Digital Compass Solution HMR3400

The Honeywell HMR3400 is a digital compass solution designed for use in navigation and precision pointing applications. Honeywell's magnetoresistive sensor technology is coupled with a MEMS accelerometer to provide a miniature, reliable tilt-compensated electronic compass. Using a common set of commands from the legacy HMR3300 digital compass solution, the HMR3400 is designed to be easily integrated into host systems with a regulated 5 volt supply and a UART serial data interface.

The HMR3400 includes a MEMS accelerometer for a horizontal three-axis, tilt compensated precision compass for performance up to a ±60° tilt range.



Honeywell continues to maintain product excellence and performance by introducing innovative solid-state magnetic sensor solutions. These are highly reliable, top performance products that are delivered when promised. Honeywell's magnetic sensor products provide real solutions you can count on.

FEATURES	BENEFITS
Compact Solution on a 0.6 by 1.5" PCB	Narrow Dimensions and Small Size for Tight Mounting Conditions, Minimal Layout Constraints
Precision Compass Accuracy	±1° at Level Heading Accuracy
Tilt-Compensated	Up to ±60° of Pitch and Roll Angles Using a MEMS Accelerometer
-40° to +85°C Operating Temp Range	Consumer and Industrial Environment Uses
8 Hz Continuous Update Rate	Rapid Heading Computations for Guidance Applications
Hard-Iron Compensation Routine	User Driven Calibration to Null Stray Fields
0.5° Repeatability	Magnetoresistive Sensor Technology for Consistency

SPECIFICATIONS

Characteristics	Conditions	Min	Typ	Max	Units
Heading					
Accuracy	Level 0° to ±30° ±30° to ±60°		1.0 3.0 4.0		deg RMS
Resolution			0.1		deg
Hysteresis			0.2	0.4	deg
Repeatability			0.2	0.4	deg
Pitch and Roll					
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	Externally Regulated	4.8	5.0	5.2	volts DC
Current	At 5.0 volts DC		15	24	mA
Digital Interface					
UART	ASCII (1 Start, 8 Data, 1 Stop, 0 Parity) User Selectable Baud Rate	2400	-	19200	Baud
Update	Continuous/Strobed/Averaged		8		Hz
Connections	Edge Connector (4-Contact) or PTH		4		pins
Physical					
Dimensions	Circuit Board Assembly		0.6 x 1.5		inches
Weight	HMR3300		3.75		grams
Environment					
Temperature	Operating Storage	-20 -55	- -	+70 +125	°C

* Null zeroing prior to use of the HMR3400 and upon exposure to temperature excursions beyond the Operating Temperature limits is required to achieve highest performance.

PIN CONFIGURATION

Pin Number	Pin Name	Description
1	GND	Power and Signal Ground
2	RXD	UART Receive Data/SPI Data Output
3	TXD	UART Transmit Data/SPI Data Input
4	+5VDC	+5 VDC Regulated Power Input

BASIC DEVICE OPERATION

The HMR3400 Digital Compass Solution includes all the basic sensors and electronics to provide a digital indication of heading. The HMR3400 uses three magnetic sensors plus a MEMS accelerometer to provide tilt (pitch and roll) sensing relative to the board's horizontal (flat) position.

The HMR3400 circuit starts with Honeywell HMC1022 and HMC1021Z 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.

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 HMR3400 circuits is regulated +5 volts allowing the user to directly provide the regulated supply voltage to minimize PCB size. The power supply distrbution is a dual ground (analog and digital) system to control internal noise and maximize measurment accuracy.

PHYSICAL CHARACTERISTICS

The circuit board for the HMR3400 Digital Compassing Solution is approximately 0.6 by 1.5 inches. An 4-Pin header may optionally be placed at the edge connector plated through holes for pinned user interface. Figure 1 shows the typical circuit board with dimensions.

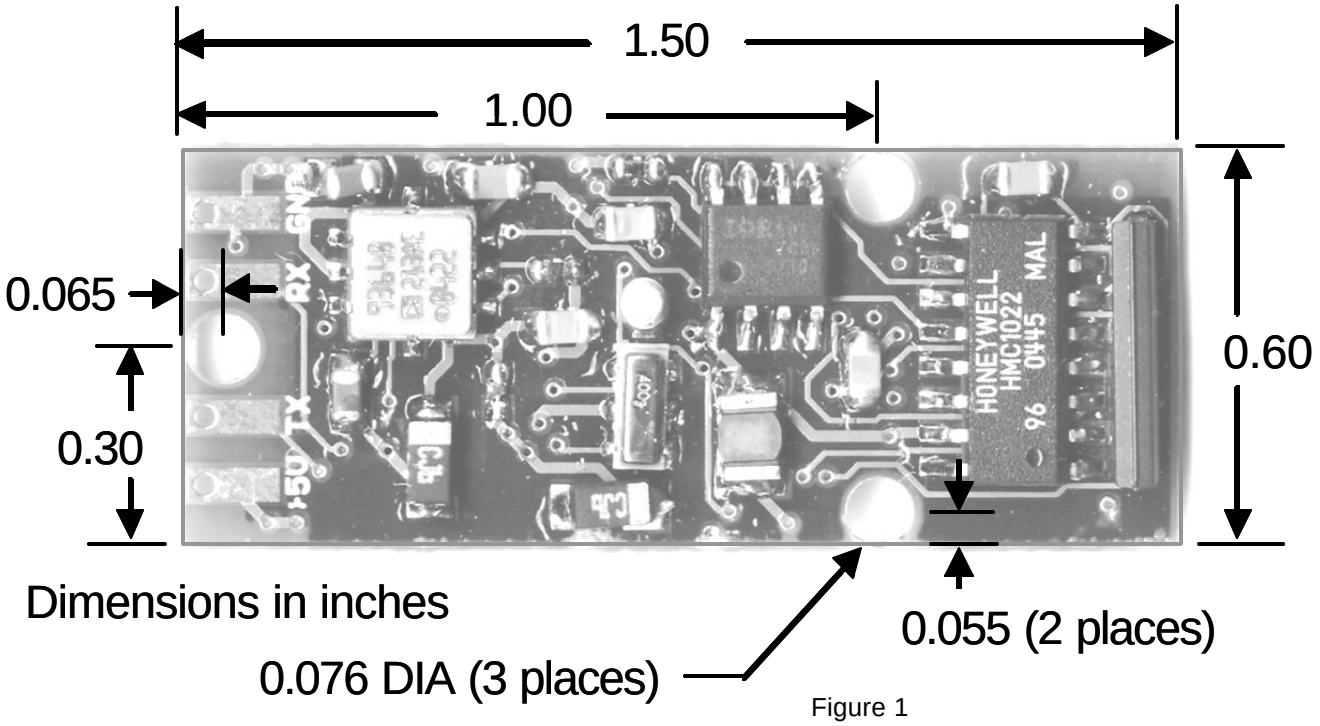


Figure 1

MOUNTING CONSIDERATIONS

The following is the recommend printed circuit board (PCB) footprint for the HMR3400. Three small mounting holes are provided to hold the HMR3400 mechanically to the host PCB or chassis. The goal is to hold the part horizontal and parallel with the forward and side surfaces of the end product.

The HMC1021Z part is an 8-pin SIP device that is shipped carefully in a nearly perfectly vertical orientation with respect to the horizontal referenced circuit board. Do not bend or reposition this part, or the factory magnetic calibration will be no

longer valid. Should the part be accidentally bent, return for recalibration is possible or align the part vertical to recapture most of the accuracy. Correct flat orientation of the compass modules is with the pins pointing downward.

CIRCUIT DESCRIPTION

The HMR3400 Digital Compass Solution includes all the basic sensors and electronics to provide a digital indication of heading. The HMR3400 uses three magnetic sensors and includes an accelerometer to provide tilt (pitch and roll) sensing relative to the board's horizontal (flat) position. HMR3400 is derived from the HMR3300 product baseline, and is a shrink in terms of size and flexibility of power supplied.

The HMR3400 circuit starts with Honeywell HMC1021Z and HMC1022 single and two-axis magnetic sensors providing X, Y, and Z axis magnetic sensing of the earth's field. The HMC1022 provides the horizontal components (X and Y), and HMC1021Z provides the vertical (Z) axis component of the incident magnetic field into cartesian magnitudes at orthognal angles. 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 a multiplexed 16-bit 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.

The HMR3400 contains an additional pair of data inputs from the ±2g accelerometer (Analog Devices ADXL213) 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. If the board is held horizontal, the pitch and roll angles are zero and the X and Y sensor inputs dominate the heading equation. When tilted, the Z magnetic sensor plus the accelerometer's pitch and roll angles enter into heading computation.

The power supply for the HMR3400 circuit is designed for regulated +5 volt provision from a regulated supply source. The power supply is a dual ground (analog and digital) system to control internal noise and maximize measurment accuracy.

APPLICATION NOTES

When To Calibrate

The HMR3400 comes with an optional user hard-iron calibration routine to null modest intensity hard-iron distortion. For many users in cleaner magnetic environments, the factory calibration will be better and yield more accurate readings than after a user calibration.

The calibration routine is not cure-all for nasty magnetic environments. If a needle compass is thrown off from true readings, then it is very likely the HMR3400 will have poor accuracy too. Most compass error sources come from ferrous metals (steel, iron, nickel, cobalt, etc.) located too close to the compass location and are known as soft-irons creating soft-iron distortion. Soft-iron distortion will change the intensity and direction of the magnetic fields on any nearby compass, and the calibration routine can not remove these flux concentration and bending errors. A good rule of thumb is to keep soft-irons at least two largest dimensions away from the compass. For example, a half-inch stainless steel panhead bolt should be at least an inch away from the HMC1021Z and HMC1022 sensor locations.

Other nasty magnetic environments are man-made AC and DC magnetic fields created from nearby motors and high current conductors. These fields should also require compass or source relocation when possible. In some cases, ferrous metal shielding may help if the shield material is thin and far enough away from the compass.

Hard-iron distortion can be calibrated out, and is composed of soft-irons that are also magnetized and create remnant (stray) magnetic flux. Classic hard-iron distortion typically comes from large vehicle chassis components and engine blocks that have up to ±2 gauss on the parts. Locating the compass away from hard and soft-irons is the first line of defense to preserve accuracy, and the calibration routine will null out the remaining hard-iron influences.

Calibration Procedure

For the HMR3400, one complete turn in a level plane is the starting point to expose the XY sensors to all headings to compute the calibration offsets. Since the compass collects data at a 8 samples per second rate, a sample per degree of rotation or slower is a good guideline. If slow turns are not possible, multiple faster turns are a good substitute. The goodness of the calibration or the amount of hard-iron present is found by checking the Xof, Yof, and Zof values after the calibration routine is complete. In known clean magnetic environments, the horizontal values (XY = level, YZ = upright)

should be ±200 ADC counts or less in these offset variables. Sending these Xof, Yof, and Zof values back to zero returns the compass to the factory calibration state.

For the HMR3400, the above described level turns will calibrate the XY axis', but the Z-axis should also be calibrated as well One full rotation with as much pitch and roll variation included as application allows. If only mild pitch and roll variations are possible, complete the level rotations, exit the calibration routine, and force the Zof value to zero. Some accuracy maybe lost in this zeroing, but the mild tilt would likely never cause serious tilt-compensation heading error.

UART COMMUNICATION PROTOCOL

HMR3400 module communicates through ASCII characters with the * or # characters as start bytes. The data bit format is 1 Start, 8 Data, 1 Stop, and No parity bits. Factory baud rate is set to 19,200. Asynchronous communication has the complete menu of commands. Synchronous communication is limited to direct heading queries and no other commands.

POWER-ON/RESET

The compasses require a hard power-on transition on the power supply voltage to serve as an internal hardware reset and clock-start. Some bench power supplies may create a soft-start condition and the HMR3400 my not react if not reset suddenly. An in-line power supply switch (mechanical or electrical) may be required when prototyping to avoid soft-starts.

Upon application of power or after a Reset Command, the HMR3400 will run about an 800 milli-second initialization routine to set the onboard hardware and grab EEPROM variables and shadow them in controller RAM locations for operation.

INITIAL STATUS OUTPUT

The HMR3400 will begin sending ASCII characters immediately after the initialization routine ends. The first line of text will be the model number of the compass and the internal firmware revision number. A second response string will be sent, starting with a # character and either the N, W or A characters. The #N response indicates normal operation and is the always expected response from the HMR3200. The #W and #A responses indicate the low temperature warning and alarm environments had been encountered. These responses will be reset to normal when the user sends the pitch and roll re-zero commands to re-calibrate the MEMS accelerometer for best tilt-compensation performance and accurate tilt indications.

After initialization, the compasses automatically begin streaming heading or magnetometer output data at 8Hz. Users must send a start/stop command (*S) to exit continuous streaming data, and to get the controller's full attention to the next commands.

OPERATIONAL COMMANDS

Syntax: *X<cr><lf> Sends command for an operational mode change. The * prefix indicates command type. A #I response indicates an invalid command was sent.

Heading Output Command

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

Selects the Heading output mode (factory set default). This configuration is saved in non-volatile memory. All data are in decimal degrees.

Response Format: Heading, Pitch, Roll<cr><lf>

Eg: 123.4, 18.6, -0.5<cr><lf>

Magnetometer Output Command

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

Selects the magnetometer output mode. This configuration is saved in non-volatile memory. All data are in signed decimal values with user calibration offsets included.

Response Format: MagX, MagY, MagZ<cr><lf>

Eg: 1256, -234, -1894<cr><lf>

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). Continuous data streaming control. Most commands require the compass to be in a stop condition for the controller to immediately execute the desired command.

Query Output

***Q<cr><lf>**

Query for a single output response string in the currently selected mode (Magnetometer/Heading). The *Q commands are allowed only in Stop data mode. Query commands allow the user to slow the data flow by requesting each response string.

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°). Clears Alarm or Warning status after command receipt.

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°). Clears Alarm or Warning status after command receipt.

Averaged Output

***A<cr><lf>**

Same result as the query command except that the data are the result of an averaging of 20 readings. The *A commands are allowed only in Stop data mode. The command response will not occur until the 20 readings accrue.

Split Filter Toggle

***F<cr><lf>**

This command toggles the split filter bit in the configuration status bytes. The parameter setting is saved in the EEPROM immediately, but not in shadowed in RAM. Requires power cycling or a reset command (*R) to activate. A set bit indicates the System Filter only smoothes the accelerometer data (Tilt Filter), and the Magnetic Filter is now active to smooth magnetic sensor data. A cleared filter bit resumes the same smoothing for both the tilt and magnetometer data.

Reset

***R<cr><lf>**

Resets compass to power-up condition. A one second initialization routine starts and EEPROM data (non-volatile memory) is uploaded (shadowed) into RAM. Continuous streaming data begins after initialization and status output.

User Calibration

***C<cr><lf>**

The command to be issued to enter and exit the calibration mode. Once in the calibration mode, the device will send one or more magnetometer data strings appended by a “C” character to indicate the Calibration Mode operation.

Eg. 123,834,1489,C<cr><lf>

See the calibration procedure notes earlier in this datasheet. At the completion of the calibration movements, 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 declination angle between magnetic north and geographic north. The declination angle is subtracted from the magnetic north heading computed to create a geographic north heading. Values typically range in the ±25 degree area. For example New York has a -14 degree declination angle, and Los Angles has a +14 degree declination angle.

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. The Deviation angle is subtracted from the predicted heading to compensate for mechanical misalignment.

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. These values are recomputed after a calibration routine. Also fixed offsets can be inserted to correct for known magnetic shifts. Values are in ADC counts.

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 transmit and recieve baud rate. 19200, 9600, 4800 and 2400 are the only allowed values. Baud rate can not be queried and is sent to the EEPROM to overwrite the present setting. Factory default is 19200.

Eg: #XBau=9600<cr><lf> sets the Baud Rate to 9600 after the next Reset command or power cycle.

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 both 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. Values between 0 and 255 are valid, with a factory default of 3. A good reason to increase the filter value would be in the presence of high mechanical vibration environments.

Eg: #SFL=6<cr><lf> Sets the system filter value of 6.

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. Values between 0 and 255 are valid, with a factory default of 3. A good reason to increase the magnetic filter value would be the presence of AC magnetic fields from nearby conductors or motors.

Eg: #SFL=0<cr><lf> Sets the magnetic filter value of zero (no filtering).

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 the two byte configuration status. 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 (X, Y, Z)
H Out	1	Heading Output Sentence selected (H, P, R)
Warn	1	Device temperature has fallen below -10 C during this session of operation. Rezero pitch and roll to clear after low temp.
Alarm	1	Device temperature has fallen below -20 C during this session of operation. Rezero pitch and roll to clear after low temp.
SplitFilter	1	Independent Filter values for Magnetic and Tilt are used

Eg: #CON? Returns a response of #D=2088<cr><lf> meaning same filters used for magnetic and tilt data (bit 10 clear) 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 numeric data requested in decimal format.

#I<cr><lf>

Invalid command response. Response to any invalid command.

ORDERING INFORMATION

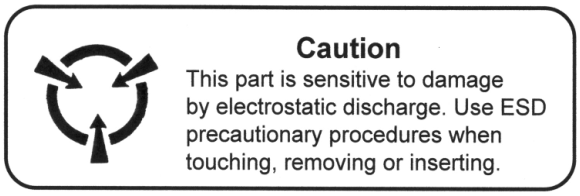
Ordering Number	Product
HMR3400	Digital Compass Solution

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For more information on Honeywell's Magnetic Sensors visit us online at www.magneticsensors.com or contact us at 800-323-8295 (763-954-2474 internationally).

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U.S. Patents 5,583,776 5.952,825 6, 522,266 6,539,639 6,543,146 6,667,682 6,813,582 6,842,991 6,877,237 and 7,095,226 apply to the technology described. Honeywell reserves the right to make changes to any products or technology herein to improve reliability, function or design. Honeywell does not assume any liability arising out of the application or use of any product; neither does it convey any license under its patent rights nor the rights of others.



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Form #900335
June 2009
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