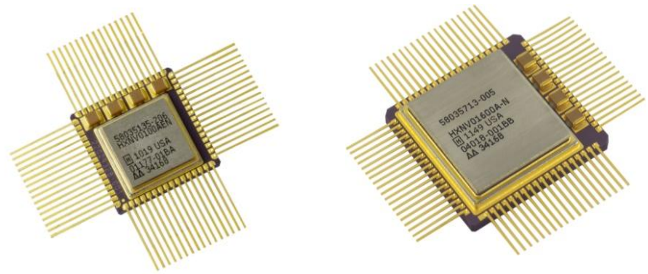
MRAM Application Note: AN-316
Stray Magnetic Fields (SMFs): Introduction and Product Handling Guidelines



Introduction

Honeywell's family of radiation hardened low power nonvolatile Magnetic Random Access Memories (MRAMs) use robust magnetic (magneto-resistive) technology to store millions of bits of information reliably, with desirable endurance, data retention and performance attributes. Data sheets provide specific details on MRAM products.

One general concern users may have is the effect of external Stray Magnetic Fields (SMFs) on MRAMs. SMFs are the magnetic fields produced by objects that contain magnetic materials and by current-carrying conductors. MRAMs have been designed to perform robustly when exposed up to certain SMF levels through the use of inherent disturb-resistant MRAM technology and package magnetic shielding.

This document provides an introduction to SMFs; how SMFs can be measured; what SMF exposure limits for MRAMs are recommended; and practices for handling, transporting, using, and storing MRAMs. Following straightforward board design and handling practices as described here safeguards MRAMs from SMFs.

Stray Magnetic Fields and Units

A brief discussion regarding units is provided here to help quantify and set acceptable SMF levels for the MRAM. In practice, Gaussmeters are used to measure magnetic flux densities which in turn are used to calculate SMF values.

Two sets of units are commonly used to describe SMFs and magnetic flux density. For a stray magnetic field, H, the CGS (Gaussian) unit is the Oersted (abbreviated as Oe) and the MKS (SI) unit is amperes per meter (A/m). For magnetic flux density, B, the CGS (Gaussian) unit is the Gauss (abbreviated as G) and the MKS (SI) unit for magnetic flux density is the Tesla (T).

The following equations allow converting between these two sets of units:

$$1\ \text{Oe} = 1000\ /\ (4\pi)\ \text{A/m} \approx 80\ \text{A/m} \qquad (1)$$

$$1\ \text{A/m} = 4\pi\ /\ 1000\ \text{Oe} \approx 0.0125\ \text{Oe} \qquad (2)$$

$$1\ \text{T} = 10{,}000\ \text{G} \qquad (3)$$

$$1\ \text{G} = 0.0001\ \text{T} \qquad (4)$$

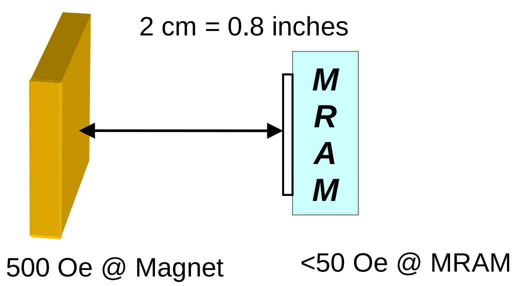
In addition, when measured in a vacuum or in an air environment, the magnetic flux density value is equal to the stray magnetic field value. This relationship is important when SMF values need to be determined from Gaussmeter measurements of magnetic flux density. Therefore, the following constitutive relation results using convenient CGS (Gaussian) units:

$$1\ \text{Oe} = 1\ \text{G (in vacuum and in air)} \qquad (5)$$

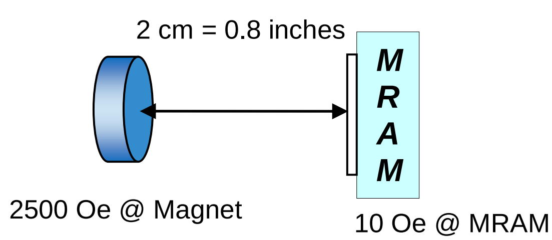
SMF Attenuation with Distance

The strengths of SMFs attenuate rapidly with distance. Separating MRAMs from SMFs sources by even small distances is the key guideline for safeguarding MRAMs, noting the magnetic object geometry affects the rate of attenuation. Several examples shown below illustrate the effectiveness of distance to make SMFs inconsequential to MRAMs.

Example 1: A rectangular permanent magnet with dimensions of 2.5 cm x 2 cm x 0.5 cm and a surface SMF of 500 Oe produces an SMF less than 50 Oe at a distance of 2 cm from the MRAM. The SMF is therefore attenuated by more than a factor of ten in a distance less than one inch. An SMF of 50 Oe, which is approximately 100 times greater than the Earth's magnetic field of 0.5 Oe, will not affect the MRAM.



Example 2: A cylindrical permanent magnet with a diameter of 0.5 cm, thickness of 0.2 cm, and a surface magnetic field of 2,500 Oe, produces, at a distance of 2 cm, a magnetic field of 10 Oe, which is well below the protection threshold of the MRAM. The SMF value for this case is attenuated by more than a factor of 250 in a distance less than one inch.

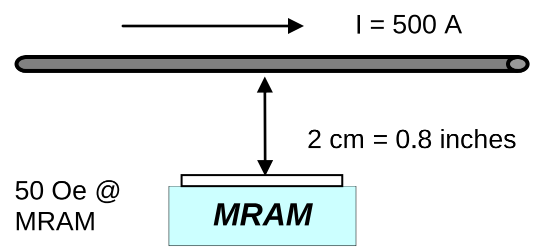


Example 3: The magnetic field produced by a current can be calculated using Ampere's law. An equation for calculating the SMF from a current flowing in a long cylindrical wire is given by:

$$H = \frac{I}{5r} \tag{6}$$

where H is the SMF in Oe, I is the current in Amperes (A), and r is the radial distance, in centimeters (cm), outside the wire as measured perpendicularly from the wire's central axis.

Thus, a cylindrical wire conducting a current of 500 A would have to be brought to within 2 cm (0.8 inches) of the MRAM to generate 50 Oe at the surface of the MRAM. Such a situation is extremely unlikely for electronic assemblies. In addition, even a 50 Oe SMF will not disturb the MRAM.



Tabulated below, based on Equation 6 for the given current, are minimum separations, in four distance units, between the surface of the cylindrical wire and the surface of the MRAM, that result in attenuation to 50 Oe of the SMF from the current in the wire:

Current	Distance from wire center			
A	cm	µm	inches	mils
1000	4	40000	1.6	1600
100	0.4	4000	0.16	160
10	0.04	400	0.016	16
1	0.004	40	0.0016	1.6
0.1	0.0004	4	0.00016	0.16
0.01	0.00004	0.4	0.000016	0.016
0.001	0.000004	0.04	0.0000016	0.0016

The entries in the table above demonstrate that even very small distances allow SMFs from currents in wires to attenuate to levels acceptable for MRAMs. As an example, the center of a wire conducting a current of 100 A would need to be placed within 0.4 cm, 4 mm, or 160 mils of the surface of the MRAM to produce an SMF of 50 Oe, which are, respectively, very practical and very small spacings from an applications standpoint, at SMF levels inconsequential to MRAMs.

Key information about SMFs and MRAMs is summarized as follows:

- SMFs attenuate rapidly with distance.
- Flowing currents and objects containing iron, nickel, and/or cobalt are sources of SMFs.
- The Earth's SMF is approximately 0.5 Oe.
- MRAM functionality is based on the operation of magnetic elements contained within the MRAMs.
- Magnetic shielding has been added to MRAMs to protect the magnetic elements and to provide considerable robustness from SMFs. Extremely strong external magnetic fields near MRAMs could disturb the magnetic elements and induce errors.
- MRAM parts offer robustness for withstanding SMFs, e.g., up to 65 Oe when the MRAM is writing, and 100 Oe in unbiased, read, and standby modes.

As shown above, with modest spacings, producing SMFs greater than 50 Oe is difficult to achieve. Even if sources of SMFs are present, they are easily managed by performing measurements to be described next and/or applying analysis and making board and area modifications. The MRAM's static SMF specification shown in the MRAM's data sheet, e.g., 100 Oe, provides a large margin of protection during handling, transporting, storage, and board assembly.

Handling MRAMs

This section identifies recommended practices for managing the environment and handling of MRAMs. Implementing practices to manage SMFs is analogous to the use of well-established and commonly applied practices for managing electro-static discharge (ESD) effects in electronics that can be caused by stray electric charges and electric fields.

Everyday items that are commonly used can also be magnetic and produce SMFs. All tools and materials used in the handling of MRAMs should be checked for SMFs, as these items should be non-magnetic. Tools, shelving, transport trays, test equipment, board assembly machines, etc. need to be checked, as discussed below, and maintained to assure acceptable SMF levels with any needed spacings are put and kept in place. Electronic equipment must be tested for SMFs when powered-up and powered-down.

SMFs from permanent magnets and electrical currents are produced in many common items and technologies, including telephone, cell phone, and radio speakers; electrical lines, disk drives, actuators and motors, production equipment, transformers, and solenoids. The following table shows sample results based on SMF measurements made on common items and equipment.

Item	Results from Measured SMF Values (Oe)
Earth's magnetic field	0.5
Pens and caps	1 to 7
Electronic equipment	1 to 150
Magnetic screwdrivers	1 to 220
Telephones	15 to 250
Cell phones and cases	60 to 800
Jewelry	1 to 1000
Permanent magnets	100 to 3000

In order to safeguard MRAMs, the maximum recommended SMF level for an environment containing MRAMs is 25 Oe. This maximum recommended SMF level can be measured, and provides margin to the specifications provided in product data sheets. Spacings can be created between MRAMs and sources of SMFs to keep the SMF level lower than 25 Oe in an area or environment where MRAMs are present. It is noted that extremely strong external magnetic fields near MRAMs could disturb the magnetic elements and induce errors.

Gaussmeters are magnetometers that measure the magnetic flux density, B, in Gauss (G). For measurements made in vacuum or in air environments, which is generally the case for practical applications, the corresponding SMF value is calculated by multiplying the measured magnetic flux density value by the conversion factor of 1 Oe/G that is shown in Equation 5.

A Gaussmeter can be used to measure SMFs from objects on a board, to be used on a board, or in an area or environment where MRAMs are present. A Gaussmeter can also be used to measure SMF levels in order to determine that the maximum recommended SMF level is met for an environment containing MRAMs. Checking for SMFs can be done in as little as a few minutes.

Maintaining practical and safe distances between SMF sources and MRAMs is a practical approach for safeguarding MRAMs. If a source of high SMF cannot be removed, magnetic shielding using high-permeability magnetic material can be placed to shunt SMFs.

Personnel who work with MRAMs need to be aware of sources of SMFs, SMF effects, SMF requirements, and practices for managing the MRAM environment with respect to SMFs. Personnel should not bring or possess materials capable of generating SMFs while handling MRAMs. SMF levels need to be kept low in areas where MRAMs are stored, transported, mounted, installed, and used.

Areas that have been checked for and meet SMF handling requirements and specifications can be marked using visual management methods. Visual management methods might include using standardized colors, patterns, and text instructions that are assigned uniquely to identify and to maintain SMF requirements. It is recommended MRAM parts be transported and stored in specially marked non-magnetic containers that incorporate visual management methods. Periodic training, reviews, discussion sessions, and area walk-throughs are helpful for maintaining acceptable SMF environments and robust SMF practices.

Typical actions that can be performed when handling MRAMs are as follows:

- Handling
  - Before handling MRAMs, which includes processing, transporting, storing, working with, and using MRAMs, personnel need to verify they are not carrying material capable of producing SMFs.
  - An inspection of the area/environment should be performed for objects and equipment that may produce SMFs.
  - All MRAMs should be stored in an area which does not contain high SMF levels.

- Maintenance of Equipment and Handling Areas
  - MRAMs should be placed in an area with acceptable SMF levels before maintenance is performed in areas or on equipment that is used to handle MRAMs.
  - All service personnel, either internal or external, need to be informed of SMF requirements and briefed on any modifications to equipment before being given access to equipment.
  - After maintenance is complete, trained personnel should be required to inspect and to verify SMF conformance, including that any necessary spacing rules and magnetic shielding are in place to achieve acceptable SMF levels.

Summary

Stray Magnetic Fields (SMFs) can be kept to low levels that are inconsequential to MRAMs. Maintaining separation between MRAMs and sources of SMFs is a common and generally practical means for keeping SMF levels low and safeguarding MRAMs from SMFs. Measurements of SMFs can be performed to confirm that SMF levels are low in MRAM environments. Consult the product datasheets for specific detailed specifications.

Contact Honeywell for any special cases, other questions, or assistance on MRAM applications or performance.

To learn more about Honeywell's radiation hardened integrated circuit products and technologies, visit www.honeywellmicroelectronics.com

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