

# Digital Compass Solutions

## HMR3300

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The Honeywell HMR3300 is a digital compass solution for use in precision heading applications. Honeywell's magnetoresistive sensor is utilized to provide the reliability and accuracy of these small, solid state compass designs. This compass solution is designed for generic precision compass integration into customer systems using a 5-voltage logic level serial data interface with commands in ASCII format.

The HMR3300 includes a MEMS accelerometer for a horizontal three-axis, tilt compensated precision compass for performance up to a  $\pm 60^\circ$  tilt range.

Honeywell continues to maintain product excellence and performance by introducing innovative solid-state magnetic sensor solutions. The HMR3300 is a highly reliable, top performance product that is delivered when promised. Honeywell's magnetic sensor solution provides real solutions you can count on.



### FEATURES

- ▶ Compact Solution on a 1.0" by 1.5" PCB
- ▶ Precision Compass Accuracy
- ▶ Tilt-Compensated (HMR3300 only)
- ▶ 0.5° Repeatability
- ▶ 8 Hz Continuous Update Rate
- ▶ Hard-Iron Compensation Routine
- ▶ -40° to +85°C Operating Temp Range
- ▶ Demonstration Kit Available
- ▶ UART and SPI Communication

### BENEFITS

- ▶ Small Size and Pin Interface for Daughter/Motherboard Integration
- ▶  $\pm 1^\circ$  at Level Heading Accuracy,  $\pm 0.1^\circ$  Resolution
- ▶ Up to  $\pm 60^\circ$  of Pitch and Roll Angles Using a MEMS Accelerometer
- ▶ Magnetoresistive Sensor Technology for Consistency
- ▶ Rapid Heading Computations for Control System Applications
- ▶ User Driven Calibration to Null Stray Fields
- ▶ Consumer and Industrial Environment Uses
- ▶ Includes RS-232 Motherboard PCB, Cable, 9-volt power supply, PC Demo Software, and a Carrying Case
- ▶ Intuitive Command Language

# HMR3300

## SPECIFICATIONS

Characteristics	Conditions	Min	Typ	Max	Units
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### Heading

Accuracy	Level 0° to ±30° (HMR3300 only) ±30° to ±60° (HMR3300 only)		1.0 3.0 4.0		deg RMS
Hysteresis	HMR3300		0.2	0.4	deg
Repeatability	HMR3300		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 Hysteresis -40° to +85°C Thermal Hysteresis		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 Regulated	6 4.75	- -	15 5.25	volts DC
Current	HMR3300		22	24	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 Pseudo Master				
Update	Continuous/Strobed/Averaged HMR3300		8		Hz
Connector	In-Line 8-Pin Block (0.1" spacing)				

### Physical

Dimensions	Circuit Board Assembly		25.4 x 36.8 x 11		mm
Weight	HMR3300		7.50		grams

### Environment

Temperature	Operating Storage	-20 -55	-	+70 +125	°C
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\* 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.

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## PHYSICAL CHARACTERISTICS

The circuit board for the HMR3300 Digital Compassing Solutions is approximately 1.45 by 1 inches. An 8-Pin header protrudes down on the rear edge of the compass circuit board for the user electrical interface to the motherboard. The header pins extend 5/16" below the board plane with the bottom-side mounted magnetic sensor integrated circuits (HMC1021Z and HMC1022) extending 3/16" below the board plane. Components on the top-side have a maximum height of 1/8".

In addition two single pins, identical to the 8 header pins, are placed on the sides toward the forward edge of the circuit board (HMC1021Z is at the magnetic front or north reference). These single pins are for mechanical mounting and do not have electrical connections to the compass electronics.

## POWER SUPPLY INTERFACE

Rotary switch (SW1) is located near pins 6 and 7, and is used to select the customer provided power supply voltage type. The HMR3300 is factory set with this switch fully clockwise, for selection of unregulated input (+6 to+15) voltage from the V+ pin (pin 8). By rotating the switch fully counter-clockwise, users may provide a regulated +5 volt supply to the +5 pin (pin 6) as an alternative. Incorrect switch settings may cause no response or faulty responses. Upon correct power application, light emitting diode D2 turns on for about one second afterwards to indicate the execution of the initialization firmware. Do not use both power inputs simultaneously.

Figure 1 shows a typical HMR3300 circuit board assembly with the basic dimensions.

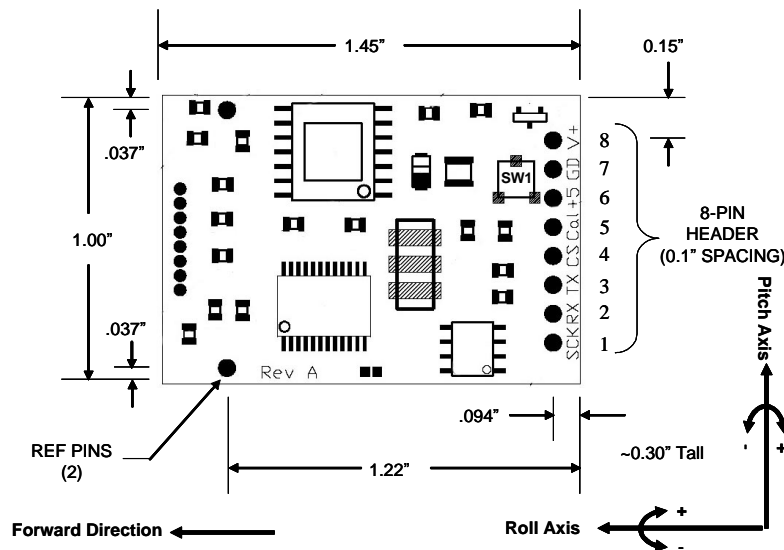


Figure 1

## MOUNTING CONSIDERATIONS

The HMR3300 precision compass uses the ten integrated circuit style pins to plug into compatible motherboards for electrical interface, and to be orientated mechanically. The pins are nominally 0.030" in diameter and 0.200 in length. Trimming the pin lengths or removing the pins voids the warranty, as Honeywell can not retest the modified compasses (socketized test fixtures). Wires can be substituted for the pins, but caution should be used in soldering to not damage the pin solder pads.

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.

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## CIRCUIT DESCRIPTION

The HMR3300 Digital Compass Solution includes all the basic sensors and electronics to provide a digital indication of heading. 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 HMR3300 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 orthogonal 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.

For the HMR3300, an additional pair of data inputs from the  $\pm 2g$  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 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 measurement accuracy.

## ELECTRICAL INTERFACE PINOUT

Pin Number	Pin Name	Description
1	SCK	Synchronous Data Clock (Pulled high in UART mode and left open)
2	RX	Receive Data, 5V CMOS Input
3	TX	Transmit Data, 5V CMOS Output
4	CS	Chip Select (Pulled high in UART mode and left open)
5	Cal	Calibration Input (No connection normally, consult for details)
6	+5	+5 Volt Regulated Power Input (SW1 must be fully CCW)
7	GD	Logic and Power Return (Ground)
8	V+	Unregulated Power Input (+6 to +15 volts, factory default, SW1 must be CW)

## APPLICATION NOTES

### When To Calibrate

The HMR3300 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 HMR3300 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.

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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  $\pm 2$  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 HMR3300, one complete turn in a level plane is the best way to expose the sensors to all headings to compute the calibration offsets for the X- and Y-axis. However, the Z-axis must also be calibrated. Since the compass collects data at a 15 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  $\pm 200$  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. 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

The HMR3300 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 HMR3300 may react with a constant-on LED illumination 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 HMR3300 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. The LED will illuminate during the routine and extinguish upon completion.

## INITIAL STATUS OUTPUT

The HMR3300 will begin sending ASCII characters immediately after the initialization routine ends and the LED extinguishes. The first line of text will be the model number of the compass and the internal firmware revision number. For the HMR3300, a second response string will be sent, starting with a # character and either the W or A characters. 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 compass automatically begins 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.

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## OPERATIONAL COMMANDS

**Syntax:** \*X<cr><lf> Sends command for an operational mode change. The \* prefix indicates command type.  
A #! 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> (8 times per second)

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 ( $\pm 0.3^\circ$ ). 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 ( $\pm 0.3^\circ$ ). Clears Alarm or Warning status after command receipt.

### Averaged Output

\*A<cr><lf>

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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 smooths 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= $\pm$ xxxx<cr><lf>** Sets parameter value

**#Dev?<cr><lf>** Queries for the parameter value

### Variation Input (Declination Angle Correction)

**#Var= $\pm$ nnnn<cr><lf>** where the variation is  $\pm$  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  $\pm 25$  degree area. For example New York has a -14 degree declination angle, and Los Angeles 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= $\pm$ nnnn<cr><lf>** where the angle is  $\pm$  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.

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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 receive 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



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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.

## SPI Interface

SPI operating Mode is as follows:

SCK idles low (mode CKP=0, CKE=0)  
Data Output after falling edge of SCK  
Data sampled before rising edge of SCK

## Synchronous Communication Protocol

The 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 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

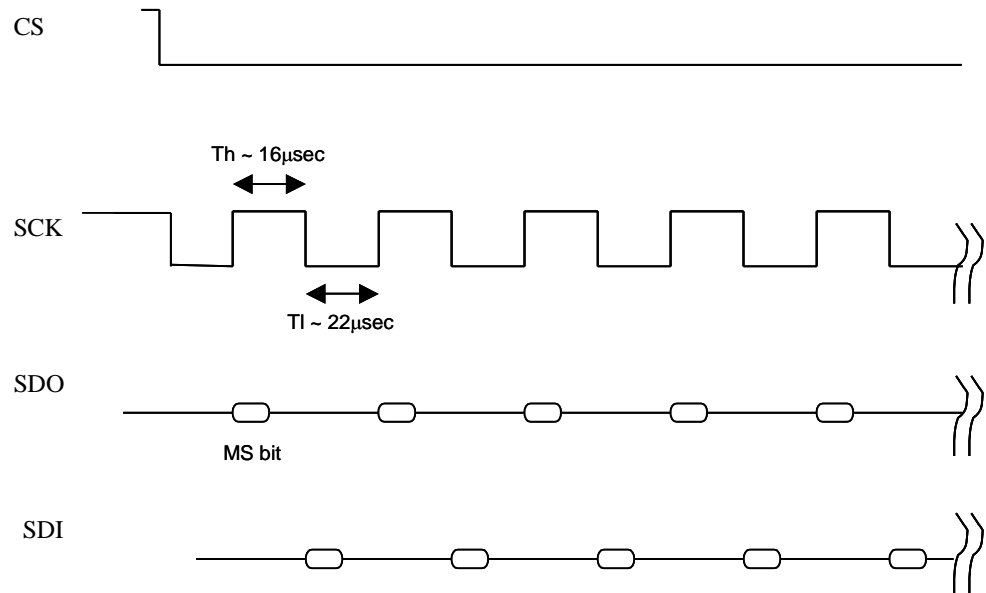
Heading Output: In response to an H or h command, HMR3300 module shall send two bytes of data. The MSByte is transmitted first. These two bytes represent the integer value equal to 10\*Heading. The MSbit is transmitted first for each byte.

# HMR3300

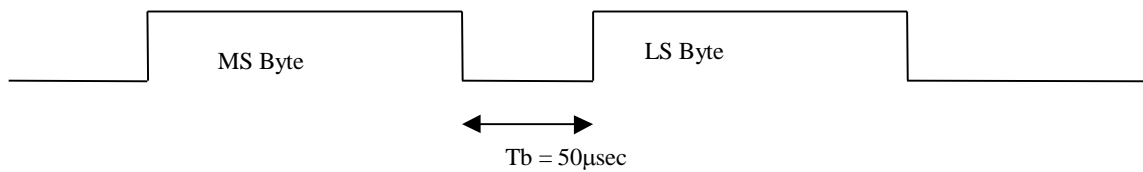
## SPI Timing

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



# HMR3300

## COMPASS DEMONSTRATION KIT

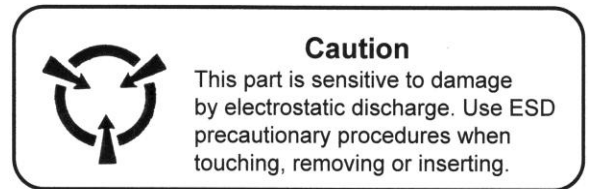
The HMR3300 Demo kit includes additional hardware and Windows software to form a development kit for electronic compassing. This kit includes the HMR3300 Printed Circuit Board (PCB) module as a daughter board, a TTL to RS-232 motherboard with a D9 serial port connector, 6' serial port cable with attached AC adapter power supply, and a Windows demo software CD with documentation. The cable is a 4-wire design with pins 2 and 3 NOT flipped (DTE to DCE, not null modem) with pin 5 as the ground reference. Pin 9 is the unregulated positive voltage reference and is factory connected to the AC adapter. Either cable side may be used for the compass demo kit or computer serial port.

The AC adapter is a universal type and factory set for 120 VAC input, 9 volt DC output, and positive polarity. Users can rewire the cable for battery operation for remote usage. Batteries chosen must apply the required 6 to 15 volt supply range with at least 24mA current capability. If compact 9 volt batteries are used, it is recommended that two batteries of the same chemistry be wired in parallel to have reasonable operational life.

The TTL to RS-232 motherboard is designed to handle only unregulated power supply voltages and routes the supply directly to the V+ pin of the HMR3300 daughterboard. The electronics on the motherboard convert the RX and TX 5 volt logic to the  $\pm 6$  volt RS-232 drive logic for computer serial ports.

## ORDERING INFORMATION

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



**CAUTION: ESDS CAT. 1B**

## Find out more

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

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

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