UM0424
User manual

STM32 USB-FS-Device development kit

Introduction

The STM32 USB-FS-Device development kit is a complete firmware and software package including examples and demos for all USB transfer types (control, interrupt, bulk and isochronous).

The aim of the STM32 USB-FS-Device development kit is to use the STM32 USB-FS-Device library with at least one firmware demo per USB transfer type.

This document presents a description of all the components of the STM32 USB-FS-Device development kit, including:

- STM32 USB-FS-Device library: All processes related to default endpoint and standard requests
- Device firmware upgrade (DFU) demo: Control transfer
- Joystick mouse demo: Interrupt transfer
- Custom HID demo: Interrupt transfer
- Mass storage demo: Bulk transfer
- Virtual COM port: Interrupt and bulk transfer
- CDC LoopBack demo: Interrupt and bulk transfer
- Composite Example: Interrupt and bulk transfer
- USB voice speaker demo (USB speaker): Isochronous transfer

Table 1. Applicable products

Type	Part numbers or product categories
Microcontrollers	STM32F102xx and STM32F103xx series
	STM32 L1 Ultra Low Power
	STM32 F3 Series

Note: Starting from this release, STM32F105/F107 are no longer supported. These devices are supported by the STM32 USB OTG Host and Device Library. For more details, please refer to user manual UM1021.

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1 Related documents

For more information on using the microcontroller devices listed in *Table 1: Applicable products*, please refer to the reference manuals below:

Table 2. Reference manual name related to each STM32 device

Device name	Reference manual
STM32L151xx and STM32L152xx	RM0038
STM32F102xx and STM32F103xx	RM0008
STM32F302xx and STM32F303xx	RM0316
STM32F372xx and STM32F373xx	RM0313

The STM32 USB-FS-Device library is designed for use with the following evaluation boards:

Table 3. User manual name related to each evaluation board

Eval board name	User manual	Device name
STM3210E-EVAL	UM0488	STM32F103ZGT6
STM3210B-EVAL	UM0426	STM32F103VBT6
STM32L152-EVAL	UM1018	STM32L152VBT6
STM32L152D-EVAL	UM1521	STM32L152ZDT6
STM32373C-EVAL	UM1564	STM32F373VCT6
STM32303C-EVAL	UM1567	STM32F303VCT6

2 STM32 microcontroller family overview

In this document, STM32 refers to the following devices:

- Low-density devices: STM32F101xx, STM32F102xx and STM32F103xx microcontrollers where the Flash memory density ranges between 16 and 32 Kbytes.
  Medium-density devices: STM32F101xx, STM32F102xx and STM32F103xx microcontrollers where the Flash memory density ranges between 64 and 128 Kbytes.
- High-density devices: STM32F101xx and STM32F103xx microcontrollers where the Flash memory density ranges between 256 and 512 Kbytes.
- XL-density devices: STM32F101xx and STM32F103xx microcontrollers where the Flash memory density ranges between 512 and 1024 Kbytes.
- Medium-density Low-Power devices: STM32L15xx microcontrollers where the Flash memory density ranges between 64 and 128 Kbytes.
- Low Power Medium-density Plus devices:STM32L15xx and STM32L162xx microcontrollers where the Flash memory density is 256 Kbytes.
- Low Power High-density devices: STM32L15xx and STM32L162xx microcontrollers where the Flash memory density is 384 Kbytes.
- STM32F3 Series:
  - STM32F30xx microcontrollers where the Flash memory density ranges between 128 and 256 Kbytes.
  - STM32F37xx microcontrollers where the Flash memory density ranges between 64 and 256 Kbytes.

3 STM32 USB-FS-Device firmware library

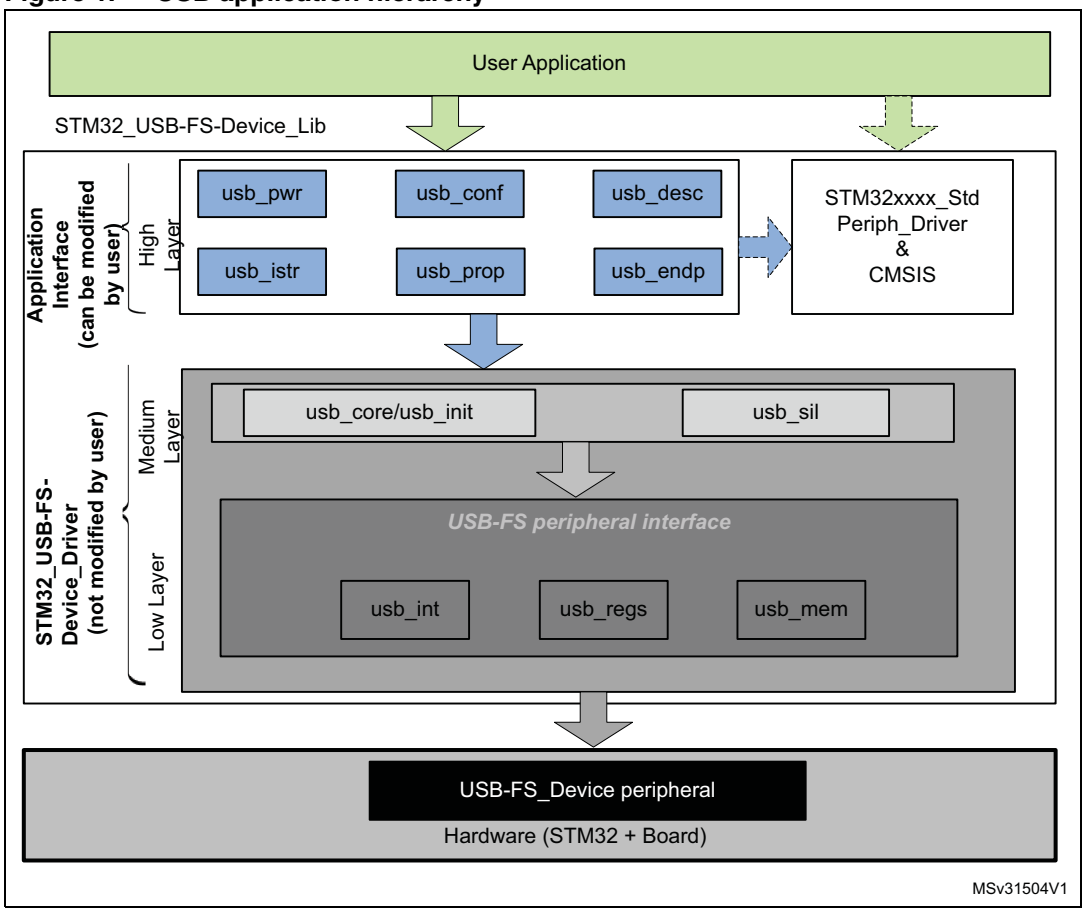
This section describes the firmware interface (called USB-FS-Device Library) used to manage the STM32 USB 2.0 full-speed device peripheral. In the rest of the document, it will be referred to as USB-FS_Device peripheral .

The main purpose of this firmware library is to provide resources to ease the development of applications for each USB transfer type using the USB-FS_Device peripheral in the STM32 microcontroller families.

3.1 USB application hierarchy

Figure 1 shows the interaction between the different components of a typical USB application and the USB-FS-Device library.

Figure 1. USB application hierarchy



As seen in *Figure 1*, the USB-FS-Device library is divided into two layers:

- **STM32_USB-FS_Device_Driver:** this layer manages the direct communication with the USB-FS_Device peripheral and the USB standard protocol. The STM32_USB-FS_Device_Driver is compliant with the USB 2.0 specification and is separate from the standard STM32 standard peripheral library
- **Application Interface layer:** this layer provides the user with a complete interface between the library core and the final application.

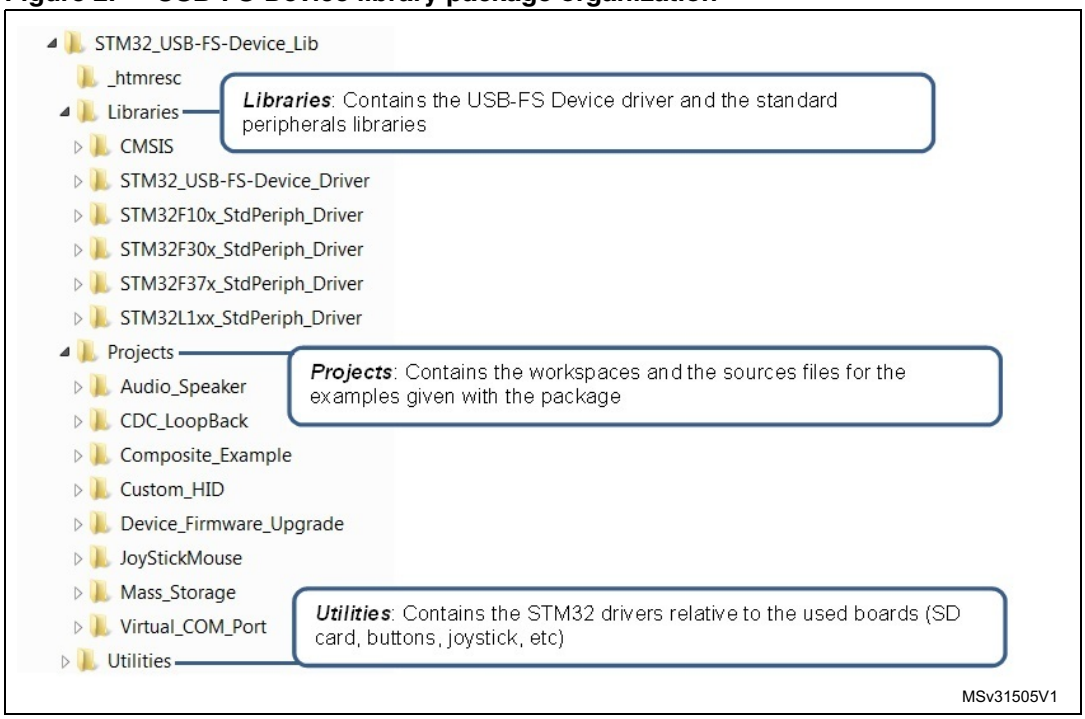
Note: The USB-FS peripheral interface layer is loaded (through defines at compile time) and used as the peripheral interface layer.

The application interface layer and the final application can communicate with the standard peripherals library to manage the hardware needs of the application.

A detailed description of these layers with coding rules is provided in the next sections.

Figure 2 shows the package organization of the USB-FS-Device library with all the demonstrations and subfolders.

Figure 2. USB-FS-Device library package organization



3.2 USB-FS_Device peripheral interface

Table 4 presents the USB-FS_Device peripheral interface modules.

Table 4. USB-FS_Device peripheral interface modules

File	Description
usb_reg (.h, .c)	Hardware abstraction layer
usb_int.c	Correct transfer interrupt service routine
usb_mem(.h,.c)	Data transfer management (from/to packet memory area)

3.2.1 usb_reg(.h, .c)

The **usb_regs** module implements the hardware abstraction layer, it offers a set of basic functions for accessing the USB-FS_Device peripheral registers.

Note: The available functions have two call versions:

- As a macro: the call is: _NameofFunction(parameter1, ...)
- As a subroutine: the call is: NameofFunction(parameter1, ...)

Common register functions

The functions in *Table 5* can be used to set or get the various common USB-FS_Device peripheral registers.

Table 5. Common register functions

Register	Function
CNTR	`void SetCNTR (uint16_t wValue)`
	`uint16_t GetCNTR (void)`
ISTR	`void SetISTR (uint16_t wValue)`
	`uint16_t GetISTR (void)`
FNR	`uint16_t GetFNR (void)`
DADDR	`void SetDADDR (uint16_t wValue)`
	`uint16_t GetDADDR (void)`
BTABLE	`void SetBTABLE (uint16_t wValue)`
	`uint16_t GetBTABLE (void)`

Endpoint register functions

All operations with endpoint registers can be obtained with the `SetENDPOINT` and `GetENDPOINT` functions. However, many functions are derived from these to offer the advantage of a direct action on a specific field.

a) Endpoint set/get value

```
SetENDPOINT : void SetENDPOINT(uint8_t bEpNum,uint16_t wRegValue)
bEpNum = Endpoint number, wRegValue = Value to write
GetENDPOINT : uint16_t GetENDPOINT(uint8_t bEpNum)
bEpNum = Endpoint number
return value: the endpoint register value
```

b) Endpoint TYPE field

The EP_TYPE field of the endpoint register can assume the defined values below:

```
#define EP_BULK              (0x0000)   // Endpoint BULK
#define EP_CONTROL           (0x0200)   // Endpoint CONTROL
#define EP_ISOCHRNOUS        (0x0400)   // Endpoint ISOCHRONOUS
#define EP_INTERRUPT         (0x0600)   // Endpoint INTERRUPT

SetEPType :   void SetEPType (uint8_t bEpNum, uint16_t wtype)
bEpNum = Endpoint number, wtype = Endpoint type (value from the
above define's)
GetEPType :   uint16_t GetEPType (uint8_t bEpNum)
bEpNum = Endpoint number
return value: a value from the above define's
```

c) Endpoint STATUS field

The STAT_TX / STAT_RX fields of the endpoint register can assume the defined values below:

```
#define EP_TX_DIS            (0x0000)   // Endpoint TX DISabled
#define EP_TX_STALL          (0x0010)   // Endpoint TX STALLed
#define EP_TX_NAK            (0x0020)   // Endpoint TX NAKed
#define EP_TX_VALID          (0x0030)   // Endpoint TX VALID
#define EP_RX_DIS            (0x0000)   // Endpoint RX DISabled
#define EP_RX_STALL          (0x1000)   // Endpoint RX STALLed
#define EP_RX_NAK            (0x2000)   // Endpoint RX NAKed
#define EP_RX_VALID          (0x3000)   // Endpoint RX VALID
SetEPTxStatus : void SetEPTxStatus(uint8_t bEpNum,uint16_t wState)
SetEPRxStatus : void SetEPRxStatus(uint8_t bEpNum,uint16_t wState)
bEpNum = Endpoint number, wState = a value from the above define's
GetEPTxStatus : uint16_t GetEPTxStatus(uint8_t bEpNum)
GetEPRxStatus : uint16_t GetEPRxStatus(uint8_t bEpNum)
bEpNum = endpoint number
return value:a value from the above define's
```

d) Endpoint KIND field

```
SetEP_KIND    :  void SetEP_KIND(uint8_t bEpNum)
ClearEP_KIND  :  void ClearEP_KIND(uint8_t bEpNum)
bEpNum = endpoint number
Set_Status_Out    :  void Set_Status_Out(uint8_t bEpNum)
Clear_Status_Out  :  void Clear_Status_Out(uint8_t bEpNum)
bEpNum = endpoint number
SetEPDoubleBuff    :  void SetEPDoubleBuff(uint8_t bEpNum)
ClearEPDoubleBuff  :  void ClearEPDoubleBuff(uint8_t bEpNum)
bEpNum = endpoint number

Correct Transfer Rx/Tx fields
ClearEP_CTR_RX  :  void ClearEP_CTR_RX(uint8_t bEpNum)
ClearEP_CTR_TX  :  void ClearEP_CTR_TX(uint8_t bEpNum)
bEpNum = endpoint number
```

e) Data Toggle Rx/Tx fields

```
ToggleDTOG_RX  :  void ToggleDTOG_RX(uint8_t bEpNum)
ToggleDTOG_TX  :  void ToggleDTOG_TX(uint8_t bEpNum)
bEpNum = endpoint number
```

f) Address field

```
SetEPAdress  :  void SetEPAddress(uint8_t bEpNum,uint8_t bAddr)
bEpNum = endpoint number
bAddr  = address to be set
GetEPAdress  : uint8_t GetEPAddress(uint8_t bEpNum)
bEpNum = endpoint number
```

Buffer description table functions

These functions are used in order to set or get the endpoints' receive and transmit buffer addresses and sizes.

a) Tx/Rx buffer address fields

```
SetEPTxAddr : void SetEPTxAddr(uint8_t bEpNum,uint16_t wAddr);
SetEPRxAddr : void SetEPRxAddr(uint8_t bEpNum,uint16_t wAddr);
bEpNum = endpoint number
wAddr  = address to be set (expressed as PMA buffer address)
GetEPTxAddr : uint16_t GetEPTxAddr(uint8_t bEpNum);
GetEPRxAddr : uint16_t GetEPRxAddr(uint8_t bEpNum);
bEpNum = endpoint number
return value : address value (expressed as PMA buffer address)
```

b) Tx/Rx buffer counter fields

```
SetEPTxCount : void SetEPTxCount(uint8_t bEpNum,uint16_t wCount);
SetEPRxCount : void SetEPRxCount(uint8_t bEpNum,uint16_t wCount);
bEpNum = endpoint number
wCount = counter to be set
GetEPTxCount : uint16_t GetEPTxCount(uint8_t bEpNum);
GetEPRxCount : uint16_t GetEPRxCount(uint8_t bEpNum);
bEpNum = endpoint number
return value : counter value
```

Double-buffered endpoints functions

To obtain high data-transfer throughput in bulk or isochronous modes, *double-buffered* mode has to be programmed. In this operating mode some fields of the endpoint registers and buffer description table cells have different meanings.

To ease the use of this feature several functions have been developed.

- **SetEPDoubleBuff**: An endpoint programmed to work in bulk mode can be set as double-buffered by setting the EP-KIND bit. The function `SetEPDoubleBuff()` accomplishes this task:

  ```
  SetEPDoubleBuff : void SetEPDoubleBuff(uint8_t bEpNum);
  bEpNum = endpoint number
  ```

- **FreeUserBuffer**: In double-buffered mode, the endpoints become mono-directional and buffer description table cells of the unused direction are applied to handle a second buffer.

Addresses and counters must be handled in a different way. Rx and Tx Addresses and counter cells become **Buffer0** and **Buffer1** cells. Functions dedicated to this operating mode are provided for in the library.

During a bulk transfer the line fills one buffer while the other buffer is reserved to the application. A user application has to process data before the arrival of bulk needing a buffer. The buffer reserved to the application has to be freed in time.

To free the buffer in use from the application, the `FreeUserBuffer` function is provided:

```
FreeUserBuffer: void FreeUserBuffer(uint8_t bEpNum, uint8_t
bDir);
bEpNum = endpoint number
```

a) Double buffer addresses

These functions set or get buffer address value in the buffer description table for double buffered mode.

SetEPDblBuffAddr : void SetEPDblBuffAddr(uint8_t bEpNum,uint16_t wBuf0Addr,uint16_t wBuf1Addr);

SetEPDblbuf0Addr : void SetEPDblBuf0Addr(uint8_t bEpNum,uint16_t wBuf0Addr);

SetEPDblbuf1Addr : void SetEPDblBuf1Addr(uint8_t bEpNum,uint16_t wBuf1Addr);

bEpNum = endpoint number

wBuf0Addr, wBuf1Addr = buffer addresses (expressed as PMA buffer addresses)

GetEPDblBuf0Addr : uint16_t GetEPDblBuf0Addr(uint8_t bEpNum);

GetEPDblbuf1Addr : uint16_t GetEPDblBuf1Addr(uint8_t bEpNum);

bEpNum = endpoint number

return value : buffer addresses

b) Double buffer counters

These functions set or get buffer counter value in the buffer description table for double buffered mode.

SetEPDblBuffCount: void SetEPDblBuffCount(uint8_t bEpNum, uint8_t bDir, uint16_t wCount);

SetEPDblBuf0Count: void SetEPDblBuf0Count(uint8_t bEpNum, uint8_t bDir, uint16_t wCount);

SetEPDblBuf1Count: void SetEPDblBuf1Count(uint8_t bEpNum, uint8_t bDir, uint16_t wCount);

bEpNum = endpoint number

bDir = endpoint direction

wCount = buffer counter

GetEPDblBuf0Count : uint16_t GetEPDblBuf0Count(uint8_t bEpNum);

GetEPDblBuf1Count : uint16_t GetEPDblBuf1Count(uint8_t bEpNum);

bEpNum = endpoint number

return value : buffer counter

c) Double buffer STATUS

The simple and double buffer modes use the same functions to manage the Endpoint STATUS except for the STALL status for double buffer mode. This functionality is managed by the function:

SetDouBleBuffEPStall: void SetDouBleBuffEPStall(uint8_t bEpNum,uint8_t bDir)

bEpNum = endpoint number

bDir = endpoint direction

3.2.2 usb_int (.h , .c)

The **usb_int** module handles the correct transfer interrupt service routines; it offers the link between the USB device protocol events and the library.

The STM32 USB-FS_Device peripheral provides two transfer routines:

- Low-priority interrupt: managed by the function `CTR_LP()` and used for control, interrupt and bulk (in simple buffer mode).
- High-priority interrupt: managed by the function `CTR_HP()` and used for faster transfer mode like Isochronous and bulk (in double buffer mode).

3.2.3 usb_mem (.h , .c)

The **usb_mem** copies a buffer data from the user memory area to the packet memory area (PMA) and vice versa. It provides two different functions:

- void UserToPMABufferCopy(uint8_t *pbUsrBuf,uint16_t wPMABufAddr, uint16_t wNBytes);
- void PMAToUserBufferCopy(uint8_t *pbUsrBuf,uint16_t wPMABufAddr, uint16_t wNBytes);

Where:

- pbUsrBuf is the pointer to the user memory area generally in the product's SRAM.
- wPMABufAddr is the address in PMA (512-byte packet memory area dedicated to USB).
- wNBytes is the number of bytes to be copied.

3.3 USB-FS-Device_Driver medium layer

Table 6 presents the USB-FS-Device_Driver medium layer modules:

Table 6. USB-FS-Device_Driver medium layer modules

File	Description
usb_init (.h,.c)	USB device initialization global variables
usb_core (.h , .c)	USB protocol management (compliant with chapter 9 of the *USB 2.0 specification*)
usb_sil (.h,.c)	Simplified functions for read & write accesses to the endpoints (abstraction layer for the USB-FS_Device peripheral)
usb_def.h / usb_type.h	USB definitions and types used in the library
platform_config.h	Defines the hardware depending on the evaluation board used

3.3.1 usb_init(.h,.c)

This module sets initialization routines and global variables that will be used in the library.

3.3.2 usb_core (.h , .c)

This module is the "kernel" of the library. It implements all the functions described in Chapter 9 of the *USB 2.0 specification*.

The available subroutines cover handling of USB standard requests related to the control endpoint (ENDP0), offering the necessary code to accomplish the sequence of enumeration phase.

A state machine is implemented in order to process the different stages of the setup transactions.

The USB core module also implements a dynamic interface between the standard request and the user implementation using the structure **User_Standard_Requests**.

The USB core dispatches the class specific requests and some bus events to user program whenever it is necessary. User handling procedures are given in the **Device_Property** structure.

The different data and function structures used by the kernel are described in the following paragraphs.

1. **Device table structure**

   The core keeps device level information in the **Device_Table** structure. **Device_Table** is of the type: **DEVICE**.

```
typedef struct _DEVICE {
     uint8_t Total_Endpoint;
     uint8_t Total_Configuration;
} DEVICE;
```

2. **Device information structure**

   The USB core keeps the setup packet from the host for the implemented USB Device in the **Device_Info** structure. This structure has the type: **DEVICE_INFO**.

```
typedef struct _DEVICE_INFO {
     uint8_t USBbmRequestType;
     uint8_t USBbRequest;
     uint16_t_uint8_t USBwValues;
     uint16_t_uint8_t USBwIndexs;
     uint16_t_uint8_t USBwLengths;
     uint8_t ControlState;
     uint8_t Current_Feature;
     uint8_t Current_Configuration;
     uint8_t Current_Interface;
     uint8_t Current_AlternateSetting;
     ENDPOINT_INFO Ctrl_Info;
} DEVICE_INFO;
```

   An union **uint16_t_uint8_t** is defined to easily access some fields in the **DEVICE_INFO** in either **uint16_t** or **uint8_t** format.

```
typedef union {
     uint16_t w;
     struct BW {
     uint8_t bb1;
     uint8_t bb0;
     } bw;
} uint16_t_uint8_t;
```

Description of the structure fields:

- **USBbmRequestType** is the copy of the *bmRequestType* of a setup packet
- **USBbRequest** is the copy of the *bRequest* of a setup packet
- **USBwValues** is defined as type: **uint16_t_uint8_t** and can be accessed through 3 macros:

```
#define USBwValue USBwValues.w
#define USBwValue0 USBwValues.bw.bb0
#define USBwValue1 USBwValues.bw.bb1
```

  USBwValue is the copy of *the wValue* of a setup packet
  USBwValue0 is the low byte of *wValue*, and **USBwValue1** is the high byte of *wValue*.
- **USBwIndexs** is defined as USBwValues and can be accessed by 3 macros:

```
#define USBwIndex USBwIndexs.w
#define USBwIndex0 USBwIndexs.bw.bb0
#define USBwIndex1 USBwIndexs.bw.bb1
```

  USBwIndex is the copy of the *wIndex* of a setup packet
  USBwIndex0 is the low byte of *wIndex*, and **USBwIndex1** is the high byte of *wIndex*.
- **USBwLengths** is defined as type: **uint16_t_uint8_t** and can be accessed through 3 macros:

```
#define USBwLength USBwLengths.w
#define USBwLength0 USBwLengths.bw.bb0
#define USBwLength1 USBwLengths.bw.bb1
```

  USBwLength is the copy of the *wLength* of a setup packet
  USBwLength0 and **USBwLength1** are the low and high bytes of *wLength*, respectively.
- **ControlState** is the state of the core, the available values are defined in CONTROL_STATE.
- **Current_Feature** is the device feature at any time. It is affected by the SET_FEATURE and CLEAR_FEATURE requests and retrieved by the GET_STATUS request. User code does not use this field.
- **Current_Configuration** is the configuration the device is working on at any time. It is set and retrieved by the SET_CONFIGURATION and GET_CONFIGURATION requests, respectively.
- **Current_Interface** is the selected interface.
- **Current_Alternatesetting** is the alternative setting which has been selected for the current working configuration and interface. It is set and retrieved by the SET_INTERFACE and GET_INTERFACE requests, respectively.
- **Ctrl_Info** has type ENDPOINT_INFO.

  Since this structure is used everywhere in the library, a global variable **pInformation** is defined for easy access to the **Device_Info** table, it is a pointer to the **DEVICE_INFO** structure.

  Actually, **pInformation = &Device_Info**.

3. **Device property structure**

The USBcore dispatches the control to the user program whenever it is necessary. User handling procedures are given in an array of **Device_Property**. The structure has the type: **DEVICE_PROP**:

```
typedef struct _DEVICE_PROP {
void (*Init)(void);
void (*Reset)(void);
void (*Process_Status_IN)(void);
void (*Process_Status_OUT)(void);
RESULT (*Class_Data_Setup)(uint8_t RequestNo);
RESULT (*Class_NoData_Setup)(uint8_t RequestNo);
RESULT  (*Class_Get_Interface_Setting)(uint8_t Interface,uint8_t
AlternateSetting);
uint8_t* (*GetDeviceDescriptor)(uint16_t Length);
uint8_t* (*GetConfigDescriptor)(uint16_t Length);
uint8_t* (*GetStringDescriptor)(uint16_t Length);
void* RxEP_buffer; /* This field is not used in current library version.
It is kept only for compatibility with previous versions */
uint8_t MaxPacketSize;
} DEVICE_PROP;
```

4. **User standard request structure**

The User Standard Request Structure is the interface between the user code and the management of the standard request. The structure has the type: **USER_STANDARD_REQUESTS:**

```
typedef struct _USER_STANDARD_REQUESTS {
     void(*User_GetConfiguration)(void);
     void(*User_SetConfiguration)(void);
     void(*User_GetInterface)(void);
     void(*User_SetInterface)(void);
     void(*User_GetStatus)(void);
     void(*User_ClearFeature)(void);
     void(*User_SetEndPointFeature)(void);
     void(*User_SetDeviceFeature)(void);
     void(*User_SetDeviceAddress)(void);
} USER_STANDARD_REQUESTS;
```

If the user wants to implement specific code after receiving a standard USB Device request he has to use the corresponding functions in this structure.

An application developer must implement three structures having the **DEVICE_PROP**, **Device_Table** and **USER_STANDARD_REQUEST** types in order to manage class requests and application specific controls. The different fields of these structures are described in *Section 3.3.4: usb_type.h / usb_def.h*.

3.3.3 usb_sil(.h, .c)

The **usb_sil** module implements an additional abstraction layer for USB-FS_Device peripheral. It offers simple functions for accessing the Endpoints for Read and Write operations.

Endpoint simplified write function

The write operation to an endpoint can be performed through the following function:

```
void USB_SIL_Write(uint32_t EPNum, uint8_t* pBufferPointer, uint32_t
wBufferSize);
```

The parameters of this function are:

- EPNum: Number of the IN endpoint related to the write operation
- pBufferPointer: Pointer to the user buffer to be written to the IN endpoint.
- wBufferSize: Number of data bytes to be written to the IN endpoint.

Depending on the peripheral interface, this function gets the address of the endpoint buffer and performs the packet write operation.

Endpoint simplified read function

The read operation from an endpoint can be performed through the following function:

```
uint32_t USB_SIL_Read(uint32_t EPNum, uint8_t* pBufferPointer);
```

The parameters of this function are:

- EPNum: Number of the OUT endpoint related to the read operation
- pBufferPointer: Pointer to the user buffer to be filled with the data read form the OUT endpoint.

Depending on the peripheral interface, this function performs two successive operations:

1. Gets the number of data received from the host on the related OUT endpoint
2. Copies the received data from the USB dedicated memory to the pBufferPointer address.

Then the function returns the number of received data bytes to the user application.

3.3.4 usb_type.h / usb_def.h

These files provides the main types and USB definitions used in the library.

3.3.5 platform_config.h

This file is responsible for offering a specific configuration for each eval board. This file should be copied to the application folder, where it can then be configured by the user.

3.4 Application interface

The modules of the Application interface are provided as a template, they must be tailored by the application developer for each application. *Table 7* shows the different modules used in the application interface.

Table 7. Application interface modules

File	Description
usb_conf.h	USB-FS_Device configuration file
usb_desc (.h, .c)	USB-FS_Device descriptors
usb_prop (.h, .c)	USB-FS_Device application-specific properties
usb_endp.c	Correct transfer interrupt handler routines for non-control endpoints
usb_istr (.h,.c)	USB-FS_Device interrupt handler functions
usb_pwr (.h, .c)	USB-FS_Device power and connection management functions

3.4.1 usb_conf(.h)

The usb_conf.h is used to customize the USB demos and to configure the device as follows:

- Define the number of endpoints to be used (through the define EP_NUM).
- Enable the use of Endpoints and event callback routines by commenting the relative callback define (i.e. comment the define EP1_IN_Callback to enable and use this function when a correct transfer occurs on endpoint 1, comment the define INTR_SOFINTR_Callback in order to use and implement this function when an SOF interrupt occurs...). When a callback is to be used, its relative define in *usb_conf.h* file should be commented. Then, it should be implemented with the same name in the user application (no need to declare the callback function prototype as it is already declared in the *usb_istr.h* file). You can use the file usb_conf.h to:
  - Configure the BTABLE and all endpoint addresses in the PMA (by modifying and/or adding relative address defines: BTABLE_ADDRESS, ENDP0_RXADDR, ENDP0_TXADDR ...).
  - Define the interrupts to enable them through the interrupt mask IMR_MSK.

3.4.2 usb_desc (.h, .c)

The *usb_desc.c* file should contain all the USB descriptors related to the application. The user has to set these descriptors according to the application proprieties and class.

In all available demos in the “STM32 USB-FS_Device developer kit” there is an example implementing a unique serial number string descriptor based on the STM32 Device Unique ID register (12 digits).

The default value of the serial number string descriptor is “STM32” and during the USB initialization the `Get_SerialNum()` function reads the Device Unique ID register and sets the serial number string descriptor.

For more details regarding the Device Unique ID register, please refer to *Table 4*.

3.4.3 usb_prop (.h , .c)

The usb_prop module is used for implementing the **Device_Property**, **Device_Table** and **USER_STANDARD_REQUEST** structures used by the USB core.

Device property implementation

The device property structure fields are described below:

- **void Init(void)**: Init procedure of the USB-FS_Device peripheral. It is called once at the start of the application to manage the initialization process.
- **void Reset(void)**: Reset procedure of the USB peripheral. It is called when the macrocell receives a RESET signal from the bus. The user program should set up the endpoints in this procedure, in order to set the default control endpoint and enable it to receive.
- **void Process_Status_IN(void)**: Callback procedure, it is called when a status in a stage is finished. The user program can take control with this callback to perform class- and application-related processes.
- **void Process_Status_OUT(void)**: Callback procedure, it is called when a status out stage is finished. As with Process_Status_IN, the user program can perform actions after a status out stage.
- **RESULT** (see note below) ***(Class_Data_Setup)(uint8_t RequestNo)**: Callback procedure, it is called when a class request is recognized and this request needs a data stage. The core cannot process such requests. In this case, the user program gets the chance to use custom procedures to analyze the request, prepare the data and pass the data to the USB-FS_Device core for exchange with the host. The parameter RequestNo indicates the request number. The return parameter of this function has the type: RESULT. It indicates the result of the request processing to the core.
- **RESULT (*Class_NoData_Setup)(uint8_t RequestNo)** Callback procedure, it is called when a non-standard device request is recognized, that does not need a data stage. The core cannot process such requests. The user program can have the chance to use custom procedures to analyze the request and take action. The return parameter of this function has type: RESULT. It indicates the result of the request processing to the core.
- **RESULT (*Class_GET_Interface_Setting)(uint8_t Interface, uint8_t AlternateSetting)**: This routine is used to test the received set interface standard request. The user must verify the "Interface" and "AlternateSetting" according to their own implementation and return the USB_UNSUPPORT in case of error in these two fields.
- **uint8_t* GetDeviceDescriptor(uint16_t Length)**: The core gets the device descriptor.
- **uint8_t* GetConfigDescriptor(uint16_t Length)**: The core gets the configuration descriptor.
- **uint8_t* GetStringDescriptor(uint16_t Length)**: The core gets the string descriptor.
- **uint16_t MaxPacketSize**: The maximum packet size of the device default control endpoint.

*Note: The **RESULT** type is the following:*

```
typedef enum _RESULT {
USB_SUCCESS = 0,/* request process sucessfully */
USB_ERROR,      /* error
USB_UNSUPPORT,  /* request not supported
USB_NOT_READY/* The request process has not been finished,*/
/* endpoint will be NAK to further requests*/
} RESULT;
```

Device endpoint implementation

Description of the structure fields:

- **Total_Endpoint** is the number of endpoints the USB application uses.
- **Total_Configuration** is the number of configurations the USB application has.

USER_STANDARD_REQUEST implementation

This structure is used to manage the user implementation after receiving all standard requests (except Get descriptors). The fields of this structure are:

- **void (*User_GetConfiguration)(void)**: Called after receiving the Get Configuration Standard request.
- **void (*User_SetConfiguration)(void)**: Called after receiving the Set Configuration Standard request.
- **void (*User_GetInterface)(void)**: Called after receiving the Get interface Standard request.
- **void (*User_SetInterface)(void)**: Called after receiving the Set interface Standard request.
- **void (*User_GetStatus)(void)**: Called after receiving the Get interface Standard request.
- **void (*User_ClearFeature)(void)**: Called after receiving the Clear Feature Standard request.
- **void (*User_SetEndPointFeature)(void)**: Called after receiving the set Feature Standard request (only for endpoint recipient).
- **void (*User_SetDeviceFeature)(void)**: Called after receiving the set Feature Standard request (only for Device recipient).
- **void (*User_SetDeviceAddress)(void)**: Called after receiving the set Address Standard request.

3.4.4 usb_endp (.c)

USB_endp module is used for:

- Handling the CTR “correct transfer” routines for endpoints other than endpoint 0 (EP0) for the USB-FS_Device peripheral

For enabling the processing of these callback handlers a pre-processor switch named EPx_IN_Callback (for IN transfer) or EPx_OUT_Callback (for OUT transfer) or EPx_RX_ISOC_CALLBACK (for Isochronous Out transfer) must be defined in the ***USB_conf.h*** file.

3.4.5 usb_istr(.c)

USB_istr module provides a function named **`USB_Istr()`** which handles all USB interrupts.

For each USB interrupt source, a callback routine named `XXX_Callback` (for example, `RESET_Callback`) is provided in order to implement a user interrupt handler. To enable the processing of each callback routines, a preprocessor switch named `XXX_Callback` must be defined in the USB configuration file ***USB_conf.h***.

3.4.6 usb_pwr (.h , .c)

This module manages the power management of the USB device. It provides the functions shown in *Table 8*.

Table 8. Power management functions

Function name	Description
`RESULT Power_on(void)`	Handle switch-on conditions
`RESULT Power_off(void)`	Handle switch-off conditions
`void Suspend(void)`	Sets suspend mode operation conditions
`void Resume(RESUME_STATE eResumeSetVal)`	Handle wakeup operations

3.5 Implementing a USB-FS_Device application using the STM32 USB-FS-Device library

3.5.1 Implementing a no-data class-specific request

All class-specific requests without a data transfer phase implement the field `RESULT (*Class_NoData_Setup)(uint8_t RequestNo)` of the structure device property. The `USBbRequest` of the request is available in the `RequestNo` parameter and all other request fields are stored in the device info structure.

The user has to test all request fields. If the request is compliant with the class to implement, the function returns the USB_SUCCESS result. However if there is a problem in the request, the function returns the UNSUPPORT result status and the library responds with a STALL handshake.

3.5.2 How to implement a data class-specific request

In the event of class requests requiring a data transfer phase, the user implementation reports to the USB-FS-Device library the length of the data to transfer and the data location in the internal memory (RAM if the data is received from the host and, RAM or Flash memory if the data is sent to the host). This type of request is managed in the function: `RESULT (*Class_Data_Setup)(uint8_t RequestNo)`.

For each class data request the user has to create a specific function with the format:

```
uint8_t* My_First_Data_Request (uint16_t Length)
```

If this function is called with the `Length` parameter equal to zero, it sets the `pInformation->Ctrl_Info.Usb_wLength` field with the length of data to transfer and

returns a NULL pointer. In other cases it returns the address of the data to transfer. The following C code shows a simple example:

```
uint8_t* My_First_Data_Request (uint16_t Length)
  {
     if (Length == 0)
     {
        pInformation->Ctrl_Info.Usb_wLength  = My_Data_Length;
        return NULL;
     }
     else
        return (&My_Data_Buffer);
  }
```

The function `RESULT (*Class_Data_Setup)(uint8_t RequestNo)` manages all data requests as described in the following C code:

```
RESULT Class_Data_Setup(uint8_t RequestNo)
{
   uint8_t*(*CopyRoutine)(uint16_t);
   CopyRoutine = NULL;

   if (My_First_Condition)// test the filds of the first request
      CopyRoutine = My_First_Data_Request;
   else if(My_Second_Condition) // test the filds of the second request
      CopyRoutine = My_Second_Data_Request;
   /*
   ...   same implementation for each class data requests
   ...
   */
   if (CopyRoutine == NULL) return USB_UNSUPPORT;

   pInformation->Ctrl_Info.CopyData = CopyRoutine;
   pInformation->Ctrl_Info.Usb_wOffset = 0;
   (*CopyRoutine)(0);
   return USB_SUCCESS;
} /*End of Class_Data_Setup */
```

3.5.3 How to manage data transfers in non-control endpoint

The management of the data transfer using a pipe that is not the default one (Endpoint 0) can be managed in the *usb_end.c* file.

The user has to uncomment the line corresponding to the endpoint (with direction) in the file *usb_conf.h*.

4 Joystick mouse demo

This demo runs on thefollowing STMicroelectronicsevaluation boards, and can be easily tailored to any other hardware:

- STM3210B-EVAL
- STM3210E-EVAL
- STM32L152-EVAL
- STM32373C-EVAL
- STM32303C-EVAL
- STM32L152D-EVAL

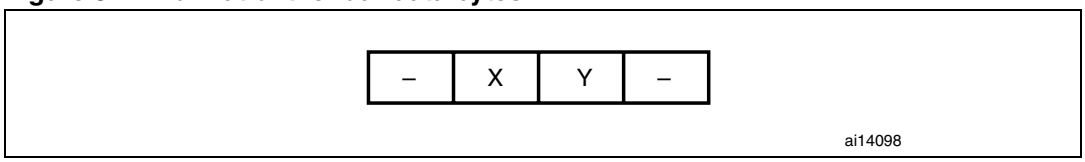
To select the STMicroelectronics evaluation board used to run the demo, uncomment the corresponding line in the *platform_config.h* file.

4.1 General description

A USB mouse (human interface device –HID– class) is a simple example of a complete USB application. The joystick mouse uses only one interrupt endpoint (endpoint 1 in the IN direction). After normal enumeration, the host requests the HID report descriptor of the mouse. This specific descriptor is presented (with standard descriptors) in the *usb_desc.c* file.

To get the mouse pointer position the host requests four bytes of data with the format shown in *Figure 3*, using pipe 1 (endpoint 1).

Figure 3. Format of the four data bytes



The purpose of the mouse demo is to set the X and Y values according to the user actions with a joystick button. The `JoyState()` function gets the user actions and returns the direction of the mouse pointer. The `Joystick_Send()` function formats the data to send to the host and validates the data transaction phase.

Note: See the hw_config.c file for details on the functions.

4.2 STM32 low-power management in suspend mode

To give an example of power management during the USB suspend/resume events, the joystick mouse demo supports the STM32 Stop mode entry and exit.

The STM32 Stop mode is based on the Cortex-M3 deepsleep mode combined with peripheral clock gating. In Stop mode, all clocks in the 1.8 V domain are stopped, the PLLs, HSI RC and HSE crystal oscillators are disabled. Wakeup from the Stop mode is possible only using one EXTI line in interrupt or event mode.

In this demo, during Stop mode, the voltage regulator is configured in low-power mode to reduce the power consumption and EXTI line 18 (USB-FS_Device Wakeup line) is used for wakeup in interrupt mode.

When a suspend event occurs on the bus, the USB-FS-Device library dispatches the request and calls the `Enter_LowPowerMode()` function (file *hw_config.c*). In this function, the STM32 is put in Stop mode.

The STM32 remains in Stop mode until it receives a wakeup (resume) event on the bus. In this case, EXTI line 18 is activated and wakes up the STM32. After wakeup, the USB-FS-Device library calls the `Leave_LowPowerMode()` function (file *hw_config.c*) to reconfigure the clock (re-enable the HSE and PLL).

To test this feature and measure the power consumption during USB-FS_Device suspend, connect current meter to the V_{DD} jumper listed in *Table 9*.

Table 9. Eval board power consumption related jumpers

Eval board name	Jumper
STM3210B-EVAL	JP9
STM3210E-EVAL	JP12
STM32L152-EVAL	JP4
STM32L152D-EVAL	JP10
STM32373C-EVAL	JP15
STM32303C-EVAL	JP12

Note: On the PC side, use the USB HS Electrical Test Toolkit available for free from usb.org to put the STM32 in the suspend/resume state.

4.3 Remote wakeup implementation

Remote wakeup is the ability of a USB device to bring a suspended bus back to the active condition. A device that supports remote wakeup reports this capability to the PC using the *bmAttributes* field of the configuration descriptor (bit D5 set to 1).

In the Joystick demo the key push-button is used as the remote wakeup source. The key button is connected to EXTI line. The table below summarizes the key push button assignment for each eval board.

Table 10. Key push button assignment

Eval board name	EXTI line number
STM3210B-EVAL	EXTI line 9 (GPIO PB.09)
STM3210E-EVAL	EXTI line 8 (GPIO PG.08)
STM32L152-EVAL / STM32L152D-EVAL	EXTI line 0 (GPIO PA.00)
STM32373C-EVAL	EXTI line 2 (GPIO PA.02)
STM32303C-EVAL	EXTI line 6 (GPIO PE.06)

When the key is pressed, the corresponding EXTI ISR is called to initiate the USB device power management state machine using the `Resume()` function. Note that remote wakeup could be disabled by the PC host using the set_feature request, so the EXTI ISR tests the current feature and sends the remote wake-up signal to the PC only if the feature is enabled.

5 Custom HID demo

This demo runs on the following STMicroelectronics evaluation boards, and can be easily tailored to any other hardware:

- STM3210B-EVAL
- STM3210E-EVAL
- STM32L152-EVAL
- STM32373C-EVAL
- STM32303C-EVAL
- STM32L152D-EVAL

To select the STMicroelectronics evaluation board used to run the demo, uncomment the corresponding line in the *platform_config.h* file.

5.1 General description

The HID (human interface device) class primarily consists of devices that are used by humans to control the operation of computer systems. Typical examples of HID class devices are standard mouse devices, keyboards, Bluetooth adaptors etc.

HID Input/Output reports can be exchanged both over the interrupt endpoint, and over the default endpoint (Get_/Set_Report requests).

The custom HID demo is a simple HID demo provided with a small PC applet to give an example of how to create a customized HID based on the native Windows HID driver. It consists of simple data exchanges between the STM32 evaluation board and the PC Host using two interrupt pipes (IN and OUT).

The custom HID demo implements feature request handling, which allows the user to send a control commands to the device. This command is sent through endpoint 0, and must be treated as a set_report request.

For more details on the HID device class, please refer to the “Device Class Definition for HID 1.11” available from the usb.org website.

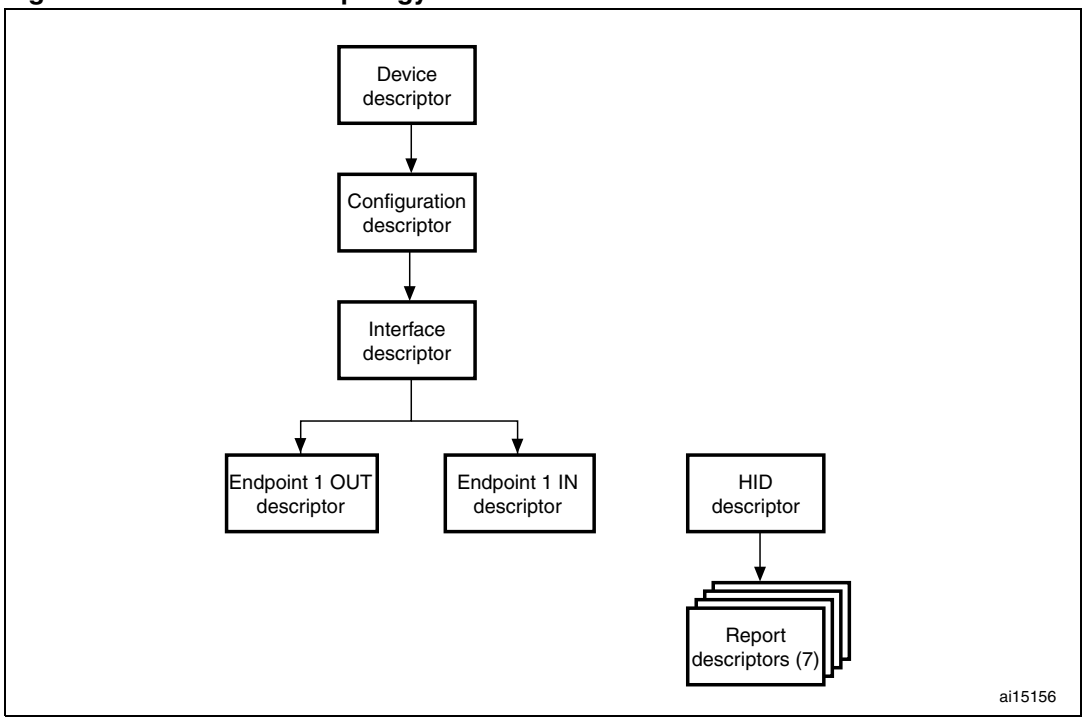
The data exchanged is related to LED commands, push-button state reports and ADC conversion values.

For more details on how to use the PC applet of the custom HID, please refer to the UM0551 user manual “*USB HID demonstrator*” available from the STMicroelectronics microcontroller website www.st.com.

5.2 Descriptor topology

The custom HID topology is based on two interrupt pipes used to handle the data transfer for seven different reports. The following chart shows the custom HID topology.

Figure 4. Custom HID topology



Each report descriptor is related to a specific component in the evaluation board (LEDs, Push-buttons or ADC). The following section describes the functionality of these reports.

5.3 Custom HID implementation

5.3.1 LED control

The STM32 evaluation boards have four LEDs. In the custom HID demo, each LED corresponds to a specific report (reports 1 to 4), and the LED states (ON/OFF) are set by the PC applet. Reports generated by the host to the device are transmitted through either the interrupt (OUT) endpoint or the default endpoint (Control) using the Set_Report request.

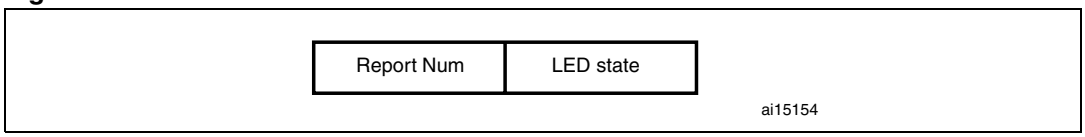
In the PC applet, the output mode is set by default to SET_REPORT, and interrupt transfer is applied.When the device receives data on endpoint 1 OUT, the `EP1_OUT_Callback()` function is called to dispatch the received state to the corresponding LED according to the report number.

When switching to the SET_FEATURE mode, control transfer is applied. The *CustomHID_SetReport_Feature()* function is called, and the host initiates a control endpoint transfer, which causes IN and OUT reports to be sent and received. *Report_Buf[]* contains both the report and the number of bytes to transmit.

The data received has the format shown in *Figure 5*, where:

- Report Num: report number from 1 to 4.
- LED state:
  - 0 -> LED off
  - 1 -> LED on

Figure 5. Data OUT format



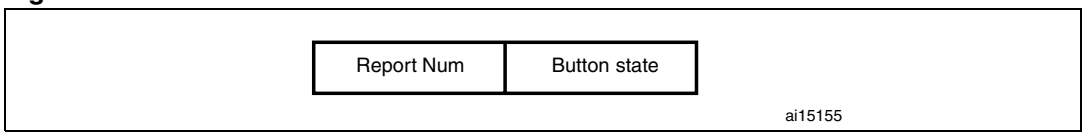
5.3.2 Push-button state report

The states of the Key and Tamper push-buttons on the STM32 evaluation boards (except for the STM32L152-EVAL board where Right and Left joystick buttons are used) are reported to the PC host using the endpoint 1 IN.

The Key push-button (or Right push-button on the STM32L152-EVAL board) corresponds to Report 5 and the Tamper push-button (or Left push-button on the STM32L152 board) to Report 6. When one of the two push-buttons is pressed, the device sends the related report number and the push-button state to the host. *Figure 6* shows the used format, where:

- Report Num: report number 5 or 6
- Button state: 1 -> button pressed

Figure 6. Data IN Format



5.3.3 ADC-converted data transfer

This part of the demo consists in transferring the result of the converted voltage connected to the potentiometer of the evaluation board to the PC host. The ADC is configured in continuous mode with DMA data transfer to a RAM variable (ADC_ConvertedValueX). After each conversion the converted value is tested against an old one (ADC_ConvertedValueX_1) and if there is a difference between the two values (potentiometer value changed by a user), the new value is sent to the PC using the endpoint 1 IN.

Note: The data format is the same as the one used for the push-buttons, but the report number (7) is followed by the MSB of the ADC conversion result.

6 Mass storage demo

This demo runs on the following STMicroelectronics evaluation boards, and can be easily tailored to any other hardware:

- STM3210B-EVAL
- STM3210E-EVAL
- STM32L152-EVAL
- STM32373C-EVAL
- STM32303C-EVAL
- STM32L152D-EVAL

To select the STMicroelectronics evaluation board used to run the demo, uncomment the corresponding line in the *platform_config.h* file.

6.1 General description

The mass storage demo gives a typical example of how to use the STM32 USB-FS_Device peripheral to communicate with the PC host using bulk transfer.

This demo supports the BOT (bulk only transfer) protocol and all needed SCSI (small computer system interface) commands, and is compatible with Windows XP (SP1, SP2, SPI3), Windows 2000 (SP4), Windows Vista and Windows 7.

6.2 Mass storage demo overview

The mass storage demo complies with USB 2.0 and USB mass storage class (bulk-only transfer subclass) specifications. After running the application, the user just has to plug the USB cable into a PC Host and the device is automatically detected without any additional drive (with Win 2000, XP, Vista and Windows 7). A new removable drive appears in the system window and write/read/format operations can be performed as with any other removable drive (see *Figure 7*).

Figure 7. New removable disk in Windows

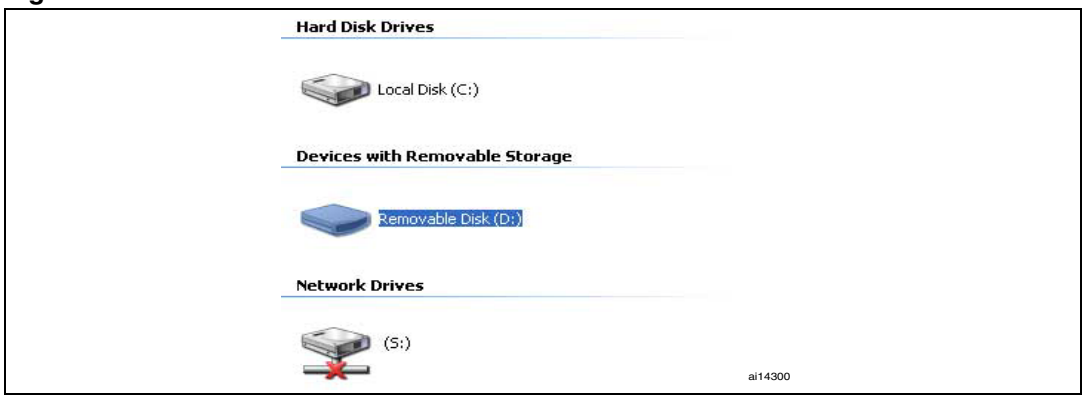


Table 11 gives details of the memory support used for each eval board.

Table 11. Eval board memory support

Eval board	Memory support	IP interface
STM3210E-EVAL	MicroSD and NAND Flash	SDIO and FSMC
STM3210B-EVAL	MicroSD	SPI
STM32L152-EVAL	MicroSD	SPI
STM32L152D-EVAL	MicroSD	SDIO
STM32373C-EVAL	MicroSD	SPI
STM32303C-EVAL	MicroSD	SPI

Note: All related firmware used to initialize, read from and write to the media are available in the stm32xxx_eval_sdio_sd.c.c/.h, stm32xxx_eval_spi_sd.c/.h and fsmc_nand.c/.h files.

Note: For mass storage class, the device firmware does not need to know or take into account the file system the host is using. The firmware just stores and sends blocks of data as requested by the host.

6.3 Mass storage protocol

6.3.1 Bulk-only transfer (BOT)

The BOT protocol uses only bulk pipes to transfer commands, status and data (no interrupt or control pipes). The default pipe (pipe 0, or in other words, Endpoint 0) is only used to clear the bulk pipe status (clear STALL status) and to issue the two class-specific requests: Mass Storage reset and Get Max LUN.

Command transfer

To send a command, the host uses a specific format called command block wrapper (CBW). The CBW is a 31-byte length packet. *Table 12* shows the different fields of a CBW.

Table 12. CBW packet fields

	7	6	5	4	3	2	1	0
0-3	dCBWSignature							
4-7	dCBWTag							
8-11	dCBWDataTransferLength							
12	bmCBWFlags							
13	Reserved (0)				bCBWLUN			
14	Reserved (0)			bCBWCBLength				
15-30	CBWCB							

- ***dCBWSignature***: 43425355 : *USBC* (in little Endian)
- ***dCBWTag***: The host specifies this field for each command. The device should return the same *dCBWTag* in the associated status.
- ***dCBWDataTransferLength***: total number of bytes to transfer (expected by the host).
- ***bmCBWFlags***: This field is used to specify the direction of the data transfer (if any). The bits of this field are defined as follows:
  - **Bit 7**: Direction bit:

    0: Data Out transfer (host to device).

    1: Data In transfer (device to host).

    Note: The device ignores this bit if the `dCBWDataTransferLength` *field is cleared to zero.*
  - **Bits 6:0**: reserved (cleared to zero).
- ***bCBWLUN***: concerned Logical Unit number.
- ***bCBWCBLength:*** this field specify the length (in bytes) of the command CBWCB.
- ***CBWCB***: the command block to be executed by the device.

Status transfer

To inform the host about the status of each received command, the device uses the command status wrapper (CSW). *Table 13* shows the different fields of a CSW.

Table 13. CSW packet fields

	7	6	5	4	3	2	1	0
0-3	dCSWSignature							
4-7	dCSWTag							
8-11	dCSWDataResidue							
12	bCSWStatus							

- ***dCSWSignature***: 53425355 *USBS* (little Endian).
- ***dCSWTag***: the device sets this field to the received value of *dCBWTag* in the concerned CBW.
- ***dCSWDataResidue***: the difference between the expected data (the value of the *dCBWDataTransferLength* field of the concerned CBW) and the real value of the data received or sent by the device.
- ***bCSWStatus***: the status of the concerned command. This field can assume one of the three non-reserved values shown in *Table 14*.

Table 14. Command block status values

Value	Description
0x00	Command passed
0x01	Command failed
0x02	Phase error
0x03=>0xFF	Reserved

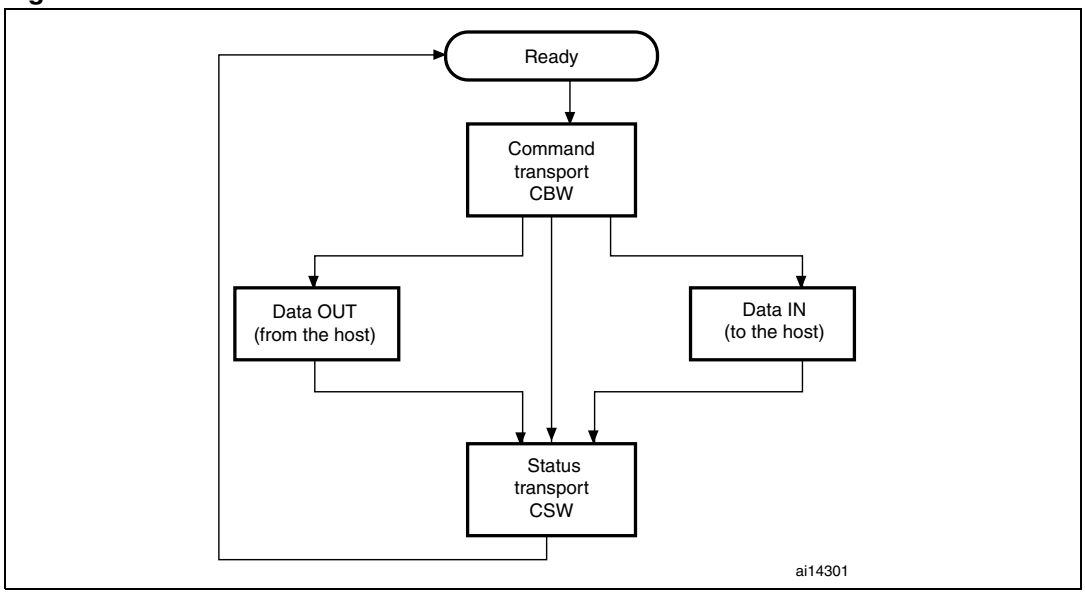
Data transfer

The data transfer phase is specified by the *dCBWDataTransferLength* and *bmCBWFlags* of the correspondent CBW. The host attempts to transfer the exact number of bytes to or from the device.

The diagram shown in *Figure 8* shows the state machine of a BOT transfer.

Note: For more information about the BOT protocol, please refer to the "Universal Serial Bus Mass Storage Class Bulk-Only Transport" specification.

Figure 8. BOT state machine



6.3.2 Small computer system interface (SCSI)

The SCSI command set is designed to provide efficient peer-to-peer operation of SCSI devices like, for example, hard desks, tapes and mass storage devices. In other words these are used to ensure the communication between an SCSI device and an operating system in a PC host.

Table 15 shows SCSI commands for removable devices. Not all commands are shown. For more information, please refer to the SPC and RBC specifications.

Table 15. SCSI command set

Command name	OpCode	Command support(1)	Description	Reference
Inquiry	0x12	M	Get device information	SPC-2
Read Format Capacities	0x23	M	Report current media capacity and formattable capacities supported by medium	SPC-2
Mode Sense (6)	0x1A	M	Report parameters to the host	SPC-2
Mode Sense (10)		M	Report parameters to the host	SPC-2
Prevent\ Allow Medium Removal	0x1E	M	Prevent or allow the removal of media from a removable media device	SPC-2
Read (10)	0x28	M	Transfer binary data from the medium to the host	RBC
Read Capacity (10)	0x25	M	Report current medium capacity	RBC
Request Sense	0x03	O	Transfer status sense data to the host	SPC-2
Start Stop Unit	0x1B	M	Enable or disable the Logical Unit for medium access operations and controls certain power conditions	RBC
Test Unit Ready	0x00	M	Request the device to report if it is ready	SPC-2
Verify (10)	0x2F	M	Verify data on the medium	RBC
Write (10)	0x2A	M	Transfer binary data from the host to the medium	RBC

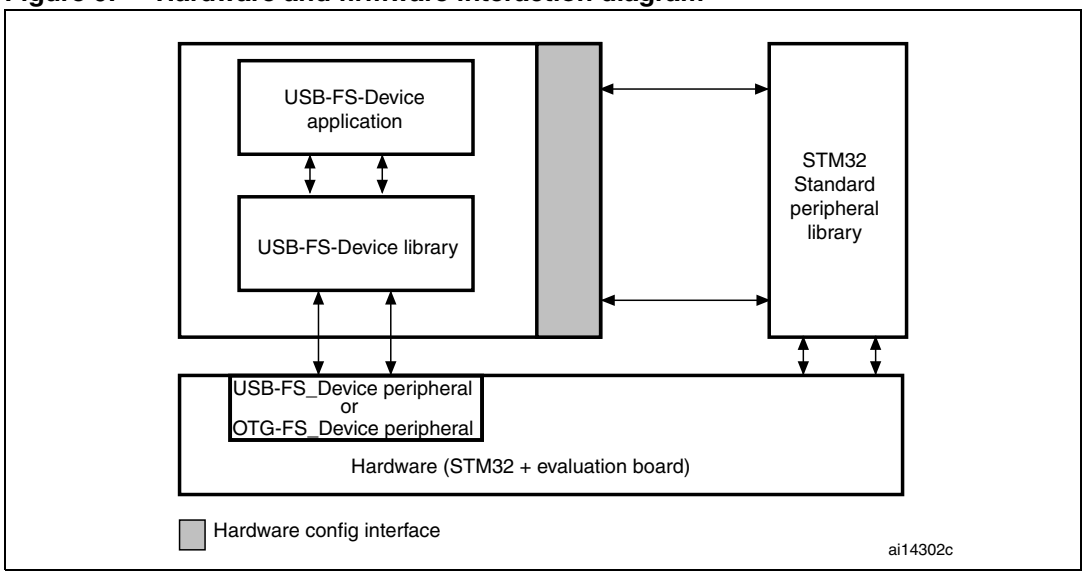
1. Command Support key: M = support is mandatory, O = support is optional.

6.4 Mass storage demo implementations

6.4.1 Hardware configuration interface

The hardware configuration interface is a layer between the USB application (in our case the Mass Storage demo) and the internal/external hardware of the STM32 microcontroller. This internal and external hardware is managed by the STM32 standard peripheral library, so from the firmware point of view, the hardware configuration interface is the firmware layer between the USB application and the standard peripheral library. *Figure 9* shows the interaction between the different firmware components and the hardware environment.

Figure 9. Hardware and firmware interaction diagram



The hardware configuration layer is represented by the two files *HW_config.c* and *HW_config.h*. For the Mass Storage demo, the hardware management layer manages the following hardware requirements:

- System and USB-FS_Device peripheral clock configuration
- Read and write LED configuration
- LED command
- Initialize the memory medium
- Get the characteristics of the memory medium (the block size and the memory capacity)

6.4.2 Endpoint configurations and data management

This section provides a description of the configuration and the data flow according to the transfer mode.

Endpoint configurations

The endpoint configurations should be done after each USB reset event, so this part of code is implemented in the `MASS_Reset` function (file *usp_prop.c*).

For all STM32 except Connectivity line devices:

To configure endpoint 0 it is necessary to:

- Configure endpoint 0 as the default control endpoint
- Configure the endpoint 0 Rx and Tx count and buffer addresses in the BTABLE (*usb_conf.h* file)
- Configure the endpoint Rx status as VALID and the Tx status as NAK.

The bulk pipes (endpoints 1 and 2) are configured as follows:

1. Configure endpoint 1 as bulk IN
2. Configure the endpoint 1 Tx count and data buffer address in the BTABLE (*usb_conf.h* file)
3. Disable the endpoint 1 Rx
4. Configure the endpoint 1 Tx status as NAK
5. Configure the endpoint 2 as bulk OUT
6. Configure the endpoint 2 Rx count and data buffer address in the BTABLE (*usb_conf.h* file)
7. Disable the endpoint 2 Tx
8. Configure the endpoint 2 Rx status as VALID.

Data management

Data management consists of the transfer of the needed data directly from the specified data buffer address in the USB memory, according to the related endpoint (IN: ENDP1TXADDR; OUT: ENDP2RXADDR). For these transfers, the following two functions are used (*usb_sil.c* file):

- **USB_SIL_Read ()**: this function transfers the received bytes from the USB memory to the internal RAM. This function is used to copy the data sent by the host to the device. The number of received data bytes is determined into the function (not passed as parameter) and this value is returned by the function at the end of the operation.
- **USB_SIL_Write ()**: this function transfers the specified number of bytes from the internal RAM to the USB memory. This function is used to send the data from the device to the host.

6.4.3 Class-specific requests

The Mass Storage Class specification describes two class-specific requests:

Bulk-only mass storage reset

This request is used to reset the Mass Storage device and its associated interface. This class-specific request makes the device ready for the next CBW sent by the PC host.

To issue the bulk-only mass storage reset, the host issues a device request on the default pipe (endpoint 0) of:

- *bmRequestType*: Class, Interface, Host to device
- *bRequest* field set to 0xFF
- *wValue* field set to 0
- *wIndex* field set to the interface number (0 for this implementation)
- *wLength* field set to 0

This request is implemented as a no-data class-specific request in the `MASS_NoData_Setup()` function (*usb_prop.c* file).

After receiving this request, the device clears the data toggle of the two bulk endpoints, initializes the CBW signature to the default value and sets the BOT state machine to the BOT_IDLE state to be ready to receive the next CBW.

GET MAX LUN request

A Mass Storage Device may implement several logical units that share common device characteristics. The host uses bCBWLUN to designate which logical unit of the device is the destination of the CBW.

The Get Max LUN device request is used to determine the number of logical units supported by the device.

To issue a Get Max LUN request the host must issue a device request on the default pipe (endpoint 0) of:

- *bmRequestType*: Class, Interface, Host to device
- *bRequest* field set to 0xFE
- *wValue* field set to 0
- *wIndex* field set to the interface number (0 for this implementation)
- *wLength* field set to 1

This request is implemented as a data class-specific request in the `MASS_Data_Setup()` function (*usb_prop.c* file). Note that in case of the STM3210E-EVAL board two LUNs are supported

6.4.4 Standard request requirements

To be compliant with the BOT specification the device must respond to the two following requirements after receiving the same standard requests:

- When the device switches from the unconfigured to the configured state, the data toggle of all endpoints must be cleared. This requirement is served by the `Mass_Storage_SetConfiguration()` function in the *usb_prop.c* file.
- When the host sends a CBW command with an invalid signature or length, the device must keep endpoints 1 and 2 both as STALL until it receives the Mass Storage Reset class-specific request. This functionality is managed by the `Mass_Storage_ClearFeature()` function in the *usb_prop.c* file.

6.4.5 BOT state machine

To provide the BOT protocol, a specific state machine with five states is implemented. The states are described below:

- **BOT_IDLE**: this is the default state after a USB reset, Bulk-Only Mass Storage Reset or after sending a CSW. In this state the device is ready to receive a new CBW from the host
- **BOT_DATA_OUT**: the device enters this state after receiving a CBW with data flow from the host to the device
- **BOT_DATA_IN**: the device enters this state after receiving a CBW with data flow from the device to the host
- **BOT_DATA_IN_LAST**: the device enters this state when sending the last of the data asked for by the host
- **BOT_CSW_SEND**: the device moves to this state when sending the CSW. When the device is in this state and a correct IN transfer occurs, the device moves to the BOT_IDLE state to be able to receive the next CBW
- **BOT_ERROR:** Error state

The BOT state machine is managed using the functions described below (*usb_bot.c* and *usb_bot.h* firmware files):

- **Mass_Storage_In ()**; **Mass_Storage_Out ()**: these two functions are called when a correct transfer (IN or OUT) occurs. The aim of these two functions is to provide the next step after receiving/sending a CBW, data or CSW
- **CBW_Decode ()**: this function is used to decode the CBW and to dispatch the firmware to the corresponding SCSI command
- **DataInTransfer ()**: this function is used to transfer the characteristic device data to the host
- **Set_CSW ()**: this function is used to set the CSW fields with the needed parameters according to the command execution
- **Bot_Abort ()**: this function is used to STALL the endpoints 1 or 2 (or both) according to the Error occurring in the BOT flow

6.4.6 SCSI protocol implementation

The aim of the SCSI Protocol is to provide a correct response to all SCSI commands needed by the operating system on the PC host. This section details the method of management for all implemented SCSI commands.

- **INQUIRY** command (OpCode = 0x12):

  Send the needed inquiry page data (in this demo only page 0 and the standard page are supported) with the needed data length according to the *ALLOCATION LENGTH* field of the command.

- **SCSI READ FORMAT CAPACITIES** command (OpCode = 0x23):

  Send the Read Format Capacity data response (`ReadFormatCapacity_Data[ ]` from the *SCSI_data.c* file) after checking the presence of the medium. If no medium has been detected a MEDIUM_NOT_PRESENT error is returned to force the host to update its internal parameters.

- **SCSI READ CAPACITY (10)** command (OpCode = 0x25):

  Send the Read Capacity (10) data response (`ReadCapacity10_Data[ ]` from the *SCSI_data.c* file) after checking the presence of the medium. If no medium has been detected a MEDIUM_NOT_PRESENT error is returned to force the host to update its internal parameters.

- **SCSI MODE SENSE (6)** command (OpCode = 0x1A):

  Send the Mode Sense (6) data response (`Mode_Sense6_data[ ]` from the *SCSI_data.c* file).

- **SCSI MODE SENSE (10)** command (OpCode = 0x5A):

  Send the Mode Sense (10) data response (`Mode_Sense10_data[ ]` from the *SCSI_data.c* file).

- **SCSI REQUEST SENSE** command (OpCode = 0x03):

  Send the Request Sense data response. Note that the `Resquest_Sense_Data [ ]` array (*SCSI_data.c* file) is updated using the `Set_Scsi_Sense_Data()` function in order to set the *Sense key* and the *ASC* fields according to any error occurring during the transfer.

- **SCSI TEST UNIT READY** command (OpCode = 0x00):

  Check the presence of the medium. If no medium has been detected a MEDIUM_NOT_PRESENT error is returned to force the host to update its internal parameters.

- **SCSI PREVENT/ALLOW MEDIUM REMOVAL** command (OpCode = 0x1E):

  Always return a CSW with COMMAND PASSED status.
- **SCSI START STOP UNIT** command (OpCode = 0x1B):

  This command is sent by the PC host when a user right-clicks on the device (in Windows) and selects the Eject operation. In this case the firmware programs the data in the internal Flash memory using the `Stor_Data_In_Flash()` function.
- **SCSI READ 10** command (OpCode = 0x28) and **SCSI WRITE 10** command (OpCode = 0x2A):

  The host issues these two commands to perform a read or a write operation. In these cases the device has to verify the address compatibility with the memory range and the direction bit in the bmFlag of the command. If the command is validated the firmware launches the read or write operation from the microSD card.
- **SCSI VERIFY 10** command (OpCode =0x2F):

  The SCSI VERIFY 10 command requests the device to verify the data written on the medium. In this case no Flash-like memory support is used, so when the SCSI VERIFY 10 command is received, the device tests the BLKVFY bit. If the BLKVFY bit is set to one, a Command Passed status is returned in the CSW.

6.4.7 Memory management

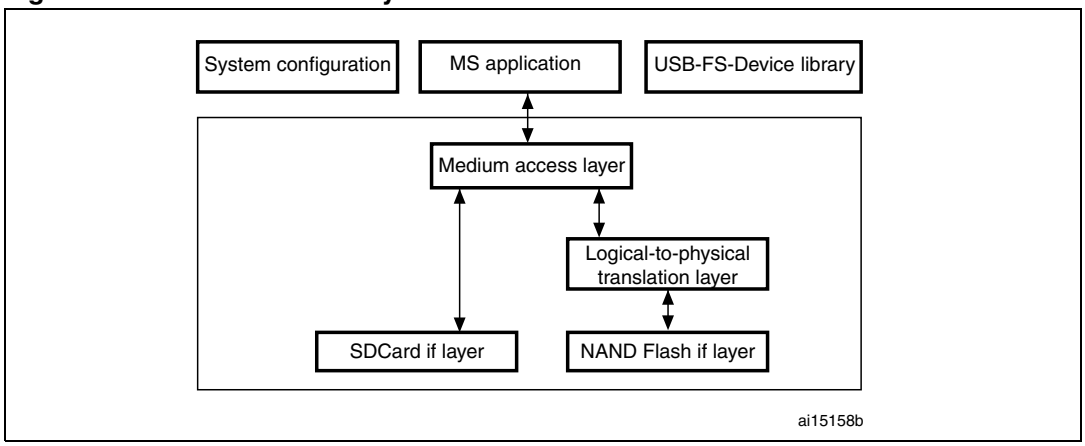
All the memory management functions are grouped in the two files: *memory.c* and *memory.h.* Memory management consists of two basic processes:

- Management and validation of the address range for the SCSI READ (10) and SCSI WRITE (10) commands: this process is done by the `Address_Management_Test()` function. The role of this function is to extract the real address and memory offset in the medium memory and test if the current transfer (Read or Write) is in the memory range. If this is not the case, the function STALLs endpoint 1 or 2 or both endpoints (according to the transfer Read or Write) and returns a bad status to disable the transfer.
- Management of the Read and Write processes: this process is done by the two functions `Read_Memory()` and `Write_Memory()`. These two functions manage the medium access based on the two functions “MAL_WriteBlock” and “MAL_ReadBlock” from the *mass_mal.c* file. After each access, the current memory offset and the next Access Address are updated using the length of the previous transfer.

6.4.8 Medium access management

Logical access to the addressed medium takes place in a separate layer called the medium access layer (mass_mal.c and mass_mal.h) through the logical unit number (LUN). This layer makes the medium access independent of the upper layer and dispatches write and read operations to the addressed medium.

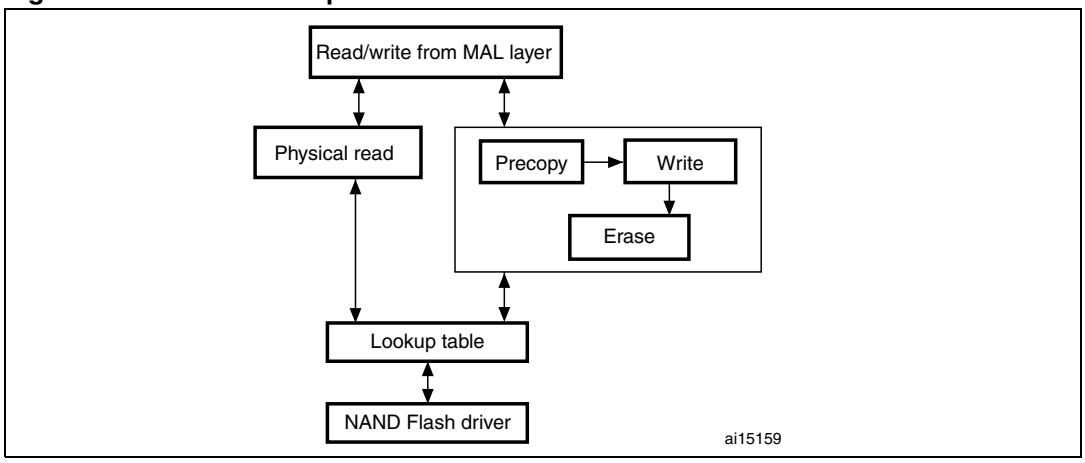
Figure 10. Medium access layer



Physical access to the NAND and physical access to the micro SD are not similar. In the case of the micro SD, write, read and erase operations can be made by page units known as logical sectors. This means that access to the medium is linear and the logical address is the same as the physical one. In the case of the NAND, write and read operations can be made by page unit but erase operations are carried out by block unit. This means that a write operation in a used block is performed in five steps as follows:

1. Allocate a free physical block.
2. Precopy old pages.
3. Write new pages.
4. Erase the old block.
5. Assign the current logical address to the new block.

Figure 11. NAND write operation



The logical-to-physical layer is used to keep a compatibility between the NAND and the microSD access methods by using the same input parameters for the two media. In the case of the NAND, the physical address is calculated internally and write and read operations are carried out in this layer.

Caution: The build look-up table (LUT) process used to translate logical addresses to physical ones and keep the block status is patented by STMicroelectronics. It is not allowed to use outside the STM32 firmware, and it should not be reproduced without STMicroelectronics's agreement.

6.5 How to customize the mass storage demo

The implemented firmware is a simple example used to demonstrate the STM32 USB peripheral capability in bulk transfer. However it can be customized according to user requirements. This customizing can be done in the three layers of the implemented mass storage protocol:

- **Customizing the BOT layer:** the user can implement their own BOT state machine or modify the implemented one just by modifying the two files *usb_BOT.c* and *usb_BOT.h* and by keeping the same data transfer method.
- **Customizing the SCSI layer:** the implemented SCSI protocol presents, more than the supported command listed in *Section 6.4.6: SCSI protocol implementation*, a list of unsupported commands. When the host sends one of these commands, a corresponding function is called by the `CBW_Decode()` function like a common command. However, all the functions related to unsupported commands are defined by the `SCSI_Invalid_Cmd()` function, (see *usb_scsi.c* file). The `SCSI_Invalid_Cmd()` function STALLs the two endpoints (1 and 2), sets the Sense data to *invalid command key* and sends a CSW with a *Command Failed* status.
  To support one of the invalid commands, the user has to comment out the concerned line and implement their own process. For example, for the need to support the `SCSI_FormatUnit` command, comment the line:
  ```
  // #define SCSI_FormatUnit_Cmd SCSI_Invalid_Cmd
  ```
  And implement a process in a function with the same name in the *usb_scsi.c* file:
  ```
  void SCSI_Invalid_Cmd (void)
  {
  // your implementation
  }
  ```
  In this way the custom function is called automatically by the `CBW_Decode()` function (*usb_BOT.c* file).
  However if you need to implement a command not listed in the previous list you have to modify the `CBW_Decode()` and implement the protocol of the new command.

Mass storage descriptors

Table 16. Device descriptor

Field	Value	Description
bLength	0x12	Size of this descriptor in bytes
bDescriptortype	0x01	Descriptor type (device descriptor)
bcdUSB	0x0200	USB specification release number: 2.0
bDeviceClass	0x00	Device Class
bDeviceSubClass	0x00	Device subclass
bDeviceProtocol	0x00	Device protocol
bMaxPacketSize0	0x40	Max Packet Size of Endpoint 0: 64 bytes
idVendor	0x0483	Vendor identifier (STMicroelectronics)
idProduct	0x5720	Product identifier
bcdDevice	0x0100	Device release number: 1.00

Table 16. Device descriptor (continued)

Field	Value	Description
iManufacturer	4	Index of the manufacturer String descriptor: 4
iProduct	42	Index of the product String descriptor: 42
iSerialNumber	96	Index of the serial number String descriptor
bNumConfigurations	0x01	Number of possible configurations: 1

Table 17. Configuration descriptor

Field	Value	Description
bLength	0x09	Size of this descriptor in bytes
bDescriptortype	0x02	Descriptor type (configuration descriptor)
wTotalLength	32	Total length (in bytes) of the returned data by this descriptor (including interface endpoint descriptors)
bNumInterfaces	0x0001	Number of interfaces supported by this configuration (only one interface)
bConfigurationValue	0x01	Configuration value
iConfiguration	0x00	Index of the Configuration String descriptor
bmAttributes	0x80	Configuration characteristics: Bus powered
Maxpower	0x32	Maximum power consumption through USB bus: 100 mA

Table 18. Interface descriptors

Field	Value	Description
bLength	0x09	Size of this descriptor in bytes
bDescriptortype	0x04	Descriptor type (Interface descriptor)
bInterfaceNumber	0x00	Interface number
bAlternateSetting	0x00	Alternate Setting number
bNumEndpoints	0x02	Number of used Endpoints: 2
bInterfaceClass	0x08	Interface class: Mass Storage class
bInterfaceSubClass	0x06	Interface subclass: SCSI transparent
bInterfaceProtocl	0x50	Interface protocol: 0x50
iInterface	106	Index of the interface String descriptor

Table 19. Endpoint descriptors

Field	Value	Description
IN endpoint		
bLength	0x07	Size of this descriptor in bytes
bDescriptortype	0x05	Descriptor type (endpoint descriptor)
bEndpointAddress	0x81	IN endpoint address 1.
bmAttributes	0x02	Bulk endpoint
wMaxPacketSize	0x40	64 bytes
bInterval	0x00	Does not apply for bulk endpoints
OUT endpoint		
bLength	0x07	Size of this descriptor in bytes
bDescriptortype	0x05	Descriptor type (endpoint descriptor)
bEndpointAddress	0x02	Out endpoint address 2
bmAttributes	0x02	Bulk endpoint
wMaxPacketSize	0x40	64 bytes
bInterval	0x00	Does not apply for bulk endpoints

7 Virtual COM port demo

This demo runs on the following STMicroelectronics evaluation boards, and can be easily tailored to any other hardware:

- STM3210B-EVAL
- STM3210E-EVAL
- STM32L152-EVAL
- STM32373C-EVAL
- STM32303C-EVAL
- STM32L152D-EVAL

To select the STMicroelectronics evaluation board used to run the demo, uncomment the corresponding line in the *platform_config.h* file.

7.1 General description

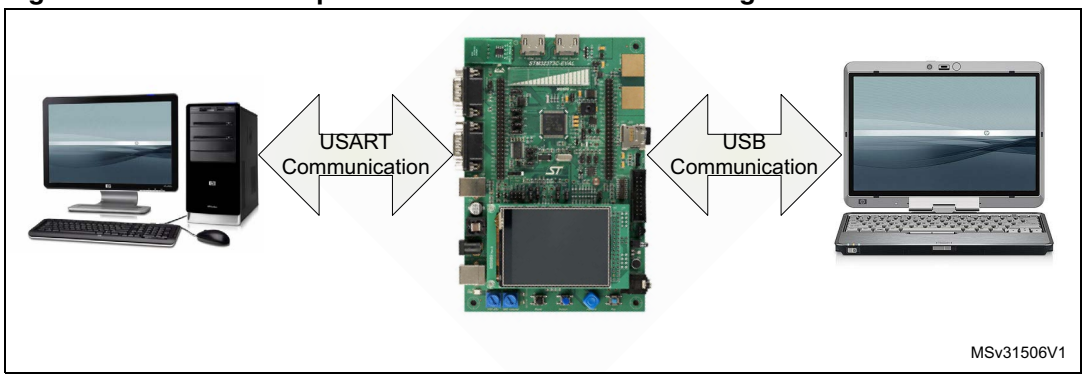
In modern PCs, USB is the standard communication port for almost all peripherals. However many industrial software applications still use the classic COM Port (UART). The Virtual COM Port Demo provides a simple solution to bypass this problem. It uses the USB device as a COM port by affecting the legacy PC application designed for COM Port communication.

The Virtual COM Port demo provides the firmware examples for the STM32 family and the PC driver. This section provides a brief description of the implementation, and shows how to run the demo.

7.2 Virtual COM port demo proposal

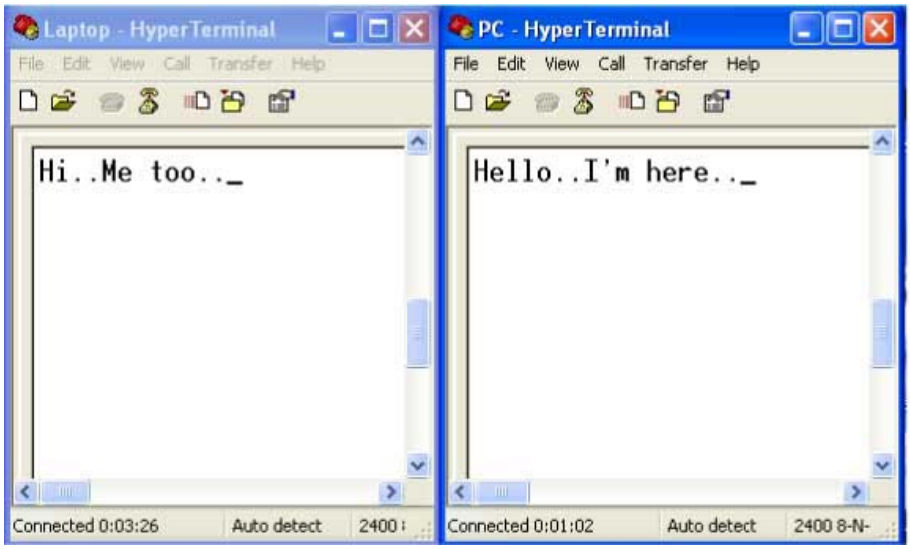
The demo proposal is to use the STM32 evaluation board as a USB-to-USART bridge and to provide communication between a laptop (without RS-232 port) and a standard PC workstation as shown in *Figure 12*.

Figure 12. Virtual COM port demo as USB-to-USART bridge



The PC application used for communication is Windows HyperTerminal. See *Figure 13*.

Figure 13. Communication example

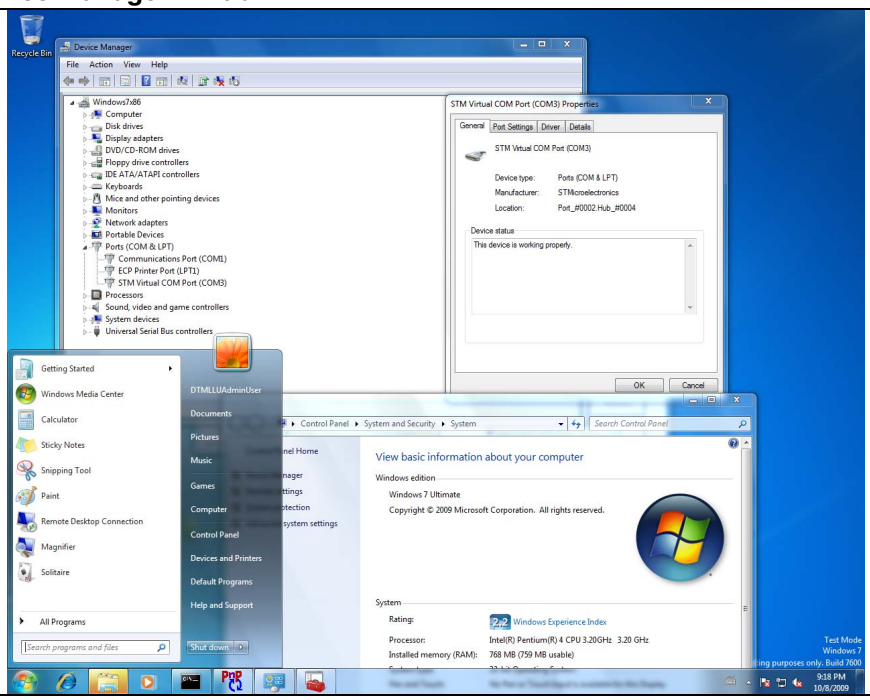


7.3 Software driver installation

To install the software driver of the Virtual COM port, download and execute the “Virtual Com Port Driver Setup” from the STMicroelectronics website: www.st.com.

At the end of the installation, a new COM port appears in the Device Manager window as shown in *Figure 14*.

Figure 14. Device manager window



7.4 Implementation

7.4.1 Hardware implementation

Table 20 lists the USART connector number for each evaluation board.

Table 20. USART connector number for each evaluation board

Eval board	USART connector
STM3210E-EVAL	USART1
STM3210B-EVAL	USART1
STM32303C-EVAL	USART1
STM32L152D-EVAL	USART1
STM32L152-EVAL	USART2
STM32373C-EVAL	USART2

Note: There is no need to add external hardware to run the demo.

7.4.2 Firmware implementation

In order to be considered as a COM port, the USB device has to implement two interfaces according to the Communication Device Class (CDC) specification:

- Abstract Control Model Communication, with 1 Interrupt IN endpoint: in our implementation this interface is declared in the descriptor but the related endpoint (endpoint 2) is not used
- Abstract Control Model Data, with 1 Bulk IN and 1 Bulk OUT endpoint: this interface is represented in the demo by endpoint 1 (IN) and endpoint 3 (OUT). Endpoint 1 is used to send the data received from the UART to the PC through USB. Endpoint 3 is used to receive the data from the PC and send it through the UART.

For more information on the CDC class please refer to the *Universal Serial Bus Class Definitions for Communication Devices* specification provided by the www.usb.org website.

Class-specific requests

To implement a virtual COM port, the device supports the following class-specific requests:

- **SET_CONTROL_LINE_STATE**: RS-232 signal used to tell the device that the Data Terminal Equipment device is now present. This request always returns a USB_SUCCESS status in the `Virtual_Com_Port_NoData_Setup()` function (*usb_prop.c* file).
- **SET_COMM_FEATURE**: controls the settings for a particular communication feature. This request always returns a USB_SUCCESS status in the `Virtual_Com_Port_NoData_Setup()` function (*usb_prop.c* file).
- **SET_LINE_CODING**: sends the configuration of the device. It includes the baud rate, stop-bits, parity, and number-of-character bits. The received data is stored in a specific data structure called “linecoding” and used to update the UART parameters.
- **GET_LINE_CODING**: This command requests the device current baud rate, stop-bits, parity, and number-of-character bits. The device responds to this request with the data stored in the “linecoding” structure.

Hardware configuration interface

The hardware configuration interface (*hw_config.c* and *.h*) in the Virtual COM port manages the following routines:

- Configure the system and peripheral (USB & USART) clock and interrupts
- Initialize the USART to default values
- Configure the USART with the parameters received by the SET_LINE_CODING request
- Send the data received by the USART to the PC through USB
- Send the data received by the USB through USART

Note: For the STM32, *the supported data formats are 7 & 8 bits (in the* HyperTerminal*), and the bandwidth range is from 1200 to 115200.*

8 VirtualComport_Loopback

This demo runs on the following STMicroelectronics evaluation boards, and can be easily tailored to any other hardware:

- STM3210B-EVAL
- STM3210E-EVAL
- STM32L152-EVAL
- STM32373C-EVAL
- STM32303C-EVAL
- STM32L152D-EVAL

To select the STMicroelectronics evaluation board used to run the demo, uncomment the corresponding line in the *platform_config.h* file.

8.1 General description

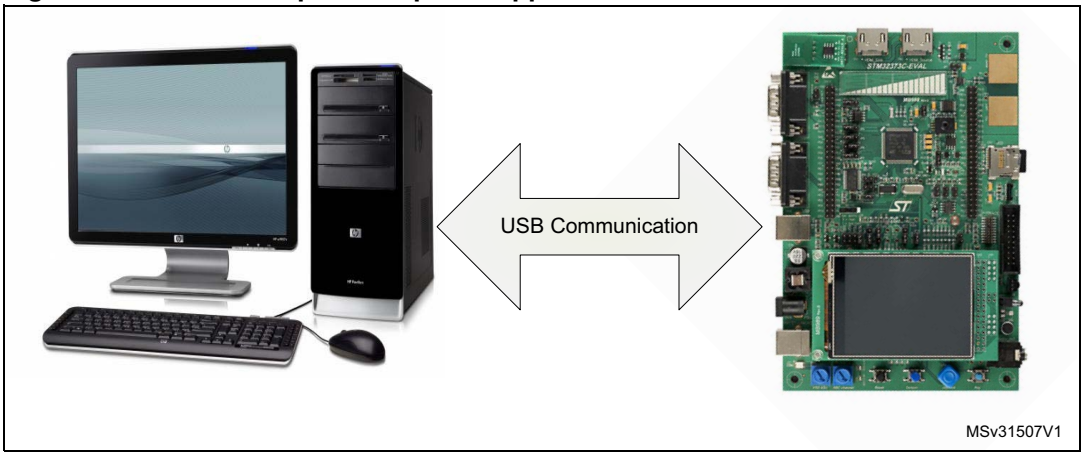
The purpose of this example is to send and receive data over USB using the CDC protocol. The USB Device VCP Example is used for this. For further details on this demo, please refer to *Chapter 7: Virtual COM port demo*.

In this example, NO serial cable connector is needed, and you can see the data transferred to and from USB. This example loops back the contents of a text file over a USB port.

8.2 Demo overview

Figure 15 shows the application's structure.

Figure 15. VirtualComport_Loopback application overview



8.3 Transferring data

Once the device has been enumerated as a virtual COM port by the host, data can easily be transferred in the loop back. There are two functions and two buffers for transferring data into and out of the device.

8.3.1 Sending data from device to host

To send the data received from the STM32 to the PC (IN transfers), put the data into the *Send_Buffer[ ]* buffer and call *CDC_Send_DATA( )*.

When a packet is sent from the STM32 on the IN pipe (EP1), EP1_IN_Callback processes the sent data.

8.3.2 Receiving data from host to device

To receive data to the STM32 (OUT transfers),store the data in the *Receive_Buffer[ ]* by calling `CDC_Receive_DATA()`.

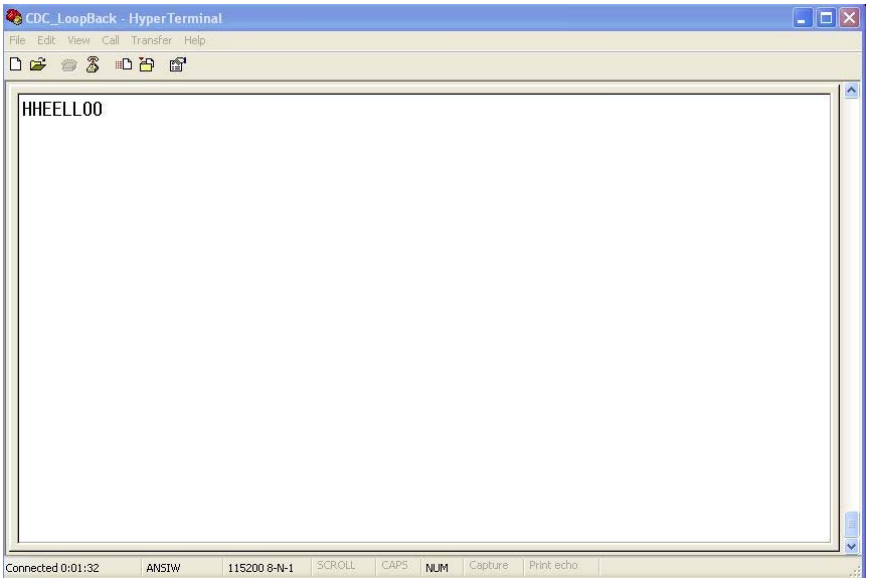
When a packet is received from the PC on the OUT pipe (EP3), EP3_IN_Callback processes the received data.

8.4 Running the demo

Follow the instructions below to start the demo:

1. Launch the Window HyperTerminal application, and select the COM port.
2. Connect the USB port of the STM32 to the PC.
3. Type any message on the PC's keyboard. It will be displayed twice. Any data shown in HyperTerminal is received from the device.

Figure 16. Window HyperTerminal message display



Note: Character echo is ON.

9 USB voice speaker demo

This demo runs on the following STMicroelectronics evaluation boards:

- STM3210B-EVAL
- STM3210E-EVAL
- STM32L152-EVAL

To select the STMicroelectronics evaluation board used to run the demo, uncomment the corresponding line in the *platform_config.h* file.

9.1 General description

The USB voice speaker demo gives examples of how to use the STM32 USB peripheral to communicate with the PC host in the isochronous transfer mode. They provide a demonstration of the correct method for configuring an isochronous endpoint, receiving or transmitting data from/to the host. They also show how to use the data in a real-time application.

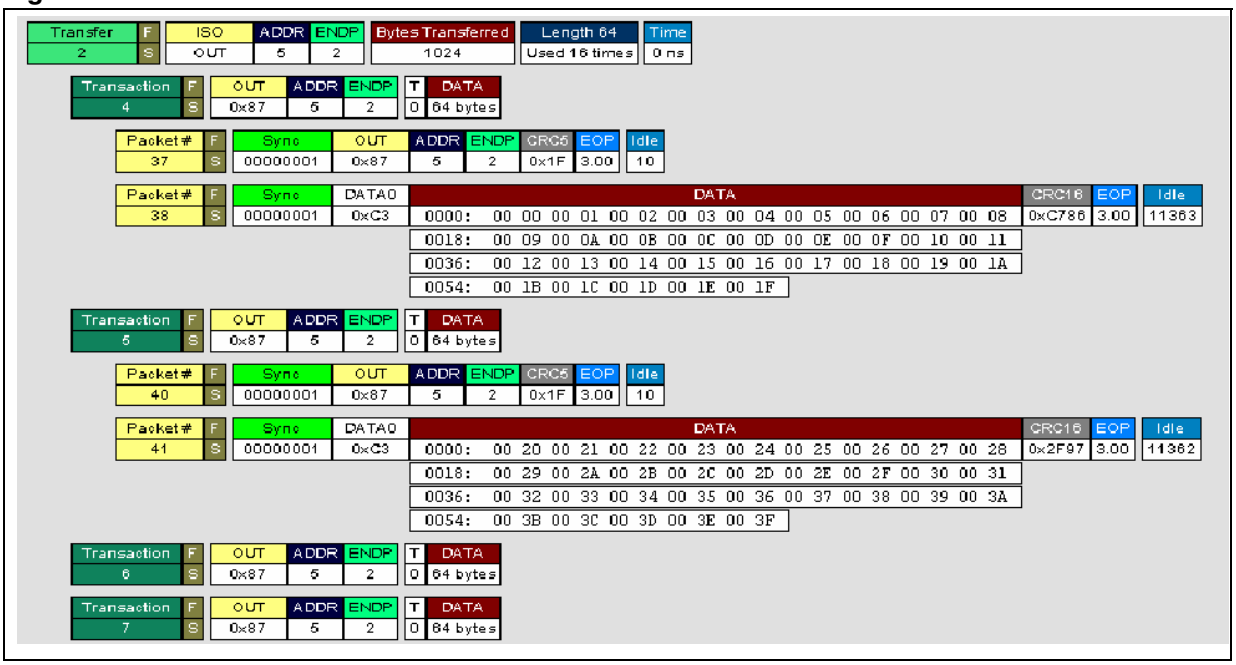
The available voice demo described in this user guide is a USB speaker.

9.2 Isochronous transfer overview

The isochronous transfer is used when the application needs to guarantee the access to the USB bandwidth with bounded latency, constant data rate and without attempting a new data transfer operation in case of failure.

In fact, an isochronous transaction does not have a handshake phase and no ACK packet is expected or sent after the data packet. *Figure 17* shows an example of an isochronous OUT transfer with 64 bytes in the data packet.

Figure 17. Isochronous OUT transfer



Typical examples of application use of the isochronous transfer mode are audio samples, compressed video streams and, in general, any sort of sampled data with strict requirements for the accuracy of the delivered frequency.

Please see the USB 2.0 specifications for more details on the USB isochronous transfer mode characteristics.

9.3 Audio device class overview

An audio device, as defined by the Universal Serial Bus Class Definition for Audio Devices specification, is a device or a function embedded in composite devices that are used to manipulate audio, voice, and sound-related functionality. This includes both audio data (analog and digital) and the functionality that is used to directly control the audio environment, such as *volume* and *tone control*.

All audio devices are grouped, from the USB point of view, in the audio interface class. This class is divided into several subclasses. The Universal Serial Bus Class Definition for Audio Devices specification details the three following subclasses:

- **AudioControl Interface subclass (AC)**: each audio function has a single AudioControl interface. The AC interface is used to control the functional behavior of a particular audio function. To achieve this functionality, this interface can use the following endpoints:
  - A control endpoint (endpoint 0) for manipulating unit and terminal settings and retrieving the state of the audio function using class-specific requests.
  - An interrupt endpoint for status returns. This endpoint is optional.

  The AudioControl interface is the single entry point to access the internals of the audio function. All requests that are concerned with the manipulation of certain audio controls within the audio function's units or terminals must be directed to the AudioControl

interface of the audio function. Likewise, all descriptors related to the internals of the audio function are part of the class-specific AudioControl interface descriptor.

The AudioControl interface of an audio function may support multiple alternate settings. Alternate settings of the AudioControl interface could for instance be used to implement audio functions that support multiple topologies by presenting different class-specific AudioControl interface descriptors for each alternate setting.

- **AudioStreaming Interface Subclass (AS):** AudioStreaming interfaces are used to interchange digital audio data streams between the host and the audio function. They are optional. An audio function can have zero or more AudioStreaming interfaces associated with it, each possibly carrying data of a different nature and format. Each AudioStreaming interface can have at most one isochronous data endpoint.
- **MIDIStreaming Interface Subclass (MIDIS)**: MIDIStreaming interfaces are used to transport MIDI data streams into and out of the audio function.

  To be able to manipulate the physical properties of an audio function, its functionality must be divided into addressable entities. Two types of such generic entities are identified and are called *units* and *terminals*. The Universal Serial Bus Class Definition for Audio Devices specification defines seven types of standard units and terminals that are considered adequate to represent most audio functions.

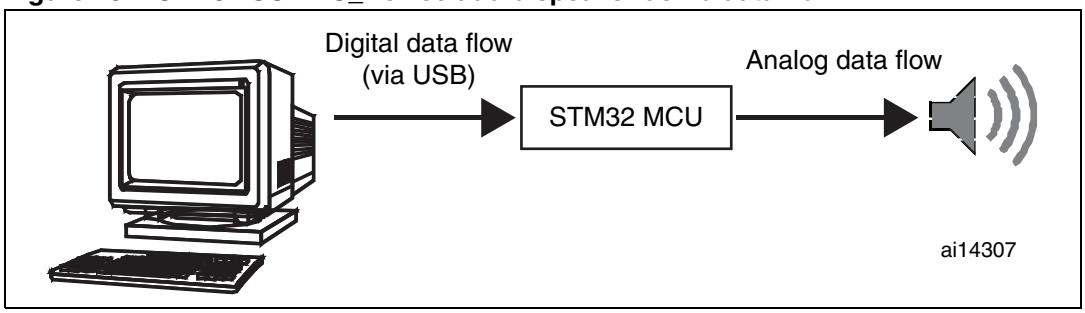
  These are:
  - Input Terminal
  - Output Terminal
  - Mixer Unit
  - Selector Unit
  - Feature Unit
  - Processing Unit
  - Extension Unit.

For more information about the audio class characteristics and requirements, please refer to the *Universal Serial Bus Device Class Definition for Audio Devices specification* provided by the usb.org website.

9.4 STM32 USB audio speaker demo

The purpose of the USB audio speaker demo is to receive the audio stream (data) from a PC host using the USB and to play it back via the STM32 MCU. *Figure 18: STM32 USB-FS_Device audio speaker demo data flow* represents the data flow between the PC host and the audio speaker.

Figure 18. STM32 USB-FS_Device audio speaker demo data flow



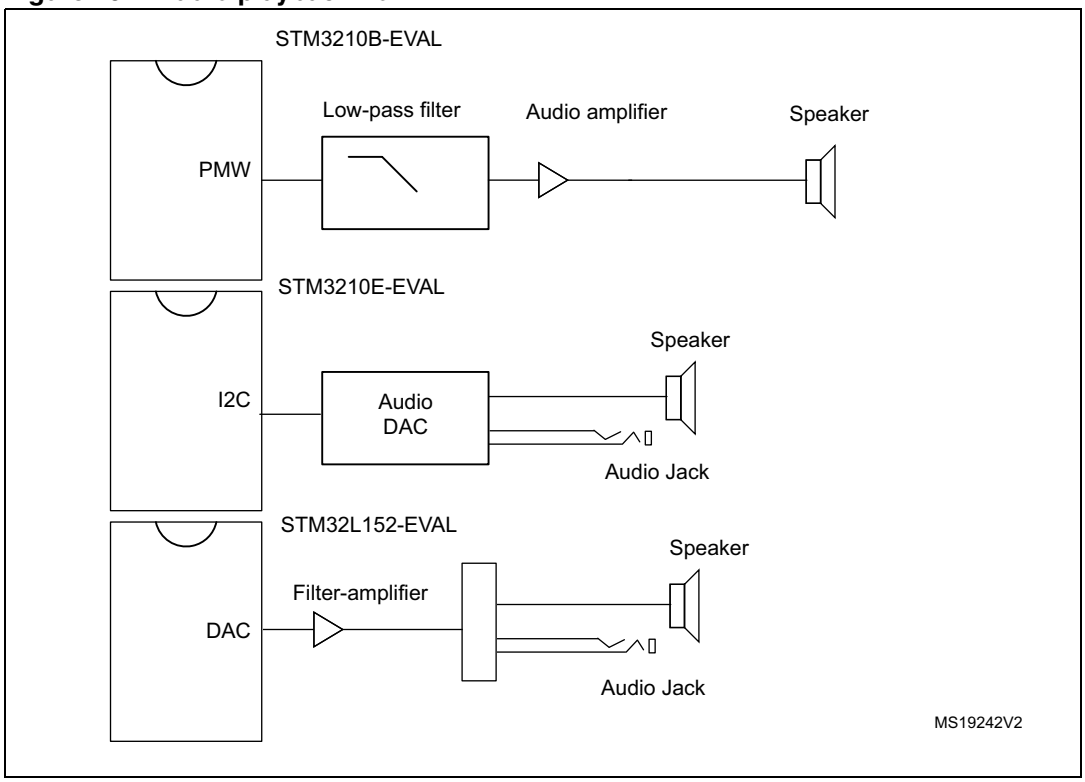
9.4.1 General characteristics

- USB device characteristics:
  - Endpoint 0: used to enumerate the device and to respond to class-specific requests. The maximum packet size of this endpoint is 64 bytes.
  - Endpoint 1 (OUT): used to receive the audio stream from the PC host with a maximum packet size up to 22 bytes.
- Audio characteristics:
  - Audio data format: Type I / PCM8 format / Mono.
  - Audio data resolution: 8 bits.
  - Sample frequency: 22 kHz.
- Hardware requirements:

  In the case of he STM3210B-EVAL board, since the STM32 MCU does not have an on-chip DAC to generate the analog data flow, an alternate method is used to implement 1 channel DAC. This method consists in using the build-in pulse width modulation (PWM) module to generate a signal whose pulse width is proportional to the amplitude of the sample data. The PWM output signal is then integrated by a low-pass filter to remove high-frequency components, leaving only the low-frequency content. The output of the low-pass filter provides a reasonable reproduction of the original analog signal.

  Figure 19 shows the Audio playback diagram flow using the built-in PWM. In the case of the STM3210E-EVAL, the I2S standalone audio peripheral is used to generate the audio data.

Figure 19. Audio playback flow



9.4.2 Implementation

This section describes the hardware and software solution used to implement a USB audio speaker using the STM32 microcontroller.

Hardware implementation

In the case of the STM3210B-EVAL board, to implement the PWM feature the following STM32 built-in timers are used:

- TIM2 in output compare timing mode to act as system timer.
- TIM4 in PWM mode

In the case of the STM3210E-EVAL board, the I^2S standalone audio peripheral directly generates the audio data.

In the case of the STM32L152-EVAL board, the embedded DAC peripheral directly generates the audio data (frame synchronization is controlled using TIM6 timer).

Firmware implementation

The aim of the STM32 speaker demo is to store the data (Audio Stream) received from the host in a specific buffer called *Stream_Buffer* and to use the PWM to play one stream (8-bit format) every 45.45 µs (~ 22 kHz).

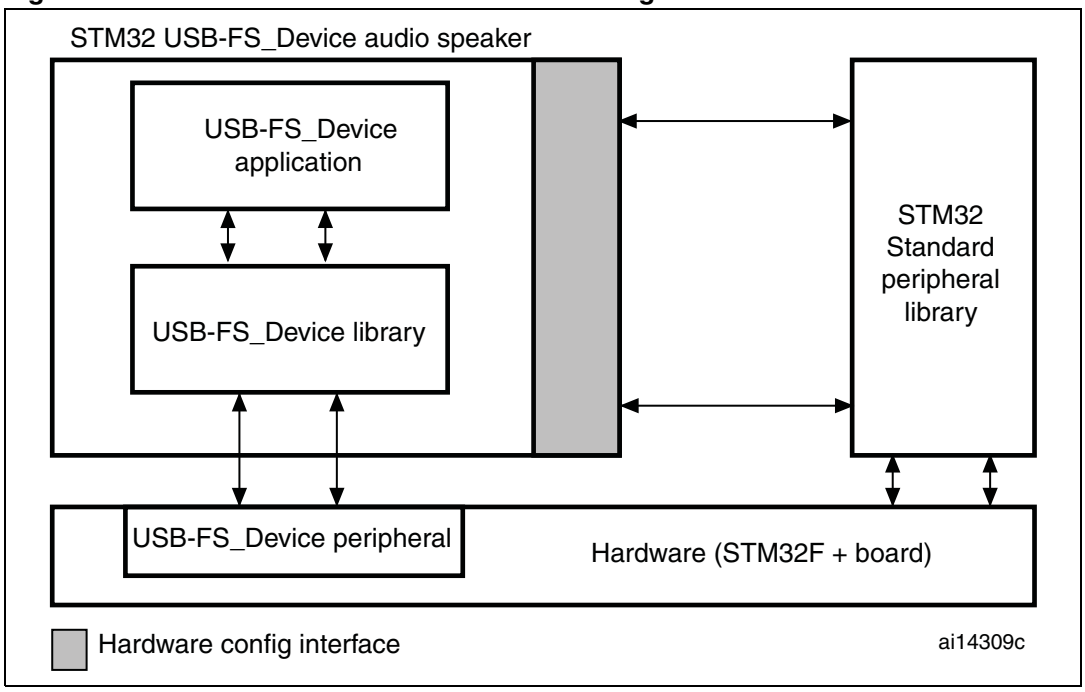
- Hardware configuration interface:

  The hardware configuration interface is a layer between the USB application (in our case the USB device Audio Speaker) and the internal/external hardware of the STM32 microcontroller. This internal and external hardware is managed by the STM32's standard peripheral library, so from the firmware point of view, the hardware configuration interface is the firmware layer between the USB-FS_Device application and the standard peripheral library. *Figure 20* shows the interaction between the different firmware components and the hardware environment.

  The hardware configuration layer is represented by the two files *hw_config.c* and *hw_config.h*. For the USB audio speaker demo, the hardware management layer manages the following hardware requirements:

  – System and USB peripheral clock configuration
  – Timer configuration (when STM3210B-EVAL is used)
  – I^2S configuration (when STM3210E-EVAL is used)
  – DAC and Timer configuration (when STM32L152-EVAL is used)

Figure 20. Hardware and firmware interaction diagram



- Endpoint configurations:

  In the STM32 USB device speaker demo, two endpoints are used to communicate with the PC host: endpoint 0 and endpoint 1. Note that endpoint 1 is an Isochronous OUT endpoint and this kind of endpoint is managed by the STM32 USB device peripheral using the double buffer mode so the firmware has to provide two data buffers in the Packet Memory Area for this endpoint. The following C code describes the method used to configure an isochronous OUT endpoint (see the *usb_prop.c* file, `Speaker_Reset ()` function).

```
/* Initialize Endpoint 1 */
    SetEPType(ENDP1, EP_ISOCHRONOUS);
    SetEPDblBuffAddr(ENDP1,ENDP1_BUF0Addr,ENDP1_BUF1Addr);
    SetEPDblBuffCount(ENDP1, EP_DBUF_OUT, 22);
    ClearDTOG_RX(ENDP1);
        ClearDTOG_TX(ENDP1);
        ToggleDTOG_TX(ENDP1);
        SetEPRxStatus(ENDP1, EP_RX_VALID);
        SetEPTxStatus(ENDP1, EP_TX_DIS);
```

- Class-specific request

  This implementation supports only Mute control. This feature is managed by the `Mute_command` function (*usb_prop.c* file).

- Isochronous data transfer management

  As detailed before, the STM32 manages the isochronous data transfer using the double buffer mode. So to copy the received data from the PMA to the *Stream_Buffer*, the swapping between the two PMA buffers (ENDP1_BUF0Addr and ENDP1_BUF1Addr) has to be managed. Swapping access to the PMA is managed according to the buffer usage between the USB peripheral and the firmware. This operation is provided by the `EP1_OUT_Callback ()` function (*usb_endp.c* file). After

the end of the copy process, a global variable called *IN_Data_Offset* is updated by the number of bytes received and copied in the Stream_Buffer.

- Audio Playing Implementation:

  To play back the audio samples received from the host when using the STM3210B-EVAL board, Timer TIM4 is programmed to generate a 125.5 kHz PWM signal and the TIM2 is programmed to generate an interrupt at a frequency equal to 22 kHz. On each TIM2 interrupt one Audio Stream is used to update the pulse of the PWM. A global variable (*Out_Data_Offset*) is used to point to the next Stream to play in Stream buffer.

  When the I^2S audio peripheral is used in the STM3210E-EVAL board, the *Out_Data_Offset* variable controls the streaming flow to synchronize the data from the USB with the Stream buffer used by the I^2S peripheral.

  When the DAC peripheral is used in the STM32L152-EVAL board, the *Out_Data_Offset* variable controls the streaming flow to synchronize the data from the USB with the Stream buffer used by the DAC peripheral.

Note: Both "IN_Data_Offset" and "Out_Data_Offset" are initialized to 0 in each Start of frame interrupt (see usb_istr.c file, SOF_Callback() function) to avoid overflowing the "Stream_Buffer".

Audio speaker descriptors

Table 21. Device descriptors

Field	Value	Description
bLength	0x12	Size of this descriptor in bytes
bDescriptortype	0x01	Descriptor type (Device descriptor)
bcdUSB	0x0200	USB specification Release number: 2.0
bDeviceClass	0x00	Device class
bDeviceSubClass	0x00	Device subclass
bDeviceProtocol	0x00	Device protocol
bMaxPacketSize0	0x40	Max packet size of Endpoint 0: 64 bytes;
idVendor	0x0483	Vendor identifier (STMicroelectronics)
idProduct	0x5730	Product identifier
bcdDevice	0x0100	Device release number: 1.00
iManufacturer	0x01	Index of the manufacturer string descriptor: 1
iProduct	0x02	Index of the product string descriptor: 2
iSerialNumber	0x03	Index of the serial number string descriptor: 3
bNumConfigurations	0x01	Number of possible configurations: 1

Table 22. Configuration descriptors

Field	Value	Description
bLength	0x09	Size of this descriptor in bytes
bDescriptortype	0x02	Descriptor type (Configuration descriptor)
wTotalLength	0x006D	Total length (in bytes) of the returned data by this descriptor (including interface endpoint descriptors)
bNumInterfaces	0x02	Number of interfaces supported by this configuration (two interfaces)
bConfigurationValue	0x01	Configuration value
iConfiguration	0x00	Index of the Configuration String descriptor
bmAttributes	0x80	Configuration characteristics: Bus powered
Maxpower	0x32	Maximum power consumption through USB bus: 100 mA

Table 23. Interface descriptors

Field	Value	Description
USB speaker standard interface AC descriptor (Interface 0, alternate setting 0)		
bLength	0x09	Size of this descriptor in bytes
bDescriptortype	0x04	Descriptor type: Interface descriptor
bInterfaceNumber	0x00	Interface number

Table 23. Interface descriptors (continued)

Field	Value	Description
bAlternateSetting	0x00	Alternate setting number
bNumEndpoints	0x00	Number of used endpoints: 0 (only endpoint 0 is used for this interface)
bInterfaceClass	0x01	Interface class: USB DEVICE CLASS AUDIO
bInterfaceSubClass	0x01	Interface subclass: AUDIO SUBCLASS AUDIOCONTROL
bInterfaceProtocol	0x00	Interface protocol: AUDIO PROTOCOL UNDEFINED
iInterface	0x00	Index of the interface string descriptor
USB speaker class-specific AC interface descriptor		
bLength	0x09	Size of this descriptor in bytes
bDescriptortype	0x24	Descriptor type: AUDIO INTERFACE DESCRIPTOR TYPE
bDescriptorSubtype	0x01	Descriptor Subtype: AUDIO CONTROL HEADER
bcdADC	0x0100	bcdADC:1.00
wTotalLength	0x0027	Total Length: 39
bInCollection	0x01	Number of streaming interfaces: 1
baInterfaceNr	0x01	baInterfaceNr: 1
USB speaker input terminal descriptor		
bLength	0x0C	Size of this descriptor in bytes: 12
bDescriptortype	0x24	Descriptor type: AUDIO INTERFACE DESCRIPTOR TYPE
bDescriptorSubtype	0x02	Descriptor Subtype: AUDIO CONTROL INPUT TERMINAL
bTerminalID	0x01	Terminal ID: 1
wTerminalType	0x0101	Terminal type: AUDIO TERMINAL USB STREAMING
bAssocTerminal	0x00	No association
bNrChannels	0x01	One channel
wChannelConfig	0x0000	Channel Configuration: MONO
iChannelNames	0x00	Unused
iTerminal	0x00	Unused
USB speaker audio feature unit descriptor		
bLength	0x09	Size of this descriptor in bytes
bDescriptortype	0x24	Descriptor type: AUDIO INTERFACE DESCRIPTOR TYPE
bDescriptorSubtype	0x06	DescriptorSubtype: AUDIO CONTROL FEATURE UNIT
bUnitID	0x02	Unit ID: 2
bSourceID	0x01	Source ID:1
bControlSize	0x01	Control Size:1
bmaControls	0x0001	Only the control of the MUTE is supported

Table 23. Interface descriptors (continued)

Field	Value	Description
iTerminal	0x00	Unused
USB speaker output terminal descriptor		
bLength	0x09	Size of this descriptor in bytes
bDescriptortype	0x24	Descriptor type: AUDIO INTERFACE DESCRIPTOR TYPE
bDescriptorSubtype	0x03	Descriptor subtype: AUDIO CONTROL OUTPUT TERMINAL
bTerminalID	0x03	Terminal ID: 3
wTerminalType	0x0301	Terminal Type: AUDIO TERMINAL SPEAKER
bAssocTerminal	0x00	No association
bSourceID	0x02	Source ID:2
iTerminal	0x00	Unused
USB speaker standard AS interface descriptor - audio streaming zero bandwidth (Interface 1, alternate setting 0)		
bLength	0x09	Size of this descriptor in bytes
bDescriptortype	0x24	Descriptor type: AUDIO INTERFACE DESCRIPTOR TYPE
bInterfaceNumber	0x01	Interface Number: 1
bAlternateSetting	0x00	Alternate Setting: 0
bNumEndpoints	0x00	not used (zero bandwidth)
bInterfaceClass	0x01	Interface class: USB DEVICE CLASS AUDIO
bInterfaceSubClass	0x02	Interface subclass: AUDIO SUBCLASS AUDIOSTREAMING
bInterfaceProtocol	0x00	Interface protocol: AUDIO PROTOCOL UNDEFINED
iInterface	0x00	Unused
USB speaker standard AS interface descriptor - audio streaming operational (Interface 1, Alternate setting 1)		
bLength	0x09	Size of this descriptor in bytes
bDescriptortype	0x24	Descriptor type: AUDIO INTERFACE DESCRIPTOR TYPE
bInterfaceNumber	0x01	Interface number: 1
bAlternateSetting	0x01	Alternate Setting: 1
bNumEndpoints	0x01	One Endpoint.
bInterfaceClass	0x01	Interface class: USB CLASS AUDIO
bInterfaceSubClass	0x02	Interface subclass: AUDIO SUBCLASS AUDIOSTREAMING
bInterfaceProtocol	0x00	Interface protocol: AUDIO PROTOCOL UNDEFINED
iInterface	0x00	Unused

Table 23. Interface descriptors (continued)

Field	Value	Description
USB speaker audio streaming interface descriptor		
bLength	0x07	Size of this descriptor in bytes
bDescriptortype	0x24	Descriptor type: AUDIO INTERFACE DESCRIPTOR TYPE
bInterfaceNumber	0x01	Interface number: 1
bAlternateSetting	0x01	Alternate Setting: 1
bNumEndpoints	0x01	One Endpoint.
wFormatTag	0x0002	PCM8 format
USB speaker audio type I format interface descriptor		
bLength	0x0B	Size of this descriptor in bytes
bDescriptortype	0x24	Descriptor type: AUDIO INTERFACE DESCRIPTOR TYPE
bDescriptorSubtype	0x03	Descriptor subtype: AUDIO STREAMING FORMAT TYPE
bFormatType	0x01	Format type: Type I
bNrChannels	0x01	Number of channels: one channel
bSubFrameSize	0x01	Subframe size: one byte per audio subframe
bBitResolution	0x08	Bit resolution: 8 bits per sample
bSamFreqType	0x01	One frequency supported
tSamFreq	0x0055F0	22 kHz

Table 24. Endpoint descriptors

Field	Value	Description
Endpoint 1 - standard descriptor		
bLength	0x07	Size of this descriptor in bytes
bDescriptortype	0x05	Descriptor type (endpoint descriptor)
bEndpointAddress	0x01	OUT Endpoint address 1.
bmAttributes	0x01	Isochronous Endpoint
wMaxPacketSize	0x0016	22 bytes
bInterval	0x00	Unused
Endpoint 1 - Audio streaming descriptor		
bLength	0x07	Size of this descriptor in bytes
bDescriptortype	0x25	Descriptor type: AUDIO ENDPOINT DESCRIPTOR TYPE
bDescriptor	0x01	AUDIO ENDPOINT GENERAL
bmAttributes	0x80	*bmAttributes*: 0x80

Table 24. Endpoint descriptors (continued)

Field	Value	Description
bLockDelayUnits	0x00	Unused
wLockDelay	0x0000	Unused

10 Device firmware upgrade

This demo runs on the following STMicroelectronics evaluation boards, and can be easily tailored to any other hardware:

- STM3210B-EVAL
- STM3210E-EVAL
- STM32L152-EVAL
- STM32373C-EVAL
- STM32303C-EVAL
- STM32L152D-EVAL

To select the STMicroelectronics evaluation board used to run the demo, uncomment the corresponding line in the *platform_config.h* file.

10.1 General description

This part of the document presents the implementation of a device firmware upgrade (DFU) capability in the STM32 microcontroller. It follows the DFU class specification defined by the USB Implementers Forum for reprogramming an application through USB. The DFU principle is particularly well suited to USB applications that need to be reprogrammed in the field:

The same USB connector can be used for both the standard operating mode and the reprogramming process.

This operation is made possible by the IAP capability featured by most of the STMicroelectronics USB Flash microcontrollers, which allows a Flash MCU to be reprogrammed by any communication channel.

The DFU process, like any other IAP process, is based on the execution of firmware located in one small part of the Flash memory and that manages the erase and program operations of the others Flash memory modules depending on the device capabilities: it could be the main program/Code Flash, data Flash/EEPROM or any other memory connected to the microcontroller even a serial Flash (Through SPI or I^2C etc.).

Table 25 shows the Flash memory type used by the STM32 DFU demo:

Table 25. Flash memory used by DFU

Eval board	Flash memory
STM3210E-EVAL	Internal Flash SPI NOR
STM3210B-EVAL	SPI
STM32303C-EVAL	Internal Flash
STM32L152D-EVAL	Internal Flash
STM32L152-EVAL	Internal Flash
STM32373C-EVAL	Internal Flash

Refer to the UM0412, *DfuSe USB device firmware upgrade STMicroelectronics extension*, for more details on the driver installation and PC user interface.

Note: If the internal Flash memory where the user application is to be programmed is write- or/and read-protected, it is required to first disable the protection prior to using the DFU.

10.2 DFU extension protocol

10.2.1 Introduction

The DFU class uses the USB as a communication channel between the microcontroller and the programming tool, generally a PC host. The DFU class specification states that, all the commands, status and data exchanges have to be performed through Control Endpoint 0. The command set, as well as the basic protocol are also defined, but the higher level protocol (Data format, error message etc.) remain vendor-specific. This means that the DFU class does not define the format of the data transferred (.s19, .hex, pure binary etc.).

Because it is impractical for a device to concurrently perform both DFU operations and its normal runtime activities, those normal activities must cease for the duration of the DFU operations. Doing so means that the device must change its operating mode; that is, a printer is **not** a printer while it is undergoing a firmware upgrade; it is a Flash/Memory programmer. However, a device that supports DFU is not capable of changing its mode of operation on its own volition. External (human or host operating system) intervention is required.

10.2.2 Phases

There are four distinct phases required to accomplish a firmware upgrade:

1. **Enumeration**

   The device informs the host of its capabilities. A DFU class-interface descriptor and associated functional descriptor embedded within the device's normal run-time descriptors serve this purpose and provide a target for class-specific requests over the control pipe.

2. **DFU enumeration**

   The host and the device agree to initiate a firmware upgrade. The host issues a USB reset to the device, and the device then exports a second set of descriptors in preparation for the Transfer phase. This deactivates the run-time device drivers associated with the device and allows the DFU driver to reprogram the device's firmware unhindered by any other communications traffic targeting the device.

3. **Transfer**

   The host transfers the firmware image to the device. The parameters specified in the functional descriptor are used to ensure correct block sizes and timing for programming the non-volatile memories. Status requests are employed to maintain synchronization between the host and the device.

4. **Manifestation**

   Once the device reports to the host that it has completed the reprogramming operations, the host issues a USB reset to the device. The device re-enumerates and executes the upgraded firmware.

To ensure that only the DFU driver is loaded, it is considered necessary to change the *id-Product* field of the device when it enumerates the DFU descriptor set. This ensures that the

DFU driver will be loaded in cases where the operating system simply matches the vendor ID and product ID to a specific driver.

10.2.3 Requests

A number of DFU class-specific requests are needed to accomplish the upgrade operations. *Table 26* summarizes the DFU class-specific requests.

Table 26. Summary of DFU class-specific requests

bmRequest	bRequest	wValue	wIndex	wLength	Data
00100001b	DFU_DETACH (0)	wTimeout	Interface	Zero	None
00100001b	DFU_DNLOAD (1)	wBlockNum	Interface	Length	Firmware
10100001b	DFU_UPLOAD (2)	wBlockNum	Interface	Length	Firmware
10100001b	DFU_GETSTATUS(3)	Zero	Interface	6	Status
00100001b	DFU_CLRSTATUS (4)	Zero	Interface	Zero	None
10100001b	DFU_GETSTATE (5)	Zero	Interface	1	State
00100001b	DFU_ABORT (6)	Zero	Interface	Zero	None

For additional information about these requests, please refer to the DFU Class specification.

10.3 DFU mode selection

The host should be able to enumerate a device with DFU capability in two ways:

- As a single device with only DFU capability
- As a composite device: HID, Mass storage, or any functional class, and with DFU capability.

During the enumeration phase, the device exposes two distinct and independent descriptor sets, each one at the appropriate time:

- Run-time descriptor set: shown when the device performs normal operations
- DFU mode descriptor set: shown when host and device agree to perform DFU operations

10.3.1 Run-time descriptor set

During normal run-time operation, the device exposes its normal set of descriptors plus two additional descriptors:

- Run-time DFU interface descriptor
- Run-time DFU functional descriptor

Note: The number of interfaces in each configuration descriptor that supports the DFU must be incremented by one to accommodate the addition of the DFU interface descriptor.

10.3.2 DFU mode descriptor set

After the host and the device agree to perform DFU operations, the host re-enumerates the device. At this time the device exports the descriptor set shown below:

- DFU Mode Device descriptor
- DFU Mode Configuration descriptor
- DFU Mode Interface descriptor
- DFU Mode Functional descriptor: identical to the Run-Time DFU Functional descriptor

DFU mode device descriptor

This descriptor is only present in the DFU mode descriptor set.

Table 27. DFU mode device descriptor

Offset	Field	Size	Value	Description
0	bLength	1	0x12	Size of this descriptor, in bytes.
1	bDescriptorType	1	0x01	DEVICE descriptor type.
2	bcdUSB	2	0x0100	USB specification release number in binary coded decimal.
4	bDeviceClass	1	0x00	See interface.
5	bDeviceSubClass	1	0x00	See interface.
6	bDeviceProtocol	1	0x00	See interface.
7	bMaxPacketSize0	1	8,16,32,64	Maximum packet size for endpoint zero.
8	idVendor	1	0x0483	Vendor ID
10	idProduct		0xDF11	Product ID
12	bcdDevice		0x011A	Version of the STMicroelectronics DFU ExtensionSpecification release
14	iManufacturer		Index	Index of string descriptor.
15	iProduct		Index	Index of string descriptor.
16	iSerialNumber		Index	*Index of string descriptor.*
17	bNumbConfigurations		0x01	One configuration only for DFU.

DFU mode configuration descriptor

This descriptor is identical to the standard configuration descriptor described in the USB specification version 1.0, with the exception that the `bInterfaceNum` field must contain the value 0x01.

DFU mode interface descriptor

This is the descriptor for the only interface available when operating in DFU mode. Therefore, the value of the `bInterfaceNumber` field is always zero.

Table 28. DFU mode interface descriptor

Offset	Field	Size	Value	Description
0	bLength	1	0x09	Size of this descriptor, in bytes.
1	bDescriptorType	1	0x04	INTERFACE descriptor type.
2	bInterfaceNumber	1	0x00	Number of this interface.
3	bAlternateSetting	1	Number	Alternate setting
4	bNumEndpoints	1	0x00	Only the control pipe is used.
5	bInterfaceClass	1	0xFE	Application Specific Class Code
6	bInterfaceSubClass	1	0x01	Device Firmware Upgrade Code
7	bInterfaceProtocol	1	0x00	The device does not use a class-specific protocol on this interface
8	iInterface	1	Index	Index of string descriptor for this interface

There is an STMicroelectronics implementation for Alternate settings with a corresponding string descriptor set, which is not specified by the standard DFU specification in *Section 10.2.3: Requests*.

Alternate settings have to be used to access additional memory segments and other memories (Flash memory, RAM, EEPROM) which may or may not be physically implemented in the CPU memory mapping, such as external serial SPI Flash memory or external NOR/NAND Flash memory.

In this case, each alternate setting employs a string descriptor to indicate the target memory segment as shown below:

```
@Target Memory Name/Start Address/Sector(1)_Count*Sector(1)_Size
Sector(1)_Type,Sector(2)_Count*Sector(2)_SizeSector(2)_Type,...
...,Sector(n)_Count*Sector(n)_SizeSector(n)_Type
```

Another example, for STM32 Flash microcontroller, is shown below:

```
@Internal Flash /0x08000000/12*001 Ka,116*001 Kg" in case of
STM3210B-EVAL board.
@Internal Flash /0x08000000/6*002 Ka,250*002 Kg" in case of
STM3210E-EVAL board.


@Internal Flash /0x08000000/48*256 Ka,464*256 Kg" in case of
STM32L152-EVAL board.
@Internal Flash /0x08000000/48*256 Ka,1488*256 Kg" in case of
STM32L152D-EVAL board.
@Internal Flash /0x08000000/12*001 Ka,116*001 Kg" in case of
STM32373C-EVAL and STM32303C-EVAL boards.
```

Each Alternate setting string descriptor must follow this memory mapping so that the PC Host Software can decode the right mapping for the selected device:

- @: To detect that this is a special mapping descriptor (to avoid decoding standard descriptor)
- /: for separator between zones
- Maximum 8 digits per address starting by “0x”
- /: for separator between zones
- Maximum of 2 digits for the number of sectors
- *: For separator between number of sectors and sector size
- Maximum 3 digits for sector size between 0 and 999
- 1 digit for the sector size multiplier. Valid entries are: B (byte), K (Kilo), M (Mega)
- 1 digit for the sector type as follows:
  - a (0x41): Readable
  - b (0x42): Erasable
  - c (0x43): Readable and Erasabled (0x44): Writeable
  - e (0x45): Readable and Writeable
  - f (0x46): Erasable and Writeable
  - g (0x47): Readable, Erasable and Writeable

Note: If the target memory is not contiguous, the user can add the new sectors to be decoded just after a slash"/" as shown in the following example:

```
"@Flash /0xF000/1*4Ka/0xE000/1*4Kg/0x8000/2*24Kg"
```

DFU functional descriptor

This descriptor is identical for both the runtime and the DFU mode descriptor sets.

Table 29. DFU functional descriptor

Offset	Field	Size	Value	Description
0	bLength	1	0x09	Size of this descriptor, in bytes.
1	bDescriptorType	1	0x21	DFU FUNCTIONAL descriptor type.
2	bmAttributes	1	0x00	*DFU attributes:* – Bit7: if bit1 is set, the device will have an accelerated upload speed of 4096 byes per upload command (*bitCanAccelerate)* 0: No 1:Yes – Bits 6:4: reserved – Bit 3: device will perform a bus detach-attach sequence when it receives a DFU_DETACH request. 0 = no 1 = yes *Note: The host must not issue a USB Reset. (bitWillDetach)* – Bit 2: device is able to communicate via USB after Manifestation phase (bitManifestation tolerant) 0 = no, must see bus reset 1 = yes – Bit 1: upload capable (bitCanUpload) 0 = no 1 = yes – Bit 0: download capable (bitCanDnload) 0 = no 1 = yes
3	wDetachTimeOut	2	Number	Time, in milliseconds, that the device waits after receipt of the DFU_DETACH request. If this time elapses without a USB reset, then the device terminates the Reconfiguration phase and reverts to normal operation. This represents the maximum time that the device can wait (depending on its timers, etc.). The host may specify a shorter timeout in the DFU_DETACH request.
5	wTransferSize	2	Number	Maximum number of bytes that the device can accept per control-write transaction: wTransferSize depends on the firmware implementation on each MCU.
7	bcdDFUVersion	2	0x011A	Version of the STMicroelectronics DFU ExtensionSpecification release.

10.4 Reconfiguration phase

Once the operator has identified the device and supplied the filename, the host and the device must negotiate to perform the upgrade.

1. The host issues a DFU_DETACH request to Control Endpoint EP0.
2. The host issues a USB reset to the device. This USB reset is not possible on some PC Host OS versions. To bypass this issue, the USB reset is performed by the MCU depending on the corresponding implementation.
3. The device enumerates with the DFU Mode descriptor set, as described above.

Note: Some Device application may not be using USB in their run-time mode such as a Motor control application or security system, and USB may be used only for memory upgrade. Those devices are called non-USB application in the scope of this document and the above sequences are not applicable.

Non-USB applications have to carry out the right procedure to enter the DFU mode. This can be done simply by plugging the USB cable or by jumping to the DFU firmware code while performing an USB reset so that the device would enumerate with the DFU descriptor set.

10.5 Transfer phase

The transfer phase begins after the device has processed the USB reset and exported the DFU Mode descriptor set. Both downloads and uploads of firmware can take place during this phase. This transfer phase consists of a succession of DFU requests according to the state diagram described in the following sections.

10.5.1 Requests

A number of DFU class-specific requests are needed to accomplish the upgrade/upload operations. *Table 30* summarizes these requests.

Table 30. Summary of DFU upgrade/upload requests

bmRequest	bRequest	wValue	wIndex	wLength	Data
00100001b	DFU_DNLOAD (1)	wBlockNum	Interface	Length	Firmware
10100001b	DFU_UPLOAD (2)	wBlockNum	Interface	Length	Firmware
10100001b	DFU_GETSTATUS(3)	Zero	Interface	6	Status
00100001b	DFU_CLRSTATUS (4)	Zero	Interface	Zero	None
10100001b	DFU_GETSTATE (5)	Zero	Interface	1	State
00100001b	DFU_ABORT (6)	Zero	Interface	Zero	None

For additional information about these requests, please refer to the DFU Class specification.

10.5.2 Special command/protocol descriptions

In order to support all features (Address decoding and Memory block to erase, etc.) of the DFU Extension implementation from STMicroelectronics, a few format rules are added to the DFU_DNLOAD request. They are defined as shown in *Table 31*.

Table 31. Special command descriptions

Command	Request	wBlockNum	wLength	Data
Get Commands	DFU_DNLOAD	0	1	**0x00**
Set Address Pointer	DFU_DNLOAD	0	5	**0x21**, Address (4bytes)
Erase Sector containing address	DFU_DNLOAD	0	5	**0x41**, Address (4bytes)

This new custom DFU implements only three supported basic commands:

- **Get commands**

  Byte0 = 0x00, then no additional bytes.

  The next DFU_UPLOAD request with wBlockNum = 0 should give the supported commands.

  The maximum size of the supported commands buffer is **256** bytes, and the buffer **must** support the following commands:

  – 0x00 (Get Commands)
  – 0x21 (Set Address Pointer)
  – 0x41 (Erase Sector containing address)

- **Set Address Pointer**

  Byte0 = 0x21, then 4 bytes containing the address Pointer from which the Blocks will be downloaded or uploaded starting from the next DFU_DNLOAD or DFU_UPLOAD request with wBlockNum >1.

- **Erase Sector containing address**

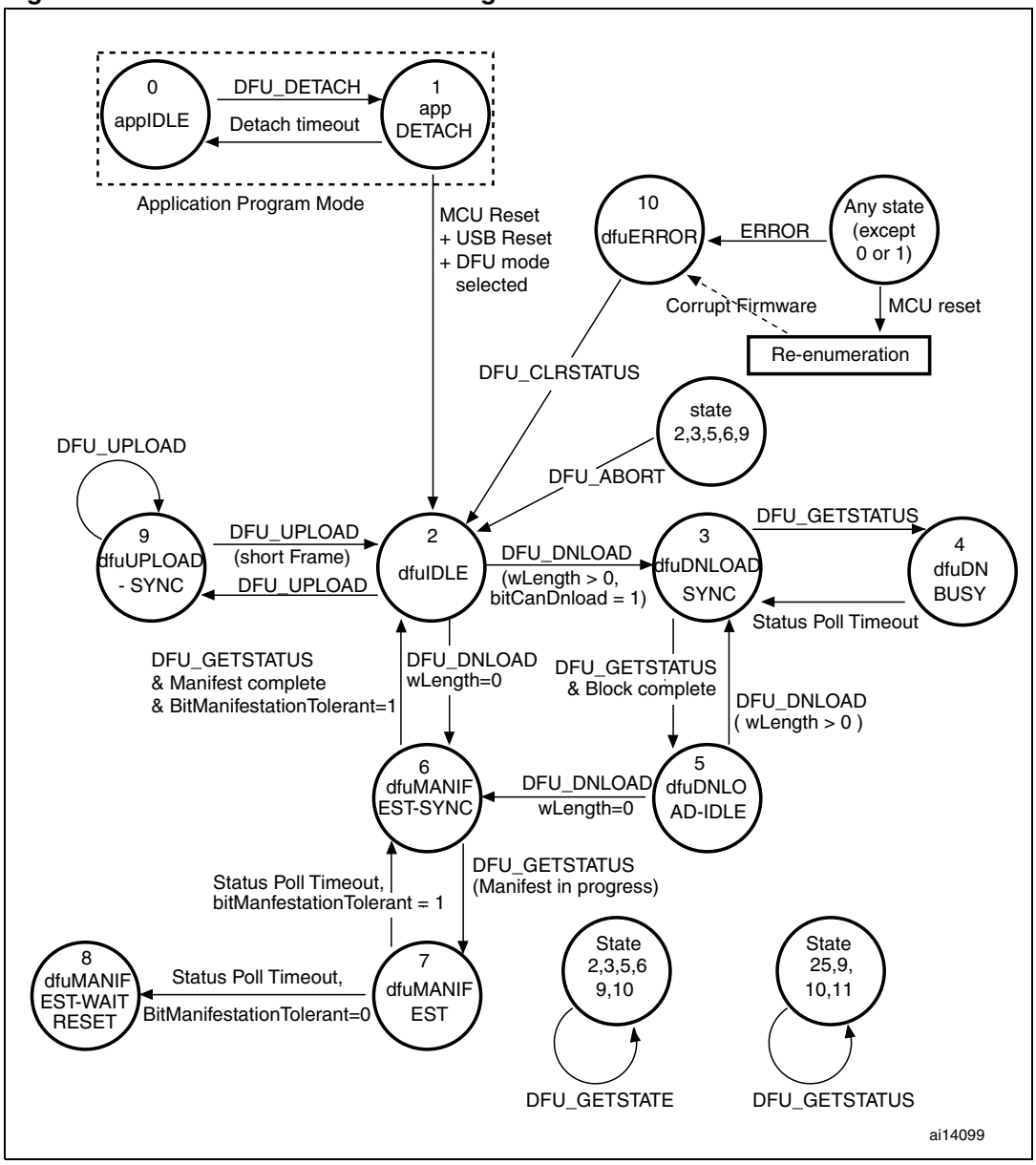
  Byte0 = 0x41, then 4 bytes containing a valid address contained in a memory sector to be erased and as already exported by the string descriptors of the Alternate settings.

Note: wBlockNum = 1 for both DFU_DNLOAD and DFU_UPLOAD requests, is reserved for future use by STMicroelectronics.

10.5.3 DFU state diagram

Figure 21 summarizes the DFU interface states and the transitions between them. The events that rigger state transitions can be thought of as arriving on multiple “input tapes” as in the classic Turing machine concept.

Figure 21. Interface state transition diagram



Note: The state transition diagram shown in Figure 21 is almost the same as that defined in the DFU Class specification (Fig A1 page 28), with the exception of the new transition from state 2 to state 6, which is additional and may or not be implemented in the device firmware.

10.5.4 Downloading and uploading

The host slices the firmware image file into N pieces and sends them to the device by means of control-write operations in the default endpoint (Endpoint 0).

The maximum number of bytes that the device can accept per control-write transaction is specified in the `wTransferSize` field of the DFU Functional Descriptor.

There are several possible download mechanisms depending on the MCU device memory mapping and the Type of the memory (that is Readable, Erasable, Writeable or a combination).

The most generic mechanism is described below, where we have a readable, erasable and writeable sector of memory:

- In addition to the data collected after the enumeration phase about the whole memory mapping, the device capabilities etc., the Host starts to send a GetCommands command in order to know additional device capabilities and which commands are supported by the DFU implementation.
- The host sends an Erase Sector Containing Address command using a `DFU_DNLOAD` request with `wBlockNum = 0` and `wLength = 5`. At this stage, the device erases the memory block where the address sent by the host is located. After the erase operation, the DFU firmware is able to write application data into the erased block.
- The host begins by sending the Set Address Pointer command using a `DFU_DNLOAD` request with `wBlockNum = 0` and `wLength = 5`. This address pointer is saved in the device RAM as an Absolute Offset.
- The host continues to send the N pieces to the device by means of `DFU_DNLOAD` requests with `wBlockNum` starting from 2 and with the maximum number of bytes that the device can accept per control-write transaction specified in the `wTransferSize` field of the DFU Functional Descriptor.

  So the last data written into the memory will be located at device address:

  Absolute Offset + `(wBlockNum - 2) × wTransferSize + wLength`, where `wBlockNum` and `wLength` are the parameters of the last DFU_DNLOAD request.

If the Host wants to upload the memory data for verification, or to retrieve and archive a device firmware, by definition the reverse of a Download is performed:

1. The host begins by sending a Set Address Pointer command using a DFU_DNLOAD request with `wBlockNum = 0` and `wLength = 5`. This address pointer is saved in the device RAM as an Absolute Offset.
2. The host continues to send N DFU_UPLOAD requests with `wBlockNum` starting from 2 and with the maximum number of bytes that the device can accept per control-write transaction specified in the `wTransferSize` field of the DFU Functional Descriptor if *bitCanAccelerate = 0*. If *bitCanAccelerate = 1* in the DFU Functional Descriptor, the value in the `wTransferSize` field is fixed to *0x4096 bytes.*

   So the last data retrieved from the memory will be located at device address:

   Absolute Offset + `(wBlockNum - 2) × wTransferSize + wLength`, where `wBlockNum` and `wLength` are the parameters of the last DFU_UPLOAD request.

10.5.5 Manifestation phase

After the transfer phase completes, the device is ready to execute the new firmware. This is achieved by performing a USB reset to re-enumerate the device in normal run-time operation.

10.6 STM32 DFU implementation

10.6.1 Supported memories

For the STM32 the DFU implementation supports the following memories:

- **Internal Flash memory**: the first pages are reserved for the DFU (read-only pages) and the remaining pages can be programmed by the DFU (application zone):
  - For the STM3210B-EVAL, STM32373C-EVAL and STM32303C-EVAL boards, the first 12 pages are read-only, and the remaining 116 pages are in the application zone.
  - For the STM3210E-EVAL board, the first 6 pages are read-only, and the remaining 250 pages are in the application zone.
  - For the STM32L152-EVAL board, the first 48 pages are read-only, and the remaining 464 pages are in the application zone.
  - For the STM32L152D-EVAL board, the first 48 pages are read-only, and the remaining 1488 pages are in the application zone.
- **External serial Flash memory (M25P64):** consists of 128 sectors of 64 Kbytes each.
- **NOR Flash memory (M29W128):** consists of 256 blocks of 64 Kbytes each. This memory is supported only by the STM3210E-EVAL board.

Note: To create a DFU image for the internal Flash memory select the Alternate Setting 00 in the DFU file Manager.

To create a DFU image for the external serial Flash memory, select the Alternate Setting 01 in the DFU file Manager.

To create a DFU image for the NORFlash memory, select the Alternate Setting 02 in the DFU file Manager.

10.6.2 DFU mode entry mechanism

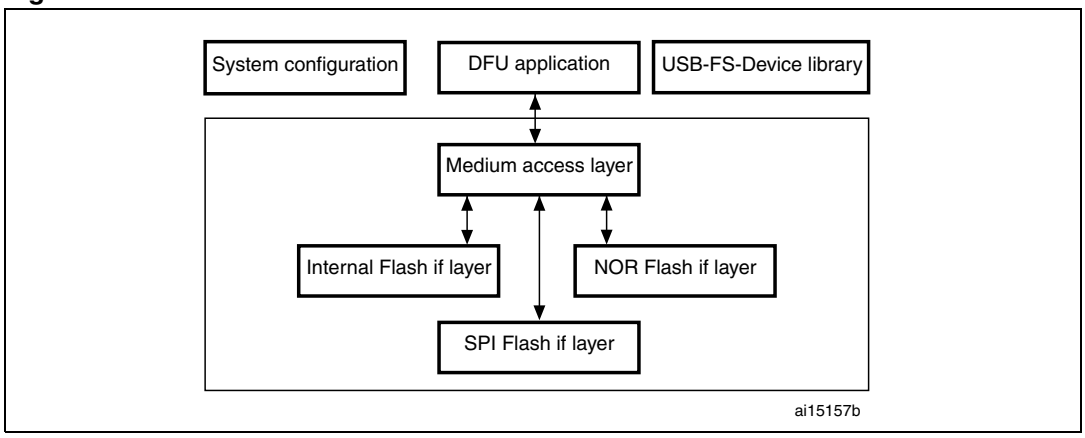
For the STM32 the DFU mode is entered after an MCU reset if:

- The DFU mode is forced by the user: the user presses the key push-button (or joystick Up push-button for STM32L152-EVAL board) after a reset.
- There is no correct code available in the application area: before jumping to the application code, the DFU code tests if there is a correct top-of-stack address in the first address in the application area of the internal Flash memory (for the STM32 the first application address is 0x0800 3000). This is done by reading the value of the first application address and verifying if the MSB half-word is equal to 0x2000 (base address of the RAM area in the STM32).

10.6.3 DFU firmware architecture

The DFU application is built around the DFU core which handles the DFU protocol and the medium access layer (MAL). The MAL is like an abstraction layer between the DFU core and the different medium drivers. The MAL uses the base address of each medium to dispatch the write, read and erase operations to the addressed medium.

Figure 22. DFU firmware architecture



10.6.4 Available DFU image for the STM32

The available DFU images in the STM32 USB development kit are:

- Joystick Mouse Demo
- Custom HID Demo
- Mass Storage Demo
- Composite Example
- CDC_LoopBack
- Virtual COM Demo
- Audio Speaker Demo (for the STM3210B-EVAL, STM3210E-EVAL and STM32L152-EVAL evaluation boards)

10.6.5 Creating a DFU image

Two steps are needed to create a DFU image:

1. Create a binary image from one of the available USB demo projects by adjusting the Flash memory base to 0x0800 3000 and by setting the vector table at the top of the Flash memory space 0x0800 3000.
2. Using the DFU file manager provided with the DFU demo package, generate the DFU file by setting target ID to 0 (internal Flash) and the start address to 0x0800 3000.

11 Composite example

This demo runs on the following STMicroelectronics evaluation boards, and can be easily tailored to any other hardware:

- STM3210B-EVAL
- STM3210E-EVAL
- STM32L152-EVAL
- STM32373C-EVAL
- STM32303C-EVAL
- STM32L152D-EVAL

To select the STMicroelectronics evaluation board used to run the demo, uncomment the corresponding line in the *platform_config.h* file.

11.1 General description

A composite device is defined in the USB specification as follows:

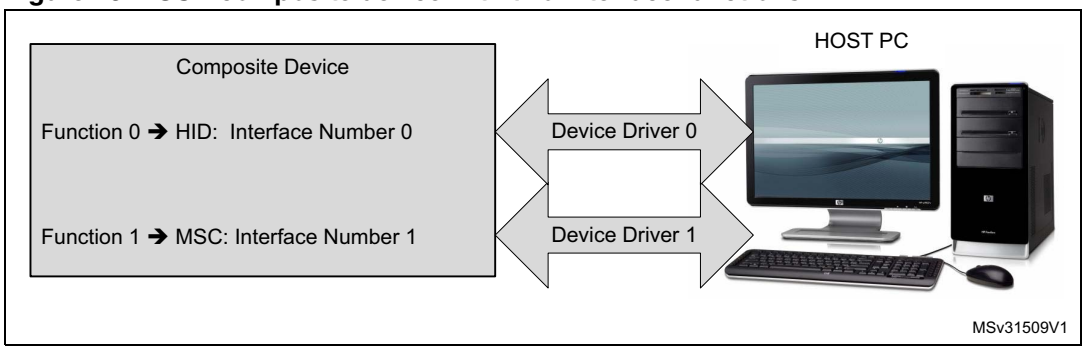
"A device that has multiple interfaces controlled independently of each other is referred to as a composite device."

For more details on composite devices, please refer to “usb_20.pdf 5.2.3”, which is available on the usb.org website.

When using such devices, multiple functions are combined into a single device. In this example, the independent interfaces are **Mass Storage (MSC)** and **HID.**

The host can see all these available functions simultaneously, and assigns a separate device driver to each Interface of the composite device as shown in *Figure 23*.

Figure 23. USB composite device with two interface functions



11.2 Architecture

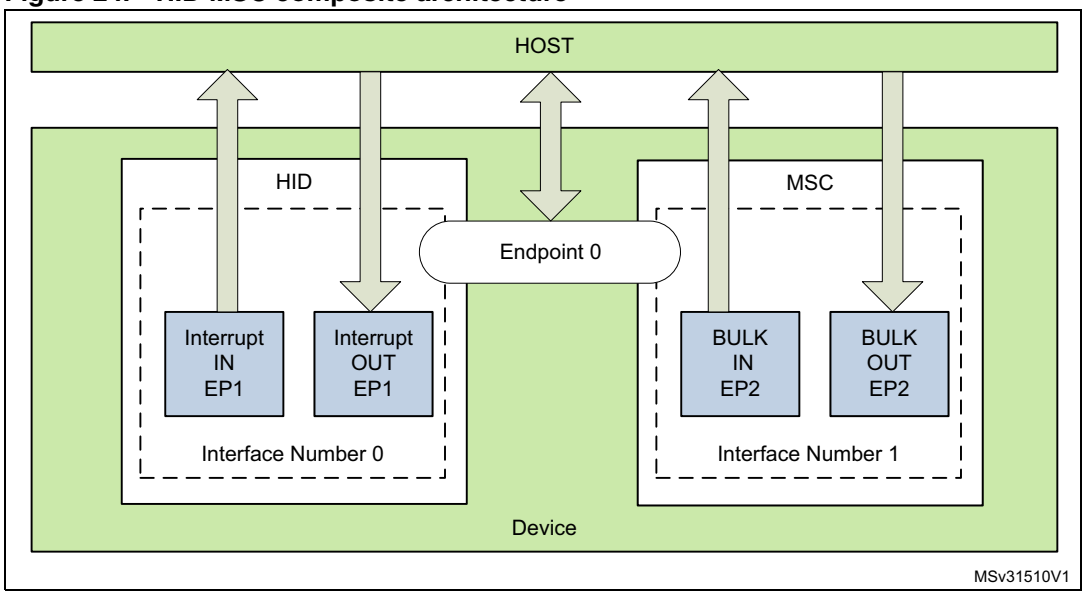
This example was created by combining the code in the Custom HID and USB MSC example projects.

Starting from the Custom HID example, a new interface and Endpoint (EP2) descriptor were added for mass storage, and the total length in the configuration descriptor was modified.

The control endpoint (endpoint 0) is shared by all functions. Each function has one interface.

The block diagram in *Figure 24* shows the architecture of the HID MSC composite example.

Figure 24. HID MSC composite architecture



11.3 USB device descriptor

bNumInterfaces tells the host how many interfaces the device uses. An interface is a point of contact where the host and the device exchange data. This demo uses two interfaces in all.

Figure 25 shows how the USB descriptor was changed in the project to add another MSC interface:

Figure 25. USB device descriptor

```
/*   All Descriptors (Configuration, Interface, Endpoint, Class, Vendor */
const uint8_t Composite_ConfigDescriptor[Composite_SIZ_CONFIG_DESC] =
  {
    0x09, /* bLength: Configuration Descriptor size */
    USB_CONFIGURATION_DESCRIPTOR_TYPE, /* bDescriptorType: Configuration */
    Composite_SIZ_CONFIG_DESC,
    /* wTotalLength: Bytes returned */
    0x00,
    0x02,         /* bNumInterfaces: 2 interfaces */
    0x01,         /* bConfigurationValue: Configuration value */
    0x00,         /* iConfiguration: Index of string descriptor describing
                                 the configuration*/
    0xC0,         /* bmAttributes: Self powered */
    0x32,         /* MaxPower 100 mA: this current is used for detecting Vbus */
```

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Note: After modifying the number of interfaces, the interface's descriptor of a Mass Storage application is added.

When even one of the device's interface classes is changed, Windows should handle it differently. However, Windows doesn't recognize the modification. To avoid conflict on Windows, assign another VID/PID to the device (idProduct = 0x5750), or delete the device instance from the device manager.

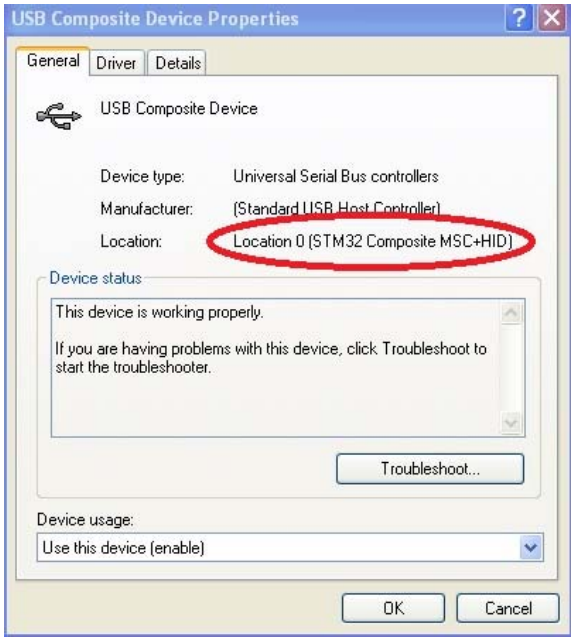
11.4 Running the demo

When attaching a device to the STM32 eval board, the composite appears in the device manager window, as shown in *Figure 26*. You can now use your board as a removable disk and for custom HID applications.

You can see two applications appear in the device manager, each of which can be used in stand alone mode.This is the purpose of the composite device.

1. **USB Mass Storage (removable disk)**: a new removable disk appears, and write, read and format operations can be performed as with any other removable drive. Refer to *Chapter 6: Mass storage demo* for more information.
2. **HID device**: refer to *Chapter 5: Custom HID demo*.

Figure 26. STM32 device enumerated as composite



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12 Revision history

Table 32. Document revision history

Date	Revision	Changes
28-May-2007	1	Initial release.
04-Oct-2007	2	Evaluation board name corrected. Reference to UM0412 added to *Section 10: Device firmware upgrade*. Note added in *Section 6.2: Mass storage demo overview*.
22-May-2008	3	STM3210E-EVAL added, user manual updated accordingly. Small text changes.
30-May-2008	4	*Section 1.5.2: Tusb_desc (.h, .c) on page 21* and *Section 5: Custom HID demo on page 30* added. *Section 4: Joystick mouse demo on page 27* modified. *Section 10.6: STM32 DFU implementation on page 78* modified. *Section 6.4.8: Medium access management on page 44* added.
13-Jun-2008	5	*Caution: on page 45* reference to firmware license agreement removed.
03-Apr-2009	6	USB replaced by USB-FS_Device. STM32 Firmware Library upgraded to the standard peripheral library.
07-May-2009	7	Corrupted pdf version replaced.
10-Nov-2009	8	Added support for OTG full-speed device peripherals. *Introduction* modified. *Section 3.1: USB application hierarchy* and *Section 3.2: USB-FS_Device peripheral interface* modified. Enhancement of the library architecture. `GetEPAdress` modified in *Endpoint register functions*. *Section 10.6.5: Creating a DFU image* modified. *Section 6.2: Mass storage demo overview* modified. *Figure 14: Device manager window* modified. *Section 8: USB audio streaming demo* added. BYTE replaced by uint8_t, WORD replaced by uint16_t. Small text changes.
31-May-2010	9	Modified *Section 3.3.2: usb_core (.h , .c) on page 17* (device property structure) and *Section 3.4.1: usb_conf(.h) on page 22*
31-Mar-2011	10	Updated title and document from "STM32F10xx" to "STM32" to take into account support for the STM32L152-EVAL evaluation boards for STM32L15xx devices.

Table 32. Document revision history (continued)

Date	Revision	Changes
26-Jun-2012	11	Added references to STM32L152D-EVAL board. Section “Device firmware upgrade” moved.
20-Dec-2012	12	Removed support for the OTG full-speed device peripheral. Removed support for STM32F105/F107. Added references to the STM32373C-EVAL and STM32303C-EVAL boards. Modified *Section 5.1: General description* and *Section 5.3.1: LED control*. Modified *Figure 1*, *Figure 2*, *Figure 9*, *Figure 12* and *Figure 25*. Removed the chapter *USB audio streaming demo*. Changed name of *CDC_Loopback* chapter to *Chapter 8: VirtualComport_Loopback*. Added *Chapter 11: Composite example*. Added the following tables: – *Table 2: Reference manual name related to each STM32 device* – *Table 3: User manual name related to each evaluation board* – *Table 10: Key push button assignment* – *Table 11: Eval board memory support* – *Table 20: USART connector number for each evaluation board* – *Table 25: Flash memory used by DFU*

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