

THREE-AXIS STRAPDOWN MAGNETOMETER

HMR2300r

FEATURES

- Strapdown Magnetometer Replaces Bulky Fluxvalves
- Microprocessor Based Smart Sensor
- Range of ± 2 Gauss— < 70 μ Gauss 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

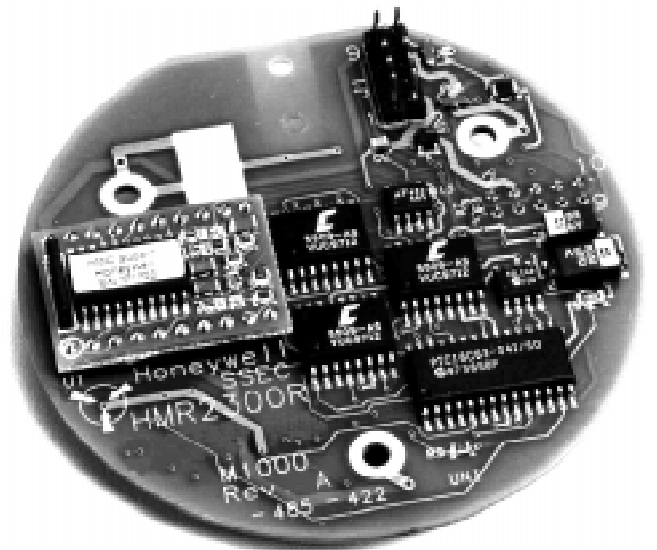
GENERAL DESCRIPTION

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.



HMR2300r

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

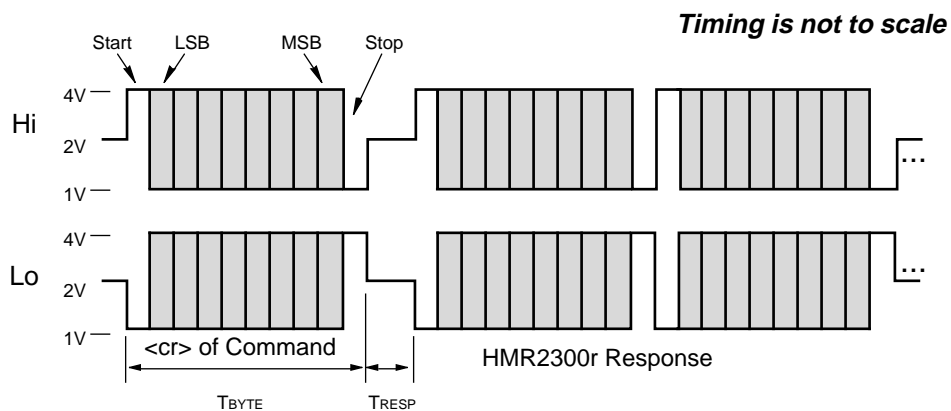
OPERATING SPECIFICATIONS—Table 1

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

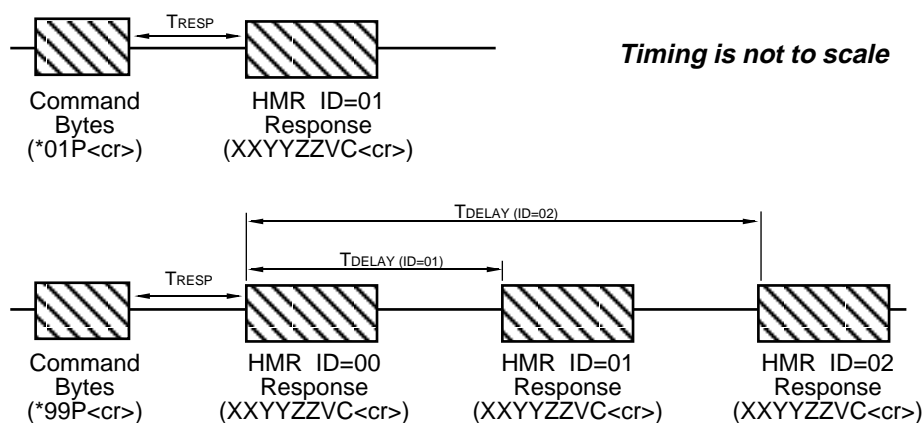
TIMING SPECIFICATIONS—Table 2

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	DATA INVALID	↓	↓	↓	34	100/120	24
50		↓	↓	↓	42	125/150	19.6
60		↓	↓	↓	51	150/180	16.1
100		↓	↓	↓	85	250/300	9.8
123		↓	↓	↓	104	308/369	8.1
154		↓	↓	↓	131	385/462	6.5

Parameter Selections versus 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	*ddC	{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	*ddJ	SET ← RST ← {Toggle}	4 4 4] character - single S/R: JS -> SET=set pulse Toggle alternates between SET and RESET pulse.
Device ID	*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: $X_{avg} = X(N)/2 + X(N-1)/4 + X(N-2)/8 + X(N-3)/16 + \dots$ *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		{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.
<i>Too Many Characters</i>	Wrong Entry	Re-enter ←	9	A command was not entered properly or 10 characters were typed after an asterisk (*) and before a <cr>.
<i>Missing WE Entry</i>	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 (Gauss)	BCD ASCII Value	Binary Value (Hex)	
		High Byte	Low Byte
+ 2 . 0	3 0 , 0 0 0	7 5	3 0
+ 1 . 5	2 2 , 5 0 0	5 7	E 4
+ 1 . 0	1 5 , 0 0 0	3 A	9 8
+ 0 . 5	7 , 5 0 0	1 D	4 C
0 . 0	0 0	0 0	0 0
- 0 . 5	- 7 , 5 0 0	E 2	B 4
- 1 . 0	- 1 5 , 0 0 0	C 3	7 4
- 1 . 5	- 2 2 , 5 0 0	A 8	1 C
- 2 . 0	- 3 0 , 0 0 0	8 A	D 0

Output Readings—Table 5

Binary Format: 9 bytes

$X_H | X_L | Y_H | Y_L | Z_H | Z_L | \text{Validity} | \text{Checksum} | \langle cr \rangle$

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

$\langle cr \rangle$ = 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

$SN | X_1 | X_2 | CM | X_3 | X_4 | X_5 | SP | SP | SN | Y_1 | Y_2 | CM | Y_3 | Y_4 | Y_5 | SP | SP | SN | Z_1 | Z_2 | CM | Z_3 | Z_4 | Z_5 | SP | SP | \langle cr \rangle$

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

$\langle cr \rangle$ = carriage return (Enter Key), Hex code = 0D

SP = space, Hex code = 20

SN (sign) = - if negative, Hex code = 2D

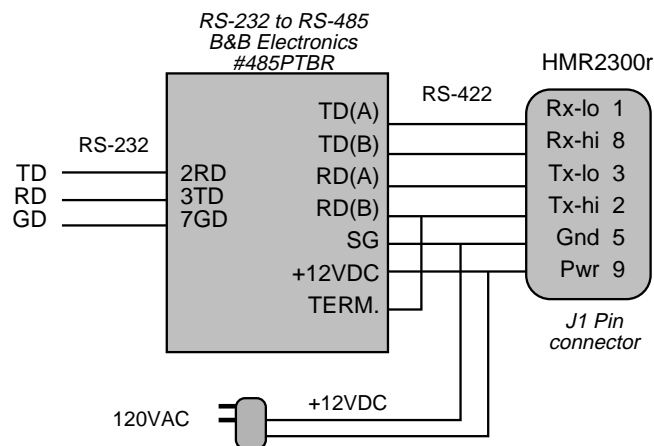
SP if positive, Hex code = 20

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

HMR2300r

DATA COMMUNICATIONS

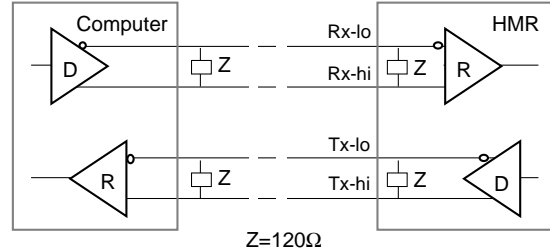
The RS-422 signals are balanced differential signals that can send and receive simultaneously (full-duplex). The RS-485 signals are also balanced differential levels but the transmit and receive signals share the same two wires. This means that only one end of the transmission line can transmit data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

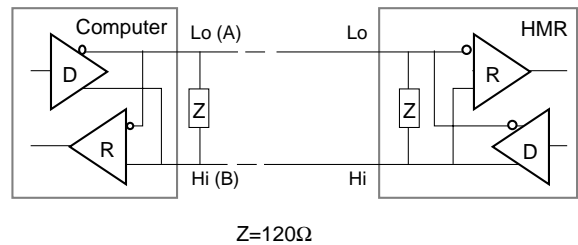
The signals being transmitted are not dependent on the absolute voltage level on either Lo or Hi but rather a difference voltage. That is, when a logic one is being transmitted, the Tx line will drive about 1.5 volts higher than the Rx line. For a logic zero, the Lo line will drive about 1.5 volts lower 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.



Z=120Ω
RS-422 Balanced (full-duplex)—Figure 4



Z=120Ω
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)

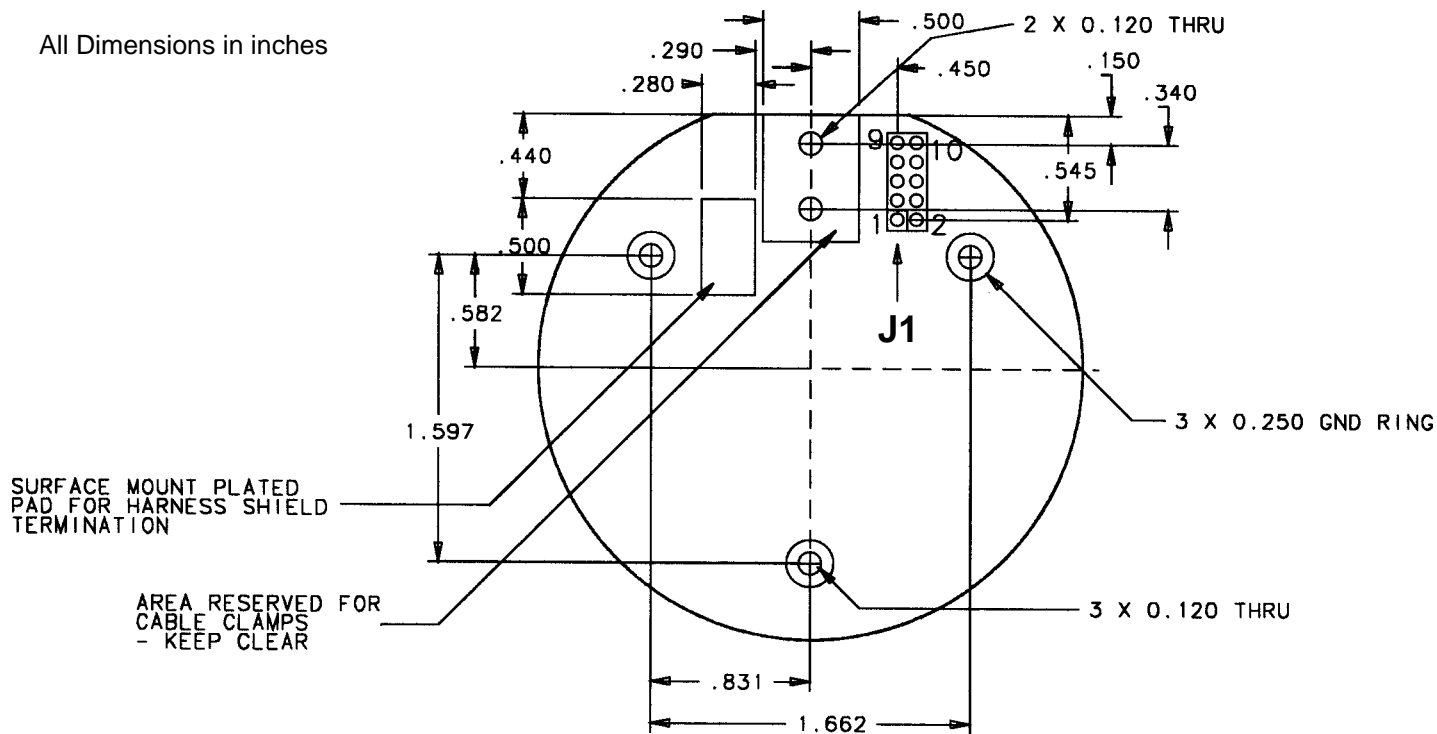
P1 Sockets	
for manufacturers use only - 9	○ ○ 10 - for manufacturers use only
nc - 7	○ ○ 8 - for manufacturers use only
+6.5 to +15VDC power - 5	○ ○ 6 - connected to J1 pin 7
+6.5 to +15VDC return - 3	○ ○ 4 - Chassis ground
nc - 1	○ ○ 2 - connected to J1 pin 6

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)

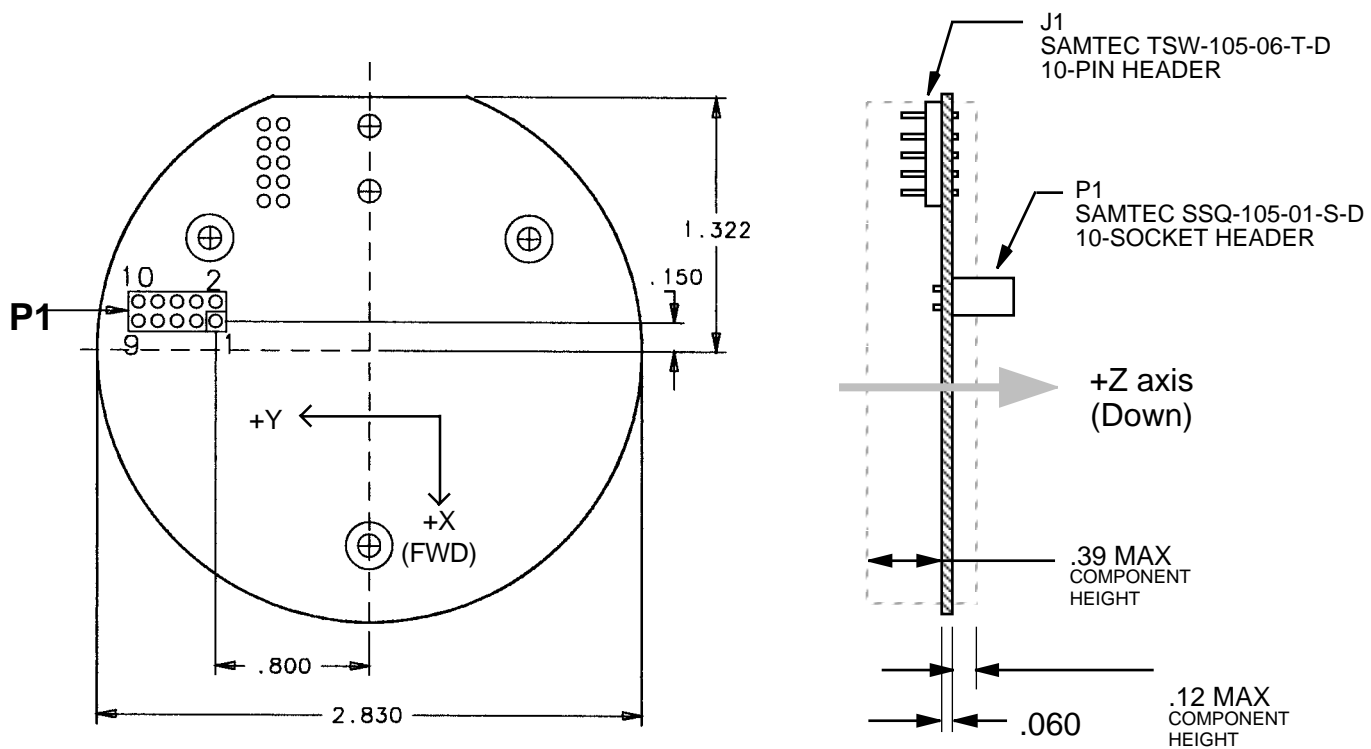
P1 Pin#	Pin Assignment
1	(no connect)
2	connected to J1 pin 6
3	+6.5 to +15VDC return
4	Chassis ground
5	+6.5 to +15VDC power
6	connected to J1 pin 7
7	(no connect)
8	for manufacturers use only
9	for manufacturers use only
10	for manufacturers use only

BOARD DIMENSIONS—FIGURE 7

All Dimensions in inches



TOP-SIDE OF CIRCUIT BOARD ASSEMBLY



BACK-SIDE OF CIRCUIT BOARD ASSEMBLY

HMR2300r

QUALITY AND ENVIRONMENTAL CONDITIONS—TABLE 6

<i>Parameter</i>	<i>Method and Test Levels</i>
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

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