

**Version**

**3.1.00**

MICROSTRAIN, INC.

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Microminiature Sensors

3DM-GX1™ Hard Iron Calibration

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## Overview

This document describes the background and method for performing a Hard Iron Calibration on MicroStrain's 3DM-GX1™ Gyro Enhanced Orientation Sensor, firmware version 3.1.00 and higher.

The document in its method refers to MicroStrain's 3DM-GX1™ Data Acquisition and Display software Version 2.0.3. The user must utilize this software version or higher to accomplish Hard Iron Calibration or must adhere to the 3DM-GX1™ Data Communication Protocol manual Version 3.1.00 or higher if they are developing their own application.

The background and method take the form of a narrative designed to guide the user through the technical understanding and the practical application of the Hard Iron Calibration.

If you are using MicroStrain's 3DM-GX1™ Data Acquisition and Display software Version 2.0.3, please review page 14 of software help file before proceeding:

<http://www.microstrain.com/pdf/3DM-GX1%20Version%20203%20Help.pdf>

If you are writing your own application, please review pages 45-47 of the MicroStrain's 3DM-GX1™ Data Communication Protocol manual before proceeding:

<http://www.microstrain.com/manuals/3DM-GX1%20Data%20Communication%20Protocol.pdf>

## Background

The 3DM-GX1™ has 3 on-board magnetometers. Magnetometers are intended to measure Earth's magnetic field direction, the horizontal component of which provides the north facing direction. However a problem occurs when the natural magnetic field that the magnetometers are measuring is disturbed by such interference as we shall describe. The issue then becomes how to compensate for the fact that there is interference present in an application.

There are two different kinds of interference that might be present. Hard iron interference or soft iron interference. Hard iron interference is caused by the presence of anything that acts like a magnet. It could be a magnet or it could be things that we don't normally think of as magnets but do have some residual magnetic field. These could be things like screwdrivers which were intentionally magnetized or even things like the sheet metal of an automobile which is not really intended to be magnetized but in the manufacturing process does tend to get magnetized. The effect of hard iron interference is that there will be a magnetic field in the local area which is generated by something acting like a magnet and that magnetic field will be superimposed on top of Earth's magnetic field. The sensor measures the sum of both vectors and consequently you are not going to get the result that you are looking for.

The other kind of magnetic interference is soft iron interference and that occurs when you have a ferromagnetic object in the vicinity of the sensor and the ferromagnetic object is made of a material that will distort an existing magnetic field; in this case we are talking about Earth's magnetic field. Steel is the primary material that's going to do this, although there are some other materials out there that are ferromagnetic. Basically anything that a magnetic would stick to is a ferromagnetic material.

So there are two different kinds of interference; hard iron and soft iron and both can be compensated for, although it's much more straightforward to compensate for hard iron interference and in fact, the errors as a result of hard iron interference are typically much bigger than the errors from soft iron interference. It therefore becomes more important to deal with the hard iron. We have now built this capability into our system.

The next important concept is to understand when it's appropriate or when it's possible to do iron compensation and expect that it might work. A requirement for doing this kind of compensation is that the source of the interference, let's just say it's a piece of metal that has some residual magnetic field, must be fixed with respect to the sensor. That means that any time the sensor rotates or moves, the interfering object also rotates and moves along with it. The typical application would be if you have a vehicle and you are trying to use the sensor as a compass essentially. The sensor is mounted to the frame of the vehicle and therefore the vehicle, which has some component that is causing interference, and the sensor are fixed relative to each other and when one moves the other moves. So, that's a situation where an attempt could be made, with some expectation of success, to do hard iron compensation.

On the other hand, let's say you have a sensor on a big industrial robot with multiple arms and feet joints. If the sensor is mounted on one limb of the robot and there's a piece of interfering material mounted on another limb of the robot and as the robot articulates the sensor and the interfering object move with respect to one another, you can not hope to do a hard iron compensation or even a soft iron compensation because the two are not fixed with respect to each other. Likewise, you could not compensate for the fact that your vehicle might be rolling over railroad tracks. The railroad tracks are causing interference in Earth's magnetic field only as the vehicle moves over and past the railroad tracks. The sensor's not fixed with respect to the interfering object.

Ok! So let's assume that you have an application where you have hard iron interference and you know that that interference is fixed with respect to the sensor. You will now want to go ahead and try out a hard interference compensation or calibration. One word of caution: there is a point where interference can be so strong that the strength of the magnetic field is so much higher than earth's normal magnetic field strength, thereby causing the sensors to saturate and under which conditions it's not plausible to get good measurements. It's only practical and doable to do a compensation or field calibration to correct for interference when you know that Earth's magnetic field is not being swamped.

To recap: Hard iron interference causes a constant value to be added to each component of the sensor's readings. If there were no interference, your X sensor would measure the X component of Earth's magnetic field, but in the presence of the interference, your X sensor measures the Earth's magnetic field plus a superimposed fixed constant. This is true for all three axes (X, Y and Z). The goal of the iron hard iron calibration in the field is to figure out what that constant is for each axis and then simply subtract it in software for all subsequent measurements that are made. The result of the field calibration will be a set of three numbers; three values which are going to be subtracted from all measurements and those values essentially quantify the strength of the magnetic field that is caused by the interfering source.

## Method

Simply stated, by rotating the sensor around in complete circles you are able to find the maximum and minimum magnetic field value that each magnetometer is able to detect. In an environment with no interference, the average of those two values should be zero. With interference, the average will not be zero and that average becomes the calibration constant that we are looking for.

The methods described below make reference to MicroStrain's 3DM-GX1™ Data Acquisition and Display software Version 2.0.3. Figures 1, 2 and 3 at the end of this document are screen shots taken during Hard Iron Calibration.

### **3D Calibration**

Let's go ahead and identify what the steps in the '3D' procedure are. When you are actually doing a field calibration, you will want to have your sensor attached in your application site with the interfering source in its position. You're going to need to be able to rotate this whole system around in circles and ideally you can rotate the application about multiple axes so that you can exercise all three axes of the sensor. For this example let's assume that your application is a 3DM-GX1™ mounted in a small remote control vehicle which you can actually pick up in your hands and turn over. The first step is to click the [Initialize Hard Iron Field Calibration] menu item. This will erase any previously done field calibration and reset internal counters that are going to be used during the calibration process. Please note that when you initialize, it doesn't matter where the sensor is oriented. The next step in this 3D calibration is to select '3D' in the Calibration drop-down box; the magnitude Z numeric scroll box is not used. The next step is to pick up the remote control vehicle and click the [Collect Hard Iron Field Calibration] menu item. The software will begin continuously collecting data until you stop it. Now we want to rotate the vehicle about its 3 axes. Let's assign in our minds a fixed X, Y and Z axis to the vehicle. Ideally, what you want to do is orient the X axis in the horizontal east-west direction and slowly rotate the vehicle about the horizontal east-west direction two full rotations (720 degrees). Temporarily stop the data collection by clicking the [Collect Hard Iron Field Calibration] menu item. Now orient your device such that its Y axis is in the east-west horizontal direction, begin collecting data again, and again rotate the system around the east-west horizontal direction two full rotations. Temporarily stop, re-orient, re-start and collect data from the Z axis. To finish, stop collection by clicking the Collect menu item.

Now the system has collected all the data it needs and the final step is to simply push the [Compute Hard Iron Field Calibration] menu item. The software will complete the computations that are necessary and it will also write the results of that into nonvolatile memory on the sensor. The sensor will immediately produce measurements that are field calibrated and it will continue to do so until the field calibration is erased. Please note that it will remember the calibration if the power is cycled and if you don't want Hard Iron Calibration in operation in future sessions you must [Erase Hard Iron Field Calibration] in the software.

The actual computed results of the Hard Iron Calibration show up in the Parameters frame (see Figure 3 below). These results can be informative, although it's not necessary to pay attention to them because the relevant values are automatically written into the 3DM-GX1™ without any additional intervention by the user.

## **2D Calibration**

We have described a class of calibrations (3D) where you have the ability to essentially pick up the application and rotate it about a horizontal east-west axis. There is another class of applications that are such that you **can not** lift up your whole apparatus and rotate it easily about a horizontal axis. For example, if you mount the 3DM-GX1™ in an automobile and the intention is to use it as a compass, you're not going to be able to pick up your automobile and rotate it. However you can get good performance under those conditions by doing a '2D' calibration.

A 2D calibration is accomplished where you can only rotate the sensor about a vertical axis. For our example we will be mounting a 3DM-GX1™ in a car. For 2D calibration to work, we must mount the sensor such that its Z axis is the vertical direction and its X and Y axis are in the two horizontal directions. In fact this is the way you'd probably want to mount it if you were trying to use it as a compass. This time the rotation procedure will be to drive your vehicle around in a circle on a flat, level piece of territory, which essentially rotates the device in a circle about a vertical axis.

Start by selecting the 2D in the Calibration drop-down box. You **are** going to use the magnitude Z numeric scroll box for this calibration; we'll speak about that below in more detail. As in 3D you first [Initialize], followed by [Collect] and as you collect, you drive around in a circle. Complete at least two full rotations in either direction. When you have completed driving, finish off with [Compute].



The limitation of the 2D calibration is that you have no way to detect and/or compensate for distortions in the Z component of Earth's magnetic field. However the magnitude Z input provides additional information to the system which allows the system to compensate for Z axis distortions. The reason that this is important to correct for Z axis distortions is if the vehicle, at any point in its operating life is undergoing situations where it's not actually level. For example, if you calibrate the vehicle by doing circles in a level parking lot, and then expose your vehicle to a hillside slope, your vehicle is no longer level and under those conditions, any kind of error in the Z axis magnetometer will result in some error in the magnetic heading determination. In order to minimize the impact of that kind of error you can use this magnitude Z component.

The magnitude Z allows you to input the magnitude of Earth's magnetic field, that is, the Z component of Earth's magnetic field in your local geographic area. Over the surface of the Earth, the magnitude Z value changes but it's substantially constant for relatively wide local geographic areas. If you are driving your car around the state, using the same value is sufficient. If you have a case where your goal is to mount the sensor on a vehicle that might be shipped half-way around the world for use, you will want to do a field calibration in the ultimate location. This is because the Z component of Earth's magnetic field can change quite substantially over the course of thousands of miles and a 2D field calibration is generally going to be valid only for the local geographic area where the calibration was done. A 3D calibration doesn't have any of these problems. A 3D calibration fully characterizes the distortion that is present and will be accurate no matter where in the world the device is being used.

You will need to find out what the Z component of Earth's magnetic field is in your local geographic area. Several sites exist on the Internet. For example: <http://www.ngdc.noaa.gov/seg/WMM/data/wmm-Z05.pdf> Please note that the numbers shown are in units of nanoTelsa. In order to convert to units of milliGauss (which is what is needed in our software), divide by 100.

### ***Screen data during 2D and 3D calibration***

Please refer to Figure 3 below. In the Collect frame you are seeing 3 sets of data collected during calibration. In the Mag Field X, Y and Z you're looking at the current reading of the magnetometers; these will continually change during calibration. In the Mag Field Min X, Y and Z you're looking at the smallest value that the magnetometers have output. In the Mag Field Max X, Y and Z you're looking at the largest value that the magnetometers have output. During calibration these Minimum and Maximum fields are constantly updated so that the smallest and largest are eventually captured. At some point they will stabilize (not change) and that is the point that you want to reach during your rotation.

If you keep rotating after the Minimum and Maximum have stabilized you occasionally might get one or two more bits change which is related to sensor noise and is inconsequential.

On the other hand, you might also make a ‘mistake’ during calibration. Let’s say you doing a 2D calibration with a vehicle and drive over a manhole cover. You might find that this event added unrepresentative data to your data set and caused your Minimum and Maximum to shift in a way that wouldn’t have if you hadn’t driven over the manhole cover. If you suspect that the data is not good clean data, then [Erase] and perform the entire calibration procedure again.

Good luck and please contact MicroStrain support with any issues that may arise.

## Figures

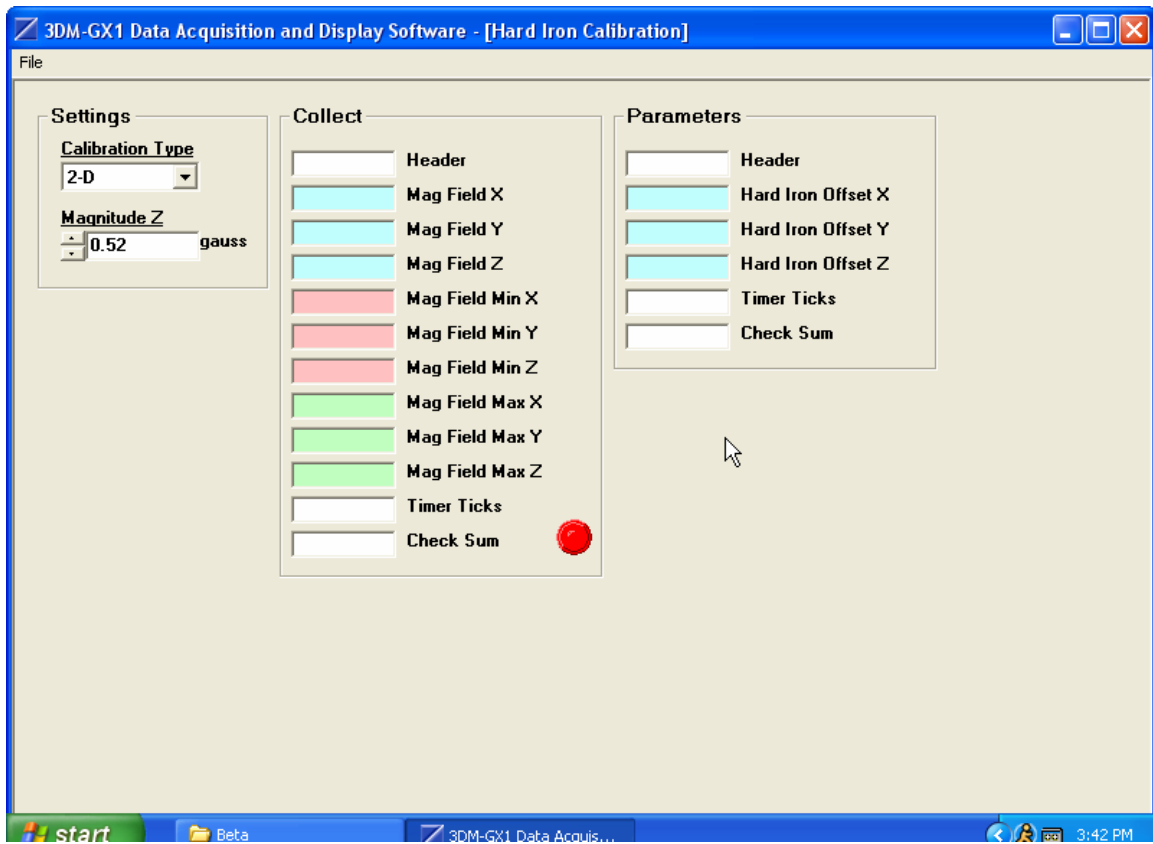


Figure 1.

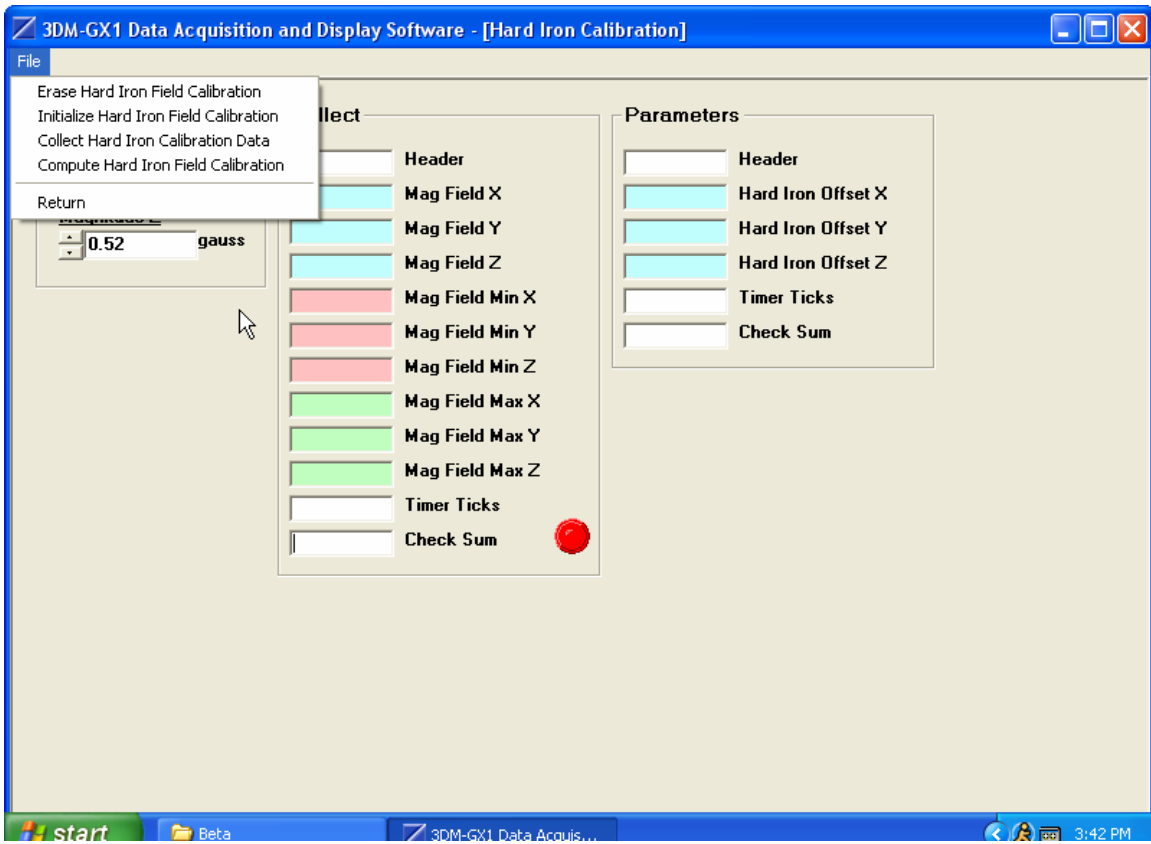


Figure 2.

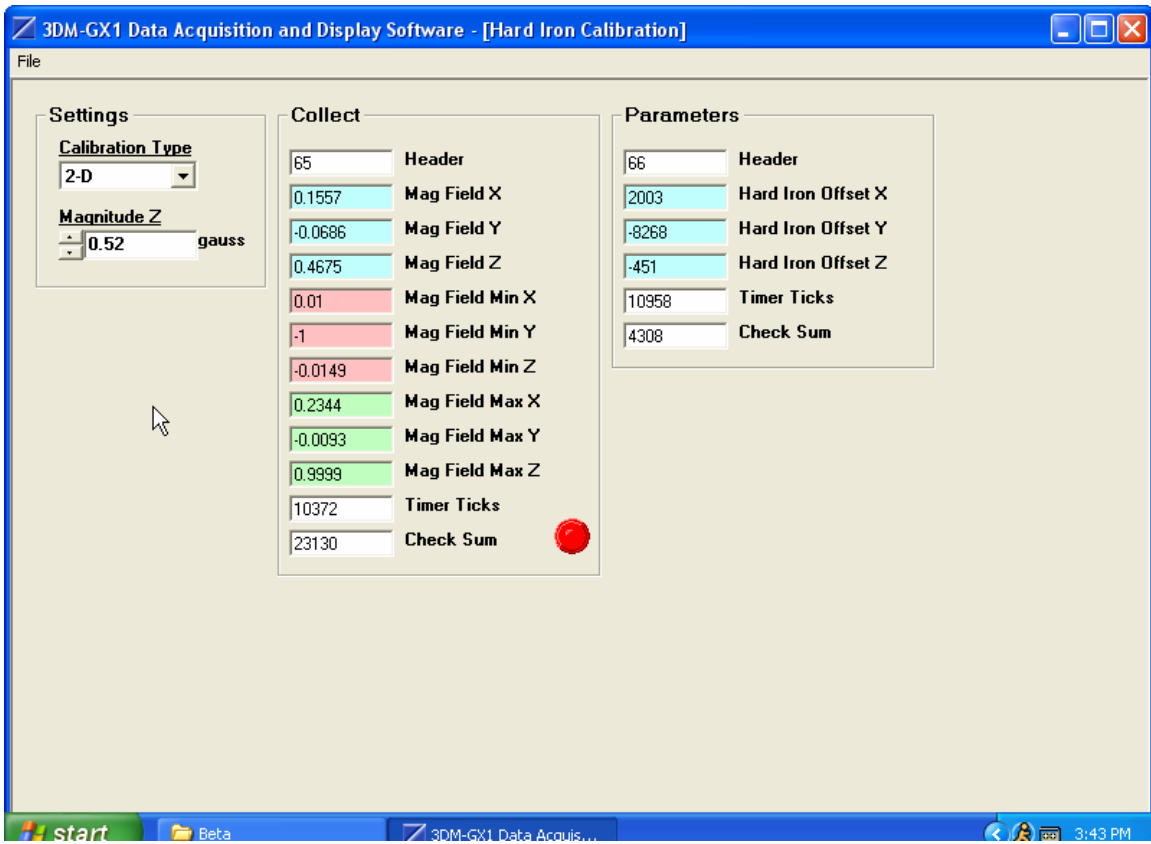


Figure 3.