Application Note:
Magnetometer Fundamentals

June 2008 **AN-00MM-001**

1. Introduction

The MEMSIC magnetometers are available in both a dual-axis and tri-axis version for magnetic field intensity measurement systems based on anisotropic magnetoresistive (AMR) technology. The magnetic sensors are designed in a Wheatstone bridge configuration to detect the changes in the external magnetic field. The magnetometer provides a store or setup function of the internal magnetization field using internal strap resistors. The MEMSIC magnetometer is ideal for electronic compass, GPS navigation and magnetic field detection applications.

2. Geomagnetic Field

The MEMSIC magnetometer is specially designed to measure low gauss field range including the geomagnetic field domain. The following is a brief introduction to geomagnetic field.

Geomagnetic field is formed by magnetic materials inside the earth. The intensity of the field depends on the location and ranges from about 0.4 gauss to 0.6 gauss. The distribution of the geomagnetic field is similar to a bar magnet. The magnetic field lines point from the earth's South Pole to its North Pole. The field lines are perpendicular to the earth surface at the poles and parallel at the equator. Thus, the earth field points downwards in the northern hemisphere and upwards in the southern hemisphere as shown in Figure 1.

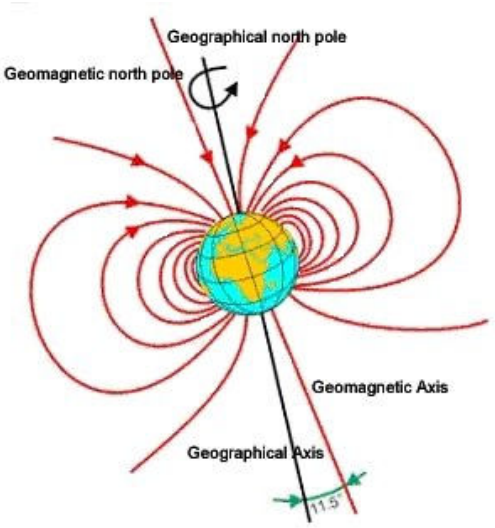

Figure 1: Geomagnetic Field

An important fact is that the magnetic poles do not coincide with the geographical poles, which are defined by the earth's axis of rotation. The angle between the magnetic and the rotation axis is about 11.5°. As a consequence, the magnetic field lines do not exactly point to geographic or "true" north. The difference in the geographical north and the magnetic north can easily be compensated if needed.

3. AMR Principles

The anisotropic magnetoresistive (AMR) sensors are special resistors that vary with the magnetic field. MEMSIC magnetometers use AMR Permalloy film as magnetic field inducting components. Figure 2 illustrates the AMR Permalloy film's characteristics under different magnetic field orientation.

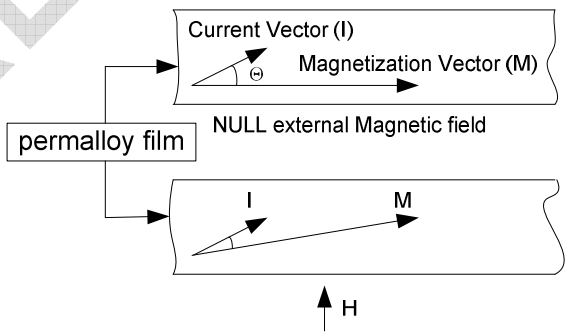

Figure 2: AMR Permalloy Film Character

During manufacturing, a strong magnetic field is applied to the film to orient its magnetic domains in the same direction, establishing a magnetization vector. When an external magnetic field (H) is applied to the

film, the magnetization vector angle changes relative to the current flowing through the permalloy film, which in turn changes the film's resistance. This resistance variation is directly proportional to the angle (Θ) between the magnetization vector (M) and current vector (I). A linear operating domain exists between the magnetization vector and the current vector as shown in Figure 3. MEMSIC's AMR sensor is optimally designed to take advantage of this domain region.

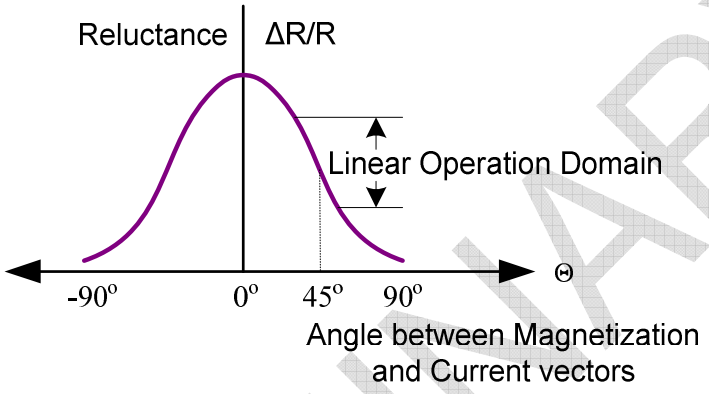

Figure 3: Reluctance Increment

The sensors inside the MEMSIC magnetometer is configured in a Wheatstone bridge (fig.4) so that the change in resistance is detected as a change in differential voltage from which the strength of the applied magnetic field is inferred. The output signal may be amplified and converted to an appropriate digital signal for processing.

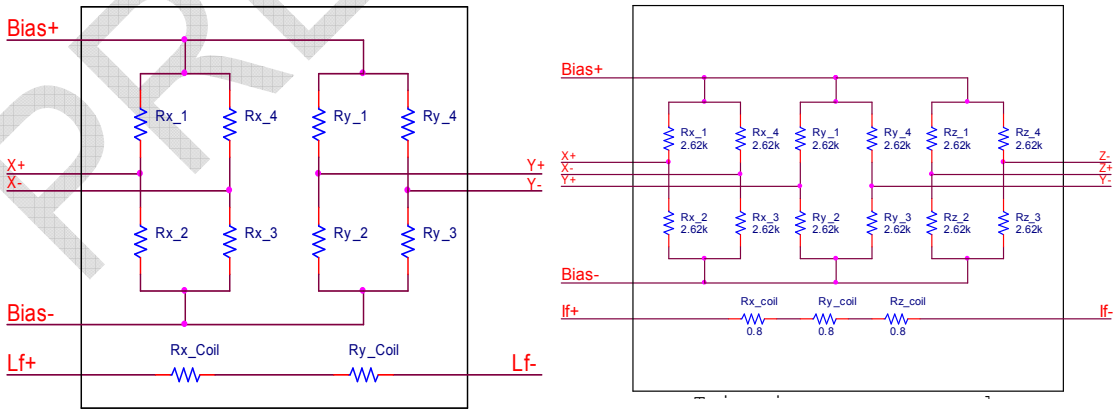

Figure 4: Dual-axis/Tri-axis Wheatstone Bridges

4. Magnetometer Characters

MEMSIC devices are capable of measuring geomagnetic field with a full-scale range from -2 gauss to +2 gauss with high resolution and with a maximum magnetic field exposure of 10,000 gauss. The devices have an I^2C interface for a digital readout of each signal path.

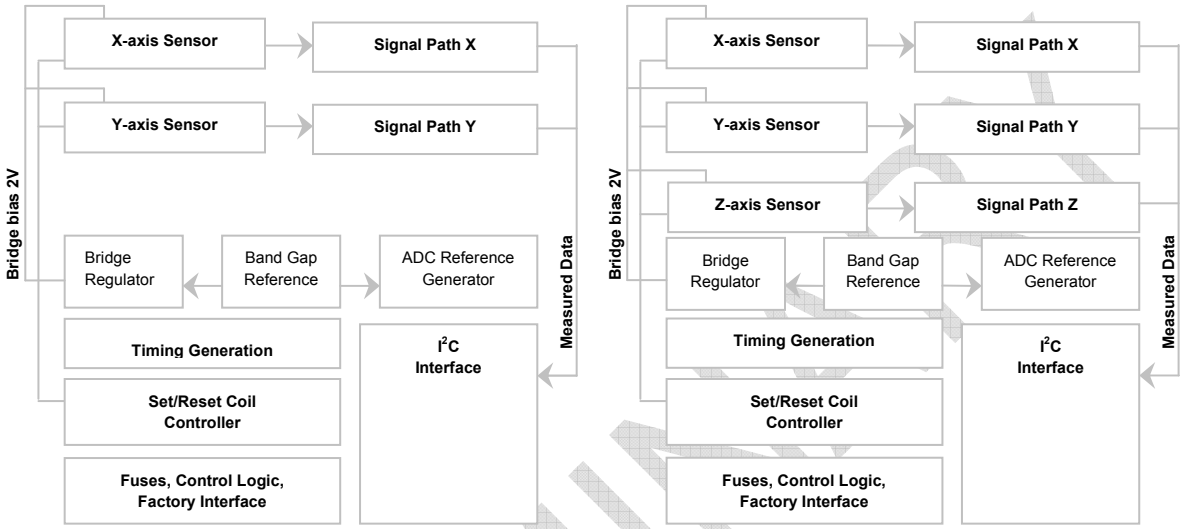

Figure 5: Functional Diagram (Dual-axis/Tri-axis)

5. Pin description and Package

a) Packaging and Operating Range

MEMSIC's magnetometers are packaged in a small low profile LGA package either a 5.0 mm x 5.0 mm x 1.2 mm or a 5.0 mm x 5.0 mm x 0.9 mm depending upon device and can operate within the temperature range of -40°C to +85°C.

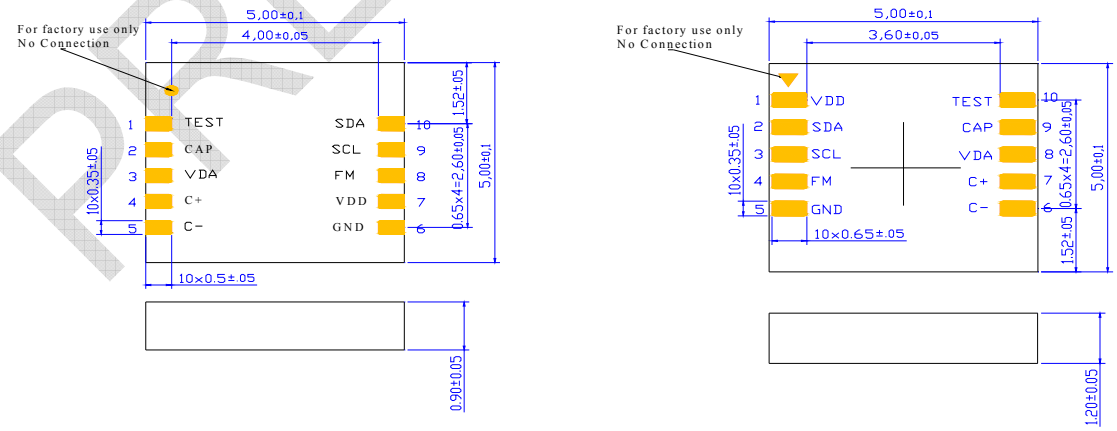

Figure 6: Package Diagram MMC212xM & MMC302xM (Top View)

b) Pin Description

Pin Description: MMC212xM, LGA-10 (5x5x0.9mm) Package

Pin	Name	Description	I/O
1	TEST	Factory Use Only	NC
2	CAP	Connected to External Capacitor	I
3	V_{DA}	Power Supply	P
4	C+	Connected to External Capacitor or Short Together	I
5	C-		I
6	GND	Connected to Ground	P
7	V_{DD}	Power Supply for I^2C bus	I
8	FM	Factory Use Only	I
9	SCL	Serial Clock Line for I^2C bus	I
10	SDA	Serial Data Line for I^2C bus	I/O

Pin Description: MMC302xM, LGA-10 (5x5x1.2mm) Package

Pin	Name	Description	I/O
1	SCK	Connected to Ground	I
2	DI	Factory Use Only	NC
3	NC	Do Not Connect	NC
4	SCL	Serial Clock Line for I^2C bus	I
5	SDA	Serial Data Line for I^2C bus	I/O
6	NC	Do Not Connect	NC
7	V_{DD}	2.7V to 5.25V	P
8	CAP	Connected to External Capacitor	I
9	TEST	Factory Use Only	NC
10	GND	Connected to Ground	P

6. Set/Reset Function

The AMR Permalloy films inside the MEMSIC magnetometer detects magnetic field after it is magnetized. However, when the Permalloy films are exposed to a strong magnetic field of more than 6 gauss the film's polarity may change causing poor to sub-optimal performance. So a strong inner magnetic pulse must be generated to restore or reset the magnetization vector of the sensor. This function is operated by a Set /Reset pulse. Flowing high current through the strap resistors inside the sensor will reestablish the magnetization field of the films. This operation can be executed manually or periodically by a micro-controller.

A recommended method is to sample data after each Set or Reset pulse as shown in Figure 7. Take the difference of two sampled data as output. The advantage of this operation is the elimination of the common mode signals caused by temperature drift or electrical parameter drift.

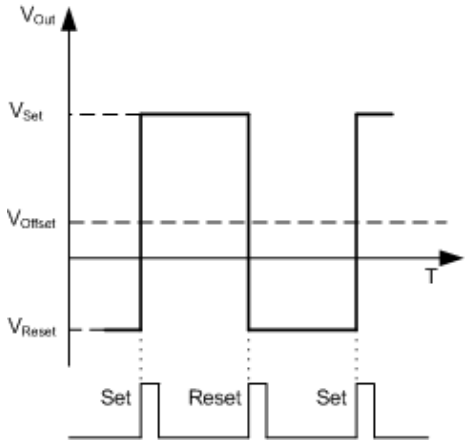

Figure 7: Set/Reset Functional Diagram

Revision History

Revision	Date	Comment
1.1	20-Mar-08	Initial Draft release (Updated format)
1.2	9-Jun-08	Update for latest pin outs

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