Executive Summary

A 75% increase in NAND demand is expected in 2011, fueled by tablet PCs, smartphones, and embedded growth, and with other applications that are expected to collectively consume more than 19.9 billion gigabytes of Flash memory.¹

In response to this boon in NAND demand, Flash memory manufacturers are offering a variety of NAND Flash memory products—including some specialized NAND solutions—with significantly different performance capabilities and features across a number of process nodes. This NAND diversification means that designers cannot simply select any NAND Flash device for their applications, but rather need to have a basic understanding of the features and benefits of each type of NAND in order to select both the proper device and the proper supplier.
NAND Flash Basics

NAND Flash memory, like many other sorts of memory, stores data in a large array of cells where each cell holds one or more bits of data. In a typical NAND Flash device, “a high voltage of 18V is applied to the control gate to draw electrons from the substrate to tunnel through the gate oxide into a polysilicon floating gate layer. To store one bit, two charge levels in the floating gate layer can be stored to distinguish between a ‘1’ and a ‘0’. Multi-level cells, discussed later, store additional charge levels within each bit cell.

Typically, a NAND Flash array is organized into many blocks. Each byte in one of these blocks can be individually written or programmed, but a single block represents the smallest erasable portion of the array. In an erased block, every bit is set to the binary 1. As an example, a monolithic 2Gb NAND Flash memory device usually consists of 2048 (128KB) blocks with 64 pages per block. "Each page has 2112 bytes total, comprised of a 2048-byte data area and a 64-byte spare area. The spare area is typically used for ECC, wear-leveling information, and other software overhead functions, although it’s physically no different from the rest of the page. NAND devices are offered with either an 8- or 16-bit interface. Host data is connected to the NAND memory through a bidirectional data bus, 8 or 16 bits wide. In 16-bit mode, commands and addresses use only the lower 8 bits. The upper 8 bits are only used during data-transfer cycles."
SLC NAND Flash – Performance First
Best for High-Performance, Medium-Density Applications

Single-level cell (SLC) NAND Flash memory is, perhaps, NAND Flash at its simplest and best. As described above, SLC NAND stores one bit of data per memory cell. SLC NAND offers relatively fast read and write capabilities, good endurance, and relatively simple error correction algorithms. SLC NAND can be more expensive per bit when compared to other NAND technologies since each bit cell stores only one bit of data. As a result, designers have to make a choice between cost and performance. If an application needs speed—like a high-performance media card, some hybrid disk drives, solid state drives (SSDs), or some embedded applications—SLC NAND may be the best choice.

MLC NAND Flash – Density and Value
Best for Higher-Density, Low-Cycle Applications

In contrast to SLC NAND, multilevel cell (MLC) NAND stores two or more bits per memory cell. To determine the state of each bit, a voltage is applied and the resulting current is detected. In an SLC device, only one voltage level is required. If current is detected, then the bit stored is 1; if no current is detected, then the bit is 0. For an MLC device, three different voltage levels are used to determine the state of both bits. Figure 2 illustrates the reference point voltages that are applied and the resulting bit values for both SLC and MLC devices.

Generally, MLC NAND offers twice the capacity as SLC NAND in the same size device and comes at a significantly lower cost-per-bit. Designers will have to make some trade-offs in terms of performance and reliability (since SLC NAND is about three times as fast as MLC NAND and offers over 10 times the endurance); but for many applications, MLC NAND offers the right combination of price and performance. In fact, MLC NAND represents nearly 80% of all NAND Flash shipments. And MLC NAND will soon become the dominant Flash memory of choice for SSDs because its performance is superior to magnetic hard disk drives.

Figure 2: SLC NAND vs. MLC NAND
High-Speed NAND Interface—Up to 200 MT/s

Ultra-Fast Read/Write Throughput for Demanding Storage Applications

Essentially, the high-speed NAND Flash interface is a source-synchronous DDR interface with speed-optimized read and write logic. In fact, the high-speed NAND interface can achieve up to five times the performance of a standard NAND Flash interface. Our high-speed NAND interface is designed to the Open NAND Flash Interface (ONFI®) 2.2 standard, which also provides easy design-in and backward compatibility with the traditional asynchronous NAND interface, also known as ONFI 1.0.

The performance features of our high-speed NAND interface make it a great fit for performance SSDs, USB 3.0, and other speed-intensive applications.

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Table 1: High-Speed NAND Flash Features and Benefits

High-Endurance NAND – Best for Intensive, Enterprise Applications

Enterprise NAND is a high-endurance NAND product family that offers significantly improved endurance over standard NAND.

The ability to store data over a number of PROGRAM/ERASE cycles is often described as endurance. A typical MLC NAND Flash memory device built on a mature process can endure approximately 5,000 PROGRAM/ERASE cycles—which is more than enough for many applications. However, for intensive enterprise applications that require significantly higher endurance, Enterprise NAND is a highly reliable, high-density, high-endurance solution.

Enterprise, or high-endurance, NAND is optimized for high-transaction data processing and high-speed server functions. Offering up to a sixfold increase for MLC, it far surpasses standard cycle rates and markedly improves product life and performance.

Choosing the Right NAND Flash Memory Technology

Micron®
Serial NAND Flash
A Lower-Cost, Higher-Density Alternative to NOR

Serial NAND Flash relies on the standard serial peripheral interface (SPI) often used for basic, low pin count communication between microcontrollers and system peripherals. SPI typically uses four pins, including a serial clock, serial data-in, serial data-out, and chip select.

EEPROMs and NOR Flash have dominated SPI memory solutions, but these technologies typically offer low-densities options that won’t work with some of the newest designs. Enter Serial NAND Flash. Serial NAND Flash has several advantages over earlier SPI memory solutions. First, it’s available in much greater densities and offers a lower cost-per-megabit than NOR. On-chip error correction code (ECC) and faster write speeds than NOR are further benefits.

As with all technologies, there are trade-offs. Serial NAND cannot read data as quickly as parallel NAND solutions—a problem serial NOR shares. Even with these minor trade-offs, Serial NAND can be the right choice for many applications that have traditionally relied on NOR.

NAND for MCPs
Flexibility for Mobile Devices

More and more NAND Flash memory is being used in multichip packages (MCPs) where it is paired with Mobile LPDRAM in a variety of form factors. NAND/LPDRAM MCPs are offered in a broad range of densities for e-MMC™ Embedded Memory.

A Managed NAND Solution: e-MMC™ Embedded Memory
Easy to Design In

Managed NAND solutions—like e-MMC embedded memory—are a great design choice if ease of development is a key factor. In essence, embedded memory transforms a program/erase/read device with bad blocks and bad bits (NAND) into a simple write/read memory. This managed interface addresses potential NAND design concerns internally, using error correction code (ECC), wear leveling, and bad block management technology.

Figure 3: Comparison of a host controller for a NAND Flash vs. a managed NAND device
Choosing the Right NAND Flash Memory Technology

NAND Flash memory requires a controller to aid with array management, ECC, wear leveling, and other functions, but where that controller resides and works can and should vary, based on a specific design’s needs.

eMMC embedded memory includes the NAND Flash die, Flash translation layer, and ECC in a single JEDEC-compliant, embedded MultiMediaCard package. And with its low-profile BGA package, eMMC can be the right choice for designers who prefer an MMC interface with application-to-application interoperability.

NAND Flash SSDs
Preferred for Their Density and as HDD Replacements

SSDs group together many NAND Flash devices and use advanced controllers to manage the arrays so designers who need NAND Flash performance and reliability can also have greater density. SSDs can be developed with high-speed or high-endurance NAND for some enterprise applications, or can be developed with less expensive MLC NAND for most notebook or consumer applications.

An SSD can emulate a magnetic HDD, including matching disk drive interfaces and protocols like SATA, while offering far greater performance and reliability. Because an SSD has no moving parts, there are no spinning platters or head actuators that can break, are more robust and attractive for many mobile and tablet computers.

Embedded USB Solutions

Embedded USBs bring the density and reliability of an SSD to networking and embedded applications with a simple universal serial bus (USB) connector. An embedded USB is physically smaller than a 1.8-inch HDD, costs far less to implement than even the cheapest hard drive, draws a mere 330mW of power when it’s actively reading or writing data, and will boot much faster than most hard drives. These embedded USB SSDs mount directly to the industry-standard USB headers found on many networking motherboards. For rugged applications, the additional mounting standoff secures the embedded USB drive to its host, all without cables, brackets, or mounting rails. Additionally, embedded USB drives are available in smaller capacities ideally tailored for embedded operating systems and applications.
ClearNAND™ Solutions

ClearNAND Flash includes a thin controller packaged in an MCP with up to eight NAND die. These products use either the asynchronous or synchronous NAND interface. The biggest hardware challenges that processors or controllers have is keeping up with the increasing NAND ECC. The ClearNAND controller manages ECC and future versions will take on other signal processing like functions, to improve data reliability. There are two versions of ClearNAND Flash.

Standard ClearNAND Flash, targeted mainly at consumer devices, implements the required ECC and provides a traditional asynchronous ONFI bus for easy migration. It is available in a range of densities, uses MLC NAND, and is offered in a 52-ball LGA package.

Enhanced ClearNAND Flash provides increased speed and high endurance for enterprise applications, along with several key features that enable better, more efficient designs. It is available in a range of densities, uses SLC or MLC NAND, is offered in a 100-ball BGA package, and supports both the asynchronous and synchronous versions of the ONFI 2.2 interface.

Conclusion

A basic knowledge of the various kinds NAND Flash-based memory solutions available can help designers make informed decisions about which NAND Flash device to specify for a particular design. This article’s general description of each of the NAND Flash options, along with a snapshot of their features and functionality, helps illustrate what makes them better suited for some applications than others. More technical information about each memory type can be found on our Web site.

References:

4. NAND.com.
5. Open NAND Flash Interface (www.onfi.org).