4.18 Flash Memory Format Specifications and Characteristics

There are numerous flash card formats. This section will give a brief overview of the predominant types.

4.18.1 PCMCIA and Compact Flash (CF)

These two cards offer the same electrical interface, but have different form factors. The PCMCIA card is the granddaddy of flash card formats, originally conceived as a means to allow PC users to add everything from DRAM to peripherals. The PCMCIA format is 85.6 x 54.0 mm in length and width, and supports three thicknesses, 3.3, 5.0, and 10.5 mm.

The CF format is the same 3.3 mm thickness of the smallest of the PCMCIA cards, but is 36.3 x 43.8 mm in length and width. A 5.0 mm thickness is also specified, but this specification appears never to have been used. CF cards were designed to be limited to flash memory, and do not support peripherals and other memory types, although very small form factor hard disk drives are now available in the CF format.

Both cards have a 50-pin socket (as opposed to the card-edge connectors used by all other card formats) and communicate by an ATA interface that supports capacities as high as 137 GB. Data transfer rates have been upgraded from 8 MBps to 66 MBps, and could be further enhanced in the future. The original PCMCIA card also can support a linear (non-ATA) interface.

4.18.2 SmartMedia and xD-Picture Card

In an effort to reduce both size and cost, Toshiba and certain key camera manufacturers introduced the Solid State Floppy Disk Card or SSFDC, which was later given a simpler name of SmartMedia card. This was a thin plastic wafer, measuring a scant 0.76 mm thick, which used card-edge connectors and did not include a flash controller in the card.
The SmartMedia card’s full dimensions were 45 × 37 × 0.76 mm. This format’s maximum capacity was 128 MB, which was relatively large when the format was first introduced in 1995, but ran out of steam in 2002, when it was replaced with the xDPicture Card format. The xD (for Extreme Digital) card has a smaller length and width of 20 × 25 mm, but is thicker, at 1.7 mm, allowing multiple NAND chips to be stacked inside the card. The xD-Picture Card’s maximum capacity has been raised to 8 GB.

4.18.3 Multimedia Cards (MMC)
SanDisk and Siemens introduced the MMC in 1997. Smaller than a SmartMedia card, this format is 32 × 24 × 1.4 mm and includes a controller. A card edge connector saves space and cost.

This format has undergone a series of evolutionary changes, shrinking in size to support the MMCmobile format at 24 × 18 × 1.4 mm, then the MMCmicro at 12 × 14 × 1 mm. Another evolutionary change has been the communication speed. Read speed has been increased from 2.5 MBps to 52 MBps over time, while write speed has increased from 200 KB/ps to as high as 10 MBps, limited only by the speed of the NAND chips within the card. The maximum capacity supported by the MMC format is 4 GB.

4.18.4 Secure Digital (SD) Cards
Shortly after the introduction of the MMC, the Secure Digital or SD card was introduced. This card has the same mechanical format as the MMC, and uses a somewhat compatible interface (MMC cards can be used in an SD slot, but not vice versa), but included a more sophisticated controller that addressed the security concerns of the media business who wanted some assurances that media would not be replicated with abandon by the users of these cards.

As card formats shrank, so did the SD card, moving to the miniSD at 21.5 × 20 × 1.4 mm, followed by the microSD at 11 × 15 × 1 mm. The SD card interface tops out at a 12.5 MBps communication rate, and the format supports capacities of up to 32 GB. The MMC specification was upgraded after the introduction of the SD card to include digital rights management features.

Memory Stick

4.18.5 Memory Stick
Sony has its own format of memory card that the company calls the Memory Stick. This is also a card with an internal controller and a card-edge connector, and measures 50 × 21.5 × 2.8 mm. As with the previously described formats, the Memory Stick has undergone a progression of shrinks to 31 × 20 × 1.6 mm (Memory Stick Duo), then 15 × 12.5 × 1.2 mm (Memory Stick Micro).

The electrical interface has also progressed from an original 2.5 MBps read speed to the current 19.7 MBps read speed. The new specification is called Memory Stick PRO. The original specification was also limited in capacity to 128 MB, but the Memory Stick PRO specification will support capacities of up to 32 GB. The internal controller supports Sony’s proprietary digital rights management scheme through the Memory Stick’s internal controller.

Table 4.1 compares the different card formats from a very high level of maximum bandwidth, capacity, and volume.

Table 4.1: Key Attributes of Leading Flash Card Formats
4.19 Flash Memory and Other Solid State Storage Technology Development

4.19.1 U3 and Applications Run from Flash Memory

One approach to selling flash is to bundle self-launching applications inside the storage device itself. This is regularly seen in the world of CD-ROMs, where self-launching code is common.

Perhaps the most prevalent piece of self-launching code that is sold along with flash is the U3 bundle, a high-security desktop that a user can employ to attain a virtual desktop on any Windows PC around the world.

The U3 concept is that a user will keep all their files in the USB drive. This lets the user feel free to use any PC anywhere. Everything from personal files to e-mail is stored in a U3 drive that will automatically synchronize with the user's own computer whenever returned to that system. Should a host PC not have certain required software, a U3 drive will supply a reasonable facsimile of that application to allow the user to accomplish the necessary task. When a U3 drive is removed from a host system, all of that drive's information will be deleted from the host, removing any security concerns.

4.19.2 Roadmap for Flash Memory Development

The driving factor for flash card and USB flash drive capacity increases is the increase in capacity of NAND flash chips. NAND chips account for as much as 95 percent of the manufacturing cost of a flash card or USB flash drive.

The increase in NAND chip capacity drives not only the amount of flash memory that can be fit into one of these card or USB formats, but it also drives the affordability of that amount of storage. At the writing of this book, a 2 GB USB flash drive is very affordable at under $20, whereas only one year earlier it would have cost twice that amount. Future readers are likely to laugh at how expensive these numbers seem.

NAND chip vendors drive their costs down and their capacities up by shrinking the minimum size feature they can image onto a piece of silicon at a continuing progression. At the writing of this book, most NAND flash vendors produced their devices using processes with minimum feature sizes of 90 nm (nanometers, or millionths of millimeters) and 70 nm. These devices were most often manufactured using the MLC technique which allowed the capacity of the chip to be doubled through some hardware tricks.
The cost of a chip is inversely proportional to the square of these numbers, that is, a 2 Gb (gigabit) chip produced on a 70 nm process would be $\frac{70^2}{90^2}$ or 60 percent of the size of a 2 Gb chip produced on a 90 nm process. This implies that the cost of a 70 nm 2 Gb chip should be about 60 percent of that of its 90 nm counterpart. This also implies that certain applications that would have just been able to fit in a 2 Gb 90 nm chip may have enough room inside to accommodate a 4 Gb 70 nm chip. As the process shrinks, the capacity that can fit onto a card is likely to go up and the price for that much capacity has room to go down.

Figure 4.10 illustrates one vendor’s road map to shrinking processes. Toshiba, a leading NAND vendor and the inventor of both NOR and NAND flash technology, shows how they have progressed from 350 nm down to 56 nm, and how they plan to move beyond that to the 30 nm range. This represents 10-to-1 shrink in minimum features, yielding a 100-to-1 reduction in cost, and a similar increase in chip density. Other techniques (changes in cell structures in the orbs at the top and changes to MLC as delineated in the lower line of higher capacity products, have pushed those reductions even further.

![Figure 4.10: Toshiba’s Process Migration for NAND Flash Memory.](image)

**Expected Growth in Storage Capacity for Flash Memory**

4.19.3 Expected Growth in Storage Capacity for Flash Memory

As Figure 4.10 illustrates, there is a steady progression in NAND chip capacity. This trend grows the amount of storage that can be sold at certain price points and how much storage can be fit into a given form factor. This evolution drives the chart in Figure 4.11, which illustrates the likely average capacity of a NAND flash chip for the next five years, and the historical perspective for the past seven years.
The chart uses logarithmic y axes, since the use of a linear y axis makes all but the extreme ends of the chart very difficult to read.

Beyond 35 nm, the progression of NAND becomes less clear, since we do not yet know how to develop flash that will successfully operate past the 35 nm node. It is possible that the industry will move to a new approach to NAND (like Toshiba's switch from LOCOS to SA-STI) but if flash cannot be coaxed past this point, then costs will stop their steady decline, making it likely that some alternative technology will be able to push past NAND's cost structure to displace the current technology and take over the NAND market.

### 4.20 Expected Change in Cost per Gigabyte of Flash Memory Formats

As was mentioned before, the major cost component in flash cards and USB flash drives (and any other flash-based storage medium) is the cost of the NAND flash chips. It is only reasonable to assume, then, that the costs of flash cards are likely to follow this in some way.

It is unlikely, though, that flash cards will go from $20 today to $10 next year, then $5 the following year, falling below $1 and onwards as the price for a gigabyte of flash falls. Instead, the price of cards is likely to follow certain consumer price points (say $20 and $100) and that the capacity of these cards will rise to meet these price points.

Figure 4.12 is an illustration of how that is likely to happen. In this chart we have taken the prices used in Figure 4.11 to determine the average capacity of cards priced at $20 and $100 over the same time frame. Certain assumptions have been made in this chart about other costs and about retail markup, but the trend is clear, the average capacity of a $20 card is likely to double every year as costs decline by a similar rate.
4.21 Other Solid State Storage Technologies

There was some mention above about the difficulties faced by flash designers as manufacturing processes continue to shrink. Since manufacturers have been anticipating a roadblock to continued process migration for quite a while now, they have invested in alternative technologies. The prevailing technologies are ferroelectrics, magnetic memories, and phase-change memories. Each of these has an acronym: FRAM, MRAM, and PRAM, in that order. There are several other contenders, including carbon nanotubes and silicon nanocrystals, but these technologies do not have the funding of the big three.

Each of these technologies has certain strong advantages. All three offer faster write cycles than NAND, and all but FRAM boast unlimited wear. Furthermore, they are all low-power technologies that promise to scale to ever-tightening processes better than is expected of NAND after 35 nm.

Are these a threat to NAND? It is likely that one of these technologies could take over the NAND business once NAND has hit a brick wall and cannot be shrunk any further. Given that this inevitable brick wall has been pushed out recently by two process generations, it appears quite possible that there will continue to be life in flash after 35 nm, and perhaps for several more process generations. In other words, as with hard disk drives and other storage technologies, brick walls are cast in sand.

Cost is what drives acceptance in the world of semiconductor memory, and since these materials are less well understood than silicon, the only way they can catch up to the semiconductor memory cost structure is if semiconductor memory stops in its progress, giving these other technologies a chance to catch up and surpass NAND's per-gigabyte costs.

It is reasonable to say that NAND will be replaced by one of these technologies before this book disintegrates from age, but it does not appear reasonable to assume that they will gain much ground over the next five years. At the writing of this chapter, two leading flash vendors, Samsung and Intel, have cast their votes with PRAM, which they believe to be the technology with the highest chance of
outstripping silicon's cost declines over the next several years.

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