Standard Products

UT8MR8M8 64Megabit Non-Volatile MRAM

Datasheet
November 2017

The most important thing we build is trust

FEATURES

- Single 3.3-V power supply
- Fast 50ns read/write access time
- Functionally compatible with traditional asynchronous SRAMs
- Equal address and chip-enable access times
- HiRel temperature range (-40°C to +105°C)
- Automatic data protection with low-voltage inhibit circuitry to prevent writes on power loss
- CMOS and TTL compatible
- Data non-volatile for > 20 years (-40°C to +105°C)
- Read/Write endurance: Unlimited for 20 years (-40°C to +105°C)
- 64-pin ceramic flatpack package
- Operational environment:
  - Total dose: 1 Mrad(Si)
  - SEL Immune: 112 MeV-cm^2/mg @125°C
  - SEU Immune: Memory Cell 112 MeV-cm^2/mg @25°C
- Standard Microelectronics Drawing (SMD) - 5962-13207
  - QML Q, Q+, and V

INTRODUCTION

The Cobham (formerly Aeroflex) 64Megabit Non-Volatile magnetoresistive random access memory (MRAM) is a high-performance memory multichip module (MCM) compatible with traditional asynchronous SRAM operations, organized as either four 2M words by 8 bits or one 8M words by 8 bits.

The MRAM is equipped with five chip enables (/En), a single write enable (/W), and a single output enable (/G) pins, allowing for significant system design flexibility without bus contention. Data is non-volatile for > 20 years at temperature and data is automatically protected against power loss by a low voltage write inhibit.

The 64Mb MRAM is designed specifically for operation in HiREL environments. As shown in Table 4, the magneto-resistive bit cells are immune to Single Event Effects (SEE). To guard against transient effects, an Error Correction Code (ECC) is included within the device. ECC check bits are generated and stored within the MRAM array during writes. The MBE pin identifies that ECC logic has detected two bit errors during the current read cycle.

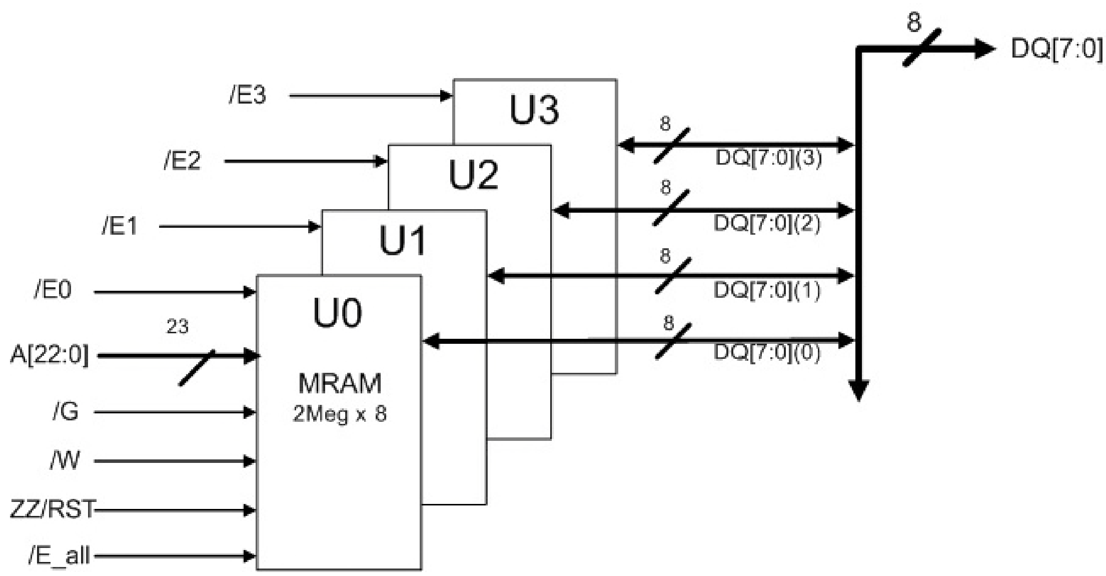


Figure 1. UT8MR8M8 MRAM Block Diagram

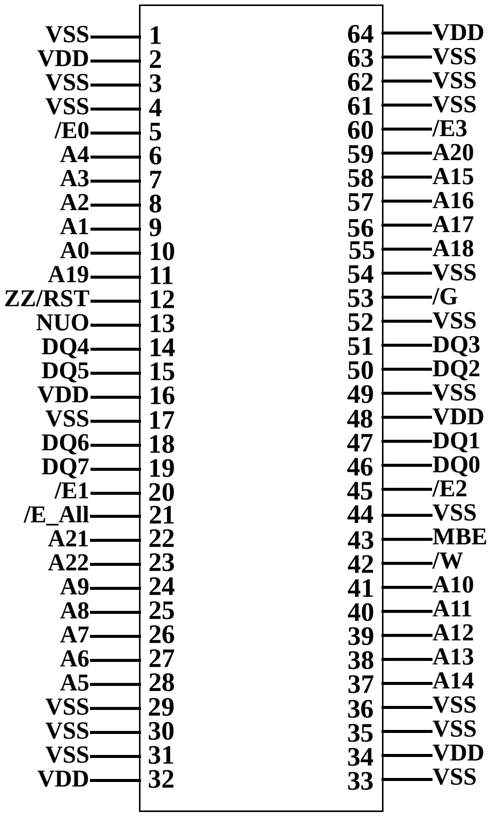


Figure 2. 40ns MRAM Pinout (64)

DEVICE OPERATION

The UT8MR8M8 has control inputs called Chip Enable (E[3:0]), Chip Enable All (/E_ALL), Write Enable (/W), Output Enable (/G), and sleep/reset mode (ZZ/RST); 23 address inputs, A[22:0]; eight bidirectional data lines, DQ[7:0]; and a Multi-bit Error Flag (MBE). /E[3:0] controls device selection, active, and standby modes. Asserting /E[3:0] enables the device, causes IDD to rise to its active value, and decodes the 21 address inputs, A[20:0], to select one of 16,777,216 words in the memory. **Note:** Only one Chip Enable may be active at any time. Asserting /E_ALL allows the device to be addressed as a single, 64Mb memory using address bits A21 and A22 to decode and select 1 of 4 MRAM die. /W controls read and write operation. During a read cycle, /G must be asserted to enable the outputs. ZZ/RST controls the sleep/reset mode operation and provides device reset capability. Enabling sleep/reset mode causes all other inputs to be don't cares. ZZ/RST places all die into internal low power even while system power is still applied to V_{DD}. The MBE pin is an open drain in which when pulled down, it identifies that ECC logic has detected two bit errors during the current read cycle. It allows for wired-or of multiple MBE when using multiple MRAMs.

PIN NAMES

Table 1. 8M x 8 Pin Functions

Signal Name	Function
A[22:0]	Address Input
/E[3:0][1]	Chip Enable
/E_All	Chip Enable All
/W	Write Enable
/G	Output Enable
DQ[7:0]	Data I/O
VDD	Power Supply
VSS	Ground
ZZ/RST	Deep Power Down/Reset (Internal pull down)
MBE[2]	Multi-Bit Error Flag
NUO	Not used output Do not connect Driven internally

***Notes:**
1.Only one /E[3:0] pin may be active at any time.
2. MBE pin is not functionally tested for prototypes.

Table 2. Chip Enable Functions Table

/E_ALL	/E_0	/E_1	/E_2	/E_3	A22	A21	Comment
0	1	1	1	1	0	0	MRAM Die 0 Enabled
0	1	1	1	1	0	1	MRAM Die 1 Enabled
0	1	1	1	1	1	0	MRAM Die 3 Enabled
0	1	1	1	1	1	1	MRAM Die 2 Enabled
1	0	1	1	1	X	X	MRAM Die 0 Enabled
1	1	0	1	1	X	X	MRAM Die 1 Enabled
1	1	1	0	1	X	X	MRAM Die 2 Enabled
1	1	1	1	0	X	X	MRAM Die 3 Enabled

***Note:** Only one /E[3:0] pin may be active at any time.

Table 3. Device Operation Truth Table

ZZ/ RST	/E[3:0]*	/G	/W	Mode	VDD Current	DQ[7:0]
H	X	X	X	Deep Sleep/ Reset Mode	Q_{IZZ}	HI-Z
L	H	X	X	Not Selected	Q_{IDD}	HI-Z
L	L	H	H	Output Disabled	I_{DDR}	HI-Z
L	L	L	H	Byte Read	I_{DDR}	D_{OUT}
L	L	X	L	Byte Write	I_{DDW}	D_{IN}

***Note:** Only one /E[3:0] pin may be active at any time.

READ CYCLE

A combination of /W greater than V_{IH} (min) and a single /En less than V_{IL} (max) defines a read cycle. Read access time is measured from the latter of chip enable, output enable, or valid address to valid data output.

MRAM Read Cycle 1, the Address Access in Figure 4a, is initiated by a change in address inputs after a single /En is asserted, /G asserted and /W deasserted. Valid data appears on data outputs DQ[7:0] after the specified t_{AVQV} is satisfied. Outputs remain active throughout the entire cycle. As long as a single chip enable and output enable are active, the address inputs may change at a rate equal to the minimum read cycle time (t_{AVAV}).

MRAM Read Cycle 2, the Chip Enable-controlled Access in Figure 4b, is initiated by a single /En going active while /G remains asserted, /W remains deasserted, and the addresses remain stable for the entire cycle. After the specified t_{ELQV} is satisfied, the eight-bit word addressed by A[20:0] is accessed and appears at the data outputs DQ[7:0].

WRITE CYCLE

A combination of /W and a single /En less than V_{IL}(max) defines a write cycle. The state of /G is a “don’t care” for a write cycle. The outputs are placed in the high-impedance state when either /G is greater than V_{IH}(min), or when /W is less than V_{IL}(max).

Write Cycle 1, the Write Enable-controlled Access in Figure 5a, is defined by a write terminated by /W going high, with a single /En still active. The write pulse width is defined by t_{WLWH} when the write is initiated by /W, and by t_{ETWH} when the write is initiated by a single /En. Unless the outputs have been previously placed in the high-impedance state by /G, the user must wait t_{WLQZ} before applying data to the nine bidirectional pins DQ[7:0] to avoid bus contention.

Write Cycle 2, the Chip Enable-controlled Access in Figure 5b, is defined by a write terminated by a single /En going inactive. The write pulse width is defined by t_{WLEH} when the write is initiated by /W, and by t_{ELEH} when the write is initiated by a single /En going active. For the /W initiated write, unless the outputs have been previously placed in the high-impedance state by /G, the user must wait t_{WLQZ} before applying data to the eight bidirectional pins DQ[7:0] to avoid bus contention.

OPERATIONAL ENVIRONMENT

The UT8MR8M8 MRAM incorporates special design and layout features which allows operation in harsh environments.

Table 4. Operational Environment Design Specifications

PARAMETER	LIMIT	UNITS
TID	1	Mrad(Si)
SEL Immunity[1]	≤ 112	MeV-cm^2/mg
SEU Memory Cell Immunity[2]	≤ 112	MeV-cm^2/mg

Notes:
1. SEL test performed at V_{DD} = 3.6V and temperature = 125^{o}C.
2. SEU test performed at V_{DD} = 3.0V and unpowered at room temperature.

POWER UP AND POWER DOWN SEQUENCING

The MRAM is protected from write operations whenever V_{DD} is less than V_{WI}. As soon as V_{DD} exceeds V_{DD}(min), there is a startup time of 2 ms before read or write operations can start. This time allows memory power supplies to stabilize. The /En and /W control signals should track V_{DD} on power up to V_{DD}-0.2 V or V_{IH} (whichever is lower) and remain high for the startup time. In most systems, this means that these signals should be pulled up with a resistor so the signal remains high if the driving signal is Hi-Z during power up. Any logic that drives /En and /W should hold the signals high with a power-on reset signal for longer than the startup time. During power loss or brownout where V_{DD} goes below V_{WI}, writes are protected and a startup time must be observed when power returns above V_{DD}(min).

The MRAM supports sleep/reset mode operation using the ZZ/RST control pin. To enter sleep mode/reset, ZZ/RST must be pulled high. The device will enter sleep/reset mode within 40ns. In order to exit sleep/reset mode, /En and /W must be high before ZZ/RST is pulled low. As soon as ZZ/RST is driven low, the user must allow 100us before performing any other operation in order for the device to properly initialize. Aeroflex recommends designing a system level method to toggle the ZZ/RST pin in order to reset the MRAM device.

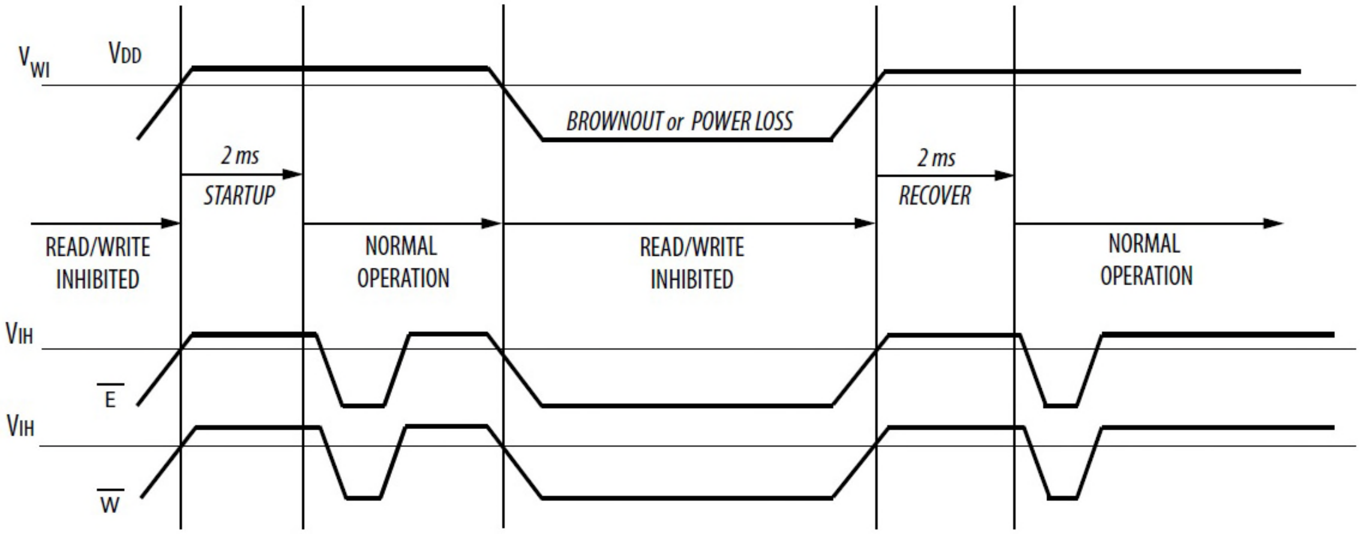


Figure 4. UT8MR2M8 Power Up and Power Down Sequencing Diagram

MBE PIN FUNCTIONALITY AND SEQUENCING

The 64M MRAM is a Multi-Chip Module (MCM) made up of four 16M MRAM die. Each die has its own open drain MBE pin and these pins are wire or connected within the UT8MR8M8 package. The MBE output is not defined after power up or after coming out of sleep until the MRAM is enabled for the first time. In order for the MBE pin to have guaranteed valid data, all die within the package must be accessed. This can be accomplished by toggling the four separate enable pins (/En[0:3]) , or by toggling through A[22:21] with /En_ALL held low. See Figures 5 and 6.

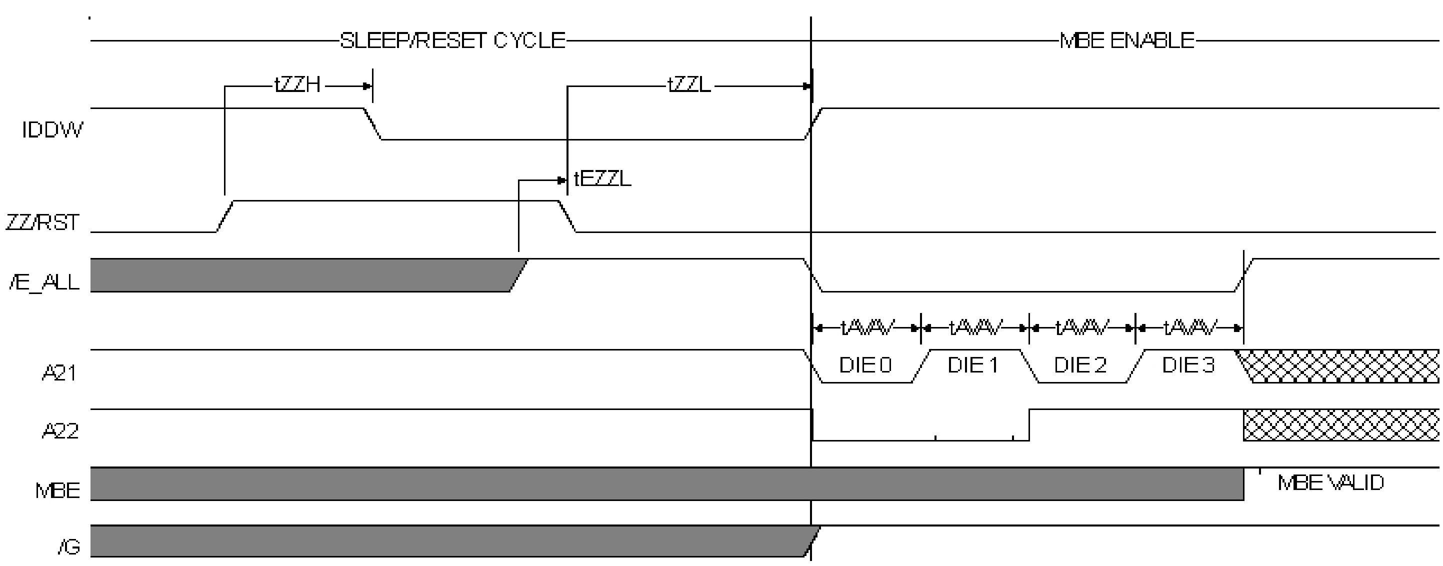


Figure 5. Post Reset MBE Enable using A21, A22, & /E_All

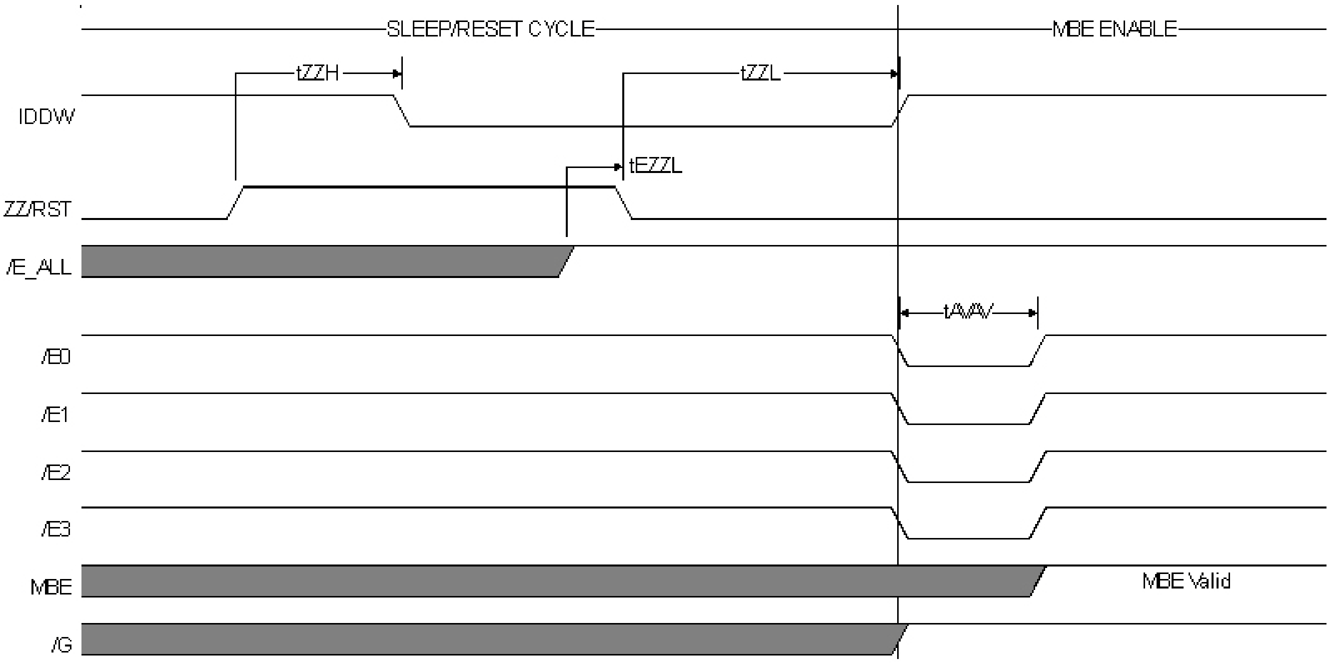


Figure 6. Post Reset MBE enable using enable pins /E[3:0]

ABSOLUTE MAXIMUM RATINGS[1]

(Referenced to V_{SS})

The device contains protection against magnetic fields. Precautions should be taken to avoid device exposure of any magnetic field intensity greater than specified.

SYMBOL	PARAMETER	VALUE	UNIT
V_{DD}	Supply Voltage[2]	-0.5 to 4.3	V
V_{IN}	Voltage on any pin[2]	-0.5 to V_{DD}+0.5	V
I_{IO}	DC I/O current per pin @ T_J = 125° for 20yrs	± 20	mA
P_D	Package power dissipation[3]	4	W
T_J	Maximum junction temperature	+150	^{o}C
θ_{JC}	Thermal resistance junction to case – Single Die	5	^{o}C/W
T_{STG}	Storage temperature	-65 to +125	^{o}C
ESD_{HBM}	ESD	>2000	V
H_{max_write}	Maximum magnetic field during write	8000	A/m
H_{max_read}	Maximum magnetic field during read or standby	8000	A/m

Notes:

1. Permanent device damage may occur if absolute maximum ratings are exceeded. Functional operation should be restricted to recommended operating conditions. Exposure to excessive voltages or magnetic fields could affect device reliability.
2. All voltages are referenced to V_{SS}.
3. Power dissipation capability depends on package characteristics and use environment

RECOMMENDED OPERATING CONDITIONS

SYMBOL	PARAMETER	LIMITS
T_C	Operating case temperature	-40^{o}C to +105^{o}C
V_{DD}	Operating supply voltage	3.0V to 3.6V
V_{WI}	Write inhibit voltage	2.5V to 3.0V[1]
V_{IH}	Input high voltage	2.2V to V_{DD}+0.3V
V_{IL}	Input low voltage	V_{SS}-0.3V to 0.8V

Notes:

1. After power up or if V_{DD} falls below V_{WI}, a waiting period of 2 ms must be observed, and /En and /W must remain high for 2 ms. Memory is designed to prevent writing for all input pin conditions if V_{DD} falls below minimum V_{WI}.

DC ELECTRICAL CHARACTERISTICS (Pre and Post-Radiation)*

V_{DD} = 3.0V to 3.6V; Unless otherwise noted, Tc is per the temperature ordered

SYMBOL	PARAMETER	CONDITION		MIN	MAX	UNIT
V_{IH}	High-level input voltage			2.0		V
V_{IL}	Low-level input voltage				0.8	V
V_{OL1}	Low-level output voltage	I_{OL} = 4mA, V_{DD} = V_{DD} (min)			0.4	V
V_{OL2}	Low-level output voltage	I_{OL} = + 100µA, V_{DD} = V_{DD} (min)			V_{SS}+0.2	V
V_{OH1}	High-level output voltage	I_{OH} = -4mA, V_{DD} = V_{DD} (min)		2.4		V
V_{OH2}	High-level output voltage	I_{OH} = -100µA, V_{DD} = V_{DD} (min)		V_{DD}-0.2		V
C_{IN}[1]	Input capacitance	f = 1MHz @ 0V			50	pF
C_{IO}[1]	Bidirectional I/O capacitance	f = 1MHz @ 0V			60	pF
I_{IN}	Input leakage current	V_{IN} = V_{DD} and V_{SS}		-1	+1	µA
I_{INZZ}	Input leakage current ZZ/RST	V_{IN} = V_{DD} and V_{SS}		-0.25	0.25	mA
I_{OZ}	Three-state output leakage current	V_O = V_{DD} and V_{SS}, V_{DD} = V_{DD} (max) /G = V_{DD} (max)		-1	+1	µA
I_{OS}[2, 3]	Short-circuit output current	V_{DD} = V_{DD} (max), V_O = V_{DD} V_{DD} = V_{DD} (max), V_O = V_{SS}		-100	+100	mA
I_{DDR}	Active read supply current	Read mode f = max (I_{OUT} = 0mA; V_{DD} = max)			140	mA
I_{DDW}	Active write supply current	Write mode f = 10 MHz (V_{DD} = max)			140	mA
QI_{DD}	Quiescent supply current	CMOS leakage current (/E = V_{DD}; all other inputs equal V_{SS} or V_{DD}; V_{DD} = max)	-40°C +25°C		30	mA
			+105°C		35	mA
QI_{ZZ}[4]	Deep power down and reset supply current	CMOS leakage current (/E = V_{DD}; all other inputs equal V_{SS} or V_{DD}; V_{DD} = max)			1	mA

Notes:

* For devices procured with a total ionizing dose tolerance guarantee, the post-irradiation performance is guaranteed at 25°C per MIL-STD-883 Method 1019, Condition A up to the maximum TID level procured.

1. Measured only for initial qualification and after process or design changes that could affect input/output capacitance.
2. Supplied as a design limit but not guaranteed or tested.
3. Not more than one output may be shorted at a time for maximum duration of one second.
4. Allow 100µs to exit sleep/reset mode before performing any other operation.

AC CHARACTERISTICS READ CYCLE[1] (Pre and Post-Radiation)*

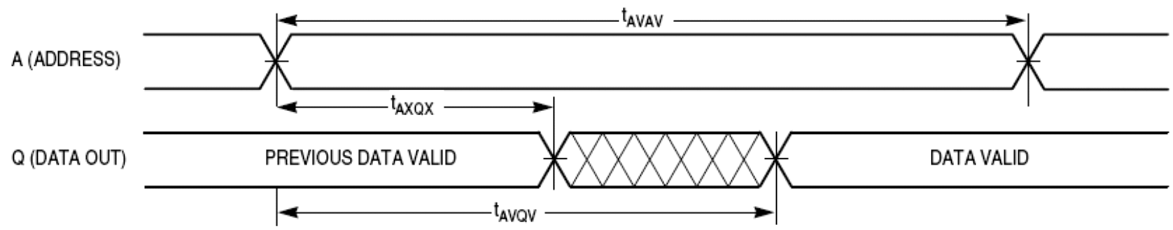
$V_{DD} = V_{DD}$ (min); Unless otherwise noted, Tc is per the temperature ordered

SYMBOL	PARAMETER	MIN	MAX	UNIT
t_{AVAV}	Read cycle time	50		ns
t_{AVQV}	Address access time		50	ns
t_{ELQV}[2]	Enable access time		50	ns
t_{GLQV}	Output enable access time		25	ns
t_{AXQX}	Output hold from address change	3		ns
t_{ELQX}[3]	Enable low to output active	3		ns
t_{GLQX}[3]	Output enable low to output active	0		ns
t_{EHQZ}[3]	Enable high to output Hi-Z	0	15	ns
t_{GHQZ}[3]	Output enable high to output Hi-Z	0	15	ns

Notes:

* For devices procured with a total ionizing dose tolerance guarantee, the post-irradiation performance is guaranteed at 25°C per MIL-STD-883 Method 1019, Condition A up to the maximum TID level procured.

1. /W is high for read cycle. Power supplies must be properly grounded and decoupled, and bus contention conditions must be minimized or eliminated during read or write cycles.
2. Address valid before or at the same time /En goes low.
3. Transition is measured at +/-400mV from the steady-state voltage.



NOTES:

Device is continuously selected **(/En ≤ V_{IL}, $\overline{G}$ ≤ V_{IL}).**

Figure 7a. MRAM Read Cycle 1

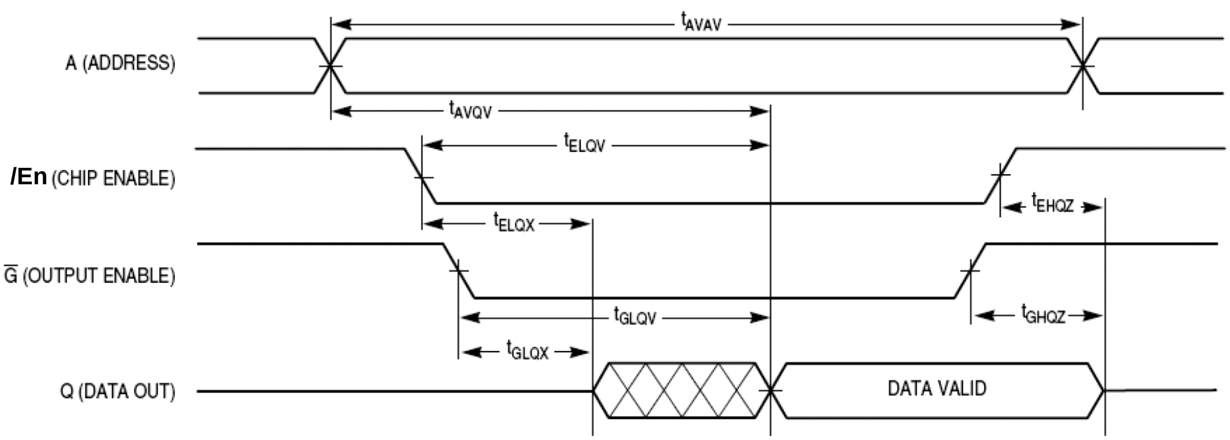


Figure 7b. MRAM Read Cycle 2

AC CHARACTERISTICS /W CONTROLLED WRITE CYCLE (Pre and Post-Radiation)*

V_{DD}= V_{DD} (min); Unless otherwise noted, Tc is per the temperature ordered.

SYMBOL	PARAMETER	MIN	MAX	UNIT
t_{AVAV}[2]	Write cycle time	50		ns
t_{AVWL}	Address set-up time	0		ns
t_{AVWH}	Address valid to end of write (/G high)	28		ns
t_{AVWH}	Address valid to end of write (/G low)	28		**ns**
t_{WLWH} t_{WLEH}	Write pulse width (/G high or low)	28		ns
t_{DVWH}	Data valid to end of write	10		ns
t_{WHDX}	Data hold time	0		ns
t_{WLQZ}[3]	Write low to data Hi-Z	0	15	ns
t_{WHQX}[3]	Write high to output active	3		ns
t_{WHAX}	Write recovery time	16		ns

Notes:

* For devices procured with a total ionizing dose tolerance guarantee, the post-irradiation performance is guaranteed at 25°C per MIL-STD-883 Method 1019, Condition A up to the maximum TID level procured.

1. All write occurs during the overlap of /En low and /W low. Power supplies must be properly grounded and decoupled, and bus contention conditions must be minimized or eliminated during read or write cycles. If /G goes low at the same time or after /W goes low, the output will remain in a high impedance state.
2. All write cycle timings are referenced from the last valid address to the first transition address.
3. Transition is measured +/-400mV from the steady-state voltage.

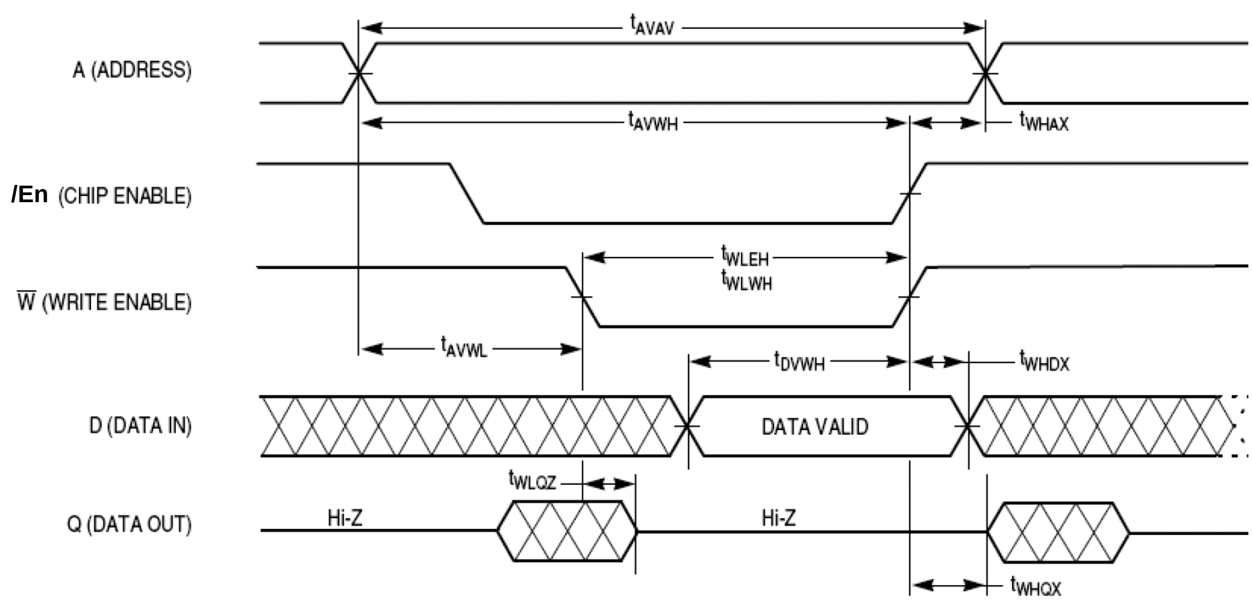


Figure 8a. MRAM Write Cycle 1 (/W Controlled Access)

AC CHARACTERISTICS /En CONTROLLED WRITE CYCLE[1] (Pre and Post-Radiation)*

V_{DD}= V_{DD} (min); Unless otherwise noted, Tc is per the temperature ordered.

SYMBOL	PARAMETER	MIN	MAX	UNIT
t_{AVAV}[2]	Write cycle time	50		ns
t_{AVEL}	Address set-up time	0		ns
t_{AVEH}	Address valid to end of write (/G high)	28		ns
t_{AVEH}	Address valid to end of write (/G low)	28		**ns**
t_{ELEH} t_{ELWH}	Enable to end of write (/G high)	28		ns
t_{ELEH}[3] t_{ELWH}[3]	Enable to end of write (/G low)	28		ns
t_{DVEH}	Data valid to end of write	10		ns
t_{EHDX}[4]	Data hold time	0		ns
t_{EHAX}[4]	Write recovery time	16		ns

Notes:

* For devices procured with a total ionizing dose tolerance guarantee, the post-irradiation performance is guaranteed at 25°C per MIL-STD-883 Method 1019, Condition A up to the maximum TID level procured.

1. All write occurs during the overlap of /En low and /W low. Power supplies must be properly grounded and decoupled, and bus contention conditions must be minimized or eliminated during read or write cycles. If /G goes low at the same time or after /W goes low, the output will remain in a high impedance state.
2. All write cycle timings are referenced from the last valid address to the first transition address.
3. If /En goes low at the same time or after /W goes low, the output will remain in a high-impedance state. If /En goes high at the same time or before /W goes high, the output will remain in a high-impedance state.
4. Transition is measured +/-400mV from the steady-state voltage.

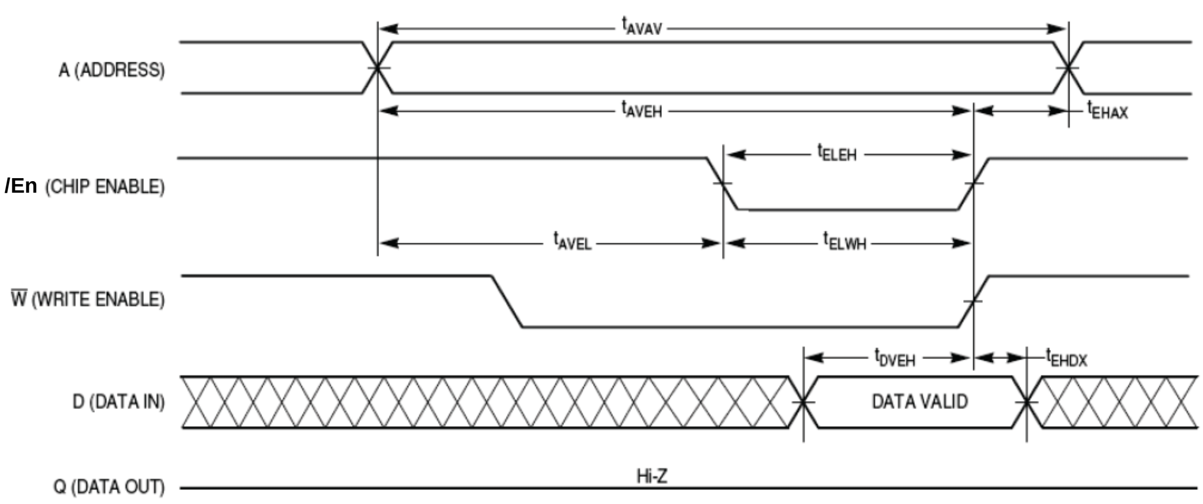


Figure 8b. MRAM Write Cycle 2 (/En Controlled)

AC CHARACTERISTICS SLEEP/RESET MODE (Pre and Post-Radiation)*

$V_{DD}= V_{DD}$ (min); Unless otherwise noted, Tc is per the temperature ordered.

SYMBOL	PARAMETER	MIN	MAX	UNIT
t_{ZZL}[1,3]	Sleep/reset mode exit delay		100	µs
t_{ZZH}[2,3]	Sleep/reset mode access time	50		ns
t_{EZZ}[3]	Sleep/reset mode exit setup time	0		ns
t_{ZZS}[3]	Sleep/reset mode settle time		200	µs

Notes:

* For devices procured with a total ionizing dose tolerance guarantee, the post-irradiation performance is guaranteed at 25°C per MIL-STD-883 Method 1019, Condition A up to the maximum TID level procured.

1. /En and /W must be high when ZZ/RST is pulled low in order to exit sleep/reset mode.
2. ZZ/RST must be high for 40ns in order to enter sleep/reset mode.
3. Parameters are supplied as a design limit, but are not tested nor guaranteed.

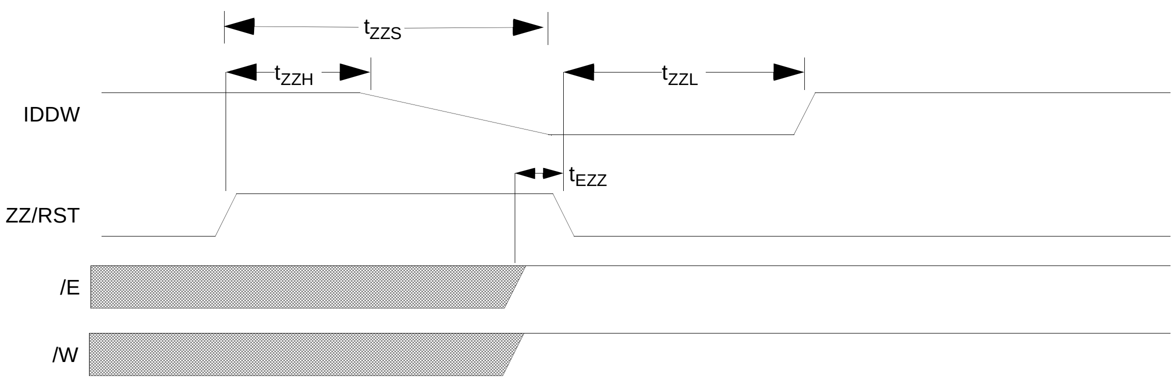
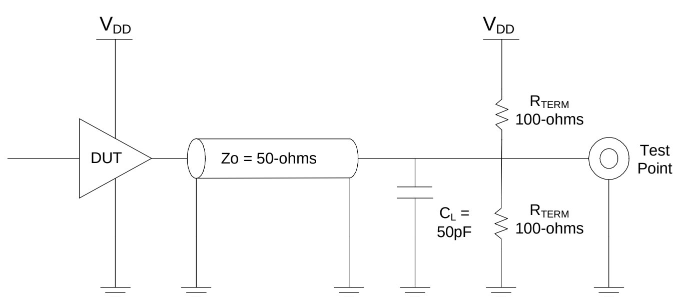


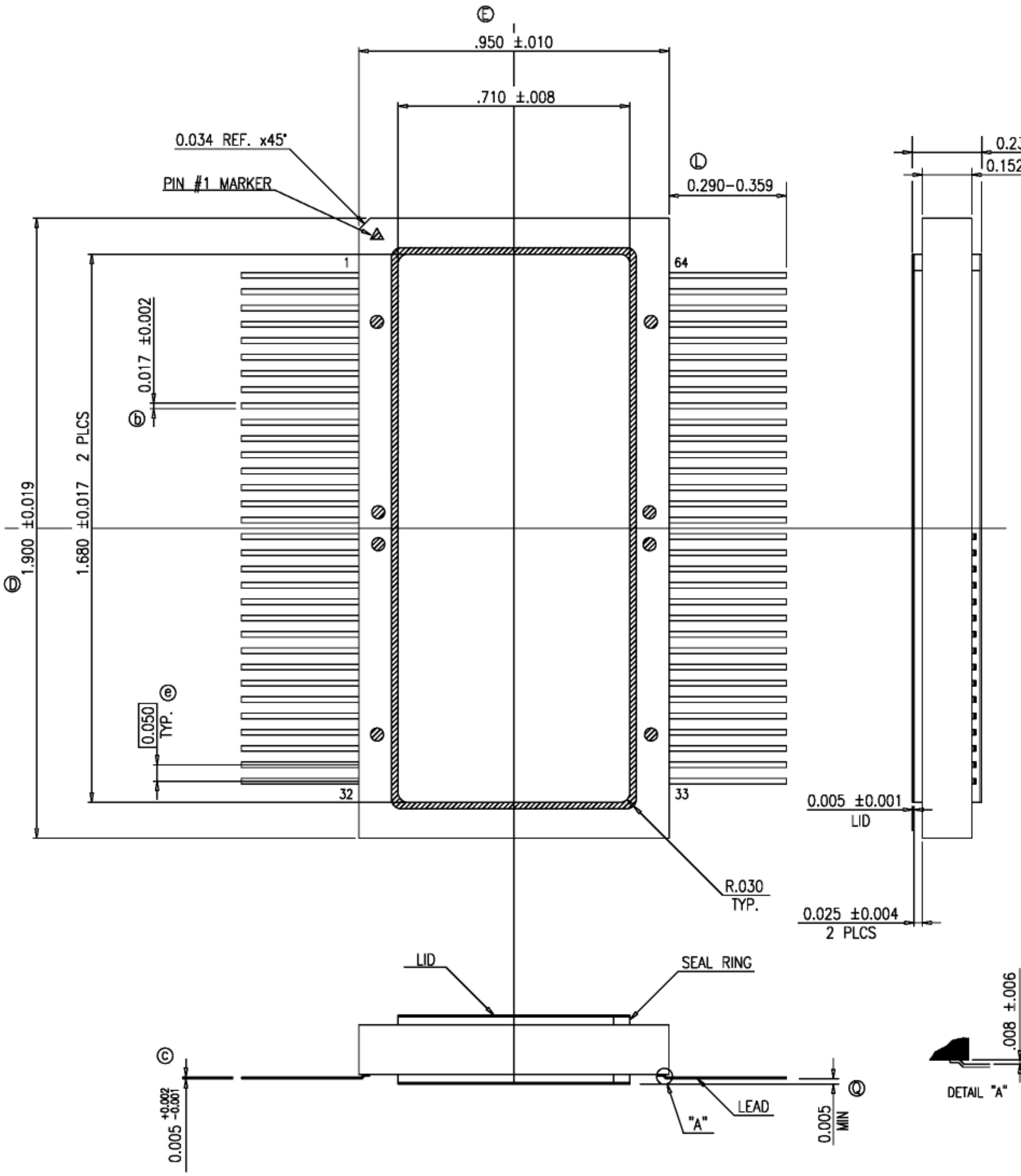
Figure 9. MRAM Sleep/Reset Mode Timing Diagram



Notes:

1. Measurement of data output occurs at the low to high or high to low transition mid-point, typically, $V_{DD}/2$.

Figure 10. AC Output Test Load or Equivalent



NOTES
1. LID IS CONNECTED TO VSS
2. UNITS ARE IN INCHES

Figure 11. 64-Pin Ceramic Flatpack

ORDERING INFORMATION

8M x 8 MRAM:

UT ****** - * * * * *

Lead Finish: **(Note 1)**
(C) = Gold

Screening: **(Note 2,3)**
(E) = HiRel flow (Temperature range: -40°C to +105°C)
(P) = Prototype flow (Temperature range: 25°C only)

Package Type:
(X) = 64-lead Ceramic Flatpack (50mil lead pitch)

Access Time:
(50) = 50ns access time

Device Type:
(8MR8M8) = 8Mx8 MRAM

Notes:
1. Lead finish is "C" (Gold) only.
2. Prototype flow per Aeroflex Colorado Springs Manufacturing Flows Document. Radiation neither tested nor guaranteed.
3. HiRel Temperature Range flow per Aeroflex Colorado Springs Manufacturing Flows Document. Radiation neither tested nor guaranteed.

8M x 8 MRAM: SMD

5962 - ******* ** * * *

Lead Finish: **(Note 1)**
(C) = Gold

Case Outline:
(X) = 64-lead Ceramic Flatpack

Class Designator:
(Q) = QML Class Q
(V) = QML Class V

Device Type **(Note 2)**
(01) = 50ns access time. Temperature Range (-40°C to +105°C)
(02) = 50ns access time (-40°C to +105°C) manufactured to QML-Q+ flow

Drawing Number: 13207

Total Dose:
(R) = 100 krad(Si)
(F) = 300 krad(Si)
(G) = 500 krad(Si)
(H) = 1 Mrad(Si)

Federal Stock Class Designator: No options

Notes:

1. Lead finish is "C" (Gold) only.
2. Aeroflex's Q+ flow, as defined in Section 4.2.2d of SMD, provides QML-Q product through the SMD that is manufactured with Aeroflex's standard QML-V flow.

Cobham Colorado Springs - Datasheet Definition

Advanced Datasheet - Product In Development

Preliminary Datasheet - Shipping Prototype

Datasheet - Shipping QML & Hi-Rel

The following United States (U.S.) Department of Commerce statement shall be applicable if these commodities, technology, or software are exported from the U.S.: These commodities, technology, or software were exported from the United States in accordance with the Export Administration Regulations. Diversion contrary to U.S. law is prohibited.

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COBHAM

DATA SHEET REVISION HISTORY

Revision Date	Description of Change	Page(s)
January 2016	Added new Cobham datasheet template, QML V Achieved, added ZZ/RST description of internal pull-down, updated maximum junction temperature to 150C, changed unit from uA to mA for the IINZZ specification, and added MBE Functionality verbiage and diagrams.	All
November 2017	Removed (T) Prototype flow (Temperature range: -40 to +105C) as an ordering option.	14

Magnetic Immunity of the MRAM Devices

Table 1: Cross Reference of Applicable Products

PRODUCT NAME	MANUFACTURER PART NUMBER	SMD #	DEVICE TYPE	INTERNAL PIC#
16Mb MRAM Device	UT8MR2M8	5962-12227	01	WP01
64Mb MRAM Device	UT8MR8M8	5962-13207	01	MQ09

*PIC = Product Identification Code

1. Overview

Aeroflex Colorado Springs offers a 16Mb and 64Mb Non-Volatile Magnetoresistive Random Access Memory (MRAM) device. The MRAM devices are designed specifically for operation in both HiRel and Space environments. This application note addresses concerns with the magnetic immunity of these devices. Aeroflex has determined that the MRAM devices have no magnetic risk in the space environment and recommends proper handling to address terrestrial environments.

2. Magnetic Fields

All magnetic fields are caused by electrical charge in motion. Even the fields from a stationary permanent magnet are the result of the rotation (quantum spin) of electrons within the material. There are two "components" of a magnetic field which are both commonly called "magnetic field." They are the B field (historically called Magnetic Induction) and the H field (historically called Magnetic Field). They are related by the equation $B = H + 4\pi M$ where M is a term called "Magnetization" or "Magnetic Polarization" and is a property of the materials through which the fields pass. Technically, M is the magnetic moment of the material per unit volume. To obtain the total B field, if considering the field in a volume of space, the free (unbound field) H plus the bound fields (magnetic dipoles) M must be known. If there are no permanent magnets in the particular volume of space being analyzed, then M is proportional to H and $B = \mu H$ where $\mu =$ magnetic permeability. Because the B field is dependent on material properties that can be introduced into any given environment, Aeroflex specifies the H field when it determines its environmental conditions.

3. Units of Measure

Both B and H fields have their own unique units of measure. As explained previously, Aeroflex specifies the magnetic field in terms of H and in CGS (centimetre-gram-second) units.

	CGS Units	S. I. Units
Magnetic Induction (B)	**Gauss (G)**	**Tesla (T)**
Magnetic Field (H)	**Oersted (Oe)**	**Amps/meter (A/m)**

1 Oe = 1G (in free space)
1 G = 10^{-4} T
1 Oe = 79.6 A/m = $10^3/4\pi$ A/m
1 nT = 1 Gamma

Figure 1: CGS vs S.I. Units

The constant 4π is present in the term μ described in the Magnetic Fields section above. The 4π is absorbed into the definition of the oersted; therefore, in regions of space where no external dipoles are present, 1 oersted = 1 Gauss. This 4π is not incorporated into the definition when converting Gauss to A/m. A conversion table is useful; however, note that B is not truly equivalent to H and can sometimes be off by a factor of 4π. The following conversion table and a link to a calculator that facilitates converting between these units can be found at http://www.smpspowersupply.com/magnetic-unit-conversion.html.

Table 2: Magnetic Field Conversion Table

QUANTITY	SYMBOL	SI UNIT	SI EQUATION	CGS UNIT	CGS EQUATION	CONVERSION FACTOR
Magnetic induction	B	tesla (T)	$B=\mu_o(H+M)$	Gauss (G)	$B = H+4\pi M$	$1\ T = 10^4\ G$
Magnetic field strength	H	ampere/meter (A/m)	$H = N\times I/lc$ (lc - magnetic path, m)	oersted (Oe)	$H = 0.4\pi N\times I/lc$ (lc - magnetic path, cm)	$1\ A/m = 4\ \pi\times 10^{-3}\ Oe$
Magnetic flux	Φ	weber (Wb)	$\Phi = B\times Ac$ (Ac - area, m^2)	maxwell (M)	$\Phi = B\times Ac$ (Ac - area, cm^2)	$1\ Wb = 10^8\ M$
Magnetization	M	ampere/meter (A/m)	M=m/V (m- total magnetic moment, V- volume, m^3)	emu/cm^3	M=m/V (m- total magnetic moment, V- volume, cm^3)	$1\ A/m = 10^{-3}\ emu / cm^3$
Magnetic permeability of vacuum	μ_o	newton/ampere	$\mu_o= 4\pi\times 10^{-7}$	1	-	$4\pi\times 10^{-7}$
Inductance	L	henry	$L=\mu_o\mu N^2Ac/lc$ (Ac- area, m^2, lc - magnetic path, m)	henry	$L=0.4\pi\mu N^2Ac/lc\times 10^{-8}$ (Ac-area, cm^2, lc - magnetic path, cm)	1
Emf (voltage)	V	volt	$V=-N\times d\Phi/dt$	volt	$V=-10^{-8}N\times d\Phi/dt$	1

4. Aeroflex MRAM Magnetic Immunity

The storage element in an MRAM stores data on magnetic layers that are switched by very localized magnetic fields developed on chip. To change the state of a memory element, the circuit applies three sequential magnetic fields to a bit cell, each with a different orientation. Without this specific pattern, the bit will not flip. This technique called “Toggle MRAM,” along with the shielding solution from Aeroflex, prevents even strong external magnetic fields from inadvertently corrupting the memory. The MRAM products are guaranteed to be immune to magnetic fields up to 8000 A/M (100 G) during reading, writing, static, or unpowered operation. The magnetic immunity specifications are valid during both powered and unpowered conditions.

5. Magnetic Shielding

Magnetic shielding can be incorporated into a package by surrounding the die with high permeability metal. Shields don't block magnetic fields, rather these shields channel magnetic flux into them much like a low resistance conductor does for electrical current. This property of high permeability materials can lead to both increased and decreased fields near the shield; therefore, a complete understanding of the physics is vital to constructing a well shielded device. Aeroflex utilized electromagnetic field solver simulation tools to create a robust shielding solution that was integrated into the MRAM package. Aeroflex also performed magnetic field immunity tests with external magnetic fields that exceeded the guaranteed magnetic field specifications.

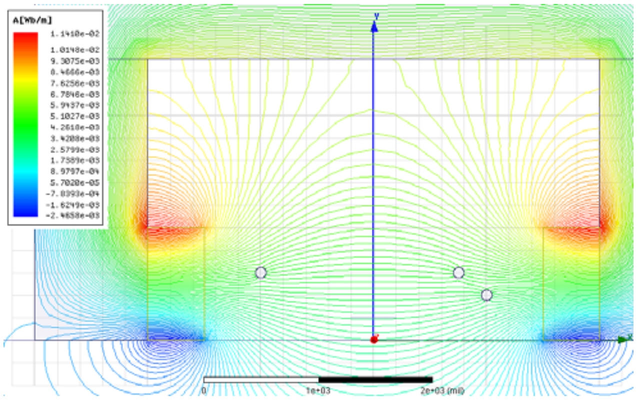

Figure 2: **Electromagnetic Field Simulation Tool**

6. Magnetic Field Environments

The earth's magnetic field is approximately 0.5G but varies depending on your location. Stray magnetic fields (SMFs), caused by electrical currents running through high current wires or from permanent magnetic fields such as those in speakers, leads to much higher values which is why shielding is imperative for the MRAM product. Although these fields can be quite strong they fall off rapidly with distance from the source. For instance a field of a phone speaker magnet may be 60G at the surface of the speaker but will fall off to < 2G at 2cm from the speaker. Below is a list of the strongest ambient magnetic fields found in the solar system along with some examples of man-made magnetic fields.

Table 3: Ambient and Man-Made Magnetic Field Strengths

SOURCE	MAGNETIC FIELD	UNITS
Typical Magnetic Storm	0.001	Gauss
Strongest Magnetic Storm in Space (measured by THEMIS)	0.14	Gauss
Earth's Magnet Field	0.5	Gauss
5cm from MT400 Magnetic Torque Arm Max Field	< 1	Gauss
Adjacent to MT400 Magnetic Torque Arm Max Field	7.6	Gauss
Field at the poles of the Sun	10	Gauss
Field at Jupiter's North Pole (Highest natural field in solar system)	15	Gauss
Field at surface of a typical phone speaker magnet	60	Gauss
Field at 2cm from typical phone speaker magnet	< 2	Gauss

7. Magnetic Fields in PCB Manufacturing

The MRAM devices can be introduced to magnetic fields during PCB manufacturing and handling. Aeroflex Colorado Springs has performed a complete facility audit for magnetic fields. Certain equipment and tools may contain rare earth magnets or can be exposed to magnetic fields that, in time, can become magnetized. Table 4 lists Aeroflex Colorado Springs PCB manufacturing equipment and its associated measured magnetic field measurement. Table 5 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 in which the magnetic field from the listed tool drops off to less than 5 gauss. It is recommended that MRAM devices be kept a minimum of this distance from the tool during PCB assembly operations. It can be observed that as a general rule stray magnetic fields drop off to levels that are safe for the Aeroflex MRAM at a minimum distance of 3 inches from most equipment.

Table 4: Magnetic Field Measurements of PCB Manufacturing Equipment/Machines at Aeroflex

Equipment/Process Description	Make	Model	Direct Measurement (G)	> 0.25 (Inches)	Drop Off (Inches)	Use Measurement (Inches)
Forming	Fancort	Universal Press	N/A	2.1	>1	5.2
Forming	Fancort	Flex Former	N/A	3.2	>1	12.4
Tinning	HMP	Solder Tinning System	<1	<1	N/A	<1
Pick and Place Y Wagon	MyData	MY19	>800	135	>1	7.3
Pick and Place Tray Wagon	MyData	MY19	195	20.6	>1	4.42
Pick and Place Head	MyData	MY19	N/A	<1	N/A	3.2
Pick and Place Motor (not running)	MyData	MY19	62.3	24	>1	N/A
Pick and Place Y Wagon	MyData	MY100	736	156	>1	5.6
Pick and Place Tray Wagon	MyData	MY100	130	32	>1	24
Pick and Place Machine Running	MyData	MY100	N/A	N/A	<1	5.3
Stream Printing Motor	MPM	Momentum	26.7	14.8	>1	0.9
Stream Printing Board Support Bar	MPM	Momentum	16.4	5.2	>1	N/A
Reflow Oven	Vitronics	Soltec	<2	<2	N/A	<2
Reflow Oven	Vitronics	Soltec	N/A	N/A	N/A	8.2
X-Ray	Station	1525	<1	<1	N/A	<1
Air-Vac	Air-Vac	DRS22	<1	<1	N/A	<1
Flying Probe Support Magnet	Genrad	Pilot	>800	152	>1	6.8
Flying Probe Probes	Genrad	Pilot	41	22	>1	4.1
AOI	Mirtec	MV-7XI	<1	<1	N/A	<1
Bake Oven	Blue-X	256	<1	<1	N/A	<1
Adhesive Dispenser Support Magnets	Camelot	FX-D	>800	254	>1.5	130
De-Paneling Router	Cencorp	TR1000	<1	<1	N/A	<1

Table 5: Magnetic Field Measurements of Miscellaneous Items Commonly Found in PCB Manufacturing

Description of Item	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
Metcal 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
Impulse 4G Cell Phone Speaker	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	1.79	N/A	<1
Lenovo Laptop Speakers (T420)	186.6	71.7	>1
Jewelry	>800	174	>1
Micrometer – Exposed to SMF's over time	>100	N/A	<1

8. Aeroflex Colorado Springs Magnetic Process and Flow

Aeroflex Colorado Springs strives to deliver product with the highest quality and reliability. Therefore, we have taken the necessary steps to ensure the MRAM products meet all performance and quality expectations of our customers. To assure we attain this high goal, Aeroflex Colorado Springs has implemented a magnetic process/flow to eliminate any potential stray magnetic fields which may interact with the MRAM devices. The following lists manufacturing specific procedures which are currently being implemented in the development of the MRAM devices:

- Added Magnetic Environment and Handling criteria to applicable internal documentation (similar to ESD control)
- Created detailed manufacturing flows for MRAM/magnetic devices
- Removal or limited use of magnetic wands/pencils/pick-up tools
- Labeling of equipment that contains magnets with Universal Magnetic Symbol

- Aeroflex Colorado Springs Training and Awareness

The following lists product specific features which are currently being implemented on the MRAM devices:

- Marked lids with a Magnetic Warning Symbol
- Magnetic Warning Labels added to shipping bags, boxes, and other packaging materials
- Shipping boxes have at least 2 inches of clearance around the MRAM device
- Application Note for Customer Awareness and Handling Recommendations added to shipping boxes

9. <u>Aeroflex Handling Recommendations for MRAM products</u>

Aeroflex Colorado Springs recommends that customer's keep the MRAM device at least three inches away from any SMF to avoid potential damage to the MRAM device. Aeroflex also recommends that customer's perform a facility audit for SMF's to include any equipment/tools that contain magnets or have been exposed to magnets. Aeroflex Colorado Springs used a Vector/Magnitude Gaussmeter Model VGM to perform a facility audit. The following is a link for detailed information regarding the Vector/Magnitude Gaussmeter Model VGM:

http://www.trifield.com/content/vector-magnitude-gaussmeter-model-vgm/

Aeroflex Colorado Springs also recommends degaussing any non-magnetic equipment/tool that measures over 100G. Degaussing is the process of decreasing or eliminating a remnant magnetic field. Aeroflex utilizes demagnetizers with a portable pistol grip rated from +60G to -60G. Aeroflex recommends that the user move the "wand" in a circular motion while moving over the entire area of the object. When the demagnetizer moves in a circular motion across the area, the demagnetizer will produce +60G and -60G and the magnetic field will decrease to zero over a certain amount of time. Aeroflex uses the following demagnetizers:

- Industrial Magnets – P/N DSC423-120
- Walker Hagou Magnetics – P/N HD2

For more information on the specific demagnetizers that Aeroflex uses, click on the following links:

http://www.magnetics.com/product.asp?ProductID=49
http://www.walkermagnet.com/other-products-demagnetizers-aperture.htm

Plate Type Demagnetizers are ideal for tool room use to demagnetize drills, cutters, ball and roller bearings, etc. The part demagnetizes by sliding it smoothly and slowly over the top of the plate, passing it clear of the demagnetizing field. The flat surface allows easy demagnetization of numerous objects.

Aperture Type Demagnetizers are widely used to demagnetize tools, cutters, small parts, bearing components, and assemblies. The item passes through the aperture and taken away from the demagnetizing field. The user must make sure that the object is well away from the demagnetizing field before the user switches off the demagnetizer.

The product specific demagnetizer manual will have detailed instructions on how to de-gauss an object. Each demagnetizer is different, so the user should understand the operation of the specific demagnetizer purchased.

10. Summary

In summary, Aeroflex MRAMs are immune to magnetic fields below 100G during reading, writing, standby, and unpowered operating conditions. Magnetic exposure is a non-issue in Space as the strongest natural field in the solar system is at Jupiter’s North Pole measuring 15G. Proper handling is required terrestrially, as indicated in this application note. By following Aeroflex’s recommendation to keep the MRAM devices at least 3 inches away from SMFs greater than 100G, is an easy way to avoid magnetic exposure to the MRAM devices. Knowing and understanding the magnetic environment surrounding the MRAM device will help enable the customer to easily and properly handle the MRAM devices.