WHITE PAPER

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F-RAM™, nvSRAM, and MRAM Magnetic Field Immunity

Abstract

This white paper compares the magnetic field immunity of three classes of nonvolatile memory: ferroelectric random-access memory (F-RAM), nonvolatile static random-access memory (nvSRAM), and magnetoresistive random-access memory (MRAM).

Introduction

Nonvolatile random-access memory (NVRAM) is memory that provides fast read and write access to any address and retains data when power is disrupted. Ferroelectric random-access memory (F-RAM™), nonvolatile static random-access memory (nvSRAM), and magnetoresistive random-access memory (MRAM) are three NVRAMs that offer faster random access times than conventional nonvolatile memories, such as flash and EEPROM. Many nonvolatile memory applications are exposed to magnetic fields; therefore, nonvolatile memory components used in these applications must be immune to the magnetic field effect to protect critical system data.

Cypress conducted a lab study in which F-RAM and nvSRAM devices were exposed to magnetic fields and compared the data from the study to an Everspin MRAM datasheet to evaluate the magnetic field immunity of the three technologies.

Devices

- 4-Mb parallel F-RAM in 44-pin TSOP II from Cypress
- 4-Mb parallel nvSRAM in 44-pin TSOP II from Cypress
- 4-Mb parallel MRAM in 44-pin TSOP II from Everspin

F-RAM and nvSRAM Test Methodology

Test Flow

Figure 1 summarizes the procedure of each test.

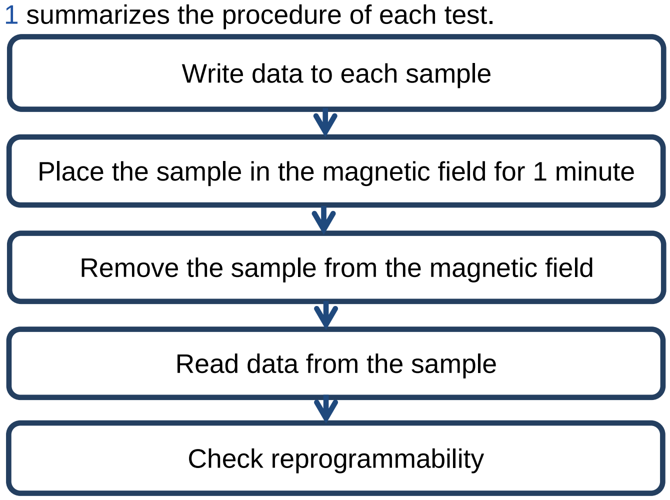

Figure 1. Test Flow Chart

Test Setup

Figure 2 shows the magnetic field setup and the two sample insertion methods—horizontal insertion and vertical insertion—of the device under test. At room temperature, nonvolatile memory samples were placed between two permanent magnets. The distance between the two magnets was adjusted to vary the magnetic field strength. Compared to horizontal insertion, vertical insertion resulted in a larger distance between the two magnets, creating a smaller magnetic field. In this setup, the maximum possible magnetic field over a horizontally oriented sample was 3,700 Gauss, while the maximum possible magnetic field over a vertically oriented sample was 2,000 Gauss.

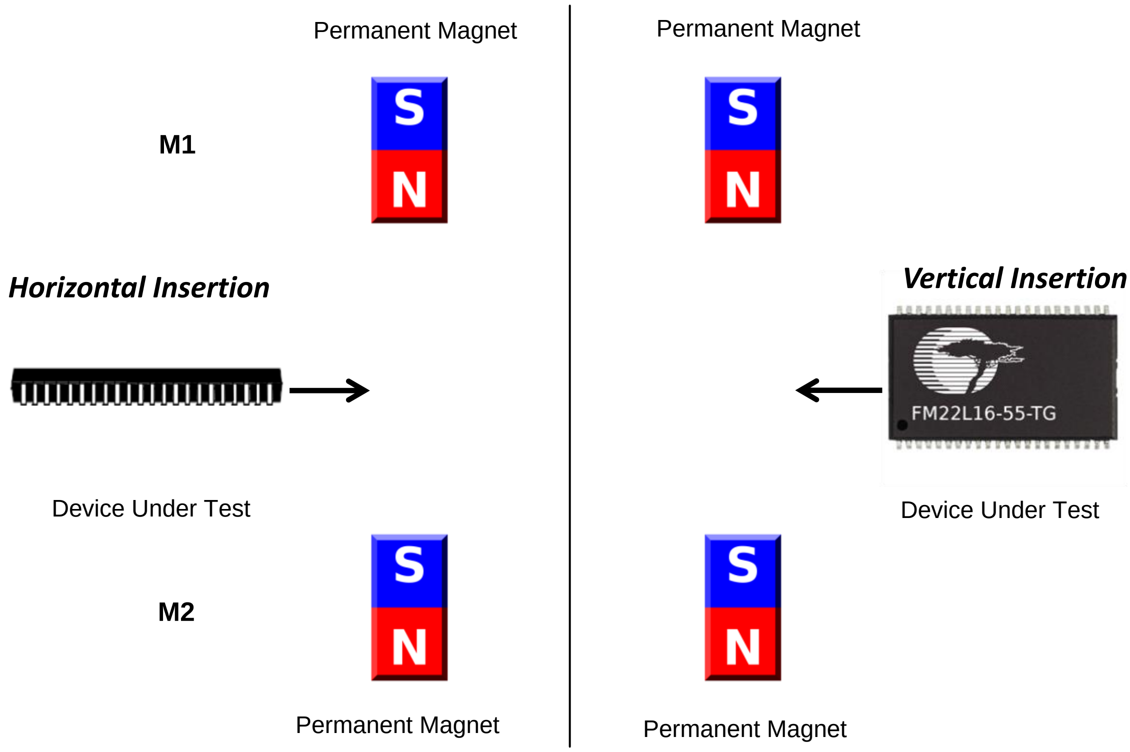

Figure 2. Magnetic Field Setup and Insertion Methods

Measurements

A Gauss/Teslameter (Model 5070 by F.W. Bell) measured the magnetic field strength in Gauss. Table 1 shows the different units of magnetic field strength and the conversion factors between them.

An ALL-100 Universal & Gang Programmer by Hi-Lo Systems wrote and read the data to and from the nvSRAM and F-RAM samples. Data written to the samples cover both data states (1 and 0) of each bit.

Quantity	CGS Unit*	SI Unit	Conversion Factor
Magnetic induction (B)	Gauss (G)	Tesla (T)	$1T = 10^4 G$
Magnetic field strength (H)	Oersted (Oe)	Ampere/meter (A/m)	$1\ A/m = 4\pi \times 10^{-3} Oe$

*In free space, 1 Oersted = 1 Gauss.

Table 1. Units for Magnetic Field Strength

F-RAM and nvSRAM Test Results

Table 2 shows the data reliability results of F-RAM samples (FM22L16-55-TG) and nvSRAM samples (CY14B104NA-ZS45XI) using the horizontal insertion method under the test magnetic field (3,700 Gauss) during write and read. No data corruption was observed, and all the tested samples were able to be rewritten to using a different data pattern. The F-RAM and nvSRAM samples were also placed under the maximum magnetic field for 12 hours to test their performance for a longer duration. Both memory types exhibited the same results.

Data Written	Magnetic Field (Gauss)	Magnetic Field (A/m)	Sample Size	Data Read	Date Rewrite
0101	3,700	2.94 x 10^5	10	0101	Yes
1010	3,700	2.94 x 10^5	10	1010	Yes
1111	3,700	2.94 x 10^5	10	1111	Yes
0000	3,700	2.94 x 10^5	10	0000	Yes

Table 2. F-RAM and nvSRAM Reliability Using Horizontal Insertion Method

Table 3 shows the data reliability results of F-RAM samples (FM22L16-55-TG) and nvSRAM samples (CY14B104NA-ZS45XI) using the vertical insertion method under the test magnetic field (2,000 Gauss) during write and read. No data corruption was observed, and all the tested samples were able to be rewritten to using a different data pattern. The F-RAM and nvSRAM samples were also placed under the maximum magnetic field for 12 hours to test their performance for a longer duration. Both memory types exhibited the same results.

Data Written	Magnetic Field (Gauss)	Magnetic Field (A/m)	Sample Size	Data Read	Data Rewrite
0101	2,000	1.59 x 10^5	5	0101	Yes
1010	2,000	1.59 x 10^5	5	1010	Yes
1111	2,000	1.59 x 10^5	5	1111	Yes
0000	2,000	1.59 x 10^5	5	0000	Yes

Table 3. F-RAM and nvSRAM Reliability Using Vertical Insertion Method

MRAM Data

Table 4 shows the magnetic field immunity data from the Everspin MR2A16A datasheet. In the best case (for industrial and extended temperatures), the MRAM device (MR2A16ACYS35/ MR2A16AVYS35) is guaranteed to endure up to 125.66 Gauss (10,000 A/m) magnetic fields without data corruption and permanent device damage.

Parameter	Temp Range*	Value in Gauss	Value in A/m
Maximum magnetic field during write	Commercial	25.13	2,000
	Industrial, Extended	125.66	10,000
	AEC-Q100 Grade 1	25.13	2,000
Maximum magnetic field during read	Commercial	100.53	8,000
	Industrial, Extended	125.66	10,000
	AEC-Q100 Grade 1	100.53	8,000

*Commercial: 0°C to +70°C, Industrial: –40°C to +85°C, Extended: –40°C to +105°C,
AEC-Q 100 Grade 1: –40°C to +125°C

Table 4. MRAM Reliability from Everspin Datasheet

Conclusion

Due to its magnetic nature, the MRAM device retains data only under limited external magnetic field exposure. Data reliability is not guaranteed for applications with a magnetic field exposure exceeding 125.66 Gauss. While the MRAM (MR2A16ACYS35/MR2A16AVYS35) device is constrained by sensitivity to external magnetic fields, the Cypress F-RAM (FM22L16-55-TG) and nvSRAM (CY14B104NA-ZS45XI) devices demonstrate strong magnetic field immunity and do not show any failures under the maximum available magnetic field strengths (3,700 Gauss for the horizontal insertion and 2,000 Gauss for the vertical insertion). In addition, the F-RAM and nvSRAM devices allow rewriting with a different data pattern after exposure to the magnetic fields.

In a high magnetic field environment, F-RAM and nvSRAM technologies demonstrate better magnetic field immunity than MRAM technology.

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