default) Binary – Output Readings in Signed 16-bit Bianary Format
Output	*ddP *ddC Esc	{x, y, z reading} {x, y, z stream} {stream stops}	7 or 28 ... 0	P = Polled – Output a Single Sample (Default) C = Continuous – Output Readings at Sample Rate Escape Key – Stops Continuous Readings
Sample Rate	*ddWE *ddR=nnn	OK¬	3	Set Sample Rate to nnn Where: Nnn = 10, 20, 25, 30, 40, 50, 60, 100, 123, or 154 Samples/sec (Default = 20)
Set/Reset Mode	*ddWE *ddTN *ddWE *ddTF *ddWE *ddT	S/R_ON¬ S/R_OFF¬ {Toggle}	7 8 7 or 8	S/R Mode: TN – ON = Auto S/R Pulses (Default) TF – OFF = Manual S/R Pulses *ddT Toggles Command (Default = On)
Set/Reset Pulse	*dd]S *dd]R *dd]	SET¬ RST¬ {Toggle}	4 4 4	] Character – Single S/R:]S -> SET = Set Pulse]R -> RST = Reset Pulse Toggle Alternates Between Set and Reset Pulse
Device ID	*99ID= *ddWE *ddID=nn	ID=_nn¬ OK¬	7 3	Read Device ID (Default = 00) Set Device ID Where nn = 00 to 98
Baud Rate	*99WE *99!BR=S *99WE *99!BR=F	OK¬ BAUD_9600¬ OK¬ BAUD=_19,200¬	14 14	Set Baud Rate to 9600 bps (Default) Set Baud Rate to 19,200 bps (8 bits, no parity, 1 stop bit)
Zero Reading	*ddWE *ddZN *ddWE *ddZF *ddWE *ddZR	ZERO_ON¬ ZERO_OFF¬ {Toggle}	8 9 8 or 9	Zero Reading Will Store and Use Current as a Negative Offset so That the Output Reads Zero Field *ddZR Toggles Command
Average Readings	*ddWE *ddVN *ddWE *ddVF *ddWE *ddV	AVG_ON¬ AVG_OFF¬ {Toggle}	7 8 7 or 8	The Average Reading for the Current Sample X(N) is: Xavg=X(N)/2 + X(N-1)/4 + X(N-2)/8 + X(N-3)/16 + ... *ddV Toggles Command
Re-Enter Response	*ddWE *ddY *ddWE *ddN	OK¬ OK¬	3 3	Turn the “Re-Enter” Error Response ON (*ddY) or OFF (*ddN). OFF is Recommended for RS-485 (Default = ON)
Query Setup	*ddQ	{See Desc.}	62-72	Read Setup Parameters. Default: ASCII, POLLED, S/R ON, ZERO OFF, AVG OFF, R ON, ID=00, 20 sps
Default Settings	*ddWE *ddD	OK¬ BAUD=_9600¬	14	Change All Command Parameter Settings to Factory Default Values
Restore Settings	*ddWE *ddRST	OK¬ BAUD=_9600¬ *or* BAUD=_19,200¬	 14 16	Change All Command Parameter Settings to the Last User Stored Values in the EEPROM
Serial Number	*dd#	SER#_nnnn¬	22	Output the HMR2300 Serial Number
Software Version	*ddF	S/W_vers:_ nnnn¬	27	Output the HMR2300 Software Version Number
Hardware Version	*ddH	H/W_vers:_ nnnn¬	19	Output the HMR2300 Hardware Version Number
Write Enable	*ddWE	OK¬	3	Activate a Write Enable. This is required before commands: Set Device ID, Baud Rate, and Store Parameters.
Store Parameters	*ddWE *ddSP	DONE¬ OK¬	8	This writes all parameter settings to EEPROM. These values will be automatically restored upon power-up.
Too Many Characters	Wrong Entry	Re-enter¬	9	A command was not entered properly or 10 characters were typed after an asterisk (*) and before a <cr>.
Missing WE Entry	Write Enable Off	WE_OFF¬	7	This error response indicates that this instruction requires a write enable command immediately before it.

(1) All inputs must be followed by a <cr> carriage return, or Enter, key. Either upper or lower case letters may be used. The device ID (dd) is a decimal number between 00 and 99. Device ID = 99 is a global address for all units.
(2) The “¬” symbol is a carriage return (hex 0D). The “_” sign is a space (hex 20). The output response will be delayed from the end of the carriage return of the input string by 2 msec (typ.), unless the command sent as a global device ID = 99.

DATA FORMATS

The HMR2300 transmits each X, Y, and Z axis as a 16-bit value. The output data format can be either 16-bit signed binary (sign plus 15 bits) or a binary coded decimal (BCD) ASCII characters. The command *ddA will select the ASCII format and *ddB will select the binary format.

The order of ouput for the binary format is Xhi, Xlo, Yhi, Ylo, Zhi, Zlo. The binary format is more efficient for a computer to interpret since only 7 bytes are transmitted. The BCD ASCII format is easiest for user interpretation but requires 28 bytes per reading. There are limitations on the output sample rate (see table below) based on the format and baud rate selected. Examples of both binary and BCD ASCII outputs are shown below for field values between ±2 gauss.

Field (gauss)	BCD ASCII Value	Binary Value (Hex) High Byte	Low Byte
+2.0	30,000	75	30
+1.5	22,500	57	E4
+1.0	15,000	3A	98
+0.5	7,500	1D	4C
0.0	00	00	00
-0.5	-7,500	E2	B4
-1.0	-15,000	C3	74
-1.5	-22,500	A8	1C
-2.0	-30,000	8A	D0

Binary Format: 7 Bytes

X_H | X_L | Y_H | Y_L | Z_H | Z_L | <cr>

X_H = Signed Byte, X axis
X_L = Low Byte, X axis
<cr> = Carriage Return (Enter key), Hex Code = 0D

ASCII Format: 28 Bytes

SN | X1 | X2 | CM | X3 | X4 | X5 | SP | SP | SN | Y1 | Y2 | CM | Y3 | Y4 | Y5 | SP | SP | SN | Z1 | Z2 | CM | Z3 | Z4 | Z5 | SP | SP |<cr>

The ASCII characters will be readable on a monitor as sign decimal numbers. This format is best when the user is interpreting the readings.

PARAMETER SELECTION VERSUS OUTPUT SAMPLE RATE

Sample Rate (sps)	ASCII		Binary		f_{3dB} (Hz)	Notch (Hz)	Command Input Rate – min. (msec)
	9600	19,200	9600	19,200			
10	yes	yes	yes	yes	17	50/60	20
20	yes	yes	yes	yes	17	50/60	20
25	yes	yes	yes	yes	21	63/75	16
30	yes	yes	yes	yes	26	75/90	14
40	no	yes	yes	yes	34	100/120	10
50	no	yes	yes	yes	42	125/150	8
60	no	no	yes	yes	51	150/180	7
100	no	no	yes	yes	85	250/300	4
123	no	no	no	yes	104	308/369	3.5
154	no	no	no	yes	131	385/462	3

DEVICE ID

The Device ID command (*ddID=nn) will change the HMR2300 ID number. A Write Enable (*ddWE) command is required before the device ID can be changed. This is required for RS-485 operation when more than one HMR2300 is on a network. A Device ID = 99 is universal and will simultaneously talk to all units on a network.

BAUD RATE COMMAND

The Baud Rate command (*dd!BR=F or S) will change the HMR2300 baud rate to either fast (19,200 baud) or slow (9600 baud). A Write Enable (*ddWE) command is required before the baud rate can be changed. The last response after this command has been accepted will be either BAUD=9600 or BAUD=19,200. This will indicate to the user to change to the identified new baud rate before communications can resume.

ZERO READING COMMAND

The Zero Reading command (*ddZN) will take a magnetic reading and store it in the HMR2300's microcontroller. This value will be subtracted from subsequent readings as an offset. The zero reading will be terminated with another command input(*ddZF) or a power down condition. This feature is useful for setting a reference attitude or nulling the earth's field before anomaly detection.

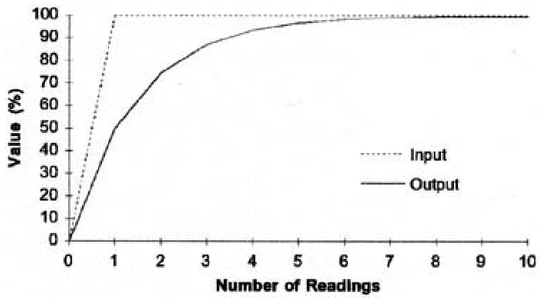
SET/RESET AND AVERAGE COMMANDS

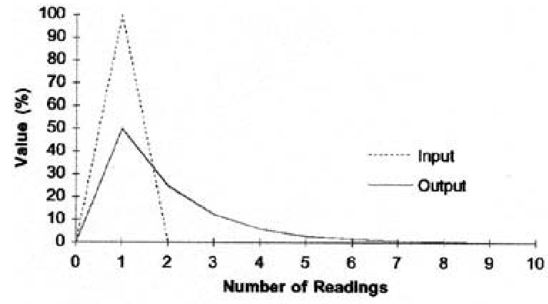
The set-reset function generates a current/magnetic field pulse to each sensor to realign the permalloy thin film magnetization. This yields the maximum output sensitivity for magnetic sensing. This pulse is generated inside the HMR2300 and consumes less than 1mA typically. The Set/Reset Mode command (*ddTN or *ddT) activates an internal switching circuit that flips the current in a "Set" and "Reset" condition. This cancels out any temperature drift effects and ensures the sensors are operating in their most sensitive region.

Fluctuations in the magnetic readings can be reduced by using the Average Readings commands (*ddVN or *ddV). These commands provide a low pass filter effect on the output readings that reduces noise due to Set/Reset switching and other environmental magnetic effects. The two figures below show the average readings effect for step and impulse responses.

Switching the set-reset state is not required to sense magnetic fields. A single Set (or Reset) pulse will maximize the output sensitivity and it will stay that way for months or years. To turn off the internal switching, enter the command *ddTF or *ddT. In this state the sensors are either in a Set or Reset mode. If the HMR2300 is exposed to a large magnetic field (>10 gauss), then another set pulse is required to maximize output sensitivity.

In the Set mode, the direction of the sensitive axis' are shown on the enclosure label and the board dimensions figure. In the Reset mode, the sensitive field directions are opposite to those shown. By typing *dd], the user can manually activate a Set or Reset pulse. The S/R pulse commands can be used the continuous read mode to flip between a Set and Reset state. Note that the first three readings immediately after these commands will be invalid due to the uncertainty of the current pulse to the sensor sample time.





DEFAULT AND RESTORE COMMANDS

The Defaut Settings command (*ddD) will force the HMR2300 to all the default parameters. This will not be a permanent change unless a Store Parameter command (*ddSP) is issued after the Write Enable command. The Restore Settings command (*ddRST) will force the HMR2300 to all the stored parameters in the EEPROM.

OUTPUT SAMPLE RATES

The sample rate can be varied from 10 samples per second (sps) to 154 sps using the *ddR=nnn command. Each sample contains an X, Y, and Z reading and can be outputted in either 16-bit signed binary or binary coded decimal (BCD) ASCII. The ASCII format shows the standard numeric characters displayed on the host computer display. Some sample rates may have restrictions on the format and baud rate used, due to transmission time constraints.

There are 7 Bytes transmitted for every reading binary format and 28 Bytes per reading in ASCII format. Transmission times for 9600 baud are about 1 msec/Byte and for 19,200 baud are about 0.5msec/Byte. The combinations of format and and baud rate selections are shown in the above Table. The default setting of ASCII format and 9600 baud will only transmit correctly up to 30 sps. Note the HMR2300 will output a higher data settings, but the readings may be incorrect and will be at alower output rate than selected.

For higher sample rates (>60 sps), it is advised that host computer settings for the terminal preferences be set so a line feed <lf> is not appended to the sent commands. This slows down the reception of data, and it will not be able to keep up with the incoming data stream.

INPUT SIGNAL ATTENUATION

Magnetic signals being measured will be attenuated based on the sample rate selected. The bandwidth, defined by the 3dB point, is shown in the above Table for each sample rate. The default rate of 20 sps has a bandwidth of 17Hz. The digital filter inside the HMR2300 is the combination of a comb filter and a low pass filter. This provides a linear phase response with a transfer function that has zeros in it.

When the 10 or 20 sps rate is used, the zeros are at the line frequencies of 50 and 60 Hz. These zeros provide better than 125 dB rejection. All multiples of the zeros extend throughout the transfer function. For example, the 10 and 20 sps rate has zeros at 50, 60, 100, 120, 150, 180, ... Hz. The multiples of the zeros apply to all the sample rates against the stated notch frequencies in the above Table.

COMMAND INPUT RATE

The HMR2300 limits how fast the command bytes can be recieved based on the sample rate selected. The above Table shows the minimum time between command bytes for the HMR2300 to correctly read them. This is usually not a problem when the user is typing the commands from the host computer. The problem could arise from an application program outputting command bytes too quickly.

CIRCUIT DESCRIPTION

The HMR2200 Smart Digital Magnetometer contains all the basic sensors and electronics to provide digital indication of magnetic field strength and direction. The HMR2300 has all three axis of magnetic sensors on the far end of the printed circuit board, away from the J1 and J2 connector interfaces. The HMR2300 uses the circuit board mounting holes or the enclosure surfaces as the reference mechanical directions. The complete HMR2300 PCB assembly consists of a mother board, daughter board, and the 9-pin D-connector (J1).

The HMR2300 circuit starts with Honeywell HMC2003 3-Axis Magnetic Sensor Hybrid to provide X, Y, and Z axis magnetic sensing of the earth's field. The HMC2003 contains the AMR sensing bridge elements, a constant current source bridge supply, three precision instrumentation amplifiers, and factory hand-selected trim resistors optimized for performance for magnetic field gain and offset. The HMC2003 is a daughter board that plugs into the HMC2300 motherboard, and the hybrid analog voltages from each axis is into analog multiplexors and then into three 16-bit Analog to Digital Converters (ADCs) for digitization. No calibration is necessary as the HMC2003 hybrid contains all the compensation for the sensors, and the set/reset routine handles the temperature drift corrections. A microcontroller integrated circuit receives the digitized magnetic field values (readings) by periodically querying the ADCs and performs any offset corrections. This microcontroller also performs the external serial data interface and other housekeeping functions. An onboard EEPROM integrated circuit is employed to retain necessary setup variables for best performance.

The power supply for the HMR2300 circuit is regulated +5 volt design (LM2931M) with series polarity power inputs diodes in case of accidental polarity reversal. A charge pump circuit is used to boost the regulated voltage for the set/reset pulse function going to the set/reset straps onboard the HMC2003. Transient protection absorbers are placed on the TD, RD, and V+ connections to J1.

APPLICATIONS PRECAUTIONS

Several precautions should be observed when using magnetometers in general:

- The presence of ferrous materials, such as nickel, iron, steel, and cobalt near the magnetometer will create disturbances in the earth's magnetic field that will distort the X, Y, and Z field measurements.
- The presence of the earth's magnetic field must be taken into account when measuring other magnetic fields.
- The variance of the earth's magnetic field must be accounted for in different parts of the world. Differences in the earth's field are quite dramatic between North America, South America and the Equator region.
- Perming effects on the HMR2300 circuit board need to be taken into account. If the HMR2300 is exposed to fields greater than 10 gauss, then it is recommended that the enclosure/circuit boards be degaussed for highest sensitivity and resolution. A possible result of perming is a high zero-field output indication that exceeds specification limits. Degaussing wands are readily available from local electronics tool suppliers and are inexpensive. Severe field offset values could result if not degaussed.

NON-FERROUS MATERIALS

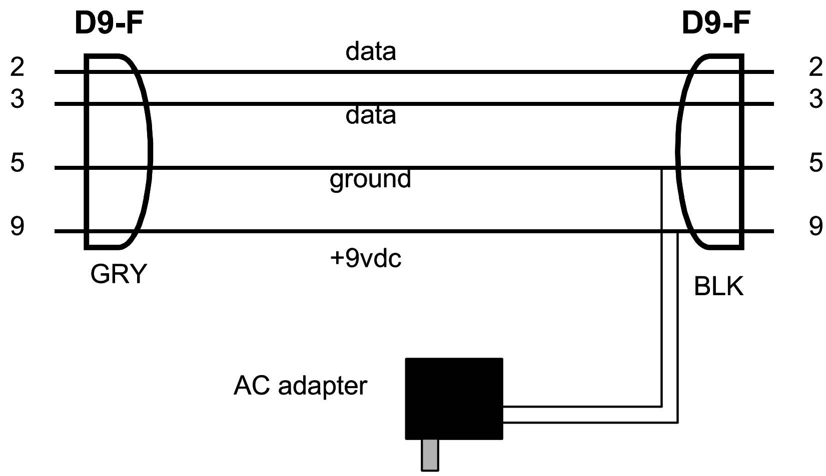
Materials that do not affect surrounding magnetic fields are: copper, brass, gold, aluminum, some stainless steels, silver, tin, silicon, and most non-metals.

HANDLING PRECAUTIONS

The HMR2300 Smart Digital Magnetometer measures fields within 2 gauss in magnitude with better than 0.1 milli-gauss resolution. Computer floppy disks (diskettes) store data with field strengths of approximately 10 gauss. This means that the HMR2300 is many times more sensitive than common floppy disks. Please treat the magnetometer with at least the same caution as your diskettes by avoiding motors, CRT video monitors, and magnets. Even though the loss of performance is recoverable, these magnetic sources will interfere with measurements.

DEMONSTRATION PCB MODULE KIT

The HMR2300 Demonstration Kit includes additional hardware and Windows software to form a development kit for with the smart digital magnetometer. This kit includes the HMR2300 PCB and enclosure, serial port cable with attached AC adapter power supply, and demo software plus documentation on a compact disk (CD). The figure below shows the schematic of the serial port cable with integral AC adapter. There will be three rotary switches on the AC adapter. These should be pointed towards the positive (+) polarity, +9 volts, and 120 or 240 VAC; depending your domestic supply of power.



ORDERING INFORMATION

Ordering Number	Product
HMR2300-D00-232	PCB Only (No Enclosure), RS-232 I/O
HMR2300-D00-485	PCB Only (No Enclosure), RS-485 I/O
HMR2300-D20-232	Flush-Base Enclosure, RS-232 I/O
HMR2300-D20-485	Flush-Base Enclosure, RS-485 I/O
HMR2300-D21-232	Extended-Base Enclosure, RS-232 I/O
HMR2300-D21-485	Extended-Base Enclosure, RS-485 I/O
HMR2300-D20-232-DEMO	Demo Kit, Flush-Base Enclosure, RS-232 I/O
HMR2300-D21-232-DEMO	Demo Kit, Extended-Base Enclosure, RS-232 I/O

900139 02-04 Rev. H

THREE-AXIS STRAPDOWN MAGNETOMETER HMR2300r

FEATURES

- Strapdown Magnetometer Replaces Bulky Fluxvalves
- Microprocessor Based Smart Sensor
- Range of ±2 Gauss—<70 µGauss Resolution
- Readings can Achieve Heading Resolution of 0.02°
- Rate Selectable—10 to 154 Samples/Sec.
- Small Size: 2.83 in.—Fits in ML-1 Style Enclosure
- Repeatable and Reliable—MTBF >50,000 hours

APPLICATIONS

- Navigation Systems—Avionics and Marine
- Fluxvalve Replacement
- Can be Slaved to AHRS System
- GPS Backup Systems
- Remote Vehicle Monitoring
- Unpiloted Air Vehicles (UAVs)
- Navigation/Attitude for Satellites

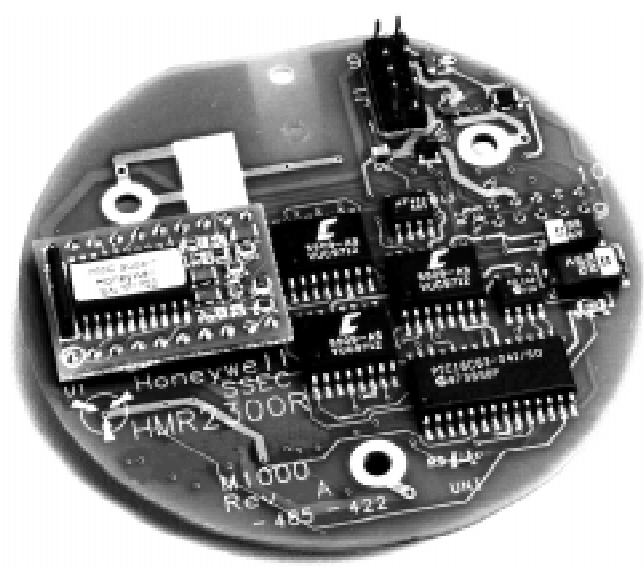
GENERAL DESCRIPTION

Honeywell's three-axis strapdown magnetometer detects the strength and direction of the earth's magnetic field and communicates the x, y, and z component directly via serial bus. The HMR2300r is compliant with applicable MIL-STD-810E requirements for military and commercial flight systems (see Table 6). It was designed to be a replacement for bulky fluxvalve magnetic sensors commonly used in aviation systems.

The HMR2300r strapdown magnetometer provides an excellent replacement of conventional fluxvalve sensors, commonly used in aviation systems today. The HMR2300r offers higher reliability (MTBF >50,000 hours) that reduces maintenance and repair cost. Since the design is strapdown, as opposed to a gimballed fluxvalve, it has no moving parts to damage or wear out during severe flight conditions. Low cost, high sensitivity, fast response, small size, and reliability are advantages over mechanical or other magnetometer alternatives. With an extremely low magnetic field sensitivity and a user configurable command set, these sensors solve a variety of problems in custom applications.

A command set is provided (see Table 4) to configure the data sample rate, output format, averaging and zero offset. An on-board EEPROM stores any configuration changes for next time power-up. In addition, the user has 55 bytes of EEPROM locations available for data storage. Other commands perform utility functions like baud rate, device ID and serial number. Also included in the HMR magnetometer is a digital filter with 50/60 Hz rejection to reduce ambient magnetic interference.

A unique switching technique is applied to the solid-state magnetic sensors to eliminate the effects of past magnetic history. This technique cancels out the bridge offset as well as any offset introduced by the electronics. The data is serially output at either 9,600 or 19,200 baud, using the RS-422 or RS-485 standard. The RS-485 standard allows connection of up to 32 devices on a single wire pair up to 4,000 feet in length. An HMR address can be stored in the on-board EEPROM to assign one of thirty-two unique ID codes to allow direct line access. An internal microcontroller handles the magnetic sensing, digital filtering, and all output communications eliminating the need for external trims and adjustments. Standard RS-422 or RS-485 drivers provide compliant electrical signalling.



1 Gauss (G) = 1 Oersted (in air), 1G = 79.58 A/m
1G = 10E-4 Tesla, 1G = 10E5 gamma
ppm - parts per million

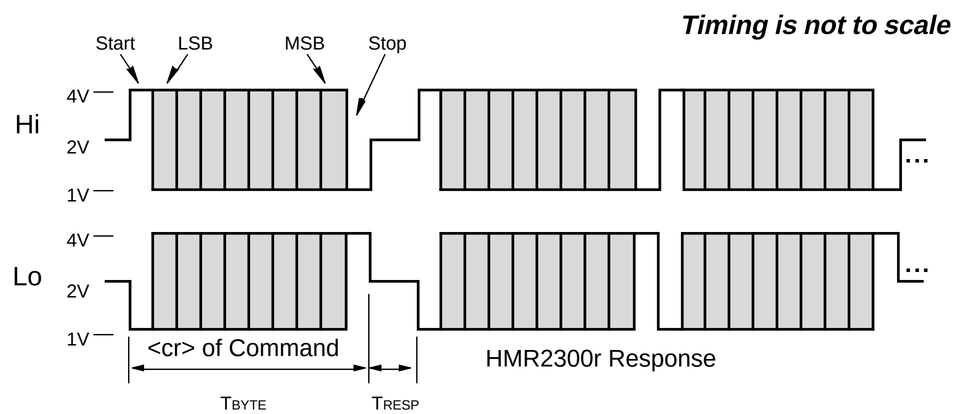
OPERATING SPECIFICATIONS—Table 1

Characteristic	Conditions	Min	Typ	Max	Unit
Supply Voltage	Pin 9 referenced to pin 5	6.5		15	Volts
Supply Current	Vsupply=15V (with 120 Ω termination)		45	55	mA
Operating Temperature	Ambient	-40		85	° C
Storage Temperature	Ambient, unbiased	-55		125	° C
Field Range	Full scale (FS)—total applied field	-2		+2	Gauss
Linearity Error	Best fit straight line ±1 Gauss		0.1 1	0.5 2	%FS
Hysteresis Error	3 sweeps across ±2 Gauss @ 25 ° C		0.01	0.02	%FS
Repeatability Error	3 sweeps across ±2 Gauss @ 25 ° C		0.05	0.10	%FS
Gain Error	Applied field for zero reading		0.05	0.10	%FS
Offset Error	Applied field for zero reading		0.01	0.03	%FS
Accuracy	RSS of all errors ±1 Gauss		0.12 1	0.52 2	%FS
Resolution	Applied field to change output	67			µGauss
Axis Alignment	Variation to 90 degrees		±1	±2	degree
Noise level	Output variation in fixed field		0.07	±0.13	mGauss
Temperature Effects	Coefficient of gain Coefficient of offset (with S/R=ON)		-0.06 ±0.01		%/° C
Power Supply Effect	From 6 to 15V with 1 Gauss applied		150		ppm/V
Vibration (operating)	5 to 10Hz for 2 hrs. 10Hz to 2KHz for 30 min.		10 2.0		mm g force
Max. Exposed Field	No perming effect on zero reading			10	Gauss
Weight	Board only			40	grams

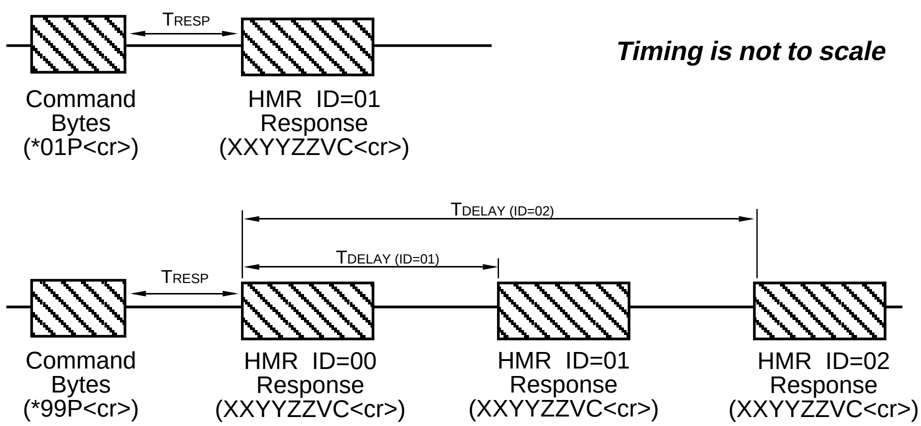
TIMING SPECIFICATIONS—Table 2

Characteristic	Conditions	Min	Typ	Max	Unit
TRESP	Timing Diagrams (Figs. 1,2) *dd command (dd=Device ID) *ddP *ddRST *ddC *99 command (exceptions below) *ddQ *99Q	1.9	2.2 2.2 6 40 2 + (dd x 40) 2 + (dd x 80) 2 + (dd x 120)	3.2 3.2 6.5 60 2 + Typ 2 + Typ 2 + Typ	msec
TDELAY	Timing Diagram (Fig. 2) *99 comand (dd=Device ID)		2+ (dd x 40)	2 + Typ	msec
TBYTE	Timing Diagrams (Fig. 1) 9600 19200		1.04 0.52		msec
TSTARTUP	Power Applied to start of Start-Up message	28	80	140	msec

RS-485 and RS-422 COMMUNICATIONS—Figure 1



GLOBAL ADDRESS (*99) DELAY—Figure 2



Sample Rate (sps)	ASCII		Binary		f3dB (Hz)	Notch (Hz)	Continuous Reading Period (msec)
	9600	19200	9600	19200			
10	*yes*	*yes*	*yes*	*yes*	17	50/60	101
20	↓	↓	↓	↓	17	50/60	51
25	↓	↓	↓	↓	21	63/75	41.5
30	↓	↓	↓	↓	26	75/90	35
40		↓	↓	↓	34	100/120	24
50		↓	↓	↓	42	125/150	19.6
60	**DATA**		↓	↓	51	150/180	16.1
100			↓	↓	85	250/300	9.8
123	**INVALID**			↓	104	308/369	8.1
154				↓	131	385/462	6.5

Parameter Selections verses Output Sample Rate—Table 3

COMMAND INPUTS—Table 4

A simple command set is used to communicate with the HMR. These commands can be typed in through a standard keyboard while running any communications software such as HyperTerminal® in Windows®.

Command	Inputs [1]	Response [2]	Bytes[3]	Description
Format	*ddWE *ddA *ddWE *ddB	ASCII_ON ← BINARY_ON ←	9 10	ASCII - Output readings in BCD ASCII format. Binary - Output signed 16 bit binary format. (default)
Output	*ddP *ddC Esc	{x, y, z reading} {x, y, z stream} {stream stops}	9 or 28 ... 0	P=Polled - Output a single sample. C=Continuous - Output readings at sample rate. (default) Escape key - Stop continuous readings.
Sample Rate	*ddWE *ddR=nnn	OK ←	3	Set sample rate to nnn where: nnn= 10, 20, 25, 30, 40, 50, 60, 100, 123, or 154 samples/sec (default 30 sps)
Set/Reset Mode	*ddWE *ddTN *ddWE *ddTF *ddWE *ddT	S/R_ON ← S/R_OFF ← {Toggle}	7 8 7 or 8	S/R mode: TN -> ON=automatic S/R pulses (default) TF -> OFF=manual S/R pulses
Set/Reset Pulse	*dd]S *dd]R *dd]	SET ← RST ← {Toggle}	4 4 4	] character - single S/R:]S -> SET=set pulse]R -> RST=reset pulse Toggle alternates between SET and RESET pulse.
Device ID	*99ID= *ddWE *ddID=nn	ID=_n n ← OK ←	7 3	Read device ID (default ID=00) Set device ID where nn=00 to 98
Baud Rate	*99WE *99!BR=S *99WE *99!BR=F	OK ← BAUD=_9600 ← OK ← BAUD=_19,200 ←	14 16	Set baud rate to 9600 bps. Set baud rate to 19,200 bps. (default) (8 bits, no parity, 1 stop bit)
Zero Reading	*ddWE *ddZN *ddWE *ddZF *ddWE *ddZR	ZERO_ON ← ZERO_OFF ← {Toggle}	8 9 8 or 9	Zero Reading will store and use current reading as a negative offset so that the output reads zero field *ddZR toggles command. (default=OFF)
Average Readings	*ddWE *ddVN *ddWE *ddVF *ddWE *ddV	AVG_ON ← AVG_OFF ← {Toggle}	7 8 7 or 8	The average reading for the current sample X(N) is: Xavg = X(N)/2 + X(N-1)/4 + X(N-2)/8 + X(N-3)/16 + ... *ddV toggles command. (default=OFF)
Re-enter Response	*ddWE *ddY *ddWE *ddN	OK ← OK ←	3 3	Turn the "Re-enter" error response ON (*ddY) or OFF (*ddN). OFF is recommended for RS-485 (default=ON)
Query Setup	*ddQ	{see Description}	62-72	Read setup parameters. default: binary, Continuous, S/R ON, ZERO OFF, AVG OFF, R ON, ID=00, 30 sps
Default Settings	*ddWE *ddD	OK ← BAUD=_19,200 ←	16	Change all command parameter settings to factory default values.
Restore Settings	*ddWE *ddRST	OK ← BAUD=_9600 *or* BAUD=_19,200	 14 16	Change all command parameter settings to the last user stored values in the EEPROM.
Serial Number	*dd#	SER#_nnnn ←	22	Output the HMR2300r serial number.
Software Version	*ddF	S/W_vers:_ nnnn ←	27	Output the HMR2300r software version number.
Hardware Version	*ddH	H/W_vers:_ nnnn ←	19	Output the HMR2300r hardware version number.
Write Enable	*ddWE	OK ←	3	Activate a write enable. This is required before commands like Set Device ID, Baud Rate, and others shown in table.
Store Parameters	*ddWE *ddSP	DONE ← OK ←	8	This writes all parameter settings to EEPROM. These values will be automatically restored upon power-up.
Too Many Characters	Wrong Entry	Re-enter ←	9	A command was not entered properly or 10 characters were typed after an asterisk (*) and before a <cr>.
Missing WE Entry	Write Enable Off	WE_OFF ←	7	This error response indicates that this instruction requires a write enable command immediately before it.

(1) All inputs must be followed by a <cr> carriage return, or Enter, key. Either upper or lower case letters may be used. The device ID (dd) is a decimal number between 00 and 99. Device ID=99 is a global address for all units.

(2) The "←"symbol is a carriage return (hex 0D). The "_" symbol is a space (hex 20). The output response will be delayed from the end of the carriage return of the input string by 2 msec (typ.), unless the command was sent as a global device ID=99 (see TDELAY).

DATA FORMATS

The HMR2300 transmits each x, y, and z axis as a 16-bit value. The output data format can either be 16-bit signed binary (sign + 15-bits) or binary coded decimal (BCD) ASCII characters. The command *ddA will select the ASCII format and *ddB will select the binary format.

The order of output for the binary format is: Xhi, Xlo, Yhi, Ylo, Zhi, Zlo. The binary format is more efficient for a computer to interpret since only 9 bytes are transmitted. The BCD ASCII format is easiest for user interpretation but requires 28 bytes per reading. There are limitations on the sample rate based on the format and baud rate selected (see Table 3). Examples of both binary and BCD ASCII outputs are shown below for field values between ±2 Gauss.

Field	BCD ASCII	Binary Value (Hex)	
(Gauss)	Value	High Byte	Low Byte
+2.0	30,000	75	30
+1.5	22,500	57	E4
+1.0	15,000	3A	98
+0.5	7,500	1D	4C
0.0	00	00	00
-0.5	- 7,500	E2	B4
-1.0	-15,000	C3	74
-1.5	-22,500	A8	1C
-2.0	-30,000	8A	D0

Output Readings—Table 5

Binary Format: 9 bytes

X_H | X_L | Y_H | Y_L | Z_H | Z_L | Validity | Checksum | <cr>

X_H = signed high byte, x axis
X_L = low byte, x axis
Y_H = signed high byte, y axis
Y_L = low byte, y axis
Z_H = signed high byte, z axis
Z_L = low byte, z axis
Validity = Validity byte is described below
Checksum= Checksum is the ones complement of the sum of the first seven bytes
<cr> = carriage return (Enter Key), Hex code = 0D

Output data format is in counts (sign + 15 bit magnitude)
Scale factor is 1 gauss = 15,000 counts
Output measurement range = ± 30,000 counts

The binary characters will be unrecognizable on a monitor and will appear as strange symbols. This format is best when a computer is interpreting the readings.

Checksum = ones complement of the sum
$(X_H + X_L + Y_H + Y_L + Z_H + Z_L + \text{Validity})$

The Validity byte indicates that the onboard microprocessor has properly executed code routines for the selected mode of operation. The various user selectable modes are shown in the table below with the corresponding validity byte and associated ASCII character.

Zero Readings	Average Readings	Auto Set/Reset	Validity Character	Validity byte
off	off	off	O	4F
off	off	on	S (1)	53
off	on	off	O	4F
off	on	on	V	56
on	off	off	P	50
on	off	on	T	54
on	on	off	P	50
on	on	on	W	57

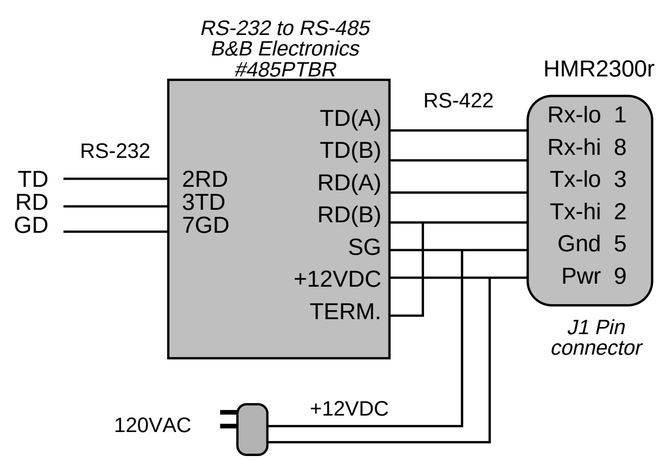
(1) Default mode. This mode can be reset using the *99we, *99rst command sequence.

ASCII Format: 28 bytes

SN | X_1 | X_2 | CM | X_3 | X_4 | X_5 | SP | SP | SN | Y_1 | Y_2 | CM | Y_3 | Y_4 | Y_5 | SP | SP | SN | Z_1 | Z_2 | CM | Z_3 | Z_4 | Z_5 | SP | SP | <cr>

The ASCII characters will be readable on a monitor as signed decimal numbers. This format is best when the user is interpreting the readings.

<cr> = carriage return (Enter Key), Hex code = 0D
SP = space, Hex code = 20
SN (sign) = - if negative, Hex code = 2D
SP if positive, Hex code = 20
CM (comma) = , if leading digits are not zero, Hex code = 2C
SP if leading digits are zero, Hex code = 20
X_1, X_2, X_3, X_4, X_5 = Decimal equivalent ASCII digit
X_1, X_2, X_3 = SP if leading digits are zero, Hex code = 20



INTERFACE CONVERTER TO RS-232—FIGURE 3

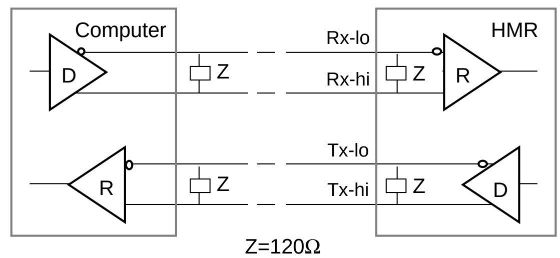
DATA COMMUNICATIONS

The RS-422 signals are balanced differential signals that can send and receive simultaneously (full-duplex). The RS-485 signals are also balanced differential levels but the transmit and receive signals share the same two wires. This means that only one end of the transmission line can transmit data at a time and the other end must be in a receive mode (half-duplex).

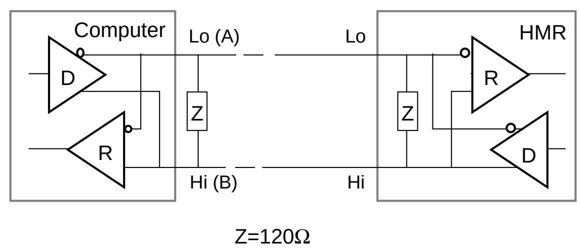
The RS-422 and RS-485 lines must be terminated at both ends with a 120 ohm resistor to reduce transmission errors. There are termination resistors built into the HMR2300r as shown in Figures 4 and 5.

The signals being transmitted are not dependent on the absolute voltage level on either Lo or Hi but rather a difference voltage. That is, when a logic one is being transmitted, the Tx line will drive about 1.5 volts higher than the Rx line. For a logic zero, the Lo line will drive about 1.5 volts lower than the Hi line. This allows signals to be transmitted in a high noise environment, or over very long distances, where line loss may otherwise be a problem—typically 4,000 feet. These signals are also slew-rate limited for error-free transmission. The receiver has a common mode input range of -7 to +12 volts. The signal connections are shown in Figure 6.

Note: When the HMR2300r is in a continuous read mode on the RS-485 bus, it may be necessary to enter several escape keys to stop the readings. If the computer taking the readings can detect a carriage return code and send the escape code immediately after it, then a systematic stop reading will occur. If an operator is trying to stop readings using the keyboard, then several (if not many) escape key entries must be given, since the RS-485 lines share the same wires for transmit and receive. If an escape key is entered during the time data is sent from the HMR2300r, then the two will produce an erroneous character that will not stop the data stream. The data stream stop only when the escape key is pressed during the time the HMR2300r is not transmitting.



RS-422 Balanced (full-duplex)—Figure 4



RS-485 Balanced (half-duplex)—Figure 5

PINOUT DIAGRAMS—FIGURE 6

J1 Pins

+6.5 to +15VDC power - 9	10 - nc
connected to P1 pin 6 - 7	8 - Rx-hi (RS-422)
+6.5 to +15VDC return - 5	6 - connected to P1 pin 2
Tx-lo (RS-422) or Lo (RS-485) - 3	4 - Chassis ground
Rx-lo (RS-422) - 1	2 - Tx-hi (RS-422) or Hi (RS-485)

P1 Sockets

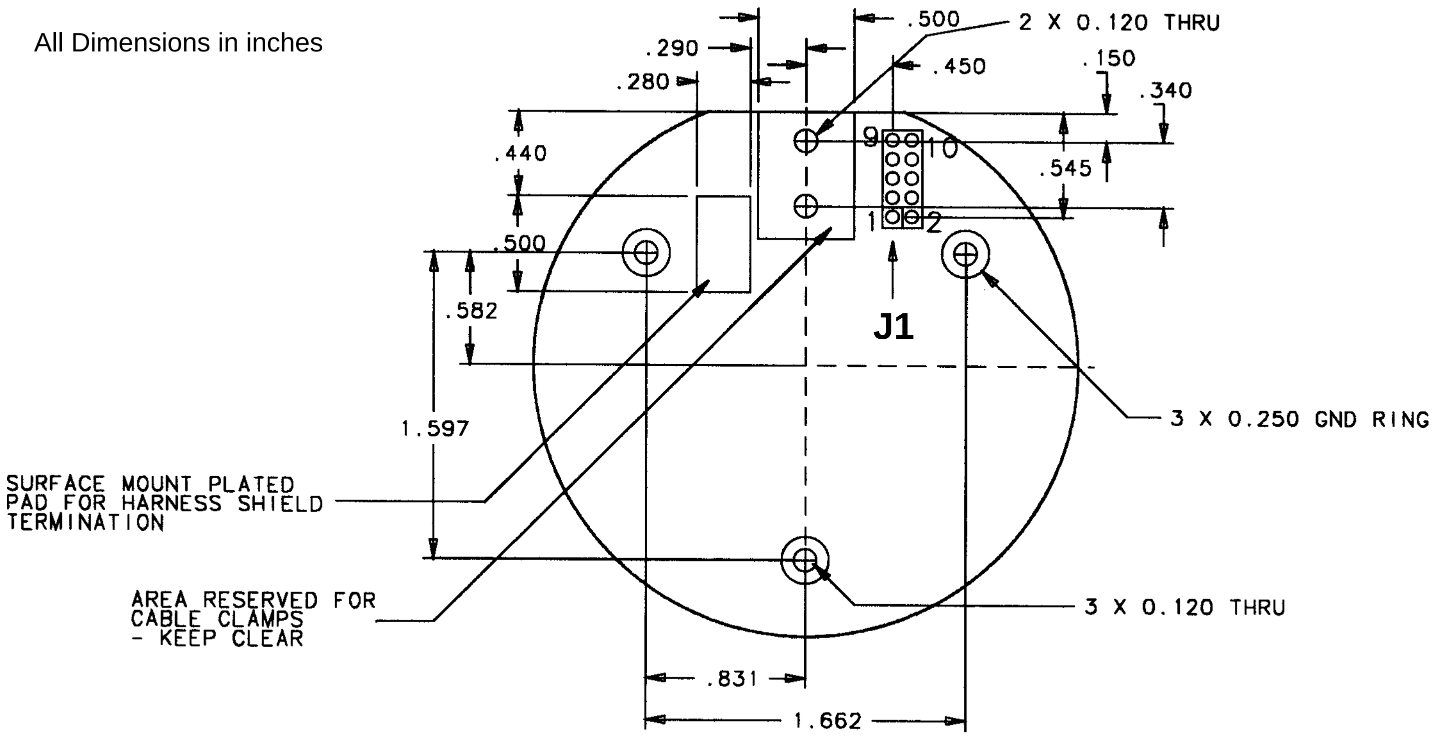
for manufacturers use only - 9	10 - for manufacturers use only
nc - 7	8 - for manufacturers use only
+6.5 to +15VDC power - 5	6 - connected to J1 pin 7
+6.5 to +15VDC return - 3	4 - Chassis ground
nc - 1	2 - connected to J1 pin 6

J1 Pin#	Pin Assignment
1	Rx-lo (RS-422)
2	Tx-hi (RS-422) or Hi(B) (RS-485)
3	Tx-lo (RS-422) or Lo(A) (RS-485)
4	Chassis ground
5	+6.5 to +15VDC return
6	connected to P1 pin 2
7	connected to P1 pin 6
8	Rx-hi (RS-422)
9	+6.5 to +15VDC power
10	(no connect)

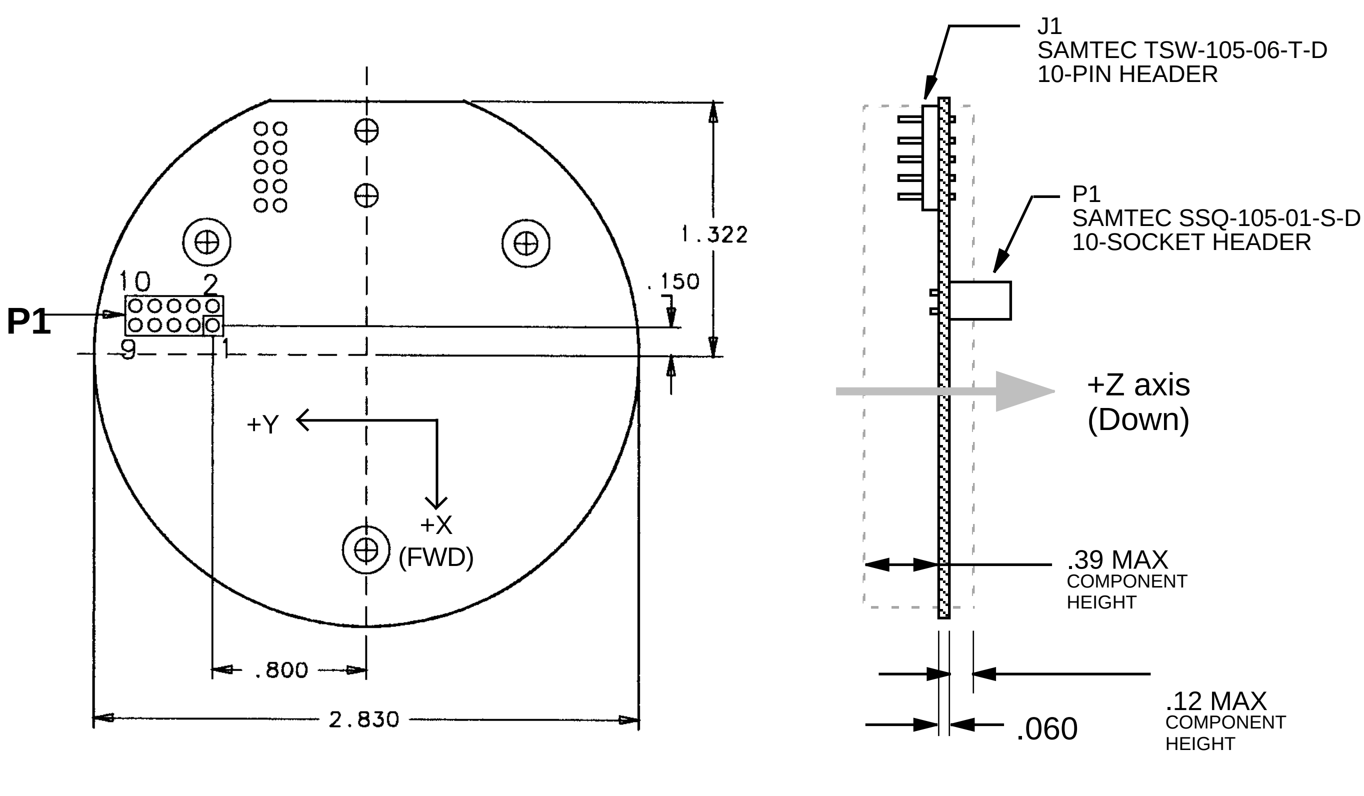
P1 Pin#	Pin Assignment
1	(no connect)
2	connected to J1 pin 6
3	+6.5 to +15VDC return
4	Chassis ground
5	+6.5 to +15VDC power
6	connected to J1 pin 7
7	(no connect)
8	for manufacturers use only
9	for manufacturers use only
10	for manufacturers use only

BOARD DIMENSIONS—FIGURE 7

All Dimensions in inches



TOP-SIDE OF CIRCUIT BOARD ASSEMBLY



BACK-SIDE OF CIRCUIT BOARD ASSEMBLY

QUALITY AND ENVIRONMENTAL CONDITIONS—TABLE 6

Parameter	*Method and Test Levels*
Printed Circuit Board	Conforms to IPC-6011 and IPC-6012, Class 3, using FR-4 laminates and prepreg per IPC-4101/21.
Assembly and Workmanship	Conforms to J-STD-001, Class 3, and IPC-A-610, Class 3, respectively.
Electrostatic Sensitive Devices	The HMR2300r shall be treated as an Electrostatic Sensitive Device (ESD) and precautionary handling and marking shall apply.
Mean Time Between Failure (MTBF)	The MTBF of the HMR2300r is 25,000 hours minimum under the environmental conditions specified.
Altitude	The HMR2300r is capable of withstanding altitudes per MIL-STD-810E, Method 520.1, Procedure III.
Fungus	The HMR2300r is constructed with non-nutrient materials and will withstand, in both operation and storage conditions, exposure to fungus growth per MIL-STD-810E, Method 508.4
Shock	The HMR2300r will perform as specified following exposure to shock IAW MIL-STD-810E, Method 513.4, Table 516.4, Procedure I, V, and VI. Functional shock (20g, 11ms, 3 shocks in both directions of 3 axes) and crash hazard shock (40g, 11ms, 2 shocks in both directions of 3 axes.
Vibration	The HMR2300r will perform as specified during exposure to random vibration per MIL-STD-810E Method 514.4, Category 10, Figure 514.4, random vibration, 4 Hz - 2000 Hz (0.04g^2/Hz to 0.0015 g^2/Hz), 3 hr./axis operating.
Salt Fog*	The HMR2300r, when clear coated, will operate as specified after 48 hrs. exposure to a salt atmosphere environment per MIL-STD-810E, Method 509.3, Procedure I *User must provide polyurethane clear coat to board.
Explosive Atmosphere	The HMR2300r will not ignite an explosive atmosphere when tested IAW MIL-STD-810E, Method 511.3, Procedure I.
Humidity	Method 507.3, Procedure III.
Temperature	10 cycles at -54° C to +71 degC operating (approx. 4 hours/cycle including stabilization time).
EMI	The HMR2300r will meet the requirements of MIL-STD-461C, Notice 2, and MIL-STD-462, Notice 5.

APPLICATIONS PRECAUTIONS

Several precautions should be observed when using magnetometers in general:

- The presence of ferrous materials—such as nickel, iron, steel, cobalt—near the magnetometer will create disturbances in the earth's magnetic field that will distort x, y and z field measurements.
- The presence of the earth's magnetic field must be taken into account when measuring other x, y and z, fields.
- The variance of the earth's magnetic field must be accounted for in different parts of the world. Differences in the earth's magnetic field are quite dramatic between North America, South America and the Equator region.
- Perming effects on the HMR board need to be taken into account. If the HMR board is exposed to fields greater than 10 Gauss (or 10 Oersted), then the board must be degaussed. The result of perming is a high zero field output code that may exceed specification limits. Degaussing devices are readily available from local electronics outlets and are inexpensive. If the HMR board is not degaussed, zero field offset values may result.

ORDERING INFORMATION

HMR2300r-422 RS-422 Communication Standard
HMR2300r-485 RS-485 Communication Standard

Customer Service Representative
1-800-238-1502 fax: (612) 954-2257
E-Mail: clr@mn14.ssec.honeywell.com

Honeywell

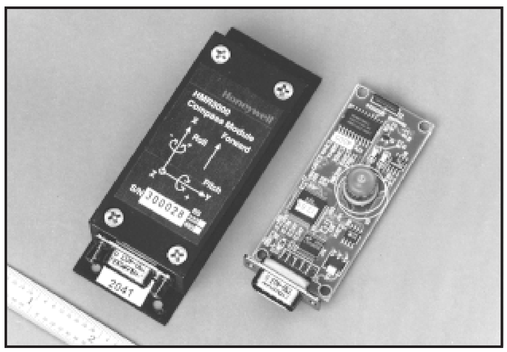
Digital Compass Module

HMR3000

Electronic compass module that provides heading, pitch and roll output for navigation and guidance systems. Honeywell's solid state magnetoresistive sensors make this strapdown compass both rugged and reliable. This compass provides fast response time up to 20 Hertz and high heading accuracy of 0.5° with 0.1° resolution.

APPLICATIONS

- Oceanographic
  - Marine Compassing
  - Positioning of Buoys, Underwater Structures
- Drilling
  - Down Hole and Directional
- Attitude Reference
- Heading
  - Navigation of Unmanned Vehicles
  - Avionic Compassing
- Integration with GPS
  - Dead Reckoning
- Satellite Antenna Positioning
- Laser Range Finders
  - Surveying Applications



FEATURES AND BENEFITS

Fast Response Time	Built with solid state magnetic sensors and no moving parts improves response time, allowing faster updates compared to gimballed fluxgates.
Small Size	Available as a circuit board 1.2 x 2.95 inches, weighing less than one ounce, or in an aluminum enclosure.
Low Power	Operates with less than 35 mA, allowing for long operation with a battery.
High Accuracy	Accuracy better than 0.5° with 0.1° resolution for critical positioning applications.
Wide Tilt Range	Tilt range of ±40° for both the roll and pitch allows operation for most applications.
Hard Iron Compensation	Calibration routines to compensate for distortion due to nearby ferrous objects and stray fields, such as vehicles.
User Configurable Features	User settings of baud rate, update rate, output format, units, filter settings, deviation angles, alarms and warnings are stored internally in non-volitile memory.

INTERFACE SIGNAL DESCRIPTIONS

Communication
HMR3000 communicates with an external host via RS-232 or RS-485 electrical standard through simple ASCII character strings. ASCII characters are transmitted and received using 1 Start bit, 8 Data bits, (LSB first, MSB always 0), no parity, and 1 Stop bit. Baud rate is user configurable to 1200, 2400, 4800, 9600, 19,200 or 38,400. HMR3000 responds to all valid inputs received with correct checksum value.

Compass Output
HMR3000 can output three NMEA standard sentences, (HDG, HDT and XDR), three proprietary sentences (HPR, RCD and CCD), and an ASCII heading output for a digital display. HDG, HDT and HPR are the most commonly used sentences; the formats are given below.

$HCHDG, Heading, Deviation, Variation
$HCHDG,85.5,0.0,E,0.0,E*77
$HCHDT, Heading, True
$HCHDT,271.1,T*2C
$PTNTHPR, Heading, Pitch and Roll
$PTNTHPR, Heading,Heading Status,Pitch,Pitch Status,Roll,Roll Status*hh<cr><lf>
$PTNTHPR,85.9,N,-0.9,N,0.8,N*2C

The table shows pin assignments for the 9-pin D-shell connector. Power input can be either regulated 5V dc or unregulated 6V to 15V. Only one of the two power pins (9 or 8) should be connected in a given installation.

Name	In/Out	Pin	Description	Typ	Min (1)	Max (1)	Units
TxD / B	Out	2	RS-232 transmit out / RS-485	—	-18	18	V dc
RxD / A	In	3	RS-232 receive in / RS-485	—	-18	18	V dc
GND	In	5	Power and signal common	—			
6-15V	In	9	Unregulated power input	6 – 15	0	30	V dc
5V	In	8	Regulated power input	5 ± 5%	0	7.5	V dc
Oper / Calib (2)	In	1	Operate / Calibrate (3) input (open = Operate)	0 – 5	-20	20	V dc
Run / Stop (2)	In	6	Run / Stop (3) input (open = Run)	0 – 5	-20	20	V dc
Ready / Sleep (2)	In	4	Ready / Sleep (3) input (open = Ready)	0 – 5	-20	20	V dc
Cont / Reset (2)	In	7	Continue / Reset (3) input (open = Continue)	0 – 5	-20	14	V dc

(1) Absolute maximum ratings.
(2) Sink current requirement; 200 (Typ) 400 (Max) µA.
(3) Open input = high logic state.

SPECIFICATIONS

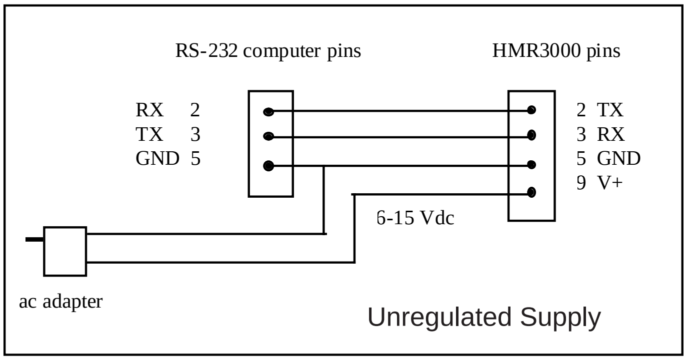
	Parameter	Value	Comments
Heading			
	Accuracy (1)	< 0.5° RMS (2) < 1.5° RMS	Dip < 50° , Tilt <20° * Dip < 75° , Tilt <20° *
	Repeatability (3) (4)	± 0.3°	
	Resolution	0.1°	
	Units	degrees / mils	User selectable
Pitch and Roll			
	Range	± 40°	
	Accuracy	± 0.4° ± 0.6°	Tilt < 20° Tilt ≥ 20° *
	Repeatability (3) (4)	± 0.2°	
	Resolution	0.1°	
	Units	degree/ mils	User selectable
Magnetic Field (3)			
	Dynamic Range	± 1.0 Gauss max	± 0.5 Gauss range
	Resolution	1 mGauss	
Electrical (4)			
	Supply Voltage	5.0 Vdc regulated 6 - 15 Vdc unregulated	
	Power	35 mA @ 6 Vdc 13 mA 2.0 mA	Normal operation STOP Mode SLEEP Mode
Interface			
	Serial	RS-232 RS-485	 Half Duplex
	Baud Rate	1200 to 38400 bps	
	Standard	NMEA 0183	
	Update Modes	Continuous Strobed	1/min to 20 Hz per sentence selectable averaging
Physical (4)			
	Weight	0.75 oz (22 g) 3.25 oz (92 g)	Circuit card only Housed
	Dimensions	1.2 x 2.95 x 0.760 1.5 x 4.2 x 0.88	Circuit card Housed compass
Environment (5)			
	Operating Temp	-20 to 70° C	
	Storage Temperature	-35 to 100° C	
	Shock	30 inch drop	MIL-STD-810E; TM 516.4
	Vibration	20 - 2000 Hz Random 2 hrs/axis	MIL-STD-810E; TM 514.4
Manufacturing			
	PCB	IPC 6012	
	Assembly	IPC 610	Class II or better

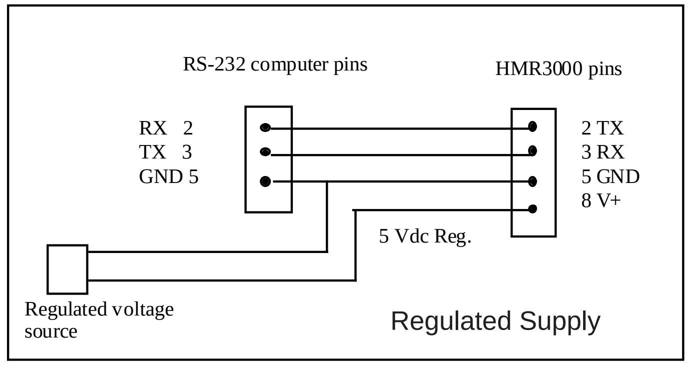
1. Heading accuracy assumes the Earth's magnetic field is only disturbed by hard iron fields, and has been compensated through calibration.
2. Calculated values.
3. Guaranteed by characterization or design.
4. Typical
5. Meet or exceed.

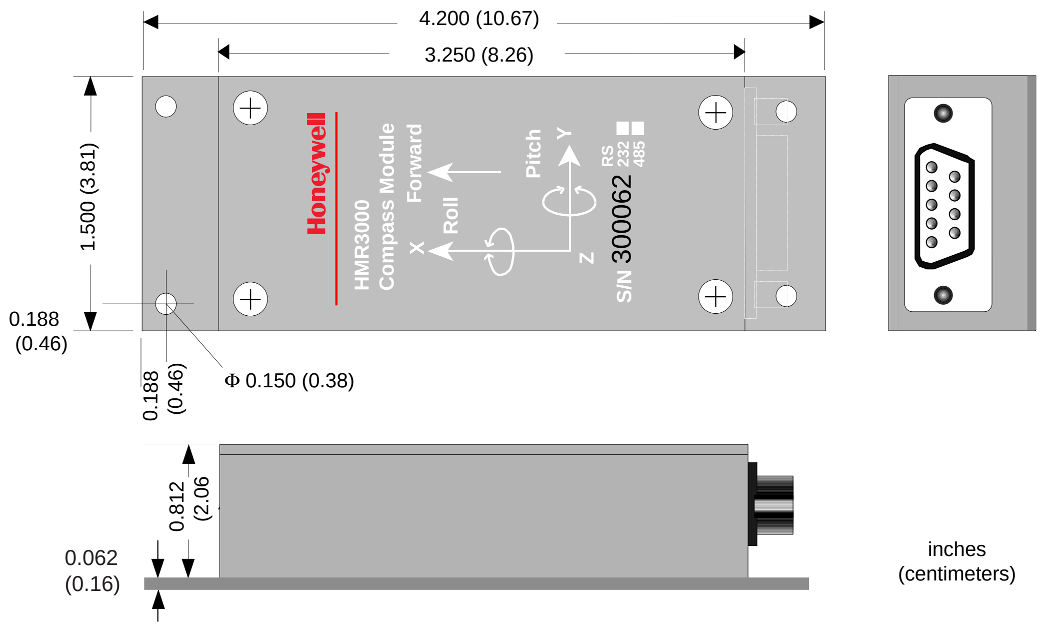
* Device orientation not to exceed 75° during operation or storage—may cause temporary loss of accuracy.

SPECIFICATIONS

HMR3000 CONNECTION DIAGRAM—COMPUTER RS232 TO HMR3000



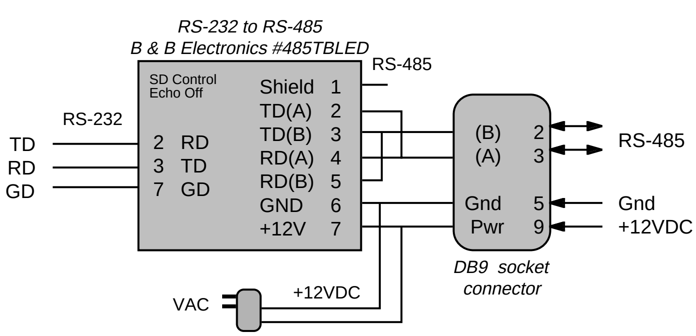




ORDERING INFORMATION

Type	Output	Enclosure
HMR3000-Demo-232*.....	RS232	
HMR3000-D00-232	RS232	None
HMR3000-D21-232	RS232	Extended Base
HMR3000-D00-485	RS485	None
HMR3000-D21-485	RS485	Extended Base

*Development Kit includes one module in aluminum enclosure, cabling with power supply, demonstration software for PC running Windows™ and User's Manual.



Honeywell

Solid State Electronics Center
12001 State Highway 55
Plymouth, MN 55441
1-800-323-8295

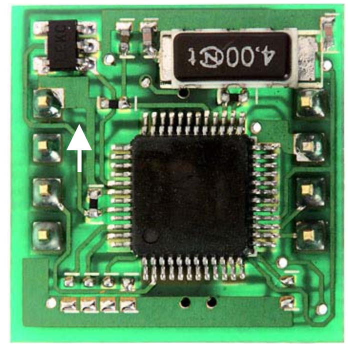
900204 Rev. B 12/99

Honeywell
SENSOR PRODUCTS

DIGITAL COMPASS SOLUTION

Features

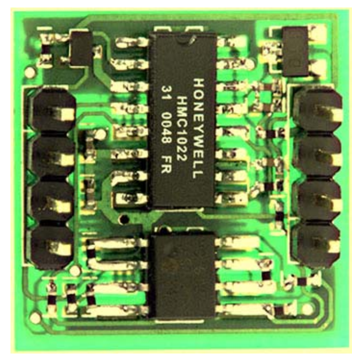
- 5° Heading Accuracy, 0.5° Resolution
- 2-axis Capability
- Small Size (19mm x 19mm x 4.5mm), Light Weight
- Advanced Hard Iron Calibration Routine for Stray Fields and Ferrous Objects
- 0° to 70°C Operating Temperature Range
- 2.6 to 5 volt DC Single Supply Operation



Top Side

General Description

The Honeywell HMR3100 is a low cost, two-axis electronic compassing solution used to derive heading output. Honeywell's magnetoresistive sensors are utilized to provide the reliability and accuracy of these small, solid state compass designs. The HMR3100 communicates through binary data and ASCII characters at four selectable baud rates of 2400, 4800, 9600, or 19200. This compass solution is easily integrated into systems using a simple USART interface.

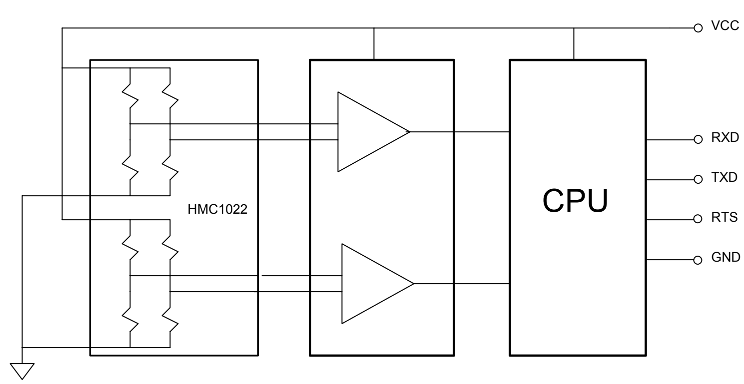


Bottom Side

APPLICATIONS

- Vehicle Compassing
- Hand-Held Electronics
- Telescope Positioning
- Navigation Systems

Block Diagram



SPECIFICATIONS

Characteristics	Conditions	Min	Typ	Max	Units
Heading					
Accuracy	Level		± 5		deg RMS
Resolution			0.5		deg
Repeatability			± 3		deg
Magnetic Field					
Range	Maximum Magnetic Flux Density		± 2		gauss
Resolution			6		milli-gauss
Electrical					
Input Voltage	Unregulated	2.6	3	5	volts DC
Current	Normal Mode (Average 1Hz Sampling)	0.1	0.2	0.5	mA
	Sleep Mode			1	μA
	Calibration	6.1	7.3	17.3	mA
Digital Interface					
USART	USART 9600.N.8.1	2400	9600	19200	Baud
Update Rate	Continuous or Polled	-	2	20	Hz
Connector	8-Pin Wide DIP				-
Physical					
Dimensions	Circuit Board Assembly		19 x 19 x 4.5		mm
Weight			1.5		grams
Environment					
Temperature	Operating	0	-	+70	°C
	Storage	-40	-	+110	°C

Circuit Description

The HMR3100 Digital Compass Solution circuit board includes the basic magnetic sensors and electronics to provide a digital indication of heading. The HMR3100 has a Honeywell HMC1022 two-axis magnetic sensor on board. The HMR3100 allows users to derive compassing (heading) measurements when the board is in a reasonably horizontal (flat) position.

The HMR3100 circuit starts with the HMC1022 two-axis magnetic sensors providing X and Y axis magnetic sensing of the earth's field. These sensors are supplied power by a switching transistor to conserve power with battery operated products. The sensor output voltages are provided to a dual operational amplifier and then to analog to digital converters (ADC) onboard a microcontroller (μC) integrated circuit. The microcontroller integrated circuit periodically samples the amplified sensor voltages, performs the offset corrections, and computes the heading. This microcontroller also performs the external serial data interface and other housekeeping functions such as the calibration routine.

The power supply for the HMR3100 circuit board is to be about a +3 to +5 volt range allowing the user to provide a single lithium battery to logic level supply voltages. The power supply architecture is a single ground system for single ended supply sources (+ and ground return).

Note the “North Arrow” printed on the HMR3100 circuit board top side. This is the mechanical reference for product alignment purposes. When placed on the development kit’s RS-232 motherboard assembly, this arrow also points toward the 9-volt batterypin block on the motherboard (away from the RJ-11 jack).

Pin Configuration

Pin Number	Pin Name	Description
1	VCC	Power Supply Input
2	NC	No Connection
3	RTS	Ready To Send Input
4	NC	No Connection
5	TXD	Transmit Data Output
6	RXD	Receive Data Input
7	GND	Power and Signal Ground
8	NC	No Connection

The HMR3100 board is 0.77” on each side with eight pins in groups of four spaced at 0.6” apart in wide-DIP format. Seated height is approximately 0.275”. See Figure 1 for further mechanical details.

USART Communication Protocol

HMR3100 module communicates through binary data and ASCII characters at four selectable baud rates of 2400, 4800, 9600, or 19200. The default data bit format is USART 9600.N.8.1. The baud rate selection is determined by the position of jumpers J1 and J3. These jumpers are zero ohm SMT resistors (jumpers) and are normally high (logic 1) when removed, and grounded (logic 0) when in place. At 2400 baud, no jumpers are present for a 1,1 logic presentation. At 4800 baud J3 is present for a 1,0 logic presentation. The factory default setting of 9600 baud is created by a jumper present on J1 for a 0,1 logic presentation. With J1 and J3 jumpers present for a 0,0 logic presentation, the compass module works at 19200 baud. See Figure 1 for jumper locations. Jumper J2 is for factory testing, and J4 is for Y-axis inversion should the end-item mount of the HMR3100 module be upside down (pins up).

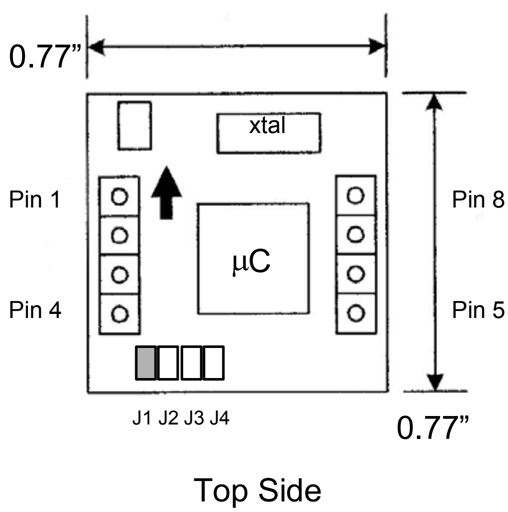


Figure 1
HMR3100 Pinout

The HMR3100 sends data via the TXD line (Pin 5) in standard serial bus form at logic levels, but uses the RTS (Pin 3) and RXD (Pin 6) to select the three active modes of operation. Normally RTS and RXD input lines are left high until data or hard-iron calibration is needed from the HMR3100. The RXD line is left high unless a calibration is requested. The RTS line will be either be pulsed low or held low to initiate an active mode. Otherwise a low-power sleep mode is the default state. The RXD and RTS data inputs are passively pulled high via the microcontroller if left open.

Normal Mode

When the host processor (external to the HMR3100), sends a RTS low pulse to the RTS pin, the HMR3100 will send status/heading data via the TXD pin. The host shall hold the RXD pin high during this mode. The RTS shall be held high when not pulsed. The HMR3100 will return to sleep mode when RTS is left high after the three-byte status/heading data packet is sent. Up to 20 heading queries per second can be accomplished given fast enough baud rates. A caution is advised that average current draw is proportional to supply voltage and amount of queries handled. At the 20 Hz rate, 1 to 5 milliamperes of current is consumed with lesser query rates taking advantage of the less than one-microampere sleep mode current draw between queries. Figure 2 shows the normal mode timing diagram.

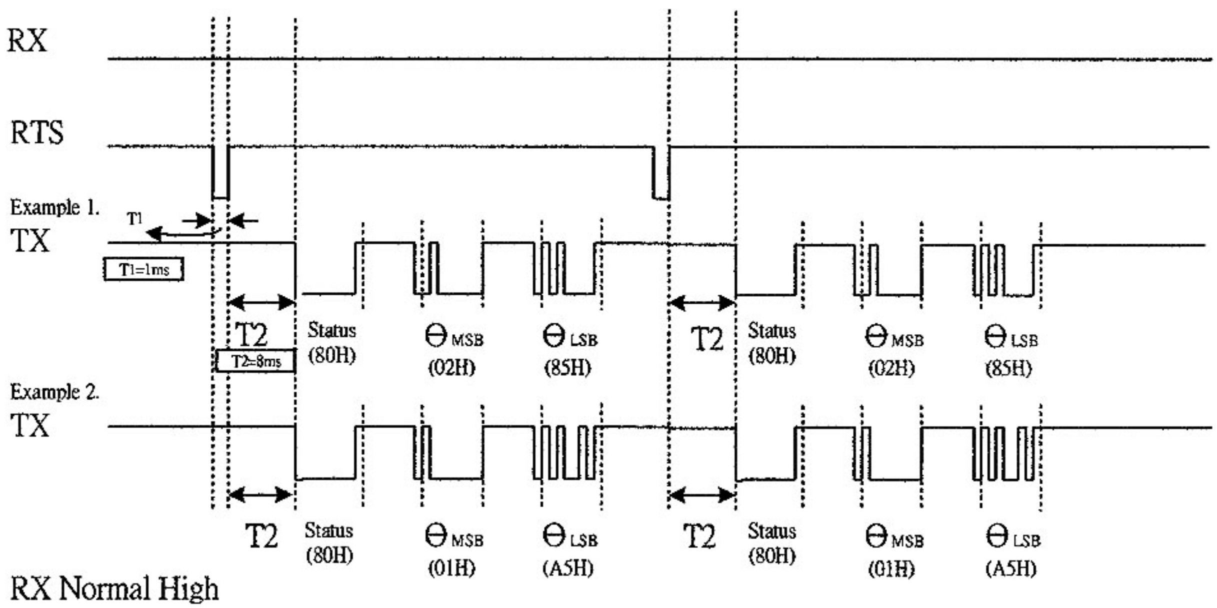


Figure 2
Normal Mode Timing Diagram

Continuous Mode

When the host processor (external to the HMR3100), holds the RTS input low, the HMR3100 will continuously send heading data via the TXD pin. The host shall hold the RXD pin high during this mode. The HMR3100 shall output the three-byte status/heading data packet at about a 2Hz rate. The HMR3100 will return to sleep mode when RTS is returned high. Figure 3 shows the continuous mode timing diagram.

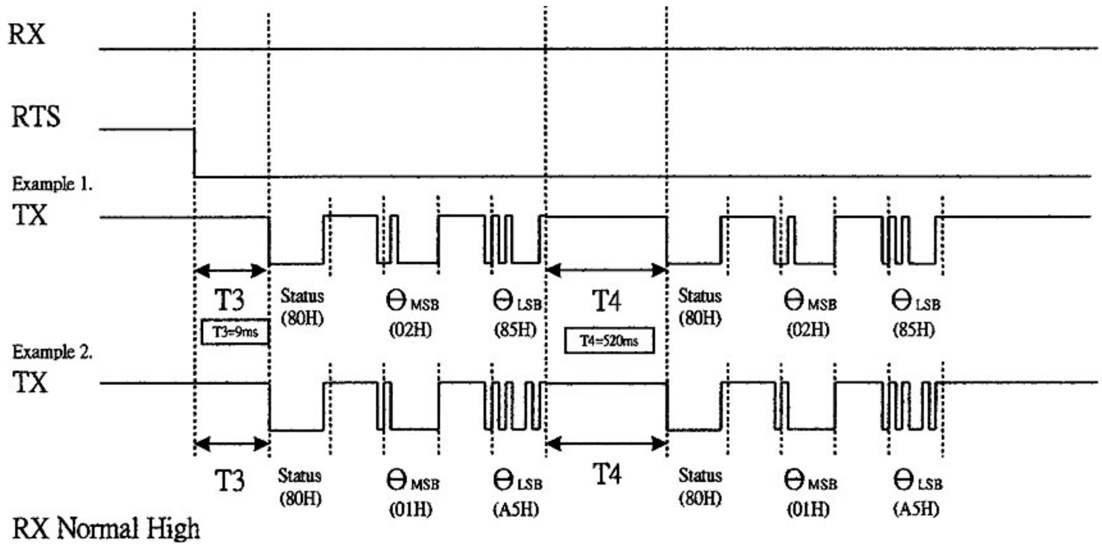


Figure 3
Continuous Mode Timing Diagram

Calibration Mode

When the host processor pulses low the RTS pin, and sends the RXD pin to a low logic level, the HMR3100 is in hard-iron calibration mode. This calibration is only for nearby magnetized metals (hard-iron) that are fixed in position with the HMR3100. At a moderate rate (5 seconds or more per rotation), rotate the HMR3100/host assembly two complete circles (on a flat, non-magnetic surface if possible) to allow the HMR3100 to take measurements for compass calibration. At the completion of the rotations, return the RXD to a high logic level. The HMR3100 will return to sleep mode until another active mode has been initiated. Upon initiation of the calibration mode, the microcontroller shall output an ASCII STA (53 54 41 hex) indicating a start of calibration and then an ASCII RDY (52 44 59 hex) at the completion of the rotations and the RXD line returned high. Figure 4 shows the calibration mode timing diagram.

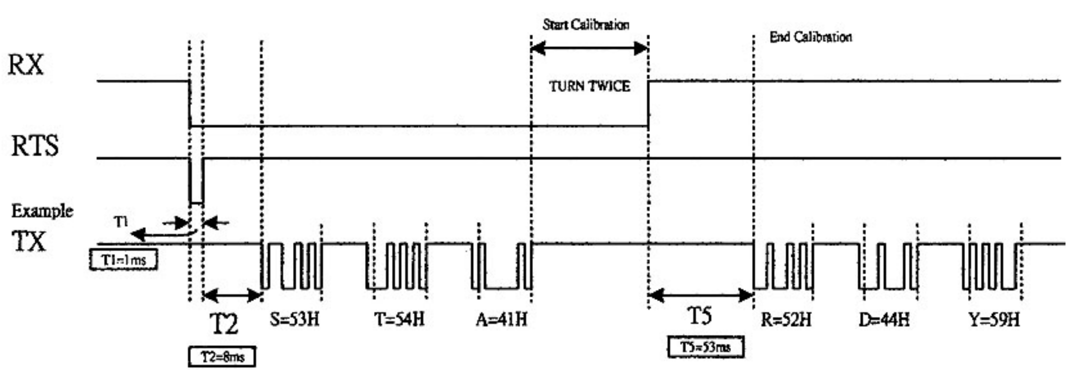


Figure 4
Calibration Mode Timing Diagram

Data Description

The HMR3100's onboard microcontroller sends a three byte status/heading data packet reply as the RTS line is brought low. The data is normally formatted in binary with the first byte being either 80(hex) or 81(hex).

If that first byte LSbit is flagged high (81 hex), it means magnetic distortion maybe present and a hard-iron calibration should be performed. Many end users may choose to ignore this indication in portable applications.

The remaining two bytes are the heading (in degrees) in MSB to LSB format. There is some data interpretation needed to derive the heading. For example, the 80 02 85 (hex) Byte pattern correlates to 322.5 degrees.

This is done by taking the MSB hex value, converting it to decimal (base ten) representation (e.g. 02 decimal) and multiplying it by 256. Then the LSB is decimalized (e.g. 85(hex) to 133(decimal)) and added to the 512(decimal) MSB. The total (512+133=645) is then divided by two to arrive at a 322.5 degree heading. This data format permits the 0.5° resolution in two bytes by doing the binary to decimal conversion and division by two.

Development Kit

The HMR3100 Development Kit includes additional hardware and Windows demo program software to form a development kit for electronic compassing. This kit includes the appropriate HMR3100 Printed Circuit Board (PCB) module soldered to an intermediate circuit board using a 0.8" spacing pin arrangement. The intermediate board assembly plugs into an RS-232 motherboard with a serial port connector. In addition, a four-foot serial port cable (RJ-11 to D-9F), nine-volt battery clip, demo program software, and user's guide is included. The RS-232 motherboard incorporates a 5-volt regulator integrated circuit to provide the necessary voltages to the onboard RS-232 converter integrated circuit and the HMR3100 daughter-board. A nine-volt battery clip is included, but other DC input voltages between 7 and 15 volts may be used. Supply currents are nominally around 8mA plus the HMR3100 current draw.

The RS-232 motherboard also contains a six-contact modular jack (RJ-11) for a compact RS-232 interface to a personal computer serial port. Ground, RTS, RXD, and TXD data lines are brought out to the jack with two contacts left open. The demo software stimulates the RTS and RXD lines and reads the data from the TXD line for graphical display on the host computer. No other support software is available. Figure 5 shows the kit board assemblies.

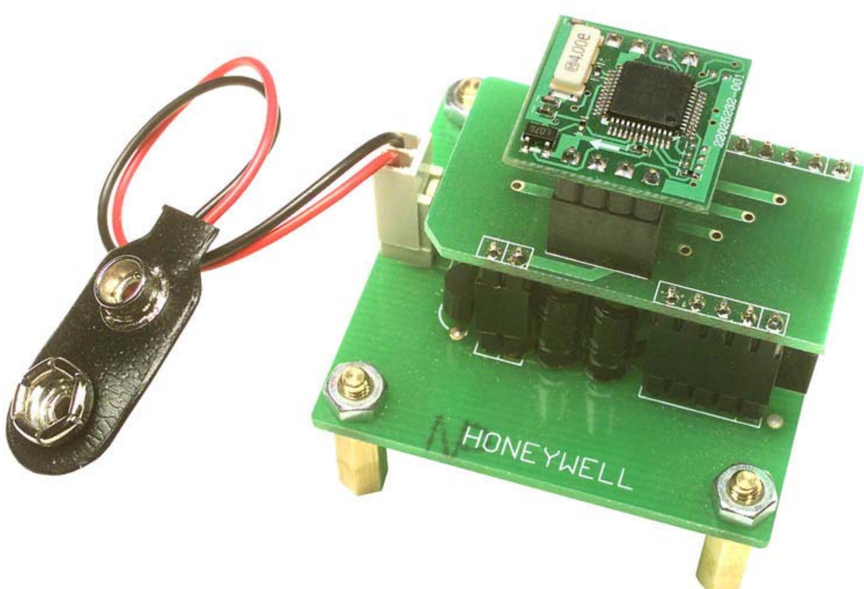


Figure 5
HMR3100 Kit Hardware

Ordering Information

Ordering Number	Product
HMR3100 HMR3100-Demo-232	PCB Module Only PCB Module with Development Kit

900268 02-04 Rev. A

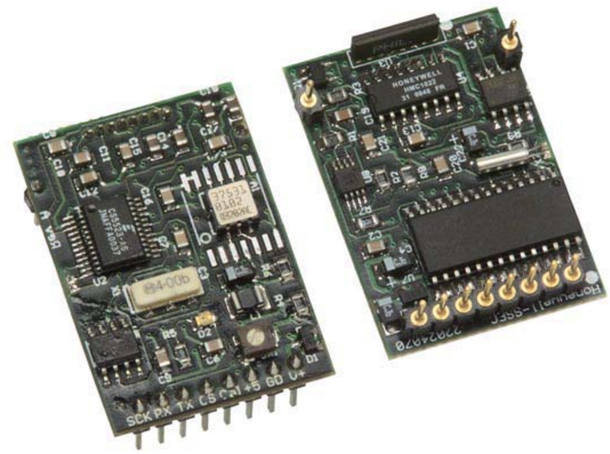
Honeywell

SENSOR PRODUCTS

DIGITAL COMPASS SOLUTIONS

Features

- 1° Heading Accuracy, 0.1° Resolution
- 0.5° Repeatability
- ±60° Tilt Range (Pitch and Roll) for HMR3300
- Small Size (1.0" x 1.45" x 0.4"), Light Weight
- Compensation for Hard Iron Distortions, Ferrous Objects, Stray Fields
- 15Hz Response Time
- -40° to 85°C Operating Temperature Range
- 6-15 volt DC unregulated or 5 volt regulated supply



General Description

The Honeywell HMR3200/HMR3300 are electronic compassing solutions for use in navigation and guidance systems. Honeywell's magnetoresistive sensors are utilized to provide the reliability and accuracy of these small, solid state compass designs. These compass solutions are easily integrated into systems using a UART or SPI interface in ASCII format.

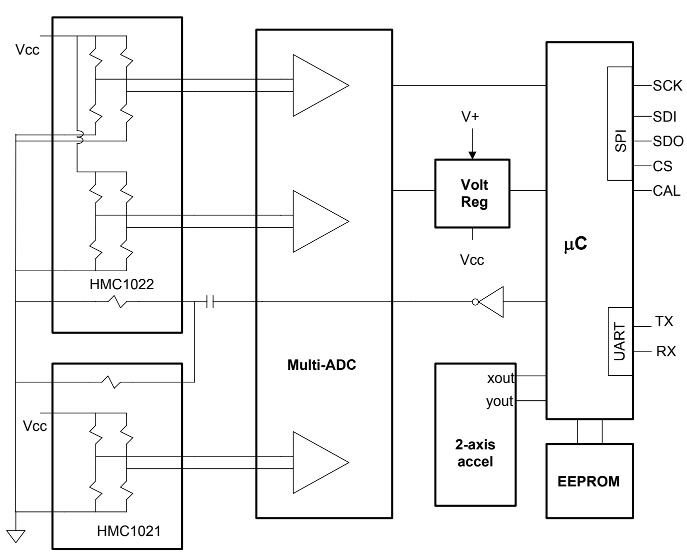
The HMR3200 is a two-axis compass, and can be used in either vertical or horizontal orientations.

The HMR3300 is a three-axis, tilt compensated compass that uses a two-axis accelerometer for enhanced performance up to a ±60° tilt range.

APPLICATIONS

- Compassing & Navigation
- Attitude Reference
- Satellite Antenna Positioning
- Platform leveling
- GPS Integration
- Laser Range Finders

Block Diagram



SPECIFICATIONS

Characteristics	Conditions	Min	Typ	Max	Units
Heading					
Accuracy	Level 0° to ±30° (HMR3300 only) ±30° to ±60° (HMR3300 only)		1.0 3.0 4.0		deg RMS
Resolution			0.1		deg
Hysteresis	HMR3200 HMR3300		0.1 0.2	0.2 0.4	deg
Repeatability	HMR3200 HMR3300		0.1 0.2	0.2 0.4	deg
Pitch and Roll	***(HMR3300 only)***				
Range	Roll and Pitch Range		± 60		deg
Accuracy	0° to ± 30° ± 30° to ± 60°		0.4 1.0	0.5 1.2	deg
Null Accuracy*	Level -20° to +70°C Thermal Hysterisis -40° to +85°C Thermal Hysterisis		0.4 1.0 5.0		deg
Resolution			0.1		deg
Hysteresis			0.2		deg
Repeatability			0.2		deg
Magnetic Field					
Range	Maximum Magnetic Flux Density		± 2		gauss
Resolution			0.1	0.5	milli-gauss
Electrical					
Input Voltage	Unregulated	6	-	15	volts DC
Current	HMR3200 HMR3300		18 22	20 24	mA mA
Digital Interface					
UART	ASCII (1 Start, 8 Data, 1 Stop, 0 Parity) User Selectable Baud Rate	2400	-	19200	Baud
SPI	CKE = 0, CKP = 0 Psuedo Master				
Update	Continuous/Strobed/Averaged HMR3200 HMR3300		 15 8		 Hz
Connector	In-Line 8-Pin Block (0.1" spacing)				

* Null zeroing prior to use of the HMR3300 and upon exposure to temperature excursions beyond the Operating Temperature limits is required to achieve highest performance.

Characteristics	Conditions	Min	Typ	Max	Units
Physical					
Dimensions	Circuit Board Assembly		25.4 x 36.8 x 11		mm
Weight	HMR3200 HMR3300		7.25 7.5		grams
Environment					
Temperature	Operating (HMR3200) Operating (HMR3300) Storage	-40 -20 -55	- -	+85 +70 +125	°C °C °C

Pin Configuration

Pin Number	Pin Name	Description
1	SCK	Serial Clock Output for SPI Mode
2	RX/SDI	UART Receive Data/SPI Data Input
3	TX/SDO	UART Transmit Data/SPI Data Output
4	CS	Chip Select for SPI Mode (active trailing edge)
5	CAL	Calibration ON/OFF Input (active trailing edge)
6	+5VDC*	+5 VDC Regulated Power Input
7	GND	Power and Signal Ground
8	+V*	Unregulated Power Input (+6 to +15 VDC)

*Note: Use either pin 6 (+5VDC) or pin 8 (+V) to power the circuit board. Hold the board with pin header edge close to you and pins pointing DOWN. Then PIN 1 is the left most pin.

CIRCUIT DESCRIPTION

The HMR3200/HMR3300 Digital Compass Solutions include all the basic sensors and electronics to provide a digital indication of heading. The HMR3200 has all three axis of magnetic sensors on board, but allows the user to select which pair of sensors for compassing (flat or upright). The HMR3300 uses all three magnetic sensors plus includes an accelerometer to provide tilt (pitch and roll) sensing relative to the board's horizontal (flat) position.

The HMR3200/HMR3300 circuit starts with Honeywell HMC1021 and HMC1022 single and two-axis magnetic sensors providing X, Y, and Z axis magnetic sensing of the earth's field. These sensors are supplied power by a constant current source to maintain best accuracy over temperature. The sensor output voltages and constant current sensor supply voltage are provided to multiplexed Analog to Digital Converter (ADC) integrated circuit. A microcontroller integrated circuit periodically queries the multiplexed ADC and performs the offset corrections and computes the heading. This microcontroller also performs the external serial data interface and other housekeeping functions such as the calibration routine. An onboard EEPROM integrated circuit is employed to retain necessary data variables for best performance.

For the HMR3300, an additional pair of data inputs from the ±2g accelerometer is received by the microcontroller. These tilt inputs (pitch and roll) are added to sensor data inputs to form a complete data set for a three dimensional computation of heading.

The power supply for the HMR3200/HMR3300 circuit is regulated +5 volt design allowing the user to directly provide the regulated supply voltage or a +6 to +15 volt unregulated supply voltage. If the unregulated supply voltage is provided, then the linear voltage regulator integrated circuit drops the excess supply voltage to a stable +5 volts. The power supply is a dual ground (analog and digital) system to control internal noise and maximize measurment accuracy.

PHYSICAL CHARACTERISTICS

The circuit board for the HMR3200/HMR3300 Digital Compassing Solutions is approximately 1.45 by 1 inches. An 8-Pin header protrudes down on one edge of the board for the user interface or the demo board. The header pins extend 5/16” below the board plane with the bottom-side mounted magnetic sensor integrated circuits (HMC1021 and HMC1022) extending 3/16” below the board plane. Components on the top-side have a maximum height of 1/8”. Figure 1 shows a typical circuit board with dimensions.

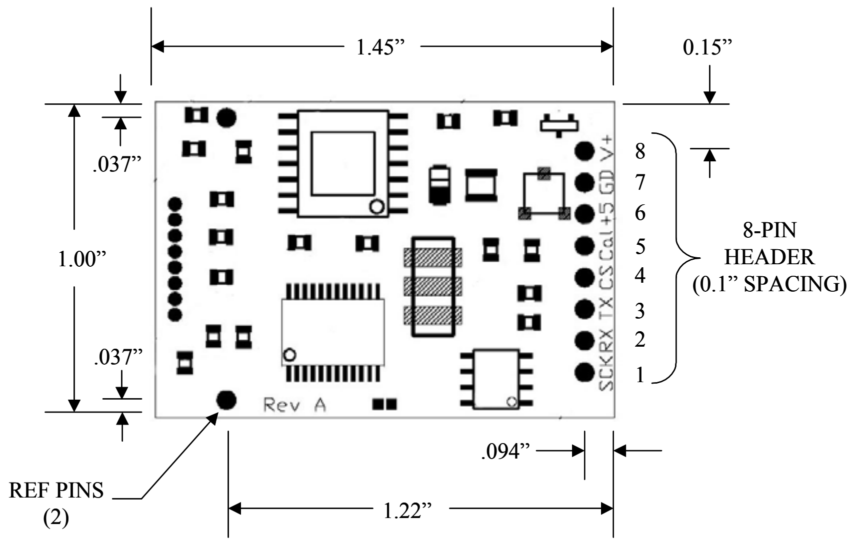


Figure 1

Application Notes

UART COMMUNICATION PROTOCOL

HMR3200/HMR3300 modules communicate through ASCII characters.   The data bit format is 1 Start, 8 Data, 1 Stop, and No parity bits. Asynchronous communication has the complete menu of commands.

OPERATIONAL COMMANDS

Syntax: *X<cr><lf>   Sends command for an operational mode change

Heading Output Command

***H<cr><lf>**

Selects the Heading output mode (factory set default). This configuration is saved in non-volatile memory.
Format: Heading, Pitch, Roll (Heading Only for HMR3200) in degrees
Eg: 235.6,-0.3,2.8   (HMR3300)
Eg: 127.5   (HMR3200)

Magnetometer Output Command

***M<cr><lf>**

Selects the magnetometer output mode. This configuration is saved in non-volatile memory.
Format: MagX, MagY, MagZ in counts
Eg: 1256,-234,1894

Compass Orientation (HMR3200 only)

***L<cr><lf>**
Heading calculation is done assuming the compass is level.
***U<cr><lf>**
Heading calculation is done assuming the compass is upright (connector end down).
These orientation commands are saved in non-volatile memory.

Starting and Stopping Data Output

***S<cr><lf>**
The data output will toggle between Start and Stop each time this command is issued (factory set default is Start, first Start/Stop command will stop data output).

Query

***Q<cr><lf>**
Query for an output in the currently selected mode (Mag/Head). Allowed only in Stop data mode.

Roll Axis Re-Zero

***O<cr><lf>**
Allows the user to zero the roll output. This command should only be issued when the roll axis is leveled (±0.3°).

Pitch Axis Re-Zero

***P<cr><lf>**
Allows the user to zero the pitch output. This command should only be used when the pitch axis is leveled (±0.3°).

Averaged Output

***A<cr><lf>**
Same result as the query command except that the data is the result of an averaging of the last 20 readings. Allowed only in Stop data mode.

Split Filter Toggle

***F<cr><lf>**
Toggles the split filter bit. The parameter setting is saved in the EEPROM immediately. Requires power cycling or a reset command to activate.

Reset

***R<cr><lf>**
Resets compass to power-up condition.

User Calibration

***C<cr><lf>**
Command to be issued to enter and exit the calibration mode.

Once in the calibration mode, the device will send magnetometer data appended by a “C” character to indicate the Calibration Mode operation.

Eg. 123,834,1489,C

During the calibration procedure, the compass and the platform to which the compass is attached is rotated at a reasonably steady speed through 360 degrees. This process should at least take one minute for best accuracy. In case of HMR3200, the rotation should be in the horizontal flat plane. For HMR3300, the rotation should include as much pitch and roll orientations possible. At the completion of the rotations, issue another *C<cr><lf> to exit the calibration mode.

CONFIGURATION COMMANDS

Syntax: #Dev=±xxxx<cr><lf> Sets parameter value
#Dev?<cr><lf> Queries for the parameter value

Variation Input (Declination Angle Correction)
#Var=±nnnn<cr><lf> where the variation is ± nnn.n degrees
Sets the angle between magnetic north and geographic north.
Eg: #Var=-203<cr><lf> sets the declination angle to –20.3 degrees.
Eg: #Var=?<cr><lf>returns the declination angle; –20.3

Deviation Input (Platform Angle Correction)
#Dev=±nnnn<cr><lf> where the angle is ± nnn.n degrees
Sets or returns the angle between compass forward direction and that of the mounting platform.
Eg: #Dev=23<cr><lf> sets the deviation angle to +2.3 degrees.
Eg: #Dev=?<cr><lf>returns the deviation angle; +2.3

User Magnetic offset values (X, Y and Z)
#Xof, #Yof, #Zof
Sets or returns the user offset values for each magnetic axis.
Eg: #Xof=+47<cr><lf> sets the x offset value to +47.
Eg: #Xof=?<cr><lf> returns the x offset value; +47.

Baud Rate
#Bau
Sets the compass baud rate. 19200, 9600, 4800 and 2400 are the only allowed values. Baud rate can not be queried.

System Filter
#SFL
Sets and reads the system IIR filter setting. When the Split Filter bit is cleared, this parameter value will become the default value for Magnetic and Tilt Filters. When the Split Filter bit is set, SFL parameter setting will control the Tilt filter value only. The parameter input is saved in the EEPROM immediately. Requires power cycling or a Reset command (*R) to become effective. The setting of the Split Filter bit can be queried via the #CON? command.

Eg: #SFL=3<cr><lf> Sets the system filter value of 3.

Magnetic Filter
#MFL
The MFL command sets and reads the Magnetic Filter setting. When the Split Filter bit is cleared, this parameter value will default to the value of SFL, the system filter. When the Split Filter bit is set, MFL parameter setting will control the Magnetic Filter value. The parameter input is saved in the EEPROM immediately. Requires power cycling or a Reset command (*R) to become effective.

Configuration
#CON?
This command queries for the configuration status of the compass module. The output of the configuration value is in decimal representation (in ASCII format) of which the 16-bit binary pattern is defined below.

bit 15	bit 14	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8
N/A	N/A	N/A	N/A	N/A	SplitFilter	Alarm	Warn

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
N/A	N/A	1	N/A	H Out	N/A	Mag Out	N/A

Parameter Name	Bit Value Reported	Effect
Mag Out	1	Magnetic Sensor Output Sentence selected
H Out	1	Heading Output Sentence selected
Warn	1	Device temperature has fallen below -10 C during this session of operation.
Alarm	1	Device temperature has fallen below -20 C during this session of operation.
SplitFilter	1	Independent Filter values for Magnetic and Tilt are used

Eg: #CON? Returns a response of #D=1028<cr><lf> meaning independent filters used for magnetic and tilt data (bit 10 set) and the compass module is sending heading data (bit 3 set).

COMMAND RESPONSES

These are compass module generated responses to commands issued by the host processor. These responses follow in format to the commands issued.

#Dxxx<cr><lf>
Returns data requested.

#I<cr><lf>
Invalid command response. Response to any invalid command.

SPI INTERFACE

SPI operating Mode is as follows:

SCK idles low
Data Output after falling edge of SCK
Data sampled before rising edge of SCK

(MODE CKP=0, CKE=0)

Synchronous Communication Protocol

The HMR3200/HMR3300 module controls the synchronous clock (SCK) and synchronous data output (SDO) pins and the host controller controls synchronous data input (SDI) and chip select (CS) pins. The host controller shall lower the HMR module's CS pin for at least 20 microseconds to initiate the SPI communication. In response the HMR module will send the ASCII bit pattern for 's', and the host shall transmit a valid command character simultaneously. The HMR module will evaluate the command character received from the host controller and send the appropriate data if the command is recognized and valid. After transmitting the required data, the HMR module will end the SPI session. If the command is invalid or was not recognized, then the HMR module will transmit ASCII bit pattern for 'e' and end the SPI session.

SPI Commands

Heading Output: In response to an ASCII H or h command, the HMR3200/HMR3300 shall send two bytes of data. The MSByte is transmitted first. These two bytes represent the integer value equal to 10*Heading. The MSbit is transmitted first for each byte. SCK shall be high for 16, and low for 22 microseconds, respectively. There is a 50 microsecond delay between consecutive bytes transmitted.

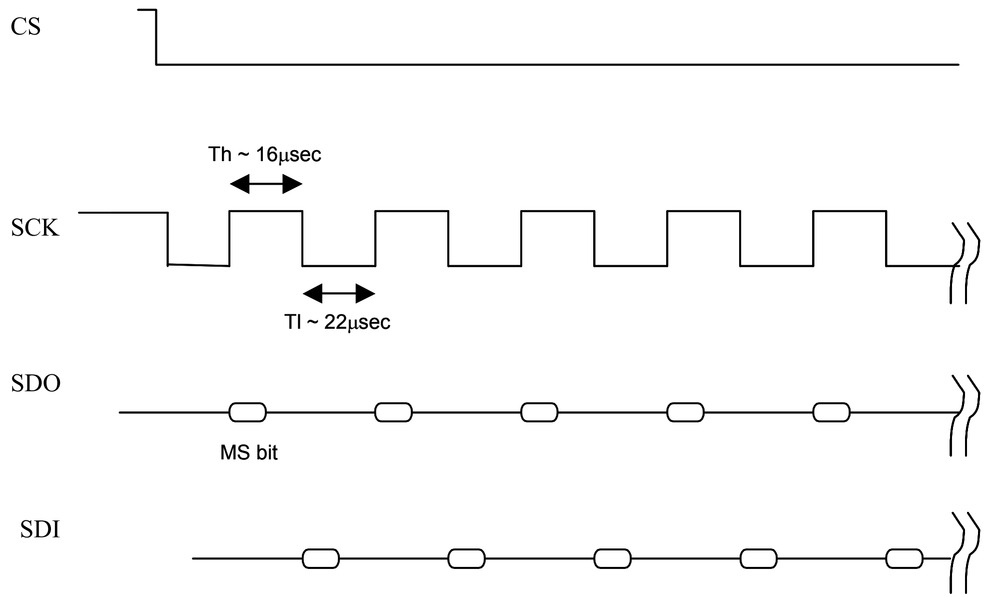
Command Character	Action	SPI Data Output	Parameter Value
H or h	Sends heading data	0000 to 3599	Heading: 000.0 to 359.9

DATA REPRESENTATION

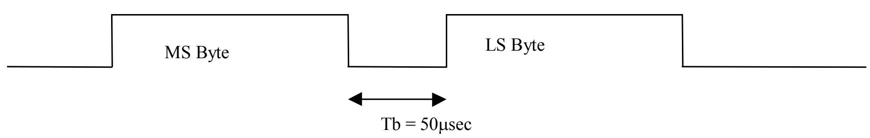
Heading Output: In response to an H or h command, HMR3200/HMR3300 module shall send two bytes of data. The MSByte is transmitted first. These two bytes represent the integer value equal to 10*Heading. The MSbit is transmitted first for each byte.

SPI TIMING

The SCK shall be high for 16, and low for 22 microseconds, respectively. There is a 50 microsecond delay between consecutive bytes transmitted.



SPI Timing Diagram



SPI Heading Output

Demonstration PCB Module Kit

The HMR3200 (HMR3300) Demo Module includes additional hardware and Windows software to form a development kit for electronic compassing. This kit includes the HMR3200 (HMR3300) Printed Circuit Board (PCB) module, an RS-232 motherboard with D9 serial port connector, serial port cable with attached AC adapter power supply, interface software, and documentation.

Ordering Information

Ordering Number	Product
HMR3200	PCB Module Only
HMR3200-Demo-232	PCB Module with Development Kit
HMR3300	PCB Module Only
HMR3300-D00-232	PCB Module and RS-232 Motherboard
HMR3300-Demo-232	PCB Module with Development Kit

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900266 02-03 Rev. D

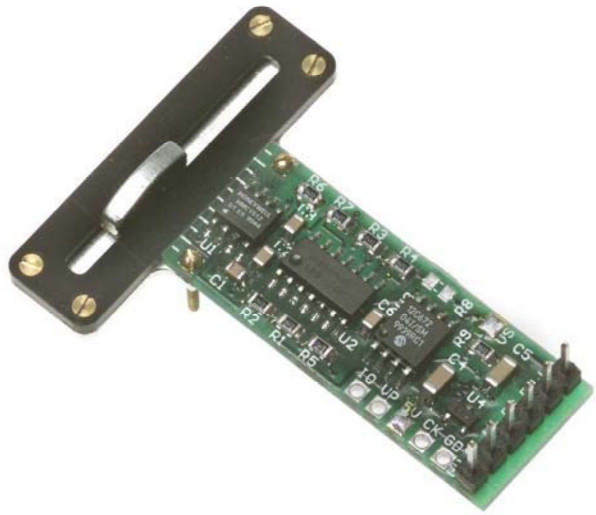
Honeywell

SENSOR PRODUCTS
Advance Information

LINEAR POSITION SENSOR MODULE

Features

- 0-10 mm Magnetic Travel (Magnet Dependent)
- Continuous PWM and Analog Voltage Outputs
- 0.2mm Accuracy (Magnet Dependent)
- 0.05mm Repeatability
- -40° to +85°C Operating Temperature Range
- 1%/100°C Temperature Effect
- Small PCB Package
- 6 to 20 volt DC Single Supply Required



General Description

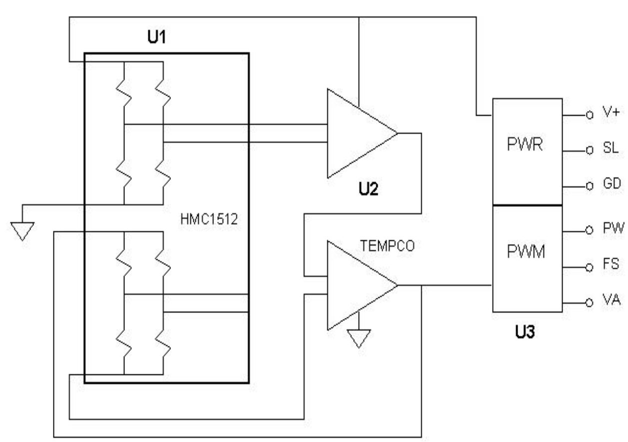
The Honeywell HMR4001 is a high-resolution single sensor module capable of measuring linear or angular position. Advantages include high sensitivity so lower cost magnets such as alnico or ceramic can be used, insensitivity to shock and vibration, and ability to withstand large variations in the gap between the sensor and the magnet.

The HMR4001 is manufactured with Honeywell's HMC1512 Magnetic Displacement Sensor IC, which provides better performance than Hall Effect devices and only needs a magnetic field source greater than 80 gauss. Dual frequency PWM and analog outputs plus a sleep mode function are included on board

APPLICATIONS

- **Linear Displacement**
- **Shaft Position**
- **Angular Displacement**
- **Proximity Detection**

Block Diagram



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Solid State Electronics Center
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Plymouth, Minnesota 55441-4799
1-800-323-8295

SPECIFICATIONS

Characteristics	Conditions	Min	HMR4001 Typ	Max	Units
Linear Position					
Range	> 80 gauss at sensor		10		mm
Accuracy	> 80 gauss at sensor		0.2		mm
Repeatability	> 80 gauss at sensor		0.05		mm
Angular Position					
Range	> 80 gauss at sensor		90		deg
Accuracy	> 80 gauss at sensor		0.1		deg
Repeatability	> 80 gauss at sensor		0.07		deg
Magnetic Field					
Strength	Repeatability <0.03% FS	80	-	-	gauss
Electrical					
Voltage	Unregulated	6	-	20	volts DC
Current Supply	Active Mode - SLEEP pin = 5V (or open) Sleep Mode - SLEEP pin = 0V		7 < 2		mA mA
PWM Output					
Frequency	FS = 5V (or open) FS = 0V		350 250		Hz Hz
Frequency Accuracy	Ambient Temperature (+23°C)	+/-8	-	-	%
PWM Range	"1" Level Duty Cycle	1	-	99	%
PWM Amplitude	"1" Level at any Position	4.5	-	5.5	Volts pk-pk
Analog Output					
Range	Ambient Temperature (+23°C)	-	4.0	-	volts
Physical					
Dimensions	circuit board only		15x48.5x12		mm
Weight	circuit board only		5		grams
Environment					
Temperature	Operating Storage	-40 -55	- -	+85 +125	°C °C

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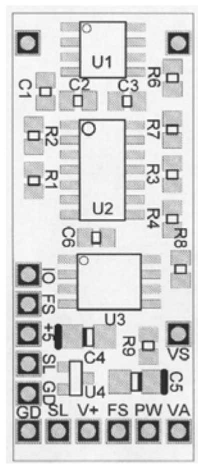
Pin Configuration

Pin	Function	Description
VA	ANALOG OUTPUT	Analog Version of the PWM Output Using a Low Pass Filter.
PW	PWM OUTPUT	Digital Signal With the "1" Level Equivalent to the Position of the Magnet. Period at 250 or 350 Hz.
FS	FREQUENCY SELECT INPUT	Selects the Pulse Width Modulation Frequency: 1=350Hz, 0=250Hz (onboard pullup)
V+	POWER SUPPLY INPUT	Power Supply Input of +6 to +20 Volts DC.
SL	SLEEP/WAKE INPUT	Selects the Wake or Sleep Mode: 1=Wake, 0=Sleep. Onboard Pullup Resistor to Keep Board in Wake Mode.
GD	GROUND	Ground Reference for Supply and I/O

Circuit Board Layout



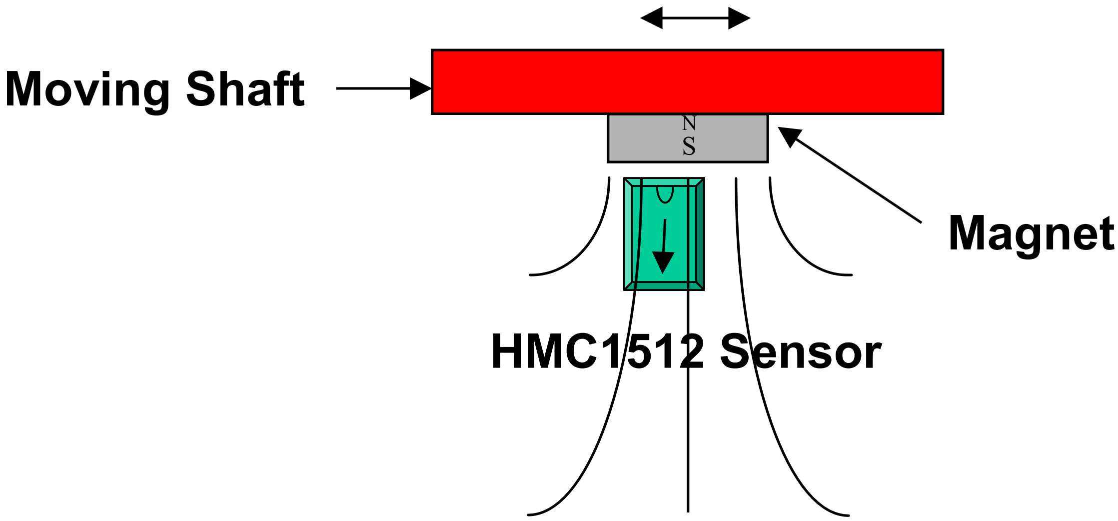
Application Notes

Very high precision position measurements using weak magnetic fields should note the influence of the earth's magnetic field (~ 0.6 gauss) bias on the sensed magnet position.

The center-line of HMC1512 sensor integrated circuit U1 is determined to be midpoint (50% Pulse Width, 2.5v Analog) for position sensing.

Only one of the two sensor bridges in the HMC1512 is used for sensing the external magnetic field. The other magneto-resistive bridge network is used as temperature compensation network to retain precise positioning over a broad temperature range. Thus the single bridge provides its linearity over a 90° sweep (+/- 45°) as opposed to when both HMC1512 bridges are working together for a 180° (+/- 90°) sweep.

For best performance, a magnetic field of at least 80 gauss measured at the sensor location should be maintained. A simple dipole magnet usually has the strongest field near its poles, and the field decreases with the distance. For example: An AlNiCo cylindrical magnet with a 0.25" diameter has field strength of 700 gauss at its surface. With a 0.25" gap between the sensor and the magnet, the field at the sensor is about 170 gauss. This is enough field strength to maintain the sensor in the saturation condition for most applications.



Demonstration PCB Module

The HMR4001 Demo Module includes an attached magnet and slide assembly for evaluating the performance of the module.

Ordering Information

Ordering Number	Product
HMR4001-D00 -DEMO	PCB Module with Attached Magnet Assembly
HMR4001-D00	PCB Module Only

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