NOR | NAND Flash guide

Selecting a flash memory solution for embedded applications

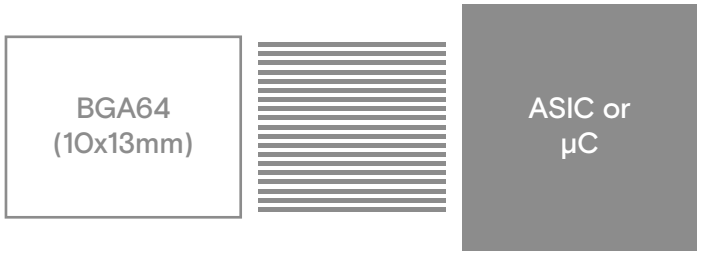
When looking for flash memory for your embedded applications, Micron has the right solution. Our many years of embedded industry experience and our broad portfolio of NOR and NAND flash memory products — from serial, octal and parallel NOR flash, to raw and managed NAND flash, to SSDs — provide you with ideal code and data storage solutions. Selecting the right solution requires an understanding of each technology, including attributes related to I/O performance, pin count, data integrity, and manufacturing longevity requirements. This guide describes the various flash technologies and provides a systematic way for embedded system designers to select the optimal nonvolatile memory solution based on key design considerations. Application requirements will ultimately dictate the right solution.

Getting to know NOR Flash

NOR flash devices, available in densities from 128Mb up to 2Gb, are primarily used for reliable code storage (boot, application, OS, and execute-in-place [XIP] code in an embedded system) and frequently changing small data storage. NOR flash provides systems with the fastest bootable memory solution for instant on performance, is easy to implement, and requires minimal ongoing management due to the underlying cell structure. Because of the cell structure, NOR flash is inherently more reliable than other solutions.

NOR low pin counts and small package solutions make it a good fit for applications like automotive ADAS (advanced driver-assist systems) and IVI (in-vehicle infotainment), IPC/factory automation, intelligent edge devices, machine to machine, healthcare, radio access networks (RAN), servers and routers, wearables, cameras, and printers.

Octal flash leverages the best of serial NOR flash and parallel NOR flash to offer system designers both high performance and low pin counts. Serial NOR flash, with its high-speed continuous read capabilities throughout the entire memory array and its small erase block sizes, is tailored for applications that shadow program code and/or store granular data. Parallel NOR flash provides direct memory access and fast random-access reads for legacy interfaces that continue to be widely adopted.



Parallel NOR Flash (50 active pins)

Xccela™ Octal Flash (11 active pins)

Getting to know NAND Flash

NAND flash devices, available in 128Mb to 2Tb+ densities, are used to store data and code. Low-density NAND flash is ideal for applications like automotive, surveillance, machine-to-machine (M2M), IPC, automation, printers and home networking while high-density NAND flash is most commonly used in data-heavy applications like SSDs, tablets, and USB drives. There is a continuous effort to reduce the cost/GB of NAND devices, so device lifecycles tend to be shorter with more frequent process lithography shrinks than NOR flash. NAND requires a controller, either internal or external, and specific firmware for error code correction (ECC), bad block management, and wear leveling.

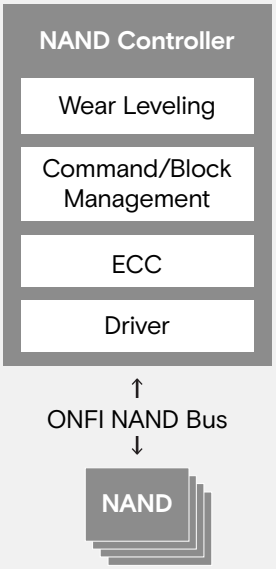
There are two primary types of NAND: raw and managed. Raw NAND comes in different flavors, including single-level cell (SLC), multi-level cell (MLC), triple-level cell (TLC) and quad-level cell (QLC). Additionally, NAND technology is migrating from planar to 3D for higher density applications. 3D NAND has an inherently larger cell, so TLC based on 3D (3D-TLC) is expected to become mainstream in the next 1-2 years. Raw NAND requires external management but is the lowest cost/GB NAND flash available. Managed NAND incorporates memory management into the package, simplifying the design-in process.

NOR and NAND features comparison

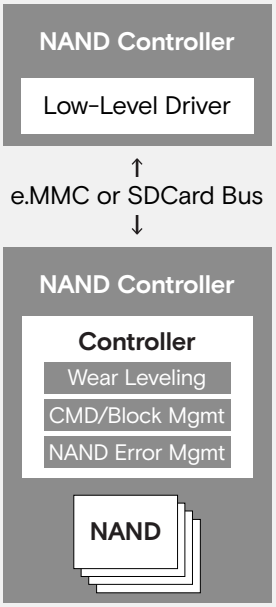
Xccela Octal Flash, Serial NOR, Parallel NOR	SLC/MLC/TLC/SPI NAND, Managed NAND
• Lower density • Low pin count (Octal and Serial) • Ease-of-use • Reliable code and data storage • Fast read and random access times • Higher endurance and data retention	• Higher density, low pin count • Requires controller management (SLC, MLC) • Mostly data-focused • Fast writes and erases • Focused on highest reliability and performance (SLC), optimum reliability and lower cost (MLC and 3D TLC), cost-focused applications (QLC), and reduced time-to-market/ease of design-in with managed NAND

Other design considerations include controller type, voltage requirements, individual parameter and feature specifications, security*, and software.

Raw NAND

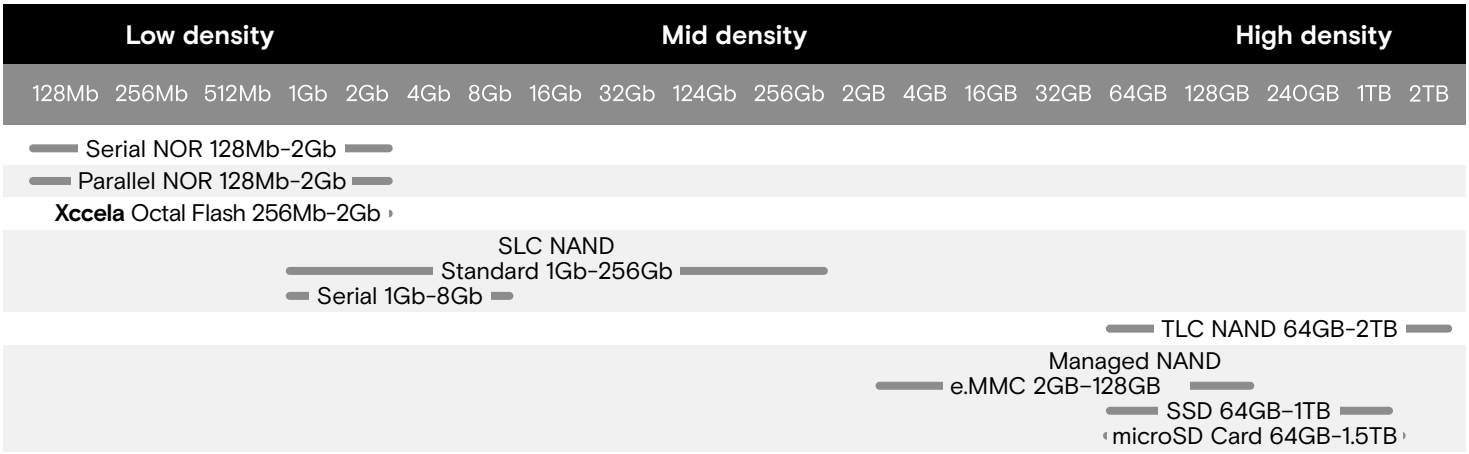


Fully Managed NAND



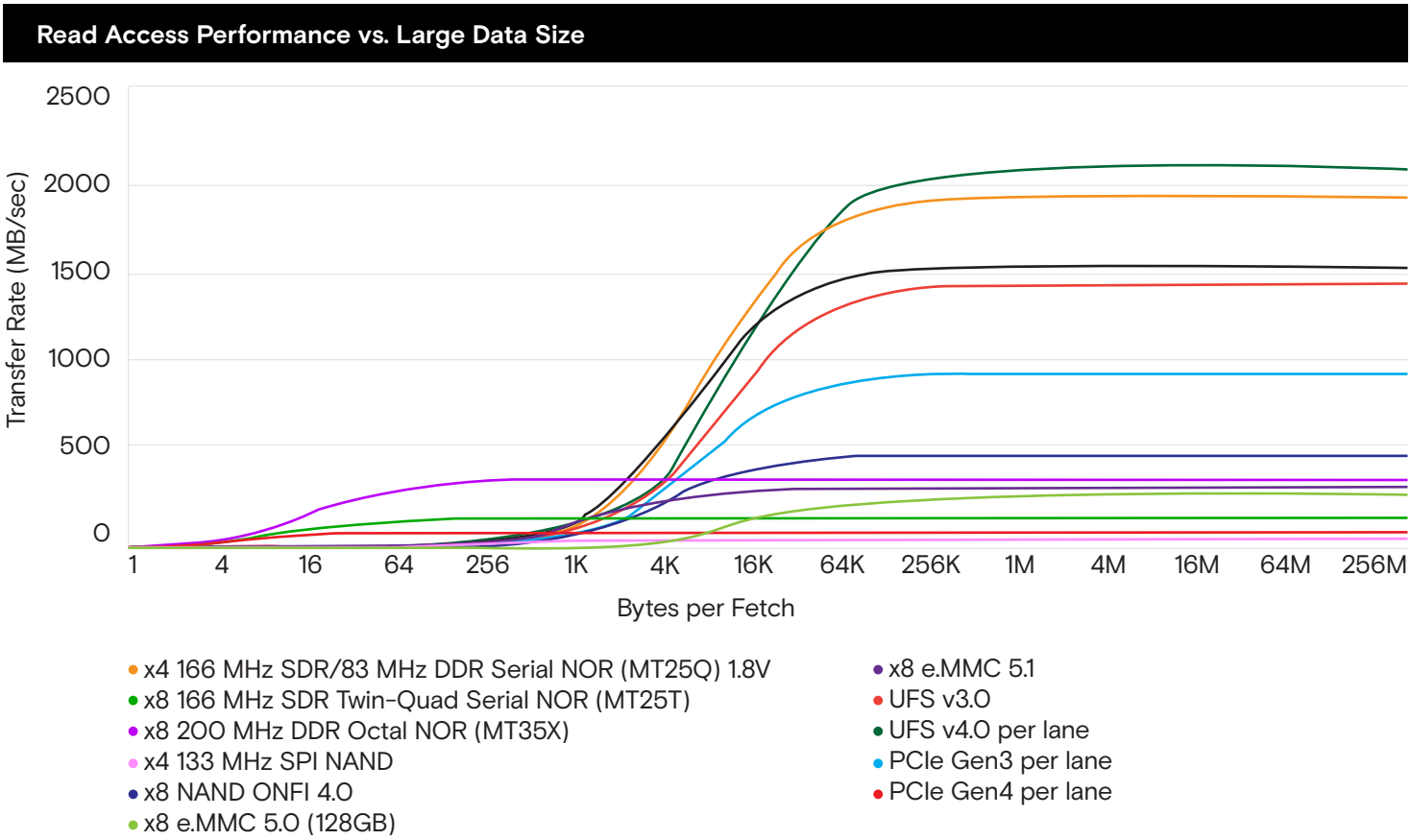
Densities offered by device type

The chart below shows various NOR and NAND density ranges to help identify the best solution for your application requirements.



NOR and NAND read performance

As shown in the figure below, read performance is mostly governed by bus width and clock speed (e.g., x16 and 133 MHz).



Micron NOR Flash portfolio

Xccela™ Octal Flash
Octal flash memory offers the highest performance, lowest pin count (only 11 active signal pins) and lowest energy consumption compared to other NOR flash solutions. Xccela Octal flash memory leverages the JEDEC compatible xSPI interface to deliver breakthrough performance. In addition to enabling one of the fastest possible direct code execution and code shadowing, Xccela Octal flash paves the way for simpler system designs, lower system costs, and lower energy consumption.

Serial NOR
Due to its interface and low pin count, Micron's serial NOR flash is an easy-to-use solution for applications that code shadow; simply provide a starting address in the memory to read and then continuously clock data out from the device throughout the entire memory array. Advanced security and memory protection features, including RPMC (replay protected monotonic counter) provide peace of mind for securing vital program code and sensitive user data*.

Micron's twin-quad serial NOR flash combines two quad I/O devices into a single package to create an 8-bit, bidirectional I/O structure, which effectively doubles the bandwidth and performance while maintaining the same footprint as a serial NOR flash.

Parallel NOR
Parallel NOR flash devices operate in page mode for use in applications where code runs directly from the device. This minimizes system boot time, making it ideal for process intensive applications that need performance. Parallel NOR devices also provide data security options* and feature expanded 1.65-3V I/O (VCCQ) voltage. Parallel NOR is offered in choice of standard packages.

NOR Flash – quick features comparison

Device	Density range[1]	Bus width	Voltage[1]	Speed	Package options[1]
Xccela™ Octal Flash (MT35X)	256Mb-2Gb	x1, x8	1.7-2.0V, 2.7-3.6V	200 MHz DDR (400 MB/s)	BGA
MT25Q	128Mb-2Gb	x1, x2, x4	1.7-2.0V, 2.7-3.6V	133-166 MHz (90 MB/s)	SOIC, DFN, BGA, CSP
MT25T	256Mb-1Gb	x1, x2, x4, x8	2.7-3.6V	133 MHz (180 MB/s)	SOIC, BGA
MT28EW	128Mb-1Gb	x8, x16	1.65-3.6V	95ns, 20ns page	TSOP, BGA
MT28FW	1Gb-2Gb	x16	1.65-3.6V	105ns, 20ns page	BGA

[1]Not all densities available in all package and voltage combinations. Some densities offered as stacked solutions.

NOR relative attributes

Device	Read performance	Design simplicity	Power savings	Security offerings[2]	Endurance/Data retention
Octal	•••••	•••••	•••••	••••	•••••
Serial	••••	•••••	•••••	•••••	•••••
Twin-quad	••••	••••	••••	••••	•••••
Parallel	•••	•••	••••	••••	•••••

= Lower; • = Low; •• = Medium; ••• = High; •••• = Higher; ••••• = Highest
[2]Serial NOR offers OTP (one time programmable) and RPMC (replay protected monotonic counter) dedicated MPNs

NOR suitability by application

Device	Automotive	Industrial	Consumer	Networking
Octal	•	•	•	•
Serial	•	•	•	•
Twin-quad	•	•		•
Parallel	•	•	•	•

Micron NAND Flash portfolio

Select from one of the industry's broadest portfolios of raw and managed NAND flash. To meet the high reliability and temperature requirements of embedded applications like automotive and industrial, many of Micron's NAND flash solutions are ISO/TS 16949-certified and have extended temperature ranges as well as long product lifecycles.

Raw NAND
Raw NAND provides the lowest cost per bit but requires an external host controller (not contained within the package) to perform all management functions (e.g., ECC, FTL).

• **Single-level cell (SLC)**
One bit per cell; high performance and write endurance and lowest cost/bit for ≤1GB densities. Low-density SLC is used for code storage in embedded applications while high-density SLC is used in mission-critical systems where high performance and best-in-class reliability are required.

• **Serial SLC NAND**
Low-density SLC devices with a NOR-like serial interface simplify system design.

• **Triple-level cell (TLC)**
Three bits per cell; high cell density, but lower performance and endurance specifications. Most often used in mass storage consumer applications (client SSDs, USB drives, SD cards) with very high cost sensitivity; however, with 3D TLC NAND, reliability is adequate for applications that use planar MLC.

• **Quad-level cell (QLC)**
Four bits per cell; higher density and larger capacity at lower cost per bit; lower endurance and slower speed compared to TLC NAND; suitable for read-intensive applications.

• **On-Die ECC NAND**
Hybrid between raw and fully managed NAND; ECC is integrated while wear leveling and bad block management are handled by the host controller.

Managed NAND
Managed NAND provides simpler solutions and accelerates time-to-market because the controller is embedded within the package to handle wear leveling, bad block management, and ECC.

• **e.MMC/UFS memory**
High-capacity NAND flash device combined with a high-speed multi-media card (MMC) controller in a single BGA package; suitable for designers looking for a fully managed device and ease of design for MMC-like, application-to-application interoperability for a wide range of networking, industrial, and automotive applications.

• **Solid State Drives (SSDs)**
NAND-based PCIe and SATA SSDs enhance reliability, reduce power, and provide faster performance compared to hard disk drives (HDDs).

• **microSD Card**
Advanced Micron 3D NAND flash memory technology-based removable storage devices are specifically designed to meet the performance, capacity and quality required for industrial devices and systems.

Selecting a NAND device

Use the following tables to help select the right NAND device to match your design requirements. For more details, see our NAND part catalogs and our Choosing the Right NAND page, or find a sales representative at micron.com.

Raw NAND – quick features comparison

Device	Density	Width	Voltage	Benefits
SLC NAND	1Gb–256Gb	x8, x16	1.8V, 3.3V	• Up to 100,000 P/E cycle endurance • Fastest NAND throughput • Compatible with the ONFI-synchronous interface
Serial (SPI) SLC NAND	1Gb–8Gb	x1, x2, x4	1.8V, 3.3V	• Ease-of-use, faster boot-up • Increased power efficiency • High performance, low power • Increased bandwidth
TLC NAND	64GB-2TB (considering RG technology)	x8	VCC 2.5V/3.3V, VCCQ 1.2V	• Higher density in the same footprint but at a lower cost than SLC
QLC NAND	128GB-2TB	x8	VCC 2.5/3.3V VCCQ 1.2V	• Larger capacity at lower cost per bit than TLC

Managed NAND – quick features comparison				
Device	Density	Interface	Voltage	Benefits
e.MMC	32GB–256GB	eMMC 5.1 JEDEC std	1.8V/3.3V	• Single package solution for designers looking for MMC-like application-to-application interoperability. • Offered in spectrum of densities and unique features suitable for various automotive and non-automotive applications. • Ideal for applications seeking balance of low price, fast performance, and high reliability
SSD	64GB–2TB	PCIe	Varies	• High performance and reliability • Designed for industrial and automotive applications
UFS	64GB–512GB	2.1, 2.2 and 3.1 JEDEC standard	1.2V for UFS 3.1 and 1.8V for UFS 2.1; UFS 2.2	• Single-package solution for an ultra-fast UFS storage interface between NAND and device host • Ideal for computing and mobile systems that require low power consumption and for advanced automotive systems that need ultra-fast boot capability and automotive-grade reliability
SD card	32GB–256GB	SD3.0 UHS-I	3.3V	• Advanced Micron 3D NAND flash memory technology-based removable storage device • On-board intelligent controller supports ECC algorithms, defect handling, sudden power-off safeguard and wear leveling.

NAND relative attributes				
Device	Endurance	ECC Compatibility	Performance	Interface Complexity
SLC NAND	•••••	•	••••	••
Serial (SPI) NAND	•••••	•	••••	•
TLC NAND	••	•••	••	•••
QLC NAND	•	•••	•	•••
MCPs—NAND with LPDRAM	•••	•	•••	••
e.MMC/UFS	••	•	••	•
eMCP—e.MMC with LPDRAM	••	None	••	•
Embedded USB (eUSB)	••••	None[1]	•••	•
SSD	••••	None	•••	•
SD and microSD cards	••	None	••	•

• = Low; •• = Medium; ••• = High; •••• = Higher; ••••• = Highest; 1. ECC circuit and processing built in.

NAND suitability by application											
Device	Card/ USBs[1]	Media players	Cameras	Connected home	Mobile handsets	Portable navigation	Automotive	Enterprise/ Industrial	Medical	Networking	STB/ DTV
SLC NAND, SPI NAND	•	•	•	•	•		•	•	•	•	•
TLC NAND	•	•			•	•		•			
QLC NAND	•	•									
Enterprise NAND								•			•
e.MMC/UFS		•	•		•	•	•	•	•	•	•
eMCP—e.MMC with LPDRAM			•	•	•			•			
MCPs—NAND with LPDRAM			•		•		•	•	•		
Embedded USB (eUSB)								•		•	
SSDs	•	•	•		•	•	•	•	•	•	•
SD and MicroSD	•	•	•	•	•	•			•	•	•

1. Performance-dependent

Benefits of partnering with an embedded memory expert

As a leading supplier of memory for 30+ years with an in-depth understanding of the embedded industry, you can rely on Micron as a single source for your embedded memory needs. Team up with us for:

Unwavering commitment

Micron is expanding its Manassas, U.S. fabrication site to support the rapidly growing need for high-quality, high-reliability memory solutions. This site manufacturers our long-lifecycle products to ensure supply continuity for the industrial and automotive markets. Delivering a leading-edge, state-of-the-art auto- and industrial-qualified memory portfolio with associated lifecycle support places Micron in a class by itself and further underscores our continued commitment to these markets.

The tools to enable your next-generation innovation

Get the right memory technology—designed for embedded industry requirements—at just the right time thanks to our ever-expanding industry knowledge base and strong relationships with chipset vendors. Coupled with support from our embedded memory experts and technical resources, you'll be armed with a total solution that is optimized for your next-generation embedded applications.

Reliability from a world-class supplier

Rely on products that are manufactured by Micron with a focus on high quality and reliability standards. We test select devices with an extended temperature range of -40˚C up to 125˚C for the highest reliability, and many of our products have also achieved ISO/TS certification. As new designs emerge and requirements shift, you can continue to depend on Micron to offer the broadest portfolio of memory solutions to fuel your embedded innovations.

Learn More: for more about Micron's flash memory solutions, or to find a sales representative or authorized distributor, go to micron.com.

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