MAN-3DMGUser100
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3DM-G
User Manual

Firmware version 1.3.00

Gyro Enhanced Orientation Sensor

310 Hurricane Lane
Williston, VT 05495
USA
Phone: 802-862-6629
Fax: 802-863-4093
Email: info@microstrain.com
www.microstrain.com

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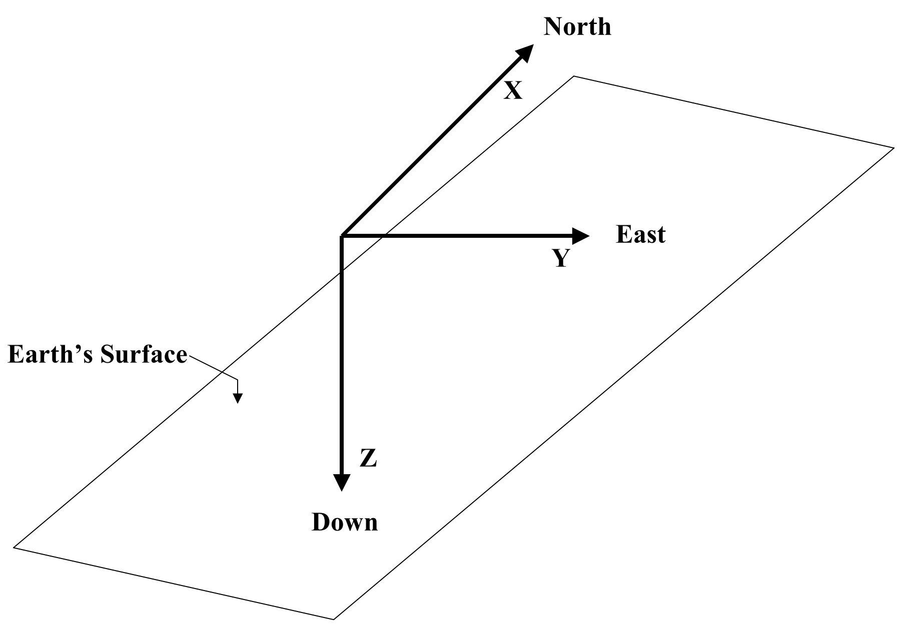
The MicroStrain 3DM-G

Welcome

This manual is intended to provide information to both users and developers of MicroStrain's 3DM-G Gyro Enhanced Orientation Sensor. Thank you for choosing MicroStrain!

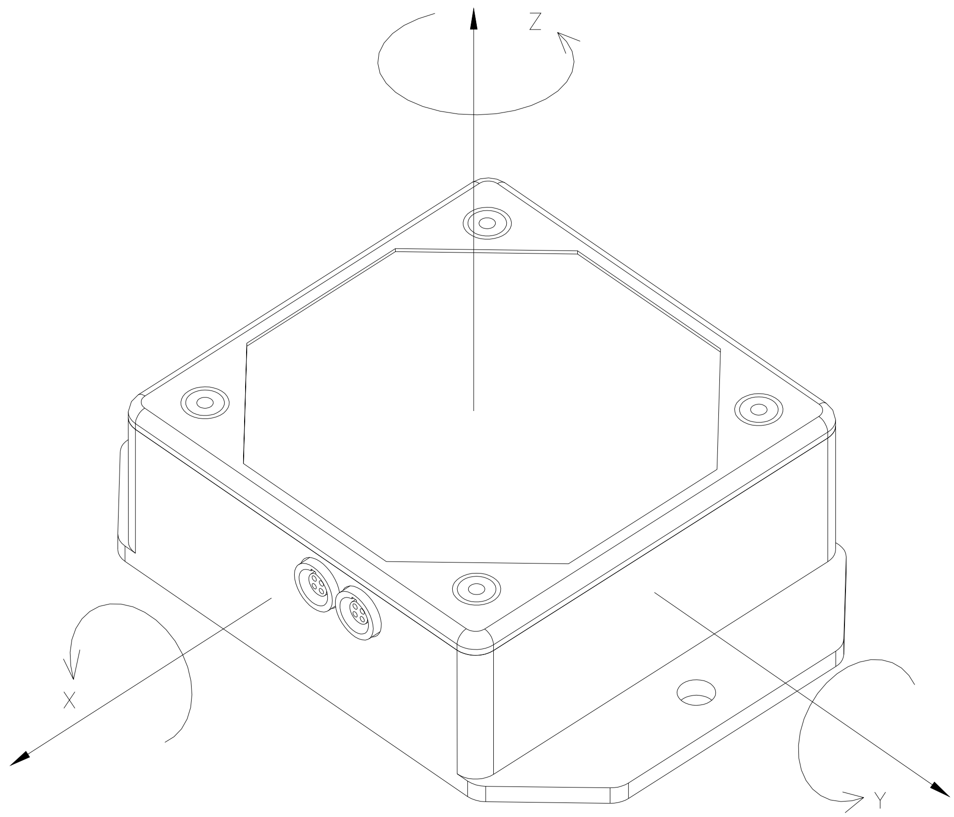
Overview

The MicroStrain 3DM-G is a self-contained sensor system that measures the 3 degrees of its orientation in space with respect to Earth. When we say Earth, we are referring to the coordinate system established by the cardinal axes of our planet Earth itself. We define a coordinate system that is 'fixed' to the Earth with the Z-axis pointing down through the center of the Earth, the X-axis pointing North and the Y-axis pointing East. By 'fixed' we mean that this coordinate system is stationary and provides us with a reference to measure against.



Earth's Coordinate System

Likewise we define a local coordinate system that is fixed to the 3DM-G with the X-axis pointing through the connector, the Y-axis pointing through the mounting holes and the Z-axis pointing perpendicular through the faceplate. The faceplate is imprinted with the 3DM-G's coordinate system for reference during use.



3DM-G Local Coordinate System

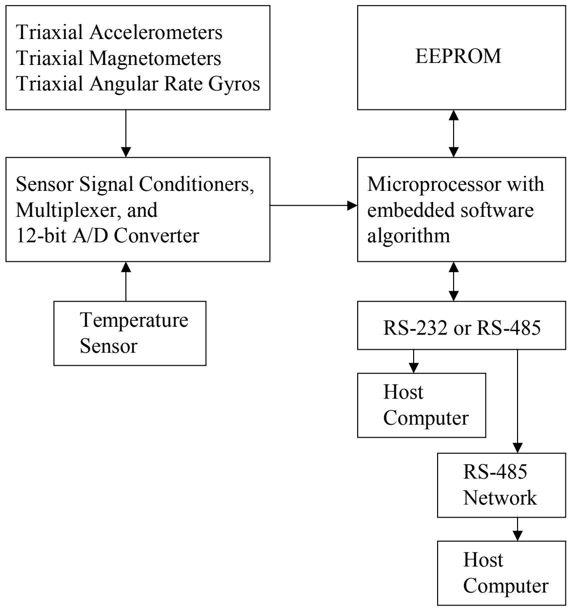
The measurements output by the 3DM-G give you the orientation of the 3DM-G's local coordinate system with respect to the Earth's coordinate system. If you orient the 3DM-G such that its Z-axis is pointing down through the center of the Earth, its X-axis is pointing North and its Y-axis is pointing East, you have aligned the 3DM-G with Earth's coordinate system. At this orientation the 3DM-G will be outputting the so-called 'identity matrix' which means the same as saying zero pitch, zero roll and zero yaw. If you turn it from there, you'll start getting non-zero pitch, roll and/or yaw.

Inside the 3DM-G

The 3DM-G incorporates:

- 3 accelerometer sensors to measure Earth's gravity;
- 3 magnetometer sensors to measure magnetic fields;
- 3 rate gyroscope sensors to measure the rate of rotation about their sensitive axis;
- a temperature sensor;
- signal conditioning amplifiers to condition the raw output of the sensors;
- a signal multiplexer to route the sensors' signals to the A/D converter;

- a 12-bit A/D converter that converts the conditioned output of the sensors into the digital domain;
- a microprocessor that carries out the processing algorithm;
- non-volatile EEPROM to store calibration, filter and other parameters;
- and a data communications port.



Block Diagram of 3DM-G Components

The accelerometers and magnetometers provide an absolute reference to gravity and North as well as a stable, long-term measurement. By themselves they can provide accurate orientation measurement in a static environment. The rate gyroscopes provide an accurate short-term measurement of the change in rotation. By themselves they can provide accurate measurement in a dynamic environment.

We take advantage of these sensors in the following way: The processor first processes the output from each individual sensor and calculates an estimate of its orientation in space. The processor then applies complimentary filtering that combines the high frequency response of the rate gyroscopes and the long-term low frequency response of the accelerometers and magnetometers. By processing the data in this way, we achieve robust orientation measurement.

A Little History

MicroStrain has been developing inclinometers and orientation sensors for several years. Our primary 3-axis product has been the 3DM which incorporates 3 accelerometers and 3 magnetometers to provide accurate orientation measurement in static environments, i.e., in situations where the orientation is being measured while the 3DM is not rotating. With the development of the rate gyroscope enhancements resulting in the 3DM-G, we are now able to accurately measure orientation even in dynamic, fast-moving conditions.

Using the 3DM-G

The 3DM-G can be used in any application where you want to know orientation relative to Earth. The 3DM-G can be used for navigation of robots and unmanned vehicles, for biomedical tracking, to capture motion into computer animation, as a tilt compensated compass, for antenna aiming, to measure shaft rotation, and so forth. Let's say that you are concerned with tipping over a tractor negotiating rough terrain and you need a tilt sensor to warn the operator. You know that the sensor will be subject to jarring bumps, differing vibrations and transient accelerations, all of which would cause significant error at any given time in non-gyroscopically enhanced sensors. Because the 3DM-G is not disrupted by these conditions due to its gyroscopic enhancement, you would be able to accurately measure the tractor's position at any given moment.

Orientation is calculated using the output of the accelerometers and the magnetometers. The accelerometers essentially measure which way is UP or DOWN. The magnetometers essentially measure which way is NORTH. If you know these two things, you can deduce EAST and calculate your 3 DEGREES OF FREEDOM orientation. The problem with accelerometers lies in the fact that they are not just measuring up or down, that is to say, the gravity vector; they are also measuring any linear acceleration that may be occurring. For example, if you take a non-enhanced sensor and shake it, you will see the output of accelerometers oscillate. The oscillation is not caused by a change in the sensor's orientation; it's because the device is undergoing linear accelerations and those linear accelerations temporarily cause the accelerometers to read the gravity vector incorrectly. One approach to correcting the accelerometer output is to introduce heavy low-pass filtering. The reason that this approach would usually work is because anytime you have a linear acceleration in one direction, you almost always have a linear acceleration in the opposite direction immediately afterwards. In other words, things typically oscillate. It's very rare that you have a situation where an object will continuously linearly accelerate in one direction for a sustained amount of time. So if the acceleration is oscillating, the error is oscillating and if you do low-pass filtering, you will end up getting the correct answer. However, the disadvantage to low-pass filtering is that it introduces a significant time delay in the output. Therefore, with this approach, your sensor output will measure orientation change but there will be a substantial delay between the onset of actual orientation change and the output of the device accurately reflecting the change. The 3DM-G ties its correction algorithm to the instantaneous measurement of rotation rate produced by its gyroscopes. No time delay is introduced and you receive accurate orientation change at any given instant.

Orientation Data

The 3DM-G provides a number of different streams of data.

In the first instance you can receive the raw sensor data output, that is, the sensors' raw signals after being amplified and digitized. The processor reads that information in as a number between 0 and 4096 from each sensor. You can obtain these numbers directly although these numbers are not particularly useful in their raw form.

You can receive what we term ‘vectors’. This is sensor data that has been scaled into physical units of G’s, magnetic field units, and/or radians per second. All of the data is orthogonal and is in true vector form. You can receive an acceleration vector, a magnetic field vector or a rotation rate vector either in what we term ‘instantaneous vector output’ or ‘gyro-stabilized vector output’.

The acceleration vector provides a good estimate of the gravity vector or in other words, which way is down. In its instantaneous form, it is subject to the transient artifacts of changing acceleration such as quick starts and stops. In its gyro-stabilized form, the transient artifacts have been removed.

The magnetic field vector provides a good estimate of the direction of Magnetic North. In its instantaneous form, it is subject to transient artifacts due to extraneous magnetic fields or ferrous objects being moved near the 3DM-G. An example of this would be to wave a screwdriver in front of the 3DM-G for a few seconds. This change in the magnetic field would be introduced into the vector. In its gyro-stabilized form, the transient artifacts such as our screwdriver example would be substantially removed.

If you have linear acceleration that is sustained for a very long time or have magnetic interference that is sustained for a very long time, eventually the gyro-stabilized accelerometer and magnetic field vectors will show artifacts. The gyro-stabilized vectors do have all the short-term transient errors removed from them in the same way they would as if you were doing low-pass filtering. However the gyro stabilization method does not introduce the time delay that normal low-pass filtering would.

The rate gyroscope vector provides a rotation rate. In its instantaneous form, the gyro bias has not been removed from the vector. In its gyro-stabilized form, the gyro bias has been removed. The bias is the output value of the gyroscope when it is <u>not</u> rotating. In order to get an accurate representation of the rotation rate, the algorithm subtracts the gyro bias from the raw vector of the gyroscopes. In addition, gyroscopes tend to have drift in their bias. The algorithm also tracks the bias drift and continually corrects for it.

The vector outputs, whether instantaneous or gyro-stabilized provide you with a complete estimate of the orientation of the device. The 3DM-G will also directly output both an orientation matrix and quaternions. These outputs are produced mathematically by the microprocessor, using the vector information already derived. They are designed to save the user a post-processing step and speed the delivery of orientation output. We have elected in this version of the 3DM-G to not directly output Euler angles. Euler angles are not entirely standardized and they have mathematical problems in certain orientations.

Orientation Data Conversion

In general you can convert between a quaternion and an orientation matrix, an orientation matrix and a quaternion, a quaternion and Euler angles, or an orientation matrix and Euler angles.

The orientation matrix and quaternions are different ways of stating the same orientation. Some users will use matrix for their applications and some will use quaternions; it's up to user on which to employ. Matrix can more easily be converted to quaternions. Matrix is a standard rotation scheme for computer graphics. Quaternions hold an advantage in that orientation is described in 4 numbers as opposed to the 9 numbers in a matrix. If the user has issues with data storage, the quaternions take less memory. If the baud rate of the serial communication is low, the quaternions represent fewer numbers to transmit.

As stated above, we do not directly output Euler angles because Euler angles don't always give you the 'right' answer. This is not a problem with the sensor or the hardware or the software, it's a problem with Euler angles themselves. For example, let's say you are using Euler angles to produce the conventional aircraft style pitch, roll and yaw. When your pitch angle is close to 90 degrees, your Euler angles are basically meaningless; they don't work.

Upon request, we will provide conversion formulas for the user to implement orientation conversions. We can also provide sample code from programs written in LabView, Basic, and C.

Timer Ticks

We have described the output of vectors, orientation matrix, quaternions and raw sensor bits. Each of these outputs also contains a 'time stamp' in the form of a tick counter. The microprocessor contains an on-board clock that 'ticks' every 6.5536 milliseconds. The current tick is sent every time data is output by the 3DM-G. The current tick represents the number of ticks since the system was started, i.e., since the 3DM-G was powered-up.

Temperature Sensor

The temperature sensor is an IC mounted on the 3DM-G circuit board. The IC provides a raw output of 10 mV per degree C which in turn is converted by the A/D converter to 0-4096 bits, 0 bits being 0 volts and 4096 bits being 5 volts. You can convert the bits by formula to degree C. We have elected to physically incorporate the temperature sensor now in anticipation of future temperature compensation functionality. You can also use the temperature sensor for any purposes you see fit. Please understand a) it isn't a true indication of environmental temperature outside the system enclosure because it's inside the box and b) there are some heat generating components inside the box that need to be factored.

RS-232 and RS-485 Communication

The standard 3DM-G comes with one LEMO connector and will function either as an RS-232 device or an RS-485 device. The 3DM-G can be optionally fitted with two LEMO connectors to allow for daisy-chained RS-485 operation. The communication mode can be switched via software.

Much flexibility is afforded the user by having access to both modes in that each mode has its advantages and disadvantages. RS-232 has a length limitation of +/-30 feet and

RS-485 can run as much as 4000 feet. RS-232 is full-duplex and RS-485 is only half-duplex.

The typical user will have a 3DM-G connected by RS-232 over a short run to the host computer. If the situation requires a very long run where RS-232's length is exceeded, the user can switch to RS-485 to overcome this limitation.

In situations where the user is running multiple 3DM-Gs from a host computer, one approach might be to connect a serial port expander to the host computer and run multiple RS-232 connections to the 3DM-Gs. Serial port expanders typically connect to the USB port of the host computer and 'break out' 4 to 8 serial ports. An RS-232 cable would then be run to each of the 3DM-Gs. The serial port expander provides an addressing scheme that allows the user to communicate with the individual 3DM-Gs. This scheme will allow faster data rates but may be cumbersome to program and operate.

An alternative approach to running multiple 3DM-Gs from a host computer is to daisy-chain the 3DM-Gs back to one serial port on the host and operate as an RS-485 network. This will simplify operation of the 3DM-Gs but requires that communications be more carefully controlled. RS-485 is half-duplex communication; either the host can communicate or an individual 3DM-G can communicate but not both at the same time. The structure of your communication programming has to deal with this issue. Specifically, you have to make sure a response from a previous host command is fully retrieved before you issue a new command; otherwise the system may fail. Because each 3DM-G has to be polled in turn and you have to complete the command-retrieval sequence for each in turn, one should be cognizant that data throughput will slow in direct proportion to the number of 3DM-Gs.

Baud Rate

The 3DM-G operates in three standard baud rates including 19.2, 38.4 and 115.2. The baud rate can be switched via software. By default the 3DM-G is set at 38.4 which is compatible with almost every modern computer. 19.2 can be employed on older computers and in cases where the cabling is at the upper length limit and/or errors are developing. 115.2 can be employed at shorter lengths to speed data traffic.

Analog Mode

The 3DM-G can optionally be fitted with 4 channels of direct analog output. This option allows the user to sample the 3DM-G with an analog device such as an oscilloscope and process the data with means of their choosing. The 3DM-G analog data is reconstructed data. The processor calculates digital values and as a last step, feeds the values into a D/A converter. These values are converted into voltages between 0 and 4.096 volts representing the 12-bit range. The 4 channels are factory-programmable and therefore represent a certain amount of customizable ability. Typically we would suggest that the best orientation to output would be the 4 components of a quaternion. By reading in the 4 voltages and converting them back to numbers, the user would be able to read the orientation of the device. Using quaternions would have none of the limitations of Euler angles and would be a mathematically complete (with no singularities) description of orientation. These quaternions could easily be converted to a matrix or Euler angles by formula.

Factory Calibration

The 3DM-G is calibrated in the factory on a rotary table with an indexing head, all under automated computer control. This equipment allows us to rotate the device at fixed increments of orientation and at constant speeds during the calibration routines. We first calibrate the accelerometers, magnetometers and rate gyroscopes, establishing their individual gains and offsets. We then create an orthogonalization matrix which is used internally to correct the system for any slight physical misalignment of the sensors occurring during manufacturing. As a result of calibration, the vectors are now output with respect to a true right-handed orthogonal coordinate system. The coordinate system for the acceleration vector is the identical coordinate system for the magnetometer magnetic field vector and for the angular rate vector.

Each 3DM-G is supplied with its actual calibration documentation, summarizing the data that was collected for calibration purposes. It shows you the performance of each individual sensor, its linearity, its gain and offset and so forth. We tabulate the values calculated for the orientation matrix and for the scaled gain and offset for each individual sensor. The calibration documentation is proof that the system will work on specifications.

In most instances you will not need to refer to the calibration documentation during use. In certain instances, the tabulation of values stored in EEPROM may be useful to the user doing customization work.

Field Calibration

The 3DM-G is generally not calibrated in the field. However, there are circumstances where the magnetometers need to be re-calibrated to account for the presence of large magnetic fields or large pieces of ferrous metal in the environment. In those cases, please contact us and we will work with you to facilitate such calibration.

Setting Parameters

3DM-G Acquisition and Display software provides the user with certain programmable parameters to condition the 3DM-G for specific applications. These parameters are found on the software's Configuration screen and are described in detail in the Configuration section of this manual.

Capture Bias

All gyroscopes are prone to drift in their 'bias'. The bias is the output value of the gyroscope when it is not rotating. Capture Bias is an aid to dealing with the drift in the bias of the 3DM-G's gyroscopes. This bias value is important to know because you need to subtract it from the sensor's output to know the actual rotation rate. The bias tends to drift over time and especially if the temperature changes. If you don't account for drift in the bias, the system becomes unusable. To account for this drift, we have an algorithm in the microprocessor that continually monitors the bias and subtracts it from the sensor output. However, the algorithm is a slow-acting algorithm and it's not expecting that the bias is going to change over a short amount of time. It typically takes 20-30 seconds to get any significant change in the bias (even if the temperature is changing), so the algorithm is intentionally slow-acting. There are circumstances, such as initial power-up or rotation exceeding the range of the gyroscopes, when you know that the bias is in error and you want to override the slow-acting algorithm. We therefore provide a Capture Bias function that instantaneously captures the bias, updates the bias tracking function and overrides the slow-acting algorithm.

It is important to understand that Capture Bias must be applied when the 3DM-G is stationary. If Capture Bias is applied while the 3DM-G is rotating in any direction, the bias correction is invalidated.

Polled and Continuous Mode

The 3DM-G can be operated in what we term POLLED mode. By this we mean it can be configured to respond with data only when the host computer commands it. For example, the host computer asks for the current sensor bits data, the 3DM-G sends the current sensor bits data, the host asks for data, the 3DM-G sends the data, and so forth. The 3DM-G can also be operated in what we term CONTINUOUS mode. By this we mean it can be configured to continuously send data. For example, the host computer asks it once to continuously send sensor bits data and the 3DM-G begins to stream sensor bits data every time it updates itself. The 3DM-G will stay in this mode until it is told by the host to go to polling, even if the 3DM-G is un-powered/re-powered. The 3DM-g can be told to stream:

- Raw Sensor Bits
- Gyro-Stabilized Vectors
- Instantaneous Vectors
- Gyro-Stabilized Quaternions
- Instantaneous Quaternions
- Gyro-Stabilized Matrix
- Instantaneous Matrix

One might choose continuous mode over polling in a particular…(Editor's Note).

Normally the device is operated in the polled mode where every time you want a piece of data you specifically request it by sending a command. Now there is some latency involved in serial communications and there is also programming overhead with issuing commands that sometimes might be undesirable, so we do offer what we call continuous mode. You put a single byte command into the memory of the system and every time a new orientation is calculated, if that continuous mode memory location has a valid command byte in it, then it will automatically transmit the data corresponding to that command without having been specifically requested. So basically it gives you a way to have the 3DM-G continuously stream data into a host computer without having any kind of bi-directional communication necessary and one of the benefits of doing that is that it gives you the fastest possible data rata because every time new data is calculated, it will be transmitted and no calculation cycle will be missed. The other advantage is that the host computer program doesn't have to do much; it just sits there reading the data as it comes in. The downside is that it's a little more complicated to handle that kind of communication because the host computer program has to be intelligent enough to parse out the data records that are coming in and handle any kind of potential communication errors.

Unpacking your 3DM-G

If you ordered a 3DM-G starter kit with RS-232 option (part # 3DM-G-SK), you should find the following items:

Qty	Item	Part#
1	3DM-G Sensor	3DM-G-M
1	Digital RS-232 Sensor Cable and Power Connector with 6VDC Power Supply	3DM-G-CBL-PWR
1	CD-ROM containing 3DM-G Data Acquisition and Display software for RS-232, User Manual and Software Help Manual	3DM-G-CD

If you ordered a 3DM-G starter kit with RS-485 option (part # 3DM-G-485-SK), you should find the following items:

Qty	Item	Part#
1	3DM-G Sensor	3DM-G-485-M
1	Digital RS-485 Sensor Cable and Power Connector with 6VDC Power Supply	3DM-G-485-PWR
1	CD-ROM containing 3DM-G Data Acquisition and Display software for RS-485, User Manual and Software Help Manual	3DM-G-CD

If you ordered a 3DM-G starter kit with ANALOG option, you will receive separate instructions for installation and operation. These instructions are not covered in this manual.

Note: If you ordered multiple units or custom configurations of either RS-232 or RS-485, please check your order carefully for all required components. If an item is missing or damaged, please immediately contact MicroStrain Support at info@microstrain.com or:

MicroStrain, Inc.	Phone: 802-862-6629
310 Hurricane Lane	Fax: 802-863-4093
Williston, VT 05495	M-F 8:30am-5:00pm EST
USA	www.microstrain.com

Software

MicroStrain provides a CD with each 3DM-G starter kit which provides several approaches to communicating with the device. Contained on the CD you will find:

- 3DM-G Data Acquisition and Display Software for RS-232
- 3DM-G RS-485 Network Software
- 3DM-G LabView Routines Library
- 3DM-G Data Communications Protocol

3DM-G Data Acquisition and Display Software for RS-232

The 3DM-G Data Acquisition and Display Software for RS-232 is a compiled executable designed for use in the Microsoft Windows operating system. A set-up installation is provided and the user is presented with an application which allows connection of a single 3DM-G to a PC through a serial port. With this application the user may configure the on-board parameters of the 3DM-G, sample and record its output of sensor bits, Euler angles, orientation matrices, quaternions and vectors, and perform several other interactive functions. The software comes with its own Software Help manual which details the software's specific utilization. This software is referenced in the Quick Start section elsewhere in this manual. This software is supported by MicroStrain support personnel. The 3DM-G Data Acquisition and Display Software for RS-232 only supports 3DM-G firmware Version 1.3.00; it does not support previous firmware versions.

3DM-G RS-485 Network Software

The 3DM-G RS-485 Network Software is a compiled executable designed for use in the Microsoft Windows operating system. A set-up installation is provided and the user is presented with an application which allows connection of an RS-485 network of one to fifteen (1 to 15) 3DM-Gs to a PC through a serial port. **Note:** An RS-485-to-RS-323 adapter is provided to make this bridge. With this application the user may configure the on-board parameters of the 3DM-Gs, sample and record their output of sensor bits, Euler angles, orientation matrices, quaternions and vectors, and perform several other interactive functions. The software comes with its own Software Help manual which details the software's specific utilization. This software is referenced in the Quick Start section elsewhere in this manual. This software is supported by MicroStrain support personnel. The 3DM-G RS-485 Network Software only supports 3DM-G firmware Version 1.3.00; it does not support previous firmware versions.

3DM-G LabView Routines Library

MicroStrain provides a set of LabView Routines (LabView VIs) specifically written for the 3DM-G. These routines may be used freely by 3DM-G customers to build custom data acquisition applications. These routines require that the customer have National Instruments LabView installed on their computer. These routines are provided "as-is". No support is available from MicroStrain and documentation is limited to that which is presented in the routines. The 3DM-G LabView Routines Library only supports 3DM-G firmware Version 1.3.00; it does not support previous firmware versions.

3DM-G Data Communications Protocol

MicroStrain provides a 3DM-G Data Communications Protocol document describing the communications protocol associated with 3DM-G firmware version 1.3.00. This document is designed to instruct application developers in the protocols, either RS-323 or RS-485, required for communication with the 3DM-G. These protocols are the same protocols used by MicroStrain to produce the three applications detailed above. The document is provided to allow users to build their own custom 3DM-G applications. These protocols are supported by MicroStrain support personnel.

Software Installation

System requirements

To use the 3DM-G Data Acquisition and Display Software for RS-232 or the 3DM-G RS-485 Network Software, your computer must have the following minimum specifications:

- Pentium Microprocessor
- Microsoft Windows 98 operating system 2^{nd} Edition
- CD-ROM drive
- Video resolution 800 X 600 High Color 16-bit
- Minimum of 16MB of memory
- Minimum of 10MB of free hard disk space
- Microsoft-compatible mouse

Software installation

Step 1: If you have any previous version of 3DM-G Data Acquisition and Display Software for RS-232 or 3DM-G RS-485 Network Software, uninstall it using the following procedure; otherwise, skip to Step 2.

- Click <Start> in lower left hand corner of your desktop.
- Click <Settings> on the pop-up menu.
- Click <Control Panel>.
- Double-click <Add/Remove Programs>. A pop-up menu entitled 'Add/Remove Program Properties' will appear.
- Click <Install/Uninstall> tab.
- Scroll the programs in the window and highlight any previous 3DM-G program.
- Click <Add/Remove> button.
- Follow uninstall instructions as stated.
- When uninstall is completed, 'Add/Remove Program Properties' screen will return.
- Click <OK>.

Step 2: Place the 3DM-G Software CD-ROM in your CD-ROM drive and close the drive.

- Double-click <My Computer> on your desktop.
- Double-click the icon that represents your CD-ROM drive.
- Click the <3DM-G Folder> to highlight it.
- Click <Copy>.
- Using the drop down arrow in the Address box, select your C:\ drive.
- Click <Paste>. The 3DM-G folder will copy from the CD-ROM to your C:\ drive.
- When the 3DM-G folder has completed pasting, double-click it.
- Double-click the <Install folder>.
- Double-click the <Setup.exe> icon.
- A "Welcome to 3DM-G Install Program" screen will appear.

- Click <OK>.
- A “Begin the Installation by Clicking the Button Below” screen will appear.
- Click <Change Directory>.
- A “Change Directory” screen appears.
- In the Directories box, browse to find C:\ 3DM-G and click that folder so that the Path box above reads C:\ 3DM-G.
- Click <OK> and you’re back to the previous screen.
- Click the big button to continue your install.
- Follow any further installation instructions. If certain files on your PC need updating, you may have to re-boot your PC during the install process and run the Setup.exe again.
- If Setup is successful, you will receive a “Successfully Installed” message.

Step 3: You may receive an error message when you first run the <Connect> menu item. The error message will say Error: 75, Description: Path/File access error. This is caused sometimes when the files from the CD are copied to your hard drive. The error is easily curable.

- Exit the 3DM-G application.
- Locate a file named ‘3DM-G.ini’ contained in the directory ‘C:\ 3DM-G\Logs’.
- Highlight the file with your mouse.
- Click your right mouse button.
- A pop-up window will appear.
- Click the <Properties> menu item.
- Another pop-up window will appear.
- Use your mouse to uncheck the <Read-only> checkbox in the attributes section.
- Click <OK>.
- Re-launch the 3DM-G application and the error will no longer occur.

Hardware Installation

RS-232 installation

It is suggested that you initially layout the installation on your desktop before you proceed with integration of the system into your specific structure or environment. This will insure that all components (hardware and software) are working correctly. Please follow these steps to complete initial layout.

- Place the 3DM-G unit on your desk as shown in the figure below.
- Insert the male LEMO connector of the sensor cable into the 3DM-G.
- Connect the female RS-232 connector of the sensor cable into a serial cable connected (or directly) to a free serial port on your computer.
- Connect the power connector of the sensor cable to the power connector of the power supply.
- Plug the power supply into an 110VAC service. The 3DM-G has no external ‘on/off’ switch and begins functioning whenever power is applied.
- **Note:** When powering-up, the device should not be moving. The device initializes a digital, high-pass filter on power-up. If the device is moving during power-up, the digital filter must be allowed to settle before accurate results can be obtained. Settling normally takes about 10 seconds.
- Proceed to the Quick Start section below and follow the further instructions.

(Editor Note: Insert Picture)

RS-485 installation

It is suggested that you initially layout the installation on your desktop before you proceed with integration of the system into your specific structure or environment. This will insure that all components (hardware and software) are working correctly. Please follow these steps to complete initial layout. For example purposes, we will describe an RS-485 network which contains four 3DM-G units.

- Place the four 3DM-G units on your desk as shown in the figure below.
- Insert one end of a sensor cable into either sensor cable connection on unit 1. Connect the other end of the cable to either sensor cable connection on unit 2.
- Insert one end of a sensor cable into the remaining sensor cable connection on unit 2. Connect the other end of the cable to either sensor cable connection on unit 3.
- Insert one end of a sensor cable into the remaining sensor cable connection on unit 3. Connect the other end of the cable to either sensor cable connection on unit 4.
- Connect the lead sensor cable from the RS-232 to RS-485 Adapter into the remaining sensor cable connection on unit 4.
- Connect the RS-232 end of the RS-232 to RS-485 Adapter to a serial cable connected to a free serial port on your computer.
- Connect the power connector of the RS-232 to RS-485 Adapter to the power connector of the power supply.
- Plug the power supply into an 110VAC service. The RS-485 network of 3DM-Gs has no external 'on/off' switch and begins functioning whenever power is applied.
- **Note:** When powering-up, the device should not be moving. The device initializes a digital, high-pass filter on power-up. If the device is moving during power-up, the digital filter must be allowed to settle before accurate results can be obtained. Settling normally takes about 10 seconds.
- Proceed to the Quick Start section below and follow the further instructions.

(Editor Note: Insert Picture)

Quick Start
When you have completed the instructions in the Software and Hardware Installation sections above, proceed with either the RS-232 or RS-485 software as follows:

RS-232 software

Run Software
Double-click the 3DM-G Data Acquisition and Display Software for RS-232 icon on your desktop. The Main screen will appear.

Connect to 3DM-G
- Go to Main screen.
- Click <File>.
- Click <Connect>. The Connect screen will appear.
- Using your mouse, click the radio button representing the serial port that you connected to the 3DM-G.
- Using your mouse, click the radio button representing the baud rate setting for the 3DM-G. The default rate from the factory is 38,400.
- Click <OK>. If the connection is successful, you will receive a confirming message. Click <OK> and you will be returned to the Main screen.
- If the connection is unsuccessful, you will receive a message indicating possible causes of failure. Correct the cause and try again.

Test 3DM-G in Angles Display
- Go to Main screen.
- Click <Display>.
- Click <Angles>. The Angles screen will appear.
- Click <Data>.
- Click <Sample Gyro-Stabilized>. A check will appear to the left of the menu item indicating sampling is in progress.
- The application will begin sampling the 3DM-G and continuously display its angles on the pitch, yaw and roll dials.
- Physically rotate the 3DM-G to insure that all axes are operating.
- Click <Data>.
- Click <Sample Gyro-Stabilized>. The check will disappear to the left of the menu item indicating sampling has stopped.

Congratulations
- You're off and running! Refer to the Software Help manual to discover all the functions that 3DM-G Data Acquisition and Display Software for RS-232 provides. You are also welcomed to contact our technical support staff on any matter at info@microstrain.com.

RS-485 software

Run Software

Double-click the 3DM-G RS-485 Network Software icon on your desktop. The Main screen will appear.

Connect to 3DM-G Network

- Go to Main screen.
- Click <File>.
- Click <Connect>. The Connect screen will appear.
- Click <Auto Detect>. The application will search for any 3DM-G RS-485 network connected to the PC.
- If the detection is successful, you will receive a confirming message. Click <OK>. The application will select the correct Comm Port, Baud Rate and will show each 3DM-G on the network, its address and serial number.
- Click <OK> and the Connect screen will disappear.
- If the detection is unsuccessful, you will receive a message indicating possible causes of failure. Correct the cause and try again.

Test 3DM-G Network in Angles Display

- Go to Main screen.
- Click <Display>.
- Click <Euler Angles>. The Euler Angles screen will appear.
- Click <Data>.
- Click <Sample Gyro-Stabilized>. A check will appear to the left of the menu item indicating sampling is in progress.
- The application will begin sampling each 3DM-G in the network in turn and continuously display the selected 3DM-G's angles on the pitch, yaw and roll dials.
- Click each 3DM-G's radio button and physically rotate the 3DM-G to insure that all axes are operating.
- Click <Data>.
- Click <Sample Gyro-Stabilized>. The check will disappear to the left of the menu item indicating sampling has stopped.

Congratulations

- You're off and running! Refer to the Software Help manual to discover all the functions that 3DM-G RS-485 Network Software provides. You are also welcomed to contact our technical support staff on any matter at info@microstrain.com.

Configuration

3DM-G Acquisition and Display Software for RS-232 provides the user with certain programmable parameters to condition the 3DM-G for specific applications. These parameters are found on the software's Configuration screen and are described below.

Capture Bias Samples
Value Range: 1-10000
The Capture Bias Samples parameter controls the number of points that will be averaged to calculate gyro bias. More points provides more stability but takes longer to process. The 3DM-G must be stationary when the Capture Bias function is performed.

Oversampling Filter
Value Range: 1-15
The Oversampling Filter parameter instructs the processor to sample the raw sensor output from 1 to 15 times at the A/D stage and take an average of the sensor's output for further processing. By default the Oversampling Filter is set at 4 which instructs the processor to take 4 successive samples of the sensor's output, add the 4 samples together, divide by 4 and produce an averaged sample for further processing. This provides an additional low-pass filtering function giving you more/less noise in your output; the downside is that it takes more CPU time to make the calculations as the filter value is increased thereby decreasing the data rate.

Baud Rate
Value Range: 19200, 38400 or 115200
The Baud Rate is the speed with which the host computer communicates with the 3DM-G. The 3DM-G can be set to any one of the three baud rates and perform as elsewhere stated in this manual.

Gyro Compensation
Enable = 1
Disable = 0
The Compensation parameter allows you to disable the gyro stabilization functions that are employed by the processor. If your not interested in the gyroscopically compensated output of the system, but instead just want to scale instantaneous vector output of the sensors themselves and you want that at the maximum possible data rate, you can disable the gyro compensation section of the algorithm which is a relatively time consuming part of the computation. If you have the compensation disabled and sample for gyro-stabilized vectors, you will receive erroneous data.

Accel Error Gain
Value Range: 0-32767
The Accelerometer Error Gain parameter controls the rate at which the errors between the gyro-stabilized and instantaneous accelerometer vectors are reduced.

Mag Field Error Gain
Value Range: 0-32767
The Magnetometer Field Error Gain parameter controls the rate at which the errors between the gyro-stabilized and instantaneous accelerometer vectors are reduced.

Bias Track Gain
Value Range: 0-32767
The Bias Track Gain parameter controls the rate at which drift in the gyroscope bias is detected and controlled.

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Support

Sales, Technical and Corporate:

MicroStrain, Inc.
310 Hurricane Lane
Williston, VT 05495
USA
Phone: 802-862-6629
Fax: 802-863-4093
Email: info@microstrain.com
M-F 8:30am-5:00pm EST

WWW: www.microstrain.com

Technical Notes:

MicroStrain provides technical notes on specific matters relating to its products. These notes are varied and provide information and instruction to general users and to application developers. These technical notes may be found at: http://www.microstrain.com/technotes/technotes.htm

Software Updates:

MicroStrain maintains a page on its web site where software updates are available for download. As improvements are made in existing software or new applications are developed, these are mounted at: http://www.microstrain.com/updates/software.htm

3DM-G Specifications

Orientation Range	360 degrees full scale (FS), all axes (Matrix, Quaternion modes)
Angular Velocity Range	+/-300 degrees/second (max)
A/D Resolution	12 bits
Dynamic Compensation	Closed loop digital control (0 to 50 Hz)
Orientation Angle Resolution	<0.1 degrees (angle resolution specifications taken at most aggressive filter setting)
Temperature Drift	single axis: +/0.025%/degrees Celsius
Nonlinearity	0.23% full scale (tested in static conditions)
Repeatability	0.10 degrees
Accuracy	+/-5 degrees typical for an arbitrary angular orientation (accuracy specifications taken at constant ambient temperature; tested with known sine and step inputs including angular rates to 300 degrees/second)
Output Modes	Matrix Quaternion Scaled Sensor Bits
Sensor Range	Gyros: +/-300 degrees/second FS (full scale) Accelerometers: +/- 2 G's FS Magnetometers: +/-1 Gauss FS
Digital Outputs	RS-232 RS-485
Output Data Rate	100 Hz (digital RS-232)
Serial Data Rate	19,200 baud 38,400 baud 115,200 baud

Supply Voltage	5.2 VDC min 12 VDC max
Supply Current	90 milliamps typical
Connectors	One keyed LEMO for RS-232 Two keyed LEMOs for RS-485
Operating Temperature	-40 to 70 degrees C with enclosure -40 to +85 degrees C without enclosure
Enclosure (w/tabs)	64mm by 90 mm by 25mm 2.5" by 3.5" by 1.0”
Weight	40 grams with enclosure 18 grams without enclosure
Shock Limit	1000g unpowered 500g powered

Data File Samples from Data Acquisition Software

Sample of Angles File

MicroStrain 3DM-G Data File Version 1.0.0
Date file created: 8/22/02
Time file created: 12:13:30 PM
Angles

Time(Seconds)	Pitch	Yaw	Roll	TimerTicks
0.02	-1.1	-14.2	-0.1	16758
0.07	-1.1	-14.1	-0.1	16765
0.09	-1	-14.2	-0.1	16768
0.12	-1	-14.2	-0.1	16773

Sample of Orientation Matrices File

MicroStrain 3DM-G Data File Version 1.0.0
Date file created: 9/4/02
Time file created: 10:12:38 AM
Matrix

Time(Seconds)	M11	M21	M31	M12	M22	M32
0.02	0.9698	0.2317	-0.0762	-0.194	0.922	0.3353
0.04	0.9708	0.2312	-0.0649	-0.2014	0.9312	0.3046
0.06	0.9723	0.2271	-0.0526	-0.205	0.9403	0.2716
0.08	0.9731	0.2252	-0.0453	-0.208	0.9475	0.243

M13	M23	M33	TimerTicks
0.1479	-0.3104	0.9391	34126
0.131	-0.2826	0.9502	34129
0.1112	-0.2534	0.9609	34132
0.0978	-0.2272	0.9689	34135

Sample of Quaternions File

MicroStrain 3DM-G Data File Version 1.0.0
Date file created: 8/14/02
Time file created: 2:31:34 PM
Quaternions

Time(Seconds)	Quat0	Quat1	Quat2	Quat3	TimerTicks
0.02	-0.0001	0.9968	0.4526	-0.6094	54086
0.04	-0.8823	-0.7161	-0.9758	1.9585	54089
0.06	2.2512	-0.792	1.5746	0.9207	54092
0.08	0.8572	-0.4456	1.3386	-1.5029	54095

Sample of Vectors File

MicroStrain 3DM-G Data File Version 1.0.0
Date file created: 8/14/02
Time file created: 2:09:20 PM
Vectors

Time(Seconds)	MagX	MagY	MagZ	AccX	AccY	AccZ
0.01	1.5659	1.7521	0.8777	3.0254	-1.1168	0.4586
0.03	0.9738	1.1628	0.8539	3.2163	-1.606	0.5835
0.05	1.134	0.6964	0.8477	3.1289	-1.4033	0.0255
0.07	1.1366	0.1956	1.0249	2.7859	-1.495	-0.0693

AngRateX	AngRateY	AngRateZ	TimerTicks
2.8114	0.5731	4.2393	47148
-6.686	0.5742	-2.9264	47152
7.6441	-1.7817	-5.3481	47154
5.2477	-1.764	-0.6185	47156

Sample of Sensor Bits File

MicroStrain 3DM-G Data File Version 1.0.0
Date file created: 9/4/02
Time file created: 10:16:45 AM
Sensor Bits

Time(Seconds)	Mag1	Mag2	Mag3	Acc1	Acc2	Acc3
0.01	2161	2093	3505	2184	1961	3369
0.07	2066	2286	3482	2368	1759	3509
0.11	2003	2518	3407	2356	1630	3193
0.15	1953	2717	3284	2454	1477	2929

AngRate1	AngRate2	AngRate3	TimerTicks
2864	1540	2113	6335
3355	1691	2141	6343
3664	1565	2131	6349
3246	1609	2128	6355

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Typical Calibration Documentation

MicroStrain, Inc
3DM-G Calibration Report

Calibration Parameter Summary

Serial Number:	1024
Firmware Version Number:	1.3.10
Calibration Date:	3/20/2003

Sensor Calibration Parameters

These values constitute the sensor calibrations, and should not be changed by the user

EEPROM Location	Description	Value
2	X Accelerometer Offset	2095
4	Y Accelerometer Offset	2052
6	Z Accelerometer Offset	2087
14	X Accelerometer Gain	1074
16	Y Accelerometer Gain	996
18	Z Accelerometer Gain	1076
48	X Accelerometer Reference	128
50	Y Accelerometer Reference	129
52	Z Accelerometer Reference	129
8	X Magnetometer Offset	2147
10	Y Magnetometer Offset	2090
12	Z Magnetometer Offset	2158
20	X Magnetometer Gain	1480
22	Y Magnetometer Gain	1466
24	Z Magnetometer Gain	1475
38	X Gyroscope Offset	2017
40	Y Gyroscope Offset	2033
42	Z Gyroscope Offset	2039
32	X Gyroscope Gain	731
34	Y Gyroscope Gain	740
36	Z Gyroscope Gain	731
56	X Gyroscope Reference	60
58	Y Gyroscope Reference	57
60	Z Gyroscope Reference	59
102	Accelerometer Orthogonality Matrix, M11	-8191
104	M21	-149
106	M31	106
108	M12	-133
110	M22	8190
112	M32	193
114	M13	-7
116	M23	24
118	M33	-8194

66	Magnetometer Orthogonality Matrix, M11	-8231
68	M21	-226
70	M31	128
72	M12	603
74	M22	8213
76	M32	-658
78	M13	-20
80	M23	-17
82	M33	8220
84	Gyroscope Orthogonality Matrix, M11	8194
86	M21	36
88	M31	-25
90	M12	-204
92	M22	8191
94	M32	-38
96	M13	-12
98	M23	29
100	M33	-8192
130	GyroGainScale	64
54	Virtual Ground	128
134	Serial Number	1024

Operating Parameters

These parameters govern the performance of the on-board filtering algorithms and communications
to the host computer. The user may alter these values to suit the application.

EEPROM Location	Description	Value
124	Acceleration Error Gain	500
126	Magnetic Field Error Gain	500
128	Bias Tracking Gain	50
44	Baud Rate (129=19200, 64=38400, 21=115200)	64
46	Comm Mode (1=RS-232, 0=RS-485)	1
30	Oversampling Filter	4
64	Node Address	1
122	Compensation Algorithm Switch (1=on, 0=off)	1
132	Continuous Mode (0=off)	0
120	Gyro Bias Comp. Type (1=Normal)	1
26	Capture Bias Samples	500

CERTIFICATE OF CALIBRATION

This document certifies that the equipment referenced below meets published specifications.

Model Number: 3DM-G

Serial Number: 1024

Calibration Date: 8/27/2002

Description: Gyro-Enhanced Inclinometer

Calibration Technician: ____________________

MicroStrain, Inc.

310 Hurricane Lane, Suite 4
Williston, VT 05495-3211
USA
Ph (802) 862-6629, Fax (802) 863-4093
www.microstrain.com
info@microstrain.com

For any questions concerning this certificate, please call MicroStrain, Inc. for an application engineer.