

# 基于STM32 的USB程序开发笔记

以前一直就有打玩 USB 的想法，最近时间充足于是决心打玩 STM32 的 USB，购买的是万利的 STM3210B-LK1 板，琢磨 USB 已有半个多月，在固件、上位机驱动以及应用程序的访问这三方面终于有所突破，这期间通过网络上授寻了许多相关资料，主要来自 ST 提供的 USB 固件，以及圈圈 (computer00) 提供的一些关于 USB 驱动开发的资料，通过这段时间的学习，了解到学习 USB 对于未接触过的朋友来说确实存在许多的知识壁垒，本着开源精神，在此对 STM32 的 USB 固件程序的编写、DriverStudio + WindowsXP DDK + VC6 驱动开发以及应用程序做了一些介绍，为更好理解，请仔细学习 STM32 USB 的参考手册以及 USB 协议，如果对 VC6 下开发还不是太熟悉或者说不曾学过，那么如果想理解有些问题，就必须学习 VC6 了。本套笔记是基于我编写的程序进行说明的，请配合该程序进行学习。

## 第一篇：需要准备的一些资料

1: STM32 的参考手册，这对于设备底层 USB 的硬件配置以及事件驱动机制的了解尤为重要，你需要了解各个寄存器的功能以及如何操作，比如 CNTR、ISTR、EPnR、DADDR 等等，如果你想学习 USB，这个手册是必须的。

2: USB2.0 协议，这个资料同样必不可少，如果因为英语阅读能力而苦苦寻找中文版的 USB2.0 协议，建议不要这么做，现在网络中的所谓的中文版的 USB2.0 协议不是官方撰写的，大多数是一些热心朋友自己翻译的，却不是很全面，如果你在寻找这类的资料而无所获时，建议认真塌实的看看官方英文版的 USB2.0 协议，官方协议阐述的十分详细，650 多页，一字一句的了解全部协议不太可行，可针对性的重点理解，比如对第 9 章 USB Device Framework 的详细理解对于你的 USB Device 固件开发不可缺少(这里就是 STM32)。

3: ST提供的USB固件库，这个类库较为散乱，但不可不参考

以下是链接包含固件、驱动以及应用程序，固件部分有些功能是不被支持的，如SR\_SetDescriptor()、SR\_SynchFrame()等等，在此说明不支持非故意如此，而是还没去更仔细深入编写完善，目前这些不被支持的部分目前不被使用到。

下载链接: <http://blog.ednchina.com/lbxxx>

如果你使用的是万利的 STM3210B-LK1 开发板，则可以烧写 hex 文件后直接进行测试。以下一组图片说明的 XP 下驱动的安装过程以及测试软件打开后的情形，仅供参考。



设备管理器

文件(F) 操作(O) 查看(V) 帮助(H)

### 找到新的硬件向导

向导正在安装软件，请稍候...



STM32 USB Customer Device



ezUSB.sys

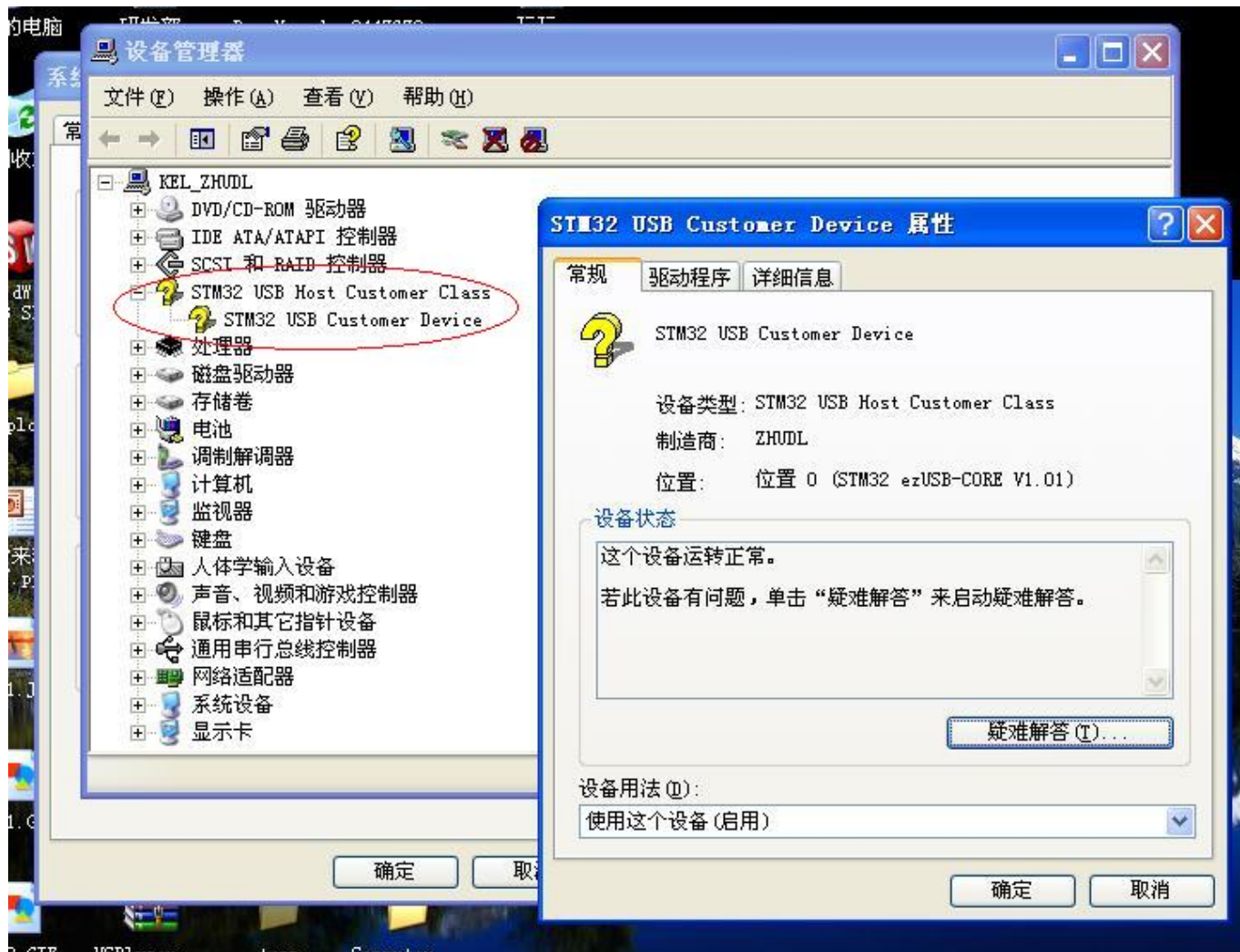
到 C:\WINDOWS\system32\DRIVERS



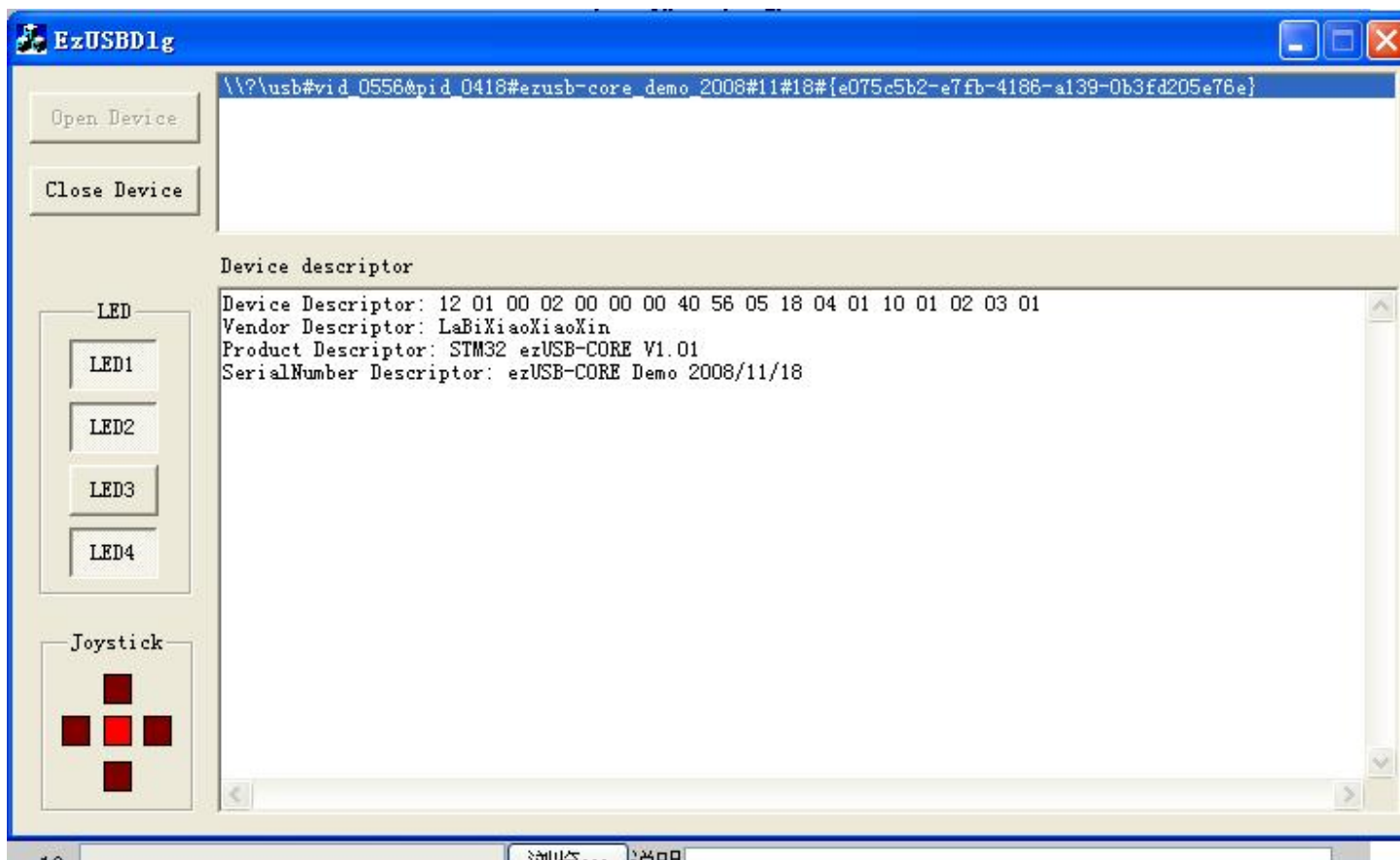
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测试软件：控制万利 STM3210B-LK1 开发板的 4 个 LED，并定时读取 Joystick 状态



## 第 2 篇：STM32 USB 固件函数的驱动原理

首先需要了解一个概念：

USB 设备 (DEVICE) 从来只是被动触发，USB 主机 (HOST) 掌握主动权，发送什么数据，什么时候发送，是给设备数据还是从设备请求数据，都是由 USB 主机完成的，USB 设备只是配合主机完成设备的枚举、数据方向和大小。根据数据特性再决定该不该回复该如何回复、该不该接收该如何接收这些动作。

了解这些，再仔细查看 STM32 的参考手册 USB 部分以及 STM32 的中断向量表，从中可以找到两个中断：

```
/******  
* Function Name   : USB_HP_CAN_TX_IRQHandler  
* Description     : This function handles USB High Priority or CAN TX interrupts  
*                 requests.  
* Input          : None  
* Output         : None  
* Return         : None  
*****/  
void USB_HP_CAN_TX_IRQHandler(void)  
{  
    USB_HPI();  
}  
  
/******  
* Function Name   : USB_LP_CAN_RX0_IRQHandler  
* Description     : This function handles USB Low Priority or CAN RX0 interrupts  
*                 requests.  
* Input          : None  
* Output         : None
```

```

* Return      : None
*****/
void USB_LP_CAN_RX0_IRQHandler(void)
{
    USB_LPI();
}

```

即 USB 的高、低优先级中断处理函数，这也是整个 STM32 USB 的事件驱动源，USB\_HPI() 与 USB\_LPI() 既而转向 usb\_core(.c,.h) 进行相关处理。中断传输(interrupt)、控制传输(control)、大流量传输(bulk)由 USB\_LPI() 响应，大流量传输(bulk)同样可能响应 USB\_HPI()，同步传输(isochronous)只响应 USB\_HPI()。

这样响应 USB 的所有请求只需要关注 usb\_core.c 文件中的 USB\_LPI() 与 USB\_HPI() 函数。由于本人也是对 USB 刚刚有所了解，因而在本例笔记中 USB\_HPI() 函数未做任何处理，在此开源希望大家能完善与纠正错误并能共享喜悦。以下是 USB\_LPI() 函数：

```

// *****
// Function Name : USB_LPI.
// Description   : Low Priority Interrupt's service routine.
// Input        :
// Output       :
// Return       :
// *****
void USB_LPI(void)
{
    unsigned short wValISTR = GetISTR();

#ifdef CNTR_MASK & ISTR_RESET // Reset
    if(wValISTR & ISTR_RESET & vwInterruptMask)

```

```
{
    SetISTR(CLR_RESET);
    INT_ISTR_RESET();
}
#endif

#if(CNTR_MASK & ISTR_DOVR) // DMA Over/Underrun
    if(wValISTR & ISTR_DOVR & vwInterruptMask)
    {
        SetISTR(CLR_DOVR);
        INT_ISTR_DOVR();
    }
#endif

#if(CNTR_MASK & ISTR_ERR) // Error
    if(wValISTR & ISTR_ERR & vwInterruptMask)
    {
        SetISTR(CLR_ERR);
        INT_ISTR_ERROR();
    }
#endif

#if(CNTR_MASK & ISTR_WKUP) // Wakeup
    if(wValISTR & ISTR_WKUP & vwInterruptMask)
    {
        SetISTR(CLR_WKUP);
    }
#endif
```



```
    INT_ISTR_WAKEUP();
}
#endif

#if(CNTR_MASK & ISTR_SUSP) // Suspend
    if(wValISTR & ISTR_SUSP & vwInterruptMask)
    {
        INT_ISTR_SUSPEND();
        SetISTR(CLR_SUSP); // must be done after setting of CNTR_FSUSP
    }
#endif

#if(CNTR_MASK & ISTR_SOF) // Start Of Frame
    if(wValISTR & ISTR_SOF & vwInterruptMask)
    {
        SetISTR(CLR_SOF);
        INT_ISTR_SOF();
    }
#endif

#if(CNTR_MASK & ISTR_ESOF) // Expected Start Of Frame
    if(wValISTR & ISTR_ESOF & vwInterruptMask)
    {
        SetISTR(CLR_ESOF);
        INT_ISTR_ESOF();
    }
}
```

```

#endif

#if(CNTR_MASK & ISTR_CTR) // Correct Transfer
    if(wValISTR & ISTR_CTR & vwInterruptMask)
    {
        INT_ISTR_CTR();
    }
#endif
}

// *****
// Function Name : USB_HPI.
// Description : High Priority Interrupt's service routine.
// Input :
// Output :
// Return :
// *****
void USB_HPI(void)
{

}

```

可以看出，在 USB\_LPI() 函数中，根据 STM32 USB 的中断状态寄存器（ISTR）的标志位的状态以及定义的 USB 控制寄存器中断事件屏蔽码，响应各自的中断事件，比如 INT\_ISTR\_RESET() 响应 USB 的复位中断，一般可在此函数内进行 USB 的寄存器的初始化；INT\_ISTR\_CTR() 响应一次正确的数据 传输中断，故名思意，在完成一次正确的数据传输操作后，就会响应此函数。具体含义请仔细查阅 STM32 参考手册。

### 第 3 篇：STM32 USB 固件函数的一些介绍

STM32 USB 中断事件为以下几种，详细情况可以查看 `usb_core(.c/.h)`：

```
void ISTR_CTR(void);
void ISTR_SOF(void);
void ISTR_ESOF(void);
void ISTR_DOVR(void);
void ISTR_ERROR(void);
void ISTR_RESET(void);
void ISTR_WAKEUP(void);
void ISTR_SUSPEND(void);
```

这些处理函数使能由定义 `CNTR_MASK` 决定：

```
// CNTR mask control
#define CNTR_MASK    CNTR_CTRM | CNTR_WKUPM | CNTR_SUSPM | CNTR_ERRM |      \
                    CNTR_SOFM | CNTR_ESOFM | CNTR_RESETM | CNTR_DOVRM    \
```

其中着重说明的是 `ISTR_RESET()` 和 `ISTR_CTR()` 函数，`ISTR_RESET()` 主要处理 USB 复位后进行一些初始化任务，`ISTR_CTR()` 则是处理数据正确传输后控制，比如说响应主机。

```
// *****
// Function Name   : INT_ISTR_RESET
// Description     : ISTR Reset Interrupt service routines.
// Input          :
// Output         :
// Return         :
```

```
// *****  
void INT_ISTR_RESET(void)  
{  
    // Set the buffer table address  
    SetBTABLE(BASEADDR_BTABLE);  
  
    // Set the endpoint type: ENDPO  
    SetEPR_Type(ENDPO, EP_CONTROL);  
    Clr_StateOut(ENDPO);  
  
    // Set the endpoint data buffer address: ENDPO RX  
    SetBuffDescTable_RXCount(ENDPO, ENDPO_PACKETSIZE);  
    SetBuffDescTable_RXAddr(ENDPO, ENDPO_RXADDR);  
  
    // Set the endpoint data buffer address: ENDPO TX  
    SetBuffDescTable_TXCount(ENDPO, 0);  
    SetBuffDescTable_TXAddr(ENDPO, ENDPO_TXADDR);  
  
    // Initialize the RX/TX status: ENDPO  
    SetEPR_RXStatus(ENDPO, EP_RX_VALID);  
    SetEPR_TXStatus(ENDPO, EP_TX_NAK);  
  
    // Set the endpoint address: ENDPO  
    SetEPR_Address(ENDPO, ENDPO);  
  
    // -----
```

```
// TODO: Add you code here
// -----
// Set the endpoint type: ENDP1
SetEPR_Type(ENDP1, EP_INTERRUPT);
Clr_StateOut(ENDP1);

// Set the endpoint data buffer address: ENDP1 RX
SetBuffDescTable_RXCount(ENDP1, ENDP1_PACKETSIZE);
SetBuffDescTable_RXAddr(ENDP1, ENDP1_RXADDR);

// Set the endpoint data buffer address: ENDP1 TX
SetBuffDescTable_TXCount(ENDP1, 0);
SetBuffDescTable_TXAddr(ENDP1, ENDP1_TXADDR);

// Initialize the RX/TX status: ENDP1
SetEPR_RXStatus(ENDP1, EP_RX_VALID);
SetEPR_TXStatus(ENDP1, EP_TX_DIS);

// Set the endpoint address: ENDP1
SetEPR_Address(ENDP1, ENDP1);

SetEPR_Type(ENDP2, EP_INTERRUPT);
Clr_StateOut(ENDP2);
```

```
// Set the endpoint data buffer address: ENDP2 RX
SetBuffDescTable_RXCount(ENDP2, ENDP2_PACKETSIZE);
SetBuffDescTable_RXAddr(ENDP2, ENDP2_RXADDR);
```

```
// Set the endpoint data buffer address: ENDP2 TX
SetBuffDescTable_TXCount(ENDP2, 0);
SetBuffDescTable_TXAddr(ENDP2, ENDP2_TXADDR);
```

```
// Initialize the RX/TX status: ENDP2
SetEPR_RXStatus(ENDP2, EP_RX_DIS);
SetEPR_TXStatus(ENDP2, EP_TX_VALID);
```

```
// Set the endpoint address: ENDP2
SetEPR_Address(ENDP2, ENDP2);
```

```
// -----
// End of you code
// -----
```

```
SetDADDR(0x0080 | vsDeviceInfo.bDeviceAddress);
vsDeviceInfo.eDeviceState = DS_DEFAULT;
vsDeviceInfo.bCurrentFeature = 0x00;
vsDeviceInfo.bCurrentConfiguration = 0x00;
vsDeviceInfo.bCurrentInterface = 0x00;
```

```

    vsDeviceInfo.bCurrentAlternateSetting = 0x00;
    vsDeviceInfo.uStatusInfo.w = 0x0000;
}

```

在这个 ISTR\_CTR() 函数中，定义了 EP0、1、2 的传输方式以及各自的缓冲描述符，其中 EP0 是默认端口，负责完成 USB 设备的枚举，一般情况是不需要更改的。其他端点配置则需根据实际应用而决定，如何设置请仔细理解 STM32 的参考手册。

值得说明的是 STM32 的端点 RX/TX 缓冲描述表是定义在 PMA 中的，他是基于分组缓冲区描述报表寄存器(BTABLE)而定位的，各端点 RX/TX 缓冲 描述表说明是数据存储地址以及大小，这个概念需要了解，ST 提供的固件很含糊，为此，我在 usb\_regs.h 文件中进行了重新定义，如下：

```

// USB_IP Packet Memory Area base address
#define PMAAddr (0x40006000L)

// Buffer Table address register
#define BTABLE ((volatile unsigned *) (RegBase + 0x50))

// *****
// Packet memory area: Total 512Bytes
// *****
#define BASEADDR_BTABLE 0x0000
// *****
// PMAAddr + BASEADDR_BTABLE + 0x00000000 : EP0_TX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x00000002 : EP0_TX_COUNT
// PMAAddr + BASEADDR_BTABLE + 0x00000004 : EP0_RX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x00000006 : EP0_RX_COUNT
//
// PMAAddr + BASEADDR_BTABLE + 0x00000008 : EP1_TX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x0000000A : EP1_TX_COUNT

```

```
// PMAAddr + BASEADDR_BTABLE + 0x0000000C : EP1_RX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x0000000E : EP1_RX_COUNT
//
// PMAAddr + BASEADDR_BTABLE + 0x00000010 : EP2_TX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x00000012 : EP2_TX_COUNT
// PMAAddr + BASEADDR_BTABLE + 0x00000014 : EP2_RX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x00000016 : EP2_RX_COUNT
//
// PMAAddr + BASEADDR_BTABLE + 0x00000018 : EP3_TX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x0000001A : EP3_TX_COUNT
// PMAAddr + BASEADDR_BTABLE + 0x0000001C : EP3_RX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x0000001E : EP3_RX_COUNT
//
// PMAAddr + BASEADDR_BTABLE + 0x00000020 : EP4_TX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x00000022 : EP4_TX_COUNT
// PMAAddr + BASEADDR_BTABLE + 0x00000024 : EP4_RX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x00000026 : EP4_RX_COUNT
//
// PMAAddr + BASEADDR_BTABLE + 0x00000028 : EP5_TX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x0000002A : EP5_TX_COUNT
// PMAAddr + BASEADDR_BTABLE + 0x0000002C : EP5_RX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x0000002E : EP5_RX_COUNT
//
// PMAAddr + BASEADDR_BTABLE + 0x00000030 : EP6_TX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x00000032 : EP6_TX_COUNT
// PMAAddr + BASEADDR_BTABLE + 0x00000034 : EP6_RX_ADDR
```



```

// PMAAddr + BASEADDR_BTABLE + 0x00000036 : EP6_RX_COUNT
//
// PMAAddr + BASEADDR_BTABLE + 0x00000038 : EP7_TX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x0000003A : EP7_TX_COUNT
// PMAAddr + BASEADDR_BTABLE + 0x0000003C : EP7_RX_ADDR
// PMAAddr + BASEADDR_BTABLE + 0x0000003E : EP7_RX_COUNT
// *****
//
// PMAAddr + BASEADDR_BTABLE + (0x00000040 - 0x000001FF) : assigned to data buffer
//
// *****
#define BASEADDR_DATA    (BASEADDR_BTABLE + 0x00000040)

// ENP0
#define ENDP0_PACKETSIZE    0x40
#define ENDP0_RXADDR        BASEADDR_DATA
#define ENDP0_TXADDR        (ENDP0_RXADDR + ENDP0_PACKETSIZE)

// ENP1
#define ENDP1_PACKETSIZE    0x40
#define ENDP1_RXADDR        (ENDP0_TXADDR + ENDP0_PACKETSIZE)
#define ENDP1_TXADDR        (ENDP1_RXADDR + ENDP1_PACKETSIZE)

// ENP2
#define ENDP2_PACKETSIZE    0x40
#define ENDP2_RXADDR        (ENDP1_TXADDR + ENDP1_PACKETSIZE)

```

```
#define ENDP2_TXADDR          (ENDP2_RXADDR + ENDP2_PACKETSIZE)

// ENP3
#define ENDP3_PACKETSIZE     0x40
#define ENDP3_RXADDR         (ENDP2_TXADDR + ENDP2_PACKETSIZE)
#define ENDP3_TXADDR         (ENDP3_RXADDR + ENDP3_PACKETSIZE)

// ENP4
#define ENDP4_PACKETSIZE     0x40
#define ENDP4_RXADDR         (ENDP3_TXADDR + ENDP3_PACKETSIZE)
#define ENDP4_TXADDR         (ENDP4_RXADDR + ENDP4_PACKETSIZE)

// ENP5
#define ENDP5_PACKETSIZE     0x40
#define ENDP5_RXADDR         (ENDP4_TXADDR + ENDP4_PACKETSIZE)
#define ENDP5_TXADDR         (ENDP5_RXADDR + ENDP5_PACKETSIZE)

// ENP6
#define ENDP6_PACKETSIZE     0x40
#define ENDP6_RXADDR         (ENDP5_TXADDR + ENDP5_PACKETSIZE)
#define ENDP6_TXADDR         (ENDP6_RXADDR + ENDP6_PACKETSIZE)

// ENP7
#define ENDP7_PACKETSIZE     0x40
#define ENDP7_RXADDR         (ENDP6_TXADDR + ENDP6_PACKETSIZE)
#define ENDP7_TXADDR         (ENDP7_RXADDR + ENDP7_PACKETSIZE)
```

这样，一般只要在 PMA 的大小区域内（512Bytes），修改端点 EPnR 的数据包大小就可以了，当然，实际情况可以根据需要进行更改。

```
// *****  
// Function Name : INT_ISTR_CTR  
// Description : ISTR Correct Transfer Interrupt service routine.  
// Input :  
// Output :  
// Return :  
// *****  
void INT_ISTR_CTR(void)  
{  
    unsigned short wEPIndex;  
    unsigned short wValISTR;  
    unsigned short wValENDP;  
  
    while( ((wValISTR=GetISTR()) & ISTR_CTR) != 0 )  
    {  
        // Get the index number of the endpoints  
        wEPIndex = wValISTR & ISTR_EP_ID;  
  
        if(wEPIndex == 0)  
        {  
            // Set endpoint0 RX/TX status: NAK (Negative-Acknowledgment)  
            SetEPR_RXStatus(ENDP0, EP_RX_NAK);  
            SetEPR_TXStatus(ENDP0, EP_TX_NAK);  
        }  
    }  
}
```

```
// Transfer direction
if((wValISTR & ISTR_DIR) == 0)
{
    // DIR=0: IN
    // DIR=0 implies that EP_CTR_TX always 1
    ClrEPR_CTR_TX(ENDP0);
    CTR_IN0();
    return;
}
else
{
    // DIR=1: SETUP or OUT
    // DIR=1 implies that CTR_TX or CTR_RX always 1
    wValENDP = GetEPR(ENDP0);
    if((wValENDP & EP_CTR_TX) != 0)
    {
        ClrEPR_CTR_TX(ENDP0);
        CTR_IN0();
        return;
    }
    else if((wValENDP & EP_SETUP) != 0)
    {
        ClrEPR_CTR_RX(ENDP0);
        CTR_SETUP0();
        return;
    }
}
```

```
    }
    else if((wValENDP & EP_CTR_RX) != 0)
    {
        ClrEPR_CTR_RX(ENDP0);
        CTR_OUT0();
        return;
    }
}
// Other endpoints
else
{
    wValENDP = GetEPR(wEPIndex);

    SetEPR_RXStatus(wEPIndex, EP_RX_NAK);
    SetEPR_TXStatus(wEPIndex, EP_TX_NAK);

    if((wValENDP & EP_CTR_TX) != 0)
    {
        ClrEPR_CTR_TX(wEPIndex);
        switch(wEPIndex)
        {
            case ENDP1: CTR_IN1(); break;
            case ENDP2: CTR_IN2(); break;
            case ENDP3: CTR_IN3(); break;
            case ENDP4: CTR_IN4(); break;
        }
    }
}
```

```
    case ENDP5: CTR_IN5(); break;
    case ENDP6: CTR_IN6(); break;
    case ENDP7: CTR_IN7(); break;
    default: break;
}
}
```

```
if((wValENDP & EP_CTR_RX) != 0)
{
    ClrEPR_CTR_RX(wEPIndex);
    switch(wEPIndex)
    {
        case ENDP1: CTR_OUT1(); break;
        case ENDP2: CTR_OUT2(); break;
        case ENDP3: CTR_OUT3(); break;
        case ENDP4: CTR_OUT4(); break;
        case ENDP5: CTR_OUT5(); break;
        case ENDP6: CTR_OUT6(); break;
        case ENDP7: CTR_OUT7(); break;
        default: break;
    }
}
```

```
}
}
```

INT\_ISTR\_CTR() 函数将各自响应事件提取出来，默认端点 EP0 也是最为复杂的，这个需要查看 STM32 的参考手册以及 USB 协议才能更好了解为何如此。到这里 STM32 USB 里数据传输事件就指向了各个对应的端点。

#### 第四篇：USB 设备的枚举（上）

USB 设备能否工作，枚举步骤，用“乡村爱情”里的话说，“必须的！”，网上也有很多资料，圈圈就提供了一份详细的枚举过程，但对 STM32 是怎么响应的没有说明，一会详细道来，先贴上圈圈的提供的那个枚举图示（希望圈圈支持，如果不妥，请与我联系）：

|      |          |     |           |      |      |                   |                     |        |                          |                 |                 |
|------|----------|-----|-----------|------|------|-------------------|---------------------|--------|--------------------------|-----------------|-----------------|
| 控制传输 | 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     |        |                          |                 |                 |
| 控制传输 | Transfer | F   | Control   | ADDR | ENDP | bRequest          | wValue              |        | Time                     | Time Stamp      |                 |
|      | 1        | S   | SET       | 0    | 0    | SET_ADDRESS       | New address 2       |        | 15.996 ms                | 00006.3524 7249 |                 |
| 控制传输 | 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 |
| 控制传输 | Transfer | F   | Control   | ADDR | ENDP | bRequest          | wValue              | wIndex | Descriptors              | Time            | Time Stamp      |
|      | 3        | S   | GET       | 2    | 0    | GET_DESCRIPTOR    | CONFIGURATION type  | 0x0000 | CONFIGURATION descriptor | 3.999 ms        | 00006.3692 6953 |
| 控制传输 | Transfer | F   | Control   | ADDR | ENDP | bRequest          | wValue              | wIndex | Descriptors              | Time            | Time Stamp      |
|      | 4        | S   | GET       | 2    | 0    | GET_DESCRIPTOR    | CONFIGURATION type  | 0x0000 | 6 descriptors            | 22.995 ms       | 00006.3724 6897 |
| 控制传输 | Transfer | F   | Control   | ADDR | ENDP | bRequest          | wValue              | wIndex | Descriptors              | Time            | Time Stamp      |
|      | 5        | S   | GET       | 2    | 0    | GET_DESCRIPTOR    | DEVICE type         | 0x0000 | DEVICE descriptor        | 4.999 ms        | 00006.3908 6573 |
| 控制传输 | Transfer | F   | Control   | ADDR | ENDP | bRequest          | wValue              | wIndex | Descriptors              | Time            | Time Stamp      |
|      | 6        | S   | GET       | 2    | 0    | GET_DESCRIPTOR    | CONFIGURATION type  | 0x0000 | 6 descriptors            | 6.998 ms        | 00006.3948 6502 |
| 控制传输 | Transfer | F   | Control   | ADDR | ENDP | bRequest          | wValue              |        | Time Stamp               |                 |                 |
|      | 7        | S   | SET       | 2    | 0    | SET_CONFIGURATION | New configuration 1 |        | 00006.4004 6404          |                 |                 |

# 1、获取设备描述符

|        |             |        |         |          |          |                         |   |                 |                   |                 |             |                 |         |      |                 |
|--------|-------------|--------|---------|----------|----------|-------------------------|---|-----------------|-------------------|-----------------|-------------|-----------------|---------|------|-----------------|
| 控制传输   | Transfer    | F      | Control | ADDR     | ENDP     | bRequest                | wValue  | wIndex          | Descriptors       | Time Stamp      |             |                 |         |      |                 |
|        | 0           | S      | GET     | 0        | 0        | GET_DESCRIPTOR          | DEVICE type                                     | 0x0000          | DEVICE descriptor | 00006.2653 1284 |             |                 |         |      |                 |
| 设置事务   | 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 |
| 初始设置步骤 | 令牌包         | Packet | Dir     | F        | 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 |         |      |                 |
|        | 数据包         | Packet | Dir     | F        | 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 |             |                 |         |      |                 |
| 握手包    | Packet      | Dir    | F       | Sync     | ACK      | EOP                     | Time  | Time Stamp      |                   |                 |             |                 |         |      |                 |
|        | 97          | <--    | S       | 00000001 | 0x4B     | 250.000 ns              | 988.183 μs                                      | 00006.2653 1984 |                   |                 |             |                 |         |      |                 |
| 输入事务   | 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   |                 |             |                 |         |      |                 |
| 可选数据步骤 | 令牌包         | Packet | Dir     | F        | 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 |         |      |                 |
|        | 数据包         | Packet | Dir     | F        | 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      |             |                 |         |      |                 |
| 握手包    | Packet      | Dir    | F       | Sync     | ACK      | EOP                     | Time  | Time Stamp      |                   |                 |             |                 |         |      |                 |
|        | 101         | -->    | S       | 00000001 | 0x4B     | 250.000 ns              | 1.982 ms  | 00006.2661 2335 |                   |                 |             |                 |         |      |                 |
| 输出事务   | Transaction | F      | OUT     | ADDR     | ENDP     | T                       | Data  | ACK             | Time Stamp        |                 |             |                 |         |      |                 |
|        | 2           | S      | 0x87    | 0        | 0        | 1                       |   | 0x4B            | 00006.2677 1247   |                 |             |                 |         |      |                 |
| 状态信息步骤 | 令牌包         | Packet | Dir     | F        | 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 |         |      |                 |
|        | 数据包         | Packet | Dir     | F        | Sync     | DATA1                   | Data  | CRC16           | EOP               | Idle            | Time Stamp  |                 |         |      |                 |
|        | 105         | -->    | S       | 00000001 | 0xD2     |                         | 0x0000  | 250.000 ns      | 350.000 ns        | 00006.2677 1432 |             |                 |         |      |                 |
| 握手包    | Packet      | Dir    | F       | Sync     | ACK      | EOP                     | Time  | Time Stamp      |                   |                 |             |                 |         |      |                 |
|        | 106         | <--    | S       | 00000001 | 0x4B     | 250.000 ns              | 1.068 ms  | 00006.2677 1628 |                   |                 |             |                 |         |      |                 |



## 2、设置地址

控制传输

| Transfer | F | Control | ADDR | ENDP | bRequest    | wValue        | Time Stamp      |
|----------|---|---------|------|------|-------------|---------------|-----------------|
| 1        | S | SET     | 0    | 0    | SET_ADDRESS | New address 2 | 00006.3524 7249 |

设置事务

| 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 |

初始设置步骤

令牌包

| Packet | Dir | F | 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 |

数据包

| Packet | Dir | F | 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 |

握手包

| Packet | Dir | F | Sync     | ACK  | EOP        | Time            | Time Stamp      |
|--------|-----|---|----------|------|------------|-----------------|-----------------|
| 190    | <-- | S | 00000001 | 0x4B | 250.000 ns | 988.100 $\mu$ s | 00006.3525 0449 |

输入事务

| Transaction | F | IN   | ADDR | ENDP | T | Data | ACK  | Time Stamp      |
|-------------|---|------|------|------|---|------|------|-----------------|
| 4           | S | 0x96 | 0    | 0    | 1 |      | 0x4B | 00006.3532 7235 |

状态信息步骤

令牌包

| Packet | Dir | F | 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 |

数据包

| Packet | Dir | F | Sync     | DATA1 | Data | CRC16  | EOP        | Idle       | Time Stamp      |
|--------|-----|---|----------|-------|------|--------|------------|------------|-----------------|
| 193    | <-- | S | 00000001 | 0xD2  |      | 0x0000 | 250.000 ns | 499.990 ns | 00006.3532 7440 |

握手包

| Packet | Dir | F | 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 |

控制传输

| Transaction | F | SETUP | ADDR | ENDP | T | D    | TP | 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 |

设置事务

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 |

握手包

| 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 |

输入事务

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       |
|--------|-----|---|----------|-------|---|--------|------------|------------|
| 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 |

握手包

| Packet | Dir | F | Sync     | ACK  | EOP        | Time       | Time Stamp      |
|--------|-----|---|----------|------|------------|------------|-----------------|
| 216    | --> | S | 00000001 | 0x4B | 233.330 ns | 982.100 μs | 00006.3661 0569 |

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

输入事务

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 |            |

握手包

| Packet | Dir | F | Sync     | ACK  | EOP        | Time       | Time Stamp      |
|--------|-----|---|----------|------|------------|------------|-----------------|
| 220    | --> | S | 00000001 | 0x4B | 233.330 ns | 991.433 μs | 00006.3668 7495 |

| 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 |

输出/状态

#### 4、获取配置描述符

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

| Setup Transaction |  | Transaction | F | SETUP | ADDR | ENDP | T | D    | TP | 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 |

| Initial Setup Step |  | Packet | Dir | F | Sync     | SETUP | ADDR                    | ENDP            | CRC5            | EOP        | Idle            | Time Stamp      |
|--------------------|--|--------|-----|---|----------|-------|-------------------------|-----------------|-----------------|------------|-----------------|-----------------|
| 令牌包                |  | 227    | --> | S | 00000001 | 0xB4  | 2                       | 0               | 0x15            | 233.330 ns | 183.320 ns      | 00006.3692 6953 |
| 数据包                |  | 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 |                 |
| 握手包                |  | Packet | Dir | F | Sync     | ACK   | EOP                     | Time            | Time Stamp      |            |                 |                 |
|                    |  | 229    | <-- | S | 00000001 | 0x4B  | 250.000 ns              | 988.167 $\mu$ s | 00006.3693 0154 |            |                 |                 |

| Input Transaction |  | 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 |

| Selectable Data Step |  | Packet | Dir | F | Sync     | IN    | ADDR                       | ENDP            | CRC5            | EOP        | Idle            | Time Stamp      |
|----------------------|--|--------|-----|---|----------|-------|----------------------------|-----------------|-----------------|------------|-----------------|-----------------|
| 令牌包                  |  | 231    | --> | S | 00000001 | 0x96  | 2                          | 0               | 0x15            | 233.330 ns | 550.000 ns      | 00006.3700 6944 |
| 数据包                  |  | 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 |                 |
| 握手包                  |  | Packet | Dir | F | Sync     | ACK   | EOP                        | Time            | Time Stamp      |            |                 |                 |
|                      |  | 233    | --> | S | 00000001 | 0x4B  | 233.330 ns                 | 986.933 $\mu$ s | 00006.3701 0214 |            |                 |                 |

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

| Status Information Step |  | Packet | Dir | F | Sync     | OUT   | ADDR       | ENDP     | CRC5            | EOP        | Idle            | Time Stamp      |
|-------------------------|--|--------|-----|---|----------|-------|------------|----------|-----------------|------------|-----------------|-----------------|
| 令牌包                     |  | 235    | --> | S | 00000001 | 0x87  | 2          | 0        | 0x15            | 233.330 ns | 183.320 ns      | 00006.3708 6930 |
| 数据包                     |  | 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 |                 |
| 握手包                     |  | 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 |                    |        |         |      |                 |      |       |            |      |            |            |          |         |            |            |                         |   |            |            |                 |  |                 |  |   |                |                    |        |     |      |                 |  |     |        |      |      |      |       |            |       |            |        |            |      |            |            |                 |  |                         |            |                 |   |                 |  |   |          |      |             |   |      |            |             |                 |  |      |      |            |      |     |      |            |     |     |   |          |            |                 |  |                 |  |                 |  |            |     |     |   |          |             |                         |             |            |             |                 |  |      |      |            |      |            |      |            |      |   |   |      |   |                 |   |                 |  |                 |     |     |   |          |      |            |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |   |      |   |                 |  |                 |   |   |      |   |   |   |   |      |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |      |      |   |                 |          |                 |  |   |      |   |   |   |   |      |            |                 |   |   |     |      |      |   |      |     |      |            |             |   |      |      |      |   |      |      |           |                 |    |   |      |   |   |   |   |      |          |                 |  |  |  |  |  |  |  |  |  |  |             |   |     |      |      |   |      |     |      |            |    |   |      |   |   |   |  |      |           |                 |
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| 12   | S   | 0xB4    | 2        | 0     | 0                       | D->H  | S               | D             | GET_DESCRIPTOR  | CONFIGURATION type | 0x0000 | 255     | 0x4B | 00006.3724 6897 |      |       |            |      |            |            |          |         |            |            |                         |   |            |            |                 |  |                 |  |   |                |                    |        |     |      |                 |  |     |        |      |      |      |       |            |       |            |        |            |      |            |            |                 |  |                         |            |                 |   |                 |  |   |          |      |             |   |      |            |             |                 |  |      |      |            |      |     |      |            |     |     |   |          |            |                 |  |                 |  |                 |  |            |     |     |   |          |             |                         |             |            |             |                 |  |      |      |            |      |            |      |            |      |   |   |      |   |                 |   |                 |  |                 |     |     |   |          |      |            |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |   |      |   |                 |  |                 |   |   |      |   |   |   |   |      |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |      |      |   |                 |          |                 |  |   |      |   |   |   |   |      |            |                 |   |   |     |      |      |   |      |     |      |            |             |   |      |      |      |   |      |      |           |                 |    |   |      |   |   |   |   |      |          |                 |  |  |  |  |  |  |  |  |  |  |             |   |     |      |      |   |      |     |      |            |    |   |      |   |   |   |  |      |           |                 |
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| 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    |        |         |      |                 |      |       |            |      |            |            |          |         |            |            |                         |   |            |            |                 |  |                 |  |   |                |                    |        |     |      |                 |  |     |        |      |      |      |       |            |       |            |        |            |      |            |            |                 |  |                         |            |                 |   |                 |  |   |          |      |             |   |      |            |             |                 |  |      |      |            |      |     |      |            |     |     |   |          |            |                 |  |                 |  |                 |  |            |     |     |   |          |             |                         |             |            |             |                 |  |      |      |            |      |            |      |            |      |   |   |      |   |                 |   |                 |  |                 |     |     |   |          |      |            |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |   |      |   |                 |  |                 |   |   |      |   |   |   |   |      |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |      |      |   |                 |          |                 |  |   |      |   |   |   |   |      |            |                 |   |   |     |      |      |   |      |     |      |            |             |   |      |      |      |   |      |      |           |                 |    |   |      |   |   |   |   |      |          |                 |  |  |  |  |  |  |  |  |  |  |             |   |     |      |      |   |      |     |      |            |    |   |      |   |   |   |  |      |           |                 |
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| 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 |                    |        |         |      |                 |      |       |            |      |            |            |          |         |            |            |                         |   |            |            |                 |  |                 |  |   |                |                    |        |     |      |                 |  |     |        |      |      |      |       |            |       |            |        |            |      |            |            |                 |  |                         |            |                 |   |                 |  |   |          |      |             |   |      |            |             |                 |  |      |      |            |      |     |      |            |     |     |   |          |            |                 |  |                 |  |                 |  |            |     |     |   |          |             |                         |             |            |             |                 |  |      |      |            |      |            |      |            |      |   |   |      |   |                 |   |                 |  |                 |     |     |   |          |      |            |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |   |      |   |                 |  |                 |   |   |      |   |   |   |   |      |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |      |      |   |                 |          |                 |  |   |      |   |   |   |   |      |            |                 |   |   |     |      |      |   |      |     |      |            |             |   |      |      |      |   |      |      |           |                 |    |   |      |   |   |   |   |      |          |                 |  |  |  |  |  |  |  |  |  |  |             |   |     |      |      |   |      |     |      |            |    |   |      |   |   |   |  |      |           |                 |
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| Packet   | Dir | F       | Sync     | ACK   | EOP                     | Time  | Time Stamp      |               |                 |                    |        |         |      |                 |      |       |            |      |            |            |          |         |            |            |                         |   |            |            |                 |  |                 |  |   |                |                    |        |     |      |                 |  |     |        |      |      |      |       |            |       |            |        |            |      |            |            |                 |  |                         |            |                 |   |                 |  |   |          |      |             |   |      |            |             |                 |  |      |      |            |      |     |      |            |     |     |   |          |            |                 |  |                 |  |                 |  |            |     |     |   |          |             |                         |             |            |             |                 |  |      |      |            |      |            |      |            |      |   |   |      |   |                 |   |                 |  |                 |     |     |   |          |      |            |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |   |      |   |                 |  |                 |   |   |      |   |   |   |   |      |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |      |      |   |                 |          |                 |  |   |      |   |   |   |   |      |            |                 |   |   |     |      |      |   |      |     |      |            |             |   |      |      |      |   |      |      |           |                 |    |   |      |   |   |   |   |      |          |                 |  |  |  |  |  |  |  |  |  |  |             |   |     |      |      |   |      |     |      |            |    |   |      |   |   |   |  |      |           |                 |
| 242  | <-- | S       | 00000001 | 0x4B  | 233.330 ns              | 988.017 μs                                      | 00006.3725 0102 |               |                 |                    |        |         |      |                 |      |       |            |      |            |            |          |         |            |            |                         |   |            |            |                 |  |                 |  |   |                |                    |        |     |      |                 |  |     |        |      |      |      |       |            |       |            |        |            |      |            |            |                 |  |                         |            |                 |   |                 |  |   |          |      |             |   |      |            |             |                 |  |      |      |            |      |     |      |            |     |     |   |          |            |                 |  |                 |  |                 |  |            |     |     |   |          |             |                         |             |            |             |                 |  |      |      |            |      |            |      |            |      |   |   |      |   |                 |   |                 |  |                 |     |     |   |          |      |            |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |   |      |   |                 |  |                 |   |   |      |   |   |   |   |      |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |      |      |   |                 |          |                 |  |   |      |   |   |   |   |      |            |                 |   |   |     |      |      |   |      |     |      |            |             |   |      |      |      |   |      |      |           |                 |    |   |      |   |   |   |   |      |          |                 |  |  |  |  |  |  |  |  |  |  |             |   |     |      |      |   |      |     |      |            |    |   |      |   |   |   |  |      |           |                 |
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| 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 |                    |        |         |      |                 |      |       |            |      |            |            |          |         |            |            |                         |   |            |            |                 |  |                 |  |   |                |                    |        |     |      |                 |  |     |        |      |      |      |       |            |       |            |        |            |      |            |            |                 |  |                         |            |                 |   |                 |  |   |          |      |             |   |      |            |             |                 |  |      |      |            |      |     |      |            |     |     |   |          |            |                 |  |                 |  |                 |  |            |     |     |   |          |             |                         |             |            |             |                 |  |      |      |            |      |            |      |            |      |   |   |      |   |                 |   |                 |  |                 |     |     |   |          |      |            |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |   |      |   |                 |  |                 |   |   |      |   |   |   |   |      |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |      |      |   |                 |          |                 |  |   |      |   |   |   |   |      |            |                 |   |   |     |      |      |   |      |     |      |            |             |   |      |      |      |   |      |      |           |                 |    |   |      |   |   |   |   |      |          |                 |  |  |  |  |  |  |  |  |  |  |             |   |     |      |      |   |      |     |      |            |    |   |      |   |   |   |  |      |           |                 |
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| 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 |                    |        |         |      |                 |      |       |            |      |            |            |          |         |            |            |                         |   |            |            |                 |  |                 |  |   |                |                    |        |     |      |                 |  |     |        |      |      |      |       |            |       |            |        |            |      |            |            |                 |  |                         |            |                 |   |                 |  |   |          |      |             |   |      |            |             |                 |  |      |      |            |      |     |      |            |     |     |   |          |            |                 |  |                 |  |                 |  |            |     |     |   |          |             |                         |             |            |             |                 |  |      |      |            |      |            |      |            |      |   |   |      |   |                 |   |                 |  |                 |     |     |   |          |      |            |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |   |      |   |                 |  |                 |   |   |      |   |   |   |   |      |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |      |      |   |                 |          |                 |  |   |      |   |   |   |   |      |            |                 |   |   |     |      |      |   |      |     |      |            |             |   |      |      |      |   |      |      |           |                 |    |   |      |   |   |   |   |      |          |                 |  |  |  |  |  |  |  |  |  |  |             |   |     |      |      |   |      |     |      |            |    |   |      |   |   |   |  |      |           |                 |
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| 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 |                    |        |         |      |                 |      |       |            |      |            |            |          |         |            |            |                         |   |            |            |                 |  |                 |  |   |                |                    |        |     |      |                 |  |     |        |      |      |      |       |            |       |            |        |            |      |            |            |                 |  |                         |            |                 |   |                 |  |   |          |      |             |   |      |            |             |                 |  |      |      |            |      |     |      |            |     |     |   |          |            |                 |  |                 |  |                 |  |            |     |     |   |          |             |                         |             |            |             |                 |  |      |      |            |      |            |      |            |      |   |   |      |   |                 |   |                 |  |                 |     |     |   |          |      |            |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |   |      |   |                 |  |                 |   |   |      |   |   |   |   |      |             |                 |  |      |      |      |      |     |      |            |      |            |             |   |      |      |      |      |   |                 |          |                 |  |   |      |   |   |   |   |      |            |                 |   |   |     |      |      |   |      |     |      |            |             |   |      |      |      |   |      |      |           |                 |    |   |      |   |   |   |   |      |          |                 |  |  |  |  |  |  |  |  |  |  |             |   |     |      |      |   |      |     |      |            |    |   |      |   |   |   |  |      |           |                 |
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| 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 | 0xE4A4 | 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 $\mu$ s | 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 Stamp      |
|--------|-----|---|----------|------|------------|-----------------|
| 323    | --> | S | 00000001 | 0x4B | 250.000 ns | 00006.4012 6799 |

说明枚举过程之前，首先说明一个变量，定义在 usb\_core.c 中：  
 volatile DEVICE\_INFO vsDeviceInfo;

看意思就知道他的作用，DEVICE\_INFO 是个结构，定义在 usb\_type.h 中：

```
// *****
```

```

// DEVICE_INFO
// *****
typedef struct _DEVICE_INFO
{
    unsigned char bDeviceAddress;

    unsigned char bCurrentFeature;
    unsigned char bCurrentConfiguration;
    unsigned char bCurrentInterface;
    unsigned char bCurrentAlternateSetting;

    WORD_2BYTE    uStatusInfo;

    DEVICE_STATE  eDeviceState;
    RESUME_STATE  eResumeState;
    CONTROL_STATE eControlState;

    SETUP_DATA    SetupData;

    TRANSFER_INFO TransInfo;
}
DEVICE_INFO,
*PDEVICE_INFO;

```

在枚举过程中，就是如何处理好 SETUP 事件，如果 STM32 USB 接收到正确的 SETUP 事件，将响应函数 CTR\_SETUP0()，SETUP 事件是特殊的 OUT 事件，数据方向 Host→Device，SETUP 事件数据长度固定为 8，数据定义在 DEVICE\_INFO.SetupData，其数据结构是(定义在

usb\_type.h 中):

```
typedef struct _SETUP_DATA
{
    unsigned char bmRequestType;           // request type
    unsigned char bRequest;               // request code

    WORD_2BYTE wValue;
    WORD_2BYTE wIndex;
    WORD_2BYTE wLength;
}
SETUP_DATA,
*PSETUP_DATA;
```

WORD\_2BYTE 是定义的一个共用体:

```
typedef union _WORD_2BYTE
{
    unsigned short w;
    struct
    {
        unsigned char LSB;
        unsigned char MSB;
    }b;
}
WORD_2BYTE;
```

为什么将 SETUP 数据结构中的 wValue, wIndex, wLength 如此定义?



1: USB 协议中所有数据传输都是依照低位在先的原则

2: 高地位字节可能功能复用

这样在后续的程序编写中就变得十分方便，ST 提供的 USB 固件方法同样如此，但这方面的处理让人有些摸不着头脑，详情可参阅。至于具体的 SETUP 数据结构含义如何，还是要具备基本知识：了解 USB 协议

CTR\_SETUP0() 函数将 SETUP 数据提取出来，SETUP 数据结构有 0 长度和非 0 长度的数据结构，详细参阅 USB2.0 官方协议第 9 章。在这将两种区别开来分别执行 SETUP0\_NoData() 和 SETUP0\_Data() 函数，并返回结果，根据返回结果再响应 USB 主机

```
// *****  
// Function Name : CTR_SETUP0  
// Description :  
// Input :  
// Output :  
// Return :  
// *****  
void CTR_SETUP0(void)  
{  
    RESULT eResult;  
  
    BufferCopy_PMAToUser( (unsigned char *)&vsDeviceInfo.SetupData,  
                        GetBuffDescTable_RXAddr(ENDP0),  
                        GetBuffDescTable_RXCount(ENDP0));  
  
    if(vsDeviceInfo.SetupData.wLength.w == 0)  
    {  
        eResult = SETUP0_NoData();  
    }  
}
```

```

else
{
    eResult = SETUP0_Data();
}

switch(eResult)
{
case RESULT_SUCCESS:

    break;

case RESULT_LASTDATA:

    break;

case RESULT_ERROR:
case RESULT_UNSUPPORT:
    SetEPR_RXStatus(ENDP0, EP_RX_VALID);
    SetEPR_TXStatus(ENDP0, EP_TX_STALL);
    break;
}
}

```

SETUP0\_Data() 和 SETUP0\_NoData() 函数支持的所有 USB 请求类型只有罗列的这些，有多少种组合都定义在 USB 协议中，程序根据请求代码，再去执行对应函数，这样做的目的就是让程序结构明了。其中注释为“// done”的部分表明此部分功能已完成。对于未完成部分，希望大家在交流中完善。

```
// *****
```

```

// Routine Groups: SETUP_Data
// *****
RESULT SETUP0_Data(void)
{
    // SetupData.bRequest: request code
    switch(vsDeviceInfo.SetupData.bRequest)
    {
        case SR_GET_STATUS:          return SR_GetStatus();           // done
        case SR_GET_DESCRIPTOR:      return SR_GetDescriptor();      // done
        case SR_SET_DESCRIPTOR:      return SR_SetDescriptor();      // unsupport
        case SR_GET_CONFIGURATION:    return SR_GetConfiguration();  // done
        case SR_GET_INTERFACE:       return SR_GetInterface();      // unsupport
        case SR_SYNCH_FRAME:         return SR_SynchFrame();        // unsupport

        default: return RESULT_UN SUPPORT;
    }
}

// *****
// Routine Groups: SETUP_NoData
// *****
RESULT SETUP0_NoData(void)
{
    // SetupData.bRequest: request code
    switch(vsDeviceInfo.SetupData.bRequest)
    {

```

```

case SR_CLEAR_FEATURE:    return SR_ClearFeature();    // unsupport
case SR_SET_FEATURE:     return SR_SetFeature();     // unsupport
case SR_SET_ADDRESS:     return SR_SetAddress();     // done
case SR_SET_CONFIGURATION: return SR_SetConfiguration(); // done
case SR_SET_INTERFACE:   return SR_SetInterface();   // unsupport

default: return RESULT_UN SUPPORT;
}
}

```

## 第五篇：USB 设备的枚举（下）

SETUP 事件正确接收后，根据该事件提供的请求类型进行对主机的响应。SETUP 数据结构的 wLength 字段说明的是请求返回或者提供的  
数据长度。

如果判断出的请求信息错误或者说不被支持，STM32 USB 设备需要中断此次请求：

```

SetEPR_RXStatus(ENDP0, EP_RX_VALID);
SetEPR_TXStatus(ENDP0, EP_TX_STALL);

```

正确获取到请求信息后，如果 wLength 为 0，设备需要发送一个 0 长度数据包以响应主机：

```

// *****
// Function Name : SETUP0_Trans0Data
// Description   :
// Input         :
// Output        :

```

```

// Return      :
// *****
RESULT SETUP0_Trans0Data(void)
{
    // Send 0-length data frame as ACK to host
    SetBuffDescTable_TXCount(ENDP0, 0);
    SetEPR_RXStatus(ENDP0, EP_RX_NAK);
    SetEPR_TXStatus(ENDP0, EP_TX_VALID);

    return RESULT_SUCCESS;
}

```

如果 wLength 不为 0，设备则需要根据请求的数据长度发送数据包以响应主机：

```

// *****
// Function Name  : SETUP0_TransData
// Description    :
// Input         :
// Output        :
// Return        :
// *****
RESULT SETUP0_TransData(void)
{
    unsigned short wLength = vsDeviceInfo.TransInfo.wLength;
    unsigned short wOffset = vsDeviceInfo.TransInfo.wOffset;
    unsigned short wMaxSize = vsDeviceInfo.TransInfo.wPacketSize;

    if(wLength)

```

```

{
    if(wLength > wMaxSize)
    {
        wLength = wMaxSize;
    }

    // Copy the transfer buffer to the endpoint0's buffer
    BufferCopy_UserToPMA( vsDeviceInfo.TransInfo.pBuffer+wOffset, // transfer buffer
                        GetBuffDescTable_TXAddr(ENDP0), // endpoint 0 TX address
                        wLength);

    SetBuffDescTable_TXCount(ENDP0, wLength);
    SetEPR_RXStatus(ENDP0, EP_RX_NAK);
    SetEPR_TXStatus(ENDP0, EP_TX_VALID);

    // Update the data lengths
    vsDeviceInfo.TransInfo.wLength -= wLength;
    vsDeviceInfo.TransInfo.wOffset += wLength;

    return RESULT_LASTDATA;
}

return RESULT_SUCCESS;
}

```

如果发送的数据长度大于端点设置的最大数据包长度，数据将分割为若干次发送，记录发送数据的状态包含在结构体 TRANSFER\_INFO 中：

```

// *****
// TRANSFER_INFO
// *****
typedef struct _TRANSFER_INFO
{
    unsigned short wLength;           // total lengths data will be transmit
    unsigned short wOffset;          // number of data be transmited
    unsigned short wPacketSize;      // endpoints packet max size
    unsigned char* pBuffer;          // address of data buffer
}
TRANSFER_INFO,
*PTRANSFER_INFO;

```

TRANSFER\_INFO.wLength 记录发送的数据长度，如果非 0，表示有数据需要被发送。

TRANSFER\_INFO.wOffset 记录已发送的数据长度，用以确定数据缓冲 TRANSFER\_INFO.pBuffer 的偏移量。

需要了解的一点：USB 主机向 USB 设备正确发送一请求后（这部分的处理由硬件完成），USB 主机将间隔若干次的向 USB 设备索取响应数据，STM32 USB TX 状态为 NAK 说明不响应 USB 主机，USB 主机在超时后退出此次请求；TX 状态为 STLL 说明中断此次请求，USB 主机将无条件退出请求；TX 状态为 VALID 说明设备已准备好数据发送，USB 主机将从 USB 设备读取数据。

以非 0 长度数据请求的 GET\_DESCRIPTOR 请求为例的响应过程：

CTR\_SETUP0()->SETUP0\_Data()->SR\_GetDescriptor()->SETUP0\_TransData()

```

RESULT SR_GetDescriptor(void)
{
    // RequestType: device->host, standard request and device recipient
    if(vsDeviceInfo.SetupData.bmRequestType == RT_D2H_STANDARD_DEVICE)
    {

```

```

// SetupData.wValue.b.MSB: descriptor type
// SetupData.wValue.b.LSB: descriptor index
switch(vsDeviceInfo.SetupData.wValue.b.MSB)
{
case DESCRIPTOR_DEVICE:           return SR_GetDescriptor_Device();
case DESCRIPTOR_CONFIG:          return SR_GetDescriptor_Config();
case DESCRIPTOR_STRING:          return SR_GetDescriptor_String();

default: return RESULT_UNSupport;
}
}

return RESULT_UNSupport;
}

```

GET\_DESCRIPTOR 请求属于 USB 协议中的标准请求（standard request）并且数据方向为设备至主机（device->host），分设备描述符、配置描述符、字符串描述符三种。已设备描述符为例：

```

RESULT SR_GetDescriptor_Device(void)
{
// Assigned the device descriptor to the transfer
vsDeviceInfo.TransInfo.wOffset = 0;
vsDeviceInfo.TransInfo.wPacketSize = ENDPO_PACKETSIZE;
vsDeviceInfo.TransInfo.pBuffer = DescBuffer_Device.pBuff;
vsDeviceInfo.TransInfo.wLength = DescBuffer_Device.wLen;
vsDeviceInfo.eControlState = CS_GET_DESCRIPTOR;

if(vsDeviceInfo.TransInfo.wLength > vsDeviceInfo.SetupData.wLength.w)

```



```

    {
        vsDeviceInfo.TransInfo.wLength = vsDeviceInfo.SetupData.wLength.w;
    }

    return SETUP0_TransData();
}

```

这里说明了发送数据的长度、缓冲、偏移、端点包大小以及当前的控制状态，并说明了如果发送的数据长度超出请求的数据长度，则将舍弃超出的部分。数据配置好后，调用 SETUP0\_TransData() 进行数据发送。

在 USB 主机查询到 USB 设备准备就绪后，将读取出这些数据，完成后，USB 设备将产生 IN 事件，此时将响应 CTR\_IN0() 函数：

```

// *****
// Function Name   : CTR_IN
// Description     :
// Input          :
// Output         :
// Return         :
// *****
void CTR_IN0(void)
{
    switch(vsDeviceInfo.eControlState)
    {
    case CS_GET_DESCRIPTOR:
        if(SETUP0_TransData() == RESULT_SUCCESS)
        {
            SetEPR_TXStatus(ENDP0, EP_TX_NAK);
            SetEPR_RXStatus(ENDP0, EP_RX_VALID);
        }
    }
}

```

```

        break;

    case CS_SET_ADDRESS:
        SetEPR_TXStatus(ENDP0, EP_TX_NAK);
        SetEPR_RXStatus(ENDP0, EP_RX_VALID);

        SetDADDR(0x0080 | vsDeviceInfo.bDeviceAddress);
        vsDeviceInfo.eDeviceState = DS_ADDRESSED;
        break;

    case CS_SET_CONFIGURATION:
        SetEPR_TXStatus(ENDP0, EP_TX_NAK);
        SetEPR_RXStatus(ENDP0, EP_RX_VALID);

        vsDeviceInfo.eDeviceState = DS_CONFIGURED;
        break;

    default:
        break;
}
}

```

再 这如果响应 GET\_DESCRIPTOR 请求发送的数据如果全部发送完毕, SETUP0\_TransData() 返回 RESULT\_SUCCESS, 并设置 TX 状态为 NAK; 否则返回 RESULT\_LASTDATA, 将继续发送剩余的数据直到数据全部被发送。至此, 整个的 GET\_DESCRIPTOR 请求 过程完成。

0 长度的数据请求在发送 0 长度数据响应后, 因为不存在可能还未传送的数据, 因而 IN 事件后直接结束此次请求。

在数据方向为 USB 主机->USB 设备时, 如果正确接收到数据, 将响应 CTR\_OUT0() 函数, 处理过程类同 CTR\_IN0() 函数。

在 USB 设备的枚举过程中, USB 的一些描述符数据结构需要了解, 具体在 USB 协议中有详细的说明, 在 usb\_desc(.c/.h) 文件中, 定义

了这些结构，这些结构是特定的：

设备描述符：长度、格式固定，其中 VENDOR\_ID 与 PRODUCT\_ID 决定上位机驱动的认识。设备分属类别决定了设备的性质，如果为自定义 USB 设备，设备分属类别值为 0，同时上位机驱动必须配合编写；如果为标准 USB 设备，则必须使用这些标准设备的驱动、数据结构等等，条件是你必须了解这些标准设备的一些信息，好处是省去一些麻烦的驱动编写。

```
const unsigned char cbDescriptor_Device[DESC_SIZE_DEVICE] =
{
    DESC_SIZE_DEVICE,      // bLength: 18
    DESCRIPTOR_DEVICE,    // descriptor type

    0x00,                  // bcdUSB LSB: USB release number -> USB2.0
    0x02,                  // bcdUSB MSB: USB release number -> USB2.0

    0x00,                  // bDeviceClass:   Class information in the interface descriptors
    0x00,                  // bDeviceSubClass:
    0x00,                  // bDeviceProtocol:
    0x40,                  // bMaxPacketSize0:  LowS(8), FullS(8, 16, 32, 64), HighS(64)

    LOWORD(VENDOR_ID),    // idVendor LSB:
    HIWORD(VENDOR_ID),    // idVendor MSB:

    LOWORD(PRODUCT_ID),   // idProduct LSB:
    HIWORD(PRODUCT_ID),   // idProduct MSB:

    LOWORD(DEVICE_VERSION), // bcdDevice LSB:
    HIWORD(DEVICE_VERSION), // bcdDevice MSB:
```

```

0x01,      // iManufacturer: Index of string descriptor describing manufacturer
0x02,      // iProduct: Index of string descriptor describing product
0x03,      // iSerialNumber: Index of string descriptor describing the device serial number

0x01       // bNumConfigurations: number of configurations
};

```

配置描述符：前 9 个字节格式固定，后面紧跟的各种描述结构跟实际配置有关，每增加一种描述结构，该描述结构的第一字节说明了结构的长度，第二直接说明了结构的类型。在配置描述符中一般包含配置描述、接口描述、端点描述，如果需要同样可增加自定义的描述。使用标准 USB 设备类别时，配置描述符的结构也必须满足 此类标准设备的数据结构。

```

const unsigned char cbDescriptor_Config[DESC_SIZE_CONFIG] =
{
    // Descriptor of configuration
    0x09,          // lengths
    DESCRIPTOR_CONFIG, // descriptor type

    DESC_SIZE_CONFIG, // Total configuration descriptor lengths LSB
    0x00,          // Total configuration descriptor lengths MSB

    0x01,      // bNumInterfaces: Total number of interfaces
    0x01,      // bConfigurationValue: Configuration value
    0x00,      // iConfiguration: Index of string descriptor describing the configuration

    0xA0,      // bmAttributes: bus powered
                // bit 4...0 : Reserved, set to 0

```

```
        // bit 5      : Remote wakeup (1:yes)
        // bit 6      : Self power (1:yes)
        // bit 7      : Reserved, set to 1

0x32,      // bMaxPower: this current is used for detecting Vbus = 100mA

// Descriptor of interface
0x09,
DESCRIPTOR_INTERFACE,

0x00,      // bInterfaceNumber: Number of Interface
0x00,      // bAlternateSetting: Alternate setting

0x02,      // bNumEndpoints: Number of endpoints except EP0
0x00,      // bInterfaceClass:
0x00,      // bInterfaceSubClass:
0x00,      // nInterfaceProtocol:

0x00,      // iInterface: Index of string descriptor describing the interface

// Descriptor of endpoint1 OUT
0x07,
DESCRIPTOR_ENDPOINT,
```

```
0x01,    // bEndpointAddress
         // bit 3...0 : the endpoint number
         // bit 6...4 : reserved
         // bit 7      : 0(OUT), 1(IN)

0x03,    // bmAttributes
         // bit 1...0 : Transfer type
         //           00(CONTROL), 01(ISOCHRONOUS), 10(BULK), 11(INTERRUPT)
         // bit 3...2 : Synchronization type
         //           00(No Synch), 01(Asynchronous), 10(Adaptive), 11(Synchronous)
         // bit 5...4 : Endpoint Usage type
         //           00(data), 01(Feedback), 10(Implicit feedback data endpoint), 11(Reserved)
         // bit 7...6 : Reserved, must be zero

0x40,    // packet size LSB
0x00,    // packet size MSB

0x20,    // polling interval time: 32ms

// Descriptor of endpoint2 IN
0x07,
DESCRIPTOR_ENDPOINT,

0x82,    // bEndpointAddress
         // bit 3...0 : the endpoint number
         // bit 6...4 : reserved
```

```

        // bit 7      : 0(OUT), 1(IN)

0x03,    // bmAttributes
        // bit 1...0 : Transfer type
        //           00(CONTROL), 01(ISOCHRONOUS), 10(BULK), 11(INTERRUPT)
        // bit 3...2 : Synchronization type
        //           00(No Synch), 01(Asynchronous), 10(Adaptive), 11(Synchronous)
        // bit 5...4 : Endpoint Usage type
        //           00(data), 01(Feedback), 10(Implicit feedback data endpoint), 11(Reserved)
        // bit 7...6 : Reserved, must be zero

0x40,    // packet size LSB
0x00,    // packet size MSB

0x20     // polling interval time: 32ms
};

```

字符串描述符：定义了与设备有关的一些信息，常见的为以下四种，如果有需要，同样可以定义自己的字符串描述符。

```

const unsigned char cbDescriptor_StringLangID[DESC_SIZE_STRING_LANGID] =
{
    DESC_SIZE_STRING_LANGID, // bLength
    DESCRIPTOR_STRING,      // bDescriptorType = String Descriptor

    0x09,                   // LangID LSB:
    0x04                     // LangID MSB: 0x0409(U.S. English)
};

```

```

const unsigned char cbDescriptor_StringVendor[DESC_SIZE_STRING_VENDOR] =
{
    DESC_SIZE_STRING_VENDOR, // bLength
    DESCRIPTOR_STRING,       // bDescriptorType = String Descriptor

    // String: "LaBiXiaoXiaoXin"
    'L',0, 'a',0, 'B',0, 'i',0, 'X',0, 'i',0, 'a',0, 'o',0,
    'X',0, 'i',0, 'a',0, 'o',0, 'X',0, 'i',0, 'n',0
};

const unsigned char cbDescriptor_StringProduct[DESC_SIZE_STRING_PRODUCT] =
{
    DESC_SIZE_STRING_PRODUCT, // bLength
    DESCRIPTOR_STRING,       // bDescriptorType = String Descriptor

    // String: "STM32 ezUSB-CORE V1.01"
    'S',0, 'T',0, 'M',0, '3',0, '2',0, ' ',0, 'e',0, 'z',0, 'U',0, 'S',0, 'B',0,
    '-',0, 'C',0, 'O',0, 'R',0, 'E',0, ' ',0, 'V',0, '1',0, '.',0, '0',0, '1',0
};

const unsigned char cbDescriptor_StringSerial[DESC_SIZE_STRING_SERIAL] =
{
    DESC_SIZE_STRING_SERIAL, // bLength
    DESCRIPTOR_STRING,       // bDescriptorType = String Descriptor

```



```
// String: "ezUSB-CORE Demo 2008/11/18"  
'e',0, 'z',0, 'U',0, 'S',0, 'B',0, '-',0, 'C',0, 'O',0, 'R',0, 'E',0, ' ',0,  
'D',0, 'e',0, 'm',0, 'o',0, ' ',0, '2',0, '0',0, '0',0, '8',0, '/',0, '1',0, '1',0, '/',0, '1',0, '8',0  
};
```

了解这些描述符的用法以及作用，最好的方法的是编写自定义的 USB 上位机驱动以及应用程序，这样你可以深刻了解 USB 设备与主机间的数据交换方式以及实现手段。

## 第六篇：XP 下 USB 驱动开发的初步准备工作

### 必须先决条件：

1: XP DDK (Driver Development Kits) , 可从 MS 网站下载。(Windows 2000 下请使用 Windows 2000 DDK) , 具备后安装 DDK, 如果你觉得只需要利用 DDK 就可以开发驱动, 那么接下来的内容完全可以不看, 在这讨论的是利用 DriverStudio 的 DriverWinziard 生成的驱动框架。因为纯粹利用 DDK 开发驱动将是项十分艰巨的工作, 需要你了解太多的系统知识, 开发全部基于 C 语言, 而且底层驱动处理稍微不当, 就容易让你系统直接挂了 (WINDOWS 著名的蓝屏)。DDK 提供了一些驱动代码, 有兴趣的朋友可以参考参考。

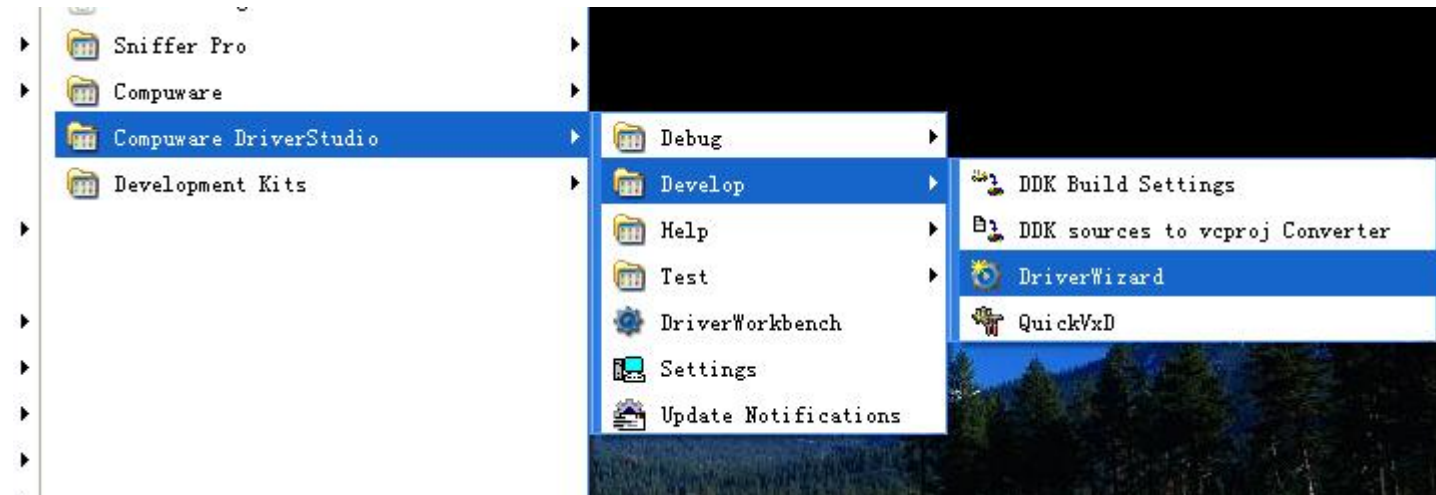
2: Compuware DriverStudio V3.2: Compuware 出品, 是进行驱动开发最常见的平台, 他封装了大部分设备驱动所必须的基本框架, 以 C++形式生成 VC6.0 或者 VS2002、2003、2005 工程, 用户一般只需要对该工程进行一些修改就可以完成最终目的。

3: 代码开发环境 VC6.0, 这个大家都知道

安装了 Windows XP DDK:



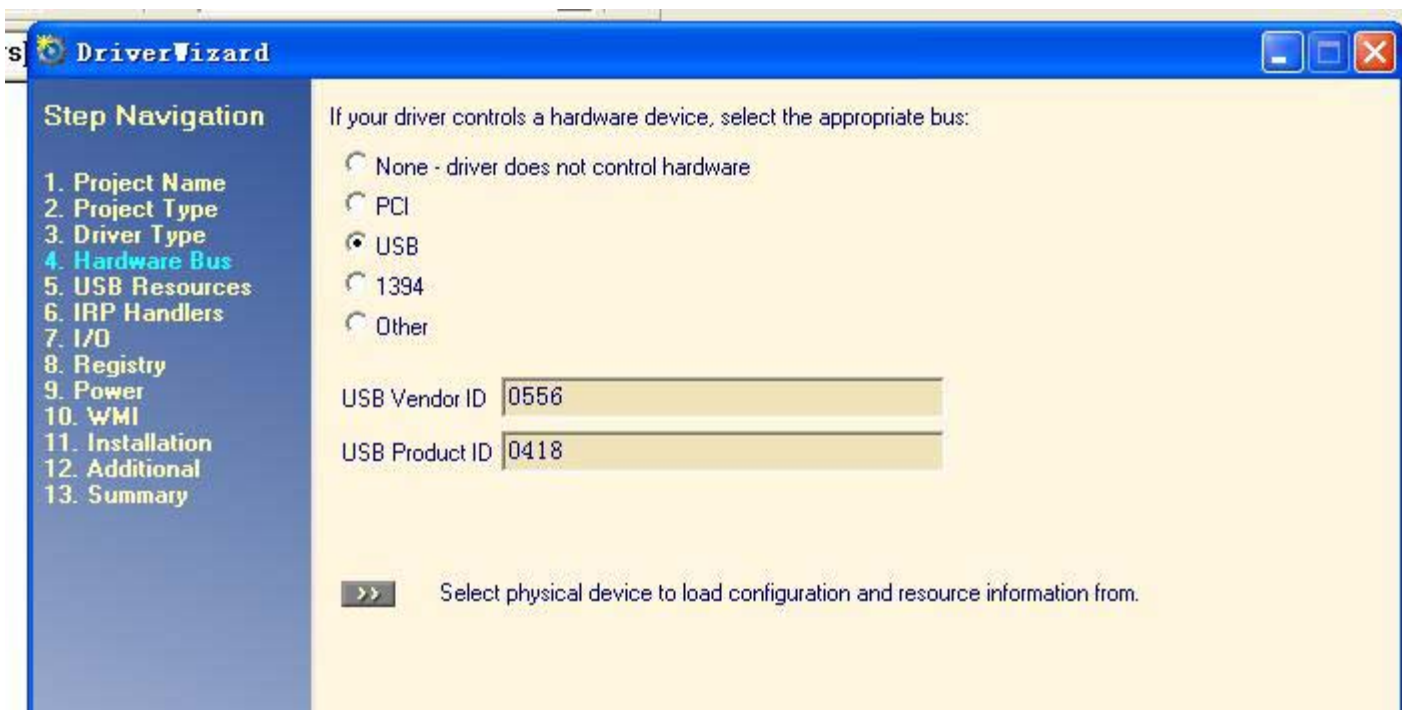
安装了 DriverStudio:



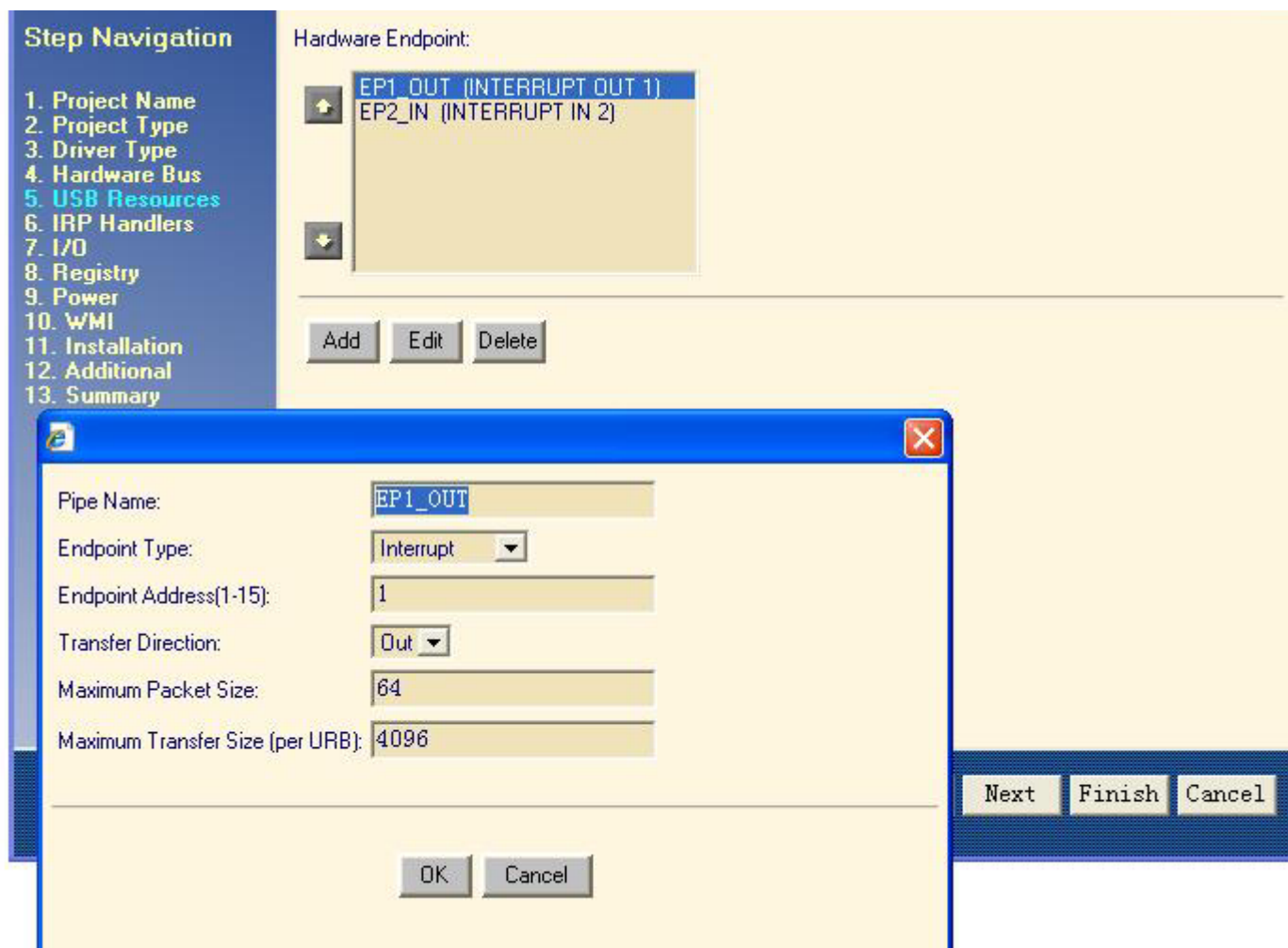
之后，DriverStudio 以插件形式嵌入到 VC6:



这样，就可以进行驱动开发了，首先打开 DriverWizard 生成需要设计的驱动框架，以 USB 驱动为例需要特殊说明的是：这里填写的 Vendor ID 和 Product ID 必须与 USB 设备固件程序里设备描述符里的 Vendor ID 和 Product ID 一致，这两个 ID 用以寻找配对的驱动。



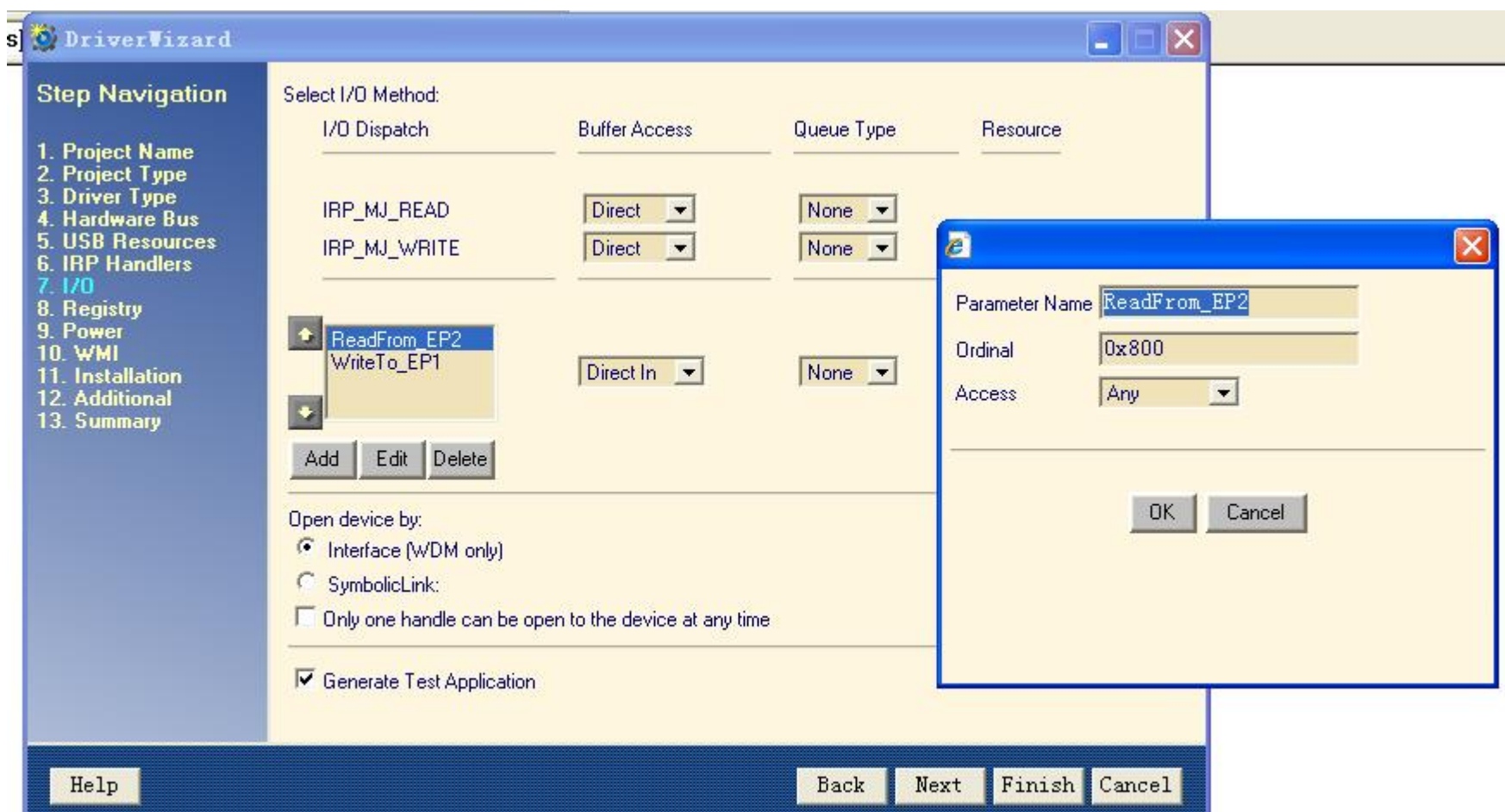
这里添加的是 USB 端点特性，在生成的程序框架中，管道名称(Pipe Name)将作为程序的内部变量成员，派属 KUsbPipe 类，端点操作函数都集成在此类中。在这设置 USB 设备 Enpoint 1 为接收端口，Enpoint 2 为发送端口。



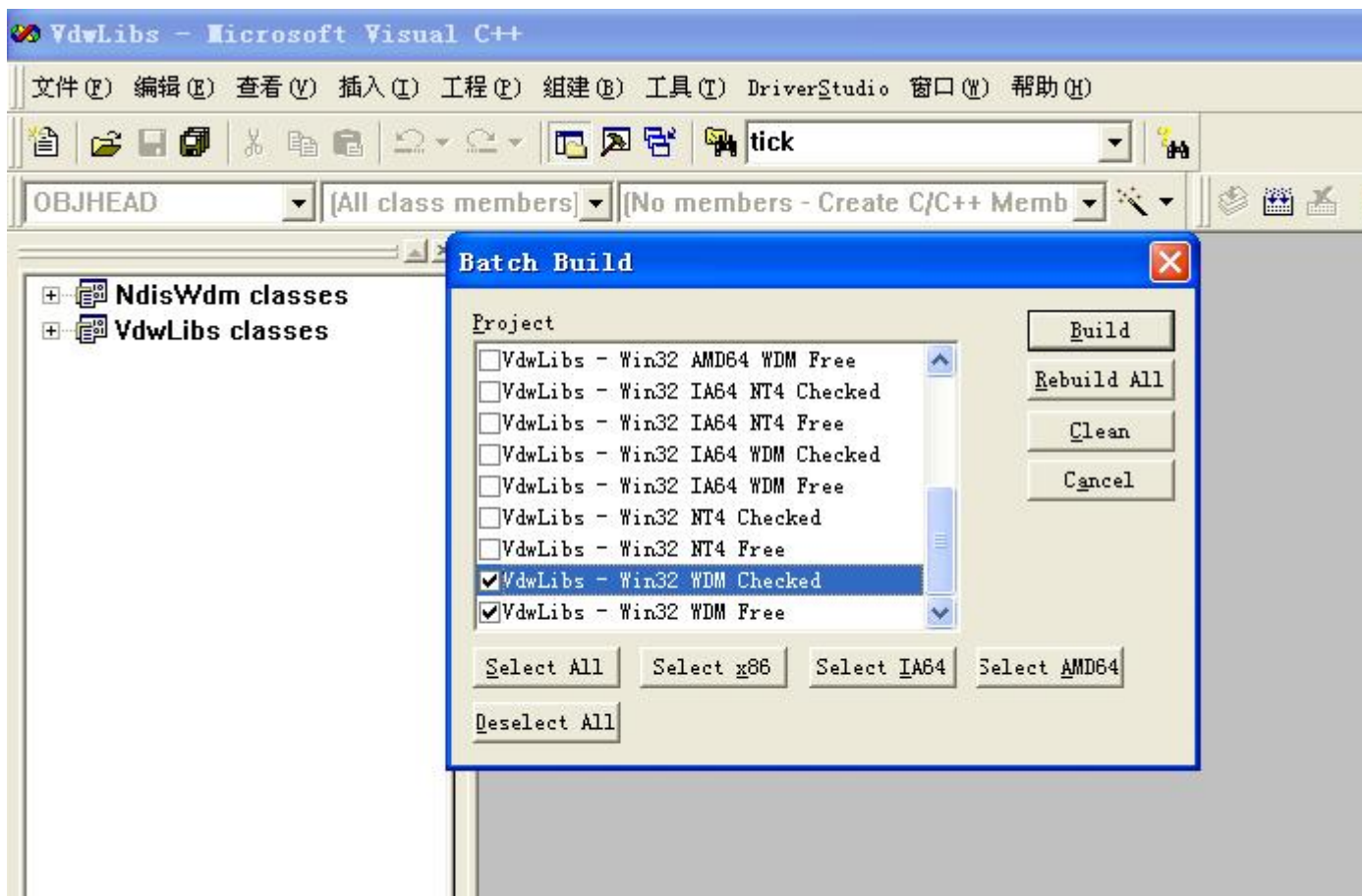
这里添加 USB 的控制操作方式，在 NT 平台下应用程序控制设备只能通过 ReadFile()/WriteFile() 和 DeviceIoControl() 两做方式，执行 ReadFile()/WriteFile() 将响应 IRP\_MJ\_READ/IRP\_MJ\_WRITE 请求，在这添加了 ReadFrom\_EP2 和 WriteTo\_EP1 两个 IRP\_MJ\_DEVICE\_CONTROL 请求代码，在执行 DeviceIoControl() 时，可以根据请求这两个请求代码进行区别，DriverWizard 生成的框架中将增添两个函数：

```
NTSTATUS ezUSBDevice::ReadFrom_EP2_Handler(KIrp I);
```

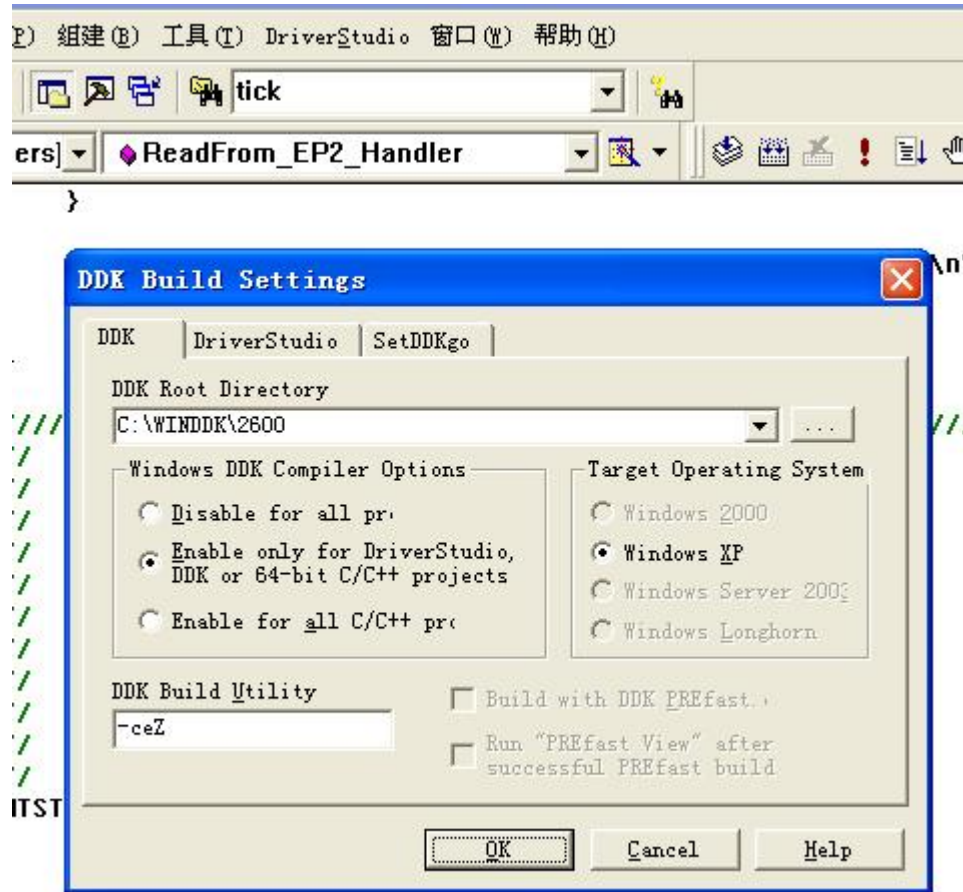
```
NTSTATUS ezUSBDevice::WriteTo_EP1_Handler(KIrp I);
```



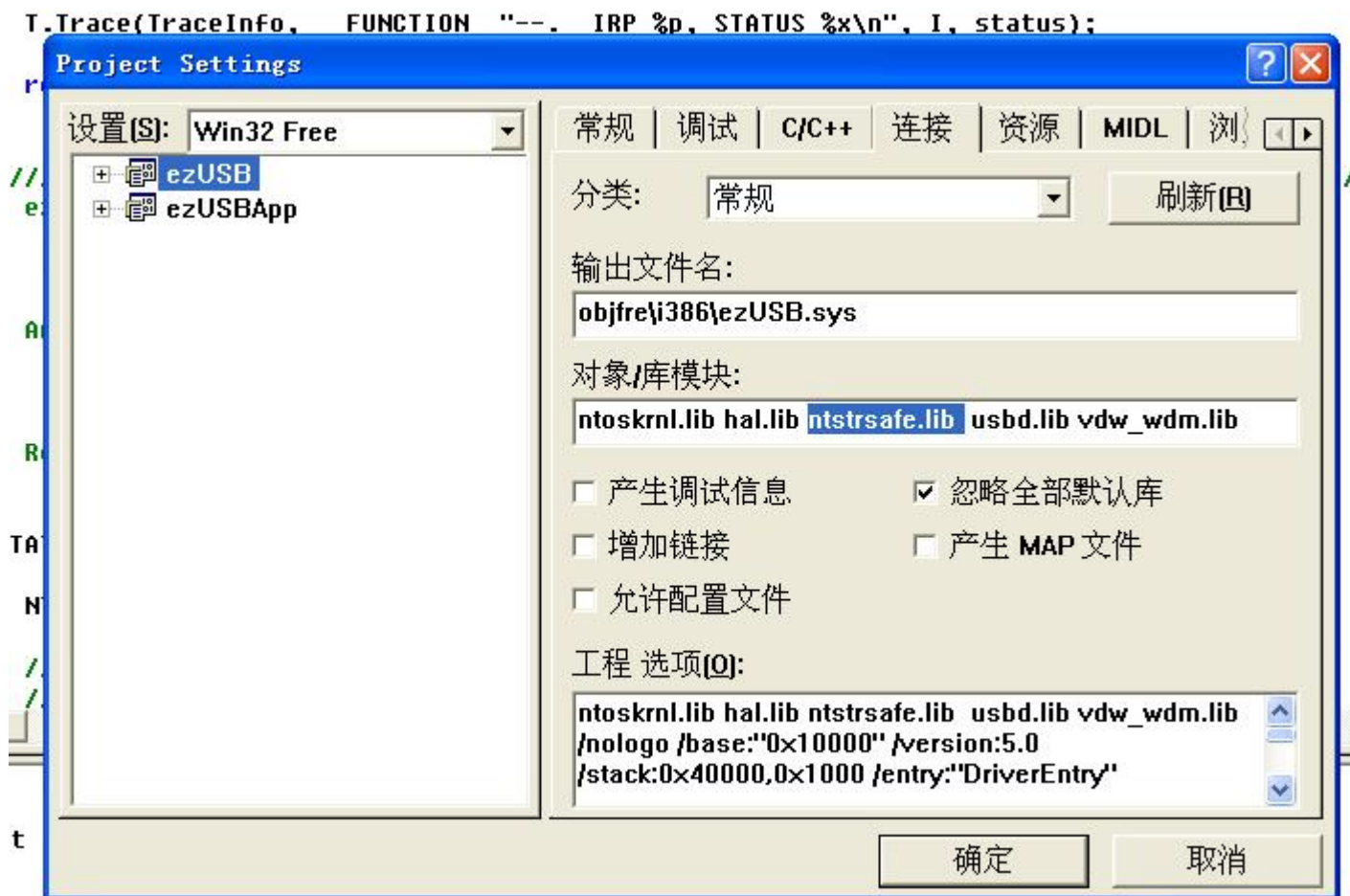
如果 DriverStudio 首次安装后, 请先利用 VC6 打开 \Compuware\DriverStudio\DriverWorks\source \VdwLibs.dsw 工程, 然后按照以下方法编译: VC6 主菜单->Build->Batch Build, 按图示设置后点击 Rebuild All, 编译成功后关闭此项目:



DriverWizard 框架生成完成后，就可以在设定的路径下找到你设置的工程，至此就可以使用 VC6 打开工程。打开后请先打开 VC6 中 DriverStudio 插件：VC6 主 菜单->DriverStudio->DDK Build Settings，选择 DDK 目录：

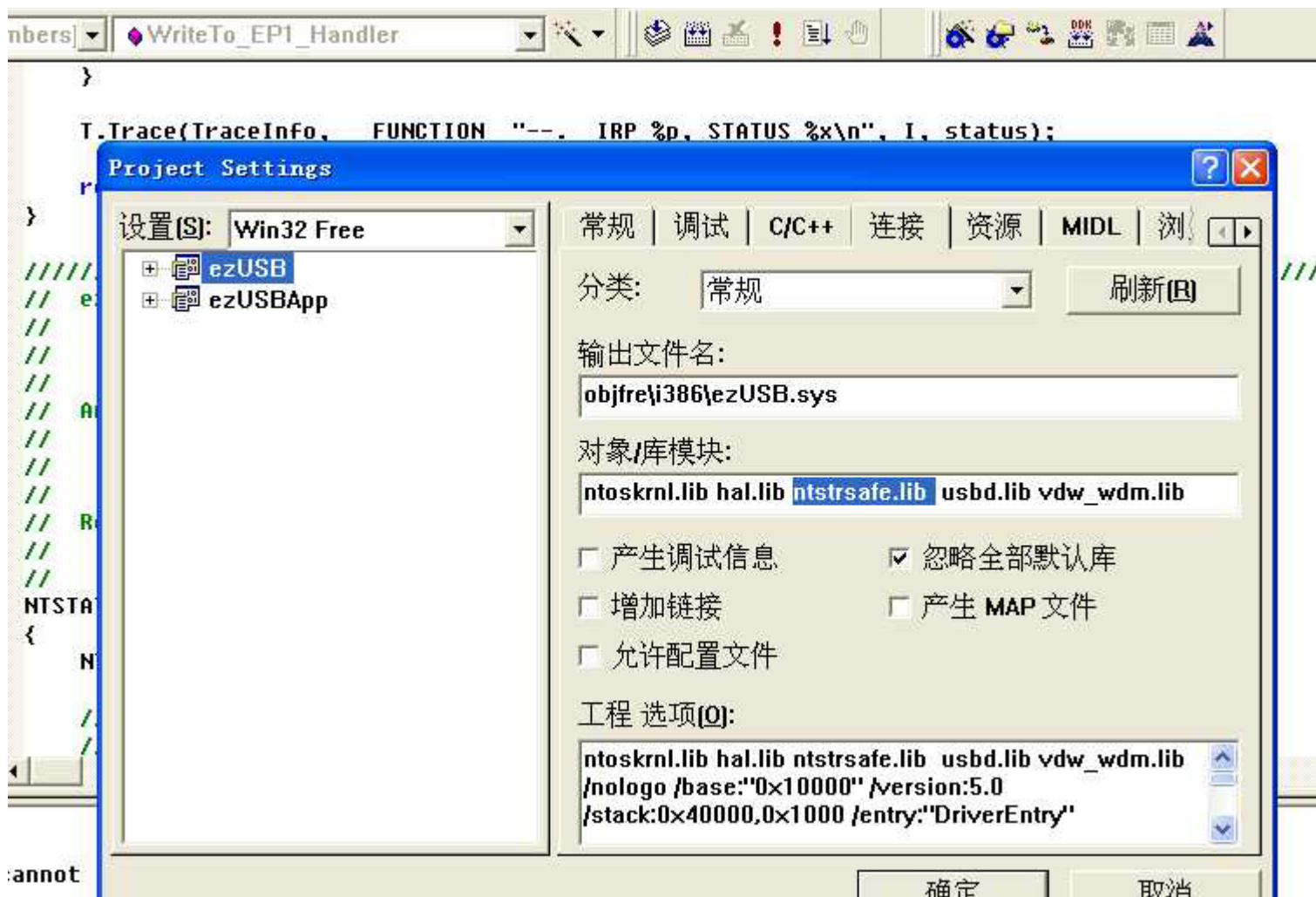


至此就可以编译该工程了，如果提示找不到库:ntstrsafe.lib，请删除此库：





到此，对利用 DriverStudio 进行 USB 驱动开发的开发环境的设置做了一些着重的介绍，具体工程如出现一些特殊情况请利用网络资源收集，下篇将介绍 USB 应用程序与驱动之间的数据交换。



## 第七篇：XP 下 USB 驱动开发的最终完成

这是我进行的唯一一次驱动开发，对 DDK 以及 DriverStudio 知之甚少，驱动代码部分不做阐述，在这我将 STM32-USB 驱动-应用程序串联起来说明。

在 VC6 环境下，连接 USB 驱动部分我写了个类 CUSBAPI 来封装该操作，在 USBAPI.h 文件中：

```
#define FILE_DEVICE_EZUSB 0x8000

#define EZUSB_IOCTL(index) \
    CTL_CODE(FILE_DEVICE_EZUSB, index, METHOD_BUFFERED, FILE_READ_DATA)

#define ReadFrom_EP2 \
    CTL_CODE(FILE_DEVICE_EZUSB, 0x800, METHOD_IN_DIRECT, FILE_ANY_ACCESS)
#define WriteTo_EP1 \
    CTL_CODE(FILE_DEVICE_EZUSB, 0x801, METHOD_OUT_DIRECT, FILE_ANY_ACCESS)
```

这部分定义的是 DeviceIoControl() 函数所需要的 I/O 控制代码，此定义在 DriverWizard 生成的 interface.h 文件中，在这可包含 interface.h 也可以复制过来进行定义。

```
typedef struct _NODE_ENUDEVICEINTERFACE
{
    CHAR    pDeviceInterfaceSymbolicName[MAX_PATH];    // Index for this node

    struct _NODE_ENUDEVICEINTERFACE *pNext;
}
NODE_ENUMDI,
```

```
*PNODE_ENUMDI;
```

这个链表用以存储 USB 设备的接口名称，需要另外说明的一点，在 USBAPI.c 文件中定义了：

```
DEFINE_GUID(GUID_DEVICEINTERFACE,
```

```
    0xE075C5B2, 0xE7FB, 0x4186, 0xA1, 0x39, 0x0B, 0x3F, 0xD2, 0x05, 0xE7, 0x6E);
```

需要通过这个 GUID\_DEVICEINTERFACE 取得该接口名称，有了该接口名称后就可以通过 CreateFile() 获取该接口的句柄，进而可以通过 ReadFile()/WriteFile() 或者 DeviceIoControl() 读写 USB 设备。获取一个设备可能有多个接口，在该类中建立了一个循环链表用以存储该信息。

```
typedef struct _STRUCT_IO
```

```
{
```

```
    HWND hTargetWnd;
```

```
    HANDLE hDevice;
```

```
    DWORD dwIoControlCode;
```

```
    PCHAR pInBuffer;
```

```
    DWORD dwInSize;
```

```
    PCHAR pOutBuffer;
```

```
    DWORD dwOutSize;
```

```
    LPDWORD lpBytesReturned;
```

```
}
```

```
STRUCT_IO,
```

```
*PSTRUCT_IO;
```

这个结构中的 hTargetWnd 定义了消息对象的窗口句柄，用以向该窗口发送读写数据完成的消息；hDevice 即 USB 设备接口的句柄；其他的含义很明了，就不说明了。

```
#define CORESTATUS_SUCCESS                0x0000L
#define CORESTATUS_DESTROY                0x0001L
#define CORESTATUS_READWRITE_EVENT_ERROR 0x0002L
#define CORESTATUS_READWRITE_THREAD_ERROR 0x0003L
#define CORESTATUS_IOCTLCONTROL_EVENT_ERROR 0x0004L
#define CORESTATUS_IOCTLCONTROL_THREAD_ERROR 0x0005L
```

这些是定义的类状态，应用程序可以获取这些状态。

```
#define MSG_READWRITE_COMPLETION          WM_USER+0x0010
#define MSG_IOCTLCONTROL_COMPLETION       WM_USER+0x0011
```

这些定义的是自定义消息码，应用程序识别此消息码可得知读写操作已完成。

```
#define ERROR_HANDLE_WINDOW              0x1000L
#define ERROR_HANDLE_DEVICE              0x1001L
#define ERROR_BUFFER_LENGTH              0x1002L
#define ERROR_BUFFER_ISNULL              0x1003L
#define ERROR_READWRITE_BUSY              0x1004L
#define ERROR_IOCTLCONTROL_BUSY          0x1005L
```

这些定义的进行读写操作时，进行的一些参数检查并返回的状态。

下面这些是类成员函数以及变量，USBAPI 类内建立了两个独立线程，这样在对 USB 设备进行读写时，就不会堵塞应用程序的窗口线程，读写操作完成后由消息 MSG\_READWRITE\_COMPLETION 和 MSG\_IOCTLCONTROL\_COMPLETION 通知应用程序。详细代码请参考源程序。

```
// *****
```

```
// Class members definition
// *****
class CUSBAPI
{
public:
    CUSBAPI();
    virtual ~CUSBAPI();

public:

    DWORD EnumDeviceInterface(LPGUID pGUID);
    HANDLE OpenDeviceInterface(PCHAR pDeviceInterfaceSymbolicName);

    DWORD Execute_ReadFile(
        HWND    hWnd,
        HANDLE   hDevice,
        PCHAR    pInBuffer,
        DWORD    dwInSize,
        LPDWORD  lpBytesReturned
    );

    DWORD Execute_WriteFile(
        HWND    hWnd,
        HANDLE   hDevice,
        PCHAR    pOutBuffer,
        DWORD    dwOutSize,
```

```
LPDWORD lpBytesReturned  
);
```

```
DWORD Execute_IoControl(  
    HWND    hWnd,  
    HANDLE   hDevice,  
    DWORD    dwIoControlCode,  
    PCHAR    pInBuffer,  
    DWORD    dwInSize,  
    PCHAR    pOutBuffer,  
    DWORD    dwOutSize,  
    LPDWORD  lpBytesReturned  
);
```

```
BOOL Node_HeadCreate(VOID);  
VOID Node_HeadDelete(VOID);  
VOID Node_RemoveAll(VOID);  
BOOL Node_Append(PCHAR pDeviceInterfaceSymbolicName);  
VOID Node_Remove(PCHAR pDeviceInterfaceSymbolicName);  
PNODE_ENUMDI Node_Find(PCHAR pDeviceInterfaceSymbolicName);
```

```
public:
```

```
GUID GUID_Device;
```

```
PNODE_ENUMDI pEnumDeviceNode;
```

```
PNODE_ENUMDI pEnumDeviceHead;
```

```
HANDLE hEvent_ReadWrite;
HANDLE hEvent_IoControl;

HANDLE hThread_ReadWrite;
HANDLE hThread_IoControl;

DWORD dwThreadID_ReadWrite;
DWORD dwThreadID_IoControl;

STRUCT_IO ReadWrite;
STRUCT_IO IoControl;

BOOL bExecuting_IoControl;
BOOL bExecuting_ReadWrite;

DWORD dwCoreStatus;
};
```

在应用程序中定义变量：CUSBAPI ezUSB;

读写操作函数也就三种：

Execute\_IoControl()、Execute\_ReadFile()、Execute\_WriteFile()

执行这些函数后，将与 USB 的驱动程序挂钩，分别响应：

```
Execute_IoControl() -> NTSTATUS ezUSBDevice::DeviceControl(KIrp I)
Execute_ReadFile() -> NTSTATUS ezUSBDevice::Read(KIrp I)
Execute_WriteFile() -> NTSTATUS ezUSBDevice::Write(KIrp I)
```

其中 NTSTATUS ezUSBDevice::DeviceControl(KIrp I) 根据 I.IoctlCode() 区别类型，按照此示例说明：

```
ReadFrom_EP2->Execute_IoControl()->NTSTATUS ezUSBDevice::ReadFrom_EP2_Handler(KIrp I)
WriteTo_EP1->Execute_IoControl()->NTSTATUS ezUSBDevice::WriteTo_EP1_Handler(KIrp I)
```

这样应用程序与 USB 驱动之间就建立了通讯渠道，在驱动函数中：

```
NTSTATUS ezUSBDevice::DeviceControl(KIrp I)
NTSTATUS ezUSBDevice::Read(KIrp I)
NTSTATUS ezUSBDevice::Write(KIrp I)
```

执行一些操作就可以与 STM32 的 USB 设备进行通讯了，此时就需要很好的掌握 DriverStudio 封装的各种类库了。

DriverStudio 向导生成的框架，一般就只需要更改这三个函数接口，当然，对于 DriverStudio 向导的一个 BUG 不可不知：

```
// Initialize each Pipe object
EP1_OUT.Initialize(m_Lower, 1, 64);
EP2_IN.Initialize(m_Lower, 82, 64);
```

Initialize() 函数第二参数是端点地址，在这这是 16 进制表示，这里需要补上 0x：

```
// Initialize each Pipe object
EP1_OUT.Initialize(m_Lower, 0x01, 64);
EP2_IN.Initialize(m_Lower, 0x82, 64);
```

忘记此处修改的后果是，执行 EP2\_IN 操作将会使系统直接蓝屏。

这三个函数接口中涉及到读写操作方式，比如说 buffer 或者 direct io，具体有什么区别，请从网络搜寻。

USB 驱动负责底层通过端口地址及方式与 STM32 连接后，



EP1\_OUT: USB 主机向 USB 设备发送数据, void CTR\_OUT1(void)函数响应

EP2\_IN: USB 主机请求 USB 设备发送数据, void CTR\_IN2(void)函数响应

示例中 CTR\_OUT1() 接收 2Bytes 数据, CTR\_IN2() 发送 2Bytes 数据, 分别控制 LED1-4 和定时获取 Joystick 的状态:

```
void CTR_OUT1(void)
{
    unsigned short portc;
    unsigned short wCount;

    wCount = GetBuffDescTable_RXCount(ENDP1);

    if(wCount == 2)
    {
        //portc = GPIO_ReadInputData(GPIOC);

        BufferCopy_PMAToUser((unsigned char *)&portc, GetBuffDescTable_RXAddr(ENDP1), 2);

        GPIO_Write(GPIOC, (GPIO_ReadInputData(GPIOC)&0xFF0F) | (portc&0x00F0));
    }

    SetEPR_RXStatus(ENDP1, EP_RX_VALID);
    SetEPR_TXStatus(ENDP1, EP_TX_STALL);
}

void CTR_IN2(void)
```

```
{
unsigned short portd = GPIO_ReadInputData(GPIOD) & 0xF800; // 11-15

// Copy the transfer buffer to the endpoint0's buffer
BufferCopy_UserToPMA( (unsigned char *)&portd, // transfer buffer
                      GetBuffDescTable_TXAddr(ENDP2), // endpoint 0 TX address
                      2);

SetBuffDescTable_TXCount(ENDP2, 2);
SetEPR_RXStatus(ENDP2, EP_RX_DIS);
SetEPR_TXStatus(ENDP2, EP_TX_VALID);
}
```

至此，整个基于 STM32 的 USB 开发过程的介绍大致说了一遍，详细情况请参考源代码，这篇学习笔记到此结束了，水平有限，错误难免！谢谢这段时间关心与支持的朋友们，欢迎朋友们一起探讨学习。

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