



NOR | NAND Flash Guide

Selecting a Flash Memory Solution for Embedded Applications

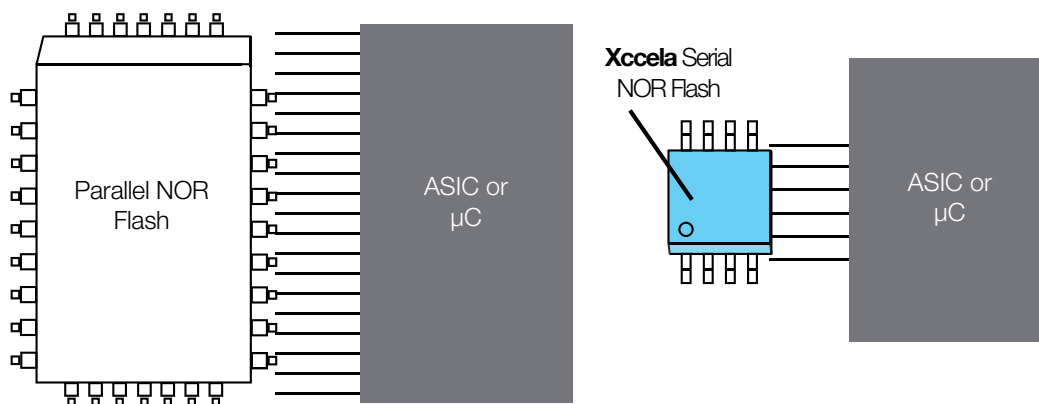
When looking for flash memory for your embedded applications, Micron has the right solution. Our many years of embedded industry experience and our broad portfolio of NOR and NAND flash memory product—from serial and parallel NOR flash, to raw and managed NAND flash, to SSDs—provide you with ideal code 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 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, 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.

There are two general categories of NOR flash—serial and parallel—that differ primarily with respect to their memory interfaces. **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. Serial NOR's low pin counts and small package solutions make it a good fit for applications like PCs, ultrathins, servers, set-top boxes (STBs), printers, Blu-ray drives/players, modems/routers, wearables, and hard disk drives (HDDs). **Parallel NOR flash** delivers fast system boot times, making it ideal for applications like digital still cameras (DSC and DSLR) that need performance, as well as other process-intensive applications like networking routers/switches, home gateways, and STBs.

Micron has created a new category of NOR flash, called **Xccela™** Octal SPI NOR flash memory, which leverages the best of serial NOR flash and parallel NOR flash so that system designers do not have to choose between high performance and low pin counts. **Xccela** flash memory sets a new record for NOR flash speeds to meet the demand for instant-on performance and fast system responsiveness in automotive, industrial, consumer, and networking applications.

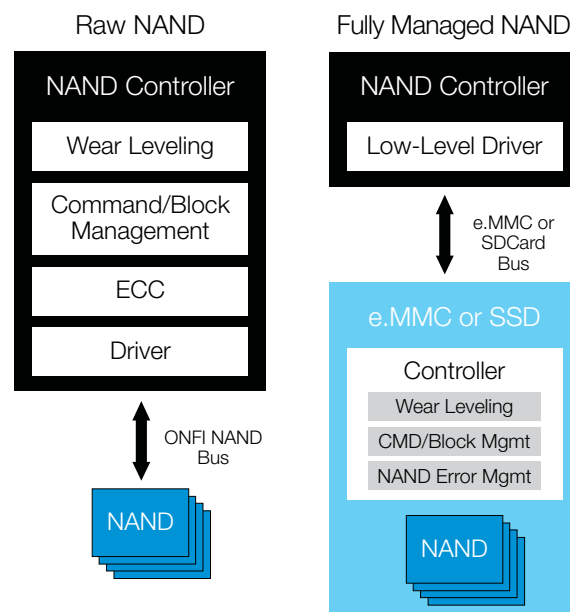


Note: Xccela flash uses TBGA-24 with only 10-11 active signals.

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 with better reliability, 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 NOR Flash | Serial NOR | Parallel NOR

- Lower density, low pin count (serial)
- Ease-of-use
- Reliable code and data storage
- Fast read and random access times
- Higher endurance and data retention

SLC/MLC/TLC/SPI NAND | Managed NAND

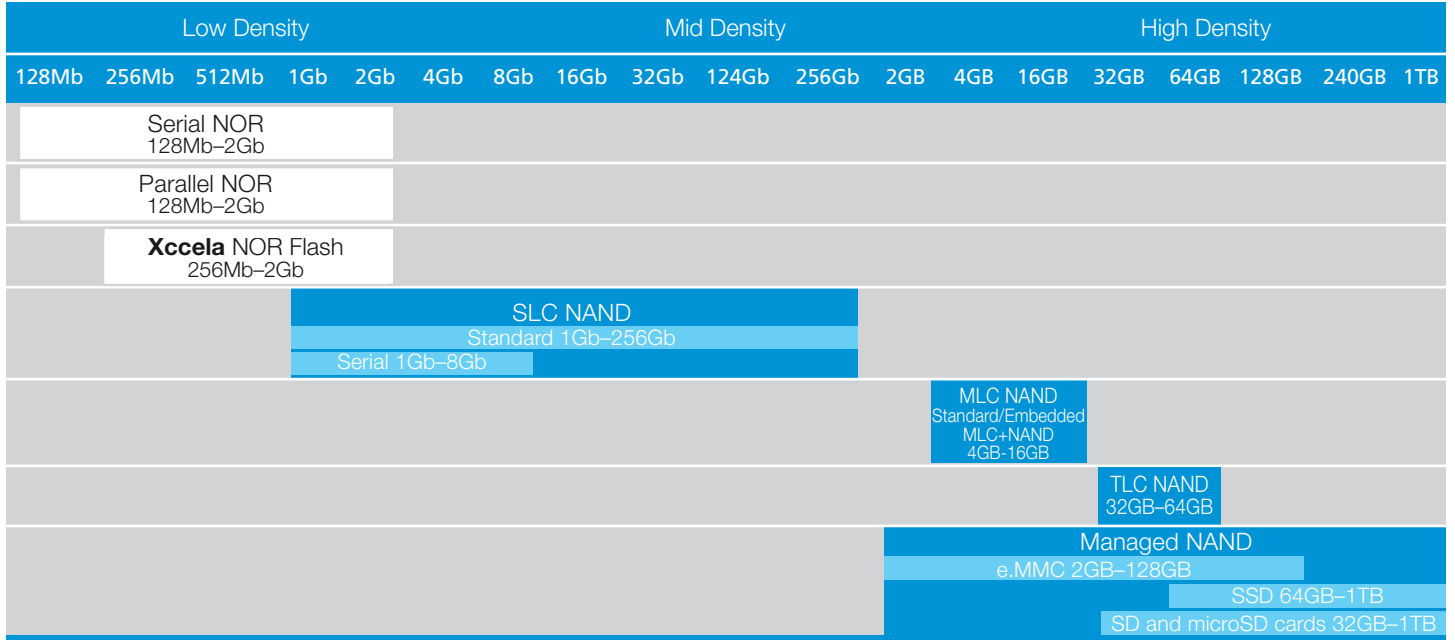
- Higher density, low pin count
- Requires controller management (SLC, MLC)
- Mostly data-focused
- Fast writes and erases
- Focused on highest reliability and performance (SLC), optimum reliability and lower cost (MLC and 3D TLC), cost-focused applications (2D TLC, QLC), and reduced time-to-market/ease of design-in with managed NAND

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



Densities Offered by Device Type

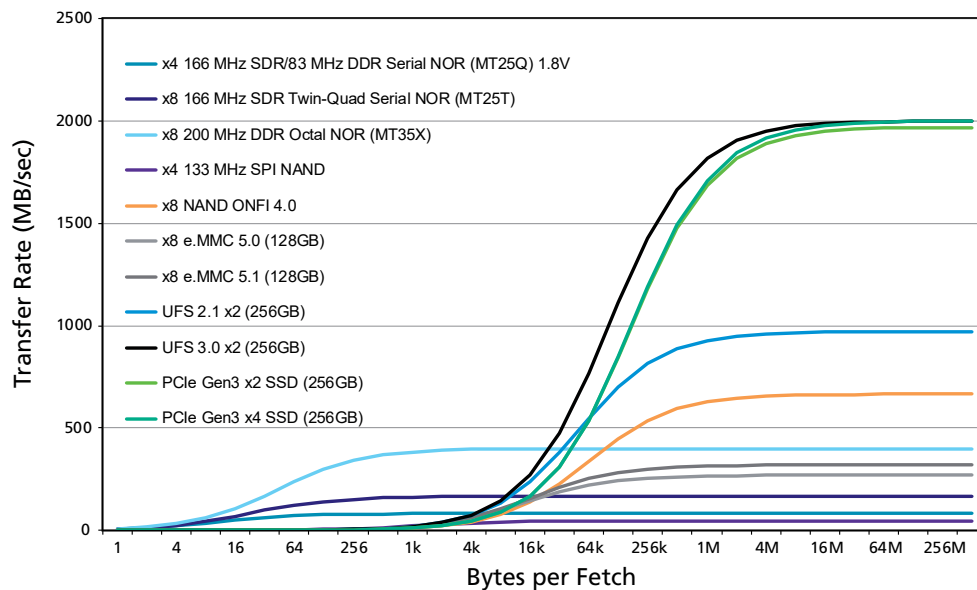
The chart below shows various NOR and NAND density ranges to help identify the best solution for your application requirements.



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).

Read Access Performance vs. Large Data Size



Micron NOR Flash Portfolio

Serial NOR

Due to its interface and low pin count, Micron's serial NOR flash is easy to use and is a simple 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. Features such as advanced security and memory protection provide peace of mind for securing vital program code and sensitive user data*. Our 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. Whatever the application, Micron has the right serial NOR flash solution.

Parallel NOR

Parallel NOR flash devices operate in page mode for use where code runs directly from the device to minimize system boot time, making it ideal for applications that need performance as well as other applications that are process-intensive. These devices enriched with many features also provide data security options* and are ideal for long-term use in industrial applications. Parallel NOR is offered in standard product types available from Micron.

Xccela Octal SPI NOR

Micron's Xccela flash memory uses our Xccela bus interface to offer significant improvement in performance, reduction in pin count (only 11 active signal pins) and energy consumption compared to other NOR flash solutions in the market. Xccela flash memory leverages the Xccela Bus open-standard interface (www.xccela.org) to deliver breakthrough performance with as few as 11 active signals. In addition to enabling one of the fastest possible direct code execution and shadowing, Xccela flash paves the way for simpler system designs, lower system costs, and lower energy consumption.

NOR Features Comparison	
Serial (SPI)	Xccela Flash
<p>Low pin count, security*, granular erase architectures</p> <p>MT25T (Twin-Quad x8 SPI Multi I/O):</p> <ul style="list-style-type: none"> • x1 x2, x4, x8 (twin-quad I/O) • 3V • 4KB subsector erase • 256Mb–1Gb • 133 MHz SDR/90 MHz DDR reads (180 MB/s) <p>MT25Q (x4 SPI Multi I/O):</p> <ul style="list-style-type: none"> • x1–x4 (quad I/O) • 1.8V or 3V • 4KB subsector erase • 128Mb–2Gb • 166 MHz SDR/90 Mhz DDR reads (90 MB/s) 	<p>Extreme performance, low pin count, low energy</p> <p>MT35X (Monolithic x8 SPI Multi I/O):</p> <ul style="list-style-type: none"> • JEDEC xSPI standard-compliant Octal SDR and DDR protocols • x1, x8 (SPI-compatible serial bus) • 1.8V or 3V • 28 pJ/bit • 4KB subsector erase • 256Mb–2Gb • Up to 200 MHz reads (400 MB/s) • 76ns latency (2 bytes)
	Parallel
	<p>Fast boot, low-latency reads, fast random access</p> <p>MT28EW:</p> <ul style="list-style-type: none"> • 3V • 128Mb–2Gb



NOR Densities

See Micron's NOR products by type and density, as well as the key products recommended for new designs, in the chart below.

Micron Embedded NOR Solutions

Device Type	128Mb	256Mb	512Mb	1Gb	2Gb
Serial 3V			MT25Q		
			MT25T		
Parallel 3V			MT28EW		
Xccela Flash 3V			MT35X		
Xccela Flash 1.8V			MT35X		

Note: This table only includes devices recommended for new designs. Not all densities available in all package and voltage combinations.

Selecting a Serial NOR Device

Use the following table to help select the right serial NOR device for your design. For more details, see the full serial NOR part catalog and find a sales representative at micron.com.

Xccela Flash Memory and Serial NOR – Quick Features Comparison

Product	Voltage Range	Erasable Sectors	Bus Width	Density Range	MAX Clock/ MAX Data Transfer Rate	Program/ Erase Cycling	Package Options
Xccela Flash (MT35X)	2.7-2.6V	4KB, 32KB, 128KB uniform	x1, x8	256Mb-2Gb	200 MHz (400 MB/s)	100,000	BGA
MT25T	2.7-3.6V	4KB, 32KB, 64KB uniform	x1, x2, x4, x8	256Mb-1Gb	133 MHz SDR/ 90 MHz DDR reads (180 MB/s)	100,000	BGA
MT25Q	2.7-3.6V	4KB, 32KB, 64KB	x1, x2, x4	256Mb-2Gb	133 MHz SDR/ 90 MHz DDR reads (180 MB/s)	100,000	DFN, BGA

Note: This table only includes devices recommended for new designs. Not all densities available in all package and voltage combinations.

Parallel NOR Family

For more details on parallel NOR, find a sales representative at micron.com.

Parallel NOR – Quick Features

Product	Core Voltage	I/O Voltage	Bus Width	Density Range	Program/ Erase Cycling	Package Options
MT28EW	2.7–3.6V	1.65–3.6V	x8, x16	128Mb–2Gb ²	100,000	56-pin TSOP 64-ball FBGA

1. This table only includes devices recommended for new designs.

2. 2Gb parallel NOR solution is an MT28FW product with x16 bus width and a dual-die package.



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 ≤ 1 GB 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.

- **Multi-level cell (MLC)**

Two bits per cell; a good balance of performance and write endurance for a wide range of cost-sensitive, high-density applications.

- **Enterprise MLC NAND**

Uses special programming algorithms to extend write endurance; typically used in high-write workloads like time shifting (pausing live TV).

- **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.

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.

- **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.

- **Solid State Drives (SSDs)**

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

- **SD and microSD Cards**

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 device 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Ease-of-use, faster boot-up Increased power efficiency High performance, low power Increased bandwidth
MLC NAND	4GB–2Tb+	x8	3.3V	<ul style="list-style-type: none"> Solid performance and endurance 2X the density of SLC NAND at a lower cost per bit Compatible with the ONFI-synchronous interface
Embedded MLC+ NAND	4GB–2Tb+	x8	3.3V	<ul style="list-style-type: none"> Optimized performance for intensive applications Compatible with ONFI interface High endurance, high capacity, high reliability Full turnkey solution ensures sophisticated NAND management solution
TLC NAND	16GB–32GB	x8	3.3V	<ul style="list-style-type: none"> Higher density in the same footprint but at a lower cost than SLC or MLC NAND

Managed NAND – Quick Features Comparison

Device	Density	Interface	Voltage	Benefits
e.MMC	2GB–128GB	4.41, 4.51 and 5.0 JEDEC standard	3.3V	<ul style="list-style-type: none"> 5.1 e.MMC interface Single-package solution for designers looking for MMC-like application-to-application interoperability Offered in a variety of densities and options
SSD	64GB–256GB 64GB–1TB	SATA 6 Gb/s PCIe NVMe	3.3V (mSATA, 5V 2.5-inch) 3.3/1.2/0.9V (BGA) and 3.3V (M.2)	<ul style="list-style-type: none"> High performance and reliability Designed for industrial and automotive applications
UFS	32GB–256GB	2.1	1.8V/3.3V	<ul style="list-style-type: none"> 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 microSD card	32GB–256GB 32GB–1TB	SD3.0 UHS-I	3.3V	<ul style="list-style-type: none"> 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	Price/GB	Interface Complexity
SLC NAND	•••••	•	•••••	\$\$\$\$	••
Serial (SPI) NAND	•••••	•	•••••	\$\$\$\$	•
Enterprise NAND – MLC ¹	•••	•••••	•	\$\$\$	•••••
MLC NAND	•••	••	•••	\$\$\$	•••
TLC NAND	•	•••	•	\$	•••
QLC NAND		•••		\$	•••
MCPs – NAND with LPDRAM	•••	•	•••	\$\$\$	••
e.MMC/UFS	••	None	••	\$\$	•
eMCP – e.MMC with LPDRAM	••	None	••	\$\$\$	•
Embedded USB (eUSB)	•••••	None ²	•••	\$\$\$\$	•
SSD	•••••	None	•••	\$\$\$\$	•
SD and microSD cards	••	None	••	\$	•

◀ = Lower; • = Low; •• = Medium; ••• = High; •••• = Higher; ••••• = Highest
 1. Requires enhanced ECC and relaxed timings. 2. 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	•	•	•	•	•		•	•	•	•	•
MLC, 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 manufactures 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.

micron.com

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