

# Space Grade Parallel Persistent SRAM Memory

(AS301GB32, AS302GB32, AS304GB32, AS308GB32)

## Features

- Interface
  - Parallel Asynchronous x32
- Technology
  - pMTJ STT-MRAM
  - Virtually unlimited Endurance and Data Retention (see Table 17)
- Density
  - 1Gb, 2Gb, 4Gb, 8Gb
- Memory Array Organization
  - 1Gb : 33,554,432 x 32
  - 2 Gb : 67,108,864 x 32
  - 4 Gb : 134,217,728 x 32
  - 8 Gb : 268,435,456 x 32
- Voltage Range
  - Operating  $V_{CC}$ : 2.50V – 3.60V
  - $V_{CCIO}$ : 1.8V, 2.5V, 3.0V, 3.3V
  - Under Radiation:  $V_{CC}$ : 2.50V – 3.00V \*
  - $V_{CCIO}$ : 1.8V, 2.5V, 3.0V \*
- Temperature Range
  - Operating -40°C to 125°C
  - Operating under radiation -40°C to 85°C \*
- Packages
  - 142-ball FBGA (15mm x 17mm)
- RoHS & REACH Compliant \*\*
- PEMS-INST-001 Flow \*\*\*

\* To assure a Safe Operating Area, limit the device to these specifications.

\*\* Leaded Balls available

\*\*\* PEMS-INST-001 Flow available as custom option through partners

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## General Description

AS3xxx332 is a Spin-transfer torque Magneto-resistive random-access memory (STT-MRAM). It is offered in 1Gbit and 4Gbit. MRAM technology is analogous to Flash technology with SRAM compatible 45ns/45ns read/write timings (Persistent SRAM, P-SRAM). Data is always non-volatile. This makes MRAM a very reliable and fast non-volatile memory solution. Data is always non-volatile with  $10^{16}$  write cycles endurance and greater than 20-year retention @85°C.

**Table 1: Technology Comparison**

	SRAM	Flash	EEPROM	MRAM
<b>Non-Volatility</b>	-	√	√	√
<b>Write Performance</b>	√	-	-	√
<b>Read Performance</b>	√	-	-	√
<b>Endurance</b>	√	-	-	√
<b>Power</b>	-	-	-	√

MRAM is a true random-access memory; allowing both reads and writes to occur randomly in memory. MRAM is ideal for applications that must store and retrieve data without incurring large latency penalties. It offers low latency, low power, high endurance, high performance and scalable memory technology.

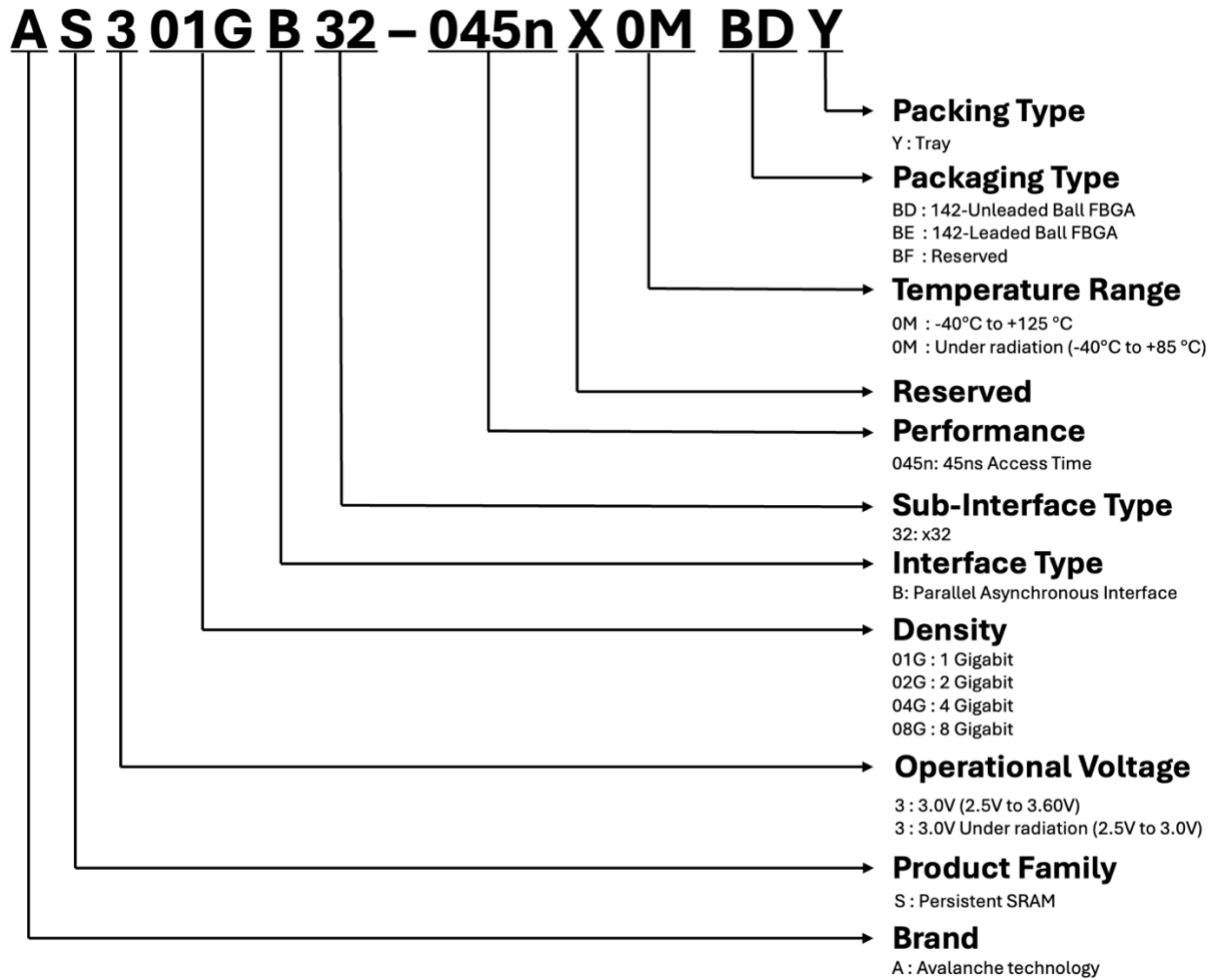
AS3xxx332 is available in small footprint (15mm x 17mm) 142 ball BGA package. In 1,2,4Gb densities the device uses one chip select E#. In this configuration one contiguous address space of 1,2,4Gb is formed. In 8Gb configuration the package has two banks of 4 dies each selectable separately and not at the same time. Each bank is selectable using either E1# and E2#. In the 8Gb configuration E1# and E2# MUST NOT be selected simultaneously as the two banks share the same I/O pins.

AS3xxx332 is offered with industrial extended (-40°C to 125°C) operating temperature ranges: This is measured as the junction temperature.

## Ordering Options

The ordering part numbers are formed by a valid combination of the following options:

**Figure 1: Part Number Ordering Options**



## Valid Combinations — Standard

Valid Combinations list includes device configurations currently available. Contact your local sales office to confirm availability of specific valid combinations and to check on newly released combinations.

**Table 2: Valid Combinations List**

Valid Combinations – 45ns				
Base Part Number	Temperature Range	Package Type	Packing Type	Part Number
AS301GB32-045nX	0M	BD	Y	AS301GB32-045nX0MBDY
AS302GB32-045nX	0M	BD	Y	AS302GB32-045nX0MBDY
AS304GB32-045nX	0M	BD	Y	AS304GB32-045nX0MBDY
AS308GB32-045nX	0M	BD	Y	AS308GB32-045nX0MBDY
AS301GB32-045nX	0M	BE	Y	AS301GB32-045nX0MBEY
AS302GB32-045nX	0M	BE	Y	AS302GB32-045nX0MBEY
AS304GB32-045nX	0M	BE	Y	AS304GB32-045nX0MBEY
AS308GB32-045nX	0M	BE	Y	AS308GB32-045nX0MBEY

## Marking Specification — Standard

The device will be marked according to the following specification:


Line #1 & Line #2 will match the part number in Table 2

Line #3 Will show: 5 digit Alphanumeric Code + Country of Origin + Date Code

Line #4 May or May not be marked. This field is reserved for Avalanche Technology

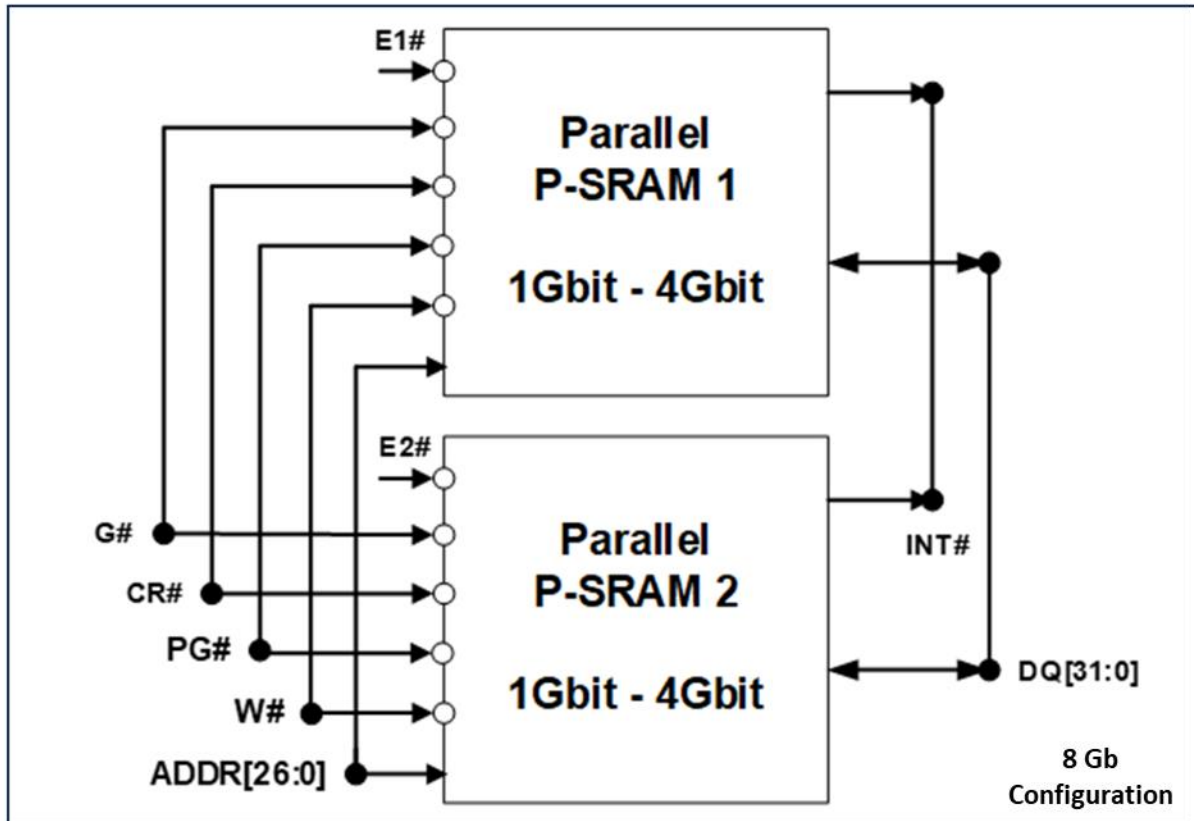
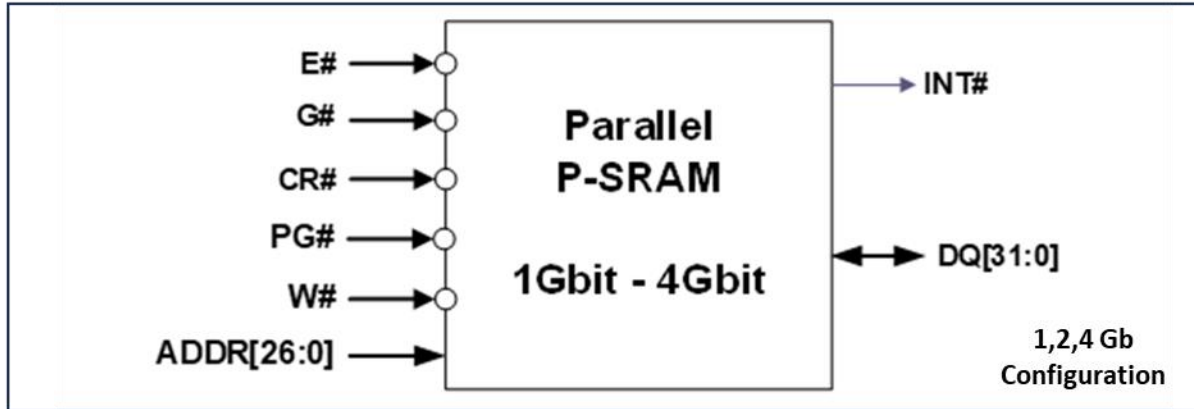
Line #5 May or May not be marked. This field is reserved for Avalanche Technology

**Figure 2: Device Marking**

	xxxx-yyyy	←	Line #5
		←	LOGO
AS304GB32-		←	Line #1
045nX0MBDY		←	Line #2
KM0YG KR 2337		←	Line #3
	bbbb	←	Line #4

## Signal Description and Assignment

Figure 3: Device Pinout



**Table 3: Signal Description**

Signal	Ball Assignment	Type	Description
<b>E# / E1#</b>	P8	Input	<b>1,2,4Gb (E#) : Chip enable:</b> Enables the MRAM array <b>8Gb (E1#) : Chip enable:</b> Enables the 1 <sup>st</sup> bank of 4 MRAM die. There is an internal 10k Pullup. <b>THIS SIGNAL MUST NOT BE ACTIVE AT THE SAME TIME AS E2#.</b>
<b>DNU / E2#</b>	K5	DNU/Input	<b>1,2,4Gb (DNU) :</b> It can be left floating and not connected. <b>8Gb (E2#) : Chip enable:</b> Enables the second bank of 4 MRAM die. <b>THIS SIGNAL MUST NOT BE ACTIVE AT THE SAME TIME AS E1#.</b>
<b>G#</b>	P7	Input	<b>Output enable:</b> Enables the output drivers for data transfer I/Os.
<b>CR#</b>	J2	Input	<b>Configuration Register enable:</b> Enables access to the Configuration registers
<b>PG#</b>	K3	Input	<b>Page Mode:</b> Enables Page mode access
<b>W#</b>	M8	Input	<b>Write enable:</b> Transfers data from the host system to the MRAM when Low (Logic '0'). Transfers data from the MRAM to the host system when High (Logic '1').
<b>ADDR[26:0]</b>	M2, L4, K13, M3, L3, M7, P12, L12, N11, N6, P6, L13, M13, P10, N10, M12, N13, L11, M11, P5, P3, N5, N4, M4, N2, N9, M9	Input	<b>Address:</b> I/Os for address transfer 1G: ADDR[24:0] – 25 Address pins for 1Gb x32 devices.* 2G: ADDR[25:0] – 26 Address pins for 2Gb x32 devices.** 4G: ADDR[26:0] – 27 Address pins for 4Gb x32 devices.
<b>DQ[31:0]</b>	E2, F2, D2, E3, E12, D10, C9, C7, G4, G3, F13, D13, C10, E8, F6, E5, E13, G11, E10, F9, C8, C6, D6, D4, G12, C12, D11, D9, E7, C5, D5, C3	Input / Output	<b>Data inputs/outputs:</b> The bidirectional I/Os transfer data [31:0].
<b>INT# ***</b>	G13	Output	<b>Interrupt:</b> Output generated by the MRAM when an unrecoverable ECC error is detected during read operation (output goes low on error): requires to have an external pull-up resistor (4.7KΩ)
<b>V<sub>ccio</sub></b>	F12, J12, E11, M10, D8, N8, D7, N7, M5, E4, F3, J3	Supply	I/O power supply.
<b>V<sub>ssio</sub></b>	F10, L10, E9, L9, F8, L8, F7, L7, E6, L6, G5,	Supply	I/O ground supply.
<b>V<sub>cc</sub></b>	C13, P13, D12, N12, C11, F11, H11, J11, K11, P11, C4, F4, H4,	Supply	Core power supply.



Signal	Ball Assignment	Type	Description
	J4, K4, P4, D3, N3, C2, P2		
Vss	A14, B14, C14, H13, R14, T14, A13, T13, A12, G10, H10, J10, K10, F5, L5, A2, T2, A1, B1, R1, T1	Supply	Core ground supply.
DNU	J13, H12, K12, P9, M6, H5, J5, H3, G2, H2, K2, L2		<b>Do Not Use:</b> DNUs must be left unconnected.

\* Unused ADDR[26:25] balls should be connected to Ground

\*\* Unused ADDR[25] balls should be connected to Ground

\*\*\* INT# is latched and must be reset/cleared by writing to the ECC Control register.

## Special Configuration Options

There are eight user accessible registers that control ECC, output drive strength and array write protection. All registers are 32-bit wide. These registers are only available during device configuration and not accessible to the user. In a multi-die configuration (2Gb, 4Gb) each 1Gb die has its own set of registers and need to be programmed individually. Each die needs to be selected using the upper 2 MSB address bits.

### ECC Registers

There are 6 registers that allow access to the ECC engine during the life of the product to access the functionality of the circuits. During normal use, the ECC engine will correct any soft errors.

### INT# functionality

As explained in the pinout, the INT# will go active if uncorrectable error is encountered. This is an open collector output which requires a pullup. In a multi-chip configuration (2G, 4G) the pin is shared between the dies. The recommended next steps are up to the system architect. The host must interrogate each die to identify which one/ones caused the interrupt to clear the INT Flag register.

**ECC Control Register – Read and Write**

Bits	Name	Description	Read / Write	Default State	Select Options
[31:2]	RSVD	Reserved	R	31'b0	Reserved for future use
[1]	Interrupt Reset	Resets the interrupt generated in response to detection of an unrecoverable error and clears the interrupt flag.	W		0: Don't reset 1: Reset ECC unrecoverable error interrupt
[0]	Error_Count_Reset	Resets the ECC Error Count Register	W	0	0: Don't reset 1: Reset ECC Error Count Register to zero

### Output Drive Strength Register

The default setting of this register is 00.

**Output Drive Strength Register – Read and Write**

Bits	Name	Description	Read / Write	Default State	Select Options			
[31:3]	RSVD	Reserved	R	0	Reserved for future use			
[2]	Enable_Drive_Strength	Enables or disables the drive strength setting	R/W	0	0: Default setting 1: Use output drive strength setting			
[1:0]	Output_Drive_Strength_Setting	Output drive strength	R/W	00		1.8V	2.5V	3.3V
					00	1mA	2.5mA	4mA
					01	3mA	5mA	8mA
					10	5mA	10mA	14mA
					11	7mA	14mA	18mA

## Device Protection Register

It is possible to write protect the Memory array as shown in the table below. Note; The term full array is defined as an array of 1Gb.

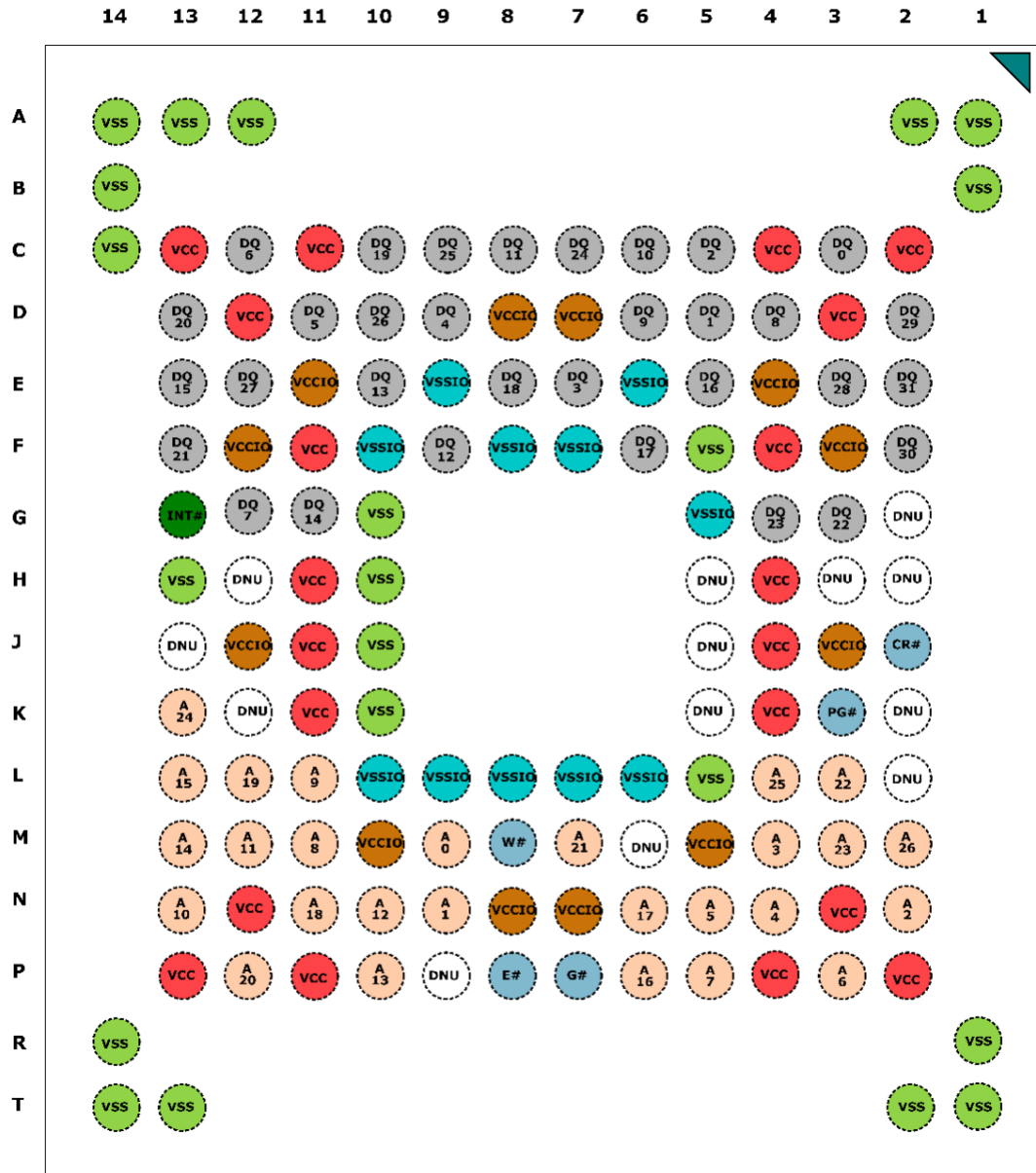
***Device Protection Register – Read and Write***

Bits	Name	Description	Read / Write	Default State	Select Options
[31:3]	RSVD	Reserved	R	29'b0	Reserved for future use
[2:0]	BPSEL[2:0]	Enables or disables block protection	R/W	3'b0	000 – Disabled 001 – Protect upper 1/64 array 010 – Protect upper 1/32 array 011 – Protect upper 1/16 array 100 – Protect upper 1/8 array 101 – Protect upper 1/4 array 110 – Protect upper 1/2 array 111 – Protect full array

## Package Options

### 142-Ball FBGA – 1,2,4Gb

### AS301GB32, AS302GB32, AS304GB32 (Bottom View)



### 142-Ball FBGA – 8Gb AS308GB32 (Bottom View)

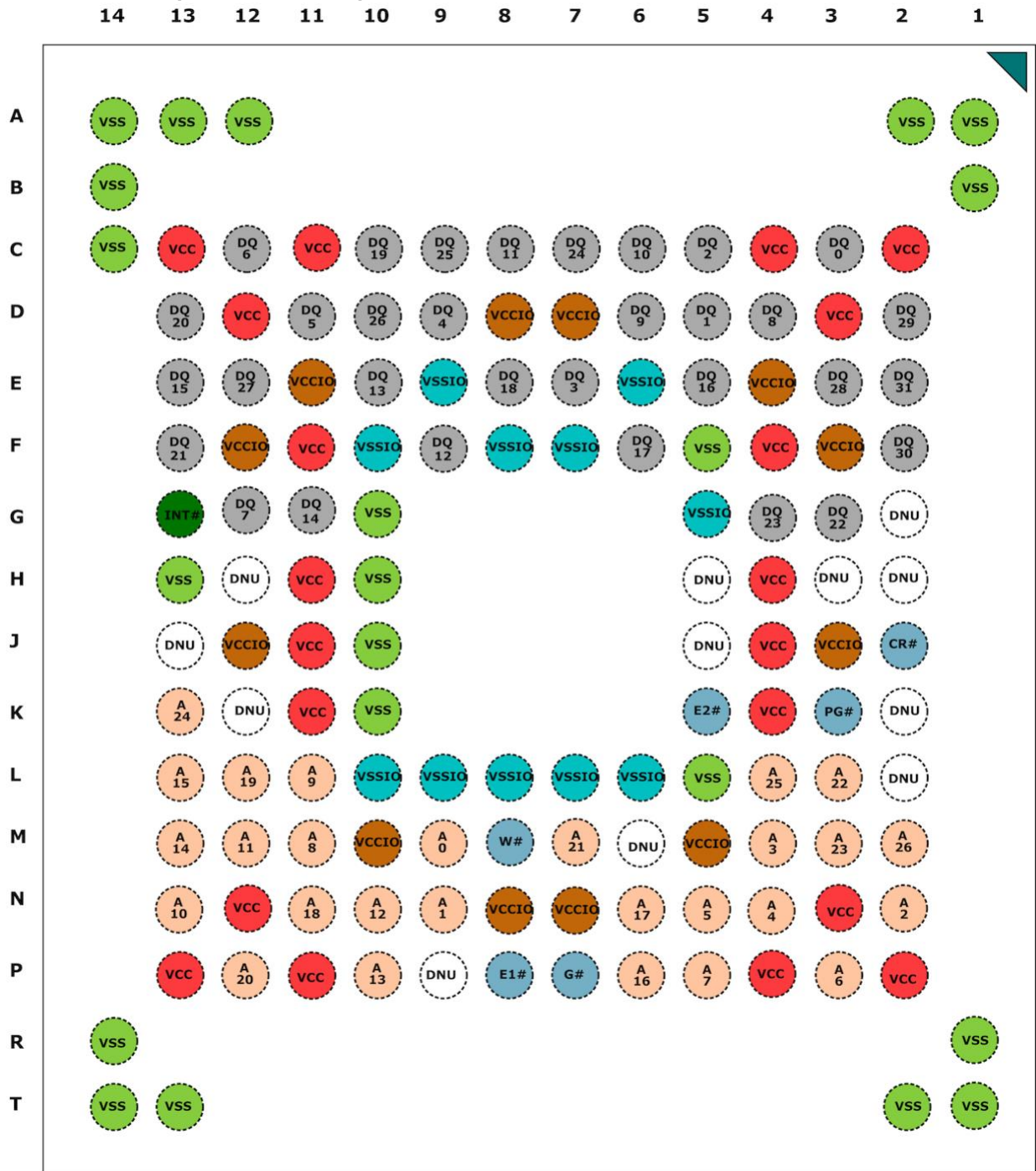
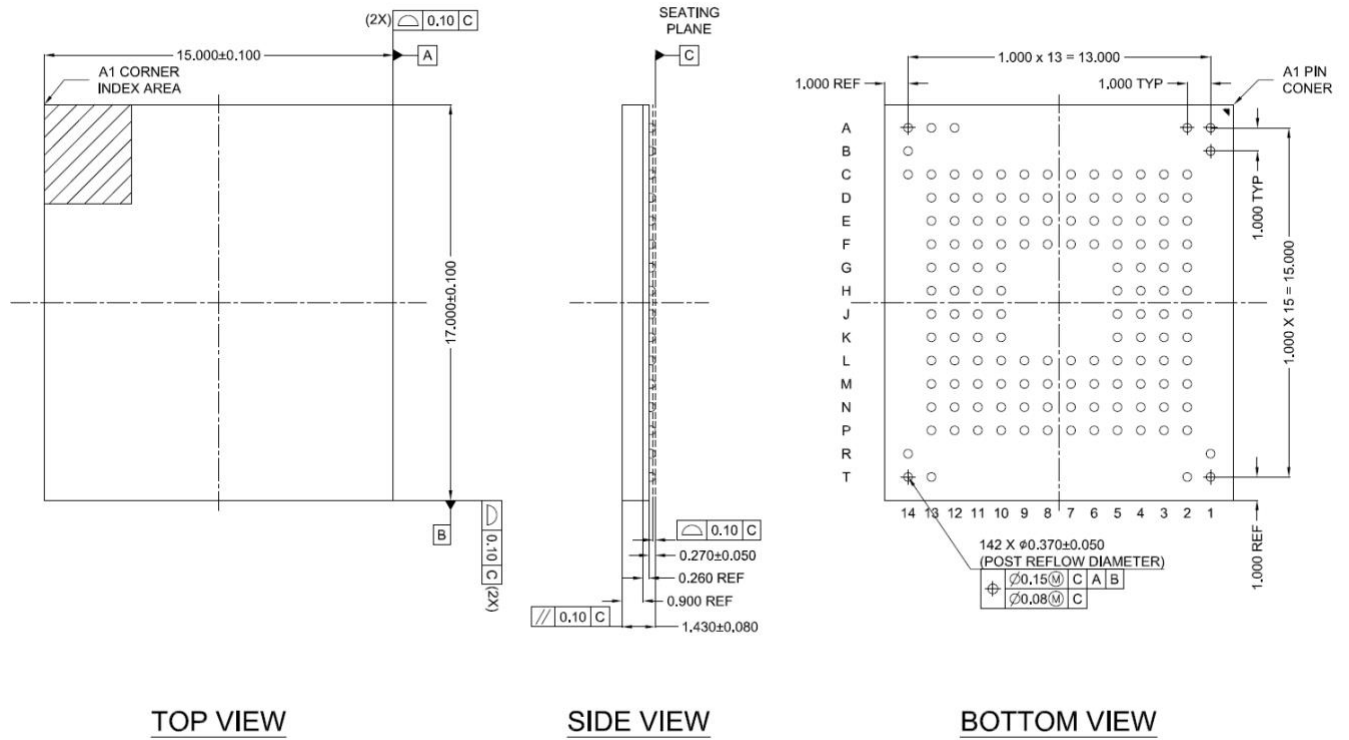


Figure 4: 142-ball FBGA

## 142-Ball FBGA Mechanical Drawing

Figure 5: 142-ball FBGA Mechanical Drawing - 1,2,4 Gb



### [NOTES]

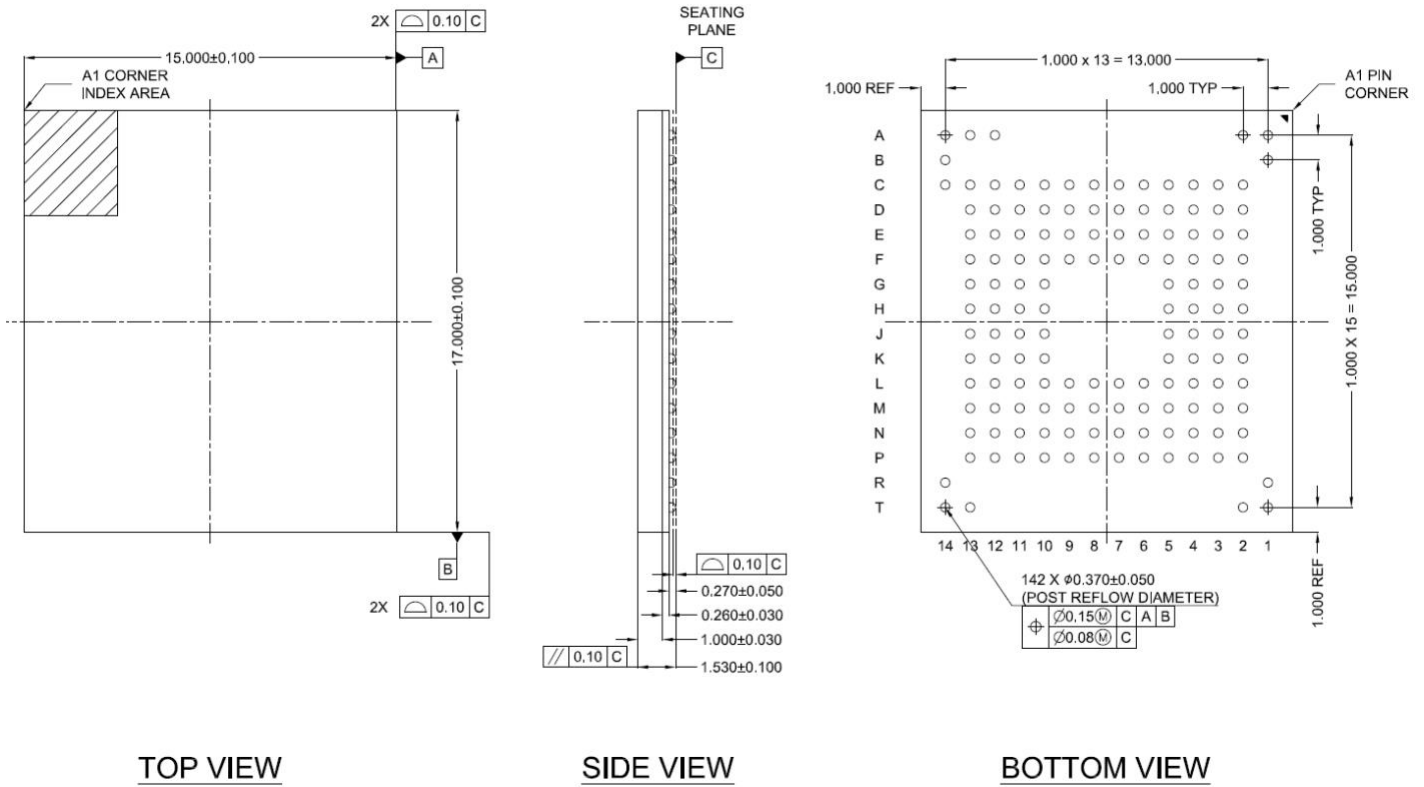
#### 1. SOLDER BALL SIZE IS

0.35 mm before reflow

0.37 (+/-0.05) mm post reflow

#### 2. SOLDER RESIST OPENING IS

0.300 mm

**Figure 6: 142-ball FBGA Mechanical Drawing - 8 Gb**

**[NOTES]**
**1. SOLDER BALL SIZE IS**

0.35 mm before reflow

0.37 (+/-0.05) mm post reflow

**2. SOLDER RESIST OPENING IS**

0.300 mm

## Architecture

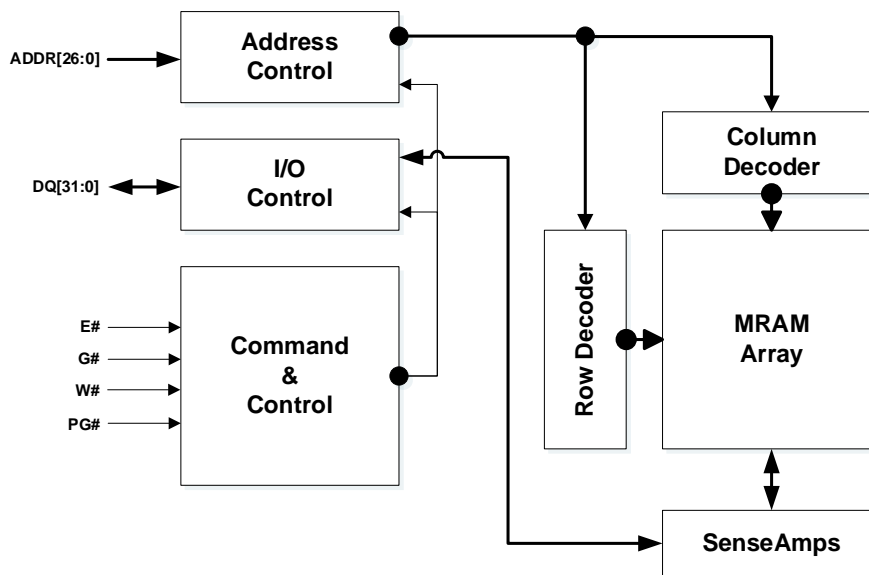
AS3xxx332 is a high performance MRAM device. Writing to and reading from the device are performed as follows:

To write to the device, drive Chip Enable (E#) and Write Enable (W#) inputs Low (Logic '0'). This enables data on I/O pins (DQ[0] to DQ[31]) to be written into the memory location specified by the address pins (ADDR[0] through ADDR[26]).

To read from the device, drive Chip Enable (E#) input Low (Logic '0'), Output Enable (G#) input Low (Logic '0') while maintaining Write Enable (W#) High (Logic '1'). This enables data from the memory location specified by the address pins (ADDR[0] through ADDR[26]) to appear on I/O pins (DQ[0] to DQ[31]).

In the case of the 8Gb device: This architecture is duplicated. Each bank of 4 dies is controlled with a separate chipselect: E1#, E2#.

**Figure 7: Functional Block Diagram**



**Table 4: Modes of Operation**

Mode	E#	G#	W#	Current	DQ[31:0]
<b>Not Selected</b>	H	X	X	I <sub>SB</sub>	Hi-Z
<b>Output Disabled</b>	L	H	H	I <sub>READ</sub>	Hi-Z
<b>Read Word</b>	L	L	H	I <sub>READ</sub>	Data-out
<b>Write Word</b>	L	X	L	I <sub>WRITE</sub>	Data-in

**Notes:**

H: High (Logic '1')      X: Don't Care  
 L: Low (Logic '0')      Hi-Z: High Impedance

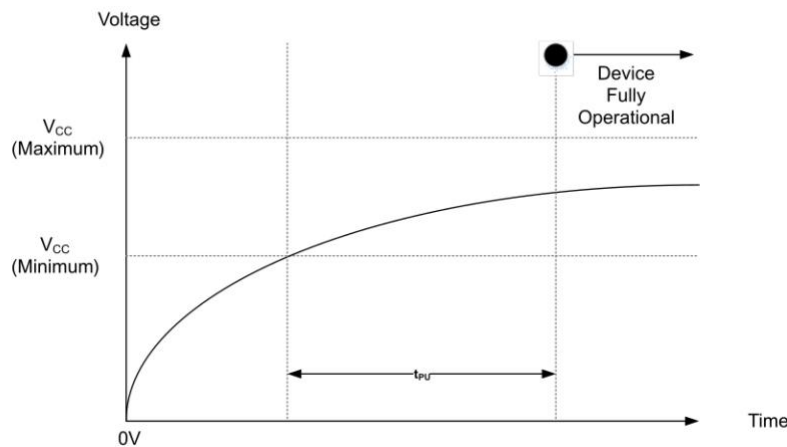


## Normal Device Initialization:

When powering up, the following procedure is required to initialize the device correctly:

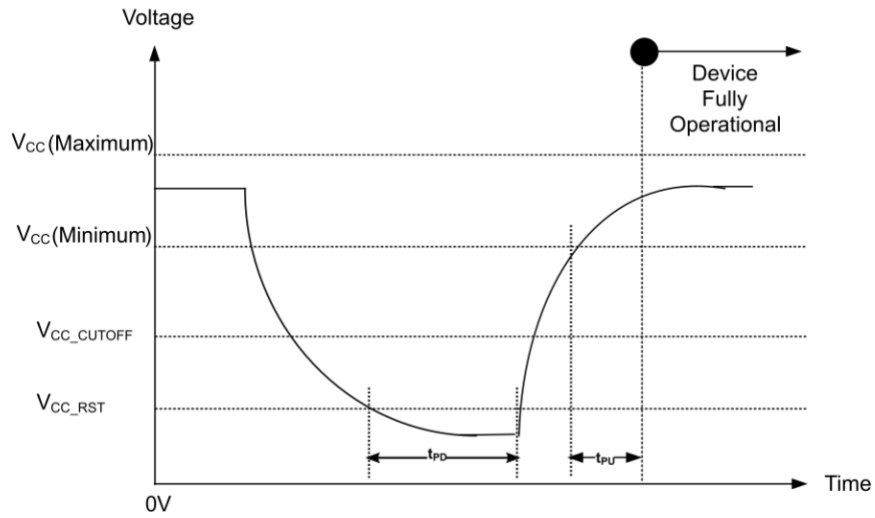
- $V_{CC}$  and  $V_{CCIO}$  can ramp up together ( $R_{VR}$ ), if not possible then  $V_{CC}$  first followed by  $V_{CCIO}$ . The maximum difference between the two voltages should not exceed 0.7V before reaching the final value of  $V_{CCIO}$ .
- The device must not be selected at power-up (a 10K $\Omega$  pull-up Resistor to  $V_{CCIO}$  on E# is recommended). Then a further delay of  $t_{PU}$  (Figure 8) until  $V_{CC}$  reaches  $V_{CC}(\text{minimum})$ .
- During Power-up, recovering from power loss or brownout, a delay of  $t_{PU}$  is required before normal operation commences (Figure 6).

**Figure 8: Power-Up Behavior**



When powering down, the following procedure is required to turn off the device correctly:

- $V_{CC}$  and  $V_{CCIO}$  can ramp down together ( $R_{VF}$ ), if not possible then  $V_{CC}$  first followed by  $V_{CCIO}$ . The maximum difference between the two voltages should not exceed 0.7V.
- The device must not be selected at power-down (a 10K $\Omega$  pull-up Resistor to  $V_{CCIO}$  on E# is recommended).
- It is recommended that no instructions are sent to the device when  $V_{CC}$  is below  $V_{CC}(\text{minimum})$ .
- During power loss or brownout, when  $V_{CC}$  goes below  $V_{CC-CUTOFF}$ . The voltage must drop below  $V_{CC}(\text{Reset})$  for a period of  $t_{PD}$ . The power-up timing needs to be observed after  $V_{CC}$  goes above  $V_{CC}(\text{minimum})$

**Figure 9: Power-Down Behavior**

**Table 4: Power Up/Down Timing and Voltages**

Parameter	Symbol	Test Conditions	Minimum	Typical	Maximum	Units
<b>V<sub>CC</sub> Range</b>		All operating voltages and temperatures	2.7	-	3.6	V
<b>V<sub>CC</sub> Ramp Up Time</b>	R <sub>VR</sub>		30	-	-	μs/V
<b>V<sub>CC</sub> Ramp Down Time</b>	R <sub>VF</sub>		20	-	-	μs/V
<b>V<sub>CC</sub> Power Up to First Instruction</b>	t <sub>PU</sub>		1	-	-	ms
<b>V<sub>CC</sub> (low) time</b>	t <sub>PD</sub>		1			ms
<b>V<sub>CC</sub> Cutoff – Must Initialize Device</b>	V <sub>CC_CUTOFF</sub>		1.6	-	-	V
<b>V<sub>CC</sub> (Reset)</b>	V <sub>CC_RST</sub>		0		0.3	V

**Table 5: Device Initialization Timing and Voltages**

Parameter	Symbol	Test Conditions	Minimum	Typical	Maximum	Units
V <sub>CC</sub> Range		All operating voltages and temperatures	2.5	-	3.6	V
V <sub>CC</sub> Ramp Up Time	R <sub>VR</sub>		30	-	-	μs/V
V <sub>CC</sub> Ramp Down Time	R <sub>VF</sub>		20	-	-	μs/V
V <sub>CC</sub> Power Up to First Instruction	t <sub>PU</sub>		250	-	-	μs
V <sub>CC</sub> Cutoff – Must Initialize Device	V <sub>CC-CUTOFF</sub>		1.6	-	-	V

## Electrical Specifications

**Table 6: Recommended Operating Conditions**

Parameter / Condition		Minimum	Typical	Maximum	Units
Normal Operation	Operating Temperature (T <sub>A</sub> )	-40.0	-	125.0	°C
	V <sub>CC</sub> Supply Voltage	2.5	3.0	3.6	V
	V <sub>CCIO</sub> Supply Voltage	1.71	1.8 - 3.0	3.6	V
Under Radiation	Operating Temperature (T <sub>A</sub> )	-40.0	-	85.0	°C
	V <sub>CC</sub> Supply Voltage	2.5	2.7	3.0	V
	V <sub>CCIO</sub> Supply Voltage	1.71	1.8 - 3.0	3.0	V
<b>V<sub>SS</sub> Supply Voltage</b>		0.0	0.0	0.0	V
<b>V<sub>SSIO</sub> Supply Voltage</b>		0.0	0.0	0.0	V
<b>V<sub>wi</sub> Write Inhibit Voltage</b>		2.1	2.3	2.5	V

**Table 7: Pin Capacitance**

Parameter	Symbol	Test Conditions	Density	Maximum	Units
Input Pin Capacitance	C <sub>IN</sub>	TEMP = 25°C; f = 1 MHz; V <sub>IN</sub> = 0V	1Gb	10.0	pF
			2/4Gb	20.0	
			8Gb	40.0	
Input / Output Pin Capacitance	C <sub>INOUT</sub>	TEMP = 25°C; f = 1 MHz; V <sub>IN</sub> = 0V	1Gb	10.0	
			2/4Gb	20.0	
			8Gb	40.0	

**Table 8: DC Characteristics**

Parameter	Symbol	Test Conditions	Density	3.0V Device (2.5V-3.6V)				Units
				Min	Typical <sup>1</sup>	85°C <sup>2</sup>	Max <sup>3</sup>	
Read Current	I <sub>READ</sub>	V <sub>CC</sub> (max), I <sub>OUT</sub> =0mA	1Gb		25	50	80	mA
			2Gb		50	100	150	
			4Gb		70	200	300	
			8Gb		140	400	600	
Write Current	I <sub>WRITE</sub>	V <sub>CC</sub> (max)	1Gb		20	50	80	mA
			2Gb		50	100	150	
			4Gb		65	200	300	
			8Gb		130	400	600	
Standby Current (-40°C to 125°C)	I <sub>SB</sub>	E#=V <sub>IH</sub> , V <sub>CC</sub> (max)	1Gb		25	50	75	mA
			2Gb		45	100	140	
			4Gb		60	180	280	
			8Gb		120	360	560	
Input Leakage Current	I <sub>LI</sub>	V <sub>IN</sub> =0 to V <sub>CC</sub> (max)		-	-		±1.0	µA
Output Leakage Current	I <sub>LO</sub>	V <sub>OUT</sub> =0 to V <sub>CC</sub> (max)		-	-		±1.0	µA
Input High Voltage (V <sub>CCIO</sub> =1.71-2.2)	V <sub>IH</sub>			0.65* V <sub>CCIO</sub>	-		V <sub>CCIO</sub> +0.2	V
Input High Voltage (V <sub>CCIO</sub> =2.2-2.7)				1.8				
Input High Voltage (V <sub>CCIO</sub> =2.7-3.6)				2.2				
Input Low Voltage (V <sub>CCIO</sub> =1.71-2.2)	V <sub>IL</sub>				-		0.35* V <sub>CCIO</sub>	V
Input Low Voltage (V <sub>CCIO</sub> =2.2-2.7)				-0.2		0.7		
Input Low Voltage (V <sub>CCIO</sub> =2.7-3.6)						0.8		
Output Low Voltage (V <sub>CCIO</sub> =1.71-2.2)	V <sub>OL</sub>	I <sub>OL</sub> = 0.1mA					0.2	V
Output Low Voltage (V <sub>CCIO</sub> =2.2-2.7)		I <sub>OL</sub> = 0.1mA			-		0.4	
Output Low Voltage (V <sub>CCIO</sub> =2.7-3.6)		I <sub>OL</sub> = 2.0mA					0.4	
Output High Voltage (V <sub>CCIO</sub> =1.71-2.2)	V <sub>OH</sub>	I <sub>OH</sub> = -0.1mA		1.4			-	V
Output High Voltage (V <sub>CCIO</sub> =2.2-2.7)		I <sub>OH</sub> = -0.1mA		2.0				
Output High Voltage (V <sub>CCIO</sub> =2.7-3.6)		I <sub>OH</sub> = -1.0mA		2.4				

 Notes: <sup>1</sup> Typical values are measured at 25°C

<sup>2</sup> 85°C values are guaranteed by characterization; not tested in production

<sup>3</sup> Max values are measured at 125°C

**Table 9: Magnetic Immunity Characteristics**

Parameter	Symbol	Maximum	Units
Magnetic Field During Write	$H_{\max\_write}$	24000	A/m
Magnetic Field During Read	$H_{\max\_read}$	24000	A/m

**Table 10: AC Test Conditions**

Parameter	Value
Input pulse levels	0.0V to $V_{CC}$
Input rise and fall times	5ns
Input and output measurement timing levels	$V_{CC}/2$
Output Load	CL = 30pF

## Absolute Maximum Ratings

Stresses greater than those listed may cause permanent damage to the device. This is a stress rating only. Exposure to maximum rating for extended periods may adversely affect reliability.

**Table 11: Absolute Maximum Ratings**

Parameter	Minimum	Maximum	Units
Magnetic Field During Write	---	24000	A/m
Magnetic Field During Read	---	24000	A/m
Temperature Under Bias	-45	130	°C
Storage Temperature	-55 to 150		°C
Supply Voltage V <sub>cc</sub>	-0.5	4.0	V
I/O Voltage V <sub>ccio</sub>	-0.5	3.8	V
Voltage on any pin except V <sub>cc</sub>	-0.5	V <sub>ccio</sub> + 0.2	V
ESD HBM (Human Body Model) ANSI/ESDA/JEDEC JS-001-2017	≥  2000 V		V
ESD CDM (Charged Device Model) ANSI/ESDA/JEDEC JS-002-2018	≥  500 V		V
Latch-Up (I-test) JESD78	≥  100 mA		mA
Latch-Up (V <sub>supply</sub> over-voltage test) JESD78	Passed		---

## Write Operation

Figure 10: Write Operation

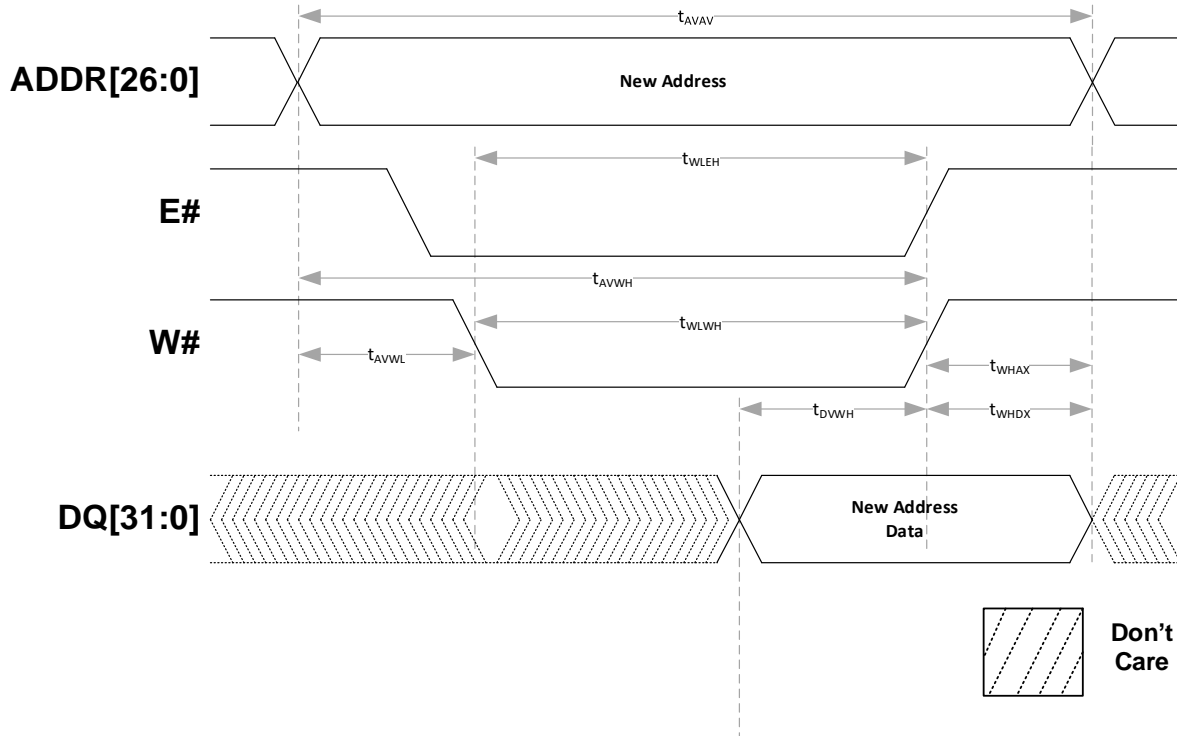


Table 12: Write Operation (W# Controlled)

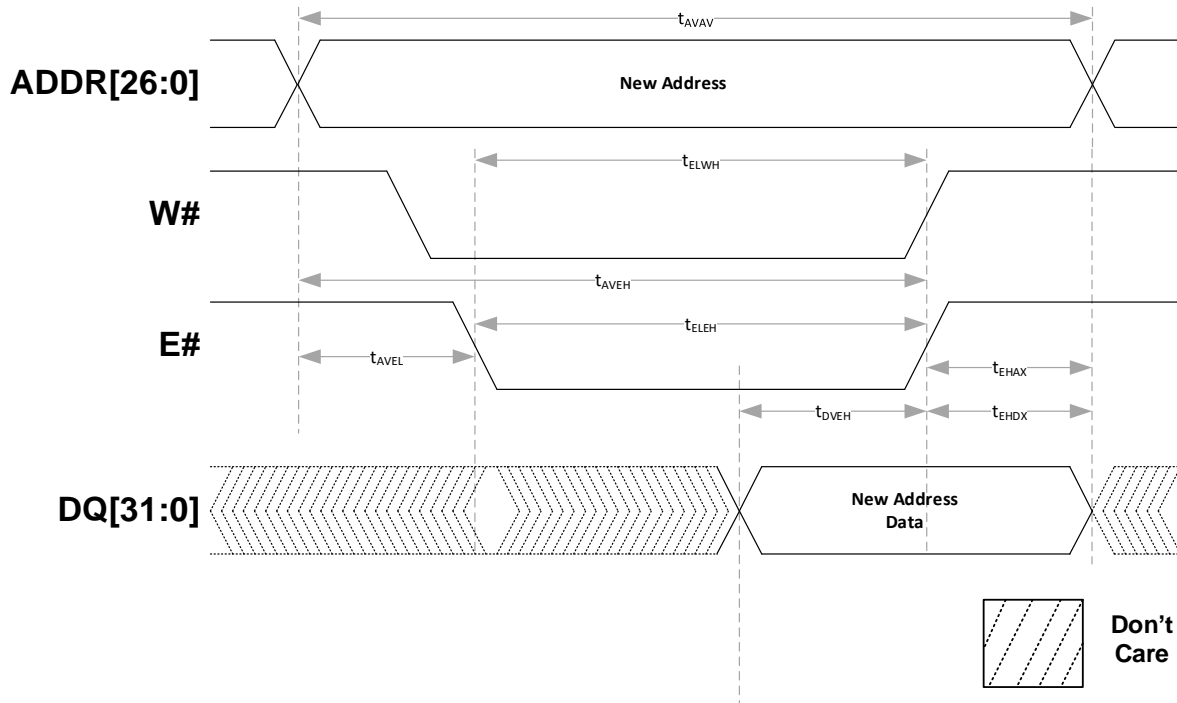
Parameter	Symbol	Minimum	Maximum	Units
Write Cycle Time	$t_{AVAV}$	45	-	ns
Address Set-Up Time	$t_{AVWL}$	0	-	ns
Address Valid to end of Write (G# High)	$t_{AVWH}$	28	-	ns
Address Valid to end of Write (G# Low)	$t_{AVWH}$	30	-	ns
Write Pulse Width (G# High)	$t_{WLVH}$ , $t_{WLEH}$	25	-	ns
Write Pulse Width (G# Low)	$t_{WLVH}$ , $t_{WLEH}$	25	-	ns
Data Valid to end of Write	$t_{DWWH}$	15	-	ns
Data Hold Time	$t_{WHDX}$	0	-	ns
Write recovery Time	$t_{WHAX}$	12	-	ns

**Notes:**

G# is High (Logic '1') for Write operation

Power supplies must be stable

Addresses valid either before or at the same time as E# goes low

**Figure 11: Write Operation (E# Controlled)**

**Table 13: Write Operation (E# Controlled)**

Parameter	Symbol	Minimum	Maximum	Units
<b>Write Cycle Time</b>	$t_{AVAV}$	45	-	ns
<b>Address Set-Up Time</b>	$t_{AVEL}$	0	-	ns
<b>Address Valid to end of Write (G# High)</b>	$t_{AVEH}$	28	-	ns
<b>Address Valid to end of Write (G# Low)</b>	$t_{AVEH}$	30	-	ns
<b>Write Pulse Width (G# High)</b>	$t_{ELWH}, t_{ELEH}$	25	-	ns
<b>Write Pulse Width (G# Low)</b>	$t_{ELWH}, t_{ELEH}$	25	-	ns
<b>Data Valid to end of Write</b>	$t_{DVEH}$	15	-	ns
<b>Data Hold Time</b>	$t_{EHDX}$	0	-	ns
<b>Write recovery Time</b>	$t_{EHAX}$	12	-	ns

**Notes:**

G# is High (Logic '1') for Write operation

Power supplies must be stable

Addresses valid either before or at the same time as W# goes low

In case of the 8G device: E# is represented by E1# or E2#



## Bus Turnaround Operation – Read to Write

Figure 12: Bus Turnaround Operation

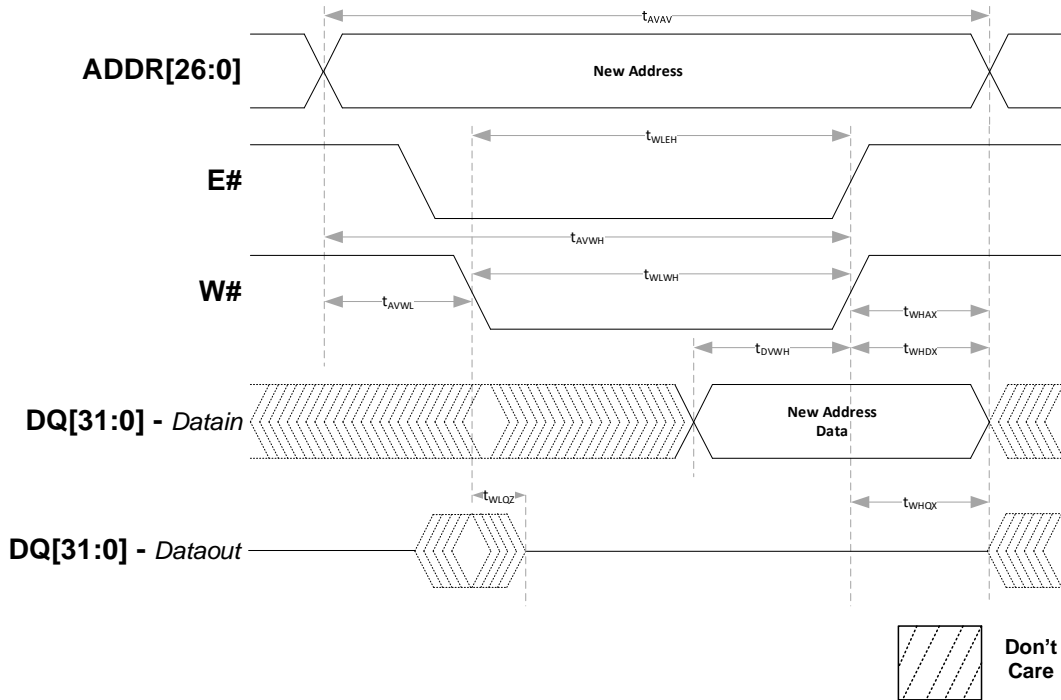


Table 14: Write Operation

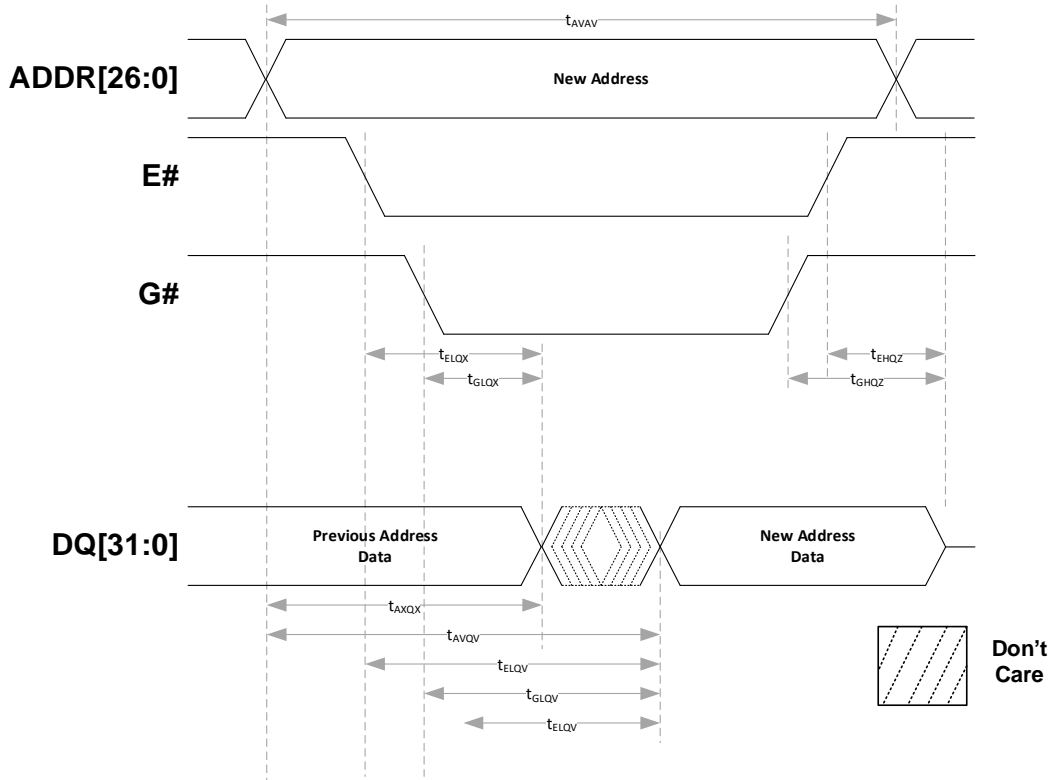
Parameter	Symbol	Minimum	Maximum	Units
W# Low to Data Hi-Z	$t_{WLQZ}$	0	15	ns
W# High to Output Active	$t_{WHQX}$	3	-	ns

**Notes:**

Power supplies must be stable  
 Addresses valid either before or at the same time as E# goes low  
 In case of the 8G device: E# is represented by E1# or E2#

## Read Operation

**Figure 13: Read Operation**



**Table 15: Read Operation**

Parameter	Symbol	Minimum	Maximum	Units
Read Cycle Time	$t_{AVAV}$	45	-	ns
Address Cycle Time	$t_{AVQV}$	-	45	ns
Chip Enable Access Time	$t_{ELQV}$	-	45	ns
Output Enable Access Time	$t_{GLQV}$	-	25	ns
Output Hold From Address Change	$t_{AXQX}$	3	-	ns
Chip Enable Low to Output Active	$t_{ELQX}$	3	-	ns
Output Enable Low to Output Active	$t_{GLQX}$	0	-	ns
Chip Enable High to Output Hi-Z	$t_{EHQZ}$	0	15	ns
Output Enable High to Output Hi-Z	$t_{GHQZ}$	0	15	ns

**Notes:**

W# is High (Logic '1') for Read operation

Power supplies must be stable

Addresses valid either before or at the same time as E# goes low

In case of the 8G device: E# is represented by E1# or E2#

## Asynchronous Page Mode

Asynchronous page mode is an extension of the legacy asynchronous read and write operations that improves the performance of the MRAM memory, as shown in Figure 11. On power up or reset, the MRAM memory defaults to legacy asynchronous mode to enable controllers to immediately access the memory. Page mode is also immediately available after asserting PG# low and E# high. No special commands or setup are necessary.

**Figure 14: 4-Word Asynchronous Page Mode Comparison with Legacy Asynchronous Mode**

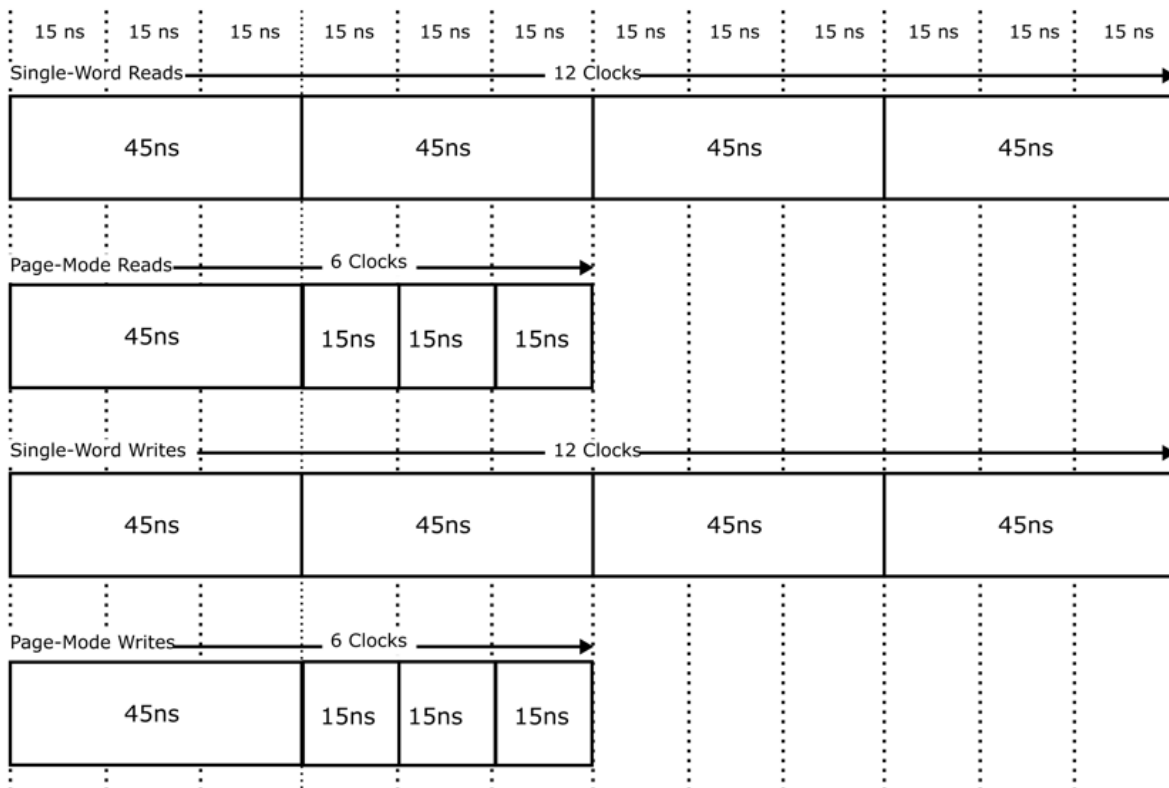
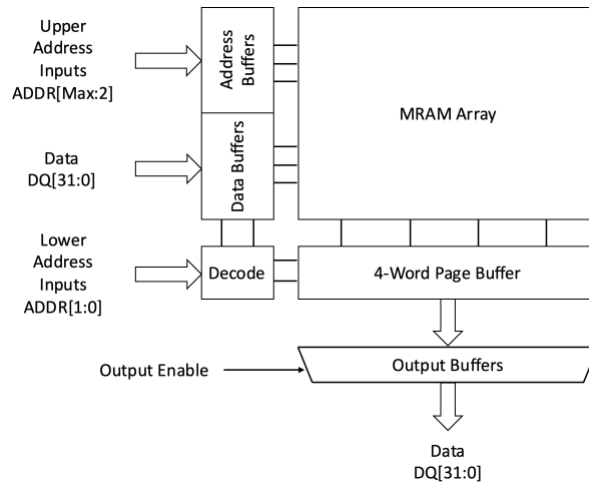
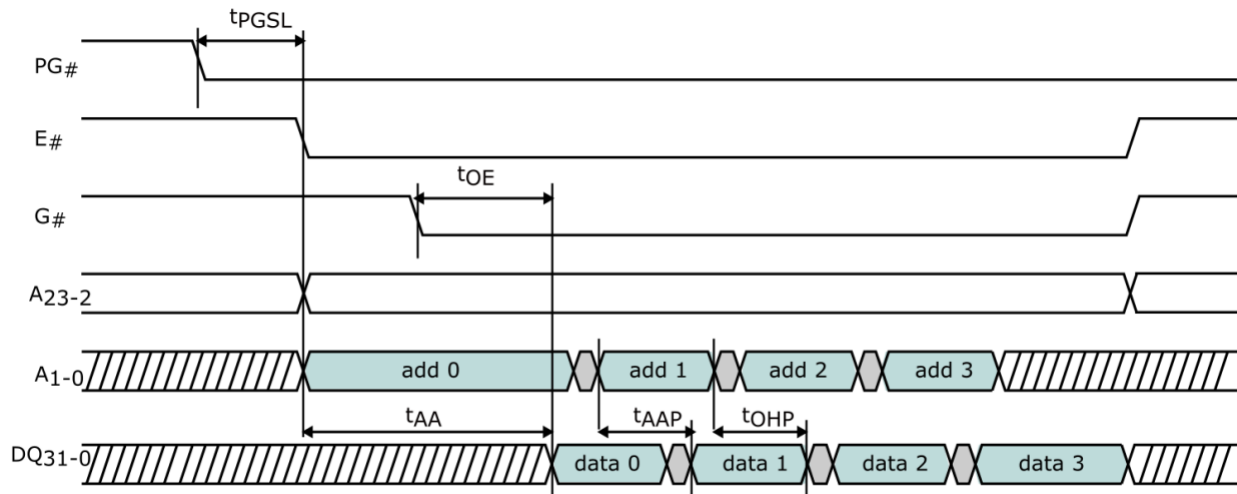


Figure 12 shows the page mode functional block diagram. During a page write, a new page is accessed by changing any of the upper addresses A[max:2]. A subsequent write commands (W# toggle) can load the data buffers with new data to be written to any of the adjacent addresses A[1:0]. During page read, an initial asynchronous read access is executed during which 4 data words are read from the memory array simultaneously, and loaded into an internal page buffer, while the first data word is output onto the memory bus. Subsequent reads are output from the data buffer, providing up to two times the read and write access speed of conventional asynchronous reads.

**Figure 15: Page Mode Functional Block Diagram**


## Asynchronous Page Mode Read Operation

Asynchronous page mode reads are initiated by the memory controller in the same way as asynchronous single-word reads by asserting E# or changing any of the upper addresses A[max:2]. In Figure 13; an address is placed on the address bus, and E# and G# are asserted. Multiple data words are “sensed” simultaneously, and loaded into an internal page buffer while the first data word is being output onto the data bus. After the initial-access delay ( $t_{AA}$ ), read data is driven onto the data bus and then sampled by the memory controller. When the next read address is within the page-buffer range A[1:0], subsequent data is output from the page buffer, not from the MRAM array. A shorter access delay ( $t_{AAP}$ ) occurs when data is read from the page buffer. The low-order address bits are used to access the page buffer, and determine which word is output. Four-word page access uses A[1:0];

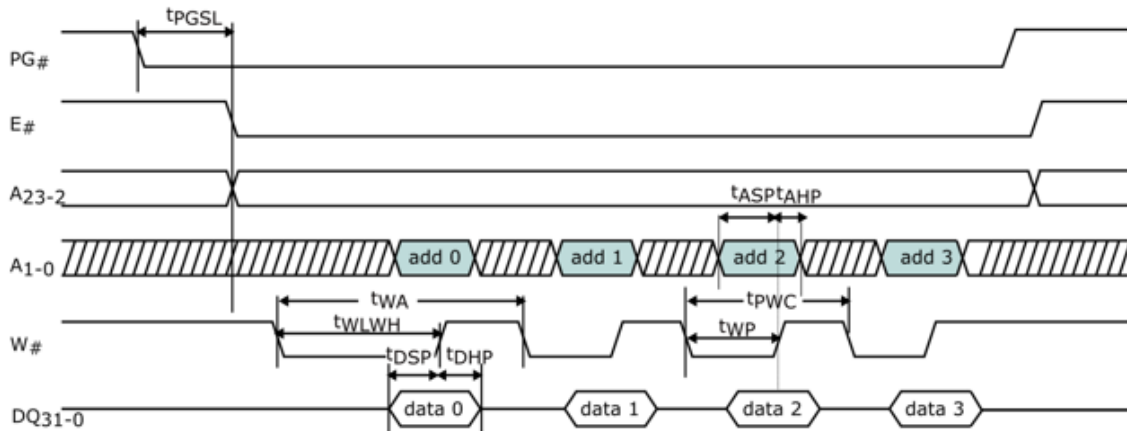
**Figure 16: Asynchronous Page Read Operation**

**Notes:**

In case of the 8G device: E# is represented by E1# or E2#

## Asynchronous Page Mode Write Operation

For Asynchronous page mode write, shown in Figure 14, the first write pulse defines the first write access ( $t_{PWC}$ ). While  $E\#$  is maintained LOW, a subsequent write pulse along with a new adjacent address  $A[1:0]$  executes a page mode write access.  $E\#$  must be LOW upon completion of a page write access. Asserting  $E\#$  HIGH at the beginning or the middle of a page access will abort it.

**Figure 17: Asynchronous Page Write Operation**



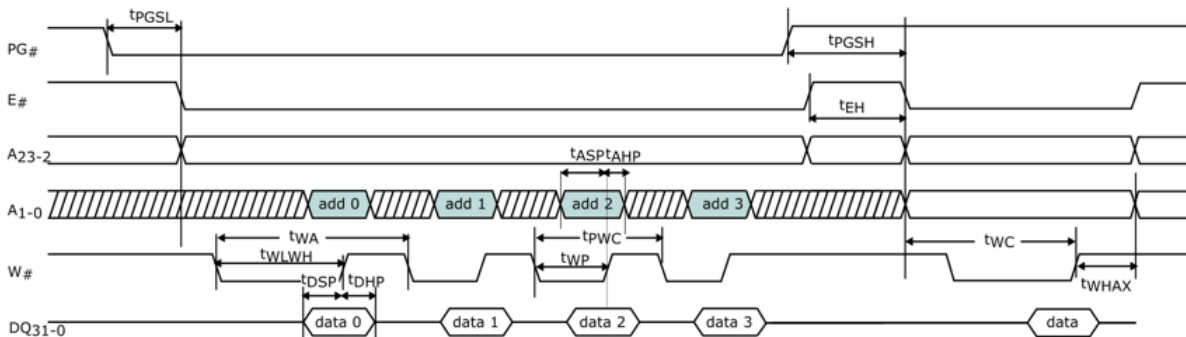
**Notes:**

In case of the 8G device:  $E\#$  is represented by  $E1\#$  or  $E2\#$

## Asynchronous Page Mode Write to Single Write

On power up or reset, the MRAM memory defaults to the legacy asynchronous mode. The page mode is immediately available after asserting  $PG\#$  low while maintaining  $E\#$  HIGH for  $t_{PGSL}$ . Returning to legacy mode can be achieved by asserting  $PG\#$  HIGH and  $E\#$  for  $t_{PGSH}$ .

**Figure 18: Page Write to Single Write Timing Diagram**



**Notes:**

In case of the 8G device:  $E\#$  is represented by  $E1\#$  or  $E2\#$

## Asynchronous Page Mode AC Timing

**Table 16: Page Mode AC Timing**

Parameters	Description	Min	Max	Unit
t <sub>WA</sub>	Write access time	45	-	ns
t <sub>WC</sub>	Chip enable LOW to write enable HIGH	30	-	ns
t <sub>WHAX</sub>	Write recovery time	15	-	ns
t <sub>WLWH</sub>	Write enable low time	25	-	ns
t <sub>AS</sub>	Address setup time (to E# Low)	0	-	ns
t <sub>E</sub>	Chip enable access time	-	45	ns
t <sub>AA</sub>	Address access time	-	45	ns
t <sub>O</sub>	Output enable access time	-	15	ns
t <sub>PWC</sub>	Page mode write access	15		ns
t <sub>WP</sub>	Page mode write enable low time	7.5		ns
t <sub>WPH</sub>	Page mode write enable high time	7.5		ns
t <sub>AHP</sub>	Page mode address hold time (to W# High)	6		ns
t <sub>ASP</sub>	Page mode address setup time (to W# High)	7.5		ns
t <sub>AAP</sub>	Page mode address access time	-	15	ns
t <sub>OHP</sub>	Page mode output hold time	5	-	ns
t <sub>PGSL</sub>	Page mode select to E# Low	10	-	ns
t <sub>PGSH</sub>	Page mode unselect to E# Low	10	-	ns
t <sub>PGH</sub>	Page mode high time	45	-	ns
t <sub>EH</sub>	E# High time	10	-	ns
t <sub>OH</sub>	Output hold time	5	-	ns
t <sub>EP</sub>	Page mode E# low time	45	-	ns
t <sub>DSP</sub>	Page mode data setup time (to W# High)	7.5	-	ns
t <sub>DHP</sub>	Page mode data hold time (to W# High)	6	-	ns

## Endurance and Data Retention

**Table 17: Endurance and Data Retention**

Parameter	Symbol	Test Conditions	Minimum	Units
<b>Write Endurance</b>	END	-	10 <sup>16</sup>	cycles
<b>Data Retention</b>	RET	125°C	10	years
		105°C	10	
		85°C	1,000	
		75°C	10,000	
		65°C	1,000,000	

## Thermal Resistance

**Table 18: Thermal Resistance Specifications 142 Ball BGA**

Parameter	Description	Test Condition	1Gb	2Gb	4Gb	8Gb	Units
$\theta_{JA}$	Thermal resistance (junction to ambient)	Test conditions follow standard test methods and procedures for measuring thermal impedance, per EIA/JESD51	17.89	TBD	17.90	TBD	°C/W
$\theta_{JC}$	Thermal resistance (junction to case)		2.10	TBD	2.19	TBD	

**Notes:**

- 1: These parameters are guaranteed by characterization; not tested in production.
- 2: Ambient temperature,  $T_A$  25 °C
- 3: Worst case Junction temp specified for Top die ( $\theta_{JA}$ ) and Bottom die ( $\theta_{JC}$ )

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## Revision History

Revision	Date	Change Summary
REV A	11/19/2019	Preliminary release
REV B	12/19/19	Removed commercial grade Added x32 configuration Removed 54-pin TSOP Added 92-ball FBGA Updated DC characteristics and pin capacitance Updated part number options
REV C	02/19/2020	Added 125 degrees option Updated 92-ball package
REV D	10/8/2020	Removed 256Mb density and added 2Gb density Removed Industrial, Industrial Extended temp grade options, added military temp grade option Removed 35ns performance option Updated 92-FBGA dimensions Added radiation specs Updated OPN decoder and valid combinations Updated Electrical Specifications, write operation specifications and read operation specifications. Added Endurance and Retention specs
REV E	10/23/2020	Removed radiation specs
REV F	3/15/2021	Added 4Gb device option Changed 92-ball BGA to 142-ball BGA; updated package ball assignments and outline drawing Added Asynchronous Page Mode Removed Industrial and Industrial Plus temp grades Removed sleep mode
REV G	5/27/2021	Updated BGA Pin assignments
REV H	6/15/2021	Corrected INT# pin assignment and updated package drawings
REV I	6/15/2021	Remove restrictions of use in Military applications Changed temp spec to -40. Plastic parts will only be qualified to -40 degrees Centigrade.
REV J	6/21/2021	Updated Package Ball assignment to conform to JEDED standard
REV K	8/23/2021	Updated Page mode timing : T <sub>pwc</sub> in table 15. Corrected lsb in summary table Added Pin descriptions for E# and PG#. Updated timing diagrams (Figures 15, 16 & 17) to show E# instead of CE#; W# instead of WE# and G# instead of OE#. Removed Byte enable from Table 14
REV L	9/3/2021	Updated package dimension to show Ball diameter Removed redundant notes describing dimensions on package dimension page. Fixed I/O Power legend to show VCCQ
REV M	9/29/2021	Removed 512Mb and 2Gb densities Removed Tape & Reel as an ordering option Added Vccio to the specification
REV N	10/20/2021	Added 64 and 256Mb densities Added Hardware RST# pin Temp spec in Part number corrected to show 0M
REV O	12/09/2021	Added V <sub>DD</sub> and V <sub>BYP</sub> pin description and PowerUp/Powerdown sequence
REV S	12/20/2021	Updated Table 5 with Vcc Ramp time

<b>REV T</b>	01/18/2022	Removed 64 and 256Mb densities from this data sheet
<b>REV U</b>	03/31/2022	Renamed VCCQ to VCCIO Added pin assignment table Relaxed Vdd spec to +-7.5% from +-5%
<b>U.1</b>	04/29/2022	Added ball assignment of ADDR[17:12] to signal description table Added package thermal
<b>U.2</b>	05/16/2022	Updated Pictures with new Figure # Updated DC Characteristics Table: Current numbers are based on UMC's analysis of their current 22nm process.
<b>U.3</b>	05/23/2022	Added V <sub>DD</sub> to supply line on Front page Updated Power sequencing description under DEVICE INITIALIZATION Added Absolute Maximum Ratings Table
<b>U.4</b>	05/25/2022	Called out specific voltages are allowed for V <sub>CCIO</sub> on front page. Removed Power sequencing case of VDD going low before VCC Added Absolute Maximum rating on V <sub>DD</sub>
<b>REV V</b>	07/01/2022	Changed the nominal height to be compatible with Gen 3 Serial devices: Nominal Thickness in Figure 4 changed from 1.39mm to 1.43mm. Leaded ball options added to Order Option Table
<b>REV W</b>	07/19/2022	Removed Performance table Added Extended Safe Operating Area as well as Normal Operating Conditions Removed redundant Package drawing table Fixed wording on use of V <sub>BYP</sub> in pin definition table
<b>REV X</b>	12/15/2022	Ball K3 (previously designated as #PG) is re-assigned as Reserved and must be pulled high to Vccio through a 10kΩ resistor (This is the fast page function. For compatibility with SRAM devices, this function is now reserved and only available for custom designs). This device is now available for use in LEO. The Extended Safe Operating Area (ESOA) is no longer described here and is only available through our partner program: As such Ball K12 (previously external Vdd) is now NC and H13 (previously V <sub>BYP</sub> ) has to be connected to Vss. Added 85°C power consumption to DC Characteristics Table 8.
<b>X.1</b>	03/28/2023	Nominal Thikcness in Figure 4 changed from 1.43mm to 1.51mm.
<b>X.2</b>	04/10/2023	Added 4.7KΩ pull up to INT# Added Asynchronous Page Mode Read & Write: This functionality has always been in the silicon. It is now fully tested and verified effective with date code: 2250 for 1Gb devices and 2240 for 4Gb devices.
<b>X.3</b>	05/01/2023	Voltage Ramp Up rate has been clarified in the Normal Device Initialization. Input & Output Low & High Voltage levels have been redefined as references to V <sub>CCIO</sub> rather than V <sub>CC</sub> in the DC Characteristics Table 8.
<b>X.4</b>	05/08/2023	Page Mode write Timing was updated to match the read timing. Lead cycle is the same 45ns for Read and Write. Specified Max temp to be junction rather than ambiet
<b>X.5</b>	07/20/2023	K12 was mislabelled in Figure 3 as "NC". It is "DNU" Corrected the picture.
<b>X.6</b>	08/31/2023	Added 2Gb density Updated Input & Output Low and High Voltage levels DC Charaterstics table 8 to be consistent at 1.8V operation Clarification that PEMS-INST-001 flow version of product will be supplied through a partner
<b>X.7</b>	10/17/2023	Table 3: Signal descption: Corrected definition of W# and removed RFU. Table 11: Corrected signal name: Changed V <sub>DD</sub> to V <sub>CC</sub> Guideline on normal device initialization corrected to say: pullup on E# is to V <sub>CCIO</sub> Fixed Typo in Signal pin description Table 3 DQ[31:0] Added Special Configuration Registers

<b>X.8</b>	12/13/2023	Added 8Gb density Updated Maximum rating table 11 Updated Solder ball and Solder resist opening dimensions on the Package drawing
	01/04/2024	Updated Table 16 Page Mode AC Timing signal name/descriptions Package naming convention: Ball assignement pictures used to say: Top View. The label should have read: Bottom View
	01/18/2024	Added Mechanical drawing for 8Gb
	03/26/2024	Corrected Modes Of Operation Table "Removed Output Disabled mode with E#, G#, W# set to L, X, X". Removed DC output Current lout from Absolute Maximum Ratings Table: Correct Maximum Current should be taken from the DC Charcterstics table base don number of dies in the device. INT# definition was updated: When triggered this signal remains low and must be cleared by writing to the ECC Control register.
<b>REV Y</b>	03/28/2024	Added Safe Operating Area Specification: Extended the Operational
	04/05/2024	voltage to 2.5V as a minimum. Added Marking Specification.
	04/09/2024	Corrected 8Gb Ball Map to be consistent with the 1/2/4Gb Ball Map.