Applied Physics Systems

Model 1540

Fluxgate Magnetometer
User Manual

www.appliedphysics.com
281 East Java Drive Sunnyvale, CA. 94089 USA • 650.965.0500 • Fax: 650.965.0404 • service@appliedphysics.com

Copyright

Trademarks

Contact Information

Applied Physics Systems
Corporate Headquarters
281 East Java Drive
Sunnyvale, California 94089
USA

Phone: 650.965.0500
Fax: 650.965.0404
Email: service@appliedphysics.com
Web: www.appliedphysics.com

Technical Support Hours:
Monday - Friday
9:00 AM - 5:00 PM
Pacific Standard Time

Document Number

260-0183-02-0417

Revision History

Revision	Description	Date
1	Initial draft of this manual.	June 2014
2	Renamed “binary constant” to “byte constant”.	April 2017
	Renamed “floating constant” to “float constant”.	
	Updated system specifications. See Table 1 - Model 1540 System Specifications on page 3.	
	Updated the 1540 mechanical drawing. See Figure 1 - Model 1540 Cylindrical Magnetometer Mechanical Drawing on page 5.	
	Updated the 1540S mechanical drawing. See Figure 2 - Model 1540S Rectangular Magnetometer Mechanical Drawing on page 6.	
	Updated the Model 1540 and 1540S electrical interface. See Figure 2 - Model 1540 Electrical Interface on page 7. See Figure 3 - Model 1540S Electrical Interface on page 8.	
	Updated the 1540 sensor commands. See Table 4 - Model 1540 Commands on page 12.	
	Updated the byte constants. See Table 5 - Commonly Used Byte Constants on page 14. See Table 12 - 1540 Byte Constants on page 29.	
	Updated the float constants. See Table 13 - 1540 Float Constants on page 32.	

Contents

Figures

Tables

This page is intentionally left blank.

1 - Introduction

The Applied Physics Systems Model 1540 is a high speed 3-axis fluxgate magnetometer employing 24-bit analog-to-digital converters. Magnetic field data transmitted by the 1540 is expressed in Gauss (G).

The 1540 system employs three ring core fluxgate sensors together with analog processing electronics to produce analog output voltages proportional to the measured magnetic field along three orthogonal axes. The analog output voltages are converted to digital form using three 24-bit A/D converters. Using 24-bit converters enables the 1540 system to measure magnetic field magnitudes from ±0.65 G down to the system noise level (5 µG peak to peak) using a single range.

The 1540 system microprocessor (MSP430) performs the following digital control functions:

- control and acquisition of data from the 24-bit A/D converter
- correction of fluxgate sensor scale, offset, and alignment factors
- implementation of serial communications between the system and an external computer

The 1540 is calibrated by placing it in a precision 3-axis Helmholtz coil, which enables the application of accurately known magnetic fields to the system. Then the Helmholtz coil is fitted with a holding fixture with alignment holes and reference V grooves that match the 1540 alignment pins and cylindrical body. The holding fixture enables the 1540 to be accurately aligned with the Helmholtz axes, so that accurate scale and alignment and offset factors can be determined. After determining the calibration factors, they are downloaded into the 1540 so the system microprocessor can make calibration corrections on measured magnetic field data before transmission.

The 1540 system communicates over a bidirectional serial interface using TTL logic levels and RS-232 levels. Three communication protocols are available: TTL or RS-232 or RS-422. Select one or more of these communications protocols when ordering a 1540 system. In addition to the ASCII data transmission mode, the 1540 system has a binary transmission mode and an IEEE 32-bit transmission mode. These modes are faster than the ASCII mode because considerably fewer characters need to be transmitted. The default baud rate is 9600 with one stop bit, no parity and 8 data bits.

An autosend data mode is included in the 1540 software. When this mode is active, data is repeatedly sent out the serial port automatically after power is applied to the system.

This page is intentionally left blank.

2 - System Specifications

Table 1. Model 1540 System Specifications

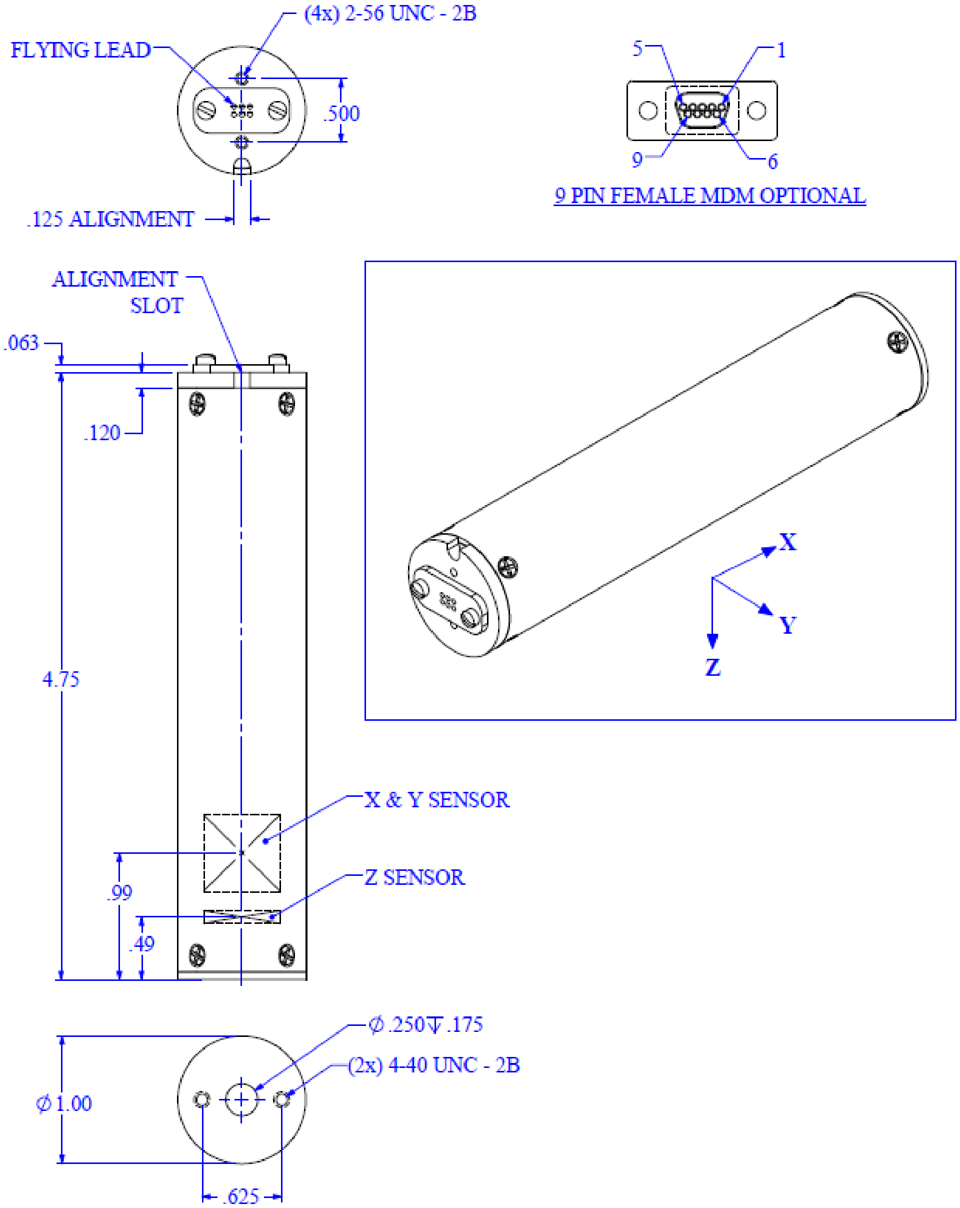
Specifications are subject to change without notice.	
Physical	
Model 1540 (cylinder)	4.81" (122.17 mm) long including the connection plate, 1.00" (25.4 mm) diameter 4.75" (120.65) long excluding connection plate See Figure 1 - Model 1540 Cylindrical Magnetometer Mechanical Drawing.
Model 1540S (rectangle)	4.75" (120.65 mm) long, not including connector 1.00" (25.4 mm) width 0.93" (23.62 mm) height
Input / Output Connections	Flying leads (Teflon insulated) #28 gauge >6" long (152.4 mm) or a 9-pin nonmagnetic MDM connector
Electrical	
Power Input	+4.95 VDC to +9 VDC @ 55 mA
Data Rate in Autosend Mode	ASCII mode: 10 transmissions/second Binary mode: 20 transmissions/second
A to D Communications	24-bit Sigma Delta TTL or RS-232 or RS-422 **Note:** One or more of the 3 communications protocols can be selected when ordering.
Baud Rate	300, 1200, 4800, 9600, 19200, 38400
Analog Bandwidth	100 Hz
Environmental	
Operating Temperature Range	-25°C to 70°C
Performance	
Noise Level	±0.5 nT (±5 μGauss) peak to peak
Dynamic Range	±65 μT (±0.65 Gauss)
Resolution	0.0001 mG
Accuracy	±0.5% FS
Scale Stability	±0.05% FS/°C
Initial Offset	<0.005 mG
Offset versus Temperature	<0.01 mG/°C
Orthogonality of Axes	Better than ±0.2°
Alignment of Axes with Package	Better than ±0.2°
Linearity	±0.05% FS
Analog Scale Factor	3 V/G

This page is intentionally left blank.

3 - Mechanical Features

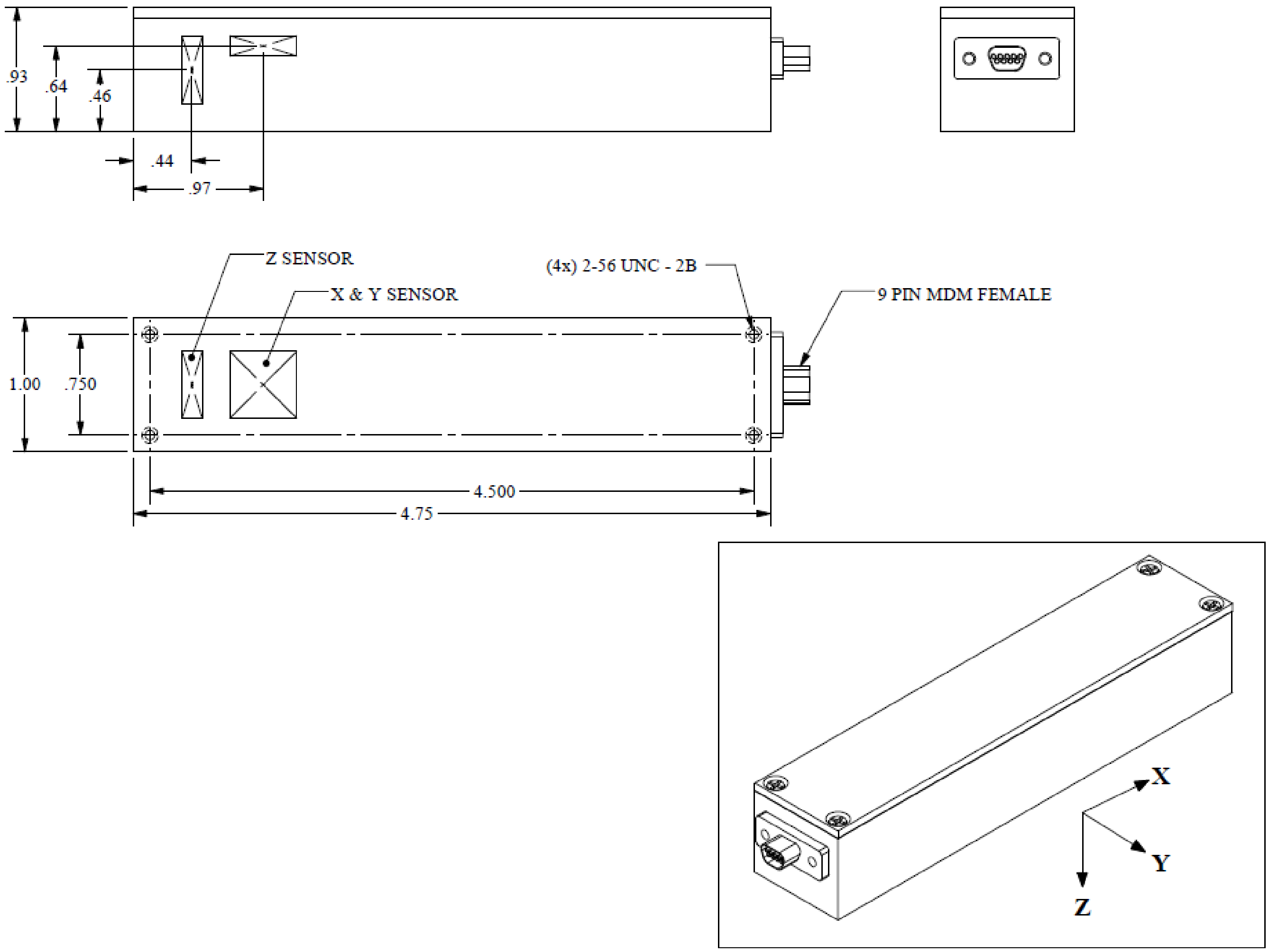
The cylindrical 1540 has an alignment slot on the top surface. This slot aligns with the Z+ axis direction. The 1540 coordinate directions are shown in Figure 1. A magnetic field direction aligned with the axis direction arrows will produce a positive output voltage.

Figure 1. Model 1540 Cylindrical Magnetometer Mechanical Drawing



The 1540 is also available in an alternative rectangular package, the Model 1540S, shown in Figure 2.

Figure 2. Model 1540S Rectangular Magnetometer Mechanical Drawing

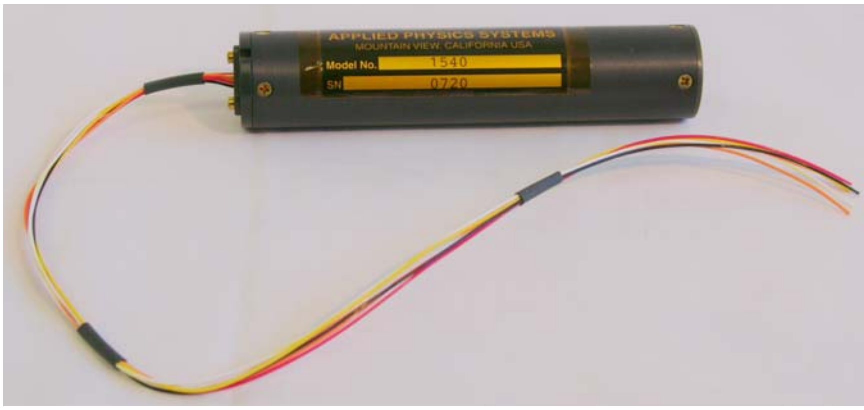


Both the Model 1540 and the Model 1540S have a 9-pin MDM connector for powering and computer interface.

4 - Electrical Interface

The Model 1540 powers from a single input voltage that can range from +4.95 V to +12 V. Six flying leads (#28 gauge Teflon insulated) are used to connect to the 1540, as shown in Figure 3.

Figure 3. Model 1540 with Leads



Optionally, a 9-pin MDM connector can be used to connect to the system. The pinouts for this connector are shown in Table 2 for the Model 1540 (cylindrical barrel) and in Table 3 for the Model 1540S (rectangular barrel).

Table 2. Model 1540 Electrical Interface

Flying Lead Wire Color	Function	MDM Connector Pin
Orange	RS-232 serial IN (or Y RS-422)	1 (black)
Yellow	RS-232 serial OUT (or Z RS-422)	2 (brown)
Red	+4.95 VDC to +12 VDC	3 (red)
Orange / White	TTL serial IN (or A RS-422)	4 (orange)
Black	Ground	5 (yellow)
Yellow / White	TTL serial OUT (or B RS-422)	6 (green)
Green	X analog output (optional)	7 (blue)
Purple	Y analog output (optional)	8 (purple)
Grey	Z analog output (optional)	9 (grey)

Table 3. Model 1540S Electrical Interface

Flying Lead Wire Color	Function	MDM Connector Pin
Black	RS-232 serial IN (or Y RS-422)	1 (black)
Brown	RS-232 serial OUT (or Z RS-422)	2 (brown)
Red	+4.95 VDC to +12 VDC	3 (red)
Orange / White	TTL serial IN (or A RS-422)	4 (orange)
Yellow	Ground	5 (yellow)
Yellow / White	TTL serial OUT (or B RS-422)	6 (green)
Green	X analog output (optional)	7 (blue)
Purple	Y analog output (optional)	8 (purple)
Grey	Z analog output (optional)	9 (grey)

4.1 - Setting Up the Electrical Connections

The 1540 serial communications interface is provided by the serial in and serial out lines. These two lines operate at RS-232 or TTL logic levels. Use the TTL interface to communicate with an internal microprocessor and the RS-232 interface to communicate with a PC through its COM port. The 1540 can also use a four-wire RS-422 serial communication protocol, if the unit has been wired for RS-422.

Serial communications default to a baud rate of 9600 and use 8 data bits, one stop bit, and no parity bit. Additional baud rates can be selected by changing the 1540 byte constants.

To connect the RS-232 interface to a PC COM port:

1. PC COM ports use 9-pin D connectors. Connect the 1540 communication flying leads to a 9-pin PC female D connector as follows:
    - Connect the yellow 1540 wire (or the brown wire for Model 1540S) to the connector pin 2. This wire provides serial communication from the 1540.
    - Connect the orange 1540 wire (or the black wire for Model 1540S) to the connector pin 3. This wire provides serial communication to the 1540.
    - Connect the black 1540 wire (or the yellow wire for Model 1540S) to the connector pin 5. This wire provides ground for the 1540.
2. Connect +V to the red wire.
3. Connect a standard 9-pin COM port cable between the 1540 D connector and a PC COM port connector on the computer.
4. Apply power to the + voltage and ground wires.
5. Adjust the input voltage to a value between +5 V and+12 V. The 1540 uses low dropout linear regulators to produce internal working voltages of ±4.5 V, so the lower the input voltage the lower the power consumed by the 1540.
6. Ensure that the input voltage does not drop below 4.90 volts on the low end to prevent the internal regulators from dropping out.
7. Start terminal emulator software, such as Procomm or Windows HyperTerminal, on the PC. Configure the terminal emulator for direct connect to an available COM port and select the baud rate 9600 with one stop bit and no parity.
8. To determine if communication with the 1540 has been established, look at 1540 sign on message that is transmitted at 9600 baud when power is turned on. Apply power to the system and verify the unit transmits a start up message similar to the following:

    APS: S/N XYZ

    VER: 3.85 Bd7716F

See Chapter 5 - Computer Interface for instructions on communicating with and configuring the Model 1540.

This page is intentionally left blank.

5 - Computer Interface

Terminal emulation software, such as Procomm or Windows HyperTerminal, can be used for communication between a PC and the 1540 system. These programs translate typed ACSII characters into a serial data stream sent to the 1540 and also display characters sent from the 1540 on the PC display.

In this mode, whatever you type on the keyboard goes out the selected serial port (for example, COM 1) and whatever comes in the serial port is displayed on the computer video display.

If you use HyperTerminal, you must select the proper COM port (for example, COM 1, COM 2...) and set the baud rate to 9600 with one stop bit and no parity. Set the port for direct connect and turn off handshaking.

Observe the PC display when the 1540 is powered up to see if communications with the 1540 has been established. The 1540 will transmit a sign on message at power up, which should appear in readable form on the PC display. If the sign on message is unreadable, you may have selected an incorrect baud rate on the computer.

After establishing communication with the 1540, data can be obtained from the system using sensor commands.

5.1 - 1540 Sensor Commands

Sensor commands are used to view or change sensor configuration. Commands are entered at the command line using terminal emulation software. Some sensor commands use byte constants (and float constants) to view or change the value of a constant.

You need to know the following when entering sensor commands.

- Sensor commands are not case sensitive. Examples in Table 4 show commands entered in uppercase or lowercase.
- Sensor commands begin with a 0 zero (not the letter O).
- Press the Enter key after typing a command on the command line.

The 1540 operating characteristics are controlled by the values of byte constants. These constants are stored in the system EEROM and can be changed using a two step process using sensor commands 0l and 0wc. The two step process is used to ensure these constants are not accidentally changed.

- Enter the 0l command (zero and the letter L) before using the write command 0wc. If you see the following error, you didn't use the 0l command using the write command.

```
Err: Not Enabled
```

Table 4 shows the 1540 sensor commands, command format and usage and output.

Table 4. Model 1540 Commands

Description	Command Format	Command Response

Send All Data	0SD
	0Send**D**ata
		`MX:+0.2589726`
		`MY:-0.3590045`
		`MZ:+0.0540982`
		`T: +23.219`

Read a Float Constant	0SC<constant number>F **0S**end**C**onstant<>**F**loat	0sc00F `1.00000000E+00`
See Table 13 - 1540 Float Constants on page 32.		

Read All Float Constants	0SC*F
	0Send**C**onstant***F**loat
	* is a wildcard.
		`00: 1.00000000E+00`
		`...`
		`42: 0.00000000E+00`

Read a Byte Constant	0SC<constant number>B **0S**end**C**onstant<>**B**yte	0sc00b `01`
See Table 5 - Commonly Used Byte Constants on page 14.		

Read All Byte Constants	0SC*B
	0Send**C**onstant***B**yte
	* is a wildcard.
		`00: 01`
		`...`
		`42: 00`

Reset A/D	0RA **0R**eset**A**nalogDigital	`Done`
Test Serial Port	0TS **0T**est**S**erialPort	`OK`
Return Software Version	0TV **0T**est**V**ersion	`APS  0777 Ver: 3.85BD7716F`
Enable Writing	0L	`Enabled!`
Write to a Float Constant	0WC<constant number>F<value> **0W**rite**C**onstant<>**F**loat<>	`Done`
See Table 13 - 1540 Float Constants on page 32.		
Write to a Byte Constant	0WC<constant number>B<number> **0W**rite**C**onstant<>**B**yte<>	`Done`
See Table 5 - Commonly Used Byte Constants on page 14.		

Table 4. Model 1540 Commands

Description	Command Format	Command Response
Normal Data 02B02	0WV0	DataDisplayMode = NORMAL Done MX:-0.0032105 MY:-0.0033949 MZ:-0.0062852 T: +24.726
See Section 5.4 - ASCII and Binary Mode.		
Data Only 02B02	0WV1	DataDisplayMode = DATA ONLY Done
-0.0032105 -0.0033949 -0.0062852 +24.711		

5.2 - 1540 Byte Constants

System constants include byte constants and float constants.

Byte constants are used to configure the 1540 system and are used when operating the 1540. See Table 5 - Commonly Used Byte Constants.

Float constants are used for system calibration, diagnostics, and troubleshooting and generally not used when operating the 1540. For more information about float constants, see Table 13 - 1540 Float Constants.

Table 5. Commonly Used Byte Constants

Byte Constant	Function
00	Command Echo Flag 00 ≠ 0 Commands are echoed. 00 = 0 Commands are not echoed. Only command responses are displayed.
01	Autostart Flag 01 = 5A Executes the selected autostart option on power up.
02	Correction Level 02 = 0 A/D Counts 02 = 2 Ortho calibrated data (vector sensor data)
08	Auto Start Mode. On power up start accepting commands and then:
08	If 01 = 00 and 08 = 10 Send All Data in text mode once.
08	If 01 = 00 and 08 = 11 Send All Data in binary mode once.
08	If 01 = 00 and 08 = 12 Send All Data in IEEE mode once.
08	If 01 = 5A and 08 = 10 Send All Data in text mode in a loop until AutoStart (01) is not 0x5A.
08	If 01 = 5A and 08 = 11 Send All Data in binary mode in a loop until AutoStart (01) is not 0x5A.
08	If 01 = 5A and 08 = 12 Send All Data in IEEE mode in a loop until AutoStart (01) is not 0x5A.
09	Baud Rate Lock 09 ≠ 5A The sensor will use 9600 baud. 09 = 5A The sensor is using a baud rate other than 9600.
10	User power on baud rate. -- Use With Caution -- For this target baud rate ==> Use a number below for byte constant 10.
10	75 ==> 37
10	150 ==> 36
10	300 ==> 35
10	600 ==> 34
10	1200 ==> 33
10	2400 ==> 32
10	4800 ==> 31
10	9600 ==> 30
10	19200 ==> 5
10	38400 ==> 6
10	Power cycle the unit or the change in baud rate will not take effect.
23	Average control (2, 4, 8, 16).
35	RTS Delay is the time in ~2 millisecond units.

5.3 - 1540 Float Constants

In addition to byte constants, the 1540 has a number of float constants. Float constants are used to store the calibration data in the 1540 Flash memory and are used for diagnostics and troubleshooting. Although float constants generally aren't used when operating the 1540 system, they are included in Appendix A.2 - 1540 Float Constants for reference.

5.4 - ASCII and Binary Mode

The Model 1540 sensor transmits data in the following formats: ASCII and binary.

ASCII - The ASCII protocol is based sending ASCII characters (commands) to the 1540 to obtain data. Data transmitted in response to a command is sent out as an ASCII data stream complete with returns and line feeds so that it can be easily displayed on a PC display terminal (provided a TTL to RS-232 conversion box is used). There are two types of ASCII responses, standard and data-only.

1. Standard Data (default) - ASCII standard transmissions have the structure shown above where each data output is preceded by a data type identifier (for example, MX:). To select the standard ASCII data transmission format issue the commands:

   0l <CR>

   0wv0<CR>

   The response will be:

   ```
   DataDisplayMode = NORMAL
   Done
   ```

   The output will be displayed in the format below.

   ```
   MX:-0.0032105
   MY:-0.0033949
   MZ:-0.0062852
   T: +24.726
   ```

2. Data Only - ASCII data only outputs a simpler structure with no identifiers:

   ```
   +0.2393145 +0.03288605 +0.1188259 +25.986
   ```

   To select the data only ASCII format issue the commands:

   0l<CR>

   0wv1<CR>

   The response will be:

   ```
   DataDisplayMode = DATA ONLY
   Done
   ```

   The output will be displayed in the format below.

   ```
   -0.0032105 -0.0033949 -0.0062852 +24.711
   ```

   The first number represents the X-axis output and the second the Y-axis output. This data output format is much easier to export to an Excel spreadsheet to easily graph the output.

Binary - The binary 1540 protocol is used for high speed computer-to-computer interchange.

In this case, one byte is sent to request data. The 1540 then responds with a multibyte data packet containing the desired data plus header, checksum, and footer. For example, to obtain data from the 1540 sensor, enter the binary command:

80

Note: On most PCs, a hex command like the one shown above (0x80) can be sent by holding down the Alt key and typing the decimal equivalent (for example, 128 for 0x80) on the keyboard number pad.

The 1540 responds by sending a data packet.

Applied Physics Systems developed Windows software to enable communication with the 1540 system. The software is described in Section 6.1 - Sensor Interface Software.

5.5 - Configuring the 1540 System

This section provides instructions about using the most common configuration options for the 1540 system.

- Changing data output modes (see Section 5.5.1 - Changing the ASCII Data Output Mode)
- Changing baud rates (see Section 5.5.2 - Changing the Baud Rate)
- Configuring for autosend (see Section 5.5.3 - Configuring the 1540 Sensor for Autosend)
- Averaging and filtering output data (see Section 5.5.4 - Averaging and Filtering Model 1540 Output Data)

5.5.1 - Changing the ASCII Data Output Mode

To change the 1540 to A/D count mode, byte constant 02 must be changed from 02 (sensor mode) to 00 (count mode).

The response will look something like this.

```
MX:-29075.0007629
MY:+270823.0018616
MZ:-255466.9857025
T: +24.223
```

The numbers following MX, MY and MZ represent the system A/D count outputs for the three sensor axes, and t represents the temperature.

The 1540 can be configured to output in raw analog to digital (ADC) counts, sensor values, or angles. Data output is determined by the value of byte constant 02 as shown in Table 6 - Changing the ASCII Data Output Mode.

Table 6. Changing the ASCII Data Output Mode

Byte 02 Value	Output Data Content (in hexadecimal format)
0x00	Raw A/D Counts (uncalibrated)
0x02	Sensor Outputs (calibrated magnetometer)

Other values of byte constant 02 can result in alternative output formats less commonly used. These other values are listed in Table 5 - Commonly Used Byte Constants.

5.5.2 - Changing the Baud Rate

Following these steps to change the communications baud rate.

1. Set byte constant 10. See Table 7 - Baud Rate Settings.
2. Set byte constant 09 = 5A.
3. Cycle power off and on.

Press the Enter key at the end of each line. Be sure to cycle the system power or the baud rate won't be changed.

Note: When byte constant 09 ≠ 5A, the system baud rate is 9600.

Table 7. Baud Rate Settings

Baud Rate	Byte 10 Value
300	0x35
1200	0x33
2400	0x32
4800	0x31
9600	0x30
19200	0x05
38400	0x06

5.5.3 - Configuring the 1540 Sensor for Autosend

The Model 1540 has an autosend mode that enables data to automatically be sent repeatedly on power up. Byte constant 01 = 5A for autosend mode to be active. The format of the data sent in autosend mode is determined by the value of byte constant 08. See Table 8 - Autosend Modes for byte constant 08 formats:

Table 8. Autosend Modes

Byte Constant 08 Value	Autosend Mode
10	Send ASCII data continuously on power up. Use for repetitive text transmissions.
11	Send binary data continuously on power up. Use for repetitive binary transmissions.

To slow down data transmissions, set byte 35 ≠ 0. For example, if byte constant 35 = 40, data transmission is slowed to about one transmission per second.

5.5.4 - Averaging and Filtering Model 1540 Output Data

Use byte constant 23 to average the acquired data, as shown in Table 9 - Averaging Values. The response times shown are for a sensor output change from 0 Gauss to 0.5 Gauss.

Table 9. Averaging Values

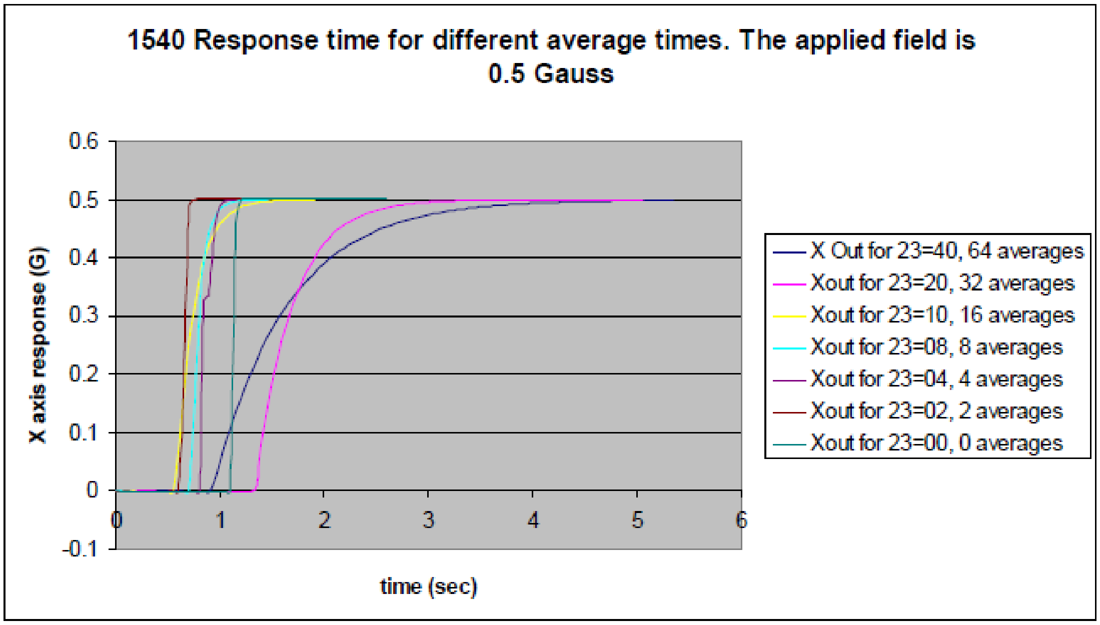
Byte Constant 23 Value	Number of Averages	Time to reach 90% of final value (in seconds)
08	8	0.25
10	16	0.5
20	32	1
40	64	2

The maximum number of data samples that can be averaged is 64.

Each data output of the 1540 is a running average of the previous n data acquisitions. When a new data point is acquired, a new average is computed by dropping the oldest data point from the average and adding the new data point.

The response of the 1540 to a 0.5 Gauss step input for various averaging values is shown in the Figure 4 - Averaging Example. The data was obtained by putting the 1540 in autosend ASCII mode with at 9600 baud.

Figure 4. Averaging Example



5.6 - Using the ASCII Communication Mode

Follow the instructions in this section to get data from the 1540 using the ASCII communication mode. Communication is initiated when the external computer issues a command such as ASCII characters 0SD. Enter this command and the 1540 returns a formatted output similar to the following vector data example, where byte constant 02 = 02.

```
MX:+0.20346
MY:+0.23165
MZ:+0.29525
TEMP: +28.148
```

When byte constant 02 = 02, the 1540 is in sensor output mode and the above numbers represent the magnetometer X, Y and Z sensor outputs in Gauss.

5.6.1 - ASCII Autosend Mode

The 1540 system can be configured for ASCII autosend mode by setting the following byte constants:

- 01 = 5A
- 08 = 10

Use the byte constant 02 (see Table 6 - Changing the ASCII Data Output Mode) to set the format of the transmitted ASCII data. For example, set the following byte constants:

- 02 = 02
- 35 = 20 (to slow down the autosend to one packet per second)
- 0WV1 (a useful ASCII data format for importation of data into an Excel spreadsheet)

5.7 - Standard Binary Communication Modes

In addition to an ASCII communication mode, the 1540 also has a binary communications mode. Single data packet binary communications are initiated by an external computer by issuing the single byte command ASCII 128. On some computers, these commands can be sent from a terminal emulator by holding the Alt key down and typing the command number on the number pad on the right side of the keyboard. The Model 1540 responds to the following binary commands:

- ASCII 128 (Send All Data as Vectors in a Binary Format)
- ASCII 129 (Send All Data as Vectors in an IEEE Float Format)

The sections below define the response format.

5.7.1 - Command <128>: Send Sensor (Vector) Data in Standard Binary Format

This section describes the contents of a binary packet. Note that when a Command <128> Send Vector Data command is issued, the response always begins with 0x80. This is because even when command echoing is disabled, the command byte for a binary command (0x80) is always echoed.

<<Sent First <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<Sent Last<<<<

10 <MX> <MY> <MZ> <MT> <V> <STATUS> <CS> <EOT>

1 B 3 B 3 B 3 B 2 B 2 B 1 B 1 B 2 B

Table 10 explains the contents:

Table 10. Command <80 Hex, 128> Data Format Key

Label	Description	Size
<SOT>	Start of transmission	1 Byte
<MX>,<MY>,<MZ>	The magnetometer data in a signed integer format encoded in a three byte signed integer format as the float value times 1,000,000. For example, 1234567 = 0.1234567Gauss.	3 Bytes for each measurement
<MT>	The temperature data is in a two byte signed integer format encoded as the float value times 100. For example, 12345 = 123.45 °C	2 Bytes
<V>	Unused with value 0x00	2 Bytes
<STATUS>	Status byte	1 Byte
<DATA CHECK SUM>	The lower 8 bits of the sum of all the bytes in the data area.	1 Byte
<EOT>	The end of the transfer, shown as 0x7FFF (should be unique in the data stream)	2 Bytes

All data is sent most significant byte first.

5.7.2 - Command <129>: Send All Data as Vectors in an IEEE Float Format

```
<<Sent First <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<Sent Last<<<<
<NDB><MX><MY><MZ><MT><V><STATUS><CS><EOT>
  1 B    4 B   4 B   4 B   4 B  4 B     1 B       1 B    2 B
```

Table 11 explains the contents:

Table 11. Command <129> Data Format Key

Label	Description	Size
<NDB>	Number of Data Bytes	1 Byte
<MX>,<MY>,<MZ>	The magnetometer data	4 Bytes for each measurement
<MT>	The temperature data	4 Bytes
<V>	Unused with value 0x00	4 Bytes
<STATUS>	Status byte	1 Byte
<DATA CHECK SUM>	The lower 8 bits of the sum of all the bytes in the data area.	1 Byte
<EOT>	The end of the transfer, shown as 0x7FFF (should be unique in the data stream)	2 Bytes

All data is sent most significant byte first.

5.7.3 - Autosend Binary Communication Mode

Standard binary protocol results in the transmission of data packets with the same structure as that described in Section 5.7.1 for the response to binary command 128. However, when in autosend mode, data packets are automatically and continuously sent out after power is applied.

Standard autosend binary mode is selected by setting up the system byte constants as follows:

- byte constant 08 = 11 selects standard autosend binary mode (see Table 8 - Autosend Modes)
- byte constant 01 = 5 enables autosend
- byte constant 35 = 10 inserts a small delay between data packets (optional)

This page is intentionally left blank.

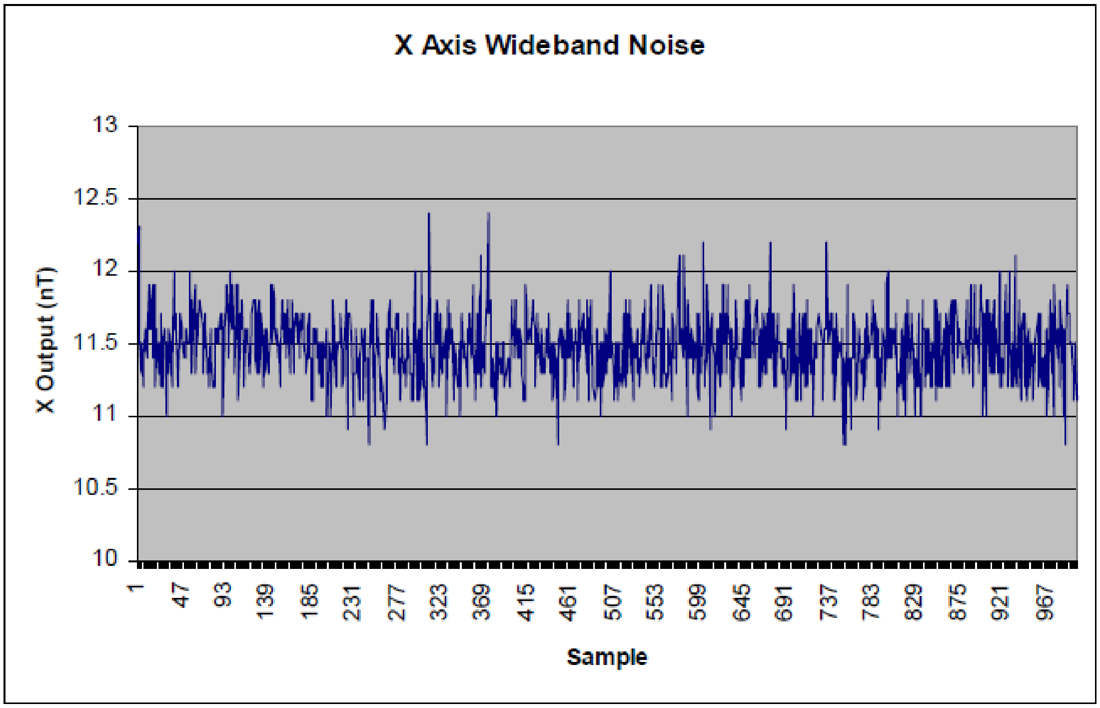
6 - Operating the Model 1540

After the Model 1540 is operational and communicating with a computer, its proper operation can be qualitatively verified by using it to measure the Earth's magnetic field. Around the globe, the magnitude of the Earth's magnetic field varies from about 0.4 Gauss to 0.6 Gauss. In the northern hemisphere, the magnetic field points north and dips into the ground (dip angle) at about 60°.

Point the X-axis generally north and down at an angle of 60° from horizontal. Verify that the X-axis reads about 0.5 Gauss and the Y and Z-axes read near zero Gauss. Repeat the measurement with the Y and Z-axes in turn, pointed into the field and verify these two axes correctly read the Earth's magnetic field magnitude.

The noise level of the 1540 can be observed by placing the sensor in a magnetic shield, which typically consists of a 2 layer mu metal shield. An example of data taken using ASCII autosend mode with the 1540 positioned in a mu metal shield is shown in Figure 5. Note that the noise level is about 0.005 Gauss or 0.5 nanotesla (nT) peak to peak. The noise level can be reduced by lowering the filter value or averaging data samples (see Section 5.5.4 - Averaging and Filtering Model 1540 Output Data). The noise data displayed in Figure 5 was sampled at a rate of 12 samples per second. Output noise is displayed nT. Note that 1 nT = 0.00001 G.

Figure 5. Model 1540 Noise Level Data



6.1 - Sensor Interface Software

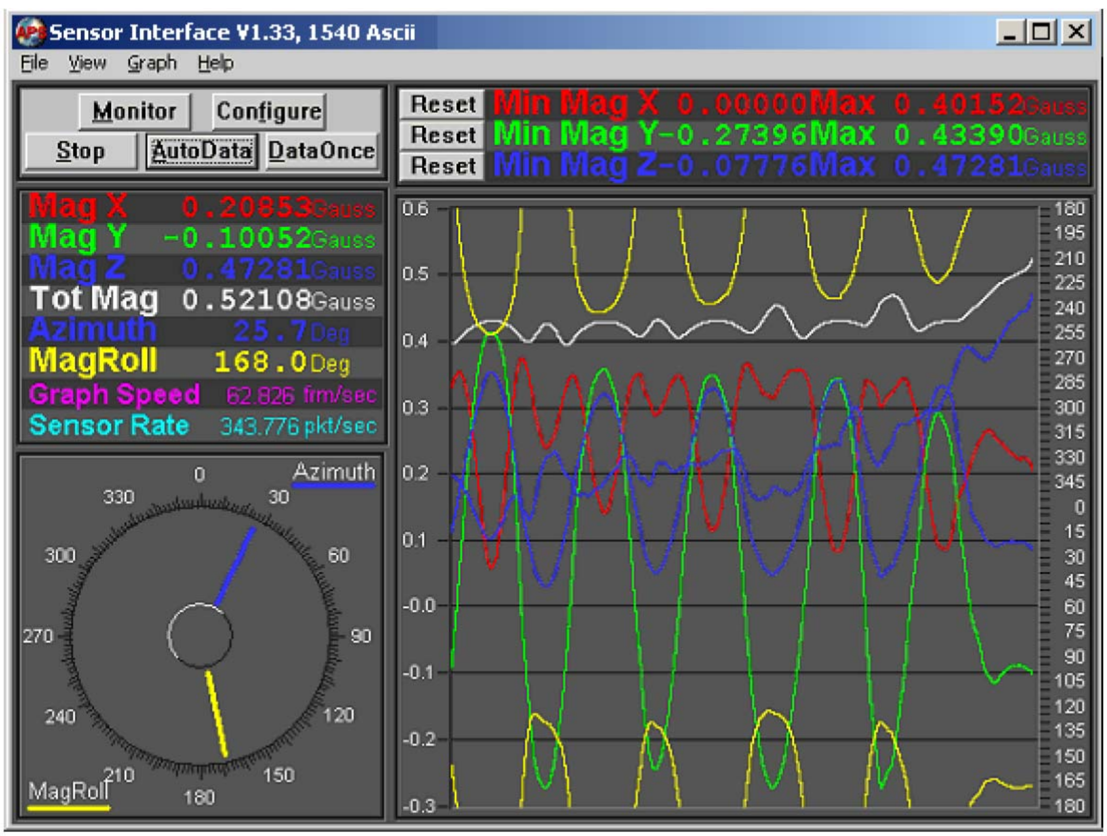
Sensor Interface software provides a graphical user interface for the magnetometer and is used to configure the system. Each sensor can be monitored in each mode the sensor can be programmed for. Each sensor can be programmed for ASCII or binary transfer modes and for corrected or non-corrected data.

Sensor Interface software also creates log files of sensor data and displays a scrolling graph of the digital data and graphical indicators of the angular data with the minimum and maximum values maintained for the magnetometer.

Follow the procedure below to install Sensor Interface software.

1. Insert the CD-ROM containing Sensor Interface software into the CD-ROM drive.
2. Click on My Computer and then select the disk drive the software disk was inserted in.
3. Left-click and hold on the Sensor Interface icon and drag it onto the desktop. Release the mouse button. The software icon should now be on your desktop and the software is ready to use.
4. Click on the icon to open the main display window.

Figure 6. Sensor Interface Main Display



The upper left corner of the main window contains the following command buttons.

- The Monitor button brings up the monitor window.
- The Configure button brings up the configuration window.
- The Stop button issues the command to the sensor to stop sending data.
- The AutoData button issues the command to the sensor to send data repeatedly.
- The Once button issues the command to send the data one time.

In the View menu, each check mark before Magnetometer Min/Max or AC/DC Magnetic enables or disables the feature from appearing on the screen. In Figure 6 the Magnetometer Min/Max is enabled.

In the Graph menu, each check mark before Magnetic X, Y, Z, T, Mag Roll and Azimuth enables or disables the item to be scrolled on the graph. The color of the item on the graph matches the color of the text in the numeric display windows.

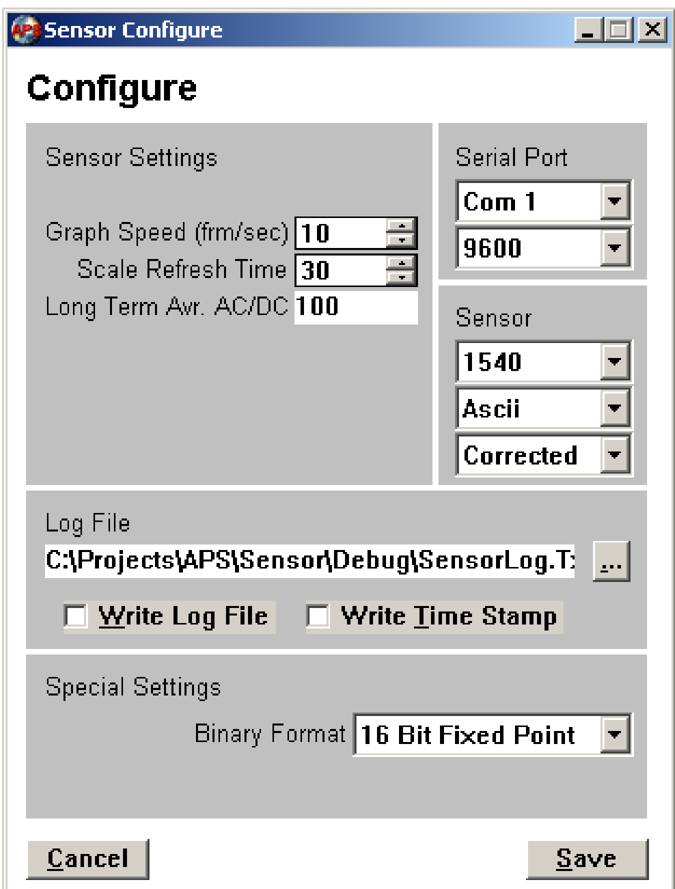
The minimum and maximum values are tracked and displayed in the upper right corner window.

The values can be reset back to zero by pressing the Reset button.

The number of packets per second the sensor is receiving is displayed as Sensor Rate. This value is continually being updated and sampled.

Click Configure to open the Sensor Configure window.

Figure 7. Sensor Configure Window



In the Sensor Settings panel:

- The Graph Speed represents the maximum scrolling speed of the graph on the main window in frames per second. The PC operating system limits the maximum scrolling speed.
- The Scale Refresh Time sets the time at which the auto-scaling routine can decrease the scale factors on the main scrolling window. When the scrolling window scale maximum output is exceeded, it is automatically increased. To decrease the scale, use Scale Refresh Time.
- The Check Sum box (optional) allows the sensor to send a checksum with each data packet from the sensor.
- Long Term Aver. AC/DC value is the number of samples of AC and DC values collected to create the AC and DC values display on the main window.

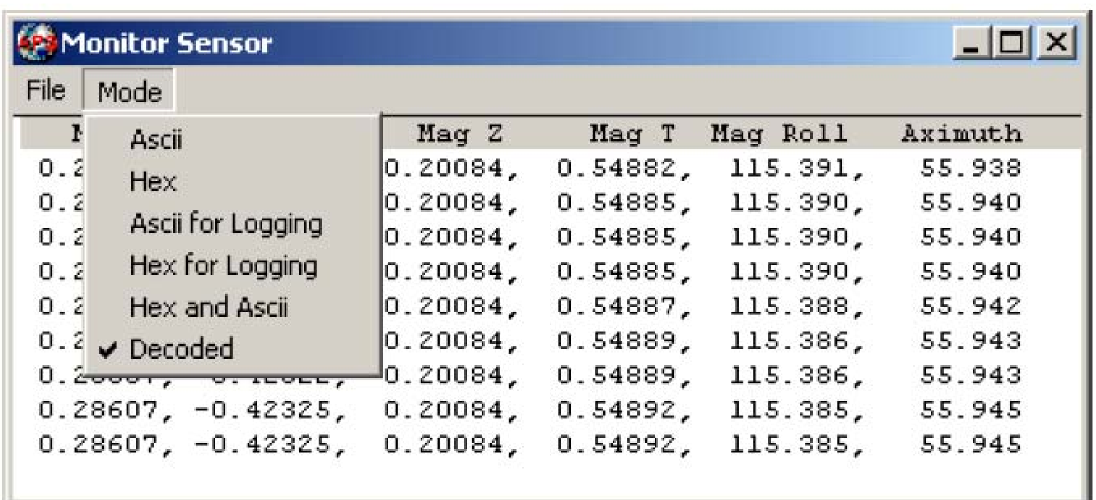
In the Serial Port panel, the computer serial port used with the 1540 can be set using COM 1 to COM 8. The default baud rate is 9600 baud. Other baud rates may be selected using this panel.

In the Sensor panel, the sensor type, transfer type (ASCII or binary), and data type (raw or corrected) are selected. ASCII transfers can be viewed from the monitor window. Binary transfers are always faster than ASCII. Raw data is expressed in A/D counts. Corrected data is expressed in Gauss and has been corrected for physical misalignments, scale factors, and offsets.

To save data output from the 1540, enter a log file name in the Log File panel. The file will capture all data sent to the software from the sensor. The type of data logged is set in the menu in the Monitor window and can be either ASCII for Logging or Hex for Logging.

The Monitor Sensor window is used to view the data being sent from the sensor and to send commands to the sensor.

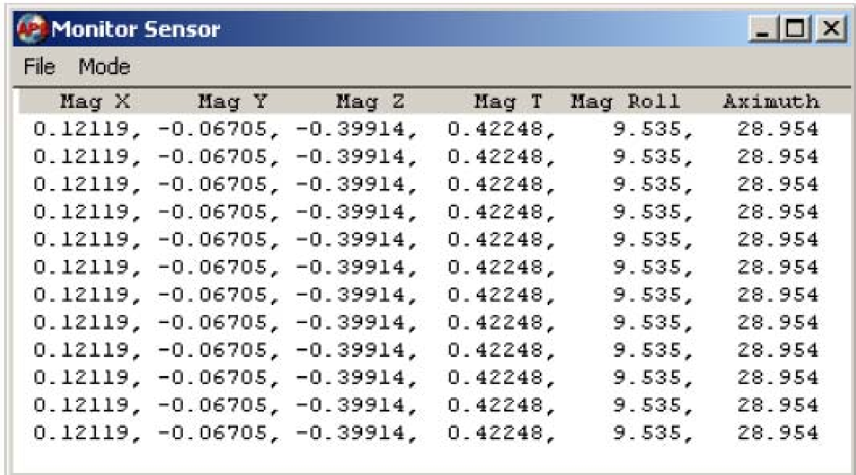
Figure 8. Monitor Sensor Window



The Monitor Sensor window has six display modes.

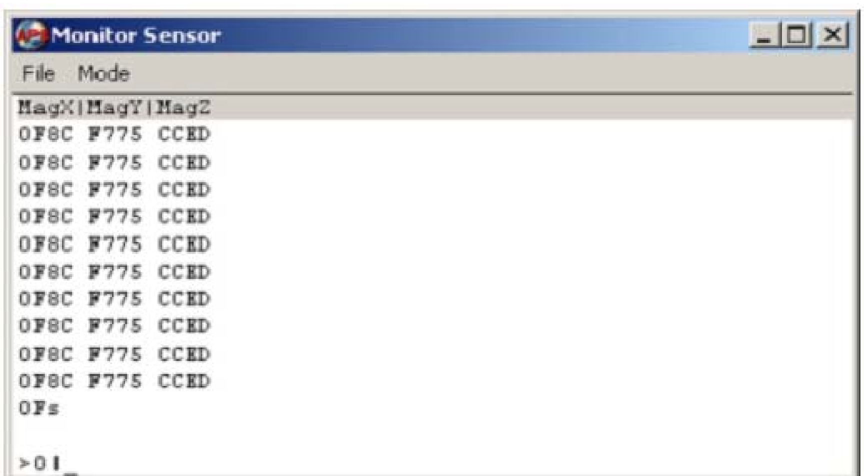
- ASCII. In ASCII mode, the Monitor Sensor window acts like a simple ASCII terminal.

Figure 9. Monitor Sensor Window - ASCII Mode



- Hex. In Hex mode, each ASCII character received is converted to the hexadecimal value that it represents, followed by a space. For example, the ASCII character 'A' would be printed as '41', which is its hexadecimal value.

Figure 10. Monitor Sensor Window - Hex Mode



- ASCII for Logging and Hex for Logging. ASCII for Logging and Hex for Logging are used with file logging mode. Data is formatted with a <CR><LF> at the end of each line it can be written to a logging file.
- Hex and ASCII. Hex and ASCII is a mixed display with hexadecimal data on the left and the same ASCII data on the right.
- Decoded. Decoded is a mode where only the processed data values are displayed.

Sensor commands can be entered from the Monitor Sensor window. The format of the commands is defined in Section 5.6 - Using the ASCII Communication Mode.

This page is intentionally left blank.

A - Byte Constants and Float Constants

A.1 - 1540 Byte Constants

Although there are many byte constants, only a subset of them is commonly used.

Table 12 displays a complete list of 1540 byte constants for your reference.

For a list of the commonly used byte constants, see Table 5 - Commonly Used Byte Constants.

Table 12. 1540 Byte Constants

Byte Constant	Function
00	Command Echo Flag 0 is no command echo else echo commands.
01	Autostart Flag. If 0x5A executes the selected autostart option on power up.
02	Correction Level: 0 - A/D Counts 2 - Ortho calibrated data (sensor vector data)
03	Not Used.
04	Version of the Calibration Software
05	Power on self test flag. If zero a self test will be done on power up.
06	Enable All Error Messages
07	This Sensor's Address Number 0-36 => 0-9,A-Z
08	Auto Start Mode. On power up start accepting commands and then:
08	If 01=00 and 08=10 Send All Data in text mode once.
08	If 01=00 and 08=11 Send All Data in binary mode once.
08	If 01=00 and 08=12 Send All Data in IEEE mode once.
08	If 01=5A and 08=10 Send All Data in text mode in a loop until AutoStart (01) is not 0x5A.
08	If 01=5A and 08=11 Send All Data in binary mode in a loop until AutoStart (01) is not 0x5A.
08	If 01=5A and 08=12 Send All Data in IEEE mode in a loop until AutoStart (01) is not 0x5A.
09	User power on baud rate lock. If 09 is not 0x5A, the sensor will use 9600 baud).
10	User power on baud rate. -- Use With Caution -- For this target baud rate ==> Use a number below for byte constant 10.
10	75 ==> 37
10	150 ==> 36
10	300 ==> 35
10	600 ==> 34

Table 12. 1540 Byte Constants

Byte Constant	Function
10	1200 ==> 33
10	2400 ==> 32
10	4800 ==> 31
10	9600 ==> 30
10	19200 ==> 5
10	38400 ==> 6
10	To change the baud rate from 9600 (default), lock the baud rate, change the baud rate, and then power cycle the unit.
11	Not Used
12	Lowest Calibration Temp. in counts. LSB
13	Lowest Calibration Temp. in counts. MSB
14	Distance in counts between Calibration Points LSB
15	Distance in counts between Calibration Points MSB
16	Number of Temp. Points in the EEPROM.
17	The Table Mag Offset Scale Value. (Offset = TableOffset / 2^<Byte#18>)
18	Not Used
19	The Table Mag Scale Scale Value. (Scale = TableScale / 2^<Byte#20>)
20	Not Used
21	The Table Mag Ortho Scale Value. (Ortho = TableOrtho / 2^<Byte#22>)
22	Not Used
23	Average control (2, 4, 8, 16).
24	Product ID String char #1
25	Product ID String char #2
26	Product ID String char #3
27	Product ID String char #4
28	Product ID String char #5
29	Product ID String char #6
30	Product ID String char #7
31	Product ID String char #8
32	Product ID String char #9
33	Product ID String char #10
34	Constant 0

Table 12. 1540 Byte Constants

Byte Constant	Function
35	RTS Delay is the time in ~2 millisecond units
40	X bow calibration factor
41	Y bow calibration factor
42	Z bow calibration factor

A.2 - 1540 Float Constants

Float constants are commonly used by Applied Physics Systems for diagnostics and troubleshooting.

Although float constants are not commonly used when operating the 1540 system, a complete list of float constants are included in Table 13 for your reference.

Table 13. 1540 Float Constants

Float Constant	Function
00	Not Applicable (Analog voltage scale factor)
01	Temperature scale factor to convert temperature sensor voltage to Kelvin
02	Not Applicable (Analog voltage offset factor)
03	Temperature Offset
04	X magnetometer offset
05	Y magnetometer offset
06	Z magnetometer offset
07 - 09	Not Used
10	X magnetometer scale
11	Y magnetometer scale
12	Z magnetometer scale
13 - 21	Not Used
22	Mag Base Ortho (X,X)
23	Mag Base Ortho (X,Y) (Denotes X axis in the Y direction)
24	Mag Base Ortho (X,Z)
25	Mag Base Ortho (Y,X)
26	Mag Base Ortho (Y,Y)
27	Mag Base Ortho (Y,Z)
28	Mag Base Ortho (Z,X)
29	Mag Base Ortho (Z,Y)
30	Mag Base Ortho (Z,Z)