

Replacing the Fujitsu MB85RS4MTY SPI-FRAM with Everspin MR2xH40xDF SPI MRAM

EVERSPIN MRAM MEMORY

Everspin is the worldwide leader in designing, manufacturing, and commercially shipping discrete Magnetoresistive RAM (MRAM) into markets and applications where data persistence and integrity, low latency, and security are paramount. The MR2xH40xDF is a family of 4,194,304-bit magnetoresistive random access memory (MRAM) devices organized as 524,288 words of 8 bits. They are the ideal memory solution for applications that must store and retrieve data and programs quickly using a small number of I/O pins. They have serial EEPROM and serial Flash compatible read/write timing with no write delays and unlimited read/write endurance. Unlike other serial memories, with the MR2xH40xDF family both reads and writes can occur randomly in memory with no delay between writes.

OVERVIEW

The MR2xH40xDF family is a SPI interface MRAM family with a memory array logically organized as 512Kx8 using the four pin interface of chip select (CS\), serial input (SI), serial output (SO) and serial clock (SCK) of the serial peripheral interface (SPI) bus. The MRAM implements a subset of commands common to SPI EEPROM and SPI Flash components. This allows the SPI MRAM to replace these components in the same socket and interoperate on a shared SPI bus. The SPI MRAM offers superior write speed, unlimited endurance, low standby & operating power, and simple, reliable data retention compared to other serial memory alternatives.

RELIABLE SUPPLY

Everspin is a long term, reliable manufacturer of MRAM products and operates a fabrication facility in Chandler, Arizona.

BENEFITS OF MR2xH40xDF

Upgrading to Everspin MRAM provides many benefits over Fujitsu FRAM:

- Faster Random Access Operation Times (50MHz/20ns tCLK and 40MHz/25ns tCLK)
- High Reliability and Data Retention (greater than 20 years at 125C Operating Temperature)
- Unlimited Read/Write Endurance
- No Wear-out Concern
- Automatic Data Protection On Power Loss
- Competitive Pricing
- Stable Manufacturing Supply Chain

COMMON PINS

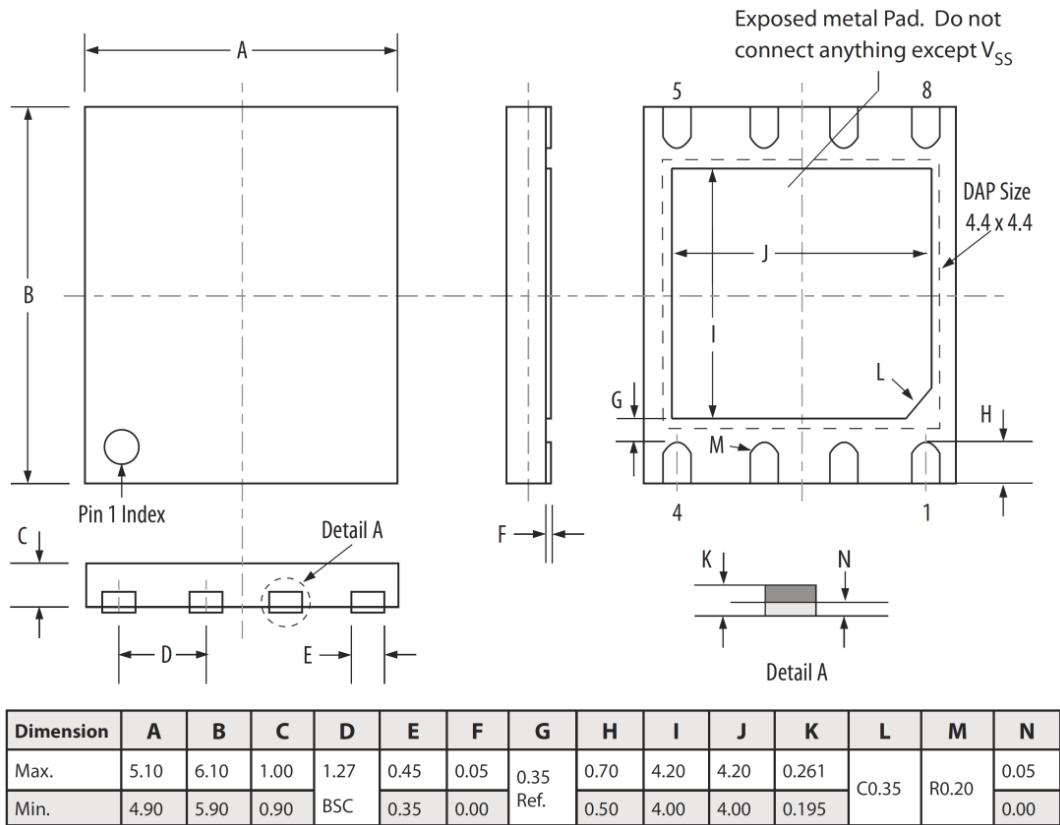
The MR2xH40xDF is a 4Mb non-volatile RAM organized 512Kx8 operating from a nominal 3.3V power supply and is compatible with FRAM. It is available in a standard 8-pin Small Flag DFN (DF version) and 8-pin DFN (DC version), which are versatile package options to make it a drop-in replacement with SPI-FRAM 8-pin plastic SOP and 8-pin DFN packages (Table 1).

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Table 1. Pin and Package Comparison

Feature/Function	SPI MRAM (MR2xH40)	SPI F-RAM (MB85RS4MTYY)	Comments
8-pin DFN Exposed Metal PAD	Do not connect anything except VSS	It is allowed for the DIE PAD on the bottom of the DFN8 package to be floating (no connection to anything) or to be connected to VSS	The Exposed Metal Pad of the MRAM 8-pin DFN package is an NC (No Connect) pad; therefore, it can be either floating or connected to VSS. Everspin does not recommend soldering the MRAM DFN Exposed Metal Pad on the PCB
8-pin packages	8-pin DFN (MR2xH40xDC) 8-pin DFN (Small Flag) (MR2xH40xDF)	8-pin plastic SOP	Both the 8-pin DFN packages of MRAM as shown in Figure 1 and Figure 2 are pin compatible and fit the Fujitsu 8-pin SOIC and DFN packages. They can be placed on a standard SOIC footprint in most designs. See also Application Note "EST01253 Everspin's New 2mm Exposed Pad DFN Package Meets Both SOIC-8 and DFN8 PCB Layouts"

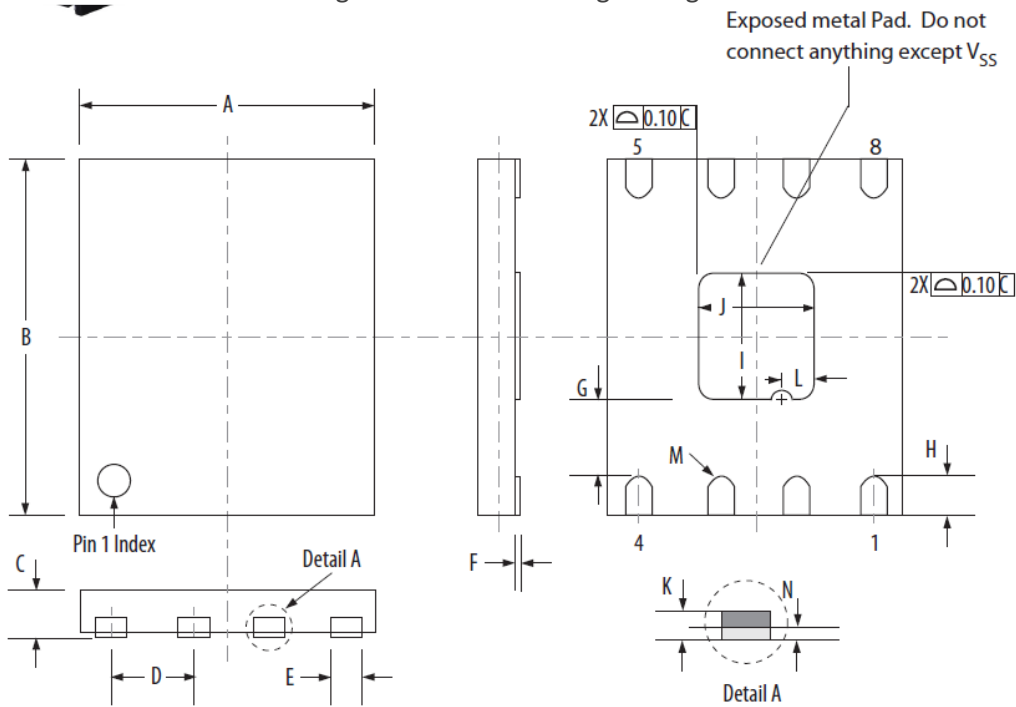
Figure 1 – 4 Mbit SPI MRAM 8-pin DFN Package Outline



The DC package option (8-DFN) is not recommended for new designs. Please select the DF (8-DFN small flag) option for new designs.

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Figure 2 - DFN Small Flag Package

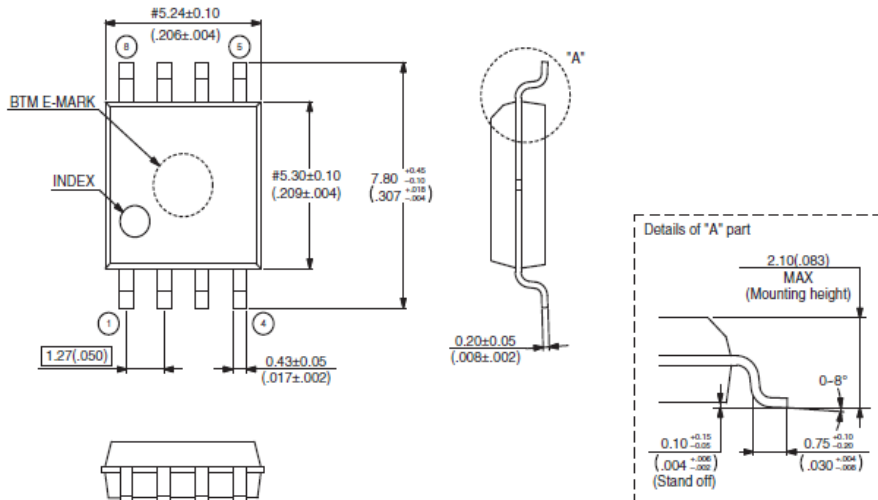


Dimension	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Max.	5.10	6.10	0.90	1.27	0.45	0.05	1.60	0.70	2.10	2.10	.210	Co.45	Ro.20	0.05
Min.	4.90	5.90	0.80	BSC	0.35	0.00	1.20	0.50	1.90	1.90	.196			0.00

Figure 3 – 4 Mbit SPI FRAM 8-pin SOP (5.30 mm × 5.24 mm × 2.10 mm) Package Outline

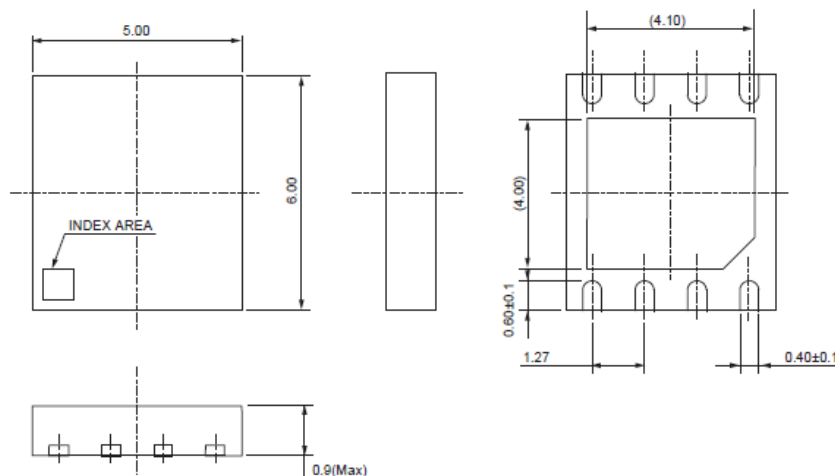
8-pin plastic SOP
(FPT-8P-M08)

Note 1) Pins width and pins thickness include plating thickness.
 Note 2) Pins width do not include tie bar cutting remainder.
 Note 3) #: These dimensions do not include resin protrusion.



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Figure 3 – 4 Mbit SPI FRAM 8-pin DFN (5 mm × 6 mm × 0.9 mm) Package Outline



The SPI MRAM Exposed Metal Pad is not connected to the die, hence it should be left floating or connected to Vss. Ensure that the Exposed Metal Pad of the SPI MRAM DFN and Small Flag DFN package is not soldered on the PCB when migrating from SPI FRAM. Doing so will cause the SPI MRAM die to be exposed to excessive heat, which could result in bit failures and margin loss.

POWER CYCLE TIMING

Timing Parameters	Description	SPI MRAM (MR2xH40)	SPI FRAM (MB85RS4MTYY)	Comments
tDP	Sleep mode entry time	3 μs	Not applicable	The SPI FRAM enters sleep as soon as CS\ toggles LOW to HIGH after the SLEEP command is entered
tPU	Power-up VDD(min) to first access (CS LOW)	400 μs	450 μs	Systems must review the impact of different t _{PU} time in the MRAM and adjust their timing accordingly
tRDP (tREC)	Recovery time from sleep	tRDP = 400 μs	tRECHIB = 450 μs	Systems must review the impact of different recovery time in the MRAM and adjust their timing accordingly
tDIS (tOD)	Output disable time	tDIS = 12 ns (min)	tOD = 10 ns (max)	
tWPS (tCSU)	WP Setup To CS Low	tWPS = 5 ns (min)	tCSU = 5 ns (min)	
tWPH (tCSH)	WP Hold From CS High	tWPH = 5 ns (min)	tCSH = 5 ns (min)	
Power Parameters	Description	SPI MRAM (MR2xH40)	SPI FRAM (MB85RS4MTY)	Comments
IOUT	DC output current per pin	±20 mA	Not specified	This is the absolute maximum rating for the device. This parameter does not influence any device operation across its operating range
VWI	Write inhibit voltage	2.2 V	Not applicable	As soon as VDD falls below VDD min limit, the SPI MRAM writes are inhibited
tVR	VDD power-up ramp rate	Not specified	50 μs/V	Systems must ensure that VDD power-up ramp rate is within the datasheet spec
tVF	VDD power-down ramp rate	Not specified	100 μs/V	Systems must ensure that VDD power-down ramp rate is within the datasheet spec

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Figure 3 – 4 Mbit SPI MRAM Power Cycle Timing

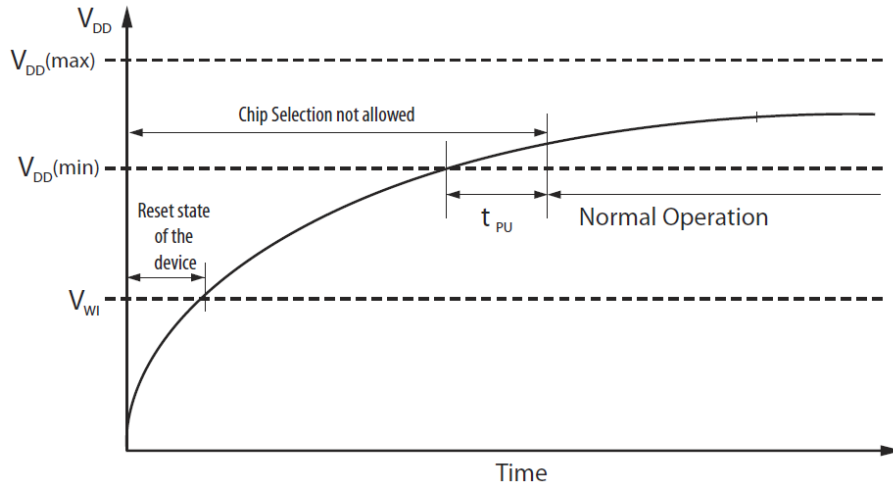
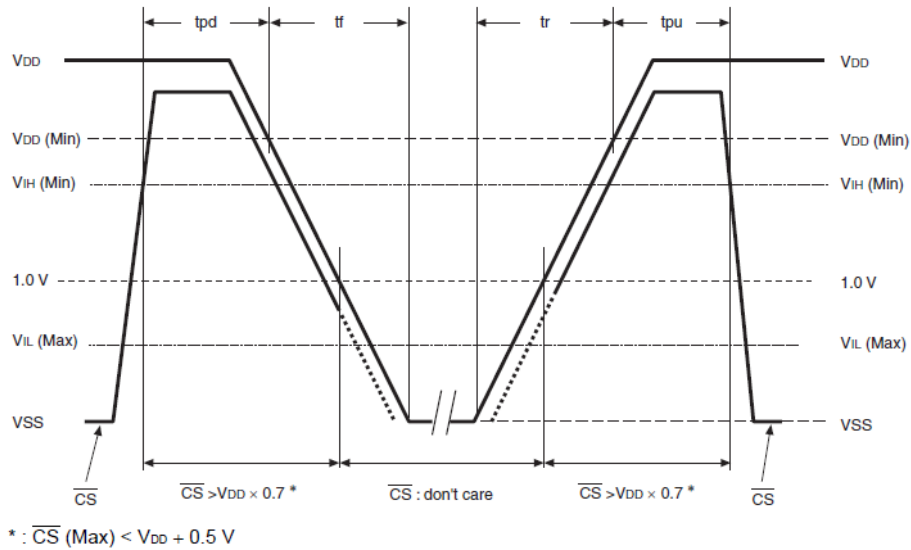


Figure 4 – 4 Mbit SPI FRAM Power Cycle Timing



Command (OPCODE) Compatibility

Command OPCODE (Hex)	Command Description	SPI MRAM (MR2xH40xDF)	SPI FRAM (MB85RS4MTY)	Comments
WREN (06h)	Write Enable	√	√	Identical functionality
WRDI (04h)	Write Disable	√	√	Identical functionality
RDSR (05h)	Read Status Register	√	√	An RDSR command cannot immediately follow a READ command. If an RDSR command immediately follows a READ command, the output data will not be correct. Any other sequence of commands is allowed. If an RDSR command is required immediately following a READ command, it is necessary that another command be inserted before the RDSR is executed. Alternatively, two successive RDSR commands can be issued following the READ command. The second RDSR will output the proper state of the Status Register
WRSR (01h)	Write Status Register	√	√	Identical functionality
READ (03h)	Read Data Bytes	√	√	Identical functionality
FSTRD (0Bh)	Fast read memory data	X	√	The 4-Mbit SPI MRAM doesn't support this command

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Command	Function	MR2xH40xDF	MB85RS4MTY	Compatibility
WRITE (02h)	Write Data Bytes	√	√	Identical functionality
SLEEP (B9h)	Enter sleep mode	√	√	The 4-Mbit SPI MRAM takes t_{DP} (3 μs) to enter sleep
WAKE (ABh)	Exit sleep mode	√	X	The 4-Mbit SPI FRAM does not support this command. Migrating from MRAM to FRAM does not require any software update because the SPI FRAM wakes up when \overline{CS} toggles HIGH to LOW and ignores the subsequent WAKE instruction sent on its input
RDID (9Fh)	Read device ID	X	√	The 4-Mbit SPI MRAM does not support this feature
DPD	Deep Power Down	X	√	The 4-Mbit SPI MRAM does not support this feature
HIBERNATE	Hibernate Mode	X	√	The 4-Mbit SPI MRAM does not support this feature
RUID	Read Unique ID	X	√	The 4-Mbit SPI MRAM does not support this feature
WRSN	Write Serial Number	X	√	The 4-Mbit SPI MRAM does not support this feature
RDSN	Read Serial Number	X	√	The 4-Mbit SPI MRAM does not support this feature
SSWR	Write Special Sector	X	√	The 4-Mbit SPI MRAM does not support this feature
SSRD	Read Special Sector	X	√	The 4-Mbit SPI MRAM does not support this feature
FSSRD	Fast Read Special Sector	X	√	The 4-Mbit SPI MRAM does not support this feature
RFU	Reserved	X	√	The 4-Mbit SPI MRAM does not support this feature

Status Register Compatibility

The Status Register access in the case of the 4-Mbit SPI MRAM and the SPI FRAM are identical. However, the value returned by the Status Register read can differ between the two parts for some bit locations. For example, the “Don’t Care” bits in the SPI MRAM Status Register are writeable and they can return either ‘0’ or ‘1’, while the “Don’t Care” bits in the SPI F-RAM Status Register are read-only bits and always return ‘0’. Table below shows the Status Register bits definition for the two parts and their compatibilities.

Status Register	SPI MRAM (MR2xH40xDF)	SPI F-RAM (MB85RS4MTY)	Comments
Bit0	Don't Care	Don't Care (0)	This bit is non-writeable in the SPI FRAM and always returns '0' upon read. This bit can be modified in the SPI MRAM
Bit1	WEL	WEL	Identical behavior
Bit2	BPO	BPO	Identical behavior (Block Protect)
Bit3	BP1	BP1	Identical behavior (Block Protect)
Bit4	Don't Care	Don't Care (0)	These bits are read-only in the SPI FRAM and always return '0' upon read. These bits can be modified in the SPI MRAM
Bit5	Don't Care	Don't Care (0)	
Bit6	Don't Care	Don't Care (1)	This bit is the read-only bit in the SPI FRAM and always returns '1' upon read. This bit can be modified in the SPI MRAM
Bit7	SRWD	WPEN	Identical behavior

Device Spec Compatibility

Everspin device is a 40 MHz/50MHz MRAM that operates at 2.7V - 3.6V, with a nominal V_{dd} = 3.3V, while the SPI-FRAM has a wider operating voltage range (1.8V to 3.6V). There are a few parameters that warrant some system level analysis before replacing the SPI-FRAM with the SPI-MRAM, including output load, start-up time and power up and power down ramps.

RELIABILITY CONSIDERATIONS FOR COMPARISON

The MB85RS4MTY FRAM architecture employs ferroelectric materials as storage devices. These materials have an intrinsic electric dipole switched into opposite polarities with an external electric field. A read operation in a FRAM is destructive because it requires switching the polarization state in order to sense its state. The read operation has to restore the polarization to its original state after the initial read which adds cycle time to the read operation. FRAM Read and Write cycles require an initial “Pre-charge” time which can increase the initial access time. Ambient operating temperatures above 85°C accelerate wear-out of FRAM due to build-up of free electric charge resulting in imprint and also impact the 10 years data retention.

Everspin MRAM will provide the most cost-effective non-volatile RAM solution. MR2xH40xDF MRAM is built using a much simpler 1-transistor, 1-magnetic tunnel junction cell. The simple Everspin MRAM cell leads to improved

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manufacturing efficiency and increased reliability. MRAM uses magnetic tunnel junction technology for non-volatile storage. Data does not leak away at high temperature and there is no wear-out mechanism to limit the number of read, write, or power cycles in this technology. Another important aspect of the reliability of toggle MRAM is the data retention against errors from thermally induced magnetization flips. Accelerated baking tests were conducted in which checkerboard patterns were written into the parts before the bake and the data was read back afterwards. The 1500 representative 4-Mb parts across three lots were baked under conditions ranging from 2000 h at 150 C to 2 h at 260 C and zero data retention flips were observed for all the parts. Extrapolation back to operating temperatures indicates a data retention lifetime exceeding 20 years. MRAM also offers radiation-hard performance due to the inherent robustness of the magnetic materials to radiation exposure. Alpha particle and neutron irradiation of 4-Mb dies showed an error rate of <0.5 FIT/Mb.

MRAM MAGNETIC TOLERANCE

Everspin Technologies SPI MRAMs provide low susceptibility to data corruption when operated in magnetic field environments, therefore helping engineers to design high magnetic tolerance reliable systems. The maximum external magnetic field that can be applied to SPI MRAMs is 12000 A/m (150 Gauss), during write, read and standby operations. Everspin Technologies provide specific guides about how to operate MRAMs in these situations.

SUMMARY

Replacing a MB85RS4MTY with Everspin's MR2xH40xDF 4Mb SPI MRAM is a straight-forward process. These devices are a drop-in replacement with some considerations of power supply and timing details shown in this application note. Everspin MRAM is also available with AEC-Q100 grade option with a data retention greater than 20 years, compared to the Fujitsu MRAM, which offers only 0.85 years of data retention at +125C, without any automotive qualification.

Table 2 – Everspin MRAM Ordering Part Numbers

Speed Grade	Temp Grade	Temperature	Package	Shipping Container	Order Part Number
50MHz	Industrial	-40 to +85 C	8-DFN Small Flag	Trays	MR20H40CDF
				Tape and Reel	MR20H40CDFR
40 MHz	Industrial	-40 to +85 C	8-DFN ¹	Trays	MR25H40CDC ¹
				Tape and Reel	MR25H40CDCR ¹
			8-DFN Small Flag	Trays	MR25H40CDF
				Tape and Reel	MR25H40CDFR
	Extended	-40 to +105 C	8-DFN Small Flag	Trays	MR25H40VDF
				Tape and Reel	MR25H40VDFR
	AEC-Q100 Grade 1	-40 to +125 C	8-DFN Small Flag	Trays	MR25H40MDF
				Tape and Reel	MR25H40MDFR

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