Aricent
.ALTRAN GROUP

SDIO

Secure Digital Input Output

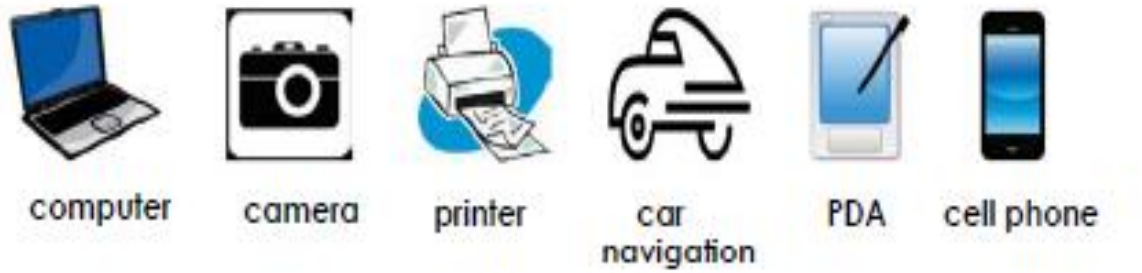
Outline

- What is SD memory interface?
- What contributes to SD Card successes?
- What is Multimedia Card (MMC)?
- SD and MMC versions
- Bandwidth vs. Speed Class
- SD speed class table
- What is SDIO and SD combo?
- What is SD bus architecture?

Outline

- What is in the SD host controller?
- The host driver software can do
- The host controller can have DMA support?
- How are electrical and timing control being handled?
- What is in the SD card design?
- What is SPI and how is it related to SD and MMC?
- What is SD vs. miniSD, microSD, embedded SD?
- What are the software requirements?
- What are the software requirements?
- Where is the file system?

What is SD memory interface?



- Secure Digital (SD) memory card first appeared at the 2000 CES trade show. Within 10 years, it has become the most popular non-volatile removable data storage media for consumer applications.
- SD memory belongs to the same class of removable data storage device that includes PC card, PCMCIA card, CompactFlash, Smart Media, Multimedia Card, Memory Stick and xD.
- SD device can typically be founded in digital camera, video recorders, cell phone, printer, laptop computer, car navigation and other applications.

What contributes to SD Card successes?

- SD card has relatively **small number of physical pins** (5 signals plus clock and power) compared to the earlier PCMCIA and CompactFlash cards.
- Data is transferred at the moderate speed of **25 MHz** (earlier version) up to **208 MHz (latest version),** making it fairly inexpensive to manufacture by using matured technologies.
- At the same time, the **synchronous data transfer protocol** is very efficient, enabling SD card to delivery adequate data bandwidth requirements for most digital and video applications.
- The combination of **small foot print**, **lower cost**, **performance** and the backing by several major manufacturers as an open standard enables SD card to become the de-facto standard for consumer electronics data storage

What is Multimedia Card (MMC)?

- MMC is closely related to SD card.
- The MMC standard precedes the SD standard by several years. The two standards **share many common features** and have the **same physical and electrical specifications**. The differences between the two standards are mainly on the **software level commands**.
- The similarities allow many hosts to accept both MMC and SD cards on the same socket

SD and MMC versions

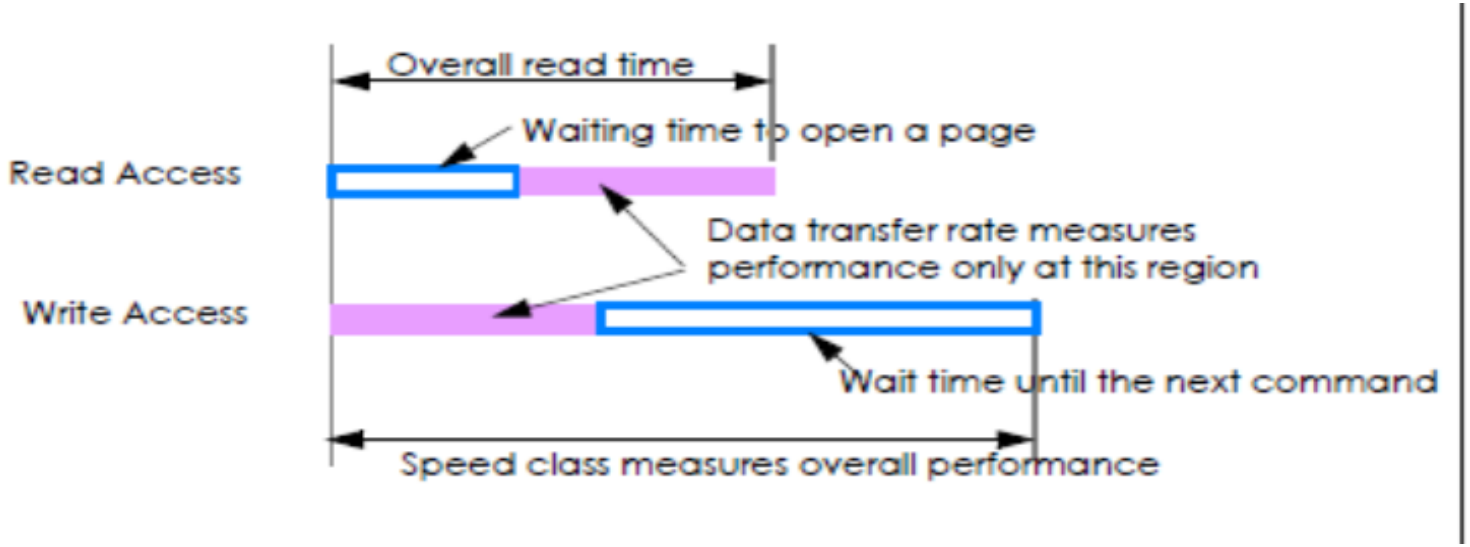
Revision	Max Clock Frequency	Data Rates
SD 1.0 to 1.01	25 MHz	12.5 Mbyte/sec
SD 1.10 to 2.0	50 MHz	25 Mbyte/sec
SD 3.0	208 MHz	104 Mbyte/sec
MMC 1.0 to 2.0	20 MHz	2.5 Mbyte/sec
MMC 4.0 to 4.3	50 MHz	50 Mbyte/sec
MMC 4.4	50 MHz	100 Mbyte/sec

Bandwidth vs. Speed Class

- The maximum data rate (**104 MByte/sec** for SD and **100 MByte/sec** for eMMC) is not always a true measure of performance of the device.
- The **data rate only specifies the performance** of the card when it is transferring data.
- The **longer is the waiting time**, the **lower is the usable bandwidth**.
- For sustained data transfer, it is just as important **to reduce the response time** as to **increase the clock rate**.
- To read data from NAND Flash, the page needs to be opened first and there are a few tens of microseconds of wait time to open a page.
- Until the page is opened, no data can be read.

Bandwidth vs. Speed Class

- For writing to the NAND Flash, after a page is transferred to the device, it takes a few hundred microseconds to a few milliseconds to program the data into the NAND Flash.
- New operation may not be allowed until the programming is completed.
- Single level cell (SLC) NAND Flash has less page open time and program time compared to multi level cell (MLC) NAND Flash but MLC has larger capacity and lower per bit price.



SD speed class table

Speed Class	Description	Revision
Class 0	These class cards to not meet the performance of other classes or does not specify its performance, including legacy cards before version 2.0	Version 1.0
Class 2	Card with 2 MBytes/second or more sustained bandwidth.	Version 2.0
Class 4	Card with 4 MBytes/second or more sustained bandwidth.	Version 2.0
Class 6	Card with 6 MBytes/second or more sustained bandwidth.	Version 2.0
Class 10	Card with 10 MBytes/second or more sustained bandwidth.	Version 3.0

SD speed class table

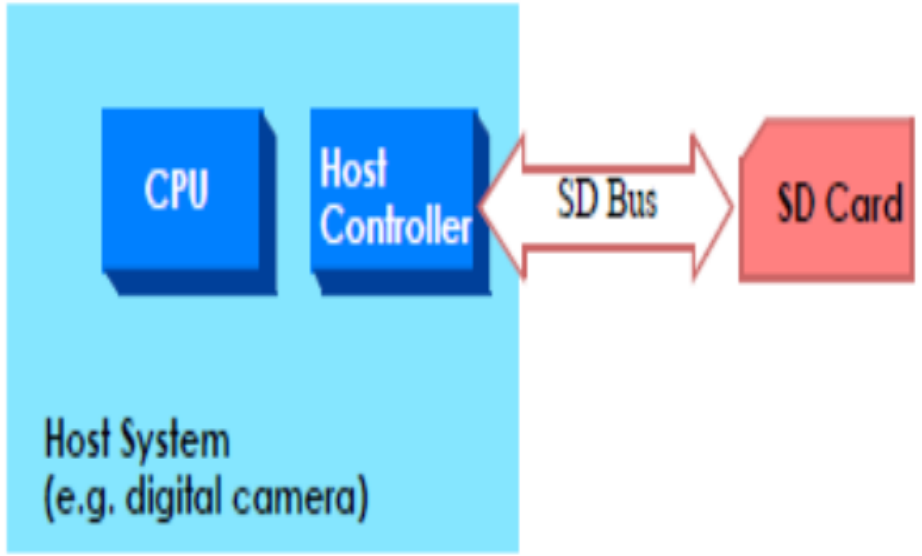
- Ones can see that there are big differences between the data rate defined by the clock rate and the sustained bandwidth defined by speed class.
- The differences are reflection of the performance of the NAND Flash storage technology, not a limitation of the SD bus protocol.
- By the same token, one can improve the performance of a SD card design by improving the memory design without using the highest clock rate of the SD bus.

What is SDIO and SD combo?

- SD bus specification defines three card types: memory only card, IO card (SDIO) and card combining memory and IO functions (SD combo).
- SDIO is an extension of the SD specification designed for IO only devices.
- New commands are defined in SDIO specification while some memory only features are removed.
- For example, SD memory card has a programming state which accounts for the programming state (in addition to read and write) of the NAND Flash device. SDIO device does not have programming state
- SD combo, as the name implies, contains both SD memory and SDIO functions. It is not as commonly used as SD memory or SDIO only device.

What is SD bus architecture?

- Diagram shows a typical SD bus system with the host controller and the SD card.
- It is fair to assume that most SD bus has a **single host** (initiator) and a **single card** (slave).
- Signals on the SD bus include a **clock pin** which is generated by the host, one bi-directional **CMD (command) pin** and 1 or 4 bi-directional DT (data) pins.

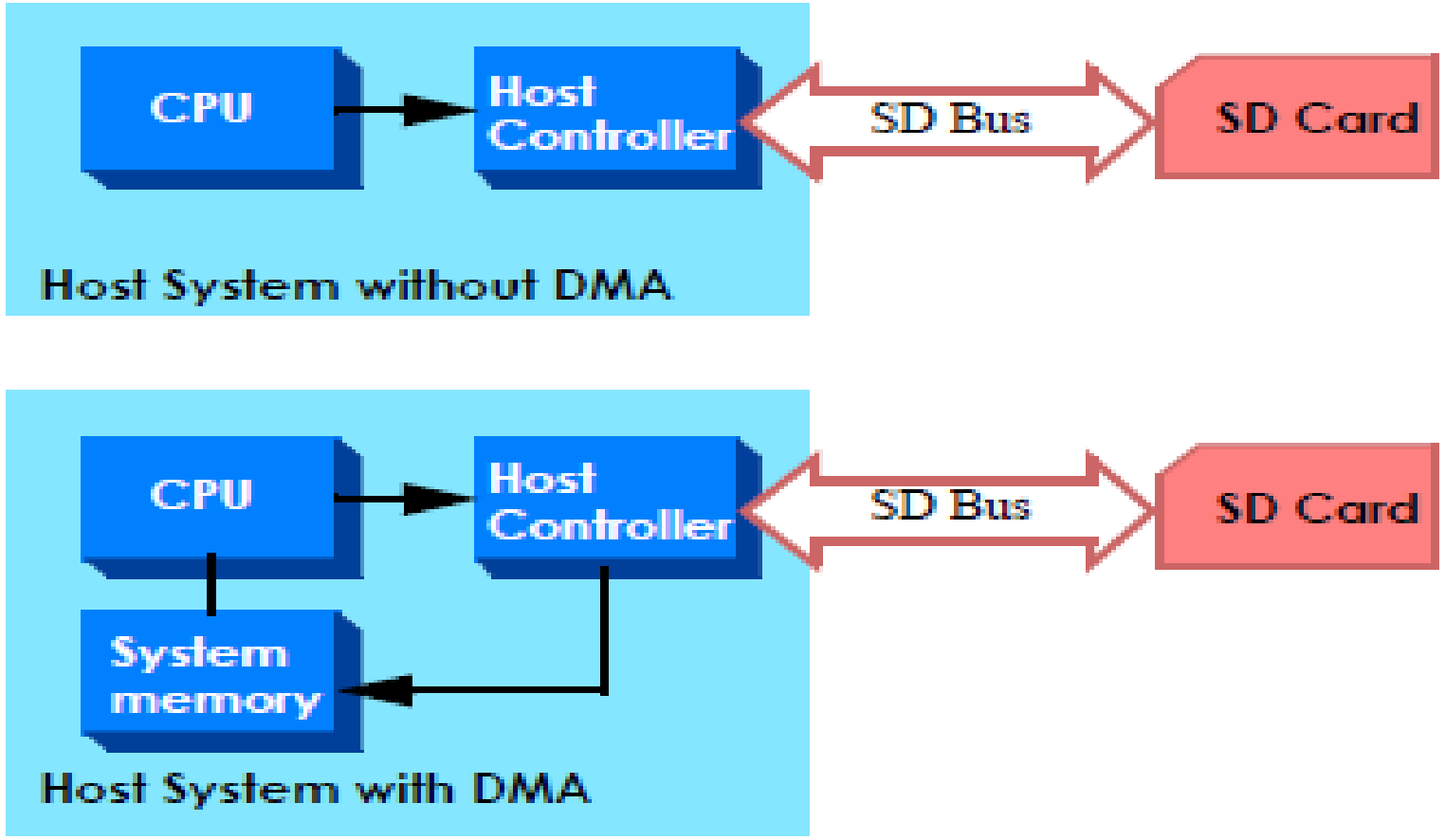


What is SD bus architecture?

- All SD bus transactions are initiated by the host through the CMD pin. All CMD and DT signaling are synchronized to the clock signal.
- Each command is a 48-bit packet and is shifted out serially by the host on the CMD pin. The following is the format of the command packet.

Start bit	Direction Bit	Commend index	Arguments	CRC	End Bit
(1 bit)	(1 bit)	(6 bit)	(32 bits)	(7 bits)	(1bit)

What is in the SD host controller?



What is in the SD host controller?

- The SD host controller is the hardware logic that forms the bridge between the host CPU and the SD bus.
- From the CPU's perspective, the host controller consists of a 256-byte register set which is mapped to the system's memory or IO space.
- Transaction on the SD bus is initiated by the software reading or writing to this register set.

The SD host controller device driver software can do

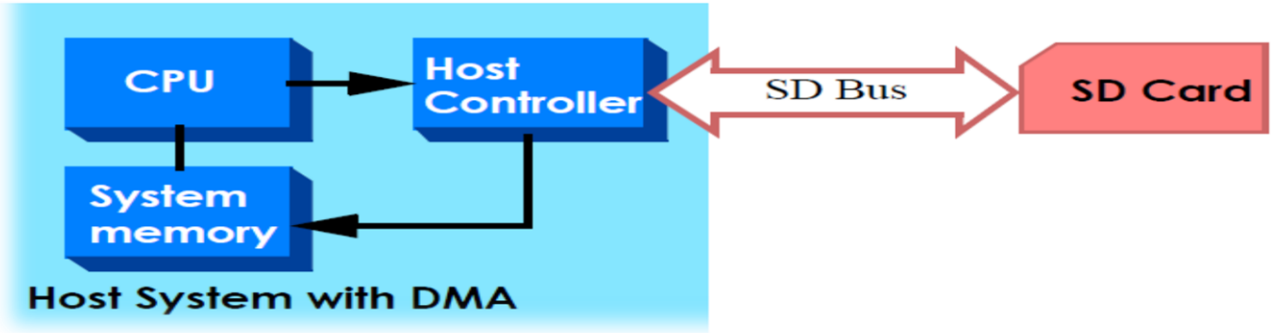
- Detect the insertion or removal of the SD card,
- Turns on and off power to the SD card,
- Enable, disable and control SD clock speed,
- Define command arguments and send commands to SD card,
- Receive command responses from the SD card,
- Read data from and write data to the SD card,
- Suspend, resume and terminate data transaction.
- Interrupt the CPU on different types of event such as command completion, CRC error , etc.

The host controller can have DMA support?

- Yes the host controller can also include DMA support.
- Without DMA, the host CPU must read or write every word of data to be transferred with the SD card.
- This takes up a significant portion of the CPU's processing power.
- With the DMA engine included in the host controller, the CPU only needs to set up the data transfer.
- Once data transfer starts, the DMA engine will read/write each word of the data between the SD host controller and system memory, thus freeing the CPU for other tasks on the system.

The host controller can have DMA support?

- Interrupt can be sent to the CPU on DMA completion. DMA is a very efficient way of transferring data but it requires the host controller to have access to the system memory.



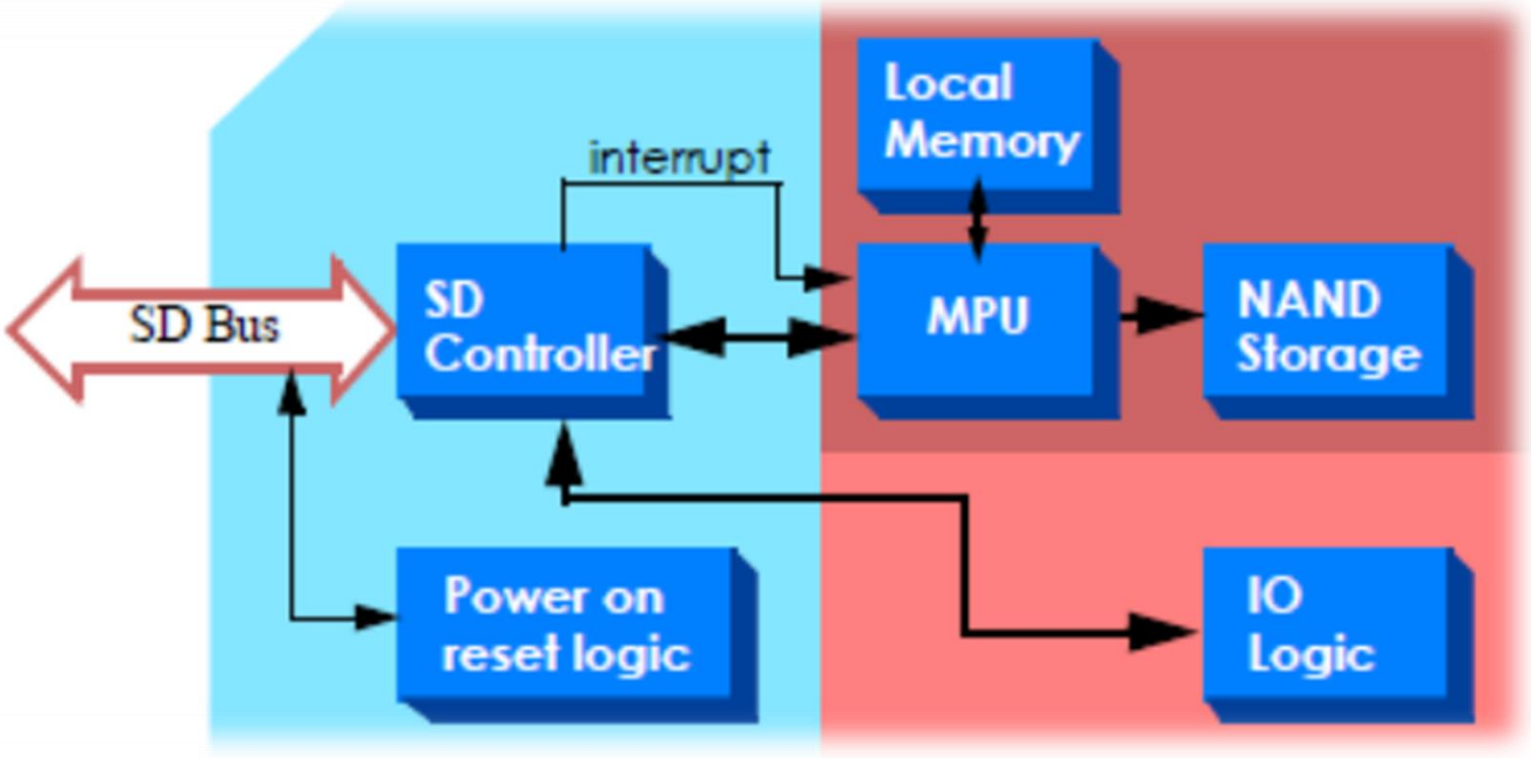
How are electrical and timing control being handled?

- The host system is responsible for **supplying power** and **timing signals** to the SD card.
- Interrupt can be generated at card insertion. Upon card insertion interrupt, the CPU can **enable power** to the SD Card through the **power control register** in the host controller.
- Default power supply of SD card is **3.3V.**

How are electrical and timing control being handled?

- The **SD host controller** is also responsible for generating **clock signal** to the SD card.
- After power is enabled, system software may enable the clock signal to the SD card at the default frequency of **400 KHz.**
- Initialization sequence is run at this frequency until the software (host controller device driver) detects the frequency and bus width capability of the card through the **card's control registers**

What is in the SD card design?



What is in the SD card design?

- The **SD Device Controller** in the above diagram handles all **physical and data link** level functions such as
  - command decoding,
  - response generation,
  - CRC,
  - status management and pre-defined SD card register set.
- The SD device controller does not directly access the NAND Flash chips.

What is in the SD card design?

- When interrupt is received by the MPU, it would query the SD Device controller module to find out the data request from the SD bus.
- If it is **a read request**, it would retrieve data from the NAND Flash and deposit read data to the SD Device controller module.
- If it is **a write request**, it would retrieve data from the SD Device controller module and program/write it into the NAND Flash.

What is SPI and how is it related to SD and MMC?

- Serial Peripheral Interface (SPI) precedes **SD** and **MMC** by many years.
- It **was originally found in microprocessors** developed by **Motorola** and others.
- The hardware interface is **very simple** and is somewhat similar to SD bus except that signals are uni-directional and supports 1 data bit only.

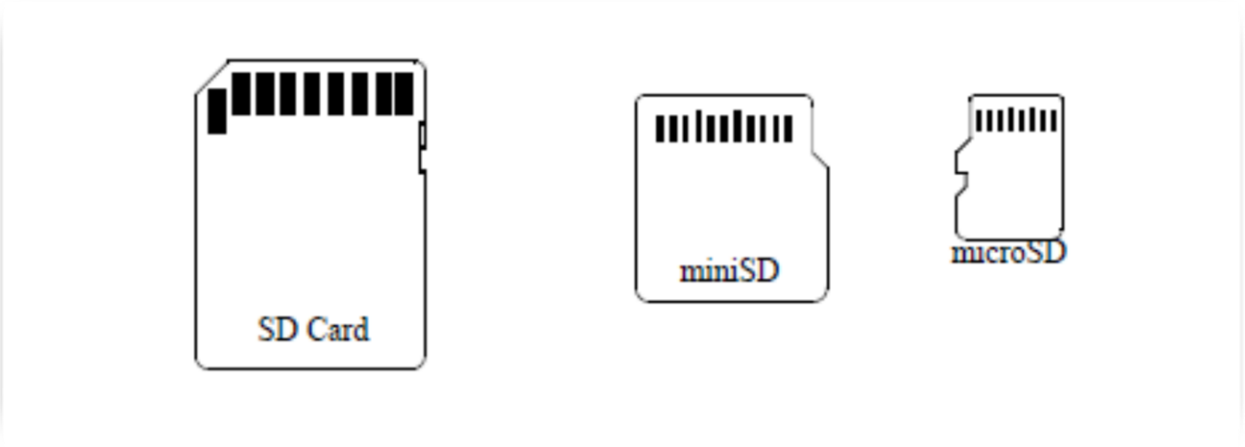
What is SPI and how is it related to SD and MMC?

- Both SD and MMC **bus initially support SPI mode** so that microprocessor equipped with SPI port can communicate with SD cards through the addition of a software driver.
- SPI mode **is not required for SD host controller** because any host designed for SD bus should implement the SD bus protocol instead of lower performance SPI protocol.
- SPI mode **support is still required** for SD card.

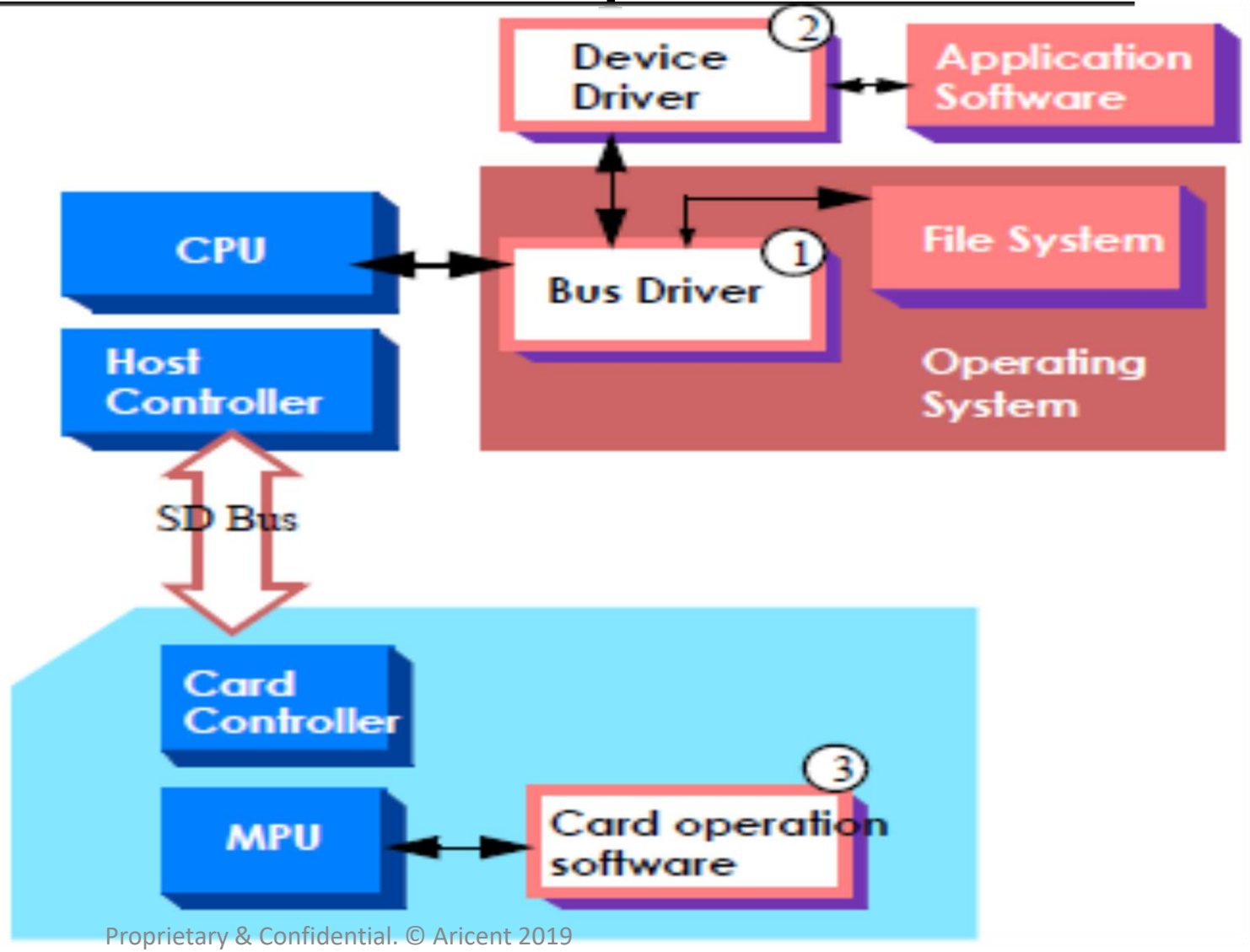
What is SD vs. miniSD, microSD, embedded SD?

- SD specification allows 3 physical sizes for SD cards
  - regular
  - miniSD
  - microSD
- All three sizes have the **same logical and functional** definitions.
- The **difference is only in the physical dimension** of the card.
- Regular size SD card is **24mm** x **32mm** x **1.4mm**. This is the card size typically found in digital camera applications.
- MiniSD card is **20mm** x **21.5mm** x **1.4mm**.
- MicroSD is the smallest of the three at **11mm** x **15mm** x **0.7mm**.
- Embedded SD is directly implemented in the SoC or board and is not implemented in a card form.

What is SD vs. miniSD, microSD?



What are the software requirements?



SDIO Introduction

SD standard offers flexibility beyond Memory cards.

SDIO offers below extended capabilities over the functions supported

- GPS
- Camera
- Wi-Fi
- Ethernet
- Barcode readers
- Bluetooth

SDIO Card Modes

Speed Mode

HIGH Speed Mode is in 25MHz and 50 Mhz

UHS-I supports below speeds

- SDR12 – 25MHz
- SDR25 - 50MHz
- SDR50 - 100MHz
- SDR104 - 208MHz
- DDR50 - 50MHz

Bus Mode

- 4-bit mode uses all 4 data lines
- 1-bit mode uses 1 data line
- SPI Mode

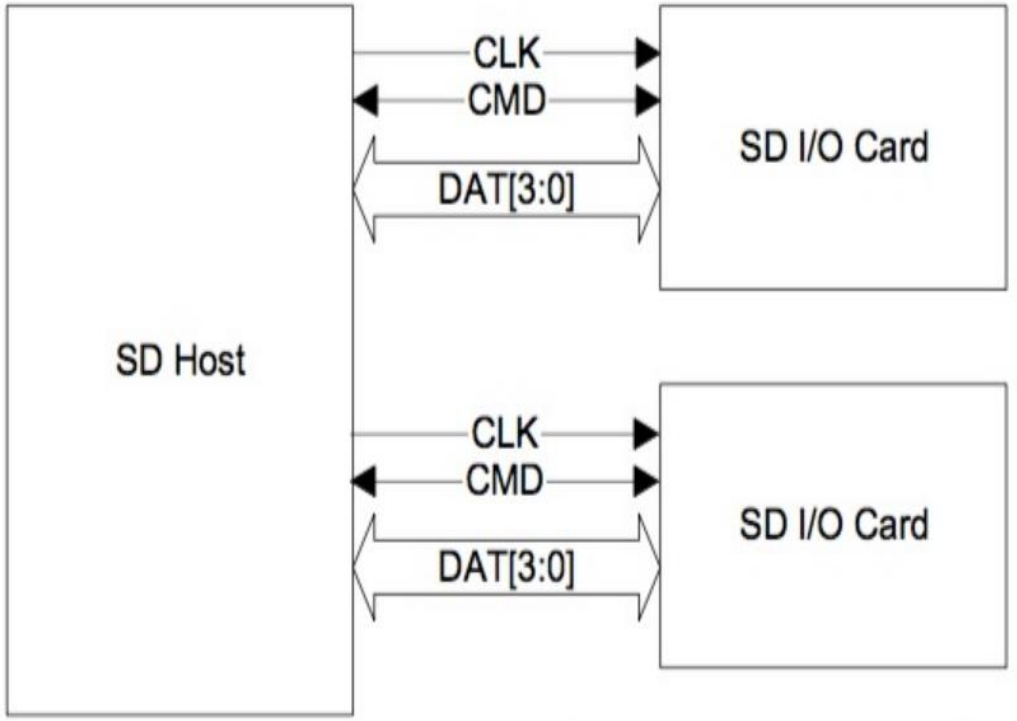
SDIO Signals

Communication over the bus is based on Command and response based on start and stop bits on the SD line

Command is send from host to card
on the command line and response
is also received on the cmd line

Data transfer happens on the Data
Lines

Interrupts from the card to host is
over the data line



SDIO Initialization + Data Transfer

- After Power On SDIO host should issue:
  - CMD5 – OP_COND command
  - CMD3 – SEND_RELATIVE_ADDRESS
  - CMD7 – SELECT/DESELECT CARD

  Card ready happens by now. Host to make sure the Initialization and data transfer functions should be detected by now.
  - CMD52- For initialitaion of Card Interrupts, IO init, Speed setting, Bus mode etc

S	D	Command Index 110100b	R/W flag	Function Number	RAW flag	Stuff	Register Address	Stuff	Write Data or Stuff Bits	CRC7	E
1	1	6	1	3	1	1	17	1	8	7	1

  - CMD53 – For data transfer

S	D	Command Index 110101b	R/W flag	Function Number	Block Mode	OP Code	Register Address	Byte/Block Count	CRC 7	E
1	1	6	1	3	1	1	17	9	7	1

Reference reads

- https://www.sdcard.org/downloads/pls/

What are the software requirements?

- SD software may mean three different things.
- It can refer to
  - (1) the operating system module that handles the initialization and the low level signaling to the SD device. – SD host controller device driver
  - (2) the device driver that runs on top of the OS to perform application specific function of the device. – SD card (slave) device driver
  - (3) the software that runs the local microprocessor inside the SD card. – SD card (slave) device firmware
- In order to enable SD bus in the system, the OS must be SD aware so SD host controller device driver must exist in the system.

What are the software requirements?

- Operating systems such as Windows and Linux not only have the basic SD host controller device driver function but also link it to the file system.
- When an SD memory card is inserted, the OS automatically assigns a drive letter to the SD memory card and it can be used for any file transfer as a disk drive.
- SD card (slave) device driver is required if the SD card is not configured as a standard SD memory device or the operating system does not connect the SD card device to the file system.
- For example, if it is an SDIO card with user specific function, the OS will only be able to detect the card existence and run through the initialization sequence.
- Specific application software and SDIO card device drivers will be needed to communicate with the SDIO card to perform the desire functions.

What are the software requirements?

- SD Card device software (firmware) typically exists in SD memory card.
- It is a concern of the card/device software developer and not related to the host software developer.
- It is the software run by the by the local processor to provide the card functions.
- If the card is an SD memory card, this software includes the interrupt service routine to service interrupt requests from the SD card controller, the wear leveling and bad block management software for the NAND Flash device.

Where is the file system?

- File System does exist in the SD memory card device if created by the host system, but the SD memory card device does not know about existence of the file system.
- The SD memory card presents itself as a flat memory space to the host.
- SD specification defines the file system for the host system.
- It is the responsibility of the host system that builds a file system on top of this flat memory space.
- The file system for SD memory card is based on Microsoft FAT and exFAT.
- The file system specification allows different host devices to exchange data through the SD memory card.

What all have we Learn?

- What is SD memory interface?
- What contributes to SD Card successes?
- What is Multimedia Card (MMC)?
- SD and MMC versions
- Bandwidth vs. Speed Class
- SD speed class table
- What is SDIO and SD combo?
- What is SD bus architecture?

What all have we Learn?

- What is in the SD host controller?
- The host driver software can do
- The host controller can have DMA support?
- How are electrical and timing control being handled?
- What is in the SD card design?
- What is SPI and how is it related to SD and MMC?
- What is SD vs. miniSD, microSD, embedded SD?
- What are the software requirements?
- What are the software requirements?
- Where is the file system?

Aricent
.ALTRAN GROUP

Any Queries?