



第六讲：制作U盘案例

USB技术 应用与开发

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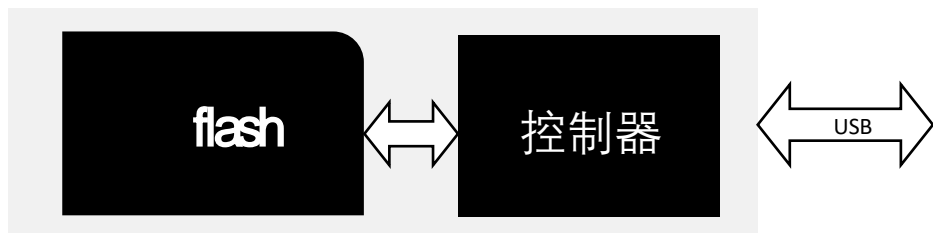
- 01 | U盘描述符
- 02 | Bulk-Only传输协议
- 03 | 常用UFI/SCSI命令
- 04 | 软件实现
及效果演示



USB大容量存储类设备

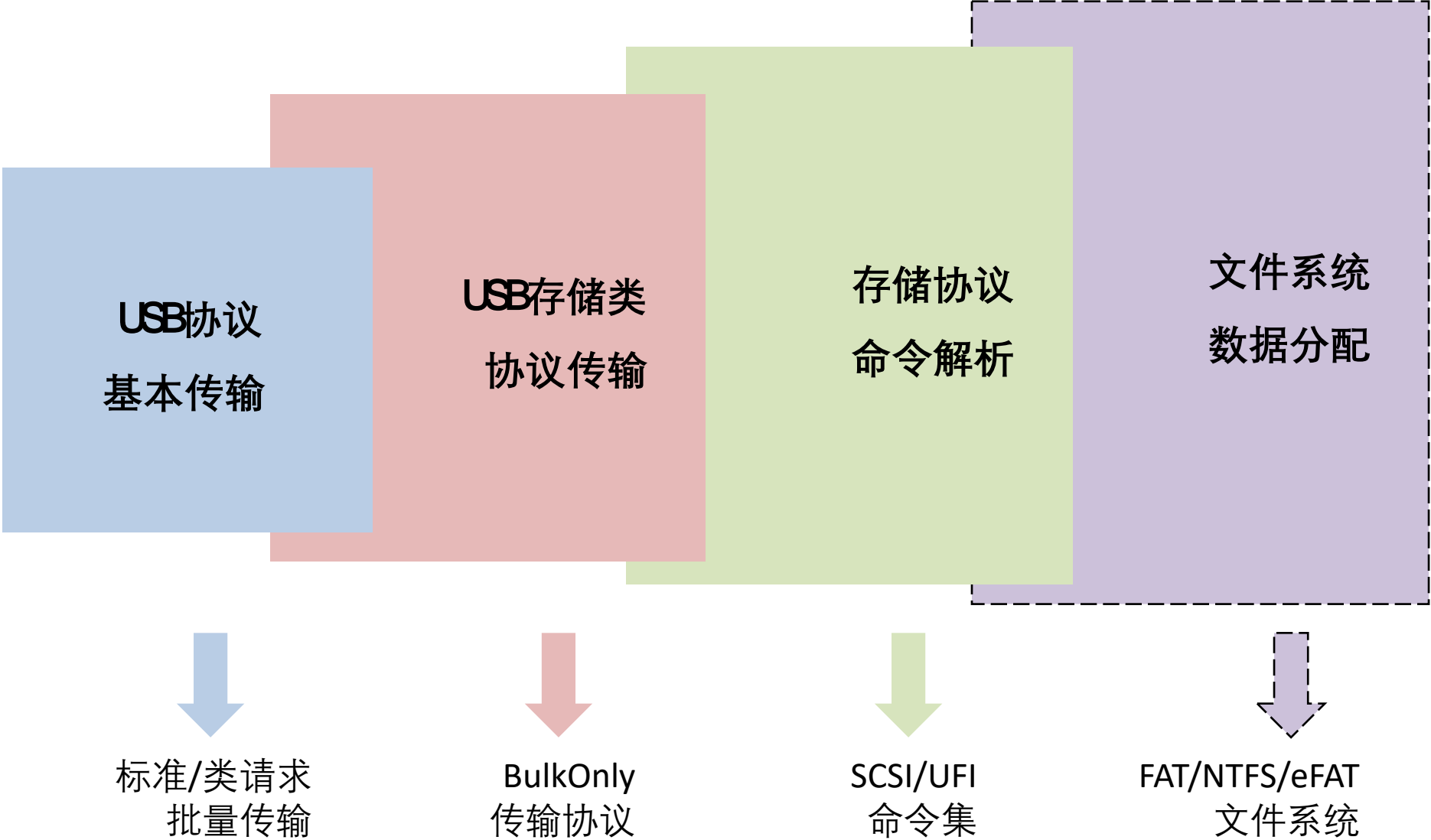
USB Mass Storage Device Class (USB MSC / UMS)

移动硬盘、读卡器、U盘、光驱等等。





U盘设备传输数据结构



01

U盘描述符

U盘描述符

设备描述符

Table 4.1 - Device Descriptor

Offset	Field	Size	Value	Description
0	<i>bLength</i>	Byte	12h	Size of this descriptor in bytes.
1	<i>bDescriptorType</i>	Byte	01h	DEVICE descriptor type.
2	<i>bcdUSB</i>	Word	???h	<i>USB Specification</i> Release Number in Binary-Coded Decimal (i.e. 2.10 = 210h). This field identifies the release of the <i>USB Specification</i> with which the device and its descriptors are compliant.
4	<i>bDeviceClass</i>	Byte	00h	Class is specified in the interface descriptor.
5	<i>bDeviceSubClass</i>	Byte	00h	Subclass is specified in the interface descriptor.
6	<i>bDeviceProtocol</i>	Byte	00h	Protocol is specified in the interface descriptor.
7	<i>bMaxPacketSize0</i>	Byte	??h	Maximum packet size for endpoint zero. (only 8, 16, 32, or 64 are valid (08h, 10h, 20h, 40h)).
8	<i>idVendor</i>	Word	???h	Vendor ID (assigned by the USB-IF).
10	<i>idProduct</i>	Word	???h	Product ID (assigned by the manufacturer).
12	<i>bcdDevice</i>	Word	???h	Device release number in binary-coded decimal.
14	<i>iManufacturer</i>	Byte	??h	Index of string descriptor describing the manufacturer.
15	<i>iProduct</i>	Byte	??h	Index of string descriptor describing this product.
16	<i>iSerialNumber</i>	Byte	??h	Index of string descriptor describing the device's serial number. (Details in 4.1.1 below)
17	<i>bNumConfigurations</i>	Byte	??h	Number of possible configurations.

U盘描述符

配置描述符

Table 4.4 - Configuration Descriptor

Offset	Field	Size	Value	Description										
0	<i>bLength</i>	Byte	09h	Size of this descriptor in bytes.										
1	<i>bDescriptorType</i>	Byte	02h	CONFIGURATION Descriptor Type.										
2	<i>wTotalLength</i>	Word	????h	Total length of data returned for this configuration. Includes the combined length of all descriptors (configuration, interface, endpoint, and class- or vendor-specific) returned for this configuration.										
4	<i>bNumInterfaces</i>	Byte	??h	Number of interfaces supported by this configuration. The device shall support at least the Bulk-Only Data Interface.										
5	<i>bConfigurationValue</i>	Byte	??h	Value to use as an argument to the <i>SetConfiguration()</i> request to select this configuration.										
6	<i>iConfiguration</i>	Byte	??h	Index of string descriptor describing this configuration.										
7	<i>bmAttributes</i>	Byte	20h	Configuration characteristics: <table><tr><th>Bit</th><th>Description</th></tr><tr><td>7</td><td>Reserved (set to one)</td></tr><tr><td>6</td><td>Self-powered</td></tr><tr><td>5</td><td>Remote Wakeup</td></tr><tr><td>4..0</td><td>Reserved (reset to zero)</td></tr></table> <p>Bit 7 is reserved and must be set to one for historical reasons. For a full description of this <i>bmAttributes</i> bitmap, see the <i>USB 1.1 Specification</i>.</p>	Bit	Description	7	Reserved (set to one)	6	Self-powered	5	Remote Wakeup	4..0	Reserved (reset to zero)
Bit	Description													
7	Reserved (set to one)													
6	Self-powered													
5	Remote Wakeup													
4..0	Reserved (reset to zero)													
8	<i>MaxPower</i>	Byte	??h	Maximum power consumption of the USB device from the bus in this specific configuration when the device is fully operational. Expressed in 2mA units (i.e. 50 = 100mA)										

U盘描述符

接口描述符

Table 4.5 – Bulk-Only Data Interface Descriptor

Offset	Field	Size	Value	Description
0	<i>bLength</i>	Byte	09h	Size of this descriptor in bytes.
1	<i>bDescriptorType</i>	Byte	04h	INTERFACE Descriptor Type.
2	<i>bInterfaceNumber</i>	Byte	0?h	Number of interface. Zero-based value identifying the index in the array of concurrent interfaces supported by this configuration.
3	<i>bAlternateSetting</i>	Byte	??h	Value used to select alternate setting for the interface identified in the prior field.
4	<i>bNumEndpoints</i>	Byte	??h	Number of endpoints used by this interface (excluding endpoint zero). This value shall be at least 2.
5	<i>bInterfaceClass</i>	Byte	08h	MASS STORAGE Class.
6	<i>bInterfaceSubClass</i>	Byte	0?h	Subclass code (assigned by the USB-IF). Indicates which industry standard command block definition to use. Does not specify a type of storage device such as a floppy disk or CD-ROM drive. (See <i>USB Mass Storage Overview Specification</i>)
7	<i>bInterfaceProtocol</i>	Byte	50h	BULK-ONLY TRANSPORT. (See <i>USB Mass Storage Overview Specification</i>)
8	<i>iInterface</i>	Byte	??h	Index to string descriptor describing this interface.

U盘描述符

端点描述符

Table 4.6 - Bulk-In Endpoint Descriptor

Offset	Field	Size	Value	Description								
0	<i>bLength</i>	Byte	07h	Size of this descriptor in bytes.								
1	<i>bDescriptorType</i>	Byte	05h	ENDPOINT Descriptor Type.								
2	<i>bEndpointAddress</i>	Byte	8?h	The address of this endpoint on the USB device. The address is encoded as follows. <table><tr><th>Bit</th><th>Description</th></tr><tr><td>3..0</td><td>The endpoint number</td></tr><tr><td>6..4</td><td>Reserved, set to 0</td></tr><tr><td>7</td><td>1 = In</td></tr></table>	Bit	Description	3..0	The endpoint number	6..4	Reserved, set to 0	7	1 = In
Bit	Description											
3..0	The endpoint number											
6..4	Reserved, set to 0											
7	1 = In											
3	<i>bmAttributes</i>	Byte	02h	This is a Bulk endpoint.								
4	<i>wMaxPacketSize</i>	Word	00??h	Maximum packet size. Shall be 8, 16, 32 or 64 bytes (08h, 10h, 20h, 40h).								
6	<i>bInterval</i>	Byte	00h	Does not apply to Bulk endpoints.								

Table 4.7 – Bulk-Out Endpoint Descriptor

Offset	Field	Size	Value	Description								
0	<i>bLength</i>	Byte	07h	Size of this descriptor in bytes.								
1	<i>bDescriptorType</i>	Byte	05h	ENDPOINT descriptor type.								
2	<i>bEndpointAddress</i>	Byte	0?h	The address of this endpoint on the USB device. This address is encoded as follows: <table><tr><th>Bit</th><th>Description</th></tr><tr><td>3..0</td><td>Endpoint number</td></tr><tr><td>6..4</td><td>Reserved, set to 0</td></tr><tr><td>7</td><td>0 = Out</td></tr></table>	Bit	Description	3..0	Endpoint number	6..4	Reserved, set to 0	7	0 = Out
Bit	Description											
3..0	Endpoint number											
6..4	Reserved, set to 0											
7	0 = Out											
3	<i>bmAttributes</i>	Byte	02h	This is a Bulk endpoint.								
4	<i>wMaxPacketSize</i>	Word	00??h	Maximum packet size. Shall be 8, 16, 32 or 64 bytes (08h, 10h, 20h, or 40h).								
6	<i>bInterval</i>	Byte	00h	Does not apply to Bulk endpoints.								

Bulk-Only Mass Storage Reset

Table 3.1 – Bulk-Only Mass Storage Reset

<i>bmRequestType</i>	<i>bRequest</i>	<i>wValue</i>	<i>wIndex</i>	<i>wLength</i>	<i>Data</i>
00100001b	11111111b	0000h	Interface	0000h	none

主机复位海量存储设备及其相关接口请求

- 控制传输。
- 一般复位存储设备和它的接口
- 设备要保存其数据端点的STALL状态和Tog同步标志
- 用于主机的下一个CBW传送

Get Max LUN

Table 3.2 –Get Max LUN

<i>bmRequestType</i>	<i>bRequest</i>	<i>wValue</i>	<i>wIndex</i>	<i>wLength</i>	<i>Data</i>
10100001b	11111110b	0000h	Interface	0001h	1 byte

主机获取磁盘最大逻辑单元号请求

- 控制传输，设备上传1字节数据（最大逻辑单元号）
- 在进行Bulk-Only传输协议前执行
- 设备最大逻辑单元号15，已有逻辑单元号要连续

主要协议规范



Mass Storage Class Specification Overview



USB Mass Storage Class Control/Bulk/Interrupt (CBI) Transport



USB Mass Storage Class Bulk-Only (BBB) Transport



USB Mass Storage Class Universal Floppy Interface (UFI) Command Specification



USB Mass Storage Class Bootability Specification



USB Mass Storage Class Compliance Test Specification



USB Lockable Storage Devices Feature Specification (LSD FS)



USB Mass Storage Class USB Attached SCSI Protocol

传输协议

命令
协议

其他

02

Bulk-Only 传输协议

传输协议结构

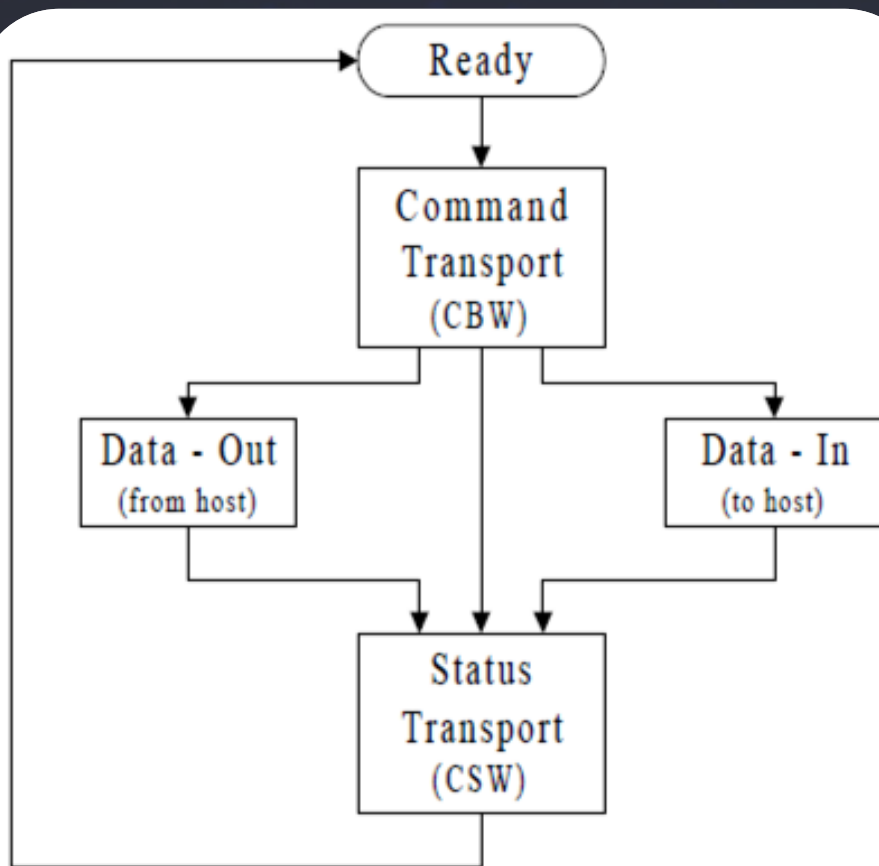


Figure 1 - Command/Data/Status Flow

主机从设备读数据

→ CBW包 (OUT, 43425355H固定开头)

→ IN_DATAx IN_DATAx IN_DATAx ...

→ CSW包 (IN, 53425355H固定开头)

主机向设备写数据

→ CBW包 (OUT, 43425355H固定开头)

→ OUT_DATAx OUT_DATAx OUT_DATAx ...

→ CSW包 (IN, 53425355H固定开头)

CBW结构

CSW: 包含命令块和信息的数据包

Table 5.1 - Command Block Wrapper

bit Byte	7	6	5	4	3	2	1	0
0-3	dCBWSignature					CSW包固定头, 43425355H（小端格式）		
4-7	dCBWTag					主机分配的4字节数据, 设备记录并在CSW包中匹配上传		
8-11 (08h-0Bh)	dCBWDataTransferLength					主机期望Data-Out/Data-In时要传输的字节长度		
12 (0Ch)	bmCBWFlags					方向标志, 指明 Data-Out/Data-In		
13 (0Dh)	Reserved (0)			bCBWLUN			磁盘逻辑单元号	
14 (0Eh)	Reserved (0)		bCBWCBLength			CBWCB命令块长度（1-16）		
15-30 (0Fh-1Eh)	CBWCB					命令块		

- 下传包 (OUT事务)
- 长度固定31字节, 前4字节固定 43425355H (小端格式)
- 在一次上传CSW包后或Bulk-OnlyReset请求后下传
- 作为一次完整的 Bulk-Only 传输开始边界

CSW：包含命令块状态的数据包

Table 5.2 - Command Status Wrapper

Byte	bit	7	6	5	4	3	2	1	0
0-3		<i>dCSWSignature</i>						CSW包固定头，53425355H（小端格式）	
4-7		<i>dCSWTag</i>						与CBW此领域数据保持一致	
8-11 (8-Bh)		<i>dCSWDataResidue</i>						CBW包中“数据传输长度”字段与实际Data-Out/Data-In数据长度差值	
12 (Ch)		<i>bCSWStatus</i>						表明命令相应成功（0）或失败（非0）	

- 上传包（IN事务）
- 长度固定13字节，前4字节固定 53425355H（小端格式）
- dCSWTag 字段必须匹配CBW里面相同字段
- 作为一次完整的 Bulk-Only 传输结束边界

03

常用的UFI/SCSI命令



SCSI - Small Computer System Interface

小型计算机系统接口

UFI - USB Floppy Interface

USB软盘接口，基于SCSI-2和 SFF-8070i 命令集合



查询磁盘信息命令块

Table 9 - INQUIRY Command

Bit	7	6	5	4	3	2	1	0
Byte								
0	Operation Code (12h)							
1	Logical Unit Number			Reserved				EVPD (0)
2	Page Code							
3	Reserved							
4	Allocation Length							
5	Reserved							
6	Reserved							
7	Reserved							
8	Reserved							
9	Reserved							
10	Reserved							
11	Reserved							

Table 10 -				
Bit	7	6	5	
Byte				
0	Reserved			
1	RMB			
2	ISO Version		EC	

Table 10 - INQUIRY Data Format

Bit	7	6	5	4	3	2	1	0
Byte								
0	Reserved			Peripheral Device Type				
1	RMB	Reserved						
2	ISO Version		ECMA Version			ANSI Version (00h)		
3	Reserved				Response Data Format			
4	Additional Length (31)							
5	Reserved							
7								
8								
15	Vendor Information							
16	Product Identification							
31								
32								
35	Product Revision Level n.nn							





读取磁盘当前容量命令块

Table 27 - READ CAPACITY Command

Bit	7	6	5	4	3	2	1	0
Byte								
0	Operation Code (25h)							
1	Logical Unit Number			Reserved				RelAdr
2	(MSB) Logical Block Address <							

Table 28 - READ CAPACITY Data

Bit	7	6	5	4	3	2	1	0
Byte								
0	(MSB) Last Logical Block Address (LSB)							
1								
2								
3								
4	(MSB) Block Length In Bytes (LSB)							
5								
6								
7								



Table 29 - READ FORMAT CAPACITIES Command

Byte	Bit	7	6	5	4	3	2	1	0
0	Operation Code (23h)								
1	Logical Unit Number				Reserved				
2	Reserved								
3	Reserved								
4	Reserved								
5	Reserved								
6	Reserved								
7									
8									
9									
10									
11									

Byte	Bit	7	6	5	4	3	2	1	0
0	(MSB) Number of Blocks (LSB)								
1									
2									
3									
4	Reserved						Descriptor Code		
5	(MSB) Block Length (LSB)								
6									
7									

Byte	Bit	7	6	5	4	3	2	1	0
0	Reserved								
1	Reserved								
2	Reserved								
3	Capacity List Length								

[illegible]



磁盘物理扇区读命令块

Table 25 - READ(10) Command

Bit	7	6	5	4	3	2	1	0
Byte								
0	Operation Code (28h)							
1	Logical Unit Number			DPO	FUA	Reserved		RelAdr
2	(MSB) Logical Block Address <							

11	Reserved
10	Reserved
9	Reserved
8	Transfer Length (LSB)



磁盘物理扇区写命令块

Table 47 - WRITE(10) Command

Bit	7	6	5	4	3	2	1	0
Byte								
0	Operation Code (2Ah)							
1	Logical Unit Number			DPO	FUA	Reserved		RelAdr
2	(MSB) Logical Block Address <							

11	Reserved
10	Reserved
9	Reserved
8	Transfer Length (LSB)



查询磁盘是否ready命令块

Table 45 - TEST UNIT READY Command

Bit	7	6	5	4	3	2	1	0
Byte								
0	Operation Code (00h)							
1	Logical Unit Number			Reserved				
2	Reserved							
3	Reserved							
4	Reserved							
5	Reserved							
6	Reserved							
7	Reserved							
8	Reserved							
9	Reserved							
10	Reserved							
11	Reserved							

11	Reserved
10	Reserved
9	Reserved
8	Reserved



没有DATA-IN或者DATA-OUT，直接回复CSW包



查询磁盘状态命令块

Table 38 - REQUEST SENSE Command

Bit	7	6	5	4	3	2	1	0
Byte								
0	Operation Code (03h)							
1	Logical Unit Number			Reserved				
2	Reserved							
3	Reserved							
4	Allocation							
5	Reserved							
6	Reserved							
7	Reserved							
8	Reserved							
9	Reserved							
10	Reserved							
11	Reserved							

Bit	7	6	5
Byte			
0	Valid		
1			
2	Reserved		
3	(MSB)		
4			

Table 39 - Re

Table 39 - Request Sense Standard Data

Bit	7	6	5	4	3	2	1	0
Byte								
0	Valid	Error Code (70h)						
1	Reserved							
2	Reserved				Sense Key			
3	(MSB) Information (LSB)							
4								
5								
6								
7	Additional Sense Length (10)							
8	Reserved							
9								
10								
11								
12	Additional Sense Code (Mandatory)							
13	Additional Sense Code Qualifier (Mandatory)							
14	Reserved							
15	Reserved							
16								
17								



04

软件实现及效果演示

硬件平台

应用：以CH549为例，作为USB主机，识别接入的USB设备，并找出HID类设备获取有效数据



供电：3.3V和5V供电系统皆可

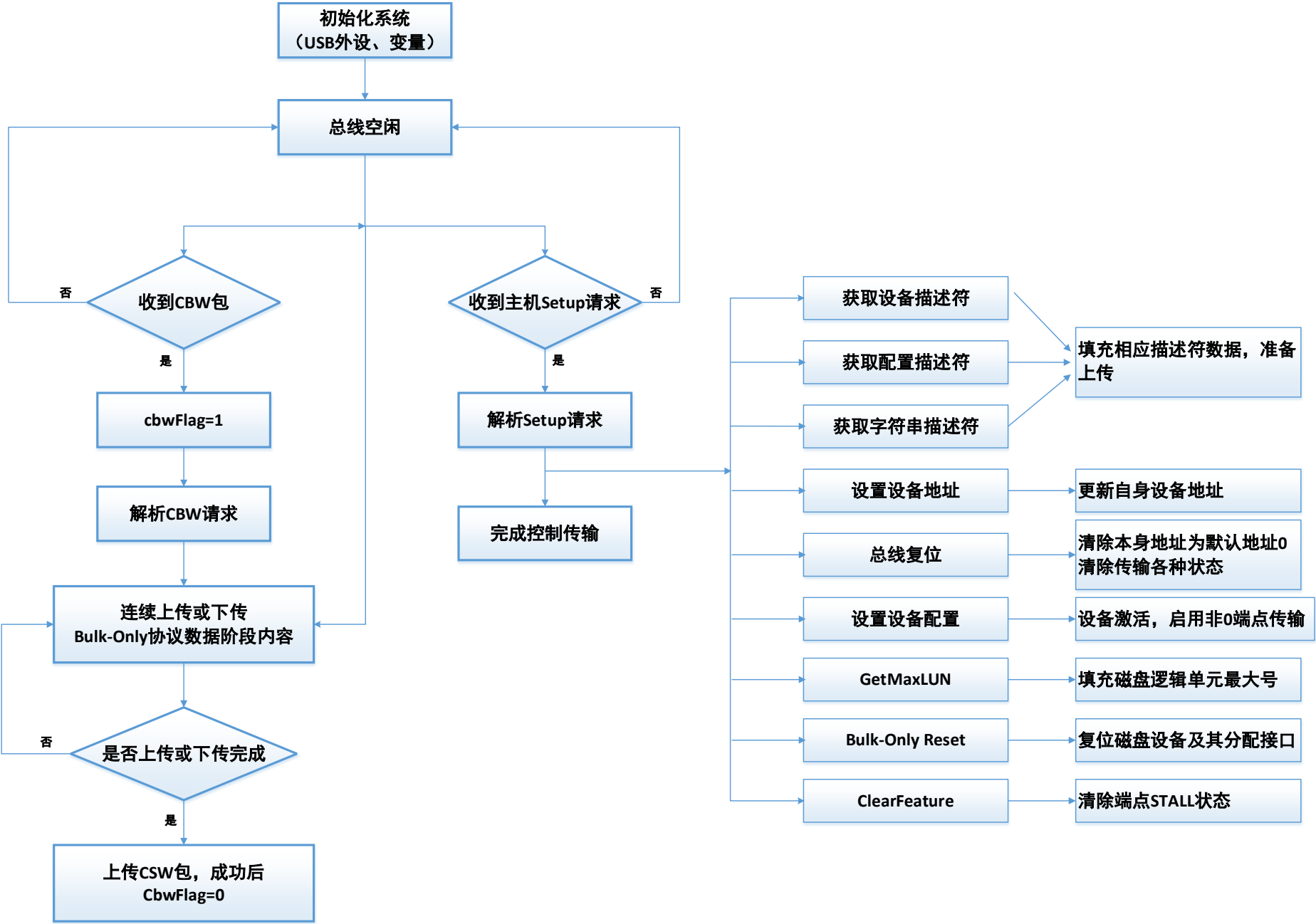
最简外围：只需2个退耦电容

USB功能：USB主设备或者USB从设备

下载方式：串口或者USB口下载

Part NO.		Freq/Max	Flash	RAM	DataFlash	USB	TouchKey	Type-C	ADC	LEDC	Timer	CAP	PWM	UART	SPI	I/O	Built-in OSC/WDOG	VDD/V	Package
CH549	L	12/48MHz	63K	2K+256	1K	1*H/1*D	16	✓	16*12b	-	3*16b	3	8	4	1	44	✓/✓	3.3/5	LQFP48
	F	12/48MHz	63K	2K+256	1K	1*H/1*D	10	✓	10*12b	-	3*16b	2	5	4	1	25	✓/✓	3.3/5	QFN28
	G	12/48MHz	63K	2K+256	1K	1*H/1*D	5	✓	5*12b	-	3*16b	2	3	2	1	13	✓/✓	3.3/5	SOP16

软件框架





Thank you

感谢观赏



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