Applied Physics Systems

MODEL 539 HIGH SPEED DIGITAL

3 AXIS FLUXGATE MAGNETOMETER

OPERATING MANUAL AND TECHNICAL REFERENCE

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I. DESCRIPTION OF THE SYSTEM

The model 539 System is a high-speed digital output 3 axis fluxgate magnetometer. The system can convert and transmit over its serial port (at 38400 baud) all three axes outputs at a rate of 200 samples per second. Slower data rates can also be selected; transmission rate and baud rates are user programmable. The 539 System uses three separate 16-bit sigma delta analog to digital (A to D) converters to achieve the high throughput. The scale factor is set so that a full scale input of 10^{-4} T (1 G) represents 32768 counts on the system A to D converters. The least count represents about 3 nT. Noise of the system is 1 - 2 counts.

The 539 System is ideally suited to situations where high-speed magnetic data must be acquired and analyzed. In the past, such systems have normally used a combination of an analog output fluxgate and an A to D board in a PC. The 539 simplifies and reduces the cost of the magnetic data acquisition system by eliminating the cumbersome A to D board.

The 539 can be used in either a command mode or Autosend mode. In the Command mode, the 539 responds to commands to transmit data issued by an external computer. In the Autosend mode, the 539 starts sending data as soon as power is applied to the unit.

The 539 can be supplied with an optional connection box that allows easy powering and connection to an external computer. A Windows compatible configuration and data acquisition and display program is supplied with the 539. This program enables the user to acquire and graphically display data as well as configure the magnetometer's send rate, baud rate, output format and other features.

II. SYSTEM SPECIFICATIONS

Accuracy	±1.0% FS
Noise level	±3 nT (±0.3 mG)
Range	±100 μT (±1 G)
Scale stability	0.01% FS/°C
Initial offset	<±200 nT (±2 mG)
Offset vs. temp	<5 nT/°C (<0.05 mG)
Orthogonality of axes	better than ±0.5°
Alignment of axes with package	better than ±0.5°
Linearity	±0.1% full scale
Maximum data transfer speed(38,400 baud)	200 3 axis samples/sec
Power	100 ma @ +5 to +9 VDC
A to D	16 bit Sigma Delta
Baud rate (user selectable)	300, 1200, 2400, 4800, 9600, 19200, 38400
Temperature range	-25 to 70°C
Size	1.60”W x 4.08”L x 1.13”H
Weight	5 oz.
Connector	9 pin nonmagnetic “D” (Female)

III. ELECTRICAL AND MECHANICAL INTERFACE

The 539 is powered from a single input voltage that can range between +7.5 and +15 VDC. Current consumption is 100 ma. Two serial interfaces are present; one that uses RS232 levels and one that uses TTL levels. The baud rate is user programmable and can be set at the following values: 300, 1200, 2400, 4800, 9600, 19200, 38400, and 72800. The data words employ 8 bits with one stop bit and no parity.

A female 9 pin D connector is used to provide an electrical interface to the 539 System. The pinout of this connector is as follows:

Pin	Function
1	Not used
2	RS232 out
3	RS232 in
4	Not used
5	Ground
6	TTL serial out
7	TTL serial in
8	Configure
9	+ V in (+7.5 to +15 VDC)

A drawing showing the dimensions and mounting hole design of the 539 is shown below.

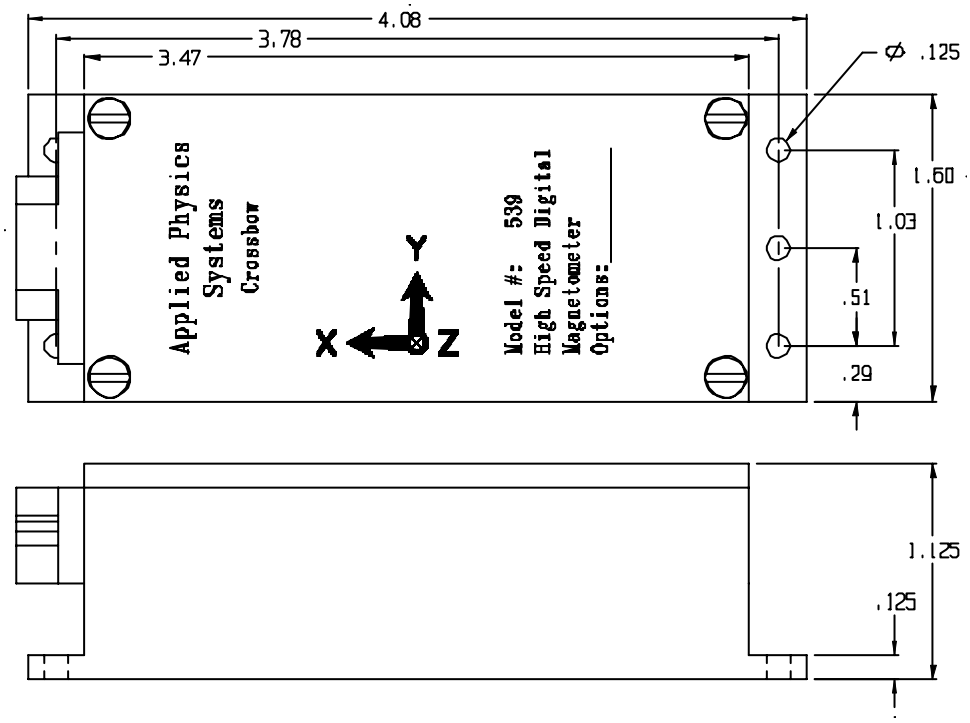

FIG. 1 MODEL 539 HIGH-SPEED DIGITAL 3 AXIS FLUXGATE MAGNETOMETER (DIMENSIONS ARE IN INCHES)

IV. SYSTEM STARTUP AND CHECKOUT

4.1 SETTING UP THE 539

The 539 is supplied with a ribbon connecting cable or an optional Model 539B Breakout Box for connecting the 539 to a computer and power supply.

Using the ribbon connecting cable: Connect the 539 to the mating connector on the ribbon cable. Plug the 9 pin D connector on the opposite end of the ribbon cable into the serial port on a computer. Connect the red and black banana plugs into a power supply set for +6 to + 15 V DC.

Using the 540B Breakout Box: Connect the 539 to the breakout box using the supplied ribbon cable (use 9 pin male on breakout box). Connect a cable from a serial port on a PC to the breakout box (use 9 pin female on connection box). Select the AUTO option on the breakout box switch. This connects pin 1 (Carrier Detect) of the 9 pin serial interface connector to the configure port on the 539. Note that on the 9 pin computer connector, pins 1, 4 and 6 are shorted and pins 7 and 8 are shorted). Connect a power supply (+7.5 to +15 V DC) to the red (positive) and black (negative) banana plugs on the breakout box.

4.2 WINDOWS SOFTWARE AND THE MODEL 539 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.

The Sensor interface program supports the Model 539, 540 and 543 sensors. 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 and the accelerometers. Each sensor's special features are supported.

Install the Sensor software by using the following procedure:

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 and drag it to the desktop. Release mouse button. The software icon should now be on your desktop and the software ready to use.

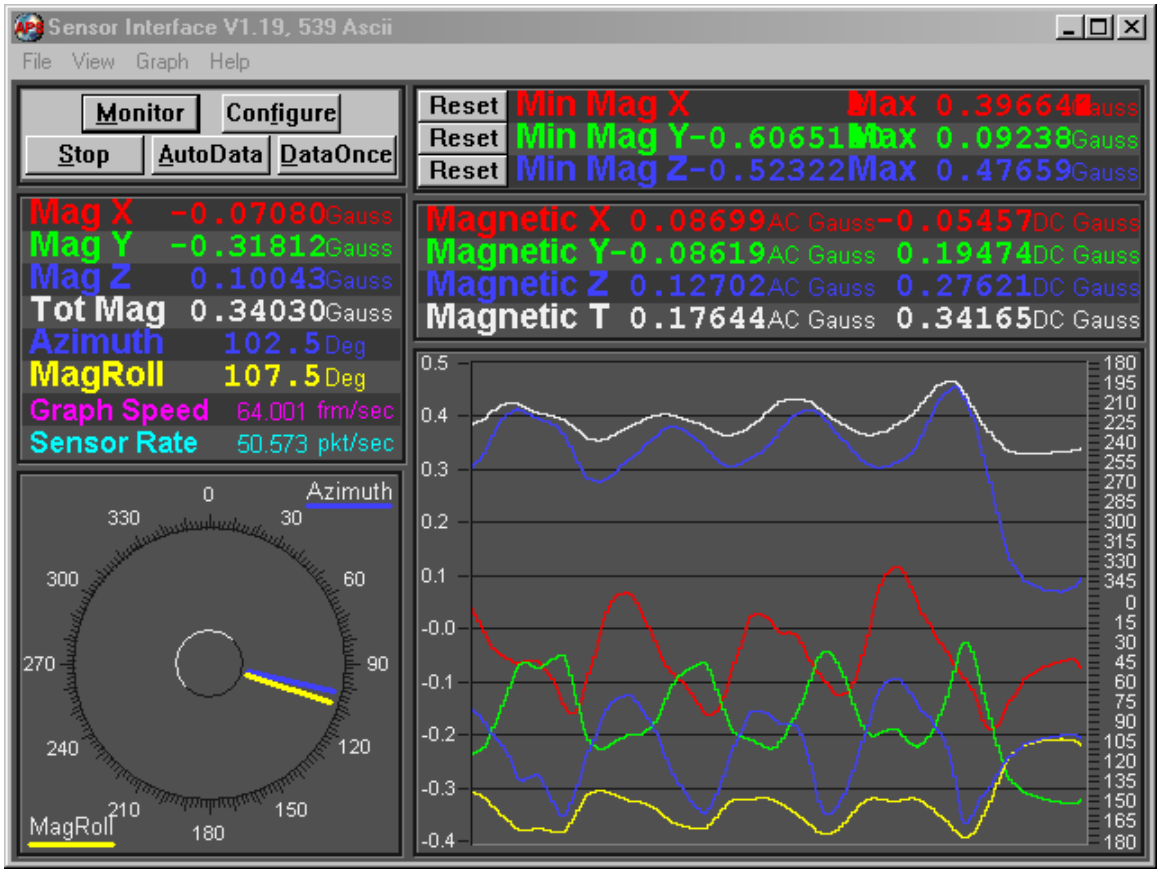

FIG. 2 SENSOR PROGRAM MODEL 539 MAIN DISPLAY

Fig. 2 shows the main display of the Sensor Interface Program. The upper left corner of the display 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 Data button issues the command to the sensor to send data repeatedly. The Data Once button issues the command to send the data one time.

In the Graph Menu, a 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.

In the View Menu, a check mark before Magnetic Min/Max enables the Minimum and Maximum Window. 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.

In the View Menu, a check mark before AC / DC Magnetic, enables the Minimum and Maximum Window.

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:

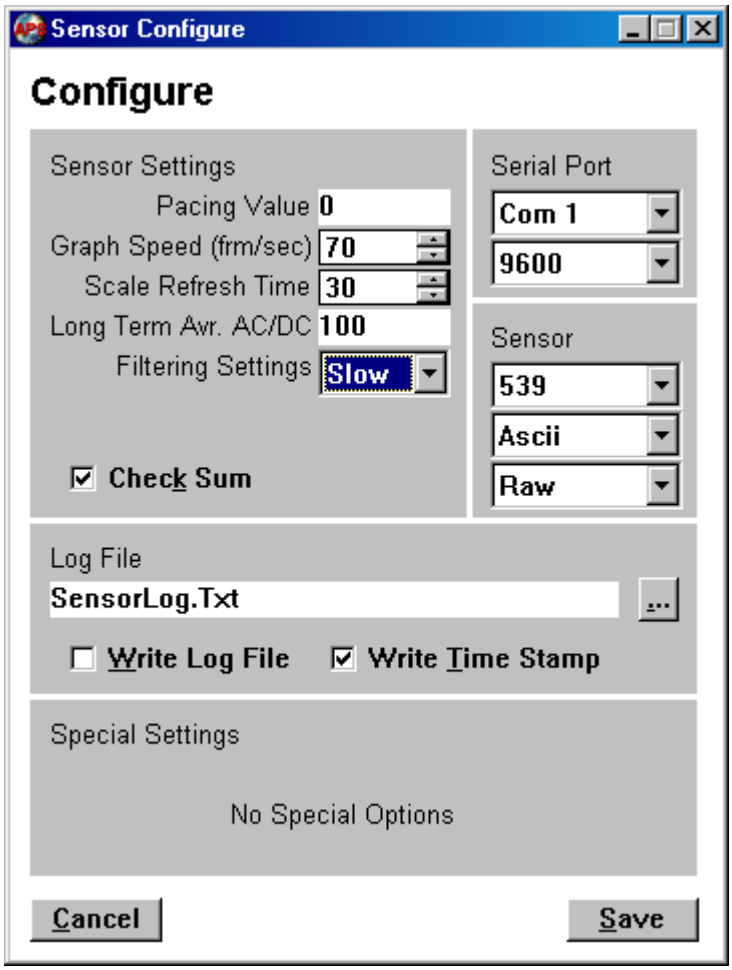

FIG. 3 SENSOR CONFIGURE WINDOW

The output of the sensor can be slowed down by entering a Pacing Value. This can keep the sensor from sending data to a computer faster than the computer can process the data. The output slows down as the Pacing Value increases. A pacing value of 0 (zero) is the fastest. The slowest output is achieved by entering the maximum pacing value of 65536, which equates to output about once every 15 seconds. 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, the Scale Refresh Timer is used. Long Term Average Value AC/DC is the count of the number of samples collected each time the AC/DC values are calculated. The Filtering Settings allows the user to use a Fast or Slow filter when the sensor collects data. A Fast filter setting will allow more samples per second to be collected. The Check Sum box allows the sensor to send a check sum

with each data packet from the sensor. The Write Time Stamp box allows the monitor window to write an ASCII time stamp before each line of monitor data.

The computer Serial Port to be used 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 539, the operator selects the 539 in the top Sensor window. In the next window, the option for ASCII or Binary transfer can be entered. ASCII transfers may easily be viewed from the monitor window. Binary transfers are always faster. The 539 can display either raw or corrected data. The 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 539, 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.

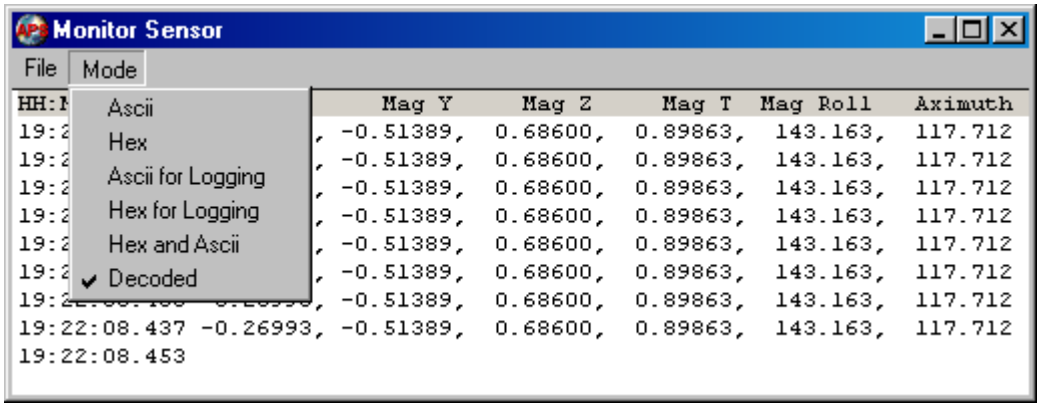

FIG. 4 MONITOR SENSOR WINDOW DISPLAY MODES

The monitor window (see Fig. 4) has a number of display modes. They are ASCII, Hex, ASCII for Logging, Hex for Logging, Hex and ASCII, and Decoded. In ASCII mode (see Fig. 5), the monitor window acts like a simple ASCII terminal. In Hex mode (see Fig. 6), 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.

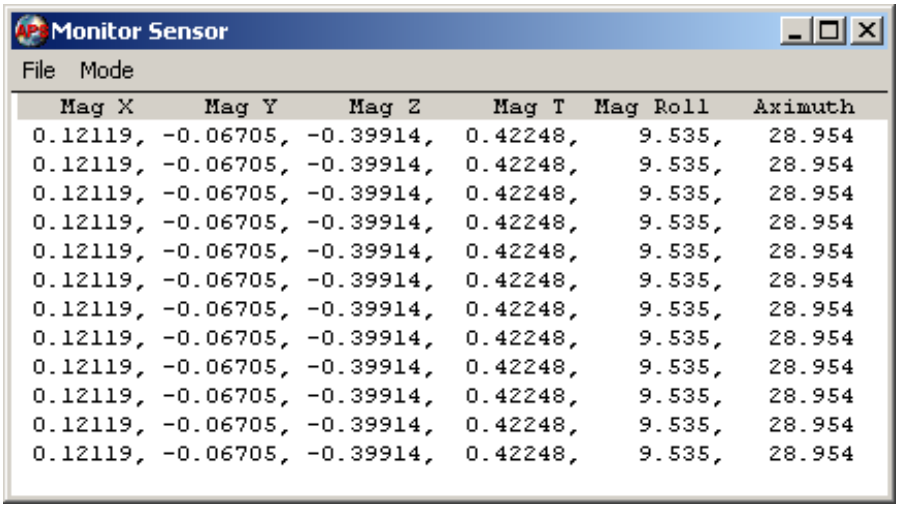

FIG. 5 MONITOR SENSOR WINDOW FOR CORRECTED ASCII MODE

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

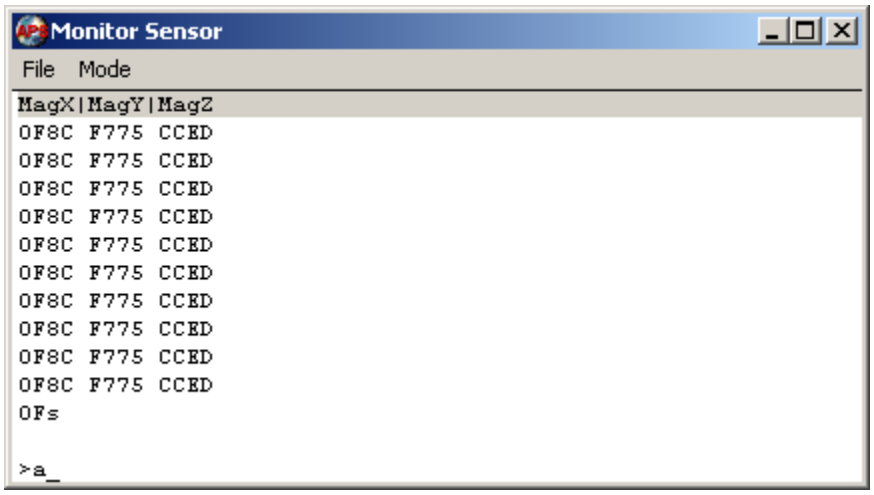

FIG. 6 MONITOR SENSOR WINDOW FOR CORRECTED HEX MODE

4.3 STARTUP USING A TERMINAL EMULATOR PROGRAM

Connect the 539 System to a computer using the ribbon cable or breakout box as described in paragraph 4.1, or according to the I/O pin functions described in Section III; use the RS232 interface when connecting to a PC COM port.

Start up a terminal emulator program on the PC, e.g. Windows Hyperterminal, PC Plus, etc. Configure the terminal emulator program for direct connect to an available COM port and select the baud rate 9600 with one stop bit and no parity. On the electrical interface to the system ground pin 8; this will put the system in Config mode and assure

that the baud rate is 9600 baud. If a connection box is used, select the "Config" option on the connection box switch.

Apply power to the system and check to see that the unit transmits a start up message:

APS 539 V1.12 Config Mode

The system can now be configured for operation in various modes as described in Appendix A by issuing commands over the serial interface.

After configuring the 539 System, unground pin 8. If a connection box is used, select the "Run" option in the connector box switch. In Run mode, the 539 sign on message sent at power on is

APS 539 V1.12.

In Run mode, most of the 539 parameters, e.g. baud rate, sample rate, etc., can be set by the user. The main differences between the system operation in Run and Configure modes are as follows:

1. The 539 can only be calibrated in Config mode (by issuing the l command). The unit is always factory calibrated and recalibration by the user is not normally required.

2. The unit always starts in the (known) baud rate of 9600 baud in Config mode.

3. The unit always starts in command mode (as opposed to Auto send mode) in Config mode.

4. The data output format is selected to be A to D count mode.

The main functions of the Config mode are to assure that the 539 System communicates using a known baud rate (9600) and to enable calibration of the system.

CAUTION: *Always operate the 539 in either Auto mode (when using the Sensor Interface Program) or Run mode (when using a terminal program) unless the baud rate setting of the unit is unknown or calibration of the unit is required. The output of the 539 in the calibrated mode (M=C) is only valid in the run and auto modes.*

4.4 SYSTEM CHECKOUT

After the 539 is operational and communicating with a computer its proper operation can be qualitatively checked out 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 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 0.5G and the Y and Z axes is read near zero. Repeat the measurement with the Y and Z axes in turn pointed into the field and verify that these two axes correctly read the earth's magnetic field magnitude.

If a terminal program is used before checking the system operation, ensure that the following commands are given:

M = T <CR>
M = C <CR>
A <CR>

These commands set the transmission mode to be Autosend calibrated text. After issuing the A command, the terminal output will display the continuous output from the 539. Orient the system in the earth's magnetic field to verify proper operation as discussed above.

V. 539 CONFIGURATION OPTIONS AND DATA OUTPUT FORMATS

The user can configure the 539 System in the following ways:

1. Mode
2. Autosend or command
3. Baud rate
4. Pacing

The mode settings are used to change the format of the data output. The user can select the data output to be raw A/D counts (M=R) or calibrated (in Gauss) (M =C) data. The serial output format can be selected to be text (M=T) or binary (M=B). The user can also choose whether to append a checksum to the transmission (M=E) or omit this (M=N).

Some examples of different data output formats and the commands used to create them follow:

Commands to set up	**Data Formats**
M=T M=R M=N	Raw data in a text hex format without a checksum: X Y Z 1234 5678 9ABC <CR> The X,Y & Z values are encoded as four digit hex values separated from each other with a single space. The last digit of the Z data is followed by a carriage and a line feed.
M=T	Raw data in a text hex format with a checksum (CS):

M=R X Y Z CS
M=E 1234 5678 9ABC 4E <CR>
This data is similar to the last example except for an addition of a space and a two-digit checksum in Hex between the last digit of Z and the carriage return. The checksum is composed of the sum of all of the digits in the X,Y & Z data values.

M=T Corrected data in a text decimal format without a checksum:
M=C X Y Z
M=N 0.23456 0.78900 0.23997 <CR>
The X,Y & Z values are encoded as decimal values in Gauss. Each is separated from the next with a single space. The last digit of the Z data is followed by a carriage return and a line feed.

M=T Corrected data in a text decimal format with a checksum:
M=C X Y Z CS
M=E 0.23456 0.78900 0.23997 4C <CR>
This just like the last example except for an addition of a space and the two digit checksum in Hex between the last digit of Z and the carriage return. The checksum is composed of the sum of all of the digits in the X,Y & Z data values.

M=B Raw Data in a binary format without a checksum:
M=R X Y Z SB
M=N 1234 5678 9ABC 5A <CR>
The X,Y & Z values are each encoded as a two byte value. The X, Y, Z data is followed by a constant synchronization byte (SB) of 5A.

M=B Raw data in a binary format with a checksum:
M=R X Y Z CS SB
M=E 1234 5678 9ABC AE 5A <CR>
The X,Y & Z values are encoded as two byte values followed by a checksum consisting of the lower eight bits of the sum of the bytes comprising the X,Y & Z Data. This is followed by a synchronization byte of 5A.

In binary mode the magnetometer data values are encoded as signed two-byte values. To obtain the magnetic field values in Gauss, divide the two-byte values by 8192. Some examples follow:

MX = 12AF = 0001001010101111
MX = 4783 (Decimal)
MX = 0.5839 Gauss

MX = F2AF
MX = -3409 (Decimal)
MX = -0.4161 Gauss

To determine the mode of a 539, issue the command M?

The Autosend command (A) enables data to be sent continuously upon power on. The output rate of the sent data is set by the pacing variable that can vary from 0000 (full speed) to FFFF (very slow). Pacing values are set by commands of the form:

P = XXXX <CR>

where XXXX is a four-digit number.

The user can set the baud rate of the 539 to the standard values from 300 to 76800 baud. The baud rate command is of the form:

B = XXX <CR>

where XXX is the first three digits of the desired baud rate.

A complete list of the 539 commands can be found in Appendix A.

Appendix A

539 command spec August 31, 2001
For use with terminal emulator program.

I. Main Commands (available in all modes)

All Commands Must be followed by a return.
All changes to the mode value are saved as the power-up mode.

M?	Send the current mode value.
M=R	All Data is Sent as raw A/D Counts in ASCII four digit Hex values or Binary Values depending on the current mode.
M=C	All Data is Sent as Gammas, Formatted as base Ten fixed point Text or Binary Values depending on the current mode.
M=B	Set Data is Formatted as Binary Numbers.
M=T	Set Data is Formatted as Text Numbers.
M=E	Send a checksum with all Data.
M=N	Don't Send a checksum.
A	Start Auto Send Data.
S	Stop Auto Send.
D	Send the current Data Value.
B?	Send the run mode Baud Rate.
B=#####	Set Run Mode Baud Rate 300 -38400 Baud is accepted. In Config Mode the baud rate is always 9600.
P?	Display the current pacing value.
P=####	Set a Pacing value to slow the data rate.
E?	Send All EEROM Data.
E####	Send EEROM Data followed by 4 hex digits address and optional 2 digits representing the number of bytes to send.
W####XX	Write EEROM Data followed by a 4 hex digit address and 2 hex digits of Data.
C	Reset and Calibrate A/D(s).
I	Send ID and many internal values.
*	Reset and Restart Sensor.
?	Display Help.

II. Calibration Commands (only available in Config mode)

L	Unlock Calibration Mode (This command is only available in Config mode)
O	Zero All the Sensors for cal. (available only after executing L)
X	+1/2 Gauss X Field Applied for cal. (available only after executing L)
Y	+1/2 Gauss Y Field Applied for cal. (available only after executing L)
Z	+1/2 Gauss Z Field Applied for cal. (available only after executing L)
Q	-1/2 Gauss Applied Field Delta for cal. (available only after executing L)

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3-AXIS FLUXGATE MAGNETOMETER