Introduction

The EMxxLX family is the latest generation of MRAM devices based on Everspin's STT (Spin-transfer Torque) technology. It is a high performance, multiple I/O, SPI compatible MRAM device featuring a low pin count SPI bus interface with supported frequencies up to 200 Mhz. When the EMxxLX is configured for DTR operation with a clock speed of 200Mhz, transfer rates of 400MBps are achievable.

Magnetic immunity is a rating of a product's ability to maintain its specified functionality when subjected to a magnetic field while reading or writing to the device. Various aspects of the magnetic field, such as field strength, distance from the magnetic field source, field orientation (In-Plane, Perpendicular to the Plane, and Intermediate (45 degree angle) are described in this application note. In addition to magnetic field orientation, the duration of field exposure, either transitory or continuous, are shown as well.

EMxxLX devices have been shown to provide a level of immunity to magnetic fields of 350 Oe. This is the level specified in the datasheet. Users should be aware of the secondary effects as well as the practical implications of a magnetic field source which are described in this application note.

Contents

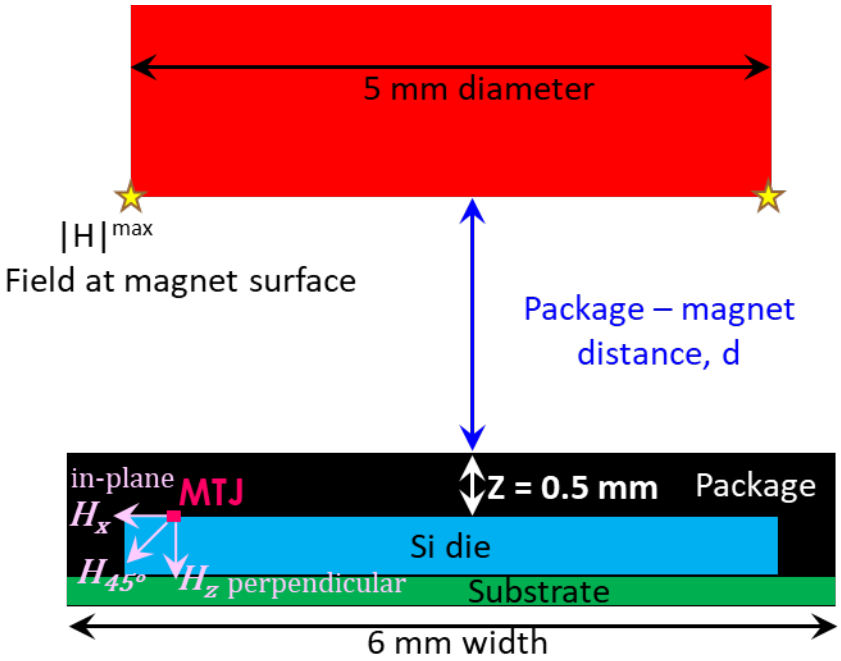
Magnetic Field Orientation and Distance

The EMxxLX device Magnetic Immunity was characterized using a bar magnet. The magnet was positioned to subject the EMxxLX to six magnetic field orientations and multiple distances from the device. The six magnetic field orientations were: Magnet on top of device 1) In-Plane, 2) Perpendicular and 3) Intermediate angle (45 degree); Magnet on side of device 4) In-Plane, 5) Perpendicular and 6) Intermediate angle (45 degree). The distance from the Magnet to the device was varied from 1 to 25mm.
The use case of active Reads and Writes while subjected to a transient field for 10 seconds was examined.

A change in functional performance as determined by a resultant increase in BER (bit error rate) was used to determine the acceptable field strength under which the EMxxLX device performs to full data sheet specifications.

Magnetic Field Strength as a Function of Distance

The measured Magnetic field strength is a function of distance between the magnet and device. To allow system designers the ability to gauge the effect of magnetic fields on EMxxLX devices we have normalized the field H, as a function of distance d (mm). The Field orientation is also considered in the normalized graph represented in Figure 1. As can be seen by the graph an incremental distance of 1mm decreases the magnetic field strength by ~ 60%.



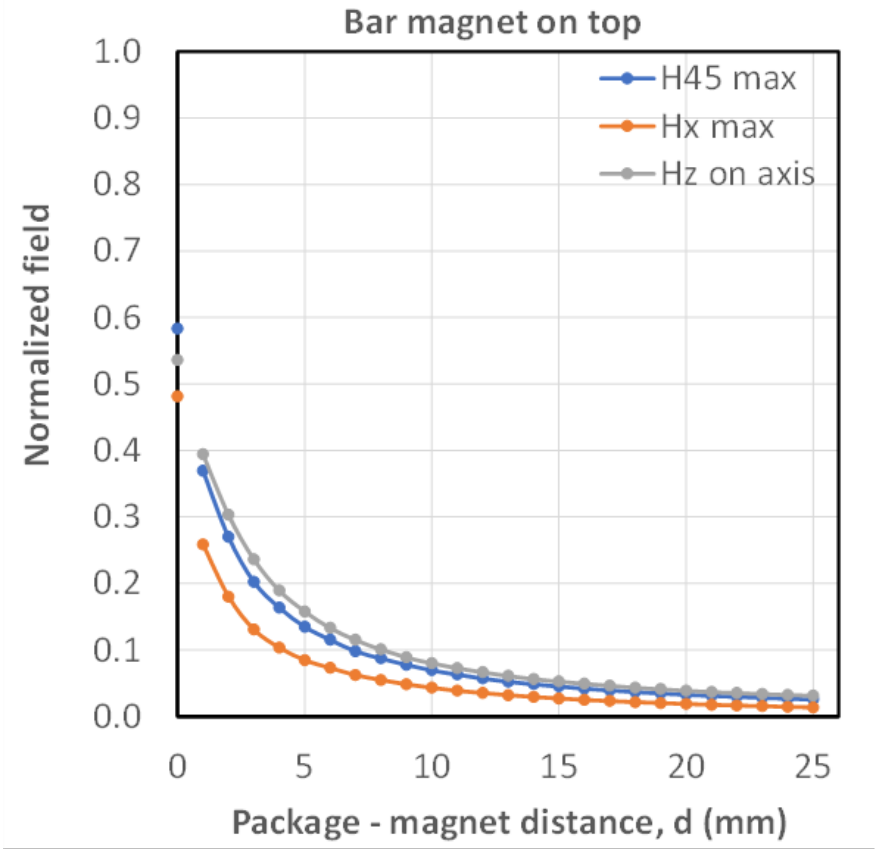


FIGURE 1 MAGNET ORIENTATION AND NORMALIZED FIELD STRENGTH

Field Immunity During Active Read/Write - Transient Field

The EMxxLX MRAM device was subjected to a transient magnetic field for 10 seconds with the Bar Magnet touching the surface of package at 85C Ambient while the device is in operation. During this test scenario, a mixed workload of 60% Writes/40% Reads was run on the EMxxLX device. The magnetic field orientation was varied as defined in the Magnetic Field Orientation section. The field distance was varied from 1-25 mm and the results for 1mm distance are shown to demonstrate the rapid drop off effect, and corresponding higher field immunity at that distance. Figure 2 contains the results of the transient field testing. The device is more sensitive to magnetic field at higher temperature. Lower operating temperature will increase the magnetic field immunity such that 25C and -40C ambient temperature will result in even higher levels than shown in Fig. 2 and Fig 3.

The typical use case in which the EMxxLX device is subjected to a transient field during a mixed workload of 60% Writes/40% Reads has been examined. For completeness, two additional use cases have been investigated. The EMxxLX device was subjected to a transient field in: 1) Standby Mode and 2) Read only mode. These two additional use cases have shown significantly higher levels of immunity over the active Read/Write use case. This results in a magnetic field immunity of >1000 Oe in Standby or Read operations.

Usage	**Active read/write in transient field for 10 sec (Oe)**					
Magnet position	Magnet on top			Magnet at side		
Field direction at MTJ	45 deg.	In-plane	Perpen	45 deg.	In-plane	Perpen
Package surface field (Oe) when bar magnet touches package	**387***	511	927	415	486	1132
Field at 1mm distance	611	951	1261	643	653	2040

*Specified at 350 Oe due to manufacturing variation

FIGURE 2 ACTIVE READ/WRITE TRANSIENT FIELD 10 SECONDS

Field Immunity During Active Read/Write - Continuous Field

The EMxxLX MRAM device was also subjected to a continuous magnetic field with the Bar Magnet touching the surface of package at 85C Ambient. This is shown for comparison to a transient field but it seems unlikely that the MRAM would be exposed to a continuous field in an actual application. During this test scenario, a mixed workload of 60% Writes/40% Reads was run on the EMxxLX device. The magnetic field orientation was varied as defined in the Magnetic Field Orientation section. Figure 3 contains the results of the continuous field testing.

Usage	**Active read/write in continuous field (Oe)**					
Magnet position	Magnet on top			Magnet at side		
Field direction at MTJ	45 deg.	In-plane	Perpen	45 deg.	In-plane	Perpen
Package surface field (Oe) when bar magnet touches package	287	380	710	309	361	867
Field at 1mm distance	454	707	966	478	485	1562

FIGURE 3 ACTIVE READ/WRITE IN A CONTINUOUS FIELD

The device is more sensitive to magnetic field at higher temperature. Lower operating temperature will increase the magnetic field immunity such that 25C and -40C ambient temperature will result in even higher levels than shown in Fig. 2 and Fig 3.

Magnetic Field Strength of PCB Manufacturing Equipment

The MRAM devices can be subjected to magnetic fields during PCB manufacturing and handling. Everspin has done a survey of common equipment in PCB manufacturing to determine magnetic field from that equipment. Certain equipment and tools may contain rare earth magnets or can be exposed to magnetic fields that, in time, can become magnetized. Table 1 lists findings for PCB manufacturing equipment and its associated measured magnetic field measurement. Table 2 lists loose and miscellaneous items commonly found in a PCB manufacturing environment along with its associated measured magnetic field measurement. The column labeled Drop Off lists the distance in inches (1in = 25.4mm) in which the magnetic field from the listed tool drops off to less than 5 gauss (1 G coincides with 1 Oe). It is recommended that MRAM devices be kept a minimum of this distance from the tool during PCB assembly operations.

Equipment/Process Description	Direct Measurement (G)	> 0.25 (Inches)	Drop Off (Inches)
Forming	N/A	2.1	<1
Forming	N/A	3.2	<1
Tinning	<1	<1	N/A
Pick and Place Y Wagon	>800	135	>1
Pick and Place Tray Wagon	195	20.6	>1
Pick and Place Head	N/A	<1	N/A
Pick and Place Motor (not running)	62.3	24	>1
Pick and Place Y Wagon	736	156	>1
Pick and Place Tray Wagon	130	32	>1
Pick and Place Machine Running	N/A	N/A	<1
Stream Printing Motor	26.7	14.8	<1
Stream Printing Board Support Bar	16.4	5.2	<1
Reflow Oven	<2	<2	N/A
Reflow Oven	N/A	N/A	N/A
X-Ray	<1	<1	N/A
Air-Vac	<1	<1	N/A
Flying Probe Support Magnet	>800	152	>1
Flying Probe Probes	41	22	>1
AOI	<1	<1	N/A
Bake Oven	<1	<1	N/A
Adhesive Dispenser Support Magnets	>800	254	>1.5
De-Paneling Router	<1	<1	N/A

TABLE 1 FIELD STRENGTH OF MANUFACTURING EQUIPMENT

Field Strength of Miscellaneous items

Equipment/Process Description	Direct Measurement (G)	> 0.25 (Inches)	Drop Off (Inches)
Magnetic Pencil/Wand	>800	185	>1
Tweezers	14.6	8.2	<1
6 inch steel ruler	12.05	1.4	<1
Magnet for board clamping	637	140	>1
Pick Up Tool	<1	N/A	<1
Metal Solder Iron	1.9	N/A	<1
Screwdriver – (Non Magnetic Tip)	36.7	12.2	<1
Plating Brush	6.5	3.1	<1
Hot Plate	<5	N/A	<1
Hot Plate Stands	<1	N/A	<1
Smart Phone	107.8	30.4	>1
iPhone ear buds	79.1	10.9	<1
Dremel Model 4000 with Flex Shaft	40.1	N/A	N/A
iPod Nano	1.8	N/A	<1
Lenovo Laptop Speakers (T420)	186.6	71.7	>1
Smart Watch/jewelry	>800	174	>1
Micrometer – Exposed to SMF's over time	>100	N/A	<1

TABLE 2 FIELD STRENGTH OF MISCELLANEOUS ITEMS IN PCB MANUFACTURING

Magnetic Immunity Specifications and Standards

Several industry standard immunity/compatibility specifications were investigated.

The following test specifications were examined:

- **EN-61000-4-8**: Electromagnetic compatibility (EMC) -Part 4-8: Testing and measurement techniques -Power frequency magnetic field immunity test
- **IEC-61000-4-3**: Testing and measurement techniques –Radiated, radio-frequency, electromagnetic field immunity test
- **ISO-11452-8**: Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy
- **J1113-21**: Electromagnetic Compatibility Measurement Procedure for Vehicle Components—Part 21: Immunity to Electromagnetic Fields, 30 MHz to 18 GHz, Absorber-Lined Chamber
- **J1113-22:** Electromagnetic Compatibility Measurement Procedure for Vehicle Components—Part 22—Immunity to Radiated Magnetic Fields

Each identified test specification was examined to determine the specific test scenario and magnetic field strength the DUT (Device Under Test) was subjected or exposed to. In all the identified test specifications, the prescribed field strengths were significantly lower than the EMxxLX 350 Oe exposure limit, precluding the necessity of additional Immunity testing.

Conclusion

Everspin's Industrial STT-MRAM is extremely tolerant of magnetic fields typically encountered in PCB and assembly manufacturing as well as industrial working environments. This application note shows the characterization of the EMxxLX device behavior when subjected to transient and continuous magnetic field at varying distance and field orientations. It is worth noting that magnetic field strength degrades exponentially in relation to distance from the magnetic field source, which effectively mitigates the effects of known stray fields of most adjacent equipment or other sources.

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