



# **GEOMETRICS**

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## **MFAM Development Kit**

### **User Guide**

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## 1.0 INTRODUCTION: WHAT MAGNETOMETERS DO

A Magnetometer measures the Earth's magnetic field, which occurs naturally and varies in the presence of ferrous materials. Magnetometers are used in a variety of applications and can be fitted to airborne, marine, and land-based surveys.

Geometrics is a leader in magnetometer development and is known worldwide for our total field magnetometers. Our magnetic sensors measure the total magnetic field, or total field, without directional information. In other words, they take the scalar measurement of the magnetic field, and produce a value that is the magnetic field intensity, regardless of the direction in which the field propagates. More information is provided in section **3.0 Performance**.

Magnetometers can be used to map and locate man-made objects and naturally occurring iron or other ferrous metals. For example, the earth's crust contains iron in the form of the mineral magnetite. Magnetometer surveys are frequently used to map concentrations of ferrous minerals in the earth's crust. Magnetite is a mineral often associated with kimberlites (diamonds), native gold, copper and other economic deposits.

Man-made ferrous objects, such as those associated with archaeology, civil engineering, unexploded ordinance, etc., alter the earth's magnetic field in a way that is detectable with a magnetometer. The strength of the altered field depends on many factors, including the object's size, iron content, orientation and depth.

### WHAT IS THE MFAM?

MFAM is an acronym for Micro-Fabricated Atomic Magnetometer. Geometrics' highly anticipated MFAM is a miniaturized scalar atomic magnetometer (sensing module) built for the purpose of measuring changes in the earth's magnetic field associated with both natural and man-made phenomena. The MFAM Sensing Module includes two laser pumped cesium sensors connected to the sensor driver electronics via flex cables. These flex cables are circuits and an integral part of the system and cannot be removed or replaced.

The MFAM is a miniature scalar atomic magnetometer that makes the performance of much larger commercially used geophysical magnetometers accessible for UAS platform integration. This is made possible by its small size (1 cubic inch for the sensor), light weight (0.5 lb.) and low power consumption (2.5W per sensor). With a typical sensitivity of 1pT/VHz, the MFAM brings the detection capability typically associated with ground-based surveys to the air. A high sampling rate of 1 kHz (1000 Hz) not only allows for fast sampling at a high spatial resolution and at high speeds, but also enables direct measurement of high frequency magnetic noise caused by rotary aircraft, thus avoiding aliasing artifacts in the data. This fast sampling rate also allows for direct measurement of 60Hz fields. The MFAM sensing module is designed to be easily integrated as a component in versatile multi-sensor systems which are commonly found in UAS. Each module has two sensors, providing flexibility for configuring redundancy or for canceling run-time measurement systematics. See the MFAM Specifications listed in Appendix C: MFAM SENSING MODULE LCS050G SPECIFICATIONS\*.

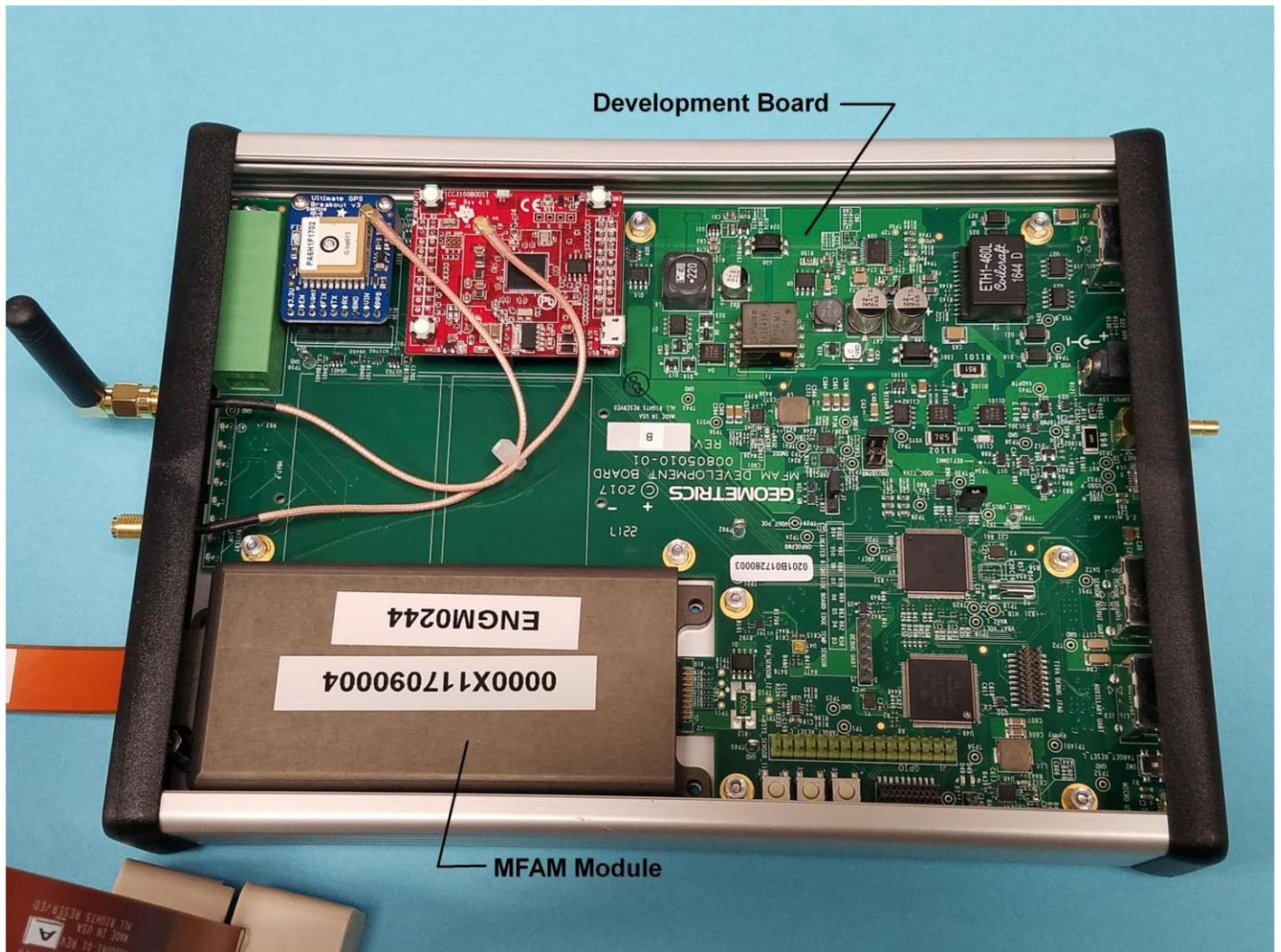
### THE MFAM DEVELOPMENT KIT

Geometrics' MFAM Development Kit is a versatile, easy to use development platform that allows system developers to quickly design custom application interfaces using the MFAM sensing module. Using the Development Kit and appropriate housing allows the MFAM magnetometer system to be used for land, airborne or even marine survey applications

The MFAM Development Kit combines the MFAM Sensing Module with an Interface platform (Development Kit) to allow for simple integration and customization into a variety of platforms or larger surveying systems. It is a technology demonstration platform that allows the MFAM output data stream to be read in, processed, converted to a variety of formats, and output via Ethernet, USB, or Wi-Fi. In addition, there is an onboard GPS module, four user-accessible differential analog inputs, two serial ports, and an on board micro-SD card slot.

## 2.0 DEVELOPMENT BOARD OVERVIEW

The MFAM Development Kit contains the Development board, which is powered by a Texas Instruments TIVA TMC1294NCPDT microcontroller, which is user programmable and has available a large library of example programs that can be copied into your design (using Texas Instruments Code Composer Studio development suite) to quickly get the MFAM system up and running. Your code would be compiled in Code Composer Studio and downloaded via a micro USB cable into the TIVA Microcontroller. The same USB cable is used for debugging. A photo of the Development Board is shown in Figure 1.



**Figure 1: Development Board with MFAM Sensor Module Installed**

The Development board / MFAM module can be powered 3 ways:

- 1) Through the Ethernet cable hooked to a Power over Ethernet (PoE) power injector.
- 2) Through an external 15 volt supply (provided).
- 3) Through the external Power Jack using external batteries. See Appendix G: Recommended Batteries and Battery Charger for recommended non-magnetic batteries.

## Kit Contents

The Development Kit with an MFAM contains the following items:

- 1) MFAM Sensing Module
- 2) Development Board in an aluminum enclosure
- 3) External power supply for running the Development board and MFAM module
- 4) External GPS Antenna and WiFi Antenna
- 5) PoE Power Injector
- 6) Micro USB programming cable
- 7) Two DB9 to RJ45 Serial Adapter Cables
- 8) Example software MagViewMFAM (Provided on a USB Stick) for displaying the MFAM data on a PC running 64-bit Windows 7 connected via Ethernet.

## Removing the Top Cover

The top cover slides out from either end of the Development Kit enclosure. Remove cables, and then remove the 4 screws as shown below (Figure 2) on the back panel display. The panel will fall away and the bezel will slide out. The panel is also held by the two upper screws at the front panel end. These will need to be removed as well. The top cover will now slide out.



Figure 2: Showing 4 Screws/Removing Lid

## Specifications

### Mechanical:

Enclosure Dimensions: 9 x 6 5/8 x 1 3/16 inches

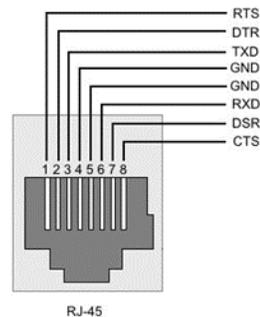
Sensor Cable length (Development box to Sensor): 20.5 inches

### Power:

AC adapter: 9.5 to 16 Volts DC at 1.0A

## Features

- 1) **TIVA TM4C1294NCPDT Microcontroller:** This is a 32 bit ARM Cortex-MF4 based microcontroller running at up to 120 MHz. It has 1024K of flash, with 256K bytes of RAM, and 6 KBytes of EEPROM.
- 2) **USB 2.0 Micro Connector:** USB functionality is provided by the TIVA microcontroller and TIVAWare support libraries. This is located on the back panel.
- 3) **Four User LEDs:** Four user-controlled LEDs are wired to TIVA microcontroller GPIO pins PK0, PK1, PN0, and PN1. These are visible through a cutout on the front panel.
- 4) **Two User Switches:** Two user-read switches are wired to the microcontroller pins PK6 and PJ1.
- 5) **One Microcontroller Reset Switch:** This switch is used to reset the microcontroller and is located on the back panel. It is recessed and will have to be activated with a narrow rod.
- 6) **Wi-Fi Port for TI CC3100 Wi-Fi Booster Pack:** The Development board layout allows a TI CC3100 Wi-Fi Booster pack to be directly plugged in. Using TIVAWare libraries, software can be developed to allow Wi-Fi communication between the Development board and a computer.
- 7) **USB XDS110 Port for Firmware Downloading and Debugging:** This second USB port located on the back panel is used as a debug/firmware download interface between the TI Code Composer Studio development suite and the Development Kit.
- 8) **Two RS-232 Serial Ports with RJ-45 Connectors:** Two general purpose serial ports are available to the user on the back panel. The first serial port is wired to TIVA microcontroller UART4, and supports RTS and CTS handshaking. The second serial port is wired to TIVA microcontroller UART5. This port supports only Tx/D and Rx/D. Both of these ports use +/- 5 volt voltage swings, and support baud rates up to 920 Kbaud. Note that these two ports are wired as Data Terminal Equipment (DTE). Thus, to connect either of these two ports to a computer would require a connection through a null modem.



**Figure 3 Serial Port Pinout**

- 9) **On Board GPS Module:** An Adafruit GPS module is included with the Development Kit. It features 66 channels, -165 dBm sensitivity, and 3 Meter accuracy. An external GPS antenna is included so that signals can be received inside the box even with the aluminum cover in place. The port to plug in the GPS antenna is located on the front panel display.

By default, the GPS powers up to 9600 baud with several GPS sentences being output. The firmware that comes with the Development Kit reconfigures the GPS to output only an RMC sentence at 115200 baud. This RMC string is sent with the output TCP data packet as described in the "Ethernet Data Format" Section 6.0 and Appendix B: Ethernet data transfer Format. The GPS is wired to UART7 on the TIVA microcontroller using 0-3.3 volt logic swings.

The 1PPS pulse from this GPS goes to the MFAM Development Module and disciplines the cycle rate to exactly 1 kiloSamples per second.

- 10) **Micro SD Card Slot for Storing Data Locally:** A micro SD card slot is available on the back panel for the user to read and write data using a SPI interface. It is connected to SPI port 1 of the TIVA microcontroller. Note that this micro SD card holder is mounted on the underside of the Development Kit PCB, so the micro SD card must be inserted upside down.
- 11) **10 MHZ Timing Reference Input Port:** Located on the back panel, this input port takes a 10 MHz reference signal from a GPS disciplined reference oscillator, buffers and squares it up, and sends it to the MFAM module. The purpose of this signal is to lock the MFAM clocking system to this reference signal so that the Larmor frequency can be measured to an absolute standard.
- 12) **Ethernet Port with Power over Ethernet Compatibility:** The TIVA microcontroller contains a fully integrated Ethernet MAC and PHY. In addition, the Ethernet port can power the Development Kit via Power over Ethernet (PoE) using an Ethernet power injector. This port is located on the back panel.
- 13) **Four Differential Analog Input Channels:** There are four differential analog inputs available for use on the front panel display. Channels 0 and 1 are +/- 2.5 volts full scale, while channels 2 and 3 are 0 to +5 volts full scale. In the firmware supplied with the Development Kit, (which sends MFAM/GPS data to the MagViewMFAM program on the computer) all four channels are sampled synchronously with the MFAM data input to the TIVA and are included in the data stream.
- 14) **On board Power/Status LEDs:** Several Status and Power LEDs are arranged along the front edge of the board. They include the four user LEDs, Power status LEDs (which power source is powering the board, and whether the battery is charging or the voltage low). They are listed in the Front and Back Panel Connection and Indicator section below.

## Power Management

Powering up the Development Kit:

- 1) **Via Power over Ethernet (PoE):** If the Ethernet port is connected to an Ethernet Power Injector port, then the Kit will be powered off PoE. In this case, the 'PoE Power' status LED will be lit (the second LED from the left in Figure 4 below).

The Ethernet Power Injector is wired in series between the Local Area Network and the Development board Ethernet port. The injector superimposes the Ethernet data on top of a nominal 48 volts DC which is connected to the Development board. The DC power and AC Ethernet data are then separated on the Development board using a transformer, and then a DC to DC convertor steps the 48 volts DC down to +12 volts to run the MFAM and Development board. On power up, the PoE injector goes through a hardware negotiation process with the Development board before applying the 48 volt power. This negotiation first establishes that the Development board is a PoE capable device, and receives back information on how much power it needs to provide. If the PoE can deliver that much power, then (and only then) will it apply the 48 volt power.

- 2) **Via an External 9.5 to 16 Volt DC Supply (Provided):** If the AC adapter is plugged in, the Dev Kit will be powered from the AC adapter. If Power over Ethernet is also applied, PoE is not used.

**Note:** Transitioning from PoE power to AC Adapter power (or vice versa) is not smooth. The microcontroller will go errant and have to be reset.

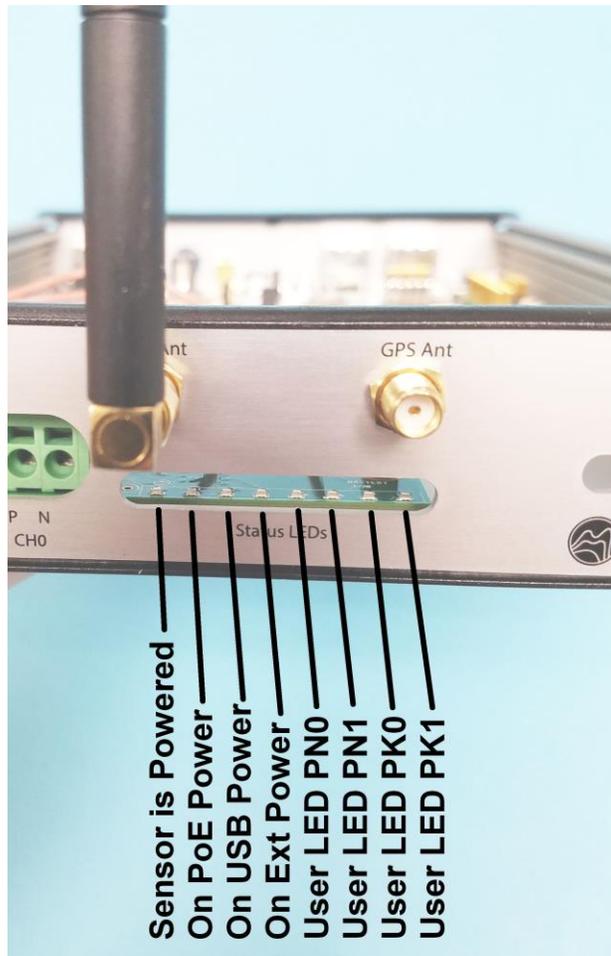


Figure 4: Status LEDs on Front Panel

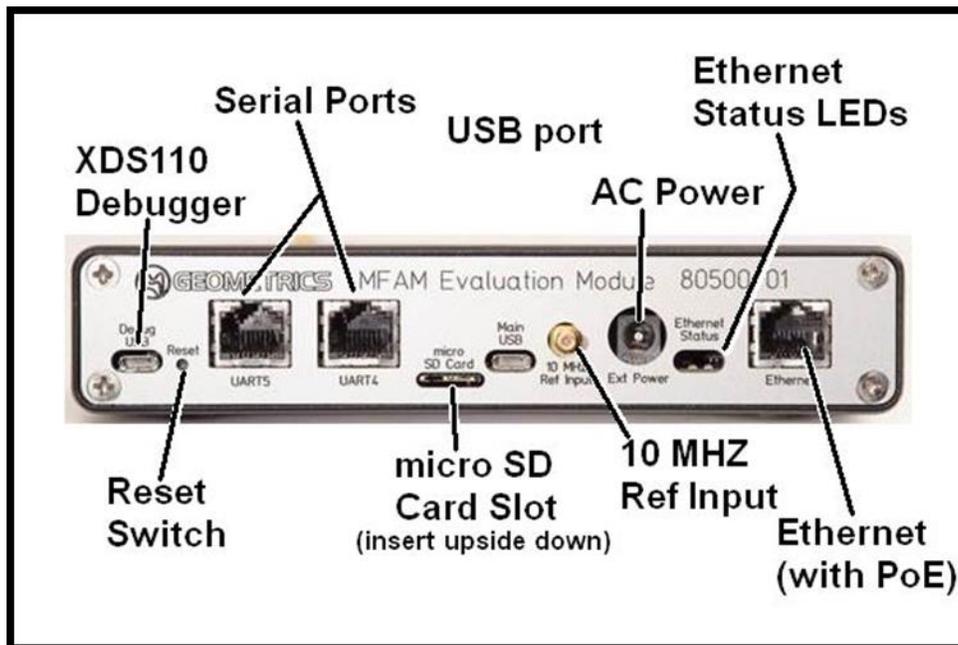


Figure 5 All Back Panel Connections

## Connecting and Disconnecting Analog Inputs

To connect or disconnect wires to the analog inputs, slide a small flat blade screwdriver into the rectangular slot above the round connection hole. This opens a spring loaded wire grabber. Insert the wire end fully, and then remove the screwdriver. Wire is now connected and firmly attached.

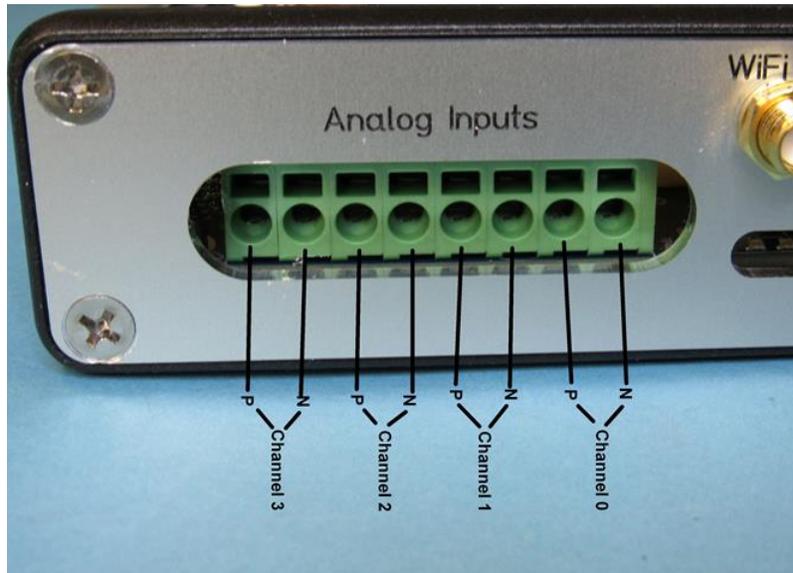


Figure 6 Close-up of the Analog Input Channels

### 3.0 PERFORMANCE

Geometrics' MFAM Development Kit is a magnetometer system which can be used for land, airborne or even marine survey applications with the proper housing. This versatile, easy to use development platform allows system developers to quickly design custom application interfaces using the MFAM magnetometer sensor. The system's microcontroller supports many different communication protocols for easy conversion of the MFAM magnetometer data into a variety of output protocols. Supported communication channels include:

- 10/100 Ethernet MAC and PHY
- USB 2.0
- Two High Speed RS-232 ports
- Wi-Fi through TI CC3100 BoosterPack

The MFAM outputs data continuously via its SPI port to the Development Kit at 1000 samples per second. Hardware exists in the development kit to then send data via RS-232, Ethernet, or WiFi, or to a Micro SD card. Example firmware for outputting data via the Ethernet port is loaded into the Development kit by default. Another example firmware takes the MFAM data and stores it to the micro SD card. The control and data interface to the Development Kit is via WiFi using any browser such as Google Chrome. How to switch between these two example firmware sets can be found in Appendix E: Switch between Ethernet and Wifi Firmware. If your Development Kit does NOT have the Bootloader firmware installed (shipped before November 2018 and not returned for service afterwards), follow the instructions in Appendix F: Loading a Precompiled Binary Executable File Into the Development Kit Using UniFlash to load the Bootloader firmware first.

The MFAM (LCS050G) operates over the earth's magnetic field range of 17,000 to 100,000nT with a noise floor of 2pT/VHz (optimal orientation). Error due to orientation of the MFAM sensor (heading error) does not exceed +/-30nT, or 60nT peak-to-peak, in spin and tumble throughout the active zones shown in Figure 7. Simple destriping may be used to remove the heading error from survey results. Environmental conditions for proper operation are -35 to +50°C (-

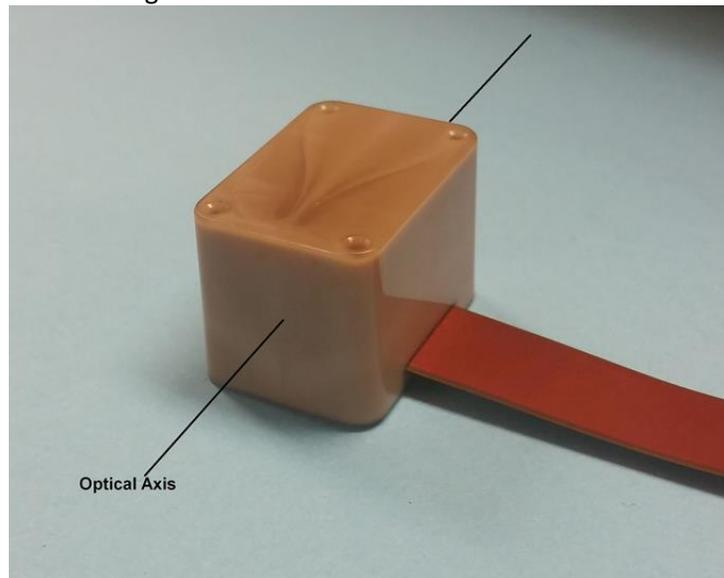
31 to +122° F), humidity to 99 percent (non-condensing), and an altitude range of 0 to 10,000 feet. See full performance specifications in Appendix C: MFAM SENSING MODULE LCS050G SPECIFICATIONS\*. For LCS100H, LCS100S and LCS100X datasheets, please go to Geometrics website.

Compensation and/or noise reduction techniques normally must be used to minimize the magnetic effect of the platform (aircraft, UAV or AUV) and its motion. Navigational and positional errors, radiated electromagnetic noise, and heading errors from the aircraft's induced and remnant magnetic fields are typically the major contributors to noise affecting the survey results.

#### 4.0 INSTALLATION AND OPERATION

The particular installation requirements must be met in order to obtain the best performance from the system. These installation requirements will depend highly on the geographical location of the magnetic survey.

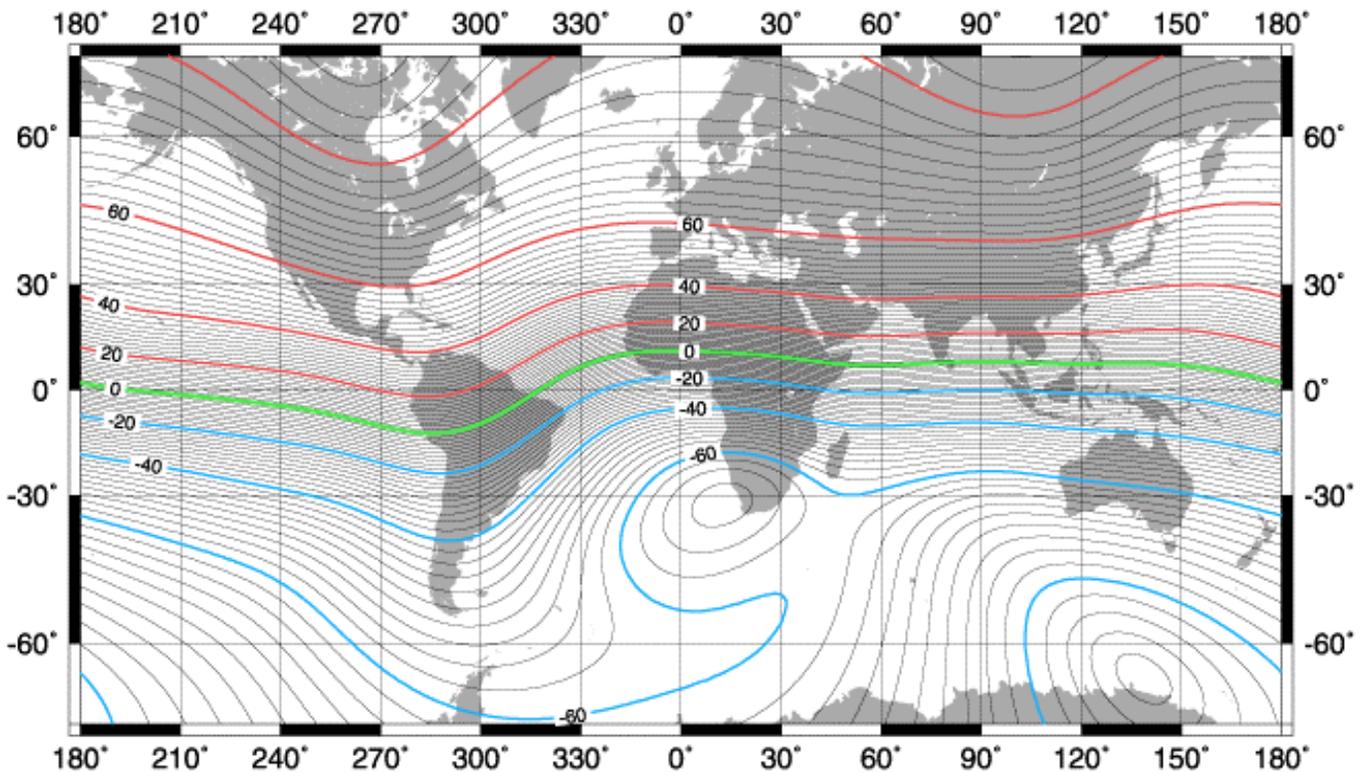
Although the MFAM measures the total field intensity of the earth's magnetic field, magnetic fields in general are vector fields. The total field is the sum of the three components as projected onto the earth's field vector which is roughly vertical at the poles and horizontal at the magnetic equator. At any point, the field is defined by its magnitude and direction. Unless the sensor is very near highly magnetic objects, the local magnetic field will be almost entirely due to the earth's magnetic field. In order for the MFAM to accurately measure the local magnetic field magnitude, it must be properly oriented relative to the local magnetic field direction.



**Figure 7 Optical Axis of the MFAM Sensor**

The MFAM sensor has one polar dead zone. If the sensor's optical axis is lined up within +/- 35 degrees of the earth's magnetic vector, little or no signal is generated. No signal or low signal indicates that the local magnetic field inclination angle (vector) is intersecting the sensor's polar dead zone. Outside of the polar dead zone, the magnitude of the earth's field will be measured pretty much independent of the orientation. The optical axis of the sensor is shown in Figure 7 above.

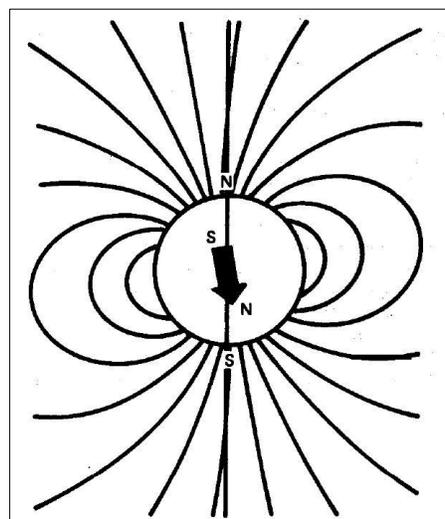
**Note:** Traditional cesium magnetometers have two dead zones – polar and an equatorial dead zone – however, one of the advantages of the MFAM is that it has just the polar dead zone.



**Figure 8 Earth's Magnetic Field Inclination**

The earth's vector varies depending on where you are on the planet. See Figure 8, which shows magnetic field vectors (inclination angles) across the globe.

The earth's magnetic field can be modeled using a large bar magnet in the center of the earth. The resulting field at the surface of the earth can be represented like this:



**Figure 9 Illustrating Magnetic Field Vector/Inclination Angle at the Earth's Surface**

At the magnetic equator, the earth's magnetic vector is horizontal to the earth's surface. At the magnetic poles, the field is vertical. Between these extremes in the northern hemisphere, the earth's magnetic vector is pointing south at an angle somewhere between 0 and 90 degrees from horizontal. In the southern hemisphere, the earth's magnetic vector is pointing north somewhere between 0 and 90 degrees from horizontal.

To get maximum signal, the earth's magnetic vector should be at right angles to the optical axis (shown in Figure 7). Thus, if the sensor and cable is oriented such that the cable is laid flat on a horizontal surface, and the cable is oriented in a north/south direction along the cable length, then the earth's magnetic vector will always intersect the optical axis at right angles regardless of where you are on the planet.

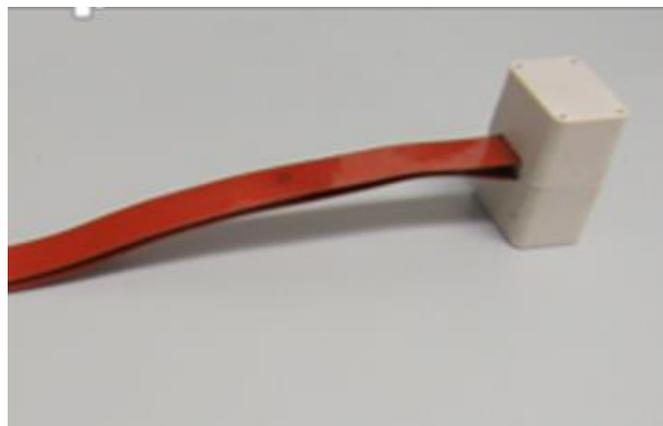
***\*For Optimal Signal, orient the sensor cable lengthwise in a North/South direction, thereby orienting the sensor's Optical Axes at right angles to the local magnetic field vector.\****

If you are only interested in only one magnetometer reading from the MFAM the two sensors can be oriented such that the intrinsic heading error of each sensor is similar and opposite to the other. Thus if the two sensors are positioned right next to each other, oriented correctly to get equal and opposite heading errors, and the two sensor values are averaged to produce a single magnetometer reading, then the result will have significantly less heading error than either sensor reading by itself.

Figure 10 shows the proper orientation of the sensors to get heading error cancellation in both Low Noise mode and Low Heading Error mode<sup>1</sup>. Note how the flex cables travel away from the sensors in opposite directions. In Low Heading Error mode, a simpler sensor orientation can also achieve heading error cancellation, as shown in Figure 11



**Figure 10 Orienting Sensors for Heading Error Cancellation in both Low Noise Mode and Low Heading Error Mode.**



**Figure 11 Orienting Sensors for Heading Error Cancellation in Low Heading Error Mode.**

<sup>1</sup> Low Heading Error mode is NOT available for Regular MFAMs. More information can be found in MFAM Module User Guide.

## 5.0 NOTES ON MAGVIEWMFAM EXAMPLE SOFTWARE

### MagViewMFAM Version 1.3.2:

This example software allows customers to gather Ethernet data from the MFAM Development Kit and view the data in real time. The magnetometer and gradient data are plotted graphically as a function of time. Both the time axis and amplitude axis are adjustable via pull down menus. In addition, the FFT plots of the two magnetometers and gradient are plotted as well in a separate graph on Page 2 of the Control Panel.

Several other windows display the values of additional data fields. These include:

- 1) Development Kit Version Number
- 2) MFAM S/N
- 3) MFAM Firmware Version Number
- 4) Fiducial Count
- 5) Mag and System Status Words
- 6) Compass Data (scaled to nT in all three axis', plus device temperature)
- 7) Accelerometer Data (scaled to G level in three axis', plus device temperature)
- 8) Gyro Data (scaled in degrees rotation per second for all three axes, plus device temperature)
- 9) FPGA Temperature (degrees C)
- 10) Supply Voltage (volts)
- 11) Cumulative Board Run Time (hours)
- 12) GPS Data
- 13) GPS Status
- 14) Analog Channels (volts)

### Minimum System Requirements:

Windows 7 operating system (or higher)

A display with a resolution of 1920 x 1080 (HDMI) or higher

## 6.0 INSTALLING AND RUNNING THE EXAMPLE SOFTWARE

### Installation:

- 1) Install the LabVIEW Runtime Engine (setup.exe and all associated files located on the supplied USB stick)
- 2) Create a folder on your hard drive and name that folder "MagViewMFAM" (Example: "C:\MagViewMFAM\") and copy the file MagViewMFAM\_V1\_3\_2\_Standard.exe into this folder (also located on supplied USB stick)
- 3) Create a shortcut to this file (right click on file, select "Create Shortcut")
- 4) Drag the shortcut to the desktop

### Operation:

- 1) Connect the Development Kit to the computer using the Ethernet cable. If your computer does not have an Ethernet port (or if you need the existing one for other uses) you can use a USB to Ethernet adapter.
- 2) Setup the Computer Ethernet port to a fixed IP address:
  - a. Manually, as outlined in Appendix A: CONNECTING THE DEVELOPMENT KIT VIA ETHERNET.
  - b. Or run the Batch file "SwitchToStaticIP.bat" on the Memory stick containing the MagViewMFAM program. **The batch file must be run in Administrator Mode.** Right on the batch file name and select

“Run as Administrator”. Note: If you have more than one USB port you may need to set up the fixed IP address manually as outlined in Appendix A: CONNECTING THE DEVELOPMENT KIT VIA ETHERNET. There is another batch file which restores the IP address assignment to DHCP. It is called “SwitchToDHCP.bat” and must also be run as Administrator.

- 3) Power up the MFAM (using the provided AC adaptor is the easiest method)
- 4) Double click the Shortcut on the computer desktop

The program will run, and the "Connected to MFAM" status LED should light up green. The MFAM may need several minutes to warm up before it will start outputting valid data. If the program stops due to errors (like the Ethernet cable is disconnected for example) then restart the program by clicking on the Arrow icon in the upper left corner of the screen.

To stop the program click on the “Stop” button next to the “Page 4” tab on the program Control Panel. **Doing this will close the program window.**

## Display Traces:

There are four traces that can be plotted on the display on page 1 of the Control Panel:

- 1) Magnetometer 1
- 2) Magnetometer 2
- 3) The difference between Mag 1 and Mag 2 (Gradient)
- 4) One of the four analog channels (channel 0 through 4)

The time base and the full scale amplitudes for the graphical plots are user selectable via pull down menus on page 1 of the Control Panel. If an analog channel is displayed the full scale value is set to the full range of the analog input (i.e. 0 to 5V for channels 2 and 3, or -2.5V to +2.5V for channels 0 and 1).

The display sample rate is also user selectable via a pull down menu. The data coming out of the MFAM module is fixed at 1 KHz. If a lower sample rate is selected the 1 KHZ data will be averaged over the sample period and then output. For example, if a sample rate of 20 hertz is selected, 50 1 KHz samples from the MFAM will be averaged and sent out every 50 millisecond.

## Screen Modes:

There are a few options for displaying the magnetometer data graphically:

- 1) **Split Screen Mode (default):** In this mode there are two screens (top and bottom) when one screen fills up it clears the other screen then switches to it.
- 2) **Single Screen Mode:** In this mode there is only one large screen. As the magnetometer data fills the graph to the right edge, the graph scrolls to the left. To enter this mode click on the "Split Screen" toggle switch located on Page 1 of the Control Panel. Click on the toggle switch again to switch back to Split Screen mode.
- 3) **Full Screen Mode:** Both Split Screen and Single Screen modes can be expanded to take up the whole display (covering up the Control Panel). Toggle between Full Screen and Normal Screen modes by clicking on the Full Screen Switch on the lower left corner of the Magnetometer Display Graph.
- 4) **FFT Graph:** A FFT (Fast Fourier Transform) graph is displayed for both magnetometers plus the difference (gradient) between them on Page 2 of the Control Panel. It is updated once per second.
- 5) **Overlap Mode:** As the magnetometer plot goes past the top or bottom of the screen it wraps back around to the other screen edge so that when zooming in on the magnetometer data it is always on screen. If the magnetometer readings fall right on the top or bottom edge of the screen the displayed trace is half on the top

edge and half on the bottom edge. To keep this from happening, invoke the “Overlap” mode by clicking on the “Overlap” toggle switch on Page 1 of the Control Panel. The screen divisions are scaled to 120% of full scale, and the top 20% overlaps the bottom 20%. This puts hysteresis in the wrap points.

## Commands:

At the bottom of page 1 of the Control panel is a MFAM Command box. This allows a few commands to be sent to the MFAM console:

- 1) **MFAM Info:** There is an auxiliary data channel in the MFAM output data stream that can have either the MFAM Serial Number or the MFAM Firmware Version Number. This command selects which data value to insert into the auxiliary data field.
- 2) **Configure Compass:** The magnetic compass built into the MFAM has selectable full scale values. By default the full scale value is 0.88 Gauss (the most sensitive), but this command allows the user to raise it to higher (less sensitive) levels. The following full scales values can be selected: [0.88G, 1.3G, 1.9G, 2.5G, 4.0G, 4.7G 5.6G, 8.1G]
- 3) **Hibernate:** When the MFAM is put into hibernate mode all servos stop. When coming out of Hibernate mode it will take a couple minutes before the MFAM produces valid magnetometer data.
- 4) **Soft Reset:** There are two soft reset choices: From Cell Heating, and From Laser Locking. These choose how far back in the startup process to restart from. From Laser Locking is the closest to the end of the startup process.
- 5) **FPGA Reset:** This starts the startup process from the beginning (like at initial power up).
- 6) **Factory Reset:** This deletes the current firmware and goes back to the original factory installed firmware. This should only be used as a last resort – such as recovering from a failed firmware update. Because this command can cause major changes in the firmware it is password protected. If this command is ever needed contact the factory for a password to invoke this command. Passwords expire two days after being issued.

## Printing Graphs:

To make a printed copy of any of the MagViewMFAM Graphs click the “Print” switch on the bottom edge of the desired graph. This will generate a png format picture file in the “C:\MagViewMFAM\” folder. Then it will call the Microsoft Paint in command line mode and instruct it to print the png file to the computers default printer.

Make sure you have setup a default printer before using this function. Also make sure that you have created a C:\MagViewMFAM folder. If desired you can overwrite the path to the png file (the path is displayed next to the “Print” button) if you want it to be stored elsewhere. You can also change the default file name in the same path window.

In the case of “Split Screen” mode, two picture files will be generated: “Picture(top).png” and “Picture(bot).png”. Both will be sent to the default printer

## Writing Data to File:

Page 3 of the Control Panel selects what and how data gets written to disk. There are two methods that can be used to write to disk, and they are quite different in their implementation. There is a binary write box and an ASCII write box. These two write methods operate independently of each other. You can use one or the other, or both at the same time. Just keep in mind the differences in how the data is processed and stored as outlined below:

Binary Format: Binary saves always stores data to disk at the 1 KHz rate straight out of the MFAM module. It is not altered by filter settings, sample rates, or any other setting within the MagViewMFAM program. It is always straight raw 1KHz data from directly from the MFAM module.

To save binary data click on the “Write to Binary File” button on page 3 of the Control Panel. The button will turn green indicating that the data is being stored to disk. The file name is generated automatically based on Date and Time. Alternatively there is another “Write to Binary File” located at the bottom of the magnetometer data graphical display.

Either button does the same thing. To stop writing to disk click one of the “Write to Binary File” buttons again and the and it will turn gray, indicating that writing to disk has stopped. The last file name of the data written to disk is remembered and displayed in the “Last File Name” window on page 3 of the Control Panel.

Writing 1 KHz data can quickly make huge files. If it is desired to have the data files broken up into smaller chunks then click on the “Break Binary Files into Chunks”. The button will turn green indicating that the files will be broken into smaller blocks. A pull down menu allows the file size / time for each block to be chosen. At the transition from closing one file and opening the next no data will be lost.

ASCII Format: To save ASCII data to disk click on the “Write to ASCII File” button on page 3 of the Control Panel. It will turn green and a file will be opened with a name based on the date and time. Or click the button on the bottom of the magnetometer data graphical display. Both buttons do the same thing. Clicking either button again will stop saving the data and close the file. The buttons will turn gray to indicate that writing to disk has stopped.

The data stored to disk is all ASCII characters. The fields are all comma delimited.

Unlike the Binary Saved Files, the ASCII files are saved at the selected sample rate. If the sample rate is set to 10 hertz then it will store 10 samples per second to disk. In addition, if any filters are set then the stored data will be filtered data. What gets stored is the same data that is being shown in the magnetometer display.

You may select what you fields want to save to disk on page 3 of the Control Panel by clicking on the selection buttons in the “File Write Additional Fields” box. These data fields include:

- 1) The Fiducial Count
- 2) System Status (written as a 4 digit hexadecimal number – i.e. ‘A06F’)
- 3) Mag 1 Status (written as a 4 digit hexadecimal number)
- 4) Mag 2 Status (written as a 4 digit hexadecimal number)
- 5) Analog Channel 1 (in volts)
- 6) Analog Channel 2 (in volts)
- 7) Analog Channel 3 (in volts)
- 8) Analog Channel 4 (in volts)
- 9) Gyro Data (3 channels: X, Y and Z in Degrees per Second, plus a fourth channel that specifies the device temperature in degrees C)
- 10) Accelerometer data (3 channels: X, Y and Z in G’s, plus a fourth channel that specifies the device temperature in degrees C)
- 11) Compass Data (3 channels: X, Y and Z in nT, plus a fourth channel that specifies the device temperature in degrees C)
- 12) The Date (MM/DD/YY)
- 13) The Time (HH:MM:SS [UTC time])
- 14) The Time Stamp Status - A single hexadecimal character:
  - a. Bit 0x8: When set indicates the cycle rate is phase locked to 1PPS
  - b. Bit 0x4: When set indicates that the 1PPS pulse is being received
  - c. Bit 0x2: When set indicates that the GPS position fix is valid
  - d. Bit 0x1: When set indicates that the GPS RMC sentence is being received
- 15) GPS Data (GPRMC String)

The GPS string (if selected for saving to disk) will always be the last item saved in the comma delimited sample line. This data comes out once per second. For faster sample rates the GPS String will be recorded with sample where it occurred. All other samples where a GPS string did not arrive will not have GPS data saved.

In the “File Write Additional Fields” box there is a button called “Trim Fields”. When not clicked (button will be gray) all saved fields will have a constant character length – padded with blanks as required to keep the field length constant.

This allows for all the fields to line up in columnar fashion if viewed in a word processor with a fixed font. Thus the fiducial field will always have four characters in every sample, the Compass X, Y, and Z fields will always have 8 characters, etc. The exception to this is the GPS string (always the last field stored in each sample), which by definition has variable length comma delimited fields, and is only recorded to disk when a new GPS output string occurs.

If the “Trim Fields” button is clicked (button will be green) all fields written to disk will have the extra spaces removed to save disk space.

Saved ASCII files can be broken into smaller contiguous files based on time. To do this click on “Break ASCII File Into Chunks” (it will turn green) and Select the length of time for each file from the “ASCII File Time” pull down window.

### **Configuration Save/Retrieve:**

In the C:\MagViewMFAM directory there is a file called “Config.txt”. When the MagViewMFAM program is started this file loads and sets all of the configuration settings in Pages 1 through 4 on the Control Panel to the values that were last saved. If the config.txt is not present, a new config.txt will be generated and set to default values.

Once you have MagViewMFAM configured the way you like click the “Save Configuration” button on page 3 of the Control Panel. Then the next time MagViewMFAM is started up, it will reload all of the configuration settings as they were when the configuration was saved automatically.

If you change the configuration and want to go back to the last saved configuration, click on the “Load Configuration” button.

### **Filters:**

On Page 2 of the Control Panel is a Filter Setup Box. There are three filters that can be set up to filter the magnetometer data:

#### High Pass Filter:

Select from:

- 1) Off
- 2) 0.1 Hertz
- 3) 0.2 Hertz
- 4) 0.5 Hertz
- 5) 1 Hertz
- 6) 2 Hertz
- 7) 5 Hertz
- 8) 10 Hertz
- 9) 20 Hertz
- 10) 50 Hertz

#### Low Pass Filter:

Select from:

- 1) Off
- 2) 1 Hertz
- 3) 2 Hertz
- 4) 5 Hertz
- 5) 10 Hertz
- 6) 20 Hertz

- 7) 50 Hertz
- 8) 100 Hertz
- 9) 200 Hertz
- 10) 500 Hertz

#### Notch Filter:

Select between 50 and 60 hertz, and On or Off. This filter is actually three filters in series. For the 60 hertz notch filter, the three filters notch out 60, 120 and 180 hertz. For the 50 hertz notch filter, the three filters notch out 50, 100, and 150 hertz.

#### **Stacked Magnetometer Data (Control Panel Page 4):**

The Stacked Magnetometer Data (page 4 of the Control Panel) is a specialized setup which was written to measure and record the magnetic field produced by a human heart (called Magneto Cardiography). This has been done before using squid magnetometers in a shielded room, but we wanted to demonstrate the MFAM magnetometer making this measurement in an ordinary office environment.

The magnetic field from a heartbeat is very small – about 50 picoTeslas peak to peak. This is well below the noise level of a typical office environment, so what we did was to record a couple hundred heartbeats, line the data from each heartbeat up, and add them together (synchronously stacking the heartbeat data). Since the heartbeats are coherent they add up proportional to the number of beats. For example adding together the data from 100 heartbeats would make a heartbeat signal 100 times bigger.

Noise, on the other hand, being random will grow proportional to the square root of the number of heart beats. Thus 100 stacks will grow the noise by 10 times (compared to a 100 times growth in heart beat signal. Therefore with a sufficient number of stacks the heartbeat magnetic signature will grow out of the noise floor and become visible.

Setup: To measure the magnetic signature of the heart two MFAM sensors were mounted 1 inch apart and then placed close to the chest wall of the patient being measured. The two sensors were oriented such that one sensor was very close to the heart while the other sensor was 1 inch further out. The idea is to have the sensor close to the heart get a bigger magnetic signature of the heart than the second sensor, but magnetic noise sources much further away (such as power line currents) will produce the same signature in both sensors. Looking at the difference between the two sensors will enhance the heartbeat signature, and partially cancel far away noise sources.

The patient must remove all magnetic material on their person, and must be positioned on a nonmagnetic platform.

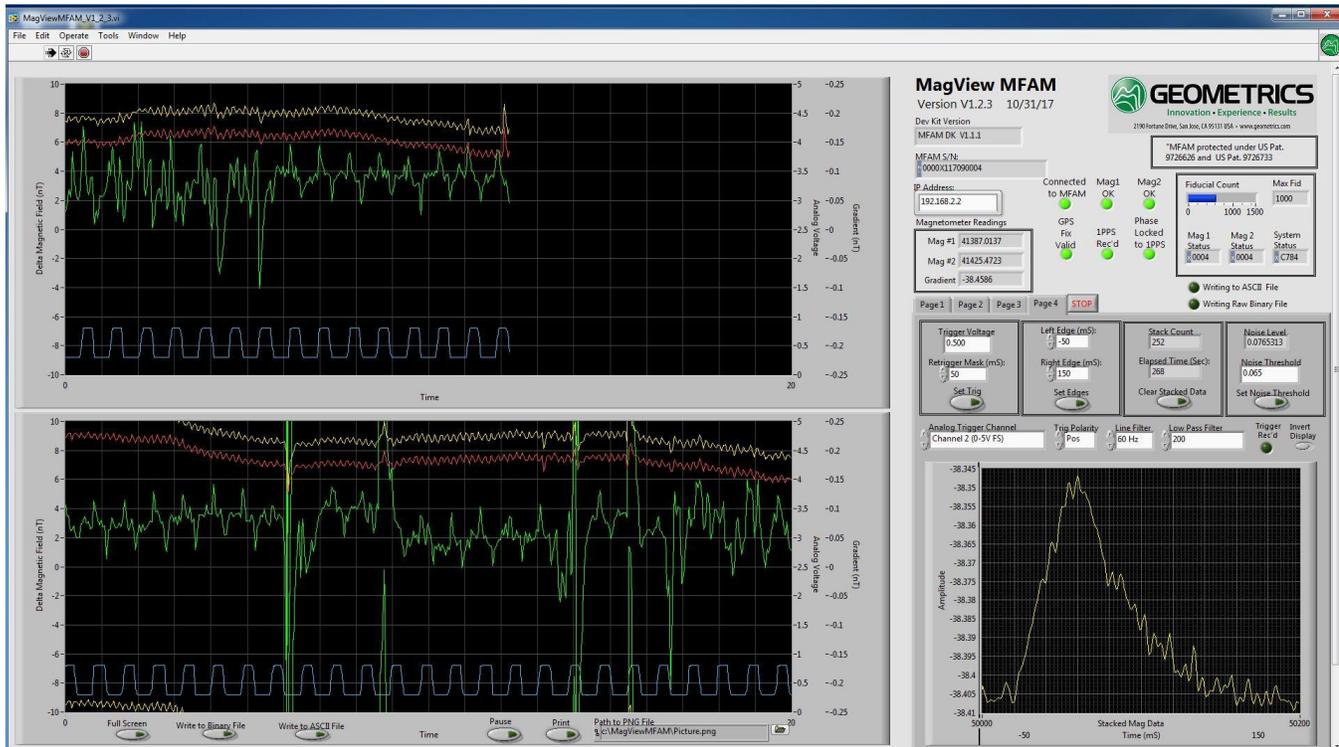
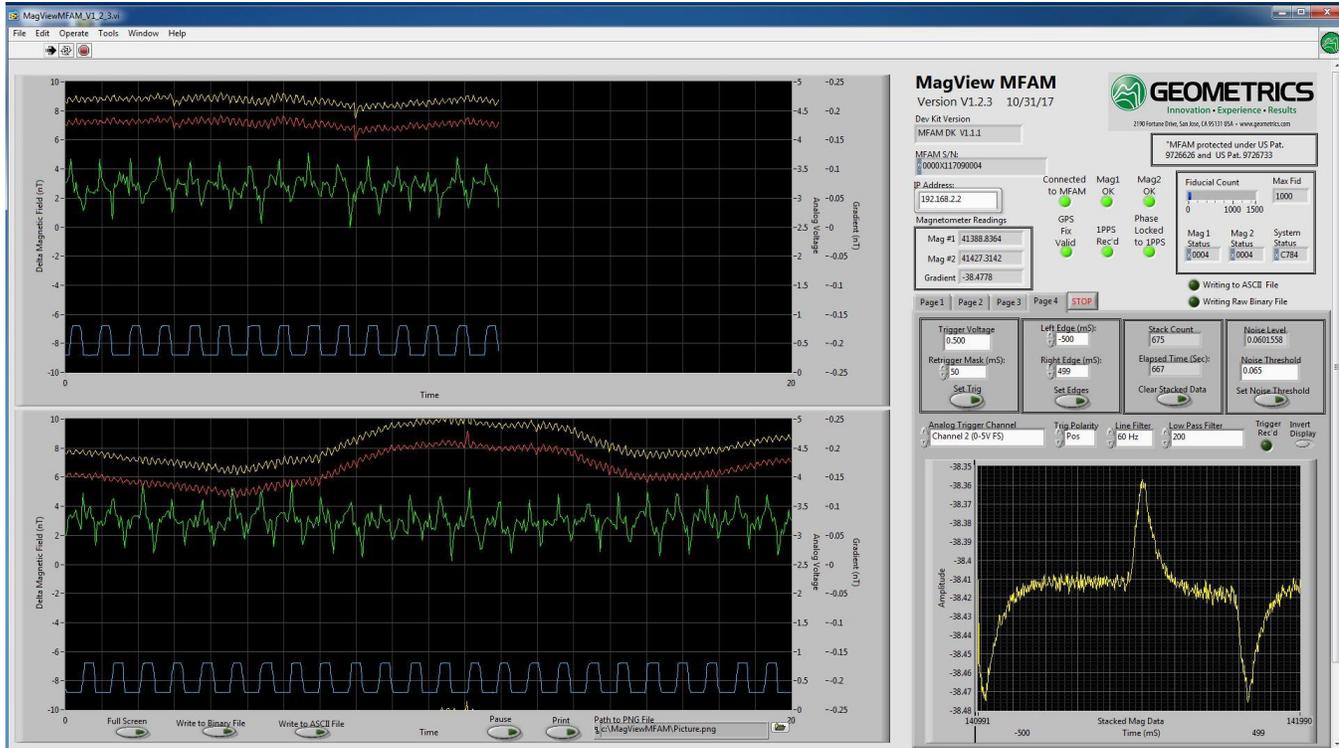
Heartbeat synchronization: To line up all the heartbeats for stacking, a Electro Cardiograph (ECG) machine is hooked up to the patient's left and right shoulder and lower left abdomen. These electrodes pick up electrical voltages from the heart from which the ECG machine makes a trigger signal that identifies the precise timing of the heartbeat.

This trigger signal is sent to an analog input in the MFAM development kit where it is digitized at a 1 KHz rate and combined with the 1 KHZ data from the MFAM module and transmitted in the Ethernet data packets.

Page 4 of the Control Panel: Below are two screen shots showing page 4 of the Control Panel. A simulated heartbeat has been made by differentiating the trigger signal and feeding a small current into a small coil. The amplitude of the magnetic field from the coil is similar in amplitude to a heartbeat when place a couple inches from the MFAM sensor pair.

The first thing to do is set up the trigger level and polarity to start the heartbeat stacking process. Then with each trigger (assuming everything else is OK) the heartbeats will stack, and over time the heartbeat signature will grow in the stacked data window

The first screen shot shows a full 1 second of stacked data (500 mS before the trigger and 500 mS after the trigger), and second one shows the stacked data window zoomed in to one edge of the simulated heartbeat.



The stacked data display is auto scaling, so that it will always take up the full height of the display. Each stack is triggered off of an analog channel which is selected on the left side of page 4 just above the stacked data chart. Usually the analog channel selected as the trigger source will be the same analog channel displayed (on page 1), but they need not be. You can trigger off one and display something different on another channel if you can think of any reason to do this.

There are three trigger parameters to set up:

- 1) The trigger polarity – you can trigger on a rising edge, or a falling edge of an analog signal. I'm triggering on a rising edge in the screen shots.
- 2) The trigger voltage – I've set the trigger voltage to 0.500 volts in this case. If you look at the analog display (blue trace) you will see that 0.5 volts is about midway up the trigger signal.
- 3) The retrigger Mask time – This sets a time in milliseconds that another trigger will not be allowed. This prevents noise from double triggering a stack event. I set it to 50 mS. I chose this value arbitrarily since the trigger wave form is free of noise.

To change the trigger voltage level or retrigger mask, enter the desired values, and press the Set Trig button to load the new values.

Each stack process stacks one second of data – 500 mS before the trigger edge to 499 mS after the trigger edge. This stacking process takes place regardless of what the stack display window is set to. You can zoom into a single heartbeat by setting the left and right edges of the stacked display. In this case the display is zeroed in on one peak of the simulated heartbeat. The left edge is set to -50 mS (50 mS before the trigger pulse), and the right edge is set to +175 mS after the trigger pulse. To change stacked display edges, type in the desired values in the edge variable, then press the Set Edges button. Again, every stack process stacks a full second of data, so you can zoom in and out without affecting the stacked data. You do not need to clear the stacked data and reacquire after zooming.

There is a window that shows the number of stacks taken as well as elapsed time in seconds. To start the process over, press the Clear Stacked Data button. The stack count and elapsed time counters will go to zero and the stacking process will restart.

In the right most window on the top is displayed the standard deviation of all the mag readings in one triggered data window (Noise Value). This updates for every triggered 1 second data window. Underneath that is a Noise Threshold setting. If the triggered data window Noise Value exceeds the Noise Threshold window the data is thrown away and not stacked into the display. In the screen shot that shows a zoomed in stack display the Noise Level shows 0.076. The Noise Threshold is set to 0.065. That triggered data window will not be stacked in the stacked display and will be thrown out.

You can set the Noise Threshold to any level desired by entering a new value and pressing the Set Noise Threshold button.

In the Screen Grab showing the zoomed in stack display you will see some noise spikes in the gradient (green) trace. These noise spikes were caused by a laser printer starting up and printing a couple pages. The laser printer was about 25 feet away. None of the simulated heartbeats during those noise bursts were stacked into the stacked display window.

Notes:

- 1) The noise threshold and data rejection process is only happening in the stacked display window. If you are recording binary to disk all the data is being recorded. The processing software which handles the save data will have to employ a similar noise measurement and rejection process.

- 2) When saving data to disk, use the binary save format. That way you will be saving full unfiltered 1 KHz data which can be post processed.

You can also set up filters for the stacked window display. You can put in a power mains notch at 50 or 60 hertz or not. You can put in a variety of low pass filter as well. Remember though, that these filters are only for the data in the stacked display. They do not affect the data displayed in the mag and gradient windows on the left, nor do they affect data saved in a binary file save. Also, the power mains notch filters are actually a bunch of notches in series. For a notch filter setting of 50 hertz there is actually 5 notches at 50, 100, 150, 200, and 250 hertz to remove 50 hertz and its harmonics. For 60 Hertz the notch frequencies are 60, 120, 180, 240, and 300 hertz.

The magnetometer display plots on the left can be filtered differently than the stacked display. The filters for the magnetometer display window are on page 2 of the Control Panel. These can be set to greatly filter out background noise so that you can easily see the heartbeat signal – even if it distorts the heartbeat signal itself enough that storing this data is not useful. Saving data in the binary format stores raw unfiltered data, so use this method instead of an ASCII format save.

The Trigger Received LED lights briefly every time an analog trigger is detected.

If the heartbeat signature looks upside down, you can flip it around with the Invert Display switch.

Note: When first starting the MagViewMFAM program stacking will not begin for several seconds if a notch filter is selected. This is because the notch filter will have to settle out before the noise level will get down below the Noise threshold setting.

This is still work in process. There are 2 known issues so far:

- 1) When starting up the program occasionally the stacking process doesn't start – even though the noise levels are below the threshold level and trigger are being received. To fix this press the Set Noise Threshold button.
- 2) Very rarely when starting up the program the stacking display window shows erratic edge settings. This can be fixed by pressing the Set Edges button

## **7.0 ETHERNET DATA FORMAT AND SAVED FILE FORMAT**

The Development board firmware gathers data from the MFAM Module and combines this data with GPS data before sending it out the Ethernet port. The data is received by the MagViewMFAM program and displayed on the computer monitor.

Data is sent over the Ethernet in groups containing forty milliseconds of data. Appendix B: ETHERNET DATA TRANSFER FORMAT contains a block diagram of the transmitted data format. Thus, in one second, the TIVA transmits 25 Ethernet packets of 1380 bytes each. Each Ethernet packet contains a header, forty magnetometer samples (taken at a 1 mS sample interval), and an 84 byte place holder for GPS information.

Each data sample is further broken down (referring to Appendix B: ETHERNET DATA TRANSFER FORMAT) into Fiducial Counts, System and Magnetometer Status, Magnetometer Readings, Auxiliary Channels, and ADC channels.

Note that in each Ethernet packet there is a place holder for GPS data. Packets are sent 25 times per second yet the GPS only gets updated once per second. Thus the GPS field is only populated when a new GPS reading arrives. At all other times the field is filled with binary zeroes.

The auxiliary channels contain different data in different samples. The primary purpose of these channels is to multiplex X, Y, Z, and T (temperature) data from the MFAM compass, Gyro, and Accelerometer modules into the data stream.

They can also be used to pass internal diagnostic information as well under special conditions. The identity of which data occupies the Auxiliary fields is specified in bits 13-11 in the Fiducial Field (see Ethernet data chart in Appendix B: Ethernet data transfer Format).

Bits 0-10 in the Fiducial Field contain a count that increments by one every sample. It rolls back to count 1 (not zero) every 2000 samples if there is no 1 PPS pulse received from the GPS. Thus the count would go from 1 to 2000, and then the next fiducial count will be 1. If a 1PPS pulse is received, the count immediately rolls back to one. Thus, when the cycle time is phase locked to the 1PPS pulse, the fiducial counts will count from 1 to 1000, and then start over at count 1.

Bits 15 and 14 in the Fiducial Field (FID in chart) specify whether the magnetometer is outputting valid magnetometer data. When bit 15 is set (M2V), Magnetometer 2 is outputting valid data. When bit 14 is set (M1V), Magnetometer 1 is outputting valid data.

In the System Status Byte, bits 15 and 14 reflect the status of the 1PPS synchronization. If bit 15 is set, the MFAM module is receiving the 1PPS pulse from the external GPS. If bit 14 is set, the internal 1 KHz sample rate is phase locked to the 1PPS input pulse to within +/- 500 nS.

Also in Appendix B: ETHERNET DATA TRANSFER FORMAT, note the byte format of all 16 bit and 32 bit words. The byte transmission format is LSB to MSB for both 16 and 32 bit words.

Each Ethernet packet starts with a 16 byte header containing the Development Kit firmware version number. This is always present in each Ethernet data packet, but if you save the data to disk using the MagViewMFAM program, this header information is stripped out. Thus the saved file format is different than the Ethernet transmission format in this one detail. The rest of the saved file format is the same.

### **Diagnostic Data (On Start Up)**

When the MFAM module is first powered on, the unit sends out a different data set format. In place of the magnetometer and auxiliary channels is internal diagnostic information documenting the start-up process. There are 5 main stages during the startup process. The Diagnostic Stage is documented as Mag Status bits 15-13.

The MagViewMFAM program can be used to save data during startup. In fact, if the start-up process does not complete, providing Geometrics with the saved start-up data can help us diagnose the problem and provide a solution quickly.

## 8.0 WIFI INTERFACE FIRMWARE

Follow the instructions in Appendix E: Switch between Ethernet and Wifi Firmware to load the Wifi firmware.

### Power

Turn power on, either by connecting external power or by plugging in an external battery.

### Restarting

From time to time you may need to restart the system. This may happen in the event of a glitch or anomaly that freezes the system. You have two options:

- Turn the power off and then back on, or
- Reset the system using the reset button on the back panel of the system.

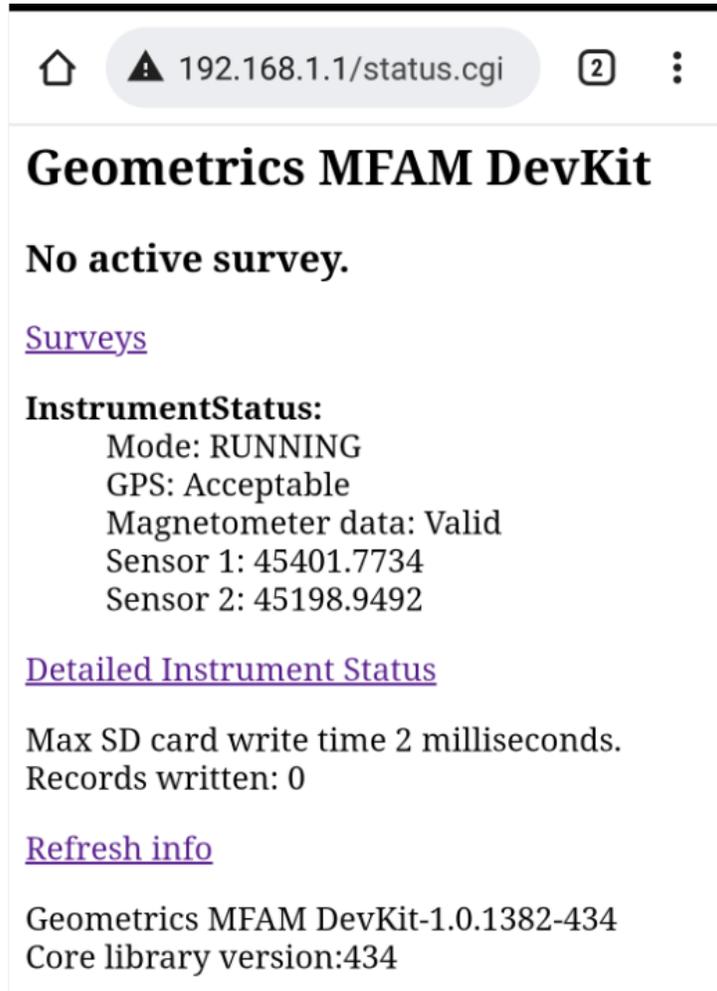
Cycling the power restarts both the system software and the magnetometer physics package, while resetting only restarts the system software and reduces the startup time significantly. Try using the reset button first, and if that does not fix the error then cycle the power.

### Wireless startup

Within a second or two after turning on power, you should see one of the LEDs in the *LED status window* pulse for a few seconds. This indicates that the system has successfully started the wireless interface. If the LED doesn't pulse, or if you're not certain that it did, then try it again. If the wireless system does not start correctly, you won't be able to communicate with the system, and you should contact Geometrics for assistance.

Your MFAM evaluation module creates a wireless access point named “Tezzeret-DK”. It is an unsecured access point: you may connect to it without a password. After you have connected with your device (most computers and portable devices will readily connect to the system), open your browser and connect to this site: 192.168.1.1/status.cgi

This will take you to the Tezzeret home page, which will look something like this:



192.168.1.1/status.cgi

## Geometrics MFAM DevKit

**No active survey.**

[Surveys](#)

**InstrumentStatus:**  
Mode: RUNNING  
GPS: Acceptable  
Magnetometer data: Valid  
Sensor 1: 45401.7734  
Sensor 2: 45198.9492

[Detailed Instrument Status](#)

Max SD card write time 2 milliseconds.  
Records written: 0

[Refresh info](#)

Geometrics MFAM DevKit-1.0.1382-434  
Core library version:434

This page shows some basic information:

1. The system does not have an *active survey*.
2. The system is not logging data.
3. Information about how long the system has been running, and how many records have been written to file.
4. You may click on “Show current status”. This will update any status information on the page.
5. You may go to the *Surveys* page.

To collect data, you must select or create a survey. Click the *Surveys* link on the home page. You should see a page like this:

---

## Geometrics MFAM DevKit

Geometrics MFAM DevKit is not logging.

[Home](#)

No surveys found.

Select "New survey". You should see a page like this:

---

## Geometrics MFAM DevKit

Geometrics MFAM DevKit is not logging.

[Home](#)

ACQU0  [Data sets](#)

Now, choose “Set Active”. This selects a survey to collect data when the system starts logging. The screen will return to the home page, and will show that this survey is active:

## Geometrics MFAM DevKit

Survey: **SRVY0/ACQU0**

[Surveys](#)

**InstrumentStatus:**  
Mode: RUNNING  
GPS: Acceptable  
Magnetometer data: Valid  
Sensor 1: 45408.7460  
Sensor 2: 45205.7617

[Detailed Instrument Status](#)

Max SD card write time 2 milliseconds.  
Records written: 0

[Refresh info](#)

Geometrics MFAM DevKit-1.0.1382-434  
Core library version:434

## Logging

To start logging data, click “Start Logging” on the main status page. The screen will refresh, to look something like this:

## Geometrics MFAM DevKit

Survey: **SRVY0/ACQU0**

**InstrumentStatus:**  
Mode: RUNNING  
GPS: Acceptable  
Magnetometer data: Valid  
Sensor 1: 45470.8789  
Sensor 2: 45267.7343

[Detailed Instrument Status](#)

Max SD card write time 2 milliseconds.  
Records written: 12

[Refresh info](#)

Geometrics MFAM DevKit-1.0.1382-434  
Core library version:434

The screen shows that Tezzeret is logging ASCII data to the micro SD card. Some basic system status information is provided as well:

- 1) GPS information is being received and is valid

- 2) Magnetometer data is valid
- 3) The last magnetometer reading for mag 1 and mag 2 at the time of the screen update are displayed.
- 4) The largest SD card write time is displayed since the beginning of this logging session. This is an indication of how well the SD card is performing.

“Show current status” will update the number of records logged (1000 records per second), and “Stop Logging” will stop data collection.

“Detailed Instrument Status” will show more detailed information about the GPS and magnetometer status. The Detailed Status screen looks like this:

## Geometrics MFAM DevKit

[Home](#)

Survey: **SRVY0/ACQU0**  
Max SD card write time 2 milliseconds.  
Records written: 30618

**InstrumentStatus:**  
Mode: Running  
Time since reset: 747 seconds  
Last GPS record: 0 seconds ago.  
Horizontal dilution of precision: 0.8099  
GPS synch to magnetometer: Locked

**Magnetometer 1 status:**  
Normal  
Data valid: YES  
Current value: 45449.5234

**Magnetometer 2 status:**  
Normal  
Data valid: YES  
Current value: 45215.2500

[Refresh info](#)

---

Geometrics MFAM DevKit-1.0.1382-434

## Retrieving Data

After you have pressed “Stop Logging” (from the “Home” screen), go to the *Surveys* page. Make sure that the survey you want is selected, then select “Data sets” for that survey. You will see a list of file names. You can delete or download each file. To keep file sizes manageable, Tezzeret closes the current log file and opens a new one every few minutes.

After retrieving a data file, you may delete it, or go back to logging. To delete a survey, you must first delete all of the individual data files in the survey.

## Geometrics MFAM DevKit

Geometrics MFAM DevKit is not logging.

[Home](#)

ACQU0  [Data sets](#)

The screen shot above shows only one survey, but there could be many surveys present. Each survey contains one or more files. As mentioned above, the survey data is broken into a group of successive files to keep file sizes to a reasonable level. To access the survey file select “Data Sets”:

## Geometrics MFAM DevKit

Geometrics MFAM DevKit is not logging.

[Home](#) >> [Surveys](#)

Showing all 5 files in acquisition ACQU0.

Name	Time	Size		
1.TXT	2021/12/17, 19:01	3778KB	<input type="button" value="Download"/>	<input type="button" value="Delete"/>
2.TXT	2021/12/17, 19:05	10317KB	<input type="button" value="Download"/>	<input type="button" value="Delete"/>
3.TXT	2021/12/17, 19:06	2715KB	<input type="button" value="Download"/>	<input type="button" value="Delete"/>
4.TXT	2021/12/17, 19:07	1093KB	<input type="button" value="Download"/>	<input type="button" value="Delete"/>
5.TXT	2021/12/17, 19:08	5176KB	<input type="button" value="Download"/>	<input type="button" value="Delete"/>

In this case there are 5 files. There could be many more. If there are more files than will fit into a screen then scroll up and down to get to the desired file.

Pressing “Download” will download the selected file to your browser’s default download directory. “Delete” will delete the file. **Be careful about selecting “Delete” – once deleted a file is gone forever.**

## Data Format

The data files produced by Tezzeret contain all ASCII characters, including the following formatted text lines:

### GPS/Time String

This is a GPS information string in the *GPRMC* format. It includes both time and location information. See the notes for the PPS string below about the timing of this message.

```
$GPRMC,153725.000,A,3724.0163,N,12153.3495,W,0.02,198.03,170117,,D*77
```

In addition to the GPRMC message the GPGGA message is output as well.

Both of these messages are placed in the data file on separate lines as received.

## PPS message

This message records the arrival of a pulse-per-second, or PPS event.

TYPE ID DATE and TIME

↓ ↓ ↓ ↓

PPS: 363596, Tue Jan 17 15:37:26 2017

### Fields:

- Type: Identifies that this is a PPS record.
- ID: Tezzeret global millisecond counter. Tezzeret maintains a global counter, which is incremented with the receipt of each magnetometer data record, or 1000 times per second when the magnetometer is functioning and in normal operational mode. During normal operation, this counter will increment at the same rate as the magnetometer frame number (explained later).

### Timing:

If you examine the PPS and GPS records, you will see that they follow a particular order: the PPS record precedes the GPS record with the same time, by about 400 magnetometer records, or about 400 milliseconds. Internally, this is what happens:

1. The GPS module applies a voltage to one of its output pins once per second, using its (very accurate) internal clock. This signal is nothing more than a simple flick of a switch, and contains no additional information. At the first PPS event we do not know the time.
2. A few hundred milliseconds later, the GPS transmits a standard GPS location message (a GPRMC or other format) that also includes a time-stamp of the preceding PPS. The delay is due to the normal processing time to assemble the data, format it, and transmit over a serial connection that is slower than the PPS output pin.
3. By adding 1 second to the time of the location and time message, we have the time of the next PPS event, and we record that time when we get that next PPS.
4. Note that the GPS location string is about 400 milliseconds out of date by the time it is received; in other words, that GPS string is associated with magnetometer readings about 400 milliseconds earlier in the data stream.

### Magnetometer reading

ID	Fiducial	FrameID	SysStat	Mag1D	Mag1S	Mag2D	Mag2S	Aux0	Aux1	Aux2	Aux3
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
362154,	558,	55854,	49152,	41534.2457,	4,	41552.6053,	4,	2995,	8080,	2349,	10222

### Fields:

- ID: Same as the PPS ID field.
- Fiducial: Fiducial number as explained in further detail below. This is a sub-field of the FrameID field.
- FrameID: As defined below.
- SysStat: As defined below.
- Mag1D: Sensor 1 measurement.
- Mag1S: Sensor 1 status

- Mag2D, Mag2S: Sensor 2 measurement and status.
- Aux0 through Aux3: More on this below...

**Note:** All the fields in the file are recorded as decimal numbers. Some of the fields will make more sense if they are first converted to binary or hexadecimal format. This is especially true of the FrameID and SysStat fields where individual bits of the 16-bit words contain system information.

#### **Fiducial:**

The fiducial count increments with every magnetometer sample (every one millisecond). It is also phase locked to the very accurate 1PPS pulse from the GPS. After the system is phase locked the fiducial number will roll over from 1000 to 1 exactly in sync with the PPS pulse. In other words the 1 KHZ sample time is servo'ed to be in sync with the 1PPS pulse, so there will always be exactly 1000 samples between PPS pulses. In addition, the fiducial number can be used as an accurate time stamp indicating when each magnetometer reading took place down to the microsecond level.

If a PPS signal is not received by the MFAM module then the fiducial number will keep on incrementing past 1000. It will climb up to 2000, then reset back to 1. This can be used to signal that the 1PPS pulse was missing. Since the 1PPS phase locked loop adjusts up or down only when a PPS pulse is received the magnetometer cycle time will free wheel at the current rate. Unless the 1PPS pulses are missing for a long time, when the PPS pulses return the timing will still be very close to the previously phase locked value, and will relock promptly.

**Note:** On power up, before the magnetometers are up and running, the fiducial number will increment all the way up to 2048 before resetting to 1.

The fiducial number is a subset of the FrameID value. In the above magnetometer sample (where the fields are defined) the FrameID value is 39470. Converting this to hexadecimal format the number is 0x9A2E (or 1001 1010 0010 1110 binary). The lower eleven bits of this word contain the fiducial number (10 0010 1110 binary, or 0x22E). Converting the subset back to decimal is 558, which is what is reported in the fiducial field.

#### **System Status word (SysStat):**

The two upper bits of this 16-bit word indicate GPS 1PPS status. In the above magnetometer reading (where the fields were defined) the SysStat field is 49152. Converting this decimal number to hexadecimal makes it 0xC000 (or 1100 0000 0000 0000 binary). Note that the upper two bits are both set. These indicate:

Bit  $2^{15}$  (MSB): 1PPS pulse is being received

Bit  $2^{14}$  (2SB): 1 KHZ sample rate is phase locked to the 1PPS pulse

The other 14 bits are for factory use only.

#### **Frame ID:**

The fiducial number is a subset of the FrameID value. In the above magnetometer sample (where the fields are defined) the FrameID value is 55854. Converting this to hexadecimal format the number is 0xDA2E (or 1101 1010 0010 1110 binary). The lower eleven bits of this word contain the fiducial number (10 0010 1110 binary, or 0x22E). Converting the subset back to decimal is 558, which is what is reported in the fiducial field.

The upper two bits indicate magnetometer status:

Bit 2<sup>15</sup> (MSB): when set indicates Mag 2 data is valid

Bit 2<sup>14</sup> (2SB): When set indicates Mag 1 data is valid

There are three bits left over (2<sup>13</sup> through 2<sup>11</sup>). They are used to define what data is present in the four Aux fields (which will be described in the next section). There are 8 different data types that can be present in the four Aux Fields, all of which are multiplexed into the same output fields. By examining these three bits, the data in the aux fields are specified. In the above magnetometer sample the three bits are 011 binary (or 3 decimal). This specifies that the data in the four aux channels contain internal diagnostic data for factory debugging. There are other Aux Channel data values that contain data from the MFAM's internal Compass, Gyro, and Accelerometer sensors. These will be described in more detail below.

### Aux Channels:

The following table is a snippet of some Dev Kit data that has downloaded and imported into a spreadsheet as comma delimited data in columns A through L. The four aux channels are in columns I through L. To identify what data is present in the multiplexed aux channels for each sample we need get the Aux identifier bits out of the Frame ID word in column C. Column N contains column C converted to hexadecimal format. Column O contains the three identifier bits (2<sup>13</sup> through 2<sup>11</sup>) pulled out and converted to a decimal number.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
402845	515	49667	49156	40542.1	4	40588.68	4	2999	8077	2349	10223		C203	0
402846	516	57860	49156	40538.14	20	40584.63	20	65159	6035	15362	7458		E204	4
402847	517	53765	49156	40535.67	4	40582.13	4	65520	65533	3	7458		D205	2
402848	518	55814	49156	40540.27	20	40586.72	20	9997	9997	11843	11726		DA06	3
402849	519	59911	49156	40550.95	4	40597.2	4	24320	3266	4096	49329		EA07	5
402850	520	61960	49156	40556.25	20	40602.66	20	2623	1743	1751	1		F208	6
402851	521	57865	49156	40554.21	4	40600.61	4	65230	6057	15367	7458		E209	4
402852	522	53770	49156	40554.18	20	40600.65	20	65520	65534	3	7458		D20A	2
402853	523	51723	49156	40557.25	4	40604.2	4	65331	350	486	2816		CA0B	1
402854	524	64012	49156	40560.75	20	40607.68	20	3	4403	16688	0		FA0C	7
402855	525	49677	49156	40563.88	4	40610.74	4	2991	8077	2346	10216		C20D	0
402856	526	57870	49156	40561.88	20	40608.98	20	65220	6057	15364	7458		E20E	4
402857	527	53775	49156	40552.41	4	40599.69	4	65522	65534	2	7458		D20F	2
402858	528	55824	49156	40544.04	20	40590.95	20	9997	9999	11843	11725		DA10	3
402859	529	59921	49156	40543.96	4	40590.76	4	61952	3264	26624	49318		EA11	5

Notice the repeating pattern of the aux identifier bits repeating every ten samples. The pattern goes:

0, 4, 2, 3, 5, 6, 4, 2, 1, 7

and then repeats. The aux identifier number specifies the data in the aux channels as:

0: Internal Diagnostic Data 1

4: Accelerometer Data

2: Gyro Data

3: Internal Diagnostic Data 2

5: Internal Diagnostic Data 3

6: Internal Diagnostic Data 4

4: Accelerometer Data

2: Gyro Data

1: Compass Data

7: Internal Diagnostic Data 5

This pattern of ten samples repeats at a 100 hertz rate (1 kHz divided by 10), but notice that the accelerometer and Gyro data gets sampled twice. Thus the Compass data output rate is 100 hertz, while the Gyro and Accelerometer data output rate is 200 hertz.

The Compass, Gyro and Accelerometer Aux Channels are defined as follows:

Aux 0: X Axis Data

Aux 1: Y axis Data

Aux 2: Z axis Data

Aux 3: Temperature

#### Scaling the Aux Channel Data:

The Aux channels contain many kinds of data. They can be a 16-bit number that is signed or unsigned. They can also be 32-bit numbers (spread across two Aux channels). The Aux data in the saved file is always stored in 16-bit unsigned words (which range from 0 to 65535, or 0x0000 to 0xFFFF in hexadecimal) regardless of whether the original number was signed or unsigned.

The Gyro, Accelerometer, and Compass data are all 16-bit *signed* numbers, so the unsigned Aux channel data must be converted back to signed numbers. The table below compares how signed numbers are represented when displayed as an unsigned number:

<b>Signed:</b>	<b>To Hex:</b>	<b>Unsigned:</b>
-32768	0x8000	32768
...	...	...
-1	0xFFFF	65535
0	0x0000	0
1	0x0001	1
...	...	...
32767	0x7FFF	32767

Note that negative signed numbers are stored in two's complement form. To convert an unsigned representation of a signed 16-bit number use the following algorithm:

Let X = unsigned representation of a signed 16-bit number:

If  $(X > 32767)$  then  $X = (X - 65536)$  else  $X = X$

In the following spread sheet (same data as above) the unsigned aux channel data in columns I through L has been converted back to signed data in columns Q through T. Only data that is identified as Gyro, Accelerometer, or Compass data has been processed:

I	J	K	L	M	N	O	P	Q	R	S	T
2999	8077	2349	10223		C203	0					
65159	6035	15362	7458		E204	4	Accel	-377	6035	15362	7458
65520	65533	3	7458		D205	2	Gyro	-16	-3	3	7458
9997	9997	11843	11726		DA06	3					
24320	3266	4096	49329		EA07	5					
2623	1743	1751	1		F208	6					
65230	6057	15367	7458		E209	4	Accel	-306	6057	15367	7458
65520	65534	3	7458		D20A	2	Gyro	-16	-2	3	7458
65331	350	486	2816		CA0B	1	Compass	-205	350	486	2816
3	4403	16688	0		FA0C	7					
2991	8077	2346	10216		C20D	0					
65220	6057	15364	7458		E20E	4	Accel	-316	6057	15364	7458
65522	65534	2	7458		D20F	2	Gyro	-14	-2	2	7458
9997	9999	11843	11725		DA10	3					
61952	3264	26624	49318		EA11	5					
2622	1743	1751	1		F212	6					
65184	6006	15373	7419		E213	4					
65523	0	3	7419		D214	2					
65331	351	490	2816		CA15	1	Compass	-205	351	490	2816
3	4403	16688	0		FA16	7					

Now that the Aux channels have been converted to signed numbers, but they must also be scaled:

#### Gyro Scaling:

X/Y/Z channels: The gyro is setup for +/- 2000 degrees per second full scale. The 16-bit signed number for the X, Y and Z axis ranges from -32768 to +32767. Divide the output value by 16.384 to convert the raw value into degrees per second.

Temp: The fourth channel contains the temperature of the BMI160 Gyro/Accelerometer chip. The gyro/accelerometer is internally temperature compensated, but they output the temperature in case someone wants to further compensate the output data. Since the Gyro outputs the temperature, the MFAM does as well. To convert the raw temp data into degrees C first divide the raw value by 512. Then add 23.

#### Accelerometer Scaling:

X/Y/Z channels: The Accelerometer is set up for +/- 2G full scale. Divide the 16-bit signed number by 16384 to convert the raw value into G's.

Temp: This is exactly the same data as for the Gyro (since they are both on the same chip). Process this exactly the same as for the Gyro.

### Compass Scaling:

X/Y/Z channels: This is a 3-axis vector magnetometer IST8308 (HMC5983 for RevA MFAMs) which is setup for +/- 2 (0.88) Gauss full scale recommended range. The output is a 12-bit signed number which ranges from -2048 to +2047 (0xF800 to 0x07FF), but that doesn't correspond exactly to +/- 2 (0.88) gauss. To convert the raw value into gauss divide the raw value by 1333.333 (1369.863). Or to convert to nanoTeslas divide the raw value by 0.01333333 (0.01369863).

Temp (only for HMC5983): This device also is internally temperature compensated, and outputs the measured temperature as well. To convert this raw value into degrees C first divide the value by 128, then add 25.

The table below shows the Aux channel data from the above table scaled into:

- 1) Accelerometer: G's and degrees C
- 2) Gyro: Degrees per Second and Degrees C
- 3) Compass: nanoTeslas and degrees C

The signed unscaled aux data is in columns Q through T, and the scaled data is in columns V through Y.

P	Q	R	S	T	U	V	W	X	Y
Accel	-377	6035	15362	7458		-0.02301	0.368347	0.937622	37.6
Gyro	-16	-3	3	7458		-0.00098	-0.00018	0.000183	37.6
Accel	-306	6057	15367	7458		-0.01868	0.36969	0.937927	37.6
Gyro	-16	-2	3	7458		-0.00098	-0.00012	0.000183	37.6
Compass	-205	350	486	2816		-14965	25550	35478	47.0
Accel	-316	6057	15364	7458		-0.01929	0.36969	0.937744	37.6
Gyro	-14	-2	2	7458		-0.00085	-0.00012	0.000122	37.6
Compass	-205	351	490	2816		-14965	25623	35770	47.0

## APPENDIX A: CONNECTING THE DEVELOPMENT KIT VIA ETHERNET

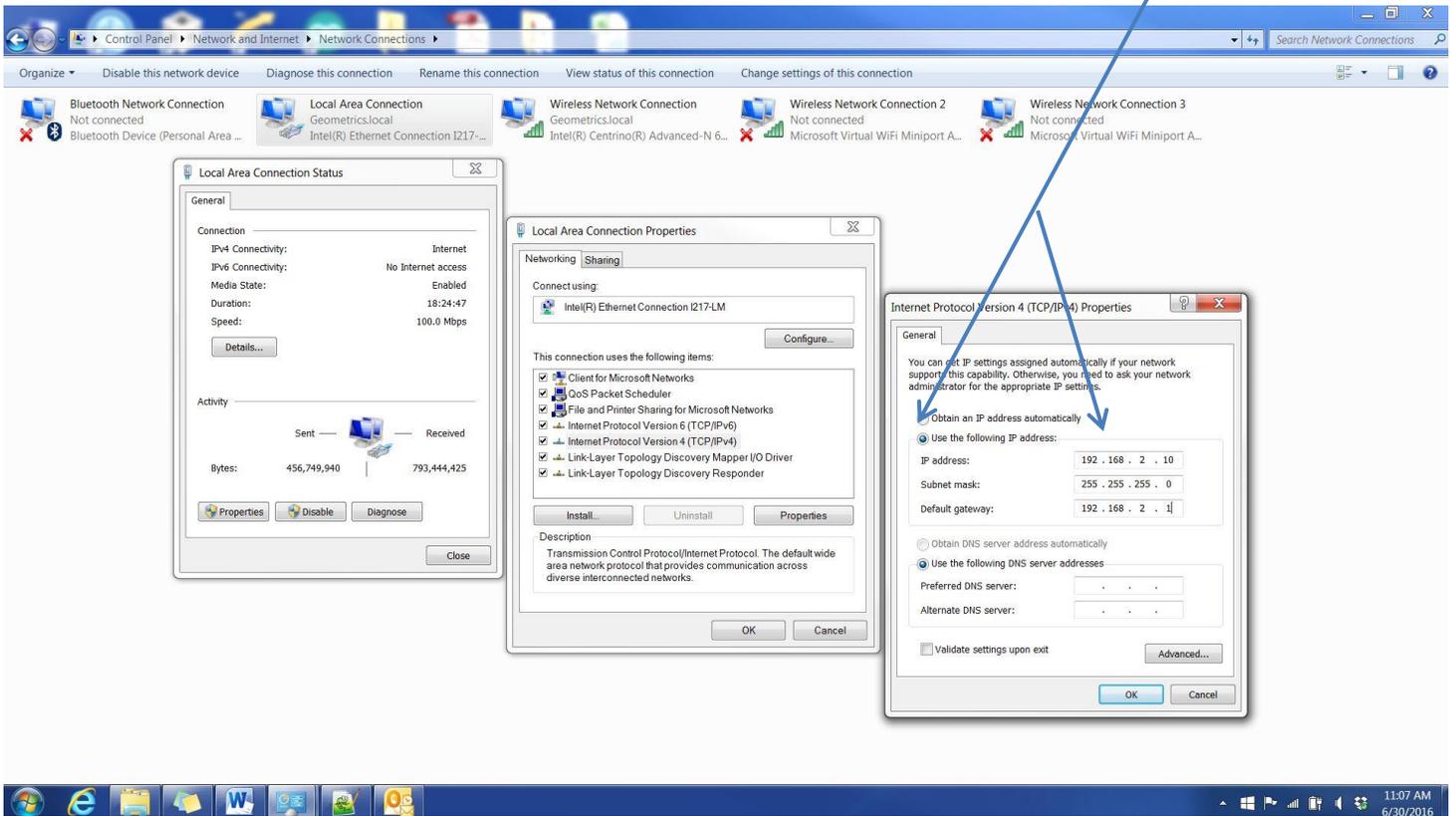
To connect to the Development Kit via Ethernet, you will need to manually set up your IP address to:

IP Address: 192.168.2.10  
Subnet Mask: 255.255.255.0  
Default Gateway: 192.168.2.1

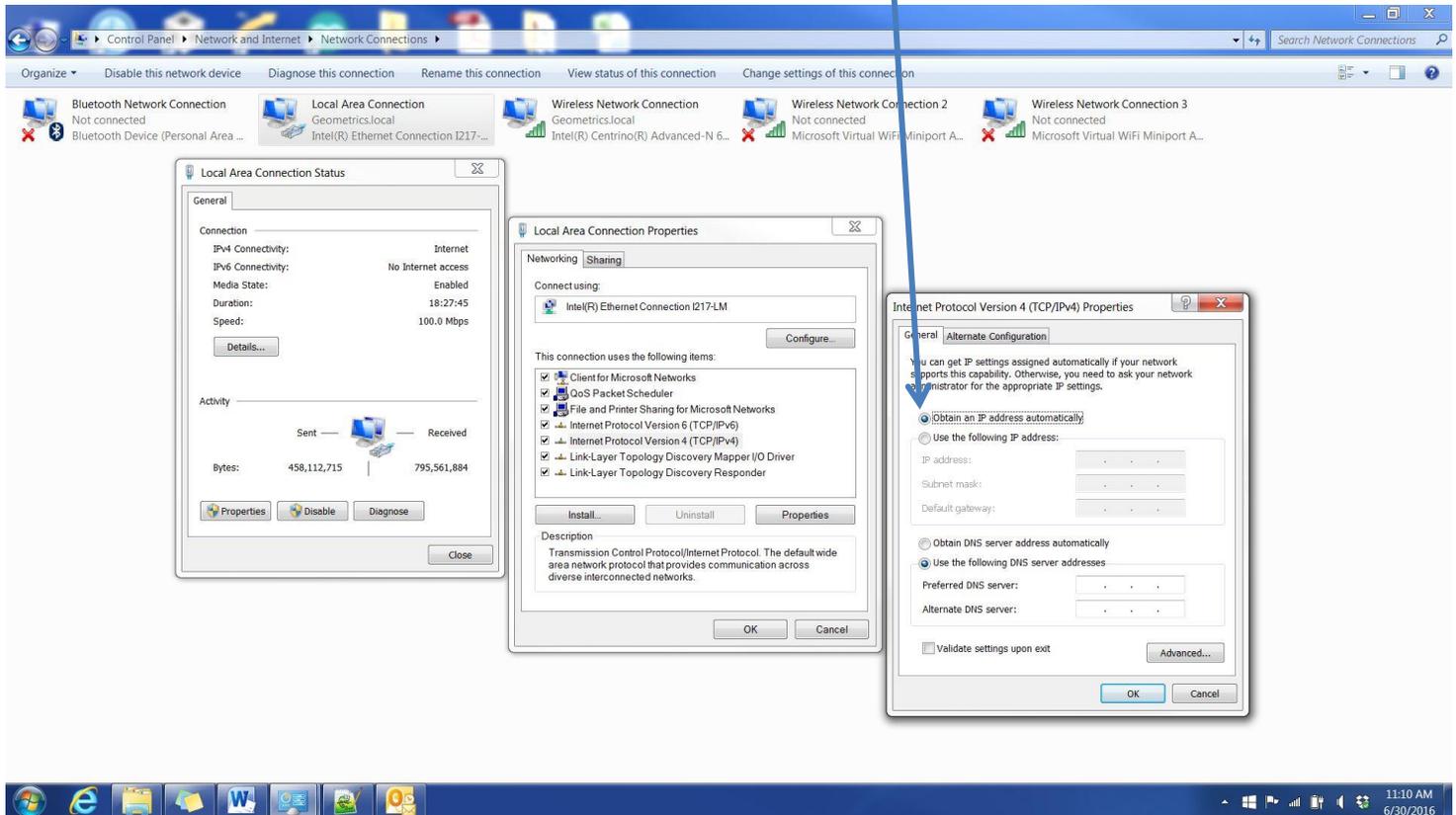
To do this open Windows Explorer, then:

- 1) Double click on "Network" at the bottom of the left pane
- 2) Open "Network and Sharing Center" (on the top title bar)
- 3) Click on Change Adapter Settings (left pane)
- 4) Double Click on "Local Area Connection"
- 5) Click on the "Properties" button
- 6) Double Click on the "Internet Protocol Versions 4 (TCP/IPv4)" line
- 7) Click on "Use the Following IP Address" (and fill out the address info as per the above)

When you open the program use the default IP address.

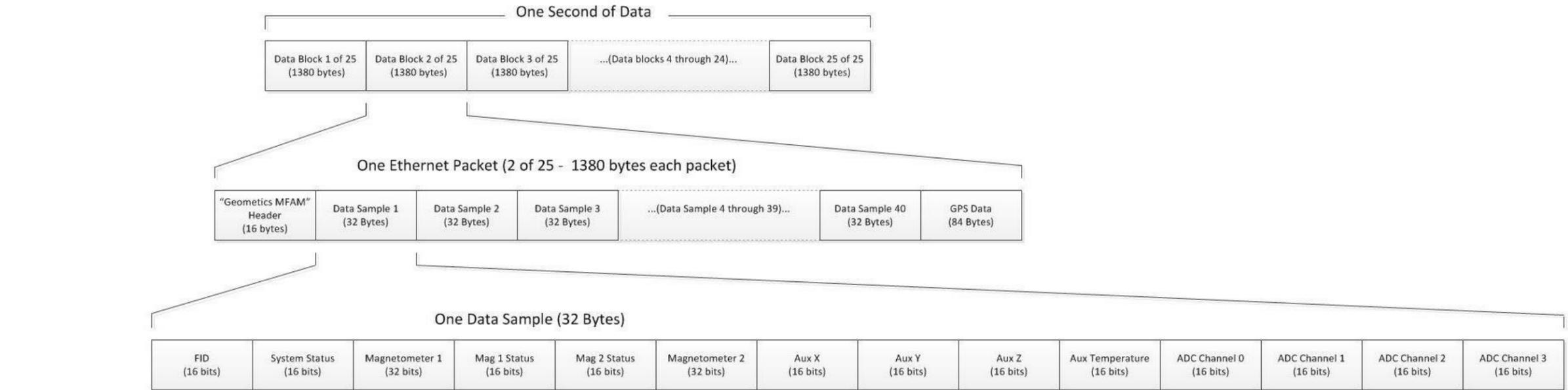


To return to the standard IP address configuration go the same steps to get to the IP address menu as in the above procedure, then click on the “Obtain IP address automatically”.



# Ethernet Data Transfer Format

Revision X3  
03/07/16



**Fid Data Format**

Aux Channel ID Bits (bits 15..11): M2V,M1V,A2,A1,A0	FID Count (bits 10..0)
--	------------------------

A2	A1	A0	
0	0	0	Reserved
0	0	1	Compass
0	1	0	Gyro
0	1	1	Reserved
1	0	0	Accelerometer
1	0	1	Reserved
1	1	0	Reserved
1	1	1	Reserved

M2V: Mag 2 Data is Valid  
M1V: Mag 1 Data is Valid

**System Status Data Format**

PPS Status (bits 15,14)	Diagnostic Stages 1 through 11 (bits 13-10)	Diagnostic Substate (bits 9-7)	Reserved for Future Use (bits 6-1)	Start Up Failed (bit 0)
-------------------------	---	--------------------------------	------------------------------------	-------------------------

Bit 15: 1PPS Pulse is Being Received  
 Bit 14: 1KHz Sample Rate is Locked to 1PPS  
 Bits 13-10: Start Up Diagnostic Stages 1-11 (internal use)  
 Bits 9-7: Start Up Diagnostic Sub Stages (internal use)  
 Bit 6-1: Reserved for Future Use  
 Bit 0: Startup has Failed

**All 32 Bit Words**

Low Byte Address Data LSB	Low Address + 1 Data MSB - 2	Low Address + 2 Data MSB - 1	High Byte Address Data MSB
------------------------------	---------------------------------	---------------------------------	-------------------------------

Example:  
 Byte Sequence: 0x16, 0x85, 0x86, 0x2F  
 Equals: 0x2F868516  
 Equals: 797345046 decimal

To Convert 32 bit value to magnetometer reading:  
 One LSB = 50 femtoTeslas  
 Therefore to convert 32 bit value to nanoTeslas:  
 reading (in nT) = [value] \* 50E-6  
 Using Example above:  
 797345046 \* 50E-6 = 39867.2523 nT

**All 16 bit Words**

Low Byte Address Data LSB	High Byte Address Data MSB
------------------------------	-------------------------------

Example:  
 Byte Sequence: 0x05, 0xC9  
 Equals: 0xC905

**APPENDIX C: MFAM SENSING MODULE LCS050G SPECIFICATIONS\***

Characteristic	Condition	Min	Typ	Max	Units
----------------	-----------	-----	-----	-----	-------

**Power Supply**

Supply Voltage	Vin referenced to GND	9.5	12	16	Volts
Average Current Draw	Vin = 12V, 25 °C ambient temperature		0.4	0.6	A
	Vin = 12V, -35 °C ambient temperature		0.65	0.85	
Average Power Draw	25 °C ambient temperature		5	7	W
	-35 °C ambient temperature		8	10	

**Performance**

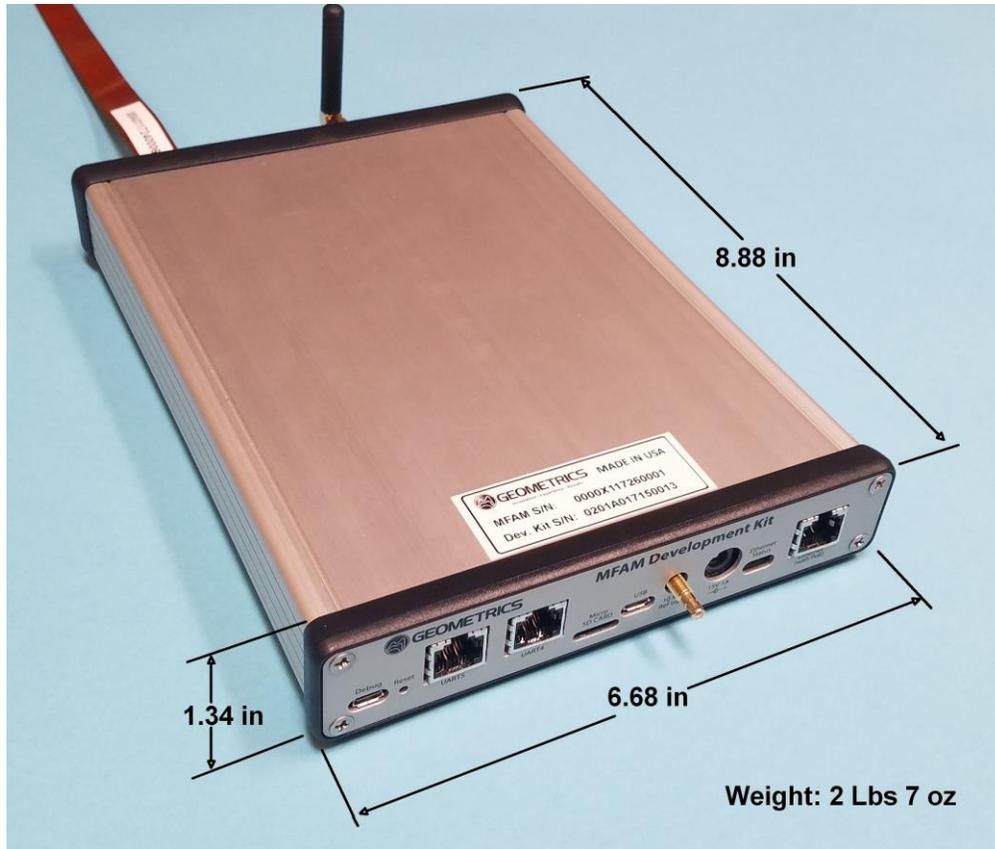
Field Range	Full scale	20		100	μT
Noise Floor	Magnetic field orthogonal to sensor optical axis		2	3	pT/VHz
Dead Zone	Polar only, included angle		60	70	degree
Heading Error	Measured at 50μT field strength		25	40	nTp
Digital Resolution	32-bit magnetometer output		0.05		pT/LSb
Output Data Rate	Continuous measurement		1000		Hz

**Environmental**

Operating Temperature	Ambient	-35		50	°C
Storage Temperature	Ambient	-40		70	°C
Operating Altitude				10000	Feet
Storage Altitude				45000	Feet

\*Preliminary Specifications can change without notice. Specs for other MFAMs can be found on Geometrics website.

**APPENDIX D: DEVELOPMENT KIT WEIGHT AND DIMENSIONS**



Note: Weight value above includes the MFAM module and sensors.

## APPENDIX E: SWITCH BETWEEN ETHERNET AND WIFI FIRMWARE

There are two versions of firmware that can be loaded into the MFAM Development kit:

### TIVA Ethernet EK V1.1.1:

This version of firmware communicates with the MFAM via an Ethernet interface. The file that needs to be loaded into the development kit is "Tiva\_Interface\_EK\_Public.bin" and is located in the "TIVA\_Ethernet\_EK V1.1.1 Firmware" folder.

### Wireless Interface:

This version stores data to a micro SD card in the MFAM Development Kit. The logging / downloading of this data is controlled via a WiFi interface to any internet browser (Smartphone, Tablet, Laptop, etc.). The file that needs to be loaded into the Development Kit is "WiFi Interface Firmware (Edition 1.0.1382-434).bin" and is located in the "WiFi Interface Firmware" folder.

### Loading the Desired Firmware:

If this is a new unit shipped after November 12, 2018 then there is a Bootloader program already stored in the MFAM Development Kit. If the unit is older than November 2018 the bootloader will need to be upgraded. See the "Bootloader Firmware" section below for information on loading the new Bootloader firmware.

Once the Bootloader firmware has been flashed then on each subsequent power up (or Reset) the Bootloader looks for a file on the micro SD card called "btb.bin". If it sees this file it flashes it into the TIVA microprocessor (in the Development Kit) alongside the bootloader and then executes it. Once flashed the new firmware is nonvolatile. The bootloader will also delete the "btb.bin" file after flashing to keep the same code from being loaded again at every power up or reset.

### To switch between firmware programs (new Bootloader Installed):

- 1) The procedure differs slightly for loading the Wireless interface versus the Ethernet Interface firmware. In both procedures the goal is to get the proper "btb.bin" file into the root folder of the micro SD card.
  - a. Ethernet Interface Firmware:
    - i. Find the "Tiva\_Interface\_EK\_Public.bin" file in the "TIVA\_Ethernet\_EK V1.1.1 Firmware" folder and use a computer to copy it to the micro SD card root folder.
    - ii. Rename this file in the root folder to "btb.bin".
    - iii. Eject the micro SD card by right clicking on the SD Card drive letter in Windows explorer and choosing "Eject". You should get a message stating that the card is safe to remove.
    - iv. Remove the card and insert it into the Development Kit micro SD card slot.
  - b. Wireless Interface Firmware:
    - i. Find the "SetupMFAMDevKit-1.0.1382-434.exe" program in the "WiFi Interface Firmware" folder and run it. Point to the micro SD card root folder and click install. This will make the "btb.bin" file on the SD card. You can also copy the "WiFi Interface Firmware (Edition 1.0.1382-434).bin" file to the micro SD card and rename it to "btb.bin".
    - ii. Eject the micro SD card by right clicking on the SD Card drive letter in Windows explorer and choosing "Eject". You should get a message stating that the card is safe to remove.
    - iii. Remove the card and insert it into the Development Kit micro SD card slot.

**Caution:** The micro SD card is inserted upside down. Also note that it is possible to miss the micro SD card holder and have it insert over the top of the holder. If this happens the card will fall inside the development kit, which will have to be opened up to retrieve the SD card.

- 2) Power up the Development Kit. This will flash the new firmware into the Development Kit alongside the Bootloader firmware.
- 3) After flashing (a couple of seconds) the code will start to run. The Bootloader will also erase the “btb.bin” file in order to keep the bootloader from reloading the same firmware over and over with each power up (or reset).

### **Bootloader Firmware:**

In the folder “Bootloader Firmware” (in the “WiFi Interface Firmware” folder) there is a copy of the bootloader code in the file “Bootloader-pactron-sd.1.0.1221-175.out”. If this is a new unit shipped after November 12, 2018 then it is there for archival purposes only. This firmware has been preloaded into the Development Kit and should not ever need to be reloaded.

If you are upgrading to the new Bootloader (units shipped before November 2018 and not returned for service afterwards), follow the instructions in Appendix F: Loading a Precompiled Binary Executable File Into the Development Kit Using UniFlash.

## APPENDIX F: LOADING A PRECOMPILED BINARY EXECUTABLE FILE INTO THE DEVELOPMENT KIT USING UNIFLASH

### You will need:

- Uniflash Software for TI processors installed on your computer
- A binary executable file to load (it will have a file name with a “.out” extension)
- A Uniflash configuration file (it will have a “.ccxml” file name extension)

Uniflash for TI microcontrollers is a free software program available from Texas Instruments. Go to [www.ti.com](http://www.ti.com) and type “Uniflash” in the search window. You’ll have to set up a TI account and agree to terms of use before you can download the installation program.

When choosing the version number use version 3.4.1.

When filling out forms on the TI website keep your answers as generic as possible. You want TI to be able to process and approve your form answers my machine parsing. If your answers are too specialized it will go through a human approval process, which usually results in no response from TI.

### Procedure:

- 1) Copy the Configuration file (\*.ccxml) and the Binary Executable file (\*.out) to your desktop. If you were given more than one \*.ccxml file, then use the proper one:
  - o If loading into a development kit use the file “MFAM\_Tiva\_Flash\_XDS110.ccxml”
- 2) Plug a micro USB cable into the “DEBUG USB” port.
  - o On the Development Kit that will be the USB port on the left side bottom of the rear panel. Power up the Development Kit.
- 3) Find the directory where Uniflash was installed and double click the Uniflash shortcut.
- 4) On the Uniflash startup screen click on the “Open Target Configuration” link.
- 5) Browse to the \*.ccxml file you just copied to your desktop and select it (and click OK). This file tells the Uniflash program which processor and what debugger version you are using.
- 6) On the upper Command bar select the “Program” pulldown menu, select “erase”, and click OK.
- 7) Your Development Kit’s built in XDS110 debugger may need to be updated. If it does then let it update, then erase the flash.
- 8) On the upper command bar select the “Program” pulldown menu again and select “Load Program”.
- 9) Browse to your desktop and select the \*.out file you copied there earlier. Click the “Open” button, then “OK”. The binary executable code will be loaded.
- 10) When the executable code has been loaded, unplug the USB cable and press the Reset button on the rear panel (next to the Debug USB connector).
- 11) The newly loaded code is now running. If the Bootloader code is successfully loaded, the *btb.bin* file in the SD card will disappear after the Development Kit is powered up.

## APPENDIX G: RECOMMENDED BATTERIES AND BATTERY CHARGER

Below are some links to Lithium Polymer batteries that can be used to power the Development Kit and MFAM via the external power connector. Unlike many LiPo batteries that use nickel straps inside (very magnetic), these batteries have a very low magnetic signature.

[https://hobbyking.com/en\\_us/zippy-flightmax-1800mah-3s1p-20c.html](https://hobbyking.com/en_us/zippy-flightmax-1800mah-3s1p-20c.html) (Zippy Flightmax 3S1P 1800 mAH)

[https://hobbyking.com/en\\_us/zippy-compact-1500mah-3s-40c-lipo-pack.html](https://hobbyking.com/en_us/zippy-compact-1500mah-3s-40c-lipo-pack.html) (Zippy Compact 3S1P 1500 mAH)

Here is universal charger that will charge the batteries:

[https://hobbyking.com/en\\_us/accuell-s60-ac-charger-us-plug.html](https://hobbyking.com/en_us/accuell-s60-ac-charger-us-plug.html)

The charger is a balanced charger (charges each of the 3 cells independently). It also has a discharge mode to automatically lower the battery charge state to 30% (required by law before shipment).

1800 mAH is enough battery to run the Development Kit and MFAM for about 2 hours.

Note: Lithium batteries can store a lot of energy and can be dangerous if mishandled. In addition there are several shipping restrictions which need to be followed when sending batteries from one location to another. These restrictions include box labeling requirements, quantity limitations, battery charge state, and many others. It is the responsibility of the end user to comply with all federal and state regulations regarding the use, charging, storage and transport of Lithium batteries.

**VERSION INFORMATION**

<i>Revision</i>	<i>Date</i>	<i>Comments</i>
X0.1	Jan 30, 2016	First Draft (LE)
X0.1b	Jan 31, 2016	Minor updates, corrections and formatting changes (RM)
X1.0	Feb 01, 2016	Released as preliminary documentation
X1.0.2	Feb 11, 2016	Added pinout definition table
X1.0.3	Feb 16, 2016	Added RS-232 Description, pinout and Picture, PoE description, redrew XYZ axis of Accel/Gyro
X1.0.4	Mar 9, 2016	EthConsole renamed to MFAMConsole, document format change that added two more analog inputs, document how to hook up analog wires
X1.0.5	Mar 16, 2016	Added Appendix G: Dead Zone description
X1.0.6	July 1, 2016	Added Appendix H: Weight and Dimensions of Eval Unit Also fixed error in the manual setup of static IP and return to DHCP Added default setting for Gyro, compass and Accelerometer in Appendix F Added description of Fiducial rollover with and without 1PPS being received
X1.0.7	Aug 02, 2016	Changed all references to Eval Kit to Development Kit. Changed all pictures of front and rear panels to match new panels. Changed RS232 connector description. Fixed Analog input and Status LED descriptions to match new Dev Kit Board layout.
X1.0.8	Sept 1, 2016	Added appendices I and J: Configuring CCS for XDS110 and using UniFlash to load binary code into the Development Kit TIVA processor.
X1.0.9	Oct 17, 2016	Added Appendix K: Upgrading the MFAM Module Firmware
X1.0.10	Dec 15, 2016	Fixed error in Samtec mating connector part # in Appendix D
X1.0.11	Mar 19, 2017	Updated formatting and added ITAR footers.
X1.0.12	Aug 24, 2017	Added Table of Contents and Figures (NJ)
	Jan 15, 2018	Added MagViewMFAM and removed MFAM Console information (NJ)
X1.0.13	Feb 06, 2018	Added Control Panel Page 4 Description, removed all references to internal batteries, updated the file writing section, fixed some errors in description (LE)
B	Sep 10, 2018	Updated Uniflash Instructions appendix J
B1,B2	Jan 07, 2022	Combined the Ethernet and Wifi user guides. Deleted obsolete Appendices and corrected minor mistakes in the text.
B3	Mar 16, 2022	Corrected minor mistakes in the text.

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