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 and parallel NOR flash, to raw and managed NAND flash, to solid state drives (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 an embedded system designer to select the optimal nonvolatile memory solution based on key design considerations. The 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.
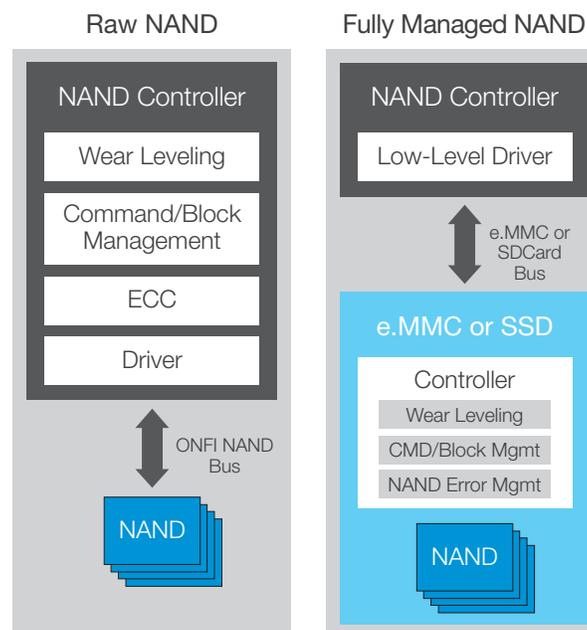
Micron has created a new category of NOR flash, called **Xccela**™ flash memory, which leverages the best of serial NOR flash and parallel NOR flash so that system designers do not have to choose between high performance and low pin counts.

Parallel NOR Flash

Xccela Flash and
Serial NOR Flash

ASIC
or
µC

ASIC
or
µC

Xccela flash uses 16-pin package
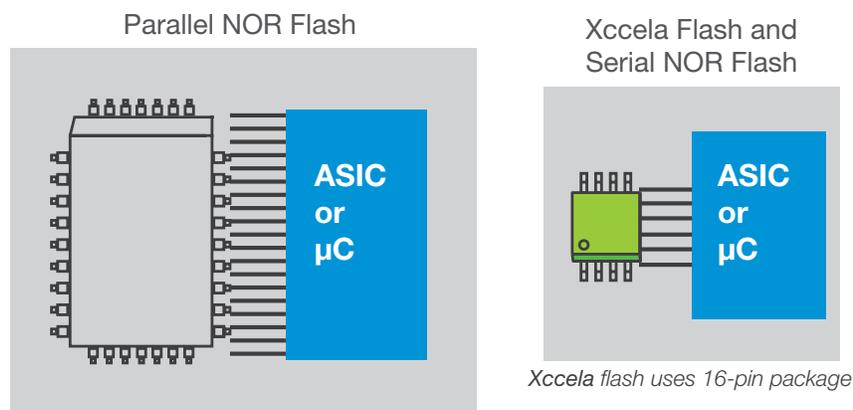
Getting to Know NAND Flash

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 STBs, digital televisions (DTVs), and DSCs 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 life cycles 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), multilevel cell (MLC), triple-level cell (TLC) and quad-level cell (QLC) in the future. 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 main-stream 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.

Raw NAND

NAND Controller

Wear Leveling

Command/Block Management

ECC

Driver

ONFI NAND Bus

NAND

Fully Managed NAND

NAND Controller

Low-Level Driver

e.MMC or SDCard Bus

e.MMC or SSD

Controller

Wear Leveling

CMD/Block Mgmt

NAND Error Mgmt

NAND

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
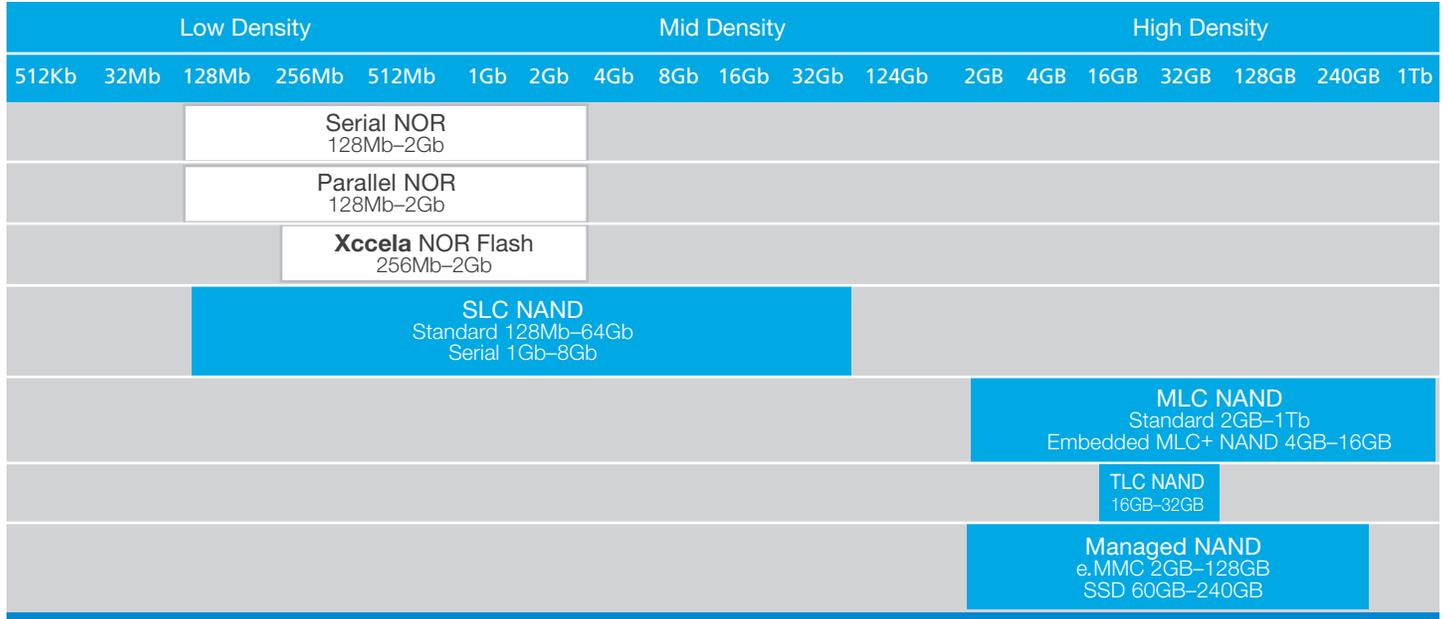- Higher endurance and data retention

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.*
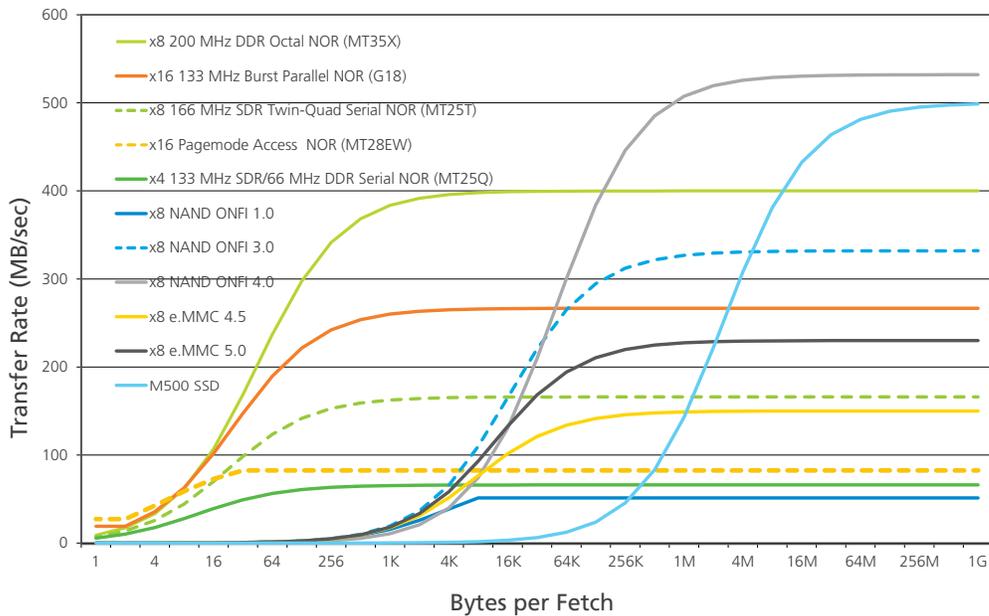
Densities Offered by Device Type

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

		Low Density						Mid Density						High Density				
512Kb	32Mb	128Mb	256Mb	512Mb	1Gb	2Gb	4Gb	8Gb	16Gb	32Gb	124Gb	2GB	4GB	16GB	32GB	128GB	240GB	1Tb

Serial NOR
128Mb–2Gb

Parallel NOR
128Mb–2Gb

Xccela NOR Flash
256Mb–2Gb

SLC NAND
Standard 128Mb–64Gb
Serial 1Gb–8Gb

MLC NAND
Standard 2GB–1Tb
Embedded MLC+ NAND 4GB–16GB

TLC NAND
16GB–32GB

Managed NAND
e.MMC 2GB–128GB
SSD 60GB–240GB

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).

Random Read Access Performance vs. Large Data Size

Legend:
- x8 200 MHz DDR Octal NOR (MT35X)
- x16 133 MHz Burst Parallel NOR (G18)
- x8 166 MHz SDR Twin-Quad Serial NOR (MT25T)
- x16 Pagemode Access NOR (MT28EW)
- x4 133 MHz SDR/66 MHz DDR Serial NOR (MT25Q)
- x8 NAND ONFI 1.0
- x8 NAND ONFI 3.0
- x8 NAND ONFI 4.0
- x8 e.MMC 4.5
- x8 e.MMC 5.0
- M500 SSD

Transfer Rate (MB/sec) vs. Bytes per Fetch

Micron NOR Flash Portfolio

Serial NOR

Due to it's 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*. Whatever the application, Micron has the right serial NOR flash solution. 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. Coupled with an operating frequency of 166 MHz, Micron's twin-quad serial NOR doubles our last-generation serial NOR maximum bandwidth rate from 83 MB/s to 166 MB/s.

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.
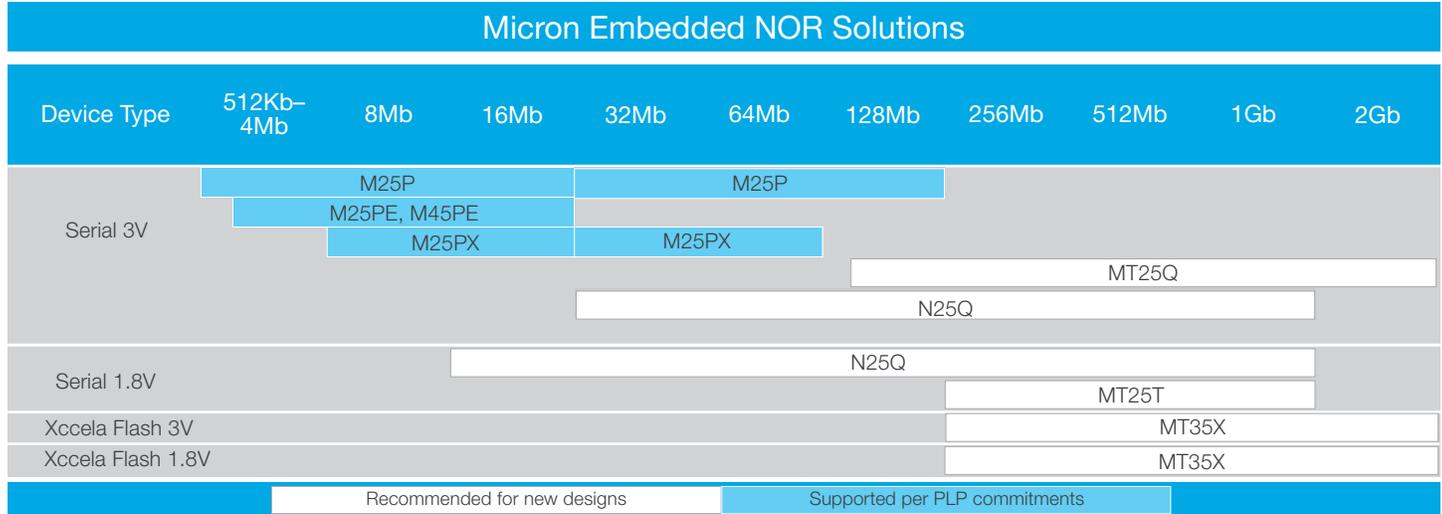
Xccela NOR Flash

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 is ideal for next-generation applications that require fast boots, instant-on access and data rendering while minimizing system cost and energy.

NOR Features Comparison	
Serial (SPI)	**Xccela Flash**
Low pin count, security*, granular erase architectures	Extreme performance, low pin count, low energy
MT25T (x8 SPI Multi I/O): • x1–x8 (twin-quad I/O) • 1.8V or 3V • 4KB subsector erase • 256Mb–1Gb • Up to 166 MHz reads (166 MB/s) **MT25Q (x4 SPI Multi I/O):** • x1–x4 (quad I/O) • 1.8V or 3V • 4KB subsector erase • 128Mb–2Gb • 166 MHz SDR/90 Mhz DDR reads (90 MB/s)	**MT35X (x8 Monolithic SPI Multi I/O):** • Octal DDR protocol • 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) • 86ns latency (2 bytes)
	Parallel
	Fast boot, low-latency reads, fast random access
	MT28EW: • 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	512Kb–4Mb	8Mb	16Mb	32Mb	64Mb	128Mb	256Mb	512Mb	1Gb	2Gb
Serial 3V	M25P			M25P						
		M25PE, M45PE								
		M25PX		M25PX						
						MT25Q				
				N25Q						
Serial 1.8V			N25Q							
							MT25T			
Xccela Flash 3V							MT35X			
Xccela Flash 1.8V							MT35X			

Recommended for new designs	Supported per PLP commitments

Selecting a Serial NOR Device

If the key features of serial NOR match your design requirements, use the following tables 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
MT35X (Xccela NOR Flash)	2.7–3.6V 1.7–2.0V	4KB, 32KB, 128KB uniform	x1, x8	256Mb–2Gb	200 MHz (400 MB/s)	100,000	SOIC, BGA
MT25T	2.7–3.6V 1.7–2.0V	4KB, 32KB, 64KB uniform	x1, x2, x4, x8	256Mb–1Gb	166 MHz (166 MB/s)	100,000	SOIC, BGA
MT25Q	2.7–3.6V 1.7–2.0V	4KB, 32KB, 64KB	x1, x2, x4	256Mb–2Gb	166 MHz (83 MB/s)	100,000	DFN, SOIC, BGA
N25Q	2.7–3.6V 1.7–2.0V	4KB, 64KB uniform	x1, x2, x4	16Mb–1Gb	108 MHz (54 MB/s)	100,000	DFN, SOIC, BGA

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

Xccela Flash Memory and Serial NOR Application Requirements by Product Family

Application Requirements	512Kb	1Mb	2Mb	4Mb	8Mb	16Mb	32Mb	64Mb	128Mb	256Mb	512Mb	1Gb	2Gb
Standard SPI									MT25Q	MT25Q/ MT25T	MT25Q/ MT25T	MT25Q/ MT25T	MT25Q
Octal SPI (extreme performance with low pin counts)										MT35X	MT35X	MT35X	MT35X
Dual-I/O usage									MT25Q	MT25Q	MT25Q	MT25Q	MT25Q
High-performance SPI, quad I/O, XIP									MT25Q	MT25Q	MT25Q	MT25Q	MT25Q
High-performance SPI, x8 I/0, XIP										MT25T	MT25T	MT25T	
1.8V (low-power consumption)									MT25Q	MT25Q/ MT25T	MT25Q/ MT25T	MT25Q/ MT25T	MT25Q

Selecting a Parallel NOR Device

If the key features of parallel NOR match your design requirements, use the following table to help select the right device. For more details, see our full parallel NOR part catalog and find a sales representative at micron.com.

Parallel NOR – Quick Features Comparison

Product	Core Voltage	I/O Voltage	Bus Width	Density Range	Sync Burst Read	Multi-Bank (Read-While-Write, Read-While-Erase)	A/D, AA/D MUX Option	Security Features*	Program/ Erase Cycling	Package Options
MT28EW	2.7–3.6V	1.65–3.6V	x8, x16	128Mb– 2Gb	No	No	No	Yes	100,000	56-pin TSOP 64-ball FBGA

Note: This table only includes devices recommended for new designs.

Micron NAND Flash Portfolio

Select from one of the industry's broadest portfolio 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 life cycles.

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 to simplify system design

Multilevel cell (MLC)

Two bits per cell; a good balanced 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 (e.g., client SSDs, USB drives or SD cards) with very high cost sensitivity; however, with 3D TLC NAND, reliability is adequate for applications that have used 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 Memory

High-capacity NAND flash device combined with a high-speed MultiMediaCard (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 drives that enhance reliability, reduce power, and provide faster performance compared to hard disk drives (HDDs)

Selecting a NAND Device

If the key features of NAND match your design requirements, use the following table to help select the right device. For more details, see our NAND part catalogs and our Choosing the Right NAND page, and find a sales representative at micron.com.

Raw NAND – Quick Features Comparison

Device	Density	Width	Voltage	Benefits
SLC NAND	128Mb–64Gb	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
MLC NAND	2GB–1Tb	x8	3.3V	• 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–16GB	x8	3.3V	• Optimized performance for intensive applications • Compatible with ONFI interface • High endurance, high capacity, and high reliability • Full turnkey solution ensures sophisticated NAND management solution
TLC NAND	16GB–32GB	x8	3.3V	• 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	• Single-package solution for designers looking for MMC-like application-to-application interoperability • Offered in a variety of densities and options
SSD	60GB–240GB	SATA 6 Gb/s	3.3V (mSATA), 5V (2.5-inch)	• Designed for industrial applications • High performance and reliability

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, and get:

A long-term partner, dedicated to your success

Get long-term support for eligible products with our Product Longevity Program (PLP) — select Micron memory products available for the full customer product life cycle, giving peace of mind that the memory you design in today will be available for 10 years or more.

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℃ up to 125℃ 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.

More Information

Learn more about Micron's flash memory solutions, and find a sales representative or authorized distributor at micron.com.

micron.com