

图解 USB 枚举过程

CATC 的 USB 协议分析仪捕捉的

Transfer	F	Control	ADDR	ENDP	bRequest	wValue	wIndex	Descriptors	Time	Time Stamp
0	S	GET	0	0	GET_DESCRIPTOR	DEVICE type	0x0000	DEVICE descriptor	4.074 ms	00006.2653 1284
Packet	Dir	Reset	Time	Time Stamp						
108	-->	26.181 ms	104.900 ms	00006.2685 5696						
1	S	SET	0	0	SET_ADDRESS	New address 2			15.996 ms	00006.3524 7249
2	S	GET	2	0	GET_DESCRIPTOR	DEVICE type	0x0000	DEVICE descriptor	4.999 ms	00006.3652 7023
3	S	GET	2	0	GET_DESCRIPTOR	CONFIGURATION type	0x0000	CONFIGURATION descriptor	3.999 ms	00006.3692 6953
4	S	GET	2	0	GET_DESCRIPTOR	CONFIGURATION type	0x0000	6 descriptors	22.995 ms	00006.3724 6897
5	S	GET	2	0	GET_DESCRIPTOR	DEVICE type	0x0000	DEVICE descriptor	4.999 ms	00006.3908 6573
6	S	GET	2	0	GET_DESCRIPTOR	CONFIGURATION type	0x0000	6 descriptors	6.998 ms	00006.3948 6502
7	S	SET	2	0	SET_CONFIGURATION	New configuration 1				00006.4004 6404

1、获取设备描述符

Transfer	F	Control	ADDR	ENDP	bRequest	wValue	wIndex	Descriptors	Time	Time Stamp					
0	S	GET	0	0	GET_DESCRIPTOR	DEVICE type	0x0000	DEVICE descriptor		00006.2653 1284					
Transaction	F	SETUP	ADDR	ENDP	T	D	TP	R	bRequest	wValue	wIndex	wLength	ACK	Time Stamp	
0	S	0xB4	0	0	0	D->H	S	D	GET_DESCRIPTOR	DEVICE type	0x0000	64	0x4B	00006.2653 1284	
Packet	Dir	Sync	SETUP	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp						
95	-->	S	00000001	0xB4	0	0	0x08	233.330 ns	183.320 ns	00006.2653 1284					
Packet	Dir	Sync	DATA0	Data	CRC16	EOP	Idle	Time Stamp							
96	-->	S	00000001	0xC3	80 06 00 01 00 00 40 00	0xBB29	233.330 ns	349.990 ns	00006.2653 1469						
Packet	Dir	Sync	ACK	EOP	Time	Time Stamp									
97	<--	S	00000001	0x4B	250.000 ns	988.183 μs	00006.2653 1984								
Transaction	F	IN	ADDR	ENDP	T	Data	ACK	Time Stamp							
1	S	0x96	0	0	1	12 01 00 01 DC 00 00 10 71 04 F0 FF 00 01 00 00	0x4B	00006.2661 1275							
Packet	Dir	Sync	IN	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp						
99	-->	S	00000001	0x96	0	0	0x08	233.330 ns	533.320 ns	00006.2661 1275					
Packet	Dir	Sync	DATA1	Data	CRC16	EOP	Idle	Time Stamp							
100	<--	S	00000001	0xD2	12 01 00 01 DC 00 00 10 71 04 F0 FF 00 01 00 00	0xC382	233.330 ns	499.990 ns	00006.2661 1481						
Packet	Dir	Sync	ACK	EOP	Time	Time Stamp									
101	-->	S	00000001	0x4B	250.000 ns	1.982 ms	00006.2661 2335								
Transaction	F	OUT	ADDR	ENDP	T	Data	ACK	Time Stamp							
2	S	0x87	0	0	1		0x4B	00006.2677 1247							
Packet	Dir	Sync	OUT	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp						
104	-->	S	00000001	0x87	0	0	0x08	250.000 ns	166.660 ns	00006.2677 1247					
Packet	Dir	Sync	DATA1	Data	CRC16	EOP	Idle	Time Stamp							
105	-->	S	00000001	0xD2		0x0000	250.000 ns	350.000 ns	00006.2677 1432						
Packet	Dir	Sync	ACK	EOP	Time	Time Stamp									
106	<--	S	00000001	0x4B	250.000 ns	1.068 ms	00006.2677 1628								

2、设置地址

Transfer	F	Control	ADDR	ENDP	bRequest	wValue	Time Stamp								
1	S	SET	0	0	SET_ADDRESS	New address 2	00006.3524 7249								
Transaction	F	SETUP	ADDR	ENDP	T	D	TP	R	bRequest	wValue	wIndex	wLength	ACK	Time Stamp	
3	S	0xB4	0	0	0	H->D	S	D	SET_ADDRESS	New address 2	0x0000	0	0x4B	00006.3524 7249	
Packet	Dir	Sync	SETUP	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp						
188	-->	S	00000001	0xB4	0	0	0x08	250.000 ns	166.670 ns	00006.3524 7249					
Packet	Dir	Sync	DATA0	Data	CRC16	EOP	Idle	Time Stamp							
189	-->	S	00000001	0xC3	00 05 02 00 00 00 00 00	0xD768	250.000 ns	333.320 ns	00006.3524 7434						
Packet	Dir	Sync	ACK	EOP	Time	Time Stamp									
190	<--	S	00000001	0x4B	250.000 ns	988.100 μs	00006.3525 0449								
Transaction	F	IN	ADDR	ENDP	T	Data	ACK	Time Stamp							
4	S	0x96	0	0	1		0x4B	00006.3532 7235							
Packet	Dir	Sync	IN	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp						
192	-->	S	00000001	0x96	0	0	0x08	250.000 ns	500.000 ns	00006.3532 7235					
Packet	Dir	Sync	DATA1	Data	CRC16	EOP	Idle	Time Stamp							
193	<--	S	00000001	0xD2		0x0000	250.000 ns	499.990 ns	00006.3532 7440						
Packet	Dir	Sync	ACK	EOP	Time	Time Stamp									
194	-->	S	00000001	0x4B	250.000 ns	14.990 ms	00006.3533 0145								

3、获取设备描述符

Transfer	F	Control	ADDR	ENDP	bRequest	wValue	wIndex	Descriptors	Time	Time Stamp
2	S	GET	2	0	GET_DESCRIPTOR	DEVICE type	0x0000	DEVICE descriptor	4.999 ms	00006.3652 7023

Transaction	F	SETUP	ADDR	ENDP	T	D	Tr	R	bRequest	wValue	wIndex	wLength	ACK	Time Stamp
5	S	0xB4	2	0	0	D->H	S	D	GET_DESCRIPTOR	DEVICE type	0x0000	18	0x4B	00006.3652 7023

初始设置步骤

Packet	Dir	F	Sync	SETUP	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp
210	-->	S	00000001	0xB4	2	0	0x15	250.000 ns	166.660 ns	00006.3652 7023
Packet	Dir	F	Sync	DATA0	Data	CRC16	EOP	Idle	Time Stamp	
211	-->	S	00000001	0xC3	80 06 00 01 00 00 12 00	0x072F	250.000 ns	350.000 ns	00006.3652 7208	
Packet	Dir	F	Sync	ACK	EOP	Time	Time Stamp			
212	<--	S	00000001	0x4B	250.000 ns	988.083 μs	00006.3653 0224			

输入事务

Transaction	F	IN	ADDR	ENDP	T	Data	ACK	Time Stamp
6	S	0x96	2	0	1	12 01 00 01 DC 00 00 10 71 04 F0 FF 00 01 00 00	0x4B	00006.3660 7009

可选数据步骤

Packet	Dir	F	Sync	IN	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp
214	-->	S	00000001	0x96	2	0	0x15	250.000 ns	533.330 ns	00006.3660 7009
Packet	Dir	F	Sync	DATA1	Data	CRC16	EOP	Idle	Time Stamp	
215	<--	S	00000001	0xD2	12 01 00 01 DC 00 00 10 71 04 F0 FF 00 01 00 00	0xC382	233.330 ns	483.330 ns	00006.3660 7216	
Packet	Dir	F	Sync	ACK	EOP	Time	Time Stamp			
216	-->	S	00000001	0x4B	233.330 ns	982.100 μs	00006.3661 0569			

输入事务

Transaction	F	IN	ADDR	ENDP	T	Data	ACK	Time Stamp
7	S	0x96	2	0	0	00 01	0x4B	00006.3668 6995

可选数据步骤

Packet	Dir	F	Sync	IN	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp
218	-->	S	00000001	0x96	2	0	0x15	250.000 ns	533.330 ns	00006.3668 6995
Packet	Dir	F	Sync	DATA0	Data	CRC16	EOP	Idle	Time Stamp	
219	<--	S	00000001	0xC3	00 01 0xFCF1	233.330 ns	566.660 ns	00006.3668 7202		
Packet	Dir	F	Sync	ACK	EOP	Time	Time Stamp			
220	-->	S	00000001	0x4B	233.330 ns	991.433 μs	00006.3668 7495			

输出/状态

Transaction	F	OUT	ADDR	ENDP	T	Data	ACK	Time	Time Stamp
8	S	0x87	2	0	1	0 bytes	0x4B	2.000 ms	00006.3676 6981

4、获取配置描述符

Transfer	F	Control	ADDR	ENDP	bRequest	wValue	wIndex	Descriptors	Time	Time Stamp
3	S	GET	2	0	GET_DESCRIPTOR	CONFIGURATION type	0x0000	CONFIGURATION descriptor	00006.3692 6953	

Transaction	F	SETUP	ADDR	ENDP	T	D	Tr	R	bRequest	wValue	wIndex	wLength	ACK	Time Stamp
9	S	0xB4	2	0	0	D->H	S	D	GET_DESCRIPTOR	CONFIGURATION type	0x0000	9	0x4B	00006.3692 6953

初始设置步骤

Packet	Dir	F	Sync	SETUP	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp
227	-->	S	00000001	0xB4	2	0	0x15	233.330 ns	183.320 ns	00006.3692 6953
Packet	Dir	F	Sync	DATA0	Data	CRC16	EOP	Idle	Time Stamp	
228	-->	S	00000001	0xC3	80 06 00 02 00 00 09 00	0x7520	233.330 ns	366.660 ns	00006.3692 7138	
Packet	Dir	F	Sync	ACK	EOP	Time	Time Stamp			
229	<--	S	00000001	0x4B	250.000 ns	988.167 μs	00006.3693 0154			

输入事务

Transaction	F	IN	ADDR	ENDP	T	Data	ACK	Time Stamp
10	S	0x96	2	0	1	09 02 2E 00 01 01 00 60 01	0x4B	00006.3700 6944

可选数据步骤

Packet	Dir	F	Sync	IN	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp
231	-->	S	00000001	0x96	2	0	0x15	233.330 ns	550.000 ns	00006.3700 6944
Packet	Dir	F	Sync	DATA1	Data	CRC16	EOP	Idle	Time Stamp	
232	<--	S	00000001	0xD2	09 02 2E 00 01 01 00 60 01	0xA01E	233.330 ns	483.320 ns	00006.3700 7151	
Packet	Dir	F	Sync	ACK	EOP	Time	Time Stamp			
233	-->	S	00000001	0x4B	233.330 ns	986.933 μs	00006.3701 0214			

输出事务

Transaction	F	OUT	ADDR	ENDP	T	Data	ACK	Time Stamp
11	S	0x87	2	0	1		0x4B	00006.3708 6930

状态信息步骤

Packet	Dir	F	Sync	OUT	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp
235	-->	S	00000001	0x87	2	0	0x15	233.330 ns	183.320 ns	00006.3708 6930
Packet	Dir	F	Sync	DATA1	Data	CRC16	EOP	Idle	Time Stamp	
236	-->	S	00000001	0xD2		0x0000	250.000 ns	350.000 ns	00006.3708 7115	
Packet	Dir	F	Sync	ACK	EOP	Time	Time Stamp			
237	<--	S	00000001	0x4B	233.330 ns	1.993 ms	00006.3708 7311			

5、获取配置描述符其他内容

Transfer	F	Control	ADDR	ENDP	bRequest	wValue	wIndex	Descriptors	Time Stamp					
4	S	GET	2	0	GET_DESCRIPTOR	CONFIGURATION type	0x0000	6 descriptors	00006.3724 6897					
Transaction	F	SETUP	ADDR	ENDP	T	D	TP	R	bRequest	wValue	wIndex	wLength	ACK	Time Stamp
12	S	0xB4	2	0	0	D->H	S	D	GET_DESCRIPTOR	CONFIGURATION type	0x0000	255	0x4B	00006.3724 6897
Packet	Dir	F	Sync	SETUP	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp				
240	-->	S	00000001	0xB4	2	0	0x15	250.000 ns	166.660 ns	00006.3724 6897				
Packet	Dir	F	Sync	DATA0	Data	CRC16	EOP	Idle	Time Stamp					
241	-->	S	00000001	0xC3	80 06 00 02 00 00 FF 00	0x9725	250.000 ns	333.330 ns	00006.3724 7082					
Packet	Dir	F	Sync	ACK	EOP	Time	Time Stamp							
242	<--	S	00000001	0x4B	233.330 ns	988.017 μs	00006.3725 0102							
Transaction	F	IN	ADDR	ENDP	T	Data	ACK	Time	Time Stamp					
13	S	0x96	2	0	1	09 02 2E 00 01 01 00 60 01 09 04 00 00 04 00 00	0x4B	999.750 μs	00006.3732 6883					
Transaction	F	IN	ADDR	ENDP	T	Data	ACK	Time	Time Stamp					
14	S	0x96	2	0	0	00 00 07 05 81 03 08 00 C8 07 05 01 03 08 00 C8	0x4B	999.767 μs	00006.3740 6868					
Transaction	F	IN	ADDR	ENDP	T	Data	ACK	Time	Time Stamp					
15	S	0x96	2	0	1	07 05 82 02 40 00 00 07 05 02 02 40 00 00	0x4B	2.000 ms	00006.3748 6854					
Transaction	F	OUT	ADDR	ENDP	T	Data	ACK	Time	Time Stamp					
16	S	0x87	2	0	1		0x4B	17.996 ms	00006.3764 6826					

6、获取设备和配置描述符

Transfer	F	Control	ADDR	ENDP	bRequest	wValue	wIndex	Descriptors	Time Stamp						
5	S	GET	2	0	GET_DESCRIPTOR	DEVICE type	0x0000	DEVICE descriptor	00006.3908 6573						
Transaction	F	SETUP	ADDR	ENDP	T	D	TP	R	bRequest	wValue	wIndex	wLength	ACK	Time Stamp	
17	S	0xB4	2	0	0	D->H	S	D	GET_DESCRIPTOR	DEVICE type	0x0000	18	0x4B	00006.3908 6573	
Packet	Dir	F	Sync	SETUP	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp					
278	-->	S	00000001	0xB4	2	0	0x15	250.000 ns	166.660 ns	00006.3908 6573					
Packet	Dir	F	Sync	DATA0	Data	CRC16	EOP	Idle	Time Stamp						
279	-->	S	00000001	0xC3	80 06 00 01 00 00 12 00	0x072F	250.000 ns	350.000 ns	00006.3908 6758						
Packet	Dir	F	Sync	ACK	EOP	Time	Time Stamp								
280	<--	S	00000001	0x4B	233.330 ns	988.067 μs	00006.3908 7274								
Transaction	F	IN	ADDR	ENDP	T	Data	ACK	Time	Time Stamp						
18	S	0x96	2	0	1	12 01 00 01 DC 00 00 10 71 04 F0 FF 00 01 00 00	0x4B	999.767 μs	00006.3916 6558						
Transaction	F	IN	ADDR	ENDP	T	Data	ACK	Time	Time Stamp						
19	S	0x96	2	0	0	00 01	0x4B	999.767 μs	00006.3924 6544						
Transaction	F	OUT	ADDR	ENDP	T	Data	ACK	Time	Time Stamp						
20	S	0x87	2	0	1		0x4B	2.000 ms	00006.3932 6530						
Transfer	F	Control	ADDR	ENDP	bRequest	wValue	wIndex	Descriptors	Time Stamp						
6	S	GET	2	0	GET_DESCRIPTOR	CONFIGURATION type	0x0000	6 descriptors	00006.3948 6502						
Transaction	F	SETUP	ADDR	ENDP	T	D	TP	R	bRequest	wValue	wIndex	wLength	ACK	Time	Time Stamp
21	S	0xB4	2	0	0	D->H	S	D	GET_DESCRIPTOR	CONFIGURATION type	0x0000	137	0x4B	999.767 μs	00006.3948 6502
Transaction	F	IN	ADDR	ENDP	T	Data	ACK	Time	Time Stamp						
22	S	0x96	2	0	1	09 02 2E 00 01 01 00 60 01 09 04 00 00 04 00 00	0x4B	999.850 μs	00006.3956 6488						
Transaction	F	IN	ADDR	ENDP	T	Data	ACK	Time	Time Stamp						
23	S	0x96	2	0	0	00 00 07 05 81 03 08 00 C8 07 05 01 03 08 00 C8	0x4B	999.683 μs	00006.3964 6479						
Transaction	F	IN	ADDR	ENDP	T	Data	ACK	Time	Time Stamp						
24	S	0x96	2	0	1	07 05 82 02 40 00 00 07 05 02 02 40 00 00	0x4B	2.000 ms	00006.3972 6460						
Transaction	F	OUT	ADDR	ENDP	T	Data	ACK	Time	Time Stamp						
25	S	0x87	2	0	1		0x4B	2.000 ms	00006.3988 6432						

7、设置配置

Transfer	F	Control	ADDR	ENDP	bRequest	wValue	Time Stamp							
7	S	SET	2	0	SET_CONFIGURATION	New configuration 1	00006.4004 6404							
Transaction	F	SETUP	ADDR	ENDP	T	D	TP	R	bRequest	wValue	wIndex	wLength	ACK	Time Stamp
26	S	0xB4	2	0	0	H->D	S	D	SET_CONFIGURATION	New configuration 1	0x0000	0	0x4B	00006.4004 6404
Packet	Dir	F	Sync	SETUP	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp				
317	-->	S	00000001	0xB4	2	0	0x15	250.000 ns	166.660 ns	00006.4004 6404				
Packet	Dir	F	Sync	DATA0	Data	CRC16	EOP	Idle	Time Stamp					
318	-->	S	00000001	0xC3	00 09 01 00 00 00 00 00	0xE444	250.000 ns	333.340 ns	00006.4004 6589					
Packet	Dir	F	Sync	ACK	EOP	Time	Time Stamp							
319	<--	S	00000001	0x4B	250.000 ns	988.083 μs	00006.4004 7104							
Transaction	F	IN	ADDR	ENDP	T	Data	ACK	Time Stamp						
27	S	0x96	2	0	1		0x4B	00006.4012 6389						
Packet	Dir	F	Sync	IN	ADDR	ENDP	CRC5	EOP	Idle	Time Stamp				
321	-->	S	00000001	0x96	2	0	0x15	250.000 ns	516.660 ns	00006.4012 6389				
Packet	Dir	F	Sync	DATA1	Data	CRC16	EOP	Idle	Time Stamp					
322	<--	S	00000001	0xD2		0x0000	250.000 ns	483.330 ns	00006.4012 6595					
Packet	Dir	F	Sync	ACK	EOP	Time	Time Stamp							
323	-->	S	00000001	0x4B	250.000 ns		00006.4012 6799							

设置事务

初始设置步骤

数据包

握手包

输入事务

状态信息步骤

数据包

握手包