Untangle the web of removable storage

Mobile Handset DesignLine
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Lately it seems like there is a new mass storage standard introduced every day. It's getting difficult to keep track of all of the new standards. CompactFlash was the only game in town for a while, but now the maker of a new device has to choose between CF, SD, SDIO, MMC, RS-MMC, MMC Plus, Memory Stick, XD, and CE-ATA mass storage devices. Sometimes a new standard has an obvious advantage, sometimes it seems like Betamax vs. VCS. In this article we'll give a brief picture of these interfaces and sort out their differences.

Compact Flash Family

The CompactFlash (CF) standard is the granddaddy of all small mass storage devices. This standard was originally developed over 10 years ago by SanDisk. It features an 8 or 16-bit parallel data bus with transfer rates ranging from 3 Mbytes / second to 66 Mbytes / second. The CF standard is still in use in many devices that require the high transfer rates of a 16-bit wide UDMA bus (66Mbytes/second) and high capacity. CF+ form factor hard drives are currently available up to 10G bytes in capacity and CF flash memory cards are available up to 8GBytes capacity.

Because the first Compact Flash cards were NOR flash, the CompactFlash standard requires the card to hide the messier aspects of interfacing to NAND flash. The host communicates to the card as if it were an IDE hard drive and the controller on the CF card performs the bad-block management, wear leveling, and logical to physical mapping required to work with NAND flash.

Development of the CompactFlash specification is continuing. The latest release (3.0) was released at the end of 2004. The major change in this version is the addition of UDMA transfer speeds up to 66Mbytes/second. This spec is available free of charge from www.compactflash.org.

CompactFlash cards never became popular as removable storage for cell phones, but they have kept a large market share in digital cameras, especially at the high end of the market, where large capacity and high speed are a must. Several other peripherals can be connected to the CF+ version of the interface, including Ethernet, RS-232, fax/modem, USB, Bluetooth, and 802.11b wireless LAN.

Multi Media Card (MMC)

The Multi-Media Card was introduced in 1997 by Siemens and SanDisk. The MMC form factor is much smaller than the CF standard, allowing the design of ever smaller portable devices.

In basic applications, MMC can be controlled via a standard 3-wire SPI interface plus a chip select. The SPI interface can be clocked up to 20 MHz. For applications that require more bandwidth, the spec provides increased bus widths of 4-bit and 8-bits. The 4.0 version of the MMC spec adds a 52 MHz transfer rate, enabling 50MByte/sec bus bandwidth!

Unlike the CompactFlash spec, the MMC spec is not free. According to www.MMCA.org, "If you are not a manufacturer of MultiMediaCards, you can order the spec 3.1 for $500 (US) or spec 4.1 (MMCmobile and MMCplus) for $1,000 (US). And… your company does not need to be a member of the MMCA."

On top of the MMC framework, there are now three types of cards: MMC Plus, MMC Mobile and MMC Micro. The MMCplus is a normal size MMC card that supports 2.7-3.6V operation, x1/x4/x8 bus widths, minimum of 2.4MB/s read/write performance and 26MHz (52MHz optional). The MMCmobile is a reduced size card that supports reduced voltage range: 1.65-1.95V and 2.7-3.6V. The MMCmobile also must support the performance required for MMCplus status. MicroSD is the latest addition to the family. At less than a third the size of miniSD, microSD is the smallest card available today.

Type	CF	MMC / RS-MMC	MMC Plus	MMCmicro	SD/SDIO	miniSD	microSD	XD Card
SD Socket	No	Yes	Yes	Adapter	Yes	Adapter	Adapter	No
Pins	50	7	13	10	9	11	8	18
Bus Width	16-bit	Serial	8-bit	4-bit	4-bit	4-bit	4-bit	8-bit
Width (mm)	36.4	24	24	12	24	20	11	20
Length (mm)	42.8	32 18 (RS)	32	14	32	21.5	15	25
Thickness (mm)	3.3	1.4	1.4	1.1	2.1	1.4	1	1.7
Volume (mm^3)	5141	1075	1075	185	1613	602	165	850
SPI mode	No	Optional	Optional	Optional	Yes	Yes	Yes	No
4 bit mode	No	No	Yes	Yes	Optional	Optional	No	No
8 bit mode	No	No	Yes	No	No	No	No	No
Max clock (MHz)	16.66	20	52	52	25	25	25	Unknown
Transfer rate (Mbyte/sec)	66	2.5	52	26	12.5	12.5	12.5	Unknown
Max SPI rate	N/A	20 Mbit/s	52 Mbit/s	52 Mbit/s	25 Mbit/s	25 Mbit/s	25 Mbit/s	Unknown
Max capacity today	10GBytes	4GBytes	4GBytes	1GBytes	4GBytes	2GBytes	1GBytes	2GBytes

DRM	No	No	No	No	Yes	Yes	Yes	Unknown
Membership cost	$2500/yr (not required)				$1500/yr (required)			Requires NDA to determine
Spec cost	**Free**	$500	$500	Unknown	Member	Member	Member	
Host license	No	No	No	No	$1000/yr+membership			
Type	**Compact Flash**	**MMC**	**MMC Plus**	**MMCmicro**	**SD**	**miniSD**	**microSD**	**XD Card**

Table 1: The Rosetta Stone of removable storage

MMC and SD (Secure Digital) – Are they the same?

The MMC standards and SD standards are often referred to as if they are a single spec. However, they are two different standards. The SD Card spec is owned by a group headed by Matsushita, Toshiba and SanDisk. The MMC spec is controlled by the MMCA (Multi-Media Card Association), led by a much broader group including Lexar, Micron and Samsung.

Surprisingly, the driving force behind the Secure Digital Card was never widely adopted. Secure digital cards contain encryption hardware similar to Sony's MagicGate which is used in MemorySticks. It took eight more years and Steve Jobs before the music industry would accept digital music distribution, and this feature is now a digital appendix. In early 2006, the MMC Association adopted version 1.1 of a competing secure card standard called secure MMC. There is a good overview of secure MMC on Samsung's website at www.samsung.com.

MMC cards can fit into a physical slot designed to hold an SD Card. SD-Cards come in two form factors: thin and standard. A thin SD card can fit into a MMC slot, but a standard SD card cannot, since it is too thick. The protocols used by MMC cards and SD cards are 100% compatible at rev 2.11 of the SD Card spec, but they have diverged somewhat since then.

The pin arrangement of both MMC and SD Cards is compatible. The maximum number of pins on a SD Card is 9, while the maximum number of pins on a MMC card is 13. From Table 2, you can see that the only function of additional pins is to increase the bus width. Since the bus width is programmable, a controller can easily find the lowest common denominator and set itself up accordingly. All of the microprocessors with built-in MMC support also support SD cards.

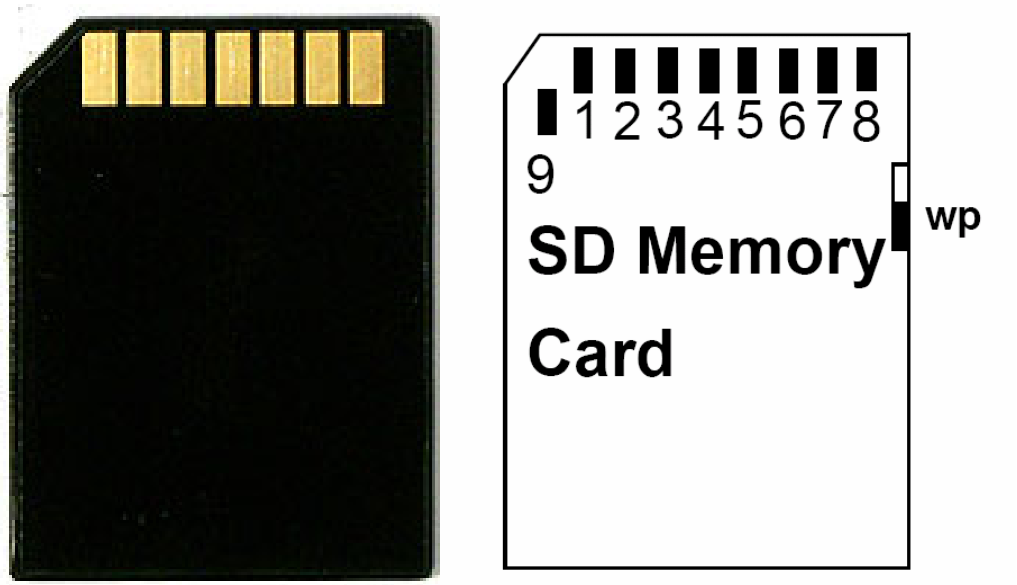

Figure 1: 7 pin MMC and 9-pin SD card

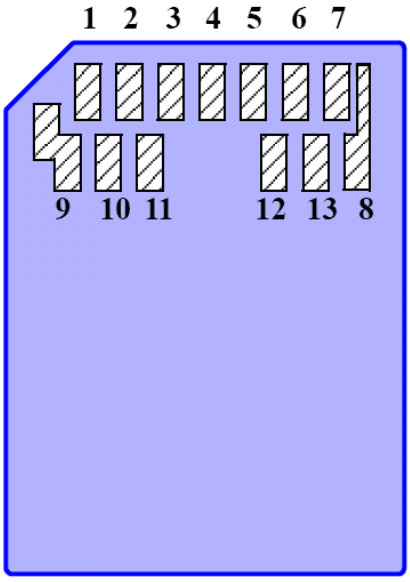

Figure 2: 13 pin MMC card -- Backward compatible

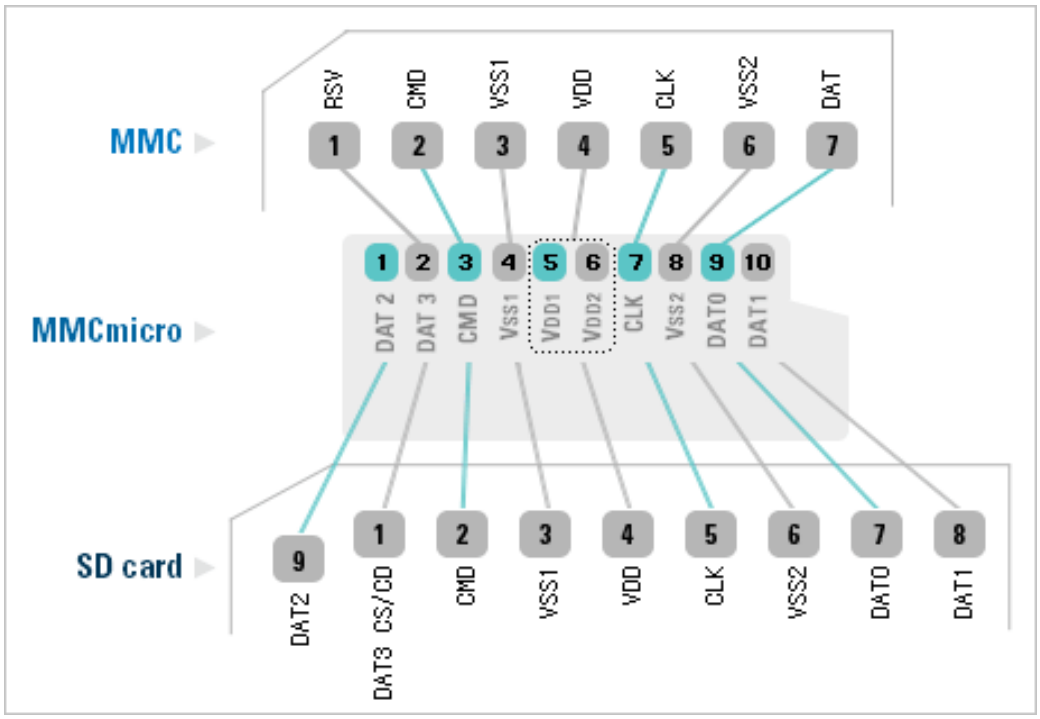

Figure 3: MMCmicro pin out vs. MMC and SD

Pin #	Name	Function (MMC / SD)	Function (SPI)
1	DAT3	Data[3]	CS
2	CMD	Command/ Response flag	Data In
3	VSS	GND	
4	VDD	Supply voltage	
5	CLK	Clock	
6	VSS(2)	GND	
7	DAT0	Data[0]	Data Out
8	DAT1	Data[1]	n/a
9	DAT2	Data[2]	n/a
10-13	DAT4-DAT7	Data[4:7]	n/a

Table 2: Pin functions for MMC / SD-Cards

Tiny Cards – MMCmicro vs. MicroSD (Trans-Flash)

The MMC and SD groups have added to the confusion by creating two different standards for tiny flash cards. MMCmicro and MicroSD (also called TransFlash) are both backward compatible with existing SD/MMC sockets using a mechanical

adapter. Both are astoundingly small, less than 200mm^3. However, MMCmicro is much faster than MicroSD. MMCmicro uses the higher 52 MHz clock rate defined by the MMC spec, while the MicroSD continues to use the 25 MHz rate. In addition, the MMCmicro card has a 4-bit data bus while MicroSD only supports serial data transfer. In addition, the MMCmicro card supports 1.8v operation, while the MicroSD only operates at 2.7-3.6v. The MMCmicro is the clear choice for small portable devices, until something even smaller and faster comes along!

Figure 4: TransFlash (MicroSD) with adapter

Figure 5: MMCmicro with adapter

XD-Picture Card

The xD-Picture Card (Extreme Digital Picture Card) was introduced in July 2002. Like Sony's Memory Stick, this is a proprietary format. Because this is a tightly-controlled proprietary format, it is difficult to get much information from the xD-Picture license authority at www.xd-picture.com. If you would like to know how

much an xD-Picture license will cost your company, you must fill out a Non-Disclosure Agreement (NDA) with the xD-Picture Licensors.

The XD-Picture Card is similar to the SmartMedia standard in that it is a packaging technology for raw NAND flash. There is no controller embedded in the XD-Picture Card so the controlling CPU is responsible for maintaining the logical to physical table, managing bad blocks, and performing ECC to correct errors. The advantage to this is that it reduces silicon area and it allows the managing CPU to have a much greater level of control over the interface, which should allow it to reduce write times. The disadvantage is that the managing CPU must implement all of the SmartMedia control functions.

SDIO

SDIO defines a peripheral interface based on the SD standard. There are two main applications for SDIO today: removable and non-removable. The existing removable devices are used as Palm and Windows Mobile expansion devices to add Bluetooth, camera, GPS and 802.11b capability to these platforms. Non-removable devices follow the same electrical standard without the requirements imposed by the physical standard. Some cell phones contain 802.11 chips that interface to the CPU via SDIO. This saves precious I/O pins for more important functions.

Bluetooth, camera, GPS and 802.11b devices Application Specifications defined for them. Application Specifications are much like the Class definitions created for PCI and USB devices. They allow any host to talk to any peripheral, as long as they both support the Application Specification.

The physical interface for SDIO is the same as SD-Card, but devices are permitted to extend out of the “top” of the card. Once they are outside the box, devices are free to expand in any direction, which enables devices like the SDIO camera shown here.

One important difference between the SDIO spec and the SD-Card spec is the addition of a low-speed card standard. This card requires only the SPI and 1-bit SD transfer modes. The intended use of Low-Speed cards is to support low-speed I/O capabilities with a minimum of hardware. The Low-Speed cards support such functions as modems, bar-code scanners, GPS receivers etc. If a card is a 'Combo card' (memory plus SDIO) then Full-Speed and 4-bit operation is mandatory for both the memory and SDIO portions of the card.

CE-ATA

CE-ATA facilitates the marriage of Consumer Electronics and ATA hard drives. Hard drives are increasingly used in consumer electronics, but the 40-pin ATA connector and 50-pin CF connector simply consume too many I/Os to be used in a small hand-held device. In the CE-ATA spec, the ATA command structure is overlaid on top of the MMC physical layer. This allows re-use of the existing MMC controllers built into Freescale's and TI's application processors.

The CE-ATA connector uses 12 pins to implement the 9-pin SD/MMC interface. The three additional pins provide a reserved pin and an extra power/ground pair so the HDD motor can operate at a different voltage than the signal lines. CE-ATA's interface performance is identical to 4-bit SD/MMC. It can transfer data up to 12.5Mbytes/sec with a 25 MHz clock or up to 26Mbytes/sec with a 52 MHz clock.

Conclusion

Although the wide variety of small storage may seem daunting at first, once you understand it you realize that choices are good. Every version has its strengths: CF has higher capacity, CE-ATA enables disk drive interfaces without higher pin counts, and the SD-Card family provides a variety of form factors with a common interface. Ultimately, the system designer must choose the right storage medium to meet the needs of their product.

REFFERENCES

SD Memory Card Specification − Part 1, Physical Layer Specification, SD Group, Version 1.1, October 15, 2004.

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