MSC

软件部 --- 邵望权

- ❑ MMC相关
- ❑ 硬件电路
- ❑ 协议---SD卡协议为主
- ❑ 硬件逻辑
- ❑ 软件实现---MMC子系统

MMC相关

- MMC（MultiMediaCard）
- MSC （Mobile Storage Controller）
- SD （Secure Digital）
  - SDSC （<=2GB）
  - SDHC （>2Gb, <=32GB ）
  - SDXC （>32GB, <= 2TB ）
- eMMC （embedded MMC）
- SDIO（Secure Digital Input and Output）

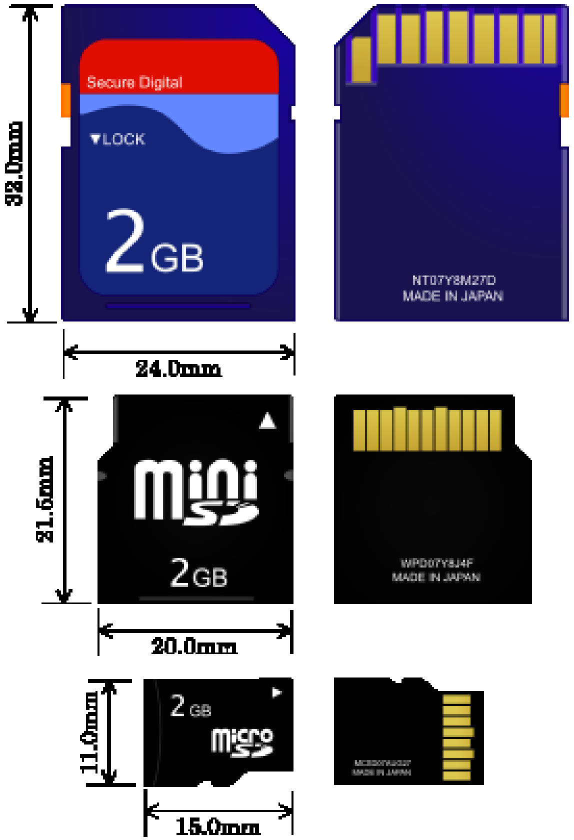
- 详情参考：https://en.wikipedia.org/wiki/Secure_Digital

规格

SD卡

miniSD

microSD---（TF Card）



BUS接口

- BUS
  - SPI模式
  - SD模式
  - UHS模式
- UHS（**Ultra High Speed**）

类型	协议
UHS-I	SD version 3.01
UHS-II	SD version 4.0
UHS-III	SD version 6.0

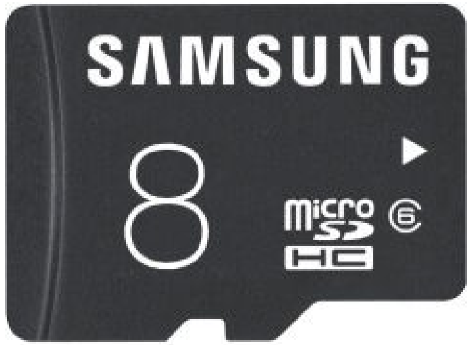
速度模式

Bus interface	Card logo	Bus logo	Bus speed	Spec version
Default Speed	SD SDHC SDXC	—	12.5 MByte/s	1.01
High Speed			25 MByte/s	2.00
UHS-I	SDHC SDXC	I	12.5 MByte/s (SDR12) 25 MByte/s (SDR25) 50 MByte/s (SDR50,DDR50) 104 MByte/s (SDR104)	3.01
UHS-II		II	156 MByte/s (FD156) 312 MByte/s (HD312)	4.00/4.10 (X2000)
UHS-III			312 MByte/s (FD312) 624 MByte/s (FD624)	6.0

速度等级

Minimum sequential writing speed	Speed Class	UHS Speed Class	Video Speed Class	Application Performance Class	Application
2 MB/s	② Class 2 (C2)	-	-	-	SD video recording
4 MB/s	④ Class 4 (C4)	-	-	-	High-definition video (HD) recording including Full HD (from 720p to 1080p/1080i)
6 MB/s	⑥ Class 6 (C6)	-	V6 Class 6 (V6)	-	
10 MB/s	⑩ Class 10 (C10)	U1 Class 1 (U1)	V10 Class 10 (V10)	A1 Class 1 (A1)	Full HD (1080p) video recording and consecutive recording of HD stills (High Speed bus, Class C10), real-time broadcasts and large HD video files (UHS bus, Classes U1 and V10) Running applications from the memory card (Class A1 - minimum 1500 read / 500 write operations per second)
30 MB/s	-	U3 Class 3 (U3)	V30 Class 30 (V30)	-	1080p and 4K video files at 60/120 fps (UHS bus)
60 MB/s	-	-	V60 Class 60 (V60)	-	8K video files at 60/120 fps (UHS bus)
90 MB/s	-	-	V90 Class 90 (V90)	-	

Card


SAMSUNG
8
micro SD HC
6

SanDisk
Ultra
64GB
micro SD XC I
1

Lexar
1000x
10
32GB
micro SD HC
3
II

USH-III

BUS与Card

	SDSC card	SDHC card	SDHC UHS-I card	SDHC UHS-II card	SDXC card	SDXC UHS-I card	SDXC UHS-II card	SDIO card
SDSC slot	Yes	No	No	No	No	No	No	No
SDHC slot	Yes	Yes	Yes	Yes]	No	No	No	No
SDHC UHS-I slot	Yes	Yes	Yes	Yes	No	No	No	No
SDHC UHS-II slot	Yes	Yes	Yes	Yes	No	No	No	No
SDXC slot	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
SDXC UHS-I slot	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
SDXC UHS-II slot	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
SDIO slot	Varies	Varies	Varies	Varies	Varies	Varies	Varies	Yes

硬件电路

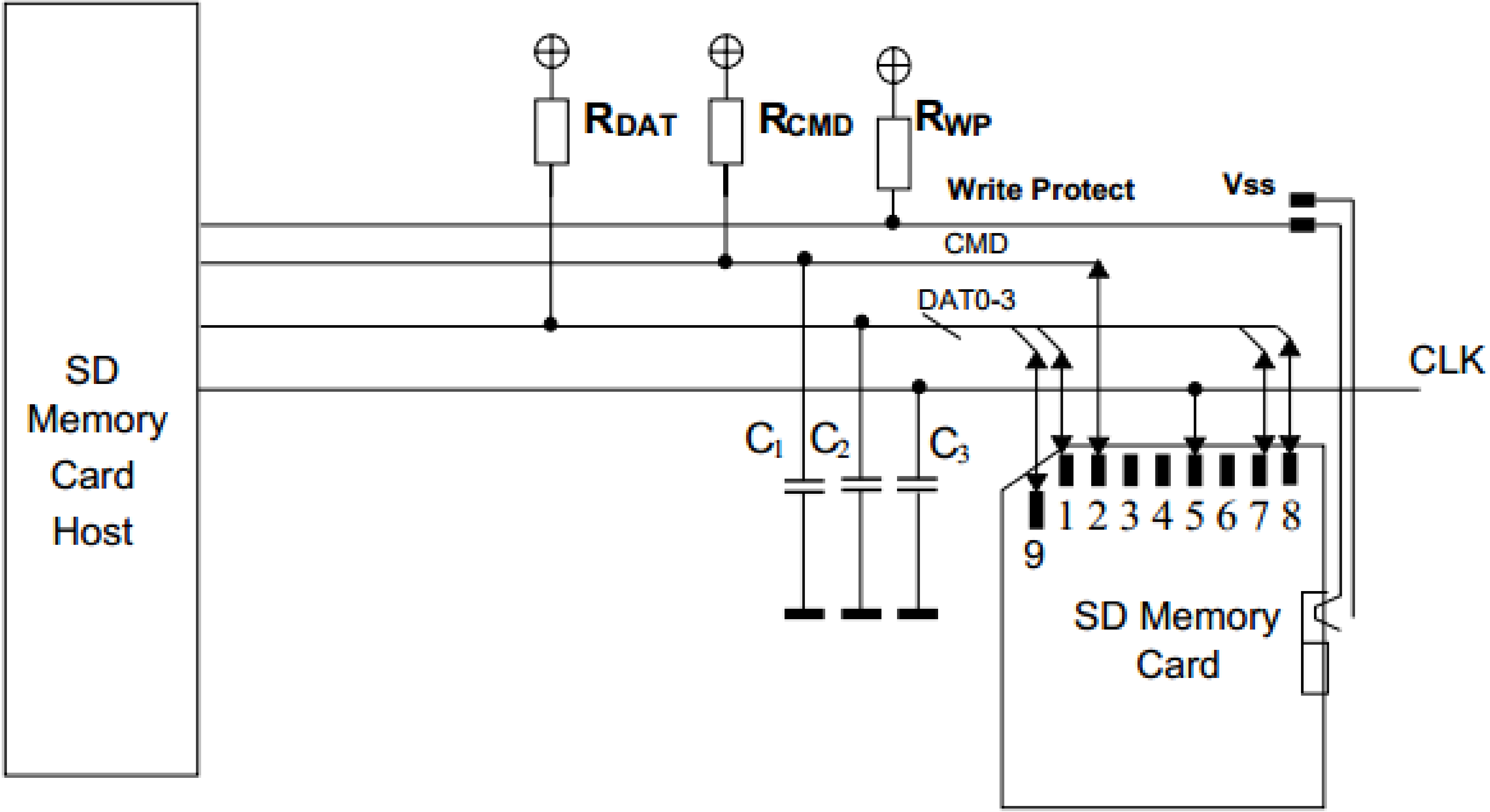


Figure 6-1: Bus Circuitry Diagram

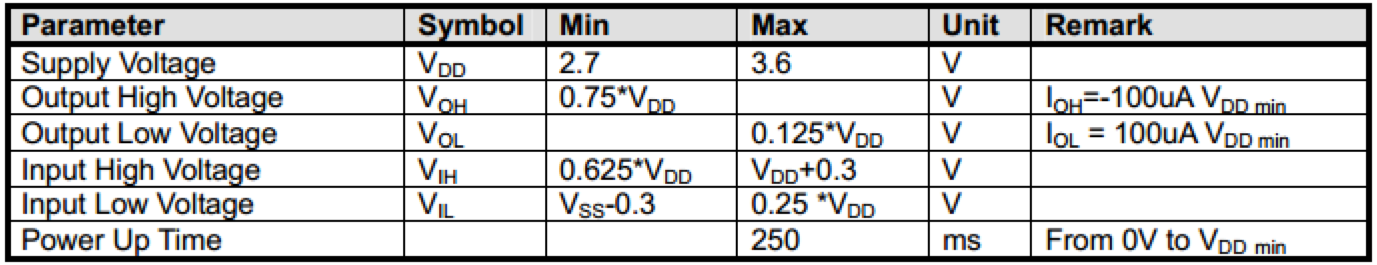
硬件说明

SD pin	microSD pin	Name	I/O	Logic	Description
1	2	DAT3	I/O	PP	SD Serial Data 3
2	3	CMD	I/O	PP, OD	Command, Response
3		VSS	S	S	Ground
4	4	VDD	S	S	Power
5	5	CLK	I	PP	Serial clock
6	6	VSS	S	S	Ground
7	7	DAT0	I/O	PP	SD Serial Data 0
8	8	DAT1 nIRQ	I/O O	PP OD	SD Serial Data 1 (memory cards) **Interrupt Period** (SDIO cards share pin via protocol)
9	1	DAT2	I/O	PP	SD Serial Data 2

注：

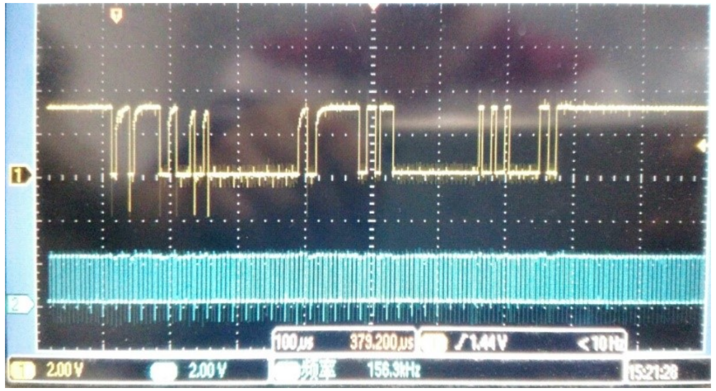
数据方向：I = Input, O = Output.
PP = Push-Pull logic（上拉）
OD = Open-Drain logic（开漏）
S = Power Supply

电压范围

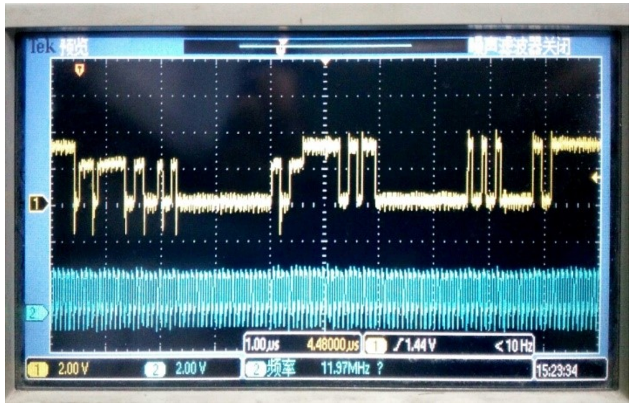


Parameter	Symbol	Min	Max	Unit	Remark
Supply Voltage	V_{DD}	2.7	3.6	V	
Output High Voltage	V_{OH}	$0.75{*}V_{DD}$		V	I_{OH}=-100uA $V_{DD\ min}$
Output Low Voltage	V_{OL}		$0.125{*}V_{DD}$	V	I_{OL} = 100uA $V_{DD\ min}$
Input High Voltage	V_{IH}	$0.625{*}V_{DD}$	V_{DD}+0.3	V	
Input Low Voltage	V_{IL}	V_{SS}-0.3	0.25 $*V_{DD}$	V	
Power Up Time			250	ms	From 0V to $V_{DD\ min}$

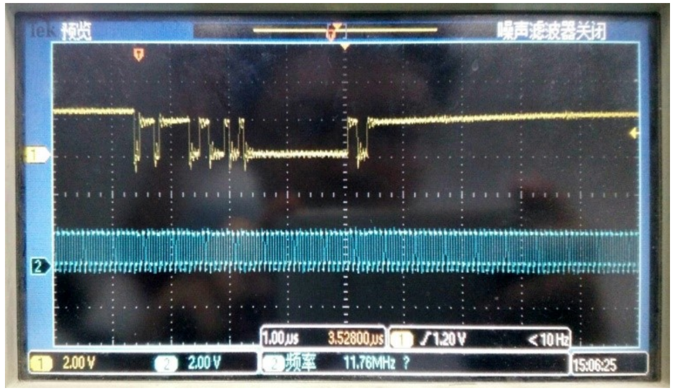
Table 6-2: Threshold Level for High Voltage



正常波形



上拉电阻大引起，但可以正常工作



上拉电阻过大，导致电压无法在规定时间（2个时钟周期）内达到一定值

上拉电阻的范围：10 ~ 100 kΩ

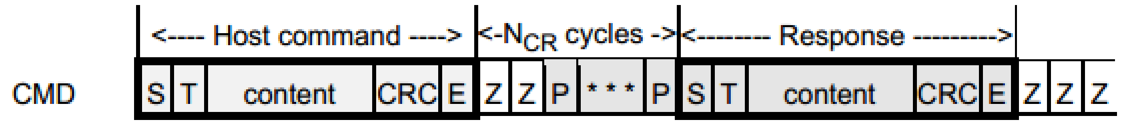
协议---SD卡协议为主

- 协议：
  - CMD
  - CMD + DATA

- CMD类型：
  - Broadcast commands (bc), no response
  - Broadcast commands with response (bcr)
  - Addressed (point-to-point) commands (ac)
  - Addressed (point-to-point) data transfer commands (adtc)

Command

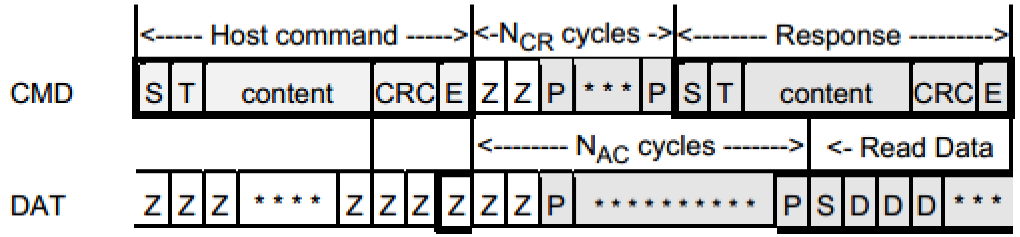
- 常规命令：



<---- Host command ---->
<-NCR cycles ->
<-------- Response --------->
CMD
S T content CRC E Z Z P * * * P S T content CRC E Z Z Z

Figure 4-14: SEND_RELATIVE_ADDR Timing

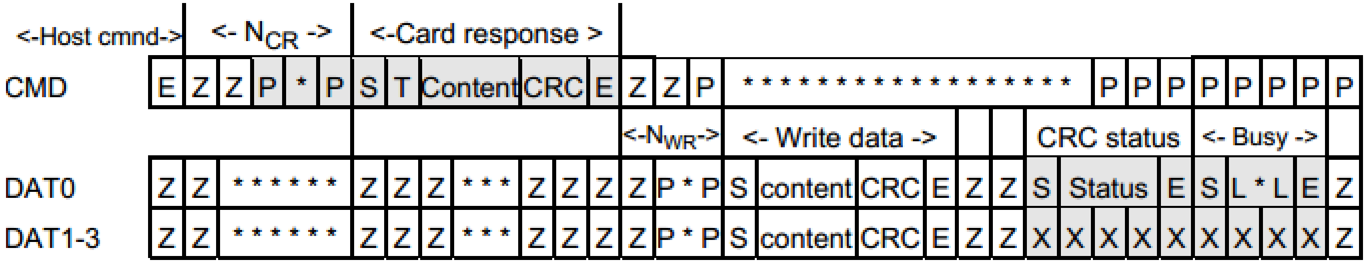
- 读： CMD17/18



<----- Host command ----->
<-NCR cycles ->
<-------- Response --------->
CMD
S T content CRC E Z Z P * * * P S T content CRC E
<-------- NAC cycles ------->
<- Read Data
DAT
Z Z Z * * * * Z Z Z Z Z Z P * * * * * * * * * * P S D D D * * *

Figure 4-18: Timing of Single Block Read Command

- 写： CMD24/25



<-Host cmnd->
<- NCR ->
<-Card response >
CMD
E Z Z P * P S T Content CRC E Z Z P * * * * * * * * * * * * * * * * * * * P P P P P P P P
<-NWR->
<- Write data ->
CRC status
<- Busy ->
DAT0
Z Z * * * * * * Z Z Z * * * Z Z Z Z P * P S content CRC E Z Z S Status E S L * L E Z
DAT1-3
Z Z * * * * * * Z Z Z * * * Z Z Z Z P * P S content CRC E Z Z X X X X X X X X X Z

Figure 4-21: Timing of Single Block Write Command

写

- 在写的过程中由于控制器需要等到卡将数据全部写完，才视一次传输完成。
- 而在卡写的过程中，只有数据完全写入后，标志数据传输完成的busy位将在DATA0返回。同时返回的还有此次写数据后的状态status(CRC校验值)。如果CRC的校验值大于“010”,将代表数据传输失败。
- CRC Status
  - “010” —— 数据被接受写入卡中
  - “101” —— 由于CRC错误，数据不被卡接受
  - “110” —— 由于写错误，数据不被卡接受

SD初始化流程

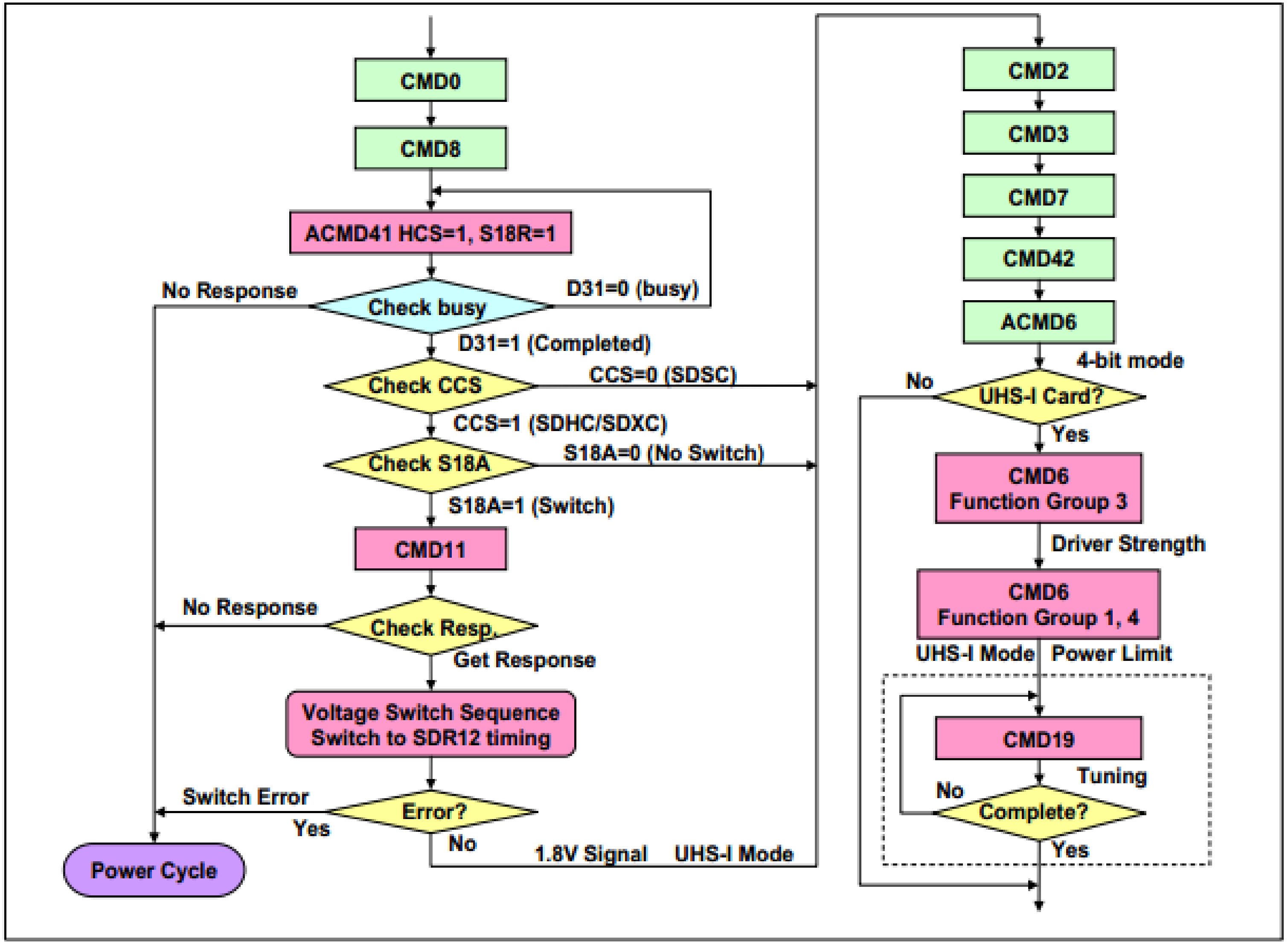
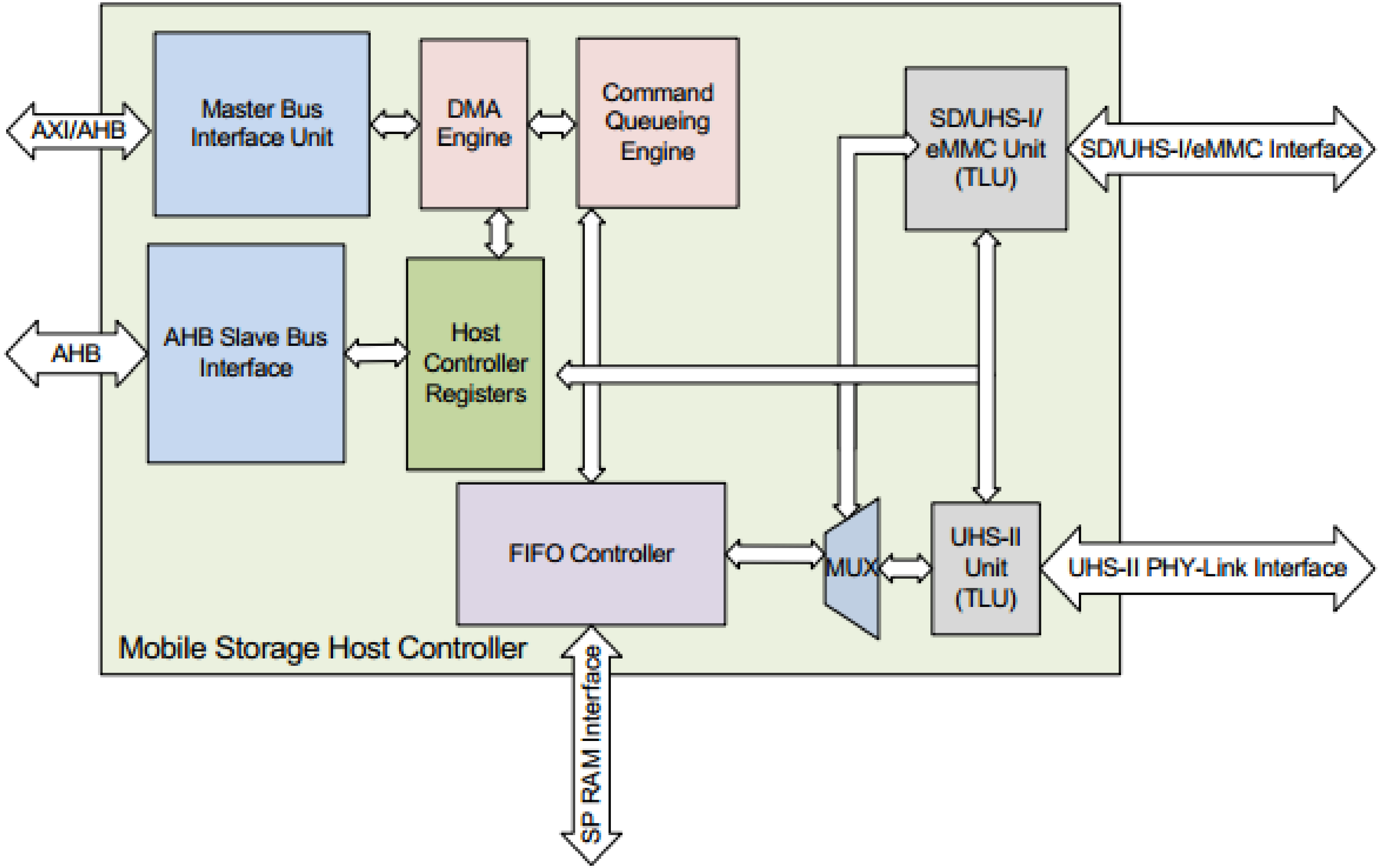
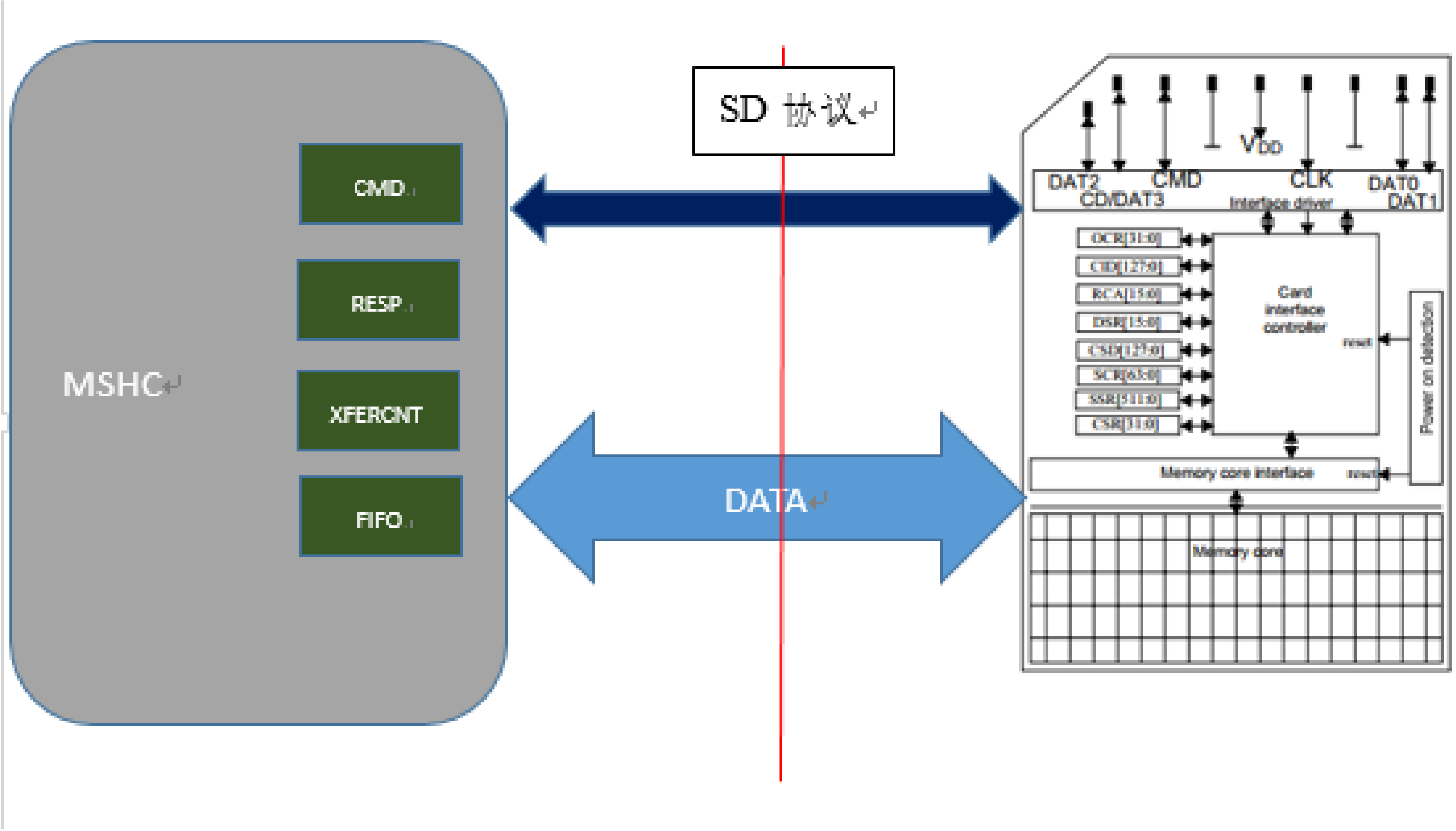


Figure 4-6 : UHS-I Host Initialization Flow Chart

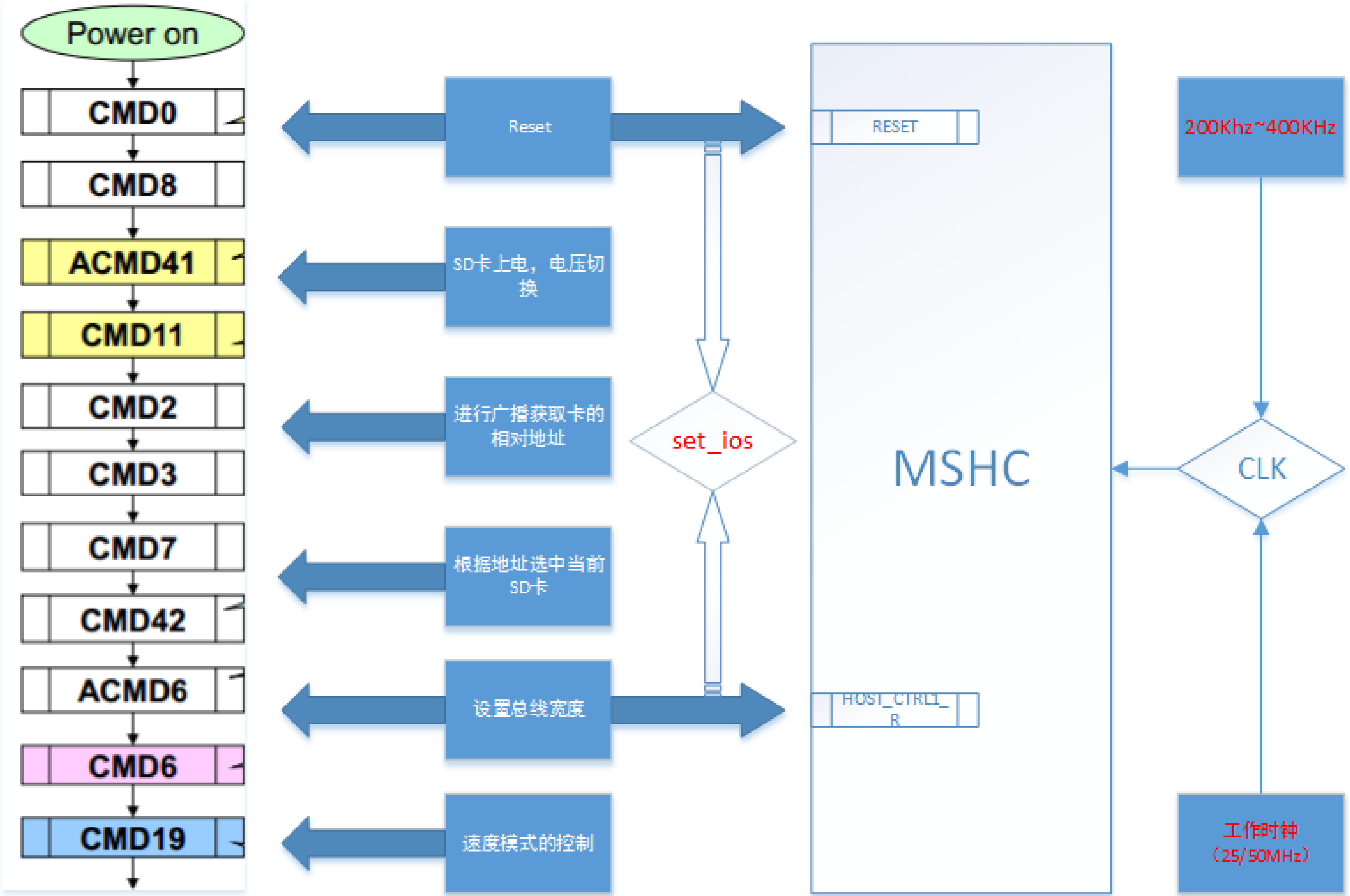
X2000控制器结构图



初始化


MSHC
CMD
RESP
XFERCNT
FIFO
SD 协议
DATA
VDD
DAT2
CD/DAT3
CMD
CLK
DAT0
DAT1
Interface driver
OCR[31:0]
CID[127:0]
RCA[15:0]
DSR[15:0]
CSD[127:0]
SCR[63:0]
SSR[511:0]
CSR[31:0]
Card interface controller
reset
Power on detection
Memory core interface
reset
Memory core

初始化流程



Power on

CMD0

CMD8

ACMD41

CMD11

CMD2

CMD3

CMD7

CMD42

ACMD6

CMD6

CMD19

Reset

SD卡上电，电压切换

进行广播获取卡的相对地址

根据地址选中当前SD卡

设置总线宽度

速度模式的控制

set_ios

MSHC

RESET

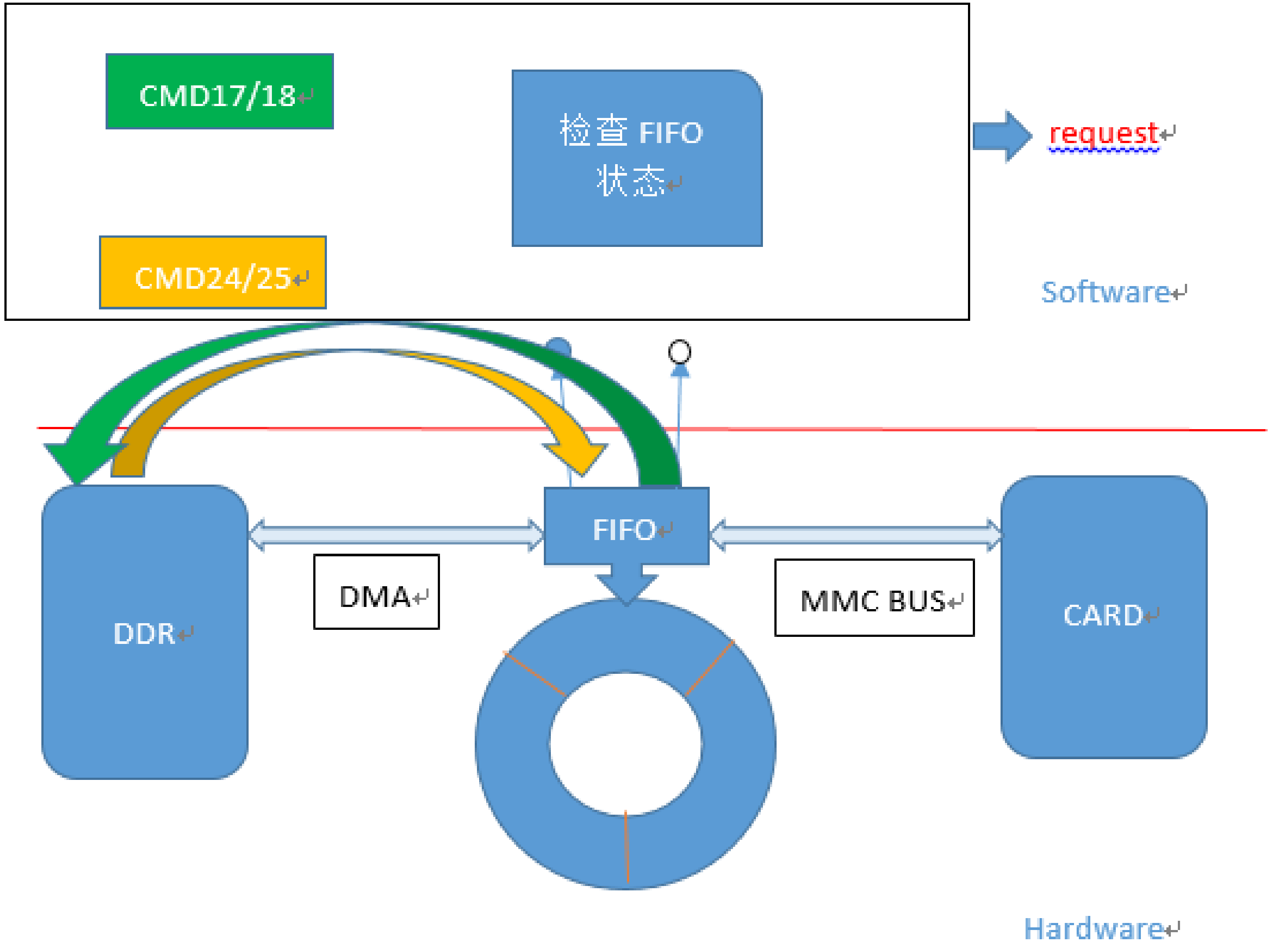
HOST_CTRL1_R

200Khz~400KHz

CLK

工作时钟（25/50MHz）

数据传输

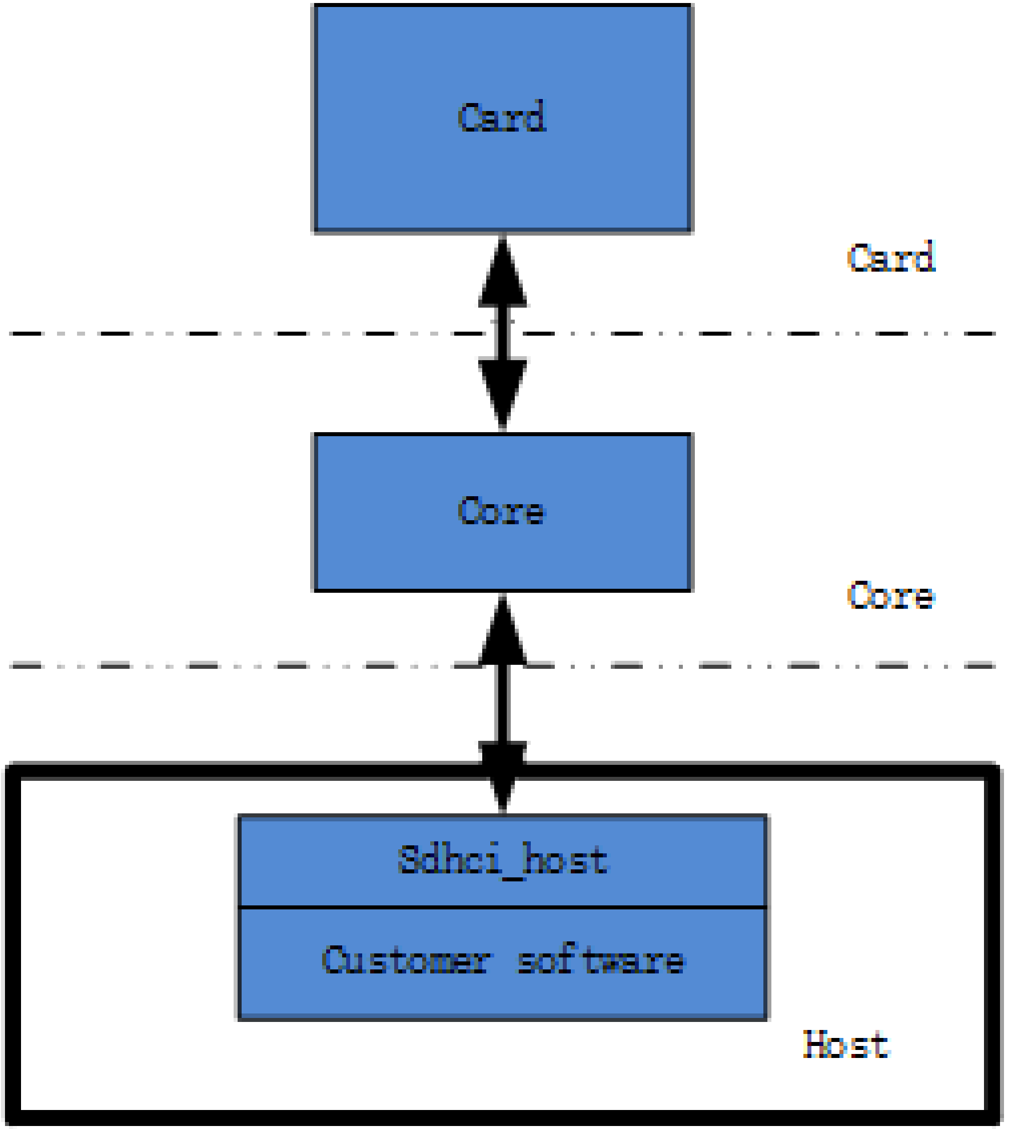


X2000 MSHC

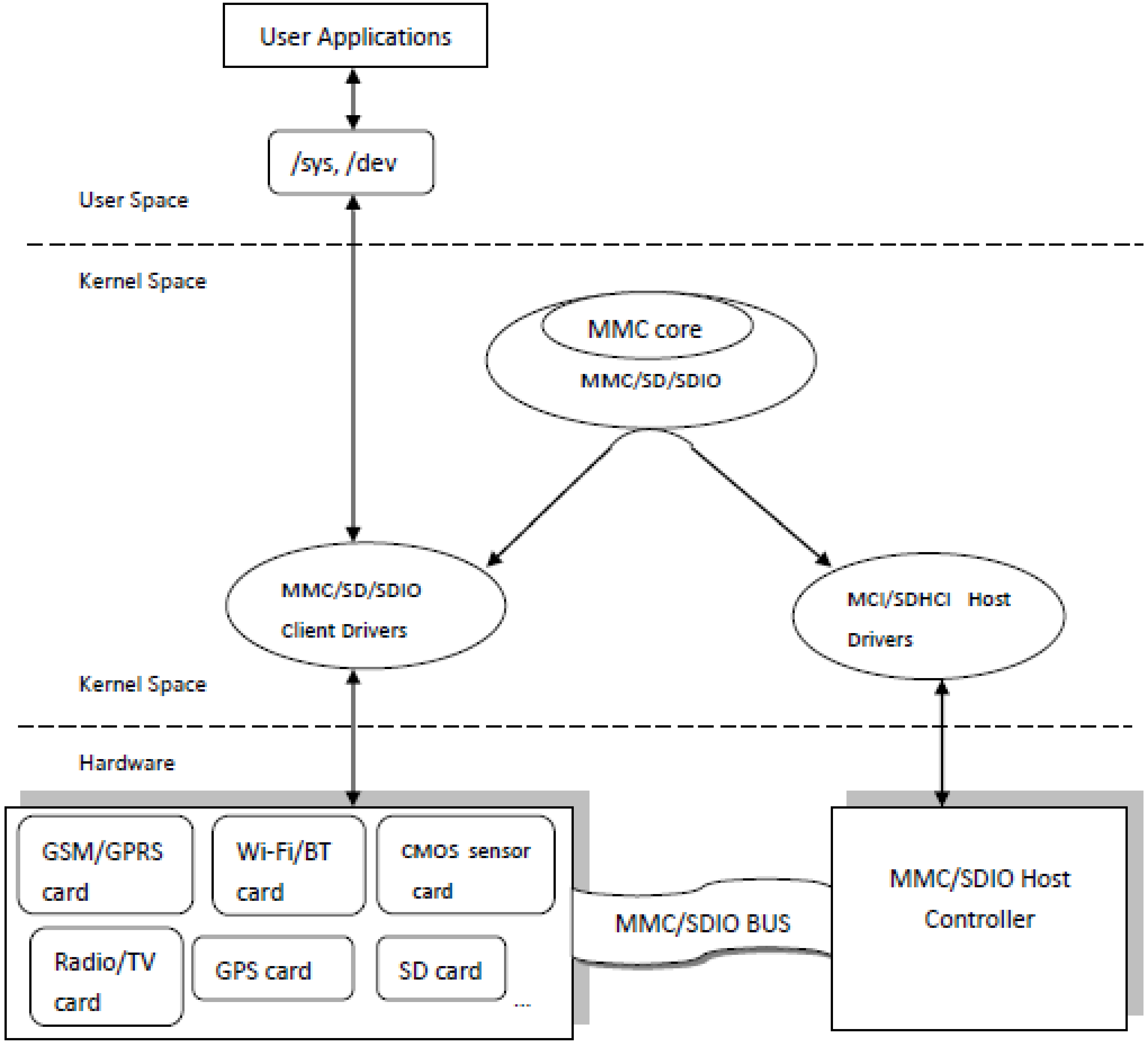
软件实现---MMC子系统

- MMC子系统代码drivers/mmc，共三个目录:
  - Card：存放闪存卡(块设备)的相关驱动
  - Core：整个MMC的核心层，这部分完成不同协议和规范的实现，为host层和设备驱动层提供接口函数。
  - Host：针对不同主机端的SDHC、MMC控制器的驱动;

X2000 MSHC驱动软件结构



软件框架


User Applications
/sys, /dev
User Space
Kernel Space
MMC core
MMC/SD/SDIO
MMC/SD/SDIO
Client Drivers
MCI/SDHCI Host
Drivers
Kernel Space
Hardware
GSM/GPRS
card
Wi-Fi/BT
card
CMOS sensor
card
Radio/TV
card
GPS card
SD card
...
MMC/SDIO BUS
MMC/SDIO Host
Controller

数据结构

```
struct mmc_host {
        struct device           *parent;、
        struct device           class_dev;
        int             index;
        const struct mmc_host_ops *ops;
        struct mmc_ios          ios;     /* current io bus settings */
        struct mmc_card         *card;  /* device attached to this host */
        const struct mmc_bus_ops *bus_ops; /* current bus driver */
        .     .     .

        unsigned long           private[0] ____cacheline_aligned;
};
```

代码：include/linux/mmc/host.h

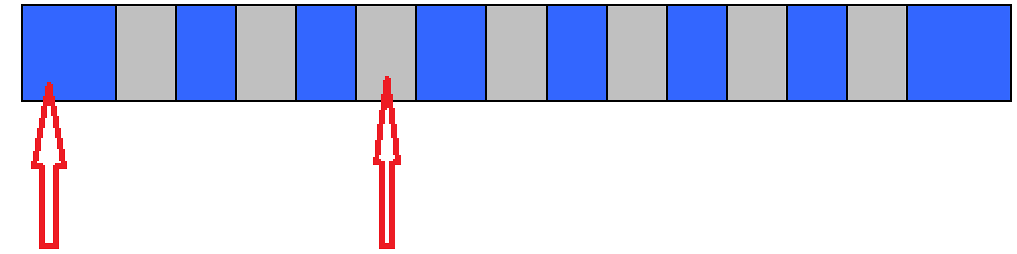
驱动实现

- MMC驱动的实现主要有两个“线程”
  - 初始化 （热插拔）
    - INIT_DELAYED_WORK(&host->detect, mmc_rescan)
  - 数据传输
    - kthread_run(mmc_queue_thread, mq, "mmcqd/%d%s", host->index, subname ? subname : "");
- 三个接口
  - mmc_add_host(struct mmc_host *host)
  - void (*set_ios)(struct mmc_host *host, struct mmc_ios *ios);
  - void (*request)(struct mmc_host *host, struct mmc_request *req);

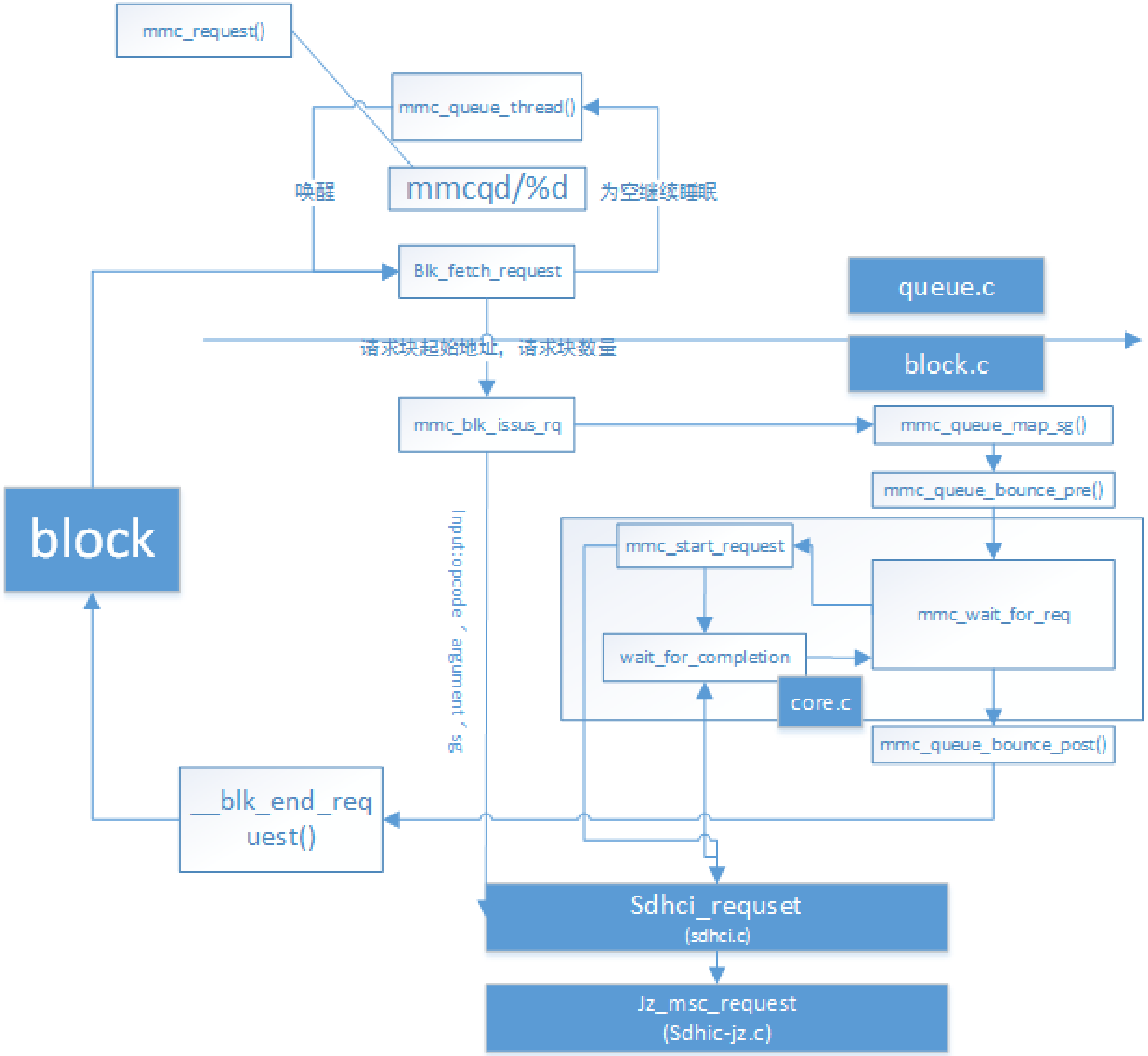
数据传输—request处理

- Request请求队列

  Block将文件系统层传入的数据按照一定的策略进行组合，最后形成一个队列。



数据传输—request处理



谢谢！