STRAPDOWN HEADING REFERENCE

OWNER'S MANUAL

PART NUMBER: SHR-360/77

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Watson Industries prides itself on solving customer problems and serving their needs in a timely fashion. This manual is intended to facilitate this goal and to provide written information about your product. We ask that you carefully read this manual. Becoming familiar with the manual will help you understand the product's capabilities and limitations, as well as provide you with a basic understanding of its operation. If, after reading the manual, you require further assistance, do not hesitate to call Watson Industries with your questions and comments.

CAUTION!

Watson Sensors are rugged devices that have been used successfully in a number of harsh environments. The components have been qualified to withstand a mechanical shock of 200g 's or greater, and most enclosures provide an added level of protection. However, dropping a sensor from waist height onto a hard floor can cause a shock level of 600g's. At this level, damage is likely to occur.

INTRODUCTION

The Strapdown Heading References provides angle and magnetic heading. It uses a 3-axis fluxgate magnetometer, 2 liquid pendulums, and a microprocessor. The unit measures the Earth's Magnetic Field with a precision 3-axis fluxgate magnetometer and uses tilt information (bank and elevation) from two pendulums for coordinate transformations. The heading information is susceptible to disturbance by acceleration since the angle sensors are sensitive to accelerations in a dynamic environment.

PRODUCT DESCRIPTION

Watson Industries SHR-360/77 uses solid-state fluxgate magnetometer and liquid pendulums. Interface to the microprocessor is done through a 16-bit A/D converter. There are no physical adjustments required by the user. All of the primary transducers are locked into position during manufacture. Adjustments for installation calibration and customization are made with the aid of PC-based maintenance software, which communicates with the SHR-360/77 via the RS-232 serial connection. Calibration is achieved by using the maintenance software to store data in non-volatile memory within the SHR-360/77. The SHR-360/77 differs from the "standard" in that the unit is mounted on a special baseplate and the software has been modified for the customer.

INSTALLATION

Orientation:

The SHR drawing, with wire call outs, is located in Figure 2. The SHR is a rugged device and will withstand harsh environments. However, due attention needs to be paid to the nature of the sensor and its prime function, which is to measure attitude and magnetic heading.

Mounting:

A mounting plate is provided for a flat surface mount. If high shock loads are expected (greater than 20G or repeated shocks greater than 10G), the appropriate shock mounting should be used to prevent damage. Vibration isolation should be used for use in 4G or greater vibration environments.

Environment:

Avoid mounting sites that are subject to significant temperature variation over the duration of the test. Temperature variation will induce bias drift, which will reflect in poor attitude and heading accuracy.

This is a magnetic device. Use non-magnetic hardware. Watson Industries provides brass connectors with the device. Ideally, the unit should be installed at least 12" away from all magnetic masses. If the unit is being installed in a vehicle, ship, etc., some calibration will still be required. Use the calibration software that is available on our website.

This is a magnetic sensitive device. Use non-magnetic hardware.

Power:

This unit has an internal regulator to allow operation over a wide voltage input range. Best operation is obtained at 24 VDC level, although operation is fully satisfactory down to 18 VDC and up to 30 VDC. Power consumption of the unit is less than 1.5 Watts. Internal capacitors are provided to remove a reasonable level of power line noise, however, capacitors should be added for long power line wiring or if noise is induced from other loads on the circuit.

THEORY OF OPERATION

The Earth's Magnetic Field can be described as a Vector T located in the horizontal geographic coordinate system $O\zeta\xi\eta$ (See Figure 1).

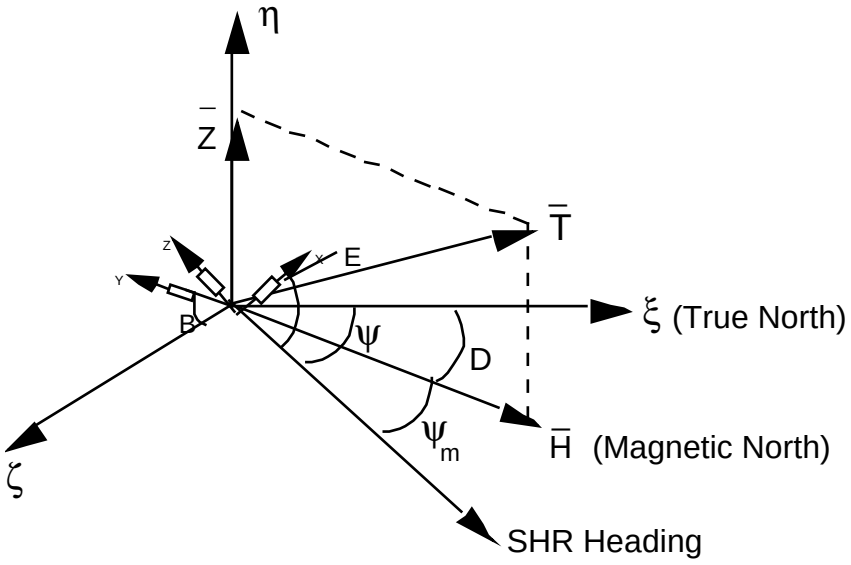


Figure 1

Where:

H - Vector of Horizontal Component of Earth's Magnetic Field
Z - Vector of Vertical Component of Earth's Magnetic Field
J - Magnetic Dip Angle
D - Magnetic Declination
Ψ_m - Magnetic Heading
Ψ - True Heading
X,Y,Z - Sense Axes for Fluxgate Magnetometer Triade
E - Elevation - With Respect to Level.
B - Bank - With Respect to Level.

The microprocessor transforms the x, y, and z measurements to a horizontal geographical coordinate system and calculates the magnetic heading Ψ_m as :

$$\Psi_m = \text{Atan}\ (-Y_T/X_T)$$

Where X_T, and Y_T are coordinate transformed to the horizontal system for Fluxgate Magnetometer measurement.

Watson Industries provides software for heading calibration in your installation package because each unit will likely have significant magnetic deviations. Your location on the globe will also cause error in the magnetic heading (Ψ_m) by Magnetic Dip Angle (J) and Leveling Error (ΔL). The following is a general relationship:

$$\Delta\Psi_m = tgJ * \Delta L$$

Table 1 lists a general relationship between Magnetic Dip Angle and Magnetic latitudes on the Earth's surface.

Magnetic Latitude	30˚	45˚	56˚	70˚	80˚
Dip Angle	45˚	60˚	68˚	80˚	85˚

Table 1 Magnetic Dip Angle versus Magnetic Latitude

Distance to Magnetic Pole (nmi)	0	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5400
Dip Angle	90˚	88˚	84˚	80˚	74˚	67˚	58˚	49˚	38˚	26˚	12˚	0˚
Relative Error *	∞	29	10	6	4	2	1.5	1	0.8	0.5	0.2	0

Table 2 Magnetic Dip Angle versus Distance to Pole

*Relative Error is the Heading Error Versus the East-West Level Error. (North – South Level Error has no effect until it crosses the Dip Angle)

Bank / Elevation	
- Range:	±9.99º
- Accuracy:	±0.05º over ±10º tilt
- Resolution:	0.01º
- Frequency Response:	DC – 0.5 Hz
Heading	
- Range:	0 - 360º
- Accuracy:	±3º to 30º Tilt (magnetic inclination < 75º)
- Resolution:	0.1º
- Frequency Response:	DC – 1 Hz
Output Format	
- Digital	RS-232 9600 Baud, one stop bit and no parity
Weight	22 Ounces
Power	18 to 30 VDC (< 1.5 Watts)
Temperature range	-20 to +50 ºC

RS-232 OUTPUT FORMAT

The nominal RS-232 output consists of a string of decimal ASCII characters sent asynchronously at regular intervals at about 11.85 strings per second. The string is sent at 9600 baud with eight data bits, one stop bit and no parity. The contents of a typical string are formed as follows:
(See Appendix A for information on how to change the data string.)

0. A single letter and a space used to indicate the start of the data string. The data will be transmitted upon the receipt of the ASCII command 'G'. The letter "N" indicates the start of a data string.

1. A five character string representing the bank angle starting with a "+" or a "-", followed by one digit, a decimal point and two digits for up to ±9.99 degrees. Delimited by space.

2. A five character string representing the elevation angle starting with a "+" or a "-", followed by one digit, a decimal point and two digits for up to ±9.99 degrees. Delimited by space.

3. A five character string representing the relative heading angle by three digits, a decimal point, and one digit for zero to 359.9 degrees. Delimited by space.

4. A six character string representing the X Axis Magnetometer starting with a "+" or a "-", followed by three digits, a decimal point and one digit for up to ±999.9 milligauss. Delimited by space.

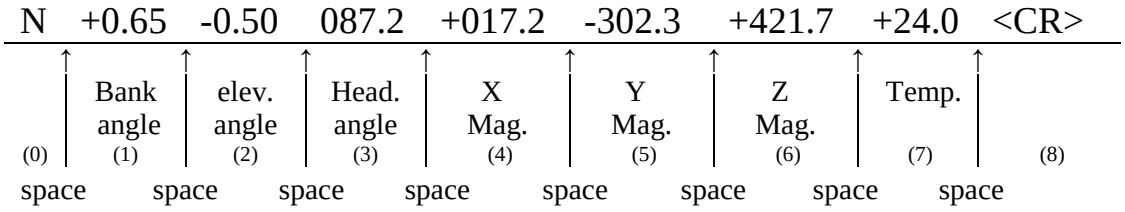
5. A six character string representing the Y Axis Magnetometer starting with a "+" or a "-", followed by three digits, a decimal point and one digit for up to ±999.9 milligauss. Delimited by space.

6. A six character string representing the Z Axis Magnetometer starting with a "+" or a "-", followed by three digits, a decimal point and one digit for up to ±999.9 milligauss. Delimited by space.

7. A five character string representing Temperature starting with a "+" or a "-", followed by two digits, a decimal point and one digit for up –40.0 to +88.0 ˚C (0.1˚ resolution). Delimited by space.

8. The string is terminated by a carriage return.

Example:



This may be reduced to attitude and heading information to improve the update rate to almost twice the previous rate by using special commands to modify the EEPROM of the unit. More channels are available for output – see Appendix A.

The system is protected from inadvertent write-over of the EEPROM by requiring two spacebar commands and nothing else during the initialization interval to access the EEPROM or related functions.

The baud rate may be changed from the nominal value of 9600 baud by modifying the default value in the EEPROM of the unit to 38400, 19200, or 4800 baud.

A text header that is sent by the SHR during initializations identifies the unit by part number and by serial number and gives the date of last calibration. Additionally, a line of text characters that identifies the data channel columns is sent if the serial output is set to ASCII decimal. This whole message can be temporarily or permanently suppressed or restored by a "*" command from the interfacing computer.

Data transmission sent by the SHR can also be suppressed or restored by a "+" command from the interfacing computer.

Internal functions which require these error values are disabled while the condition exists. The system will continue to operate in an extended time constant mode with a low level of error accumulation until the condition is cleared. Occasional blips of this condition are expected with no detectable affect on the resulting data.

The other output format available is a binary format. The binary format provides generally the same information as the decimal ASCII format, but in a compact binary file format. See Appendix B for more information on the binary format. In this format, there are nominally 13 words sent that represent 6 fourteen bit output channels followed by a carriage return. Again, this may be reduced to attitude and heading information to improve the update rate (in this case the rate would be 71.11

Hz) by using special commands to modify the EEPROM of the unit. This format is for highly experienced users only. Consult the factory for further details.

RS-232 INPUT COMMANDS

The RS-232 input commands are provided for the purpose of unit test and installation set-up. The same parameters are used as for the output (9600 baud ASCII nominal, or as reset in the units EEPROM). There are two commands intended for use by the user (others are used at the factory for alignment and calibration).

1. A "G" will transmit one line of data.

2. An "!" will reinitialize the unit. Further, the access to initialization is inhibited such that a spacebar command must be sent within 2.5 seconds of the "!" command for initialization to be engaged.

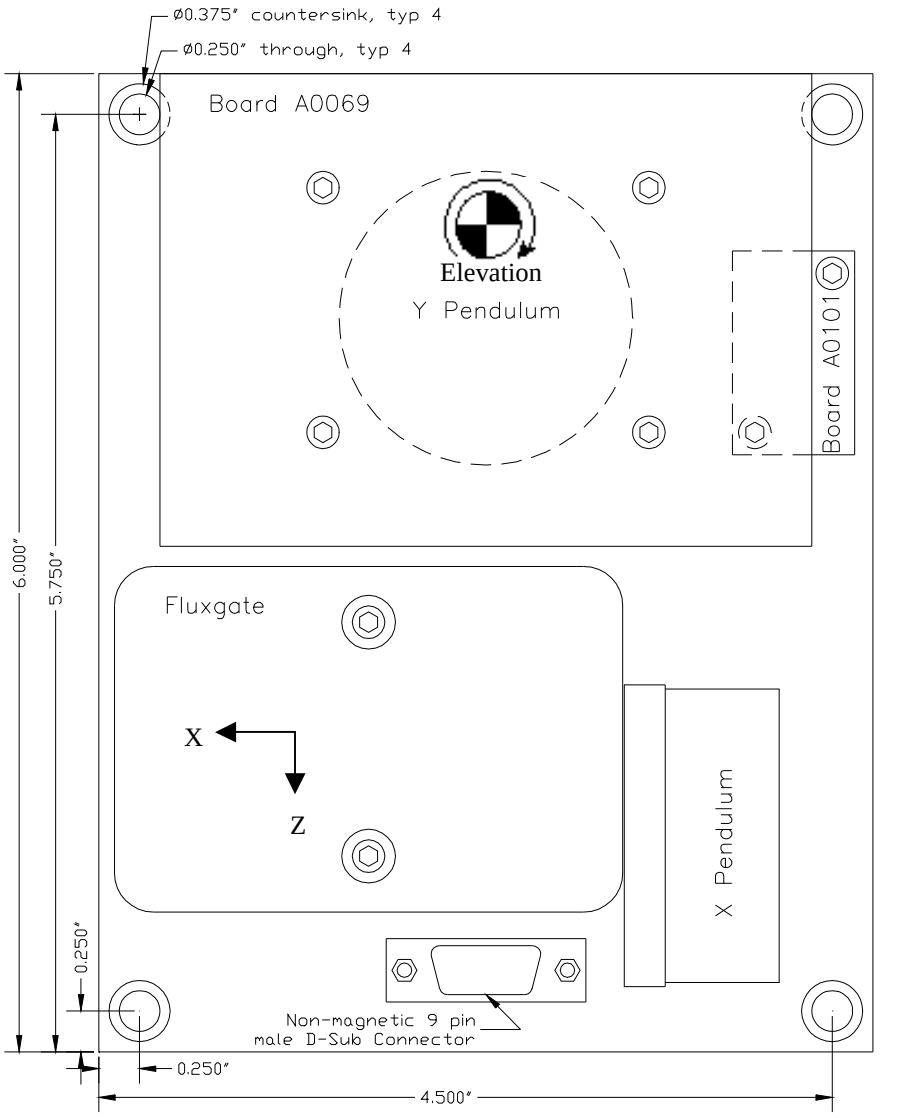
There are two output format serial commands: "_" for decimal output and "^" for binary. See second part of Appendix A for more information on change output formats. There are several interface commands as well: ":" will toggle the output to send a frame of data upon receiving any non-command character and "+" will toggle the output for no output data. These and other changes are made non-volatile in the unit on EEPROM by keying in the quote (") character. Double spacebar at initialization is required for access to these commands.

The "&" command calls a menu which allows any of several parameters to be set. These are system time constants, selection of data channels for serial output and baud rate. Double spacebar at initialization is required for access to this command.

The commands "~", "@", "#", "$", '(", ")", "{", "}", "|", "<", ">" and "?" are used by the Watson factory to calibrate the unit and should be used only with the assistance of the factory. If an undesired function is called, a "Q", and sometimes Escape or a Delete will interrupt the command and return to operation with the least disturbance to the system. All other unspecified characters such as carriage return, line feed and space are ignored by the system.

If there are problems with the system "hanging up" during the binary output mode, check for crosstalk between the serial transmit and receive line in your installation. In addition, check to see that the communications program used is not sending an echo. This will not happen in the decimal or hexadecimal modes because command characters recognized by the system are not produced in those modes.

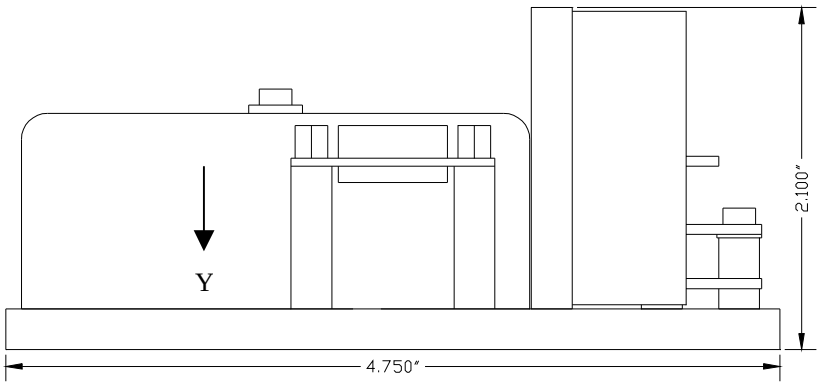
DIMENSIONS / CONNECTIONS



9 Pin Male D-Sub
RS-232 Serial Connecter

Pin	Signal	
1	Power Ground	Black
2	+24 VDC Power In	Red
3	Signal Ground	Brown
4	No Connection	
5	RS-232 RXD	Gray
6	No Connection	
7	No Connection	
8	No Connection	
9	RS-232 TXD**	White

** The user receives on this line



Bottom View

Figure 2 SHR-360/77

WARNING

Rough handling or dropping of this unit is likely to cause damage. Over-voltage and/or miswiring of this unit will cause damage. This unit should be protected against prolonged exposure to high humidity and/or salt air environments.

DISCLAIMER

The information contained in this manual is believed to be accurate and reliable; however, it is the user's responsibility to test and to determine whether a Watson Industries' product is suitable for a particular use.

Suggestion of uses should not be taken as inducements to infringe upon any patents.

WARRANTY

Watson Industries, Inc. warrants, to the original purchaser, this product to be free from defective material or workmanship for a period of one full year from the date of purchase. Watson Industries' liability under this warranty is limited to repairing or replacing, at Watson Industries' sole discretion, the defective product when returned to the factory, shipping charges prepaid, within one full year from the date of purchase. The warranty described in this paragraph shall be in lieu of any other warranty, express or implied, including but not limited to any implied warranty of merchantability or fitness for a particular purpose.

Excluded from any warranty given by Watson Industries are products that have been subject to abuse, misuse, damage or accident; that have been connected, installed or adjusted contrary to the instructions furnished by seller; or that have been repaired by persons not authorized by Watson Industries.

Watson Industries reserves the right to discontinue models, to change specifications, price or design of this product at any time without notice and without incurring any obligation whatsoever.

The purchaser agrees to assume all liabilities for any damages and/or bodily injury which may result from the use, or misuse, of this product by the purchaser, his employees or agents. The purchaser further agrees that seller shall not be liable in any way for consequential damages resulting from the use of this product.

No agent or representative of Watson Industries is authorized to assume, and Watson Industries will not be bound by any other obligation or representation made in connection with the sale and/or purchase of this product.

SERVICE

Watson Industries, Inc. has no service outlets. All service is performed at the factory. In order to insure prompt service, prior to returning a unit for repair please call, write or fax:

Watson Industries, Inc.
3041 Melby Road
Eau Claire, WI 54703
ATTN: Service Department
Telephone: (715) 839-0628
Fax: (715) 839-8248

All sensors returned under warranty will be repaired (or replaced at the sole option of Watson Industries) at no cost to the customer other than shipping charge from customer to Watson Industries (plus any export and transportation charges outside the United States).

In the case of units not under warranty, a flat repair fee will be charged. This fee can be determined by contacting Watson Industries. Modified units or those subjected to extreme abuse may be returned to the customer unrepaired.

Appendix A

The following outputs are available via the RS-232 serial link. Their full-scale ranges are listed for both decimal and binary format.

Inertial Output	Label	Full Scale Decimal	Full Scale Binary
Bank Angle	BK	±9.99º	±180º
Elevation Angle	EL	±9.99º	±180º
Heading Angle	HG	359.9º	±180º
X Magnetometer	XM	±999.9 mGauss	±1000 mGauss
Y Magnetometer	YM	±999.9 mGauss	±1000 mGauss
Z Magnetometer	ZM	±999.9 mGauss	±1000 mGauss
Bank Pendulum	XI	±89.9º	±180º
Elevation Pendulum	YI	±89.9º	±180º
Temperature	TP	-40.0º to +88.0ºC	-40º to +88ºC (7 bit)
Status Bits	ST	1 byte	1 byte

DETERMINING & SETTING OUTPUT CHANNELS

To determine which channels are present.
Hook the unit up to your computers serial port.
Use hyperterminal program to interface with unit.

Turn on unit .Wait for the startup message to appear on display.
Hit the space bar twice within the first 5 seconds of turn on.
Sometimes it takes a few tries to get the hang of this.
Wait for the data string to start transmitting.

Now the unit will take in the keyboard commands.
To determine which channel present, first type '&'.
This will bring up the menu:

```
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
   1 = SET OUTPUT CHANNELS
   2 = LIST CURRENT OUTPUT CHANNEL SELECTION
   3 = SET NEW BAUD RATE
```

typing in '2' will show which channels are currently active.

To change which channels are output type '&'(this will bring up the menu again)

Now type '1' to set up channels
The following message will appear:

```
TO SET FOR OUTPUT FOR ANY OF THE FOLLOWING DATA ITEMS, PRESS Y
TO AVOID ANY OF THE FOLLOWING DATA ITEMS, PRESS N
TO QUIT AND DISREGARD ANY OTHER DATA, PRESS Q

*** DO YOU WANT TO PROCEED? (Y/N/Q)
```

To proceed type 'Y'

Now each channel will come up one at a time
For example:

DO YOU WANT OUTPUT OF BANK ANGLE?

Type 'Y' to output channel , type 'N' to remove channel
When you get to bottom of list, this message will appear:

Y = GOBACK, N = INSTALL DATA & QUIT, Q = QUIT
DO YOU WANT TO TRY TO SET DATA AGAIN?

To accept channels type 'N', then hit space bar output data to resume.

To make this channel selection the default the next time you power the unit on
type in ‘ ” ‘ (quotation mark)

SETTING OUTPUT FORMAT

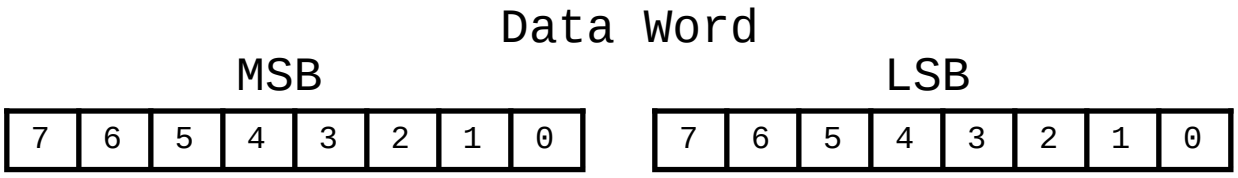
There are two output formats.
Decimal output - “_” Command.
Binary output – “^” Command.

To change the output format:
Hook the unit up to your computers serial port.
Use hyperterminal program to interface with unit.

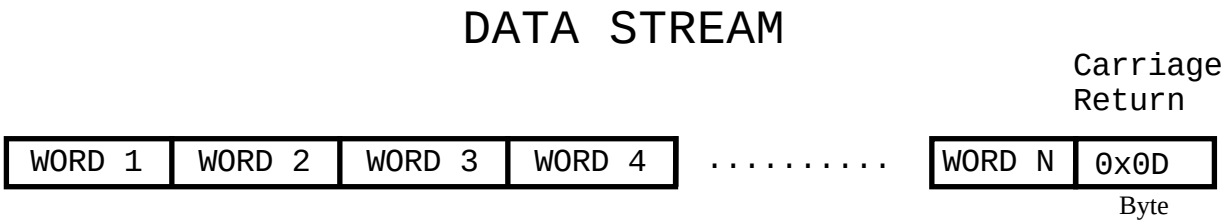
Turn on unit. Wait for the startup message to appear on display.
Hit the space bar twice within the first 5 seconds of turn on.
Sometimes it takes a few tries to get the hang of this.
Wait for the data string to start transmitting.

Now the unit will take in the keyboard commands. Press the key Command corresponding to the format you want to switch into. (for example type “_” to change into Decimal Format.)
To make this format selection the default the next time you power the unit on type ‘ ” ‘ (quotation mark)

Appendix B



As the data words are received, the LSB is shifted left to shift out the sign bit. The MSB is then connected to the LSB as a 16 bit word. This word is then shifted left to shift out the sign bit. What remains is a signed fractional word with a resolution of 13 bits plus a sign bit.



All of the data words have a high sign bit, but the delimiter byte is an ASCII carriage return character which has a low sign bit. The nominal interface settings are:

9600 Baud
8 Bit Data
1 Start Bit
1 Stop Bit
No Parity