Application Note:

Magnetic Sensor Calibration

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1 Magnetic Sensor Calibration Principle

1.1 Description

MEMSIC magnetic sensor is designed to measure the geomagnetic field intensity. The output of the sensor corresponds to the three axes of the geomagnetic field relative to the orientation of the magnetic sensor. The x, y, z components of the magnetic sensor orientation is a set of unique values in the numerical coordinate frame of the sensor. If the sensor is rotated in the 3D space, the sensor's magnetic field outputs in the numerical coordinate frame of the sensor can provide information of sensor's orientation variation.

1.2 Why We Need Calibration？

The output of a perfect magnetic sensor in a uniform steady magnetic field can be plotted in a 3 dimensional Numerical Coordinate Frame of the Sensor (NCFS). As the magnetic sensor is rotated 360^{o} about each axis the output of the sensor represents a sinusoidal curve. The vector sum of the sensor output for the x and y sinusoidal values will create a perfect circle. The geomagnetism vector sum of the output of the x, y, and z axes is a constant vector forming a sphere relative to the origin in the NCFS as shown in figure 1.

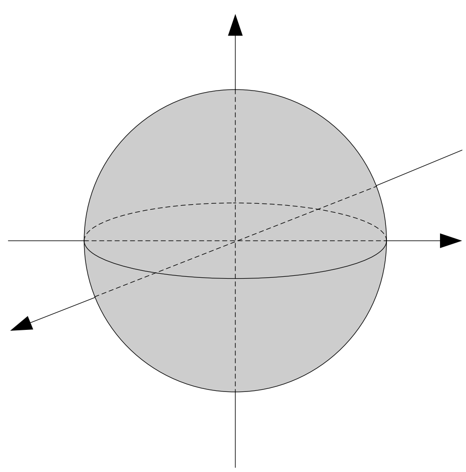

Figure 1: Local Geomagnetic Field Sphere

However, in the real environment, the output at each sensor's axis will vary due to the magnetic interferences around the magnetic sensor. Hence, the plot of the local magnetic field intensity will form an ellipsoid in the NCFS as shown in figure 2.

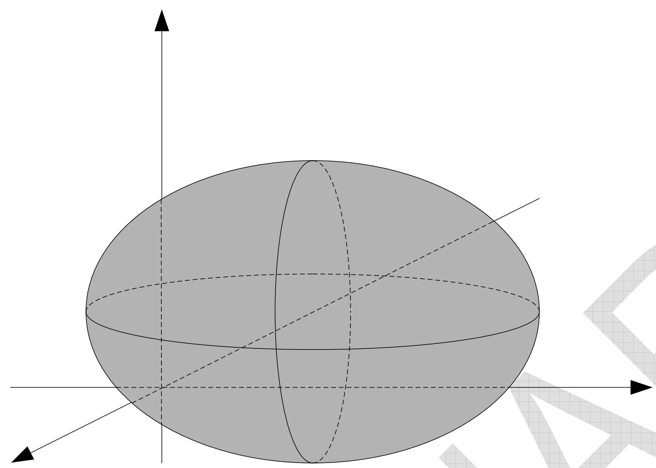

Figure 2: Local Magnetic Field Ellipsoid

There is a notable difference between the local geomagnetic field and local magnetic field. Local magnetic field is a vector sum of the local geomagnetic field and interferential magnetic fields such as hard-iron and soft-iron magnetic fields. The interferential effects are what cause the local magnetic field plot to change from a sphere into an ellipsoid.

The goal of calibration procedure is to extract the local geomagnetic field output components from the local magnetic field output by compensating for the interferential magnetic fields.

1.3 Hard-iron and Soft-iron Interferential Magnetic field

Two main sources of interference in geomagnetic field detection are hard-iron and soft-iron interferences.

Hard-iron magnetic field is formed by magnetic sources like magnets or currents. This kind of field adds to the geomagnetic field and causes an offset shift in the outputs of the magnetic sensor. In NCFS, the sphere formed by the geomagnetic field is shifted from the origin point (0, 0).

Soft-iron magnetic field is an induced magnetic field in the presence of an external magnetic field. Soft-iron magnetic material has no magnetic field of its own. However, in the presence of an external magnetic field, the soft-iron magnetic material becomes magnetized, creating a secondary magnetic field. Ferromagnetic materials like Fe, Co and Ni are magnetized by the external geomagnetic field. Soft-iron field provides an interferential influence on the magnetic sensor. The induced magnetism at the sensor location depends on the orientation of the sensor relative to the external magnetic field. Since the external magnetic field consists of three components and they each induce different secondary field detection depending on the orientation of the sensor, the total magnetic field detected by the sensor will depend on its orientation. The induced field increases the intensity of the magnetization field if aligned in the same direction as the magnetization source field and decreases if aligned in the opposite direction of the source field. It is this field variation that leads to the transformation of the sphere into an ellipsoid.

It's necessary to point out the importance of relative position between the magnetic sensor and the interferential magnetic field. If the position of the source of the interferential magnetic field is fixed relative to the sensor by being mounted on the same device or platform, the field is called mounted interferential magnetic field (MIMF). However, if the source of the interferential magnetic field is not fixed relative to the sensor, the field is called un-mounted interferential magnetic field (UIMF). The device or platform mentioned above can be a PCB board, a mobile device, or even a car or a plane. It should be noted that only MIMFs can be reduced or eliminated.

Hard-iron MIMFs are generated by components or currents on the device and their positions are fixed relative to the sensor. The offset shift parameters can be obtained by rotating the device. Soft-iron MIMFs are generated by ferromagnetic materials on the device. They change the sensitivity of the sensor both in magnitude and direction. The ellipsoid information is useful in eliminating the soft-iron MIMFs. By rotating the device the shape and orientation of the ellipsoid can be obtained.

1.4 Calibration Procedure

As mentioned before, the ellipsoid in the NCFS may be obtained if we rotate the device on which the magnetic sensor is mounted in 3D space. This ellipsoid contains enough information of the hard-iron and soft-iron interferential magnetic field. To calibrate the magnetic sensor one must obtain such information and correct the real time output of the sensor.

To eliminate the hard-iron interference the knowledge of the origin point shift of the ellipsoid is enough while to eliminate the soft-iron interference additional parameter information is needed. The calibration procedure actually includes two steps: Parameter calculation and real-time data correction.

2 Calibration Algorithms

2.2 Basic Method

2.3 Operation

Rotate the magnetic sensor in all directions to find the max and min axis output values of the ellipsoid boundaries.

2.4 Parameter Calculation

For the x axis, find the maximum output value (Mx_max) and the minimum output value (Mx_min). For y and z axes the procedure is the same.

Mx_Sensitivity=(Mx_max-Mx_min)/2
My_Sensitivity=(My_max-My_min)/2
Mz_Sensitivity=(Mz_max-Mz_min)/2
Mx_Offset=(Mx_max+Mx_min)/2
My_Offset=(My_max+My_min)/2
Mz_Offset=(Mz_max+Mz_min)/2

2.5 Correction

With the above offset and sensitivity values the real-time sensor output can be corrected by implementing the formulas below:

$$Mx\_cal = (Mx\text{-}Mx\_Offset) / Mx\_Sensitivity$$
$$My\_cal = (My\text{-}My\_Offset) / My\_Sensitivity$$
$$Mz\_cal = (Mz\text{-}Mz\_Offset) / Mz\_Sensitivity$$

2.6 Remark

This algorithm is a basic and universal version for magnetic sensor calibration. It is appropriate for the circumstance when soft-iron interferential field and axes of the magnetic sensor are in the same direction. The advantage of this algorithm is its simplicity. It needs little resources and can be implemented in all MCU platforms.

Disadvantages of this algorithm:

- Can not calibrate the rotation error caused by the soft-iron interference.
- Must rotate the sensor to all directions possible. The less the sensor is rotated the less accurate the sensor will be.

For the latest information please contact your local representative or visit us at www.memsic.com or contact us at info@memsic.com.

Revision History

Revision	Date	Comment
1.1	21-Mar-08	Initial Draft release (Updated format)

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