

SMART DIGITAL MAGNETOMETER

HMR2300

FEATURES

- Microcontroller Based Smart Sensor
- Low Cost and Easy To Use—Just Plug and Read
- Range of ± 2 Gauss— <70 μ Gauss Resolution
- High Accuracy over ± 1 Gauss— $<0.5\%$ FS
- Output Rate Selectable—10 to 154 Samples/Sec.
- Three-Axis Digital Output—BCD ASCII or Binary
- RS-232 or RS-485 Serial Output—9600 or 19200

APPLICATIONS

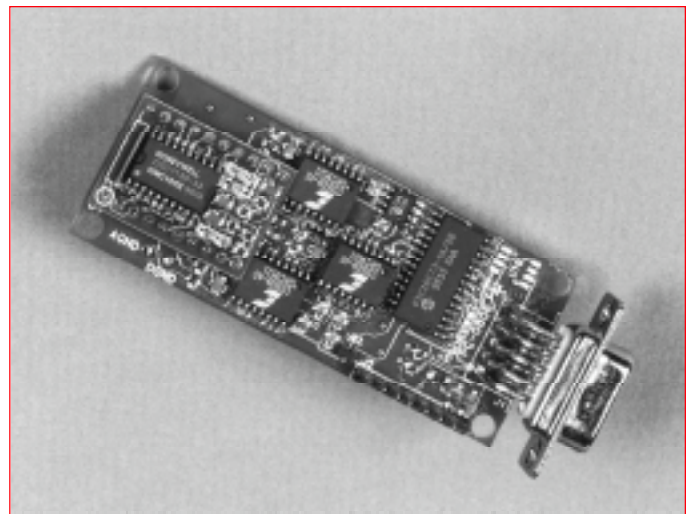
- Compassing—Avionics and Marine
- Remote Vehicle Monitoring (Roll/Pitch/Yaw)
- Process Control
- Laboratory Instrumentation
- Anomaly Detection
- Traffic and Vehicle Detection
- Security Systems

GENERAL DESCRIPTION

Honeywell's three-axis smart digital magnetometer (HMR) detects the strength and direction of a magnetic field and communicates the x, y, and z component directly to a computer. Three independent bridges are oriented to sense the x, y, and z axis of a magnetic field. The bridge outputs are then converted to a 16-bit digital value using an internal delta-sigma A/D converter. A command set is provided (see Table 1) 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. 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 permalloy bridge 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 x, y, and z digitized data is sent out as a series of bytes, either after an ID match is received from the control processor, or as a continuous data stream. The data is serially output at either 9,600 or 19,200 baud, using the RS-232 or RS-485 standard, for serial input to most personal computers. 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-485 or RS-232 drivers provide compliant electrical signalling.

Honeywell's magnetoresistive magnetometers provide an excellent means of measuring both linear and angular position and displacement. 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. The HMR2300 is available either as a circuit board with an optional 9-pin connector or in an aluminum enclosure with a 9-pin connector. Possible applications include compassing, remote vehicle monitoring, process control, laboratory instrumentation, anomaly detection, traffic and vehicle detection, and retail security systems.



OPERATING SPECIFICATIONS—Table 1

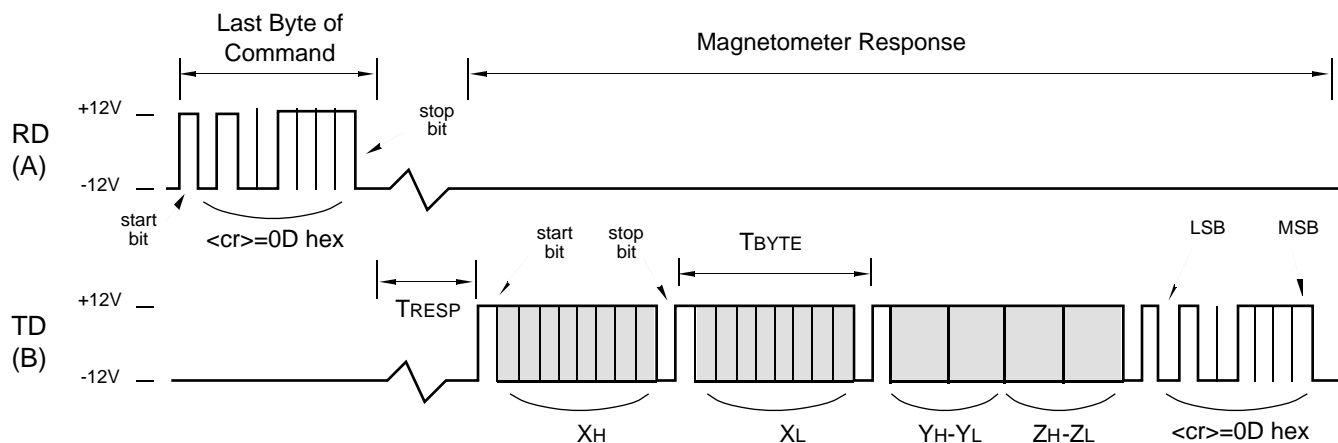
Characteristic	Conditions	Min	Typ	Max	Unit
Supply Voltage	Pin 9 referenced to pin 5	6.5		15	Volts
Supply Current	Vsupply=15V, with S/R=ON		27	35	mA
Operating Temperature	Ambient	-40		85	°C
Storage Temperature	Ambient, unbiased	-55		125	°C
Field Range	Full scale (FS) - total applied field	-2		+2	Gauss
Linearity Error	Best fit straight line (at 25°C) ±1 Gauss ±2 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 (at 25°C) ±1 Gauss ±2 Gauss		0.12 1	0.52 2	%FS
Resolution	Applied field to change output	67			μGauss
Temperature Effect	Coefficient of gain Coefficient of offset (with S/R ON)		-600 ±114		ppm/°C
Power Supply Effect	From 6 -15V with 1G applied field		150		ppm/V
Vibration (operating)	5 to 10Hz for 2 hours 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 In Aluminum Enclosure - extended - flush base		28 98 94		grams

TIMING SPECIFICATIONS—Table 2

Characteristic	Conditions	Min	Typ	Max	Unit
TRESP	Timing Diagrams (Figs. 1,2,3) *dd command (dd=Device ID) *ddP *ddRST *ddC *99 command (exceptions below) *ddQ *99Q	1.9	2 3 6 40 2 + (dd x 40) 2 + (dd x 80) 2 + (dd x 120)	2.2 3.2 6.2 60 2 + Typ 2 + Typ 2 + Typ	msec
TDELAY	Timing Diagram (Fig. 3) *dd command (dd=Device ID) *99 command	39	40 dd x 40	41 2 + Typ	msec
TBYTE	Timing Diagrams (Figs. 1,2)	9600 19200	1.04 0.52		msec
TSTARTUP	Power Applied to end of Start-Up message		50	80	msec

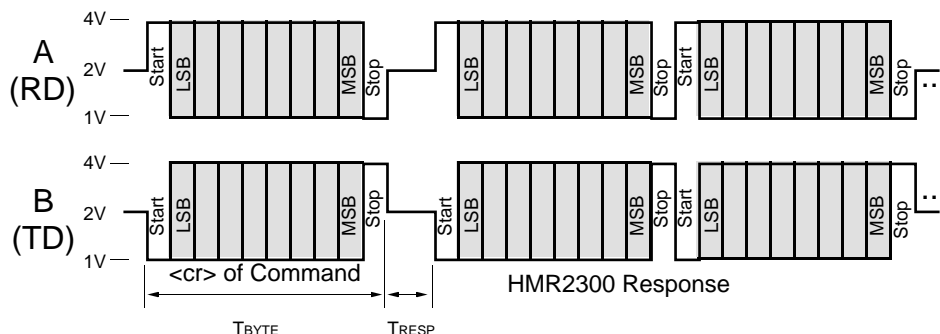
RS-232 COMMUNICATIONS—Figure 1

Timing is not to scale



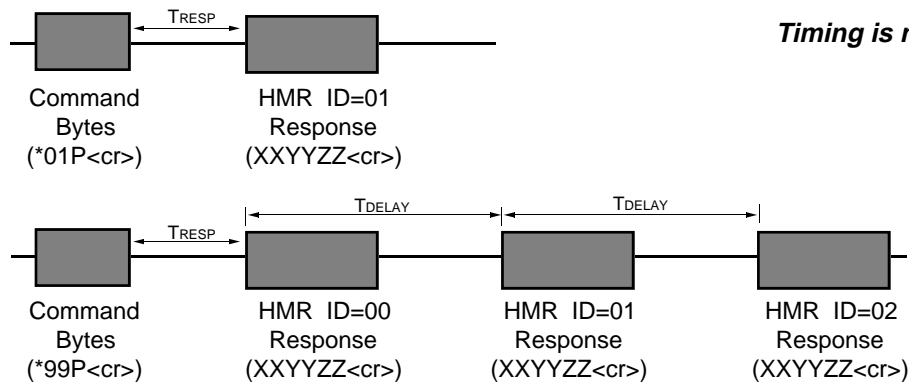
RS-485 COMMUNICATIONS—Figure 2

Timing is not to scale



GLOBAL ADDRESS (*99) DELAY—Figure 3

Timing is not to scale



COMMAND INPUTS—Table 3

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 Terminal 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. (default) Binary - Output readings in signed 16 bit binary 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 - 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=20 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 *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 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 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 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	*ddQ	{see Description}	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.
<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).

Sample Rate (sps)	ASCII		Binary		f _{3dB} (Hz)	Notch (Hz)	Command Input Rate - min. (msec)
	9600	19200	9600	19200			
10	yes	yes	yes	yes	17	50/60	20
20	↓	↓	↓	↓	17	50/60	20
25					21	63/75	16
30	↓	↓	↓	↓	26	75/90	14
40	DATA	↓	↓	↓	34	100/120	10
50		↓	↓	↓	42	125/150	8
60	DATA	DATA	↓	↓	51	150/180	7
100	DATA	DATA	↓	↓	85	250/300	4
123	INVALID	INVALID	↓	↓	104	308/369	3.5
154	INVALID	INVALID	↓	↓	131	385/462	3

Parameter Selections verses Output Sample Rate—Table 4

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 7 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 2). 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

Output Readings—Table 5

Binary Format: 7 bytes

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

X_H = signed high byte, x axis

X_L = low byte, x axis

<cr> = carriage return (Enter Key), Hex code = 0D

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.

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 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

X₁, X₂, X₃, X₄, X₅ = Decimal equivalent ASCII digit

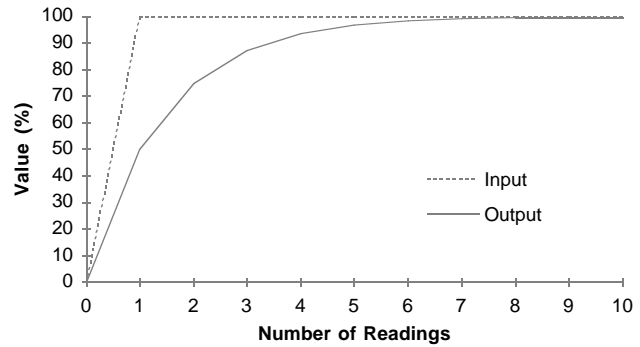
X₁, X₂, X₃ = SP if leading digits are zero, Hex code = 20

SET/RESET and AVERAGE COMMAND

The set-reset function generates a nominal 3.5 Amp pulse, or ≈ 80 Oe field, to each sensor to realign the permalloy magnetization. This yields the maximum output sensitivity for magnetic sensing. This current pulse is generated inside the HMR2300 and consumes less than 1 mA typically. The Set/Reset Mode command (*ddT, or *ddTN, for S/R=ON) 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 command: *ddV, or *ddVN, for AVG=ON. This command provides a low pass filter effect on the output readings that reduces noise due to S/R switching and environmental magnetic effects. See the figures at right for the impulse and step response of the Average Readings function.

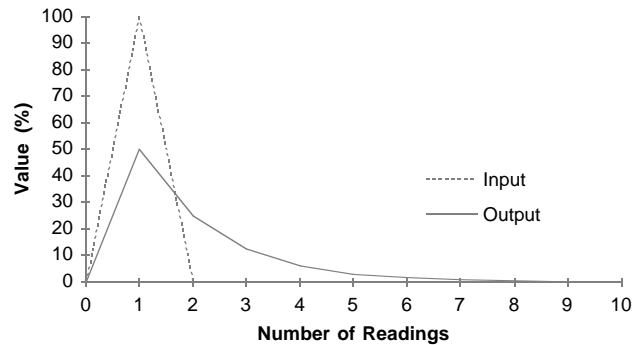
Switching the set-reset state is not required to sense magnetic fields. A single Set (or Reset) pulse will maximize the output sensitivity and it will stay that way for months or years. To turn off the internal switching, enter the command: *ddT, or *ddTF, for S/R=OFF. In this state the sensors are either in a Set or Reset mode. If the hybrid is exposed to a large magnetic field (>20 Gauss), then another set pulse is required to maximize output sensitivity.

In the Set mode, the direction of sensitive axis are shown on the package label and Board Dimensions drawing. 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 commands (*dd] , *ddS, *ddR) can be used during the continuous read mode to flip between a Set and Reset state. Note that the first three readings immediately after these command will be invalid due to the uncertainty of the current pulse to the sensor sample time.



Average Reading Response to an Input Step

Figure 4



Average Reading Response to an Impulse Input

Figure 5

DEVICE ID

The Device ID command (*99ID=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.

ZERO READING COMMAND

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

BAUD RATE COMMAND

The Baud Rate command (*ddIBR=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, or computer, to change to the identified new baud rate before communications can resume.

DEFAULT and RESTORE SETTINGS

The Default Settings command (*ddD) will force the HMR2300 to all the default parameters. This will not be a permanent change unless a Store Parameter command is issued. 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 R= 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 computers. 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 in 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 0.5 msec/byte. The combinations of format and baud selections versus the sample rates are shown in Table 2. The default setting of ASCII format and 9600 baud will only transmit correctly up to 30 sps.

Note: The HMR2300 will output at higher data rate settings but the readings may be incorrect and will be at a lower output rate than selected.

For the higher sample rates (>60 sps), it is advised that computer settings for the Terminal Preferences be set so a line feed (LF) is NOT added to the inbound data. 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 signal being measured will be attenuated based on the sample rate selected. The bandwidth, defined by the 3dB point, is shown in Table 2 for each sample rate. The default rate of 20 sps has a bandwidth of 17 Hz. 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 Table 2.

COMMAND INPUT RATE

The HMR2300 limits how fast the command bytes can be received based on the sample rate selected. Table 2 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 on a keyboard. The problem could arise from a computer program outputting command bytes (characters) too quickly.

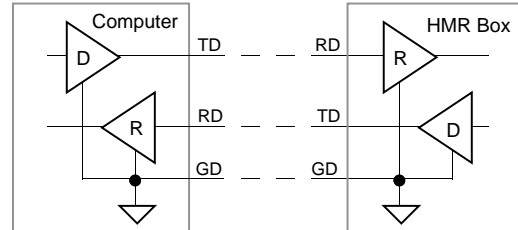
DATA COMMUNICATIONS

The RS-232 signals are single-ended unidirectional levels being sent and received simultaneously (full duplex). One signal is from the PC (Tx) to the HMR (Rx) and the other is from the HMR (Tx) to the PC (Rx). When a logic one is being transmitted, either the Tx or Rx line will drive ≈ 7 volts referenced to ground. For a logic zero, the Tx or Rx line will drive ≈ 7 volts below ground. Since the signals being transmitted are dependent on an absolute voltage level, this limits the distance of transmission due to line noise and signal loss—typically 60 feet.

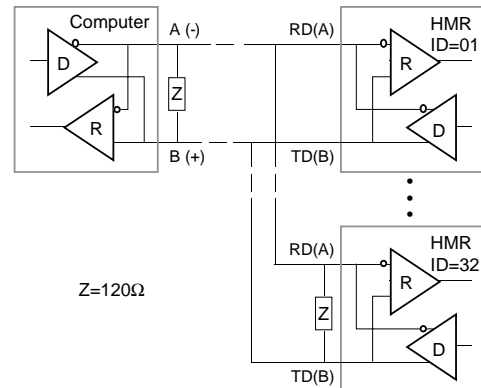
When using RS-485, the signals are balanced differential levels. That is, when a logic one is being transmitted, the Tx line will drive ≈ 1.5 volts higher than the Rx line. For a logic zero, the Tx line will drive ≈ 1.5 volts lower than the Rx line. The signals being transmitted are not dependent on an absolute voltage level on either Tx or Rx but rather a difference voltage. 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. Note that the RS-485 line must be terminated at both ends with a 120Ω resistor.

Note: When the HMR2300 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 readings will occur. If an operator is trying to stop readings using the keyboard, then several (if not many) escape key entries must be given, because 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 HMR2300, then the two will produce an erroneous character that will not stop the data stream. Only when the escape key is pressed during the time the HMR2300 is not transmitting will the data stream stop.

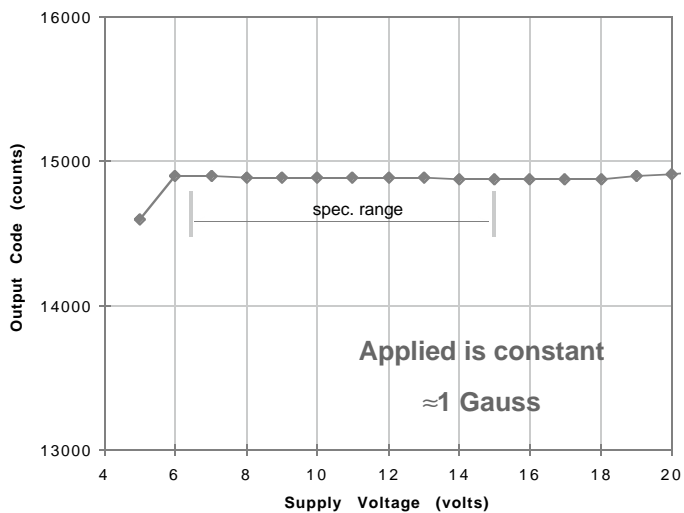
There is a safety feature built into the HMR2300 to allow multiple units to respond to a global address command on the RS-485 bus. When a command is sent with the global address (*99P), each HMR2300 will automatically delay their response by its device ID number times TDELAY. This is for operation on the RS-485 bus to allow each response to follow each other so two units do not transmit at the same time. This delay also applies to single units operating on the RS-232 bus.



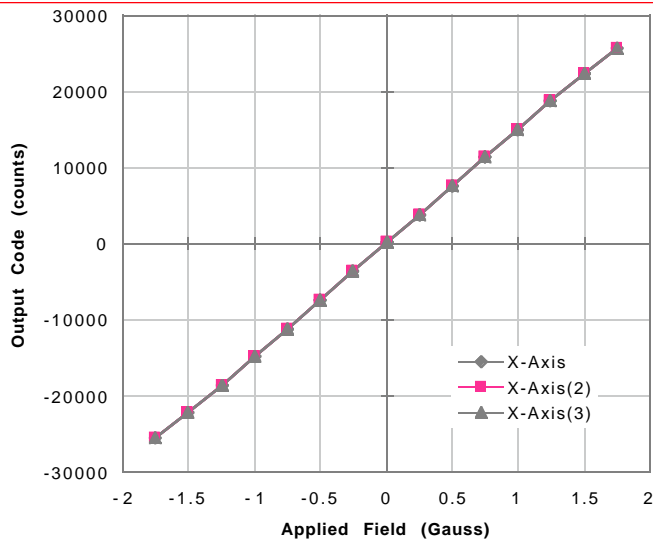
RS-232 Unbalanced (Single-Ended)—Figure 6



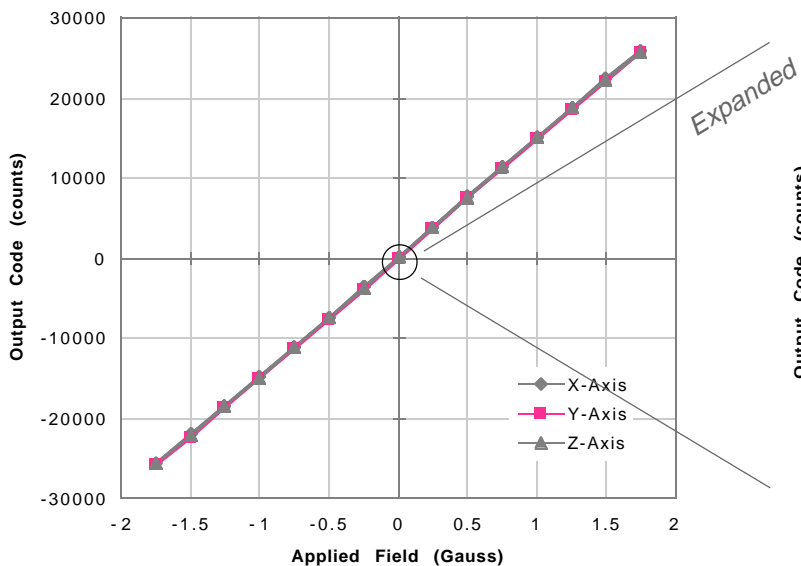
RS-485 Balanced Multiport—Figure 7



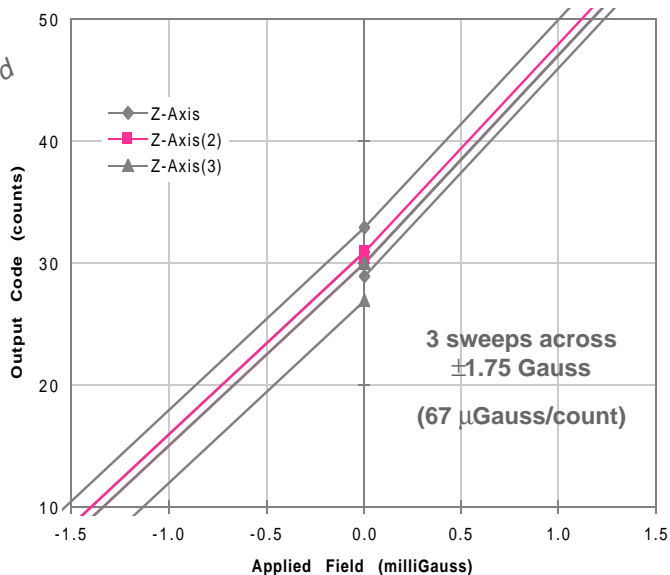
Supply Voltage Effect on Readings—Figure 8



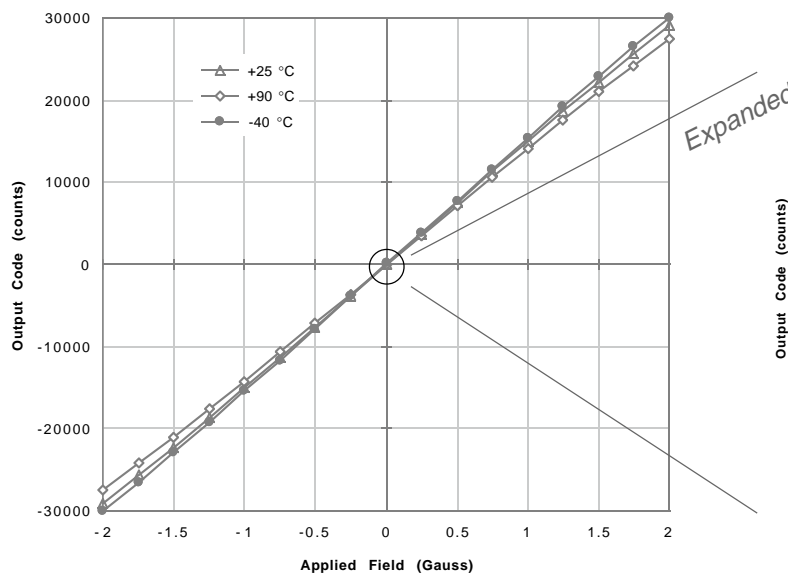
Three Sweeps of X-Axis Transfer Curve—Figure 9



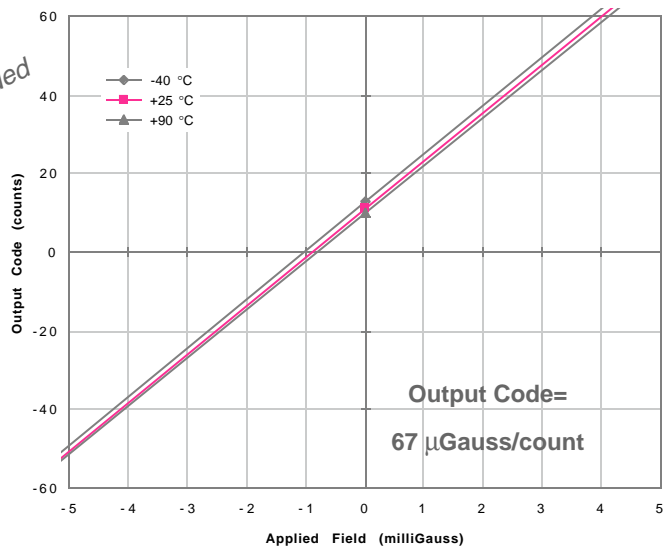
Transfer Curves for X, Y, and Z Axis—Figure 10



Magnified Z-Axis Showing Hysteresis—Figure 11



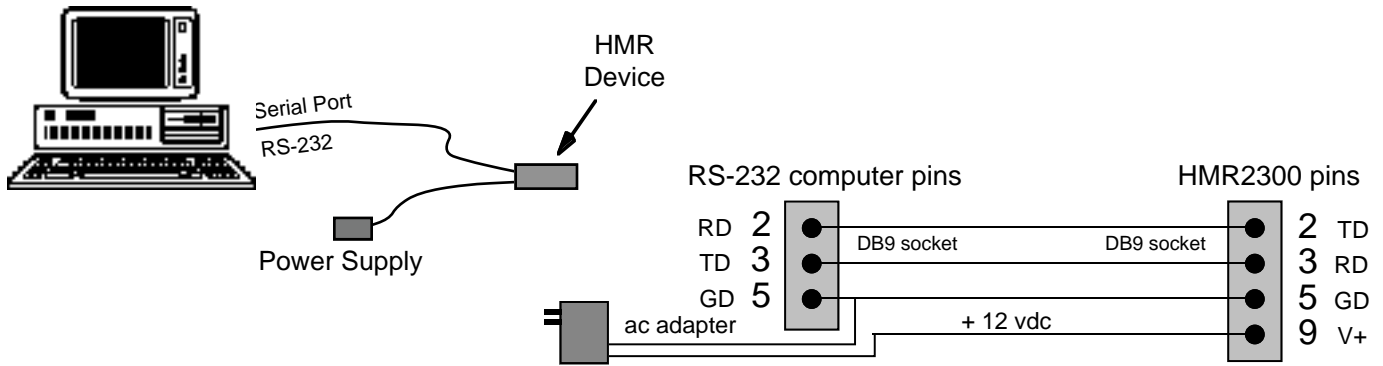
Single-Axis Temperature Effects—Figure 12



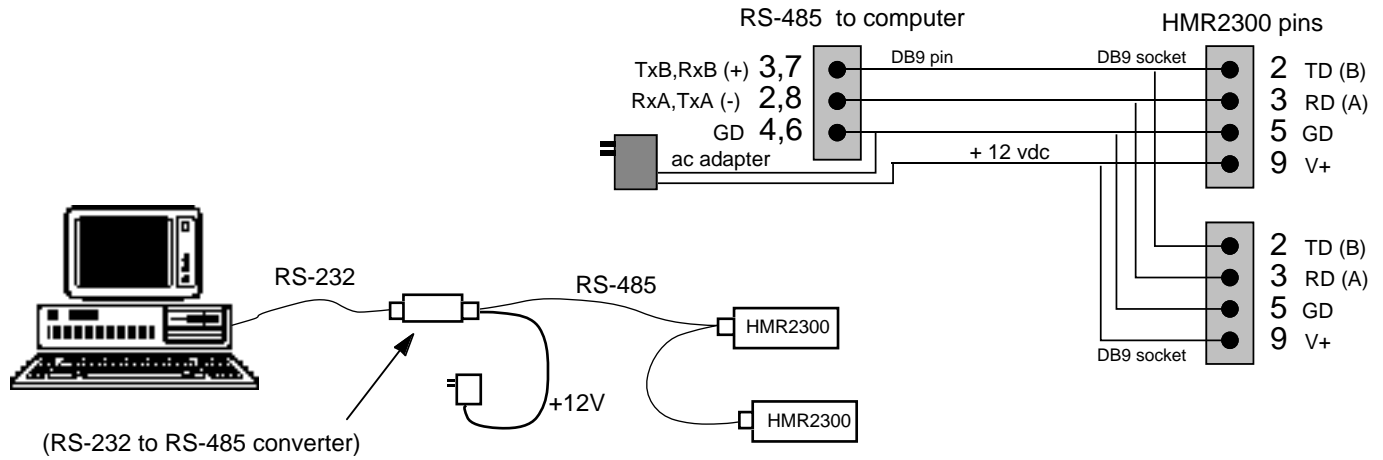
Magnified-Axis Showing Temp. Effects—Figure 13

HMR2300

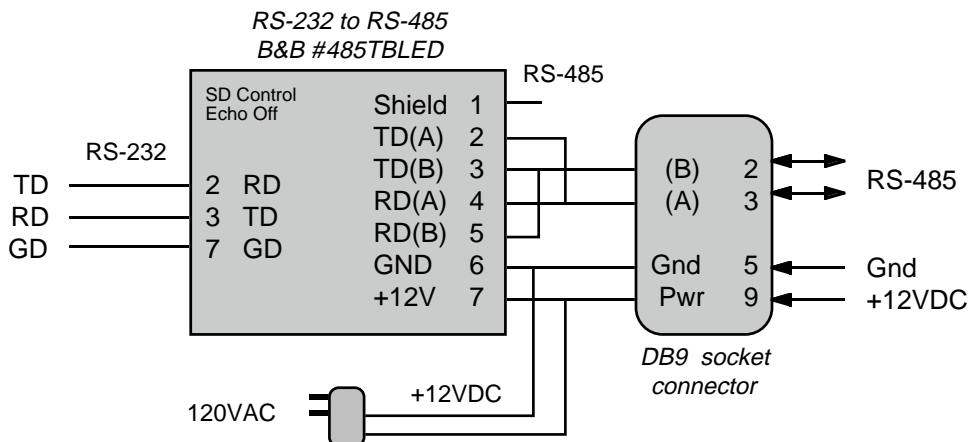
COMPUTER RS-232 TO HMR2300 CONNECTION— Figure 14



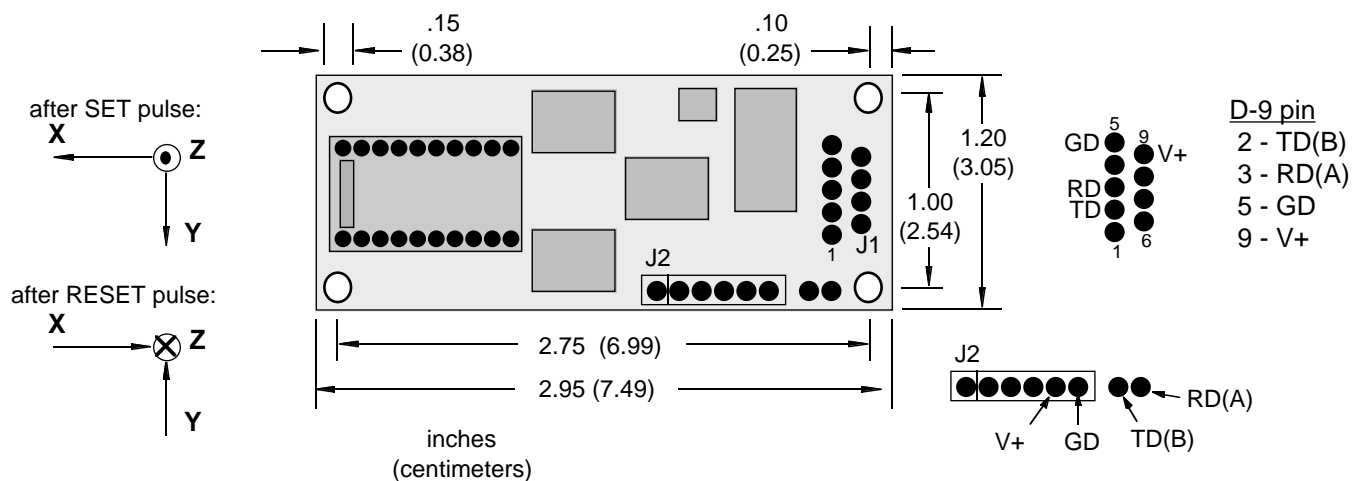
COMPUTER RS-485 TO HMR2300 CONNECTION—Figure 15



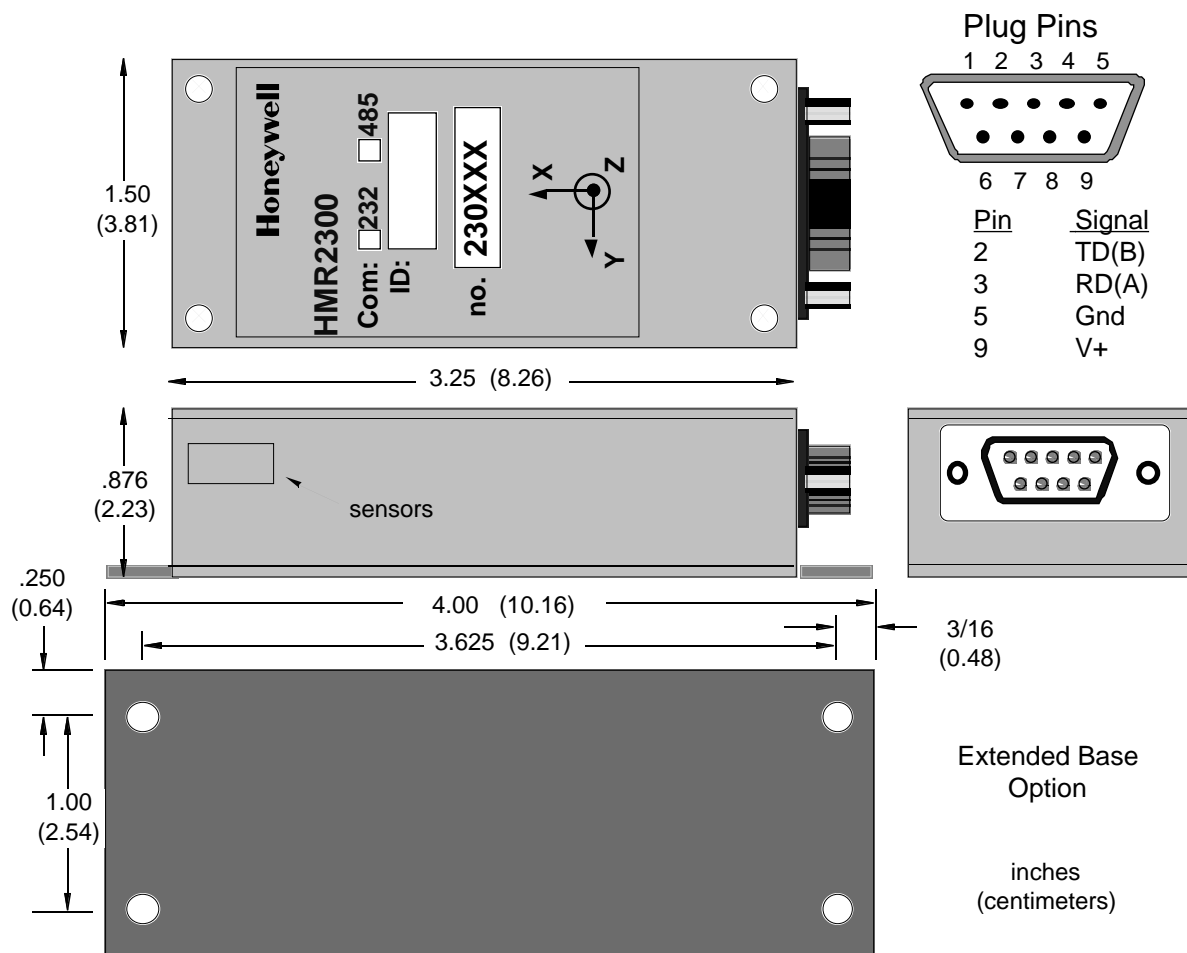
RS-232 TO RS-485 CONVERTER—Figure 16



BOARD DIMENSIONS AND PINOUT—Figure 17



CASE DIMENSIONS AND PINOUT—Figure 18



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, z field measurements.
- The presence of the earth's magnetic field must be taken into account when measuring other x, y, 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 box need to be taken into account. If the HMR box is exposed to fields greater than 10 Gauss (or 10 Oersted), then the box must be degaussed. The result of perming is a high zero field output code that exceeds specification limits. Degaussing magnets are readily available from local electronics outlets and are inexpensive. If the HMR box is not degaussed, severe zero field offset values will result.

HANDLING PRECAUTIONS

The HMR Magnetometer measures fields within 2 Gauss in magnitude with a 0.1 milliGauss resolution. Computer floppy disks (3.5" diskettes) store data with fields strengths approximately 10 Gauss. This says that the HMR Magnetometer is at least ten times more sensitive to stray magnetic fields than common floppy disks! Therefore, treat the HMR Magnetometer at least as good as your computer disks by keeping them away from motors, monitors and magnets. Even though they don't erase data like a floppy disk would, they will pick up, and retain, these magnetic fields that may interfere with x, y, z axis measurements.

NON-FERROUS MATERIALS

Materials that do not affect surrounding magnetic fields are: copper, brass, gold, aluminum, some stainless steel, silver, tin, silicon and any nonmetallic material.

ORDERING INFORMATION

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

ORDERING INFORMATION

Example: **HMR2300-D00-232**

HMR	2	3	00-	D	00-	232
Honeywell Magnetoresistive	Family	Axis	Type	Connector	Box	COM Std.
	Family	2—16-bit Delta Sigma Data Conversion				
	Axis	3—Three-Axis				
	Type	00— ±2Gauss, -40 to 85°C				
	Connector	N—No connector D—Nine-pin D-Sub Connector				
	Box	00—No Box, Board Only 20—Aluminum 3.25"x1.50"x1.13", flush base 21—Aluminum 4.00"x1.50"x1.13", extended base				
	COM Std.	232—RS-232 Communication Standard 485—RS-485 Communication Standard				

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