Model 534D

Digital 3-Axis Fluxgate Magnetometer

Technical Reference and User Manual

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Contents

1 - Introduction

The 534D Sensor is a tri-axial vector magnetometer system with a high-speed digital interface that can transmit XYZ magnetic field values at up to 140 times per second. The 534D System contains a microprocessor and a three channel 16-bit analog to digital converter. The system also contains a temperature sensor. The system microprocessor and A-to-D subsystem perform the following functions:

- Conversion of the sensor analog outputs to digital form
- Calibration of the sensor scale, offset and alignment
- Implementation of serial communications between the system and an external computer

The 534D System communicates with the outside world over a bi-directional RS232 serial interface. An ASCII character command language has been created to facilitate communication with the 534D. For instance, if the ASCII characters for 0, S and D are sent in sequence, the 534D interprets this as a "send data" command and responds by sending over the serial interface an ASCII string representing the value of the magnetometer and temperature outputs. The leading zero in this sequence denotes the system serial number.

An autosend data mode is included in the 534D software. When this mode is active, data is automatically repeatedly sent out the serial port after power is applied to the system.

The 534D magnetometers are calibrated by mounting the system in a precision holding fixture, placing this in a 3-axis Helmholtz coil and systematically applying known magnetic fields to the sensor. System calibration can be performed at a base temperature (usually 25°C) or as an option over a temperature range (for example 0-75°C).

When the system is calibrated over a temperature range, data is read from the system at temperature intervals between the minimum and maximum temperature specification. For instance, for calibration over the interval of 0-75°C, data is usually read at 25°C temperature intervals at 0°C, 25°C, 50°C, and 75°C. The data taken at each temperature includes scale, offset, and sensor alignment data. The recorded data is then used to create a look up table for scale, offset and alignment corrections. This table is then downloaded into the 534D internal EEROM memory where it can be accessed by the system internal microprocessor. Corrections to the sensor data can then be made by the internal microprocessor system before data is transmitted.

2 - System Specifications

Table 1. System Specifications

Accuracy	±1% FS
Dynamic Range	±60,000 nT (±600 mGauss) ±100,000 nT optional
Resolution	2 nT (20 µGauss)
Noise	±2 nT (±20 µGauss)
Data Rate in Autosend Mode	ASCII mode: 70 transmissions/sec Binary mode: 140 transmissions/sec
Analog Bandwidth	70 Hz
Power Input	+4.9 VDC to +15 VDC @ 50 mA
Size (PC board)	2.75"L x 0.75"W x 0.75"H
Weight	30 grams
Digital Output Protocols	RS232 and TTL, User programmable baud rate to 9600 baud
Digital Output Formats	ASCII and Binary
Leads	6" flying leads

3 - Mechanical Features

An outline drawing of the 534D System is shown in Figure 6 on page 13. The orientation of the X, Y and Z axes and the approximate location of the magnetometer sensors is also shown in Figure 6. The output polarity sense of the axes is such that a field pointing in the direction of the arrows shown in the figure will produce a positive output voltage. For example, if the X axis magnetometer is pointed north, then the output will be positive.

4 - Electrical Interface

The electrical interface to the 534D System is shown in Table 2. Flying leads (#26 gauge Teflon insulated) are used to make connection to the system.

Table 2. Electrical Interface for Model 534D Sensor

Wire	Function	
Red	+V input	1
Black	Power ground	2
Orange	RS232-in	7
Yellow	RS232-out	8
Or/Wh	TTL serial-in	10 (optional)
Yel/Wh	TTL serial-out	11 (optional)

Note: Power and COM ground are connected together on the 534D PC board.

RS232 serial communications interface to the 534D is provided by the RS232-in and RS232-out lines shown in Table 2. An external computer talks to the 534D on the serial-in line and replies from the 534D are transmitted out on the serial-out line. The serial-in and serial-out lines are normally set to operate at 9600 baud with one stop bit and no parity. The user, however, can change the baud rate by setting bits in the system EEROM. The TTL serial-out and TTL serial-in terminals on connector J5 are also serial I/Os for the 534D. These I/Os operate at TTL levels.

Two communication protocols are available: 1) ASCII and 2) Binary. The ASCII protocol is based upon sending ASCII characters to the 534D to obtain data. The 534D responds by sending out an ASCII data stream complete with carriage returns and line feeds so that it can easily be displayed on a computer terminal. The Binary protocol is used for high-speed computer-to-computer interchange. In this case, one byte is sent to request data. The 534D then responds with a data packet containing the desired data.

The Binary command of the 534D is ASCII 128. This command can typically be sent from a computer terminal by holding down the ALT key, typing 128 on the keyboard number pad and then releasing the ALT key.

The 534D response to this command is of the following form:

```
<SOT>  <MX><MY><MZ><MT><TEMP><ANAI><data check sum><EOT>
```

See “534D Binary Mode Protocol” on page 11 for more details on the Binary transfer protocol.

5 - Initial Setup of the System

In order to operate the 534D, power must be applied to it and an interface with an external computer must be set up. The 534D can be powered from dual input voltages of 4.9V to 12V or optionally, from a single 4.9 to 12V supply.

In order to set up a computer interface with the system, select the output protocol of the 534D. This can be either TTL or RS232. The TTL protocol is usually used in microprocessor-to-microprocessor communications. For this mode, the voltage levels for a 0 and 1 are approximately ground and 5V. In the idle or marking state, the output level is +5V.

Since PC's use the RS232 protocol, they can be directly connected to a 534D employing this protocol. PC's use either a 25 pin or a 9 pin D connector to implement their serial ports. This connector is always a bulkhead male connector on the PC chassis. The serial-in, serial-out, and ground connections for these connectors are shown in the Table 3.

Table 3. Serial and Ground Connections

Function	25 pin	9 pin
Serial-out	2	3
Serial-in	3	2
Ground	7	5

Connect the 534D serial output line to the computer in line and the 534D serial input line to the computer serial out line.

To communicate with the 534D, a terminal program will need to be run on the PC. The Windows HyperTerminal program is one such program. Other suitable terminal programs are ProComm and ASCII Pro. These programs turn the computer into a dumb terminal. In this mode, whatever you type on the keyboard goes out the selected serial port (e.g., 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 (e.g., COM 1, COM 2, etc.) and set the baud rate to be 9600 with one stop bit and no parity. Set the port up for direct connect and turn off any handshaking.

To decode the 534D binary response, configure the terminal emulator program (e.g., ProCom) to show a monitor screen. This will display the 534D binary response in hex encoded bytes.

The easiest method of determining if a working communications link with the 534D has been established is to observe the PC display when the 534D is powered up. The 534D transmits a power up sign-on message which should appear in readable form on the PC display as follows:

```
APS Vers: 3.60 SD16
```

The appearance of an unreadable message at power up may indicate incorrect protocol (i.e.,TTL instead of RS232) or an incorrect baud rate.

5.1 - Windows Software and the Model 534D Magnetometer

The purpose of the Sensor interface program is to provide a graphics interface to the magnetometer and allow the user to configure the system.

It allows each sensor to be monitored in every mode that the sensor can be programmed. Each sensor can be programmed to allow for ASCII or Binary transfer mode and corrected or non-corrected data. Log files of sensor data can be created. A scrolling graph of the digital data and graphical indicators of the angular data are displayed to the operator. Minimum and maximum values are maintained for the magnetometer. The sensor's special features are supported.

Install the Sensor software by using the following steps:

1. Insert the CD-ROM containing the Sensor software into the CD-ROM drive.

2. Click on "My Computer" and then the disk drive the software disk was inserted in.

3. Left-click and hold on the Sensor icon, then drag it to the desktop.

4. Release the mouse button. The software icon should now be on your desktop, and the software is ready to use.

Figure 1. Model 534D Main Display

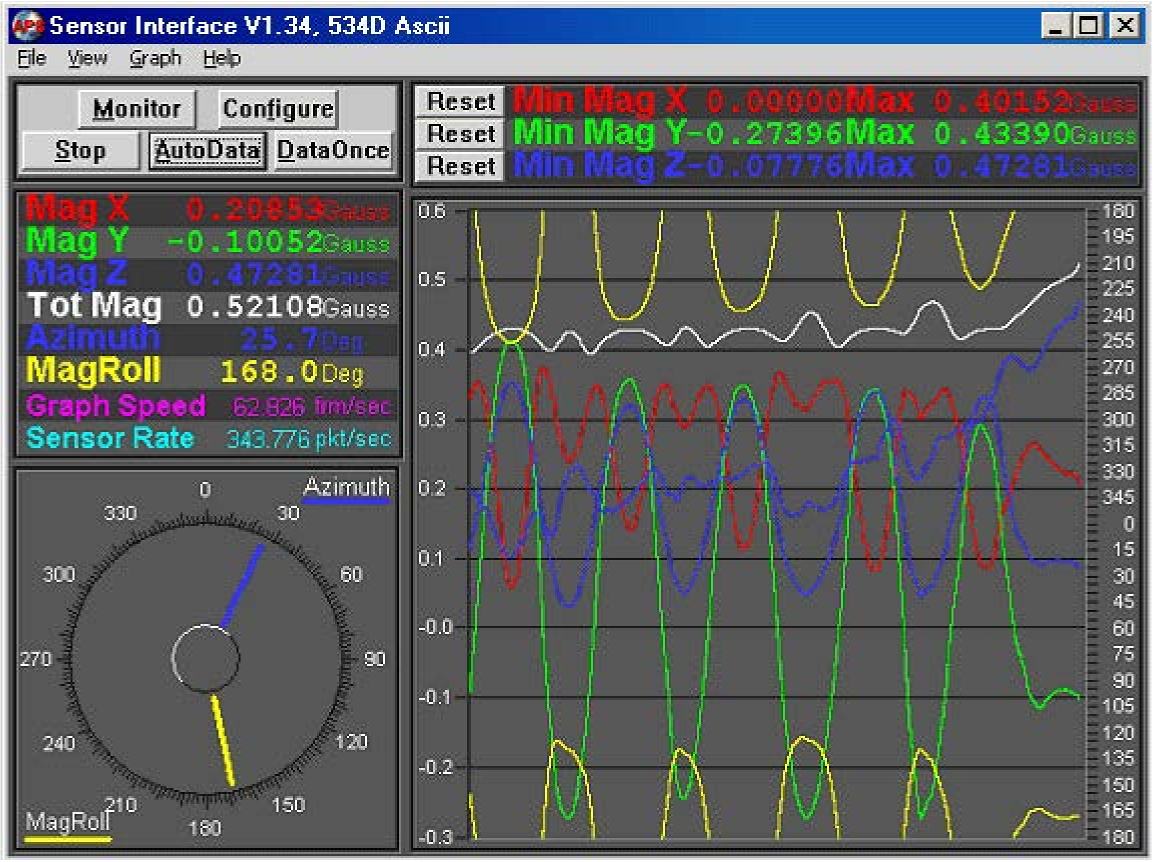


Figure 1 shows the main display of the Sensor Interface Program. The upper left corner of the main window contains the command buttons. The Monitor button brings up the monitor window and the Configure button brings up the configuration window. The Stop button issues the command to the sensor to stop sending data. The Auto button issues the command to the sensor to send data repeatedly. The Once button issues the command to send the data one time.

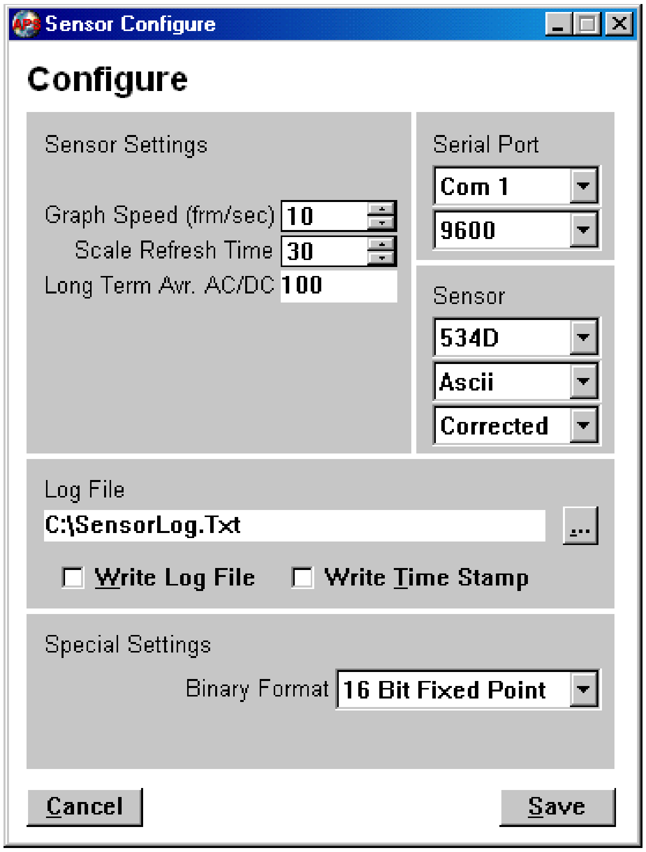
In the View menu, each check mark before Magnetometer Min/Max or AC/DC Magnetic enables or disables the feature from appearing on the screen. In the example display, the Magnetometer Min/Max is enabled.

In the Graph menu, each check mark before Magnetic X, Y, Z, T, Mag Roll and Azimuth labels 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.

When the Configure button is pressed the following window is displayed:

Figure 2. Sensor Configure Window



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, Scale Refresh Timer is used. The Check Sum box allows the sensor to send a check sum with each data packet from the sensor. The Long Term Avr. AC/DC value is the number of samples of AC and DC values that are collected in order to create the AC and DC values display on the main window.

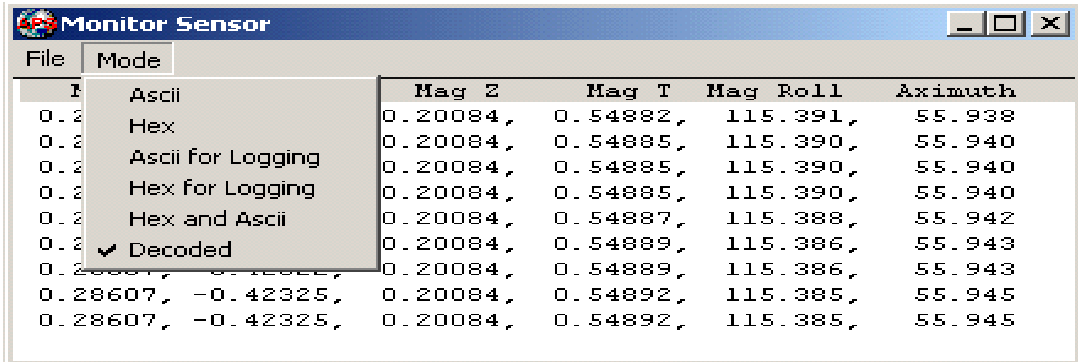
The computer serial port to be used with the 534D may be set from Com 1 to Com 8. The default baud rate is 9600 baud. Other baud rates may be selected using this panel.

To use the 534D, the operator selects the 534D in the top Sensor window. In the next window, below, the option for ASCII or Binary transfer may be entered. ASCII transfers may easily be viewed from the monitor window. Binary transfers are always faster. Raw data is expressed in A/D counts. Corrected data is in Gauss and has been corrected for physical misalignments, scale factors and offsets.

To save data output from the 534D, the operator may enter a logging file name. This file will capture all data sent to the program 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.

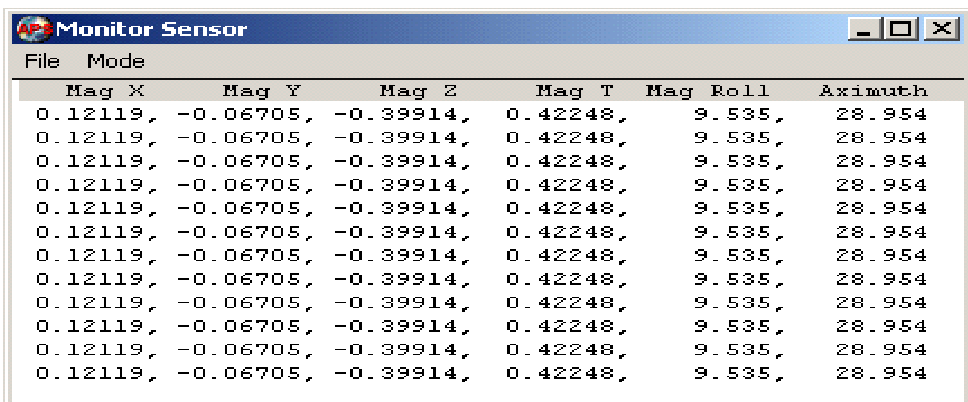
The monitor sensor window allows the operator to view the data being sent from the sensor and allows the operator to send commands to the sensor.

Figure 3. Monitor Sensor Window Display Modes



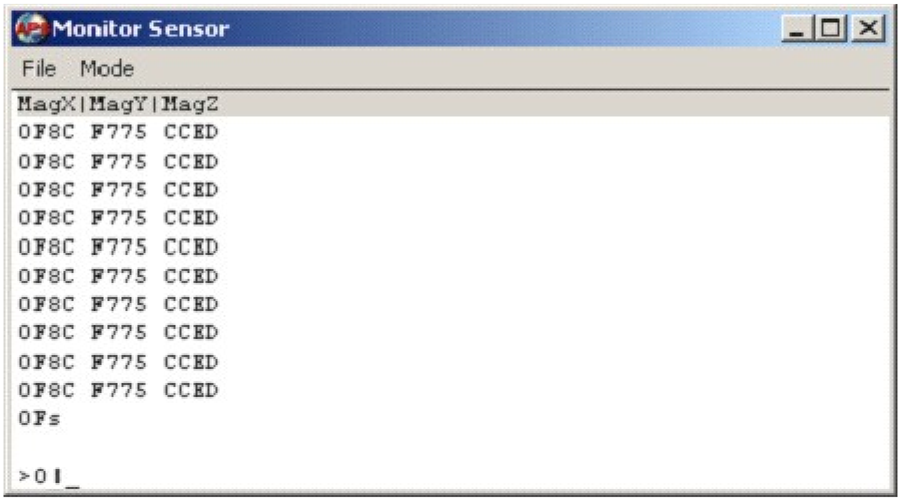
The monitor window (Figure 3) has a number of display modes. They are ASCII, Hex, ASCII for Logging, Hex for Logging, Hex and ASCII, and Decoded. In ASCII mode (Figure 4), the monitor window acts like a simple ASCII terminal. In Hex mode (Figure 5), each ASCII character received is converted to the hexadecimal value that it represents, followed by a space. For example, the ASCII character 'A' would be printed as '41', which is its hexadecimal value. ASCII for Logging and Hex for Logging are designed to be used with file logging mode. They are formatted with a <CR><LF> at the end of each line so that then can be written into a Logging file. Hex and ASCII is a mixed display with hexadecimal data on the left and the same ASCII data on the right. Decoded is a mode where only the processed data values are displayed.

Figure 4. Monitor Sensor Window for Corrected ASCII Mode



Sensor commands may be entered from the monitor windows. The format of the commands are defined in the Appendix of this manual.

Figure 5. Monitor Sensor Window for Corrected HEX Mode



6 - Operation of the System

After establishing communication with the 534D, data can be obtained from the system by sending (typing) the command 0sd (Zero Send Data). The 0 in this sequence is the default serial number of the unit. After sending this command, the 534D will respond with an output that appears as follows:

```
MX: +0.24561
MY: -0.35100
MZ: +0.01122
T: 24.63
```

The numbers following the MX, MY and MZ headers represent the magnetometer output in gauss. The temperature (°C) follows the T: header.

The 534D operating characteristics are controlled by the systems internal byte constants. The 534D also has a set of internal float constants which are used to calibrate the 534 so that it produces accurate output data. Generally, the float constants correct for scale, offset and orthogonality of the magnetic field sensors. These constants should not be altered by the user as this will invalidate the system calibration.

The system byte constants are used to control baud rate, output protocol (Binary or ASCII) and the system autosend mode. Byte constants can be changed by the user using a two-step process. For instance, if the user is interested in observing the raw A/D count outputs for the sensor this can be accomplished by changing byte 02 to 00. For calibrated sensor output, byte 02 should equal 02. To change by 02 from 02 to 00 issue the following command:

```
0l<CR>
```

where 0 is a zero, l is the letter l, and <CR> is a carriage return. Next, issue the command:

```
0WC02B00<CR>
```

Next, issue the command:

```
0sd<CR>
```

and the output data format will be raw A/D counts. Change the system configuration back to calibrated mode by returning the value of byte 02 to 02.

The 534D has an autosend mode which enables data to automatically be sent repeatedly upon power up. Byte 01 must be set equal to 5A for autosend mode to be active. The format of the data sent in autosend mode is determined by the value of byte 08. For repetitive text transmissions, set byte 08=10. For repetitive binary transmissions, set byte 08=11. To stop autosending of data, issue the command:

```
CONTROL S
```

This command is sent by holding down the control key and typing S.

To slow down transmissions in autosend mode, set byte 35 to a non-zero value. When byte 35=40 data transmission in ASCII mode is slowed down to about 1 transmission per second.

7 - 534D Binary Mode Protocol

Consider the following data transmissions from a 534D; one in ASCII mode and one in Binary mode.

ASCII

```
MX : +0.27400
MY : +0.09515
MZ : +0.91134
T : 21.75
```

Binary

```
SOT  MX      MY      MZ
10   0AB4    FC1C    255D

TEMP   ANA1     CS     EOT
087E   02BC     00AZ   7FFF
```

Binary transmissions start with a hex byte 10 and end with the hex bytes 7FFF.

Magnetometer binary transmissions can be decoded by first converting to decimal and then dividing by 10,000. For instance, in the above transmission:

```
MX = 0AB4 = 2740/10000 = 0.27400 Gauss
```

Temperature is decoded by converting to decimal and dividing by 100.

```
TEMP = 087E = 2174/100 = 21.75°C
```

The ANA1 transmission represents a transmitted voltage and is not typically used in the 534D. If used, this voltage can be decoded by dividing by 100.

```
ANA1 = 02BC = 700/100 =7.00V
```

The CS is a checksum and is calculated by summing all of the bytes in the transmission before the CS byte excluding the SOT character. For the above transmission the checksum is calculated as follows:

```
CS = 0A+B4+FC+1C+25+5D+08+7E+02+BC = 39C
```

The checksum is the lower byte of the sum, or 9C padded on the left with 00 to make the 2 byte checksum 009C.

Note: All the numbers used above to describe the binary packet are in hexadecimal.

8 - Description of the System Internal Constants

The 534D employs two types of internal constants 1) byte and 2) floating. Byte constants are used to configure the system. Floating constants are used for the system calibration. A list of the most important byte and floating constants is shown in Table 4 and Table 5, respectively.

Table 4. Byte Constants

Byte Constant	Function
00	Enables echoing of serial input characters when nonzero.
01	Enables autosend when =5A.
02	Enables sensor A/D count output when =00 and sensor output when =02.
08	Sets power on mode as follows: =01 transmits in ASCII mode once =10 transmits continually in ASCII mode =11 transmits continually in Binary mode
09	Baud rate lock (=5A if any baud rate other than 38400 is used).
10	Sets baud rate.

Table 5. Floating Constants

Float Constant	Function
04	X magnetometer offset
05	Y magnetometer offset
06	Z magnetometer offset
10	X magnetometer scale
11	Y magnetometer scale
12	Z magnetometer scale
Note: Floating constants 22 to 30 contain the system alignment constants.	

9 - Changing the Baud Rate

The communications baud rate can be changed by using the following sequence:

1. Set byte constant 10 according to the following table.

Table 6. Baud Rate Settings

Baud Rate	Byte 10 Value
300	0x35
1200	0x33
2400	0x32
4800	0x31

2. Set byte constant 09 to 5A.

3. Cycle power off and on.

Note: When byte constant 09 is set to any value other than 5A, the system baud rate is 9600.

10 - Appendix

Figure 6. Model 534D Miniature 3-Axis Fluxgate Magnetometer

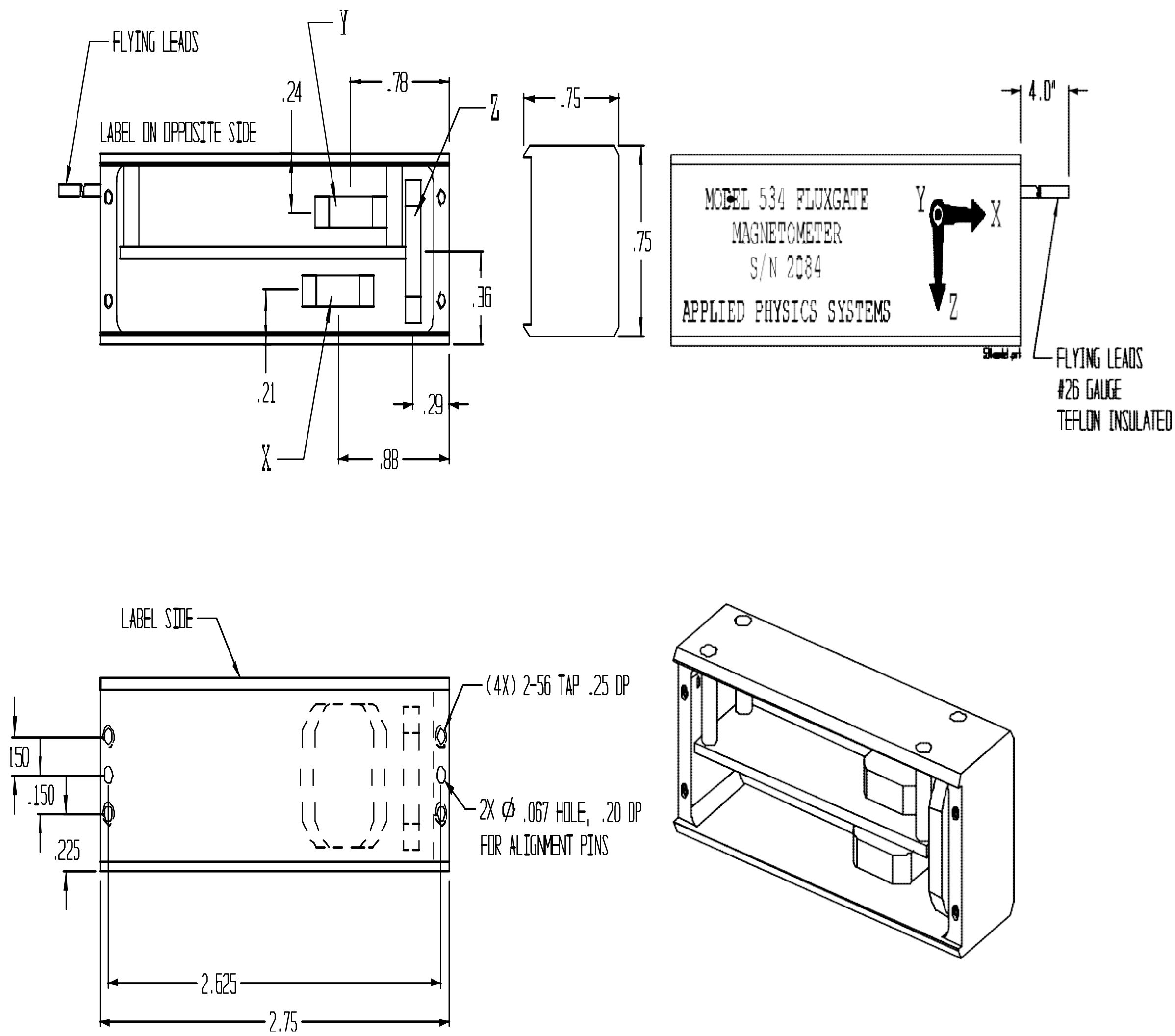


Table 7. 534D System Float Constants

Float Constant	Description	Float Constant	Description
00	Anal Scale	22	Mag Ortho XX
01	Temp Scale	23	Mag Ortho XY
02	Anal Offset	24	Mag Ortho XZ
03	Temp Offset	25	Mag Ortho YX
04	Mag X offset	26	Mag Ortho YY
05	Mag Y offset	27	Mag Ortho YZ
06	Mag Z offset	28	Mag Ortho ZX
07	Not used	29	Mag Ortho ZY
08	Not used	30	Mag OrthoZZ
09	Not used	31	Not used
10	Mag X scale	32	Not used
11	Mag Y scale	33	Not used
12	Mag Z scale	34	Not used
13	Not used	35	Not used
14	Not used	36	Not used
15	Not used	37	Not used
16	Not used	38	Not used
17	Not used	39	Not used
18	Not used	40	Not used
19	Not used	41	Not used
20	Not used	42	Not used
21	Not used		

Table 8. 534D System Byte Constants

Float Constant	Description
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 (for text commands only) 0- Raw / 2- Vectors / 3- Angles. In Angles mode Roll is labeled MX, Pitch is labelled MY, Heading is labeled MZ, Mag. Roll is labeled AX, Total Mag Field is labeled AY, Total Grav. Field is labeled AZ.
03	Months since 1/90 when device was calibrated
04	Version of the Calibration Software used
05	Power on self-test flag. If zero a self-test will be done on power up.
06	Enable extended Error Messages (Default - 0)
07	Power on delay for data stability (default - 10)
08	Auto Start Mode, On power up start accepting commands then: 0x01: Send data once in ASCII mode. 0x10: Send continuously in ASCII mode. 0x11: Send continuously in Binary mode.
09	User power on baud rate lock (if not 0x5A sensor will use 9600 Baud).
10	User power on baud rate. NOTE: Use With Caution. Target Const Target Const Baud #10 Baud #10 -- 75 37 1200 33 150 36 2400 32 300 35 4800 31 600 34 9600 30
35	RTS Delay, inserts a time delay between data byte transmissions.