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USB composite device on LPC11Uxx

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Application note

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Abstract	This document describes how to create a USB composite device on NXP Cortex-M0 LPC11Uxx. The composite device may include two or three different (or same) interfaces among HID, MSC, CDC and DFU which are some of the most commonly used USB device classes.



Revision history

Rev	Date	Description
1	20120701	Initial version.

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1. Introduction

The LPC11Uxx parts (LPC11U1x, LPC11U2x and LPC11U3x) are available with a USB 2.0 Full-Speed device controller. Extensible on-chip USB drivers are available for LPC11U2x and LPC11U3x. Refer to the User Manual for details.

A Composite Device is defined in the *USB Specification Revision 2.0* as “A device that has multiple interfaces controlled independently of each other”.

This document describes how to create a USB composite device on LPC11Uxx parts. For compatibility with all LPC11Uxx parts, the USB on-chip drivers are not used.

The commonly used USB device classes are: Human Interface Device (HID), Mass Storage Class (MSC), and Communication Device Class (CDC). If a user wants to update the firmware, a Device Firmware Upgrade (DFU) class can also be used.

The USB composite device examples created in this Application Note are shown below:

- HID+MSC
- HID+MSC
- MSC+CDC
- HID+MSC+CDC
- DFU+HID
- DFU+MSC
- DFU+MSC
- DFU+MSC+HID

All the examples are tested on a Keil MCB11U00 evaluation board (populated with LPC11U14/201, Rev. A).

2. USB composite device basics

2.1 Introduction

Normally, a USB device presents a single function to the host, such as a mouse, keyboard, serial RS-232 port or removable storage disk. One function occupies one USB cable and port; in order to use multiple functions at the same time, many USB cables and ports are needed. The composite device allows a multi-function device with only one cable and one port.

The USB Specification Revision 2.0 defines a composite device as “A device that has multiple interfaces controlled independently of each other”. It has the following features:

- Multiple interfaces and functions
- Only a single device address

Note: A Compound Device can also allow multiple functions through a single USB port, but differs in that “multiple functions are combined with a hub in a single package”. Please refer to the USB Specification Revision 2.0 for details.

2.2 Architecture

2.2.1 Communication flow

[Fig 1](#) is the typical communication flow between function (Device side) and client software (Host side). Function is defined as “A USB device that provides a capability to the host” on USB Specification Revision 2.0.

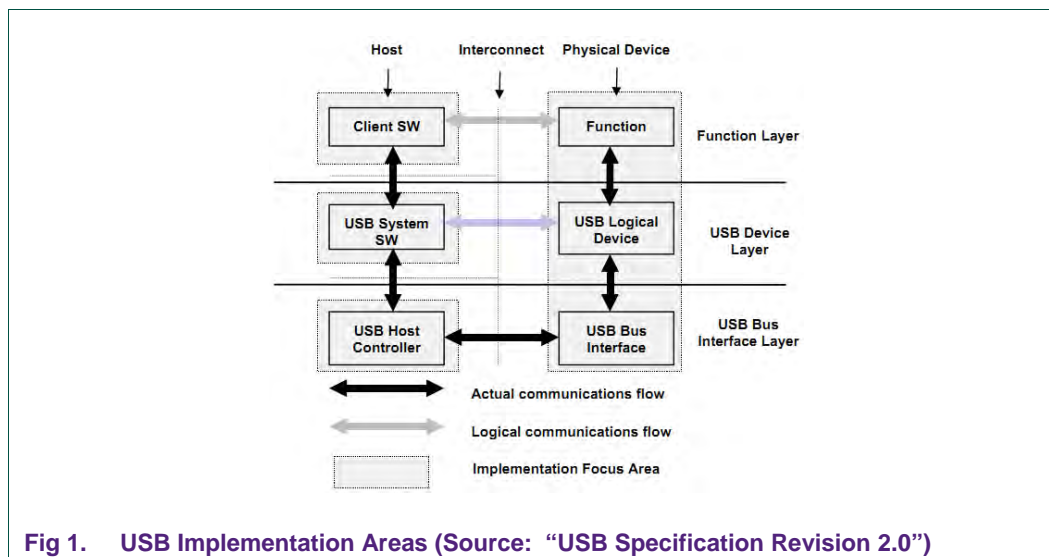


Fig 1. USB Implementation Areas (Source: “USB Specification Revision 2.0”)

Usually there is only one function for a USB device. However, a composite device contains several functions, each of which communicate with the corresponding Client SW (Device Driver) on the Host side. For example, for a composite device which contains HID and MSC, the Host will load a HID and MSC driver respectively on enumeration. A HID driver on the Host will talk to the HID function in the device and an MSC driver will talk to the MSC function in the device simultaneously.

2.2.2 Interfaces

A composite device contains several functions, and each function may have one (e.g. HID, or MSC) or more (e.g. CDC or audio) interfaces. Therefore, special care must be taken for the interface descriptor of a composite device.

For a composite device which contains a single-interface function only, e.g. HID+MSC, the interface descriptor is the concatenation of each function's interface descriptor.

For a composite device which contains multi-interface function, e.g. HID+CDC, an additional Interface Association Descriptor (IAD) should be used.

2.2.3 Endpoints

Beside the default control endpoint (EP0), the composite device should define a number of endpoints equal to the sum of the number of endpoints required for each individual function.

[Fig 2](#) shows the interface and endpoint assignment of the composite device examples in this Application Note.

	HID+MSC	HID+CDC	MSC+CDC	HID+MSC+CDC	DFU+HID	DFU+MSC	DFU+CDC	DFU+HID+MSC
Interface 0	HID	HID	MSC	HID	DFU			
Interface 1	MSC	CDC Control				MSC	CDC Control	HID
Interface 2		CDC Data					CDC Data	MSC
Interface 3				MSC				
EP0	Default Control EP (also for DFU)							
EP1		CDC Interrupt IN					CDC Interrupt IN	
EP2	MSC Bulk IN & OUT		MSC Bulk IN & OUT				MSC Bulk IN & OUT	MSC Bulk IN & OUT
EP3		CDC Bulk IN & OUT					CDC Bulk IN & OUT	
EP4	HID Interrupt IN & OUT			HID Interrupt IN & OUT				HID Interrupt IN & OUT
EP5								

Fig 2. Interface and endpoint assignment (Note: for a composite device with DFU function, the interface assignment in this table is only for run-time mode)

2.3 Host drivers

Windows recognizes the device as a composite device if it meets the following requirements:

- The device class field of the device descriptor (**bDeviceClass**) must contain a value of zero, or the class (**bDeviceClass**), subclass (**bDeviceSubClass**), and protocol (**bDeviceProtocol**) fields of the device descriptor must have the values 0xEF, 0x02 and 0x01 respectively.
- The device must have multiple interfaces.
- The device must have a single configuration.

Windows first recognizes the device as a composite device, and then loads the device driver for each function.

For HID or MSC, Windows loads a generic HID driver (*hidclass.sys* and *hidusb.sys*) or MSC driver (*usbstor.sys*) respectively.

For the CDC, USB virtual COM-port in this example, Windows loads a *usbser.sys* driver. An **INF** file should be provided that contains the device's Vendor ID and Product ID. Windows will use this INF file to select a driver to load. The INF file for CDC in this Application Note is located in \USBClass\CDC\Driver.

For DFU, Windows doesn't provide a driver for this class. This driver should be provided by the user. Windows will also need an INF file to select a driver to load. The driver and INF file for DFU in this Application Note is located in \USBClass\DFU\Driver.

For more details about the USB driver support on Windows, please refer to <http://msdn.microsoft.com/en-us/library/ff538820.aspx>

3. Descriptors of USB composite device

3.1 Device descriptor

The device descriptor of a composite device can be divided into two categories:

- Composite device without multi-interface function, e.g. HID+MSC, HID+DFU.
- Composite device with multi-interface function, e.g. HID+CDC, MSC+CDC.

[Fig 3](#) shows the device descriptor of a composite device without a multi-interface function.

```

/* USB Standard Device Descriptor */
__align(4) const uint8_t USB_DeviceDescriptor[] = {
    USB_DEVICE_DESC_SIZE,          /* bLength */
    USB_DEVICE_DESCRIPTOR_TYPE,    /* bDescriptorType */
    #if LPM_SUPPORT
        WBVAL(0x0201), /* 2.01 */    /* bcdUSB */
    #else
        WBVAL(0x0200), /* 2.00 */    /* bcdUSB */
    #endif
    0x00,                          /* bDeviceClass */
    0x00,                          /* bDeviceSubClass */
    0x00,                          /* bDeviceProtocol */
    USB_MAX_PACKET0,              /* bMaxPacketSize0 */
    WBVAL(0x1FC9),                /* idVendor */
    WBVAL(0x000B),                /* idProduct */
    WBVAL(0x0100), /* 1.00 */    /* bcdDevice */
    0x01,                          /* iManufacturer */
    0x02,                          /* iProduct */
    0x03,                          /* iSerialNumber */
    0x01                          /* bNumConfigurations */
};

```

Fig 3. Device descriptor of a composite device without multi-interface function

Fig 4 shows the device descriptor of a composite device with multi-interface function.

```

/* USB Standard Device Descriptor */
__align(4) const uint8_t USB_DeviceDescriptor[] = {
    USB_DEVICE_DESC_SIZE,          /* bLength */
    USB_DEVICE_DESCRIPTOR_TYPE,    /* bDescriptorType */
    #if LPM_SUPPORT
        WBVAL(0x0201), /* 2.01 */    /* bcdUSB */
    #else
        WBVAL(0x0200), /* 2.00 */    /* bcdUSB */
    #endif
    USB_DEVICE_CLASS_MISCELLANEOUS, /* bDeviceClass */
    0x02,                          /* bDeviceSubClass */
    0x01,                          /* bDeviceProtocol */
    USB_MAX_PACKET0,              /* bMaxPacketSize0 */
    WBVAL(0x1FC9),                /* idVendor */
    WBVAL(0x000B),                /* idProduct */
    WBVAL(0x0100), /* 1.00 */    /* bcdDevice */
    0x01,                          /* iManufacturer */
    0x02,                          /* iProduct */
    0x03,                          /* iSerialNumber */
    0x01                          /* bNumConfigurations */
};

```

Fig 4. Device descriptor of a composite device with multi-interface function

bDeviceClass, **bDeviceSubClass** and **bDeviceProtocol** must be EFH, 02H and 01H.

3.2 Configuration descriptor

For composite devices with multi-interface functions, an IAD is necessary. Therefore, the length of an IAD should be added into the total length (**wTotalLength**).

Fig 5 shows the configuration descriptor of a composite device (HID+CDC) which must include an IAD.

```

const uint8_t USB_ConfigDescriptor[] = {
    /* Configuration 1 */
    USB_CONFIGURATION_DESC_SIZE, /* bLength */
    USB_CONFIGURATION_DESCRIPTOR_TYPE, /* bDescriptorType */
    WVAL( /* wTotalLength */
        1*USB_CONFIGURATION_DESC_SIZE +
        1*USB_INTERFACE_DESC_SIZE +
        HID_DESC_SIZE +
        2*USB_ENDPOINT_DESC_SIZE +
        1*USB_INTERFACE_ASSOCIATION_DESC_SIZE + /* interface association */
        1*USB_INTERFACE_DESC_SIZE + /* communication interface */
        0x0013 + /* CDC functions */
        1*USB_ENDPOINT_DESC_SIZE + /* interrupt endpoint */
        1*USB_INTERFACE_DESC_SIZE + /* data interface */
        2*USB_ENDPOINT_DESC_SIZE /* bulk endpoints */
    ),
    0x03, /* bNumInterfaces */
    0x01, /* bConfigurationValue */
    0x00, /* iConfiguration */
    /* bmAttributes */
    USB_CONFIG_SELF_POWERED | USB_CONFIG_REMOTE_WAKEUP,
    /* else
    USB_CONFIG_SELF_POWERED,
    */
    USB_CONFIG_POWER_MA(100), /* bMaxPower */
};

```

Fig 5. Configuration descriptor of a composite device (HID+CDC)

For composite devices with single-interface functions, the total length (**wTotalLength**) of the configuration descriptor is simply the sum of all the needed descriptors' length.

[Fig 6](#) shows the configuration descriptor of a composite device (HID+MSC) which does not need the IAD.

```

const uint8_t USB_ConfigDescriptor[] = {
    /* Configuration 1 */
    USB_CONFIGURATION_DESC_SIZE, /* bLength */
    USB_CONFIGURATION_DESCRIPTOR_TYPE, /* bDescriptorType */
    WVAL( /* wTotalLength */
        1*USB_CONFIGURATION_DESC_SIZE +
        1*USB_INTERFACE_DESC_SIZE +
        USB_DFU_DESCRIPTOR_SIZE +
        1*USB_INTERFACE_DESC_SIZE +
        HID_DESC_SIZE +
        2*USB_ENDPOINT_DESC_SIZE
    ),
    0x02, /* bNumInterfaces */
    0x01, /* bConfigurationValue */
    0x00, /* iConfiguration */
    /* bmAttributes */
    USB_CONFIG_SELF_POWERED | USB_CONFIG_REMOTE_WAKEUP,
    /* else
    USB_CONFIG_SELF_POWERED,
    */
    USB_CONFIG_POWER_MA(100), /* bMaxPower */
};

```

Fig 6. Configuration descriptor of a composite device (HID+MSC)

For composite devices with DFU functions, the configuration descriptor in run-time mode and DFU mode is different. Two configurations must be defined: **USB_ConfigDescriptor** and **USB_dfuConfigDescriptor**.

USB_ConfigDescriptor is used in run-time mode and may contain HID+MSC+DFU functions.

USB_dfuConfigDescriptor is used in DFU mode and only contain DFU function.

For more details about DFU, please refer to http://www.usb.org/developers/devclass_docs/DFU_1.1.pdf

3.3 Interface descriptor

The interface descriptor for each function in a composite device is almost the same with their definitions in a single USB device except the actual interface index.

3.3.1 Interface Association Descriptor (IAD)

For composite device with multi-interface function, IAD is necessary.

[Fig 7](#) shows the IAD in HID+CDC example.

```
/* IAD to associate the two CDC interfaces */
USB_INTERFACE_ASSOCIATION_DESC_SIZE, /* bLength */
USB_INTERFACE_ASSOCIATION_DESCRIPTOR_TYPE, /* bDescriptorType */
USB_CDC_CIF_NUM, /* bFirstInterface */
2, /* bInterfaceCount */
CDC_COMMUNICATION_INTERFACE_CLASS, /* bFunctionClass */
CDC_ABSTRACT_CONTROL_MODEL, /* bFunctionSubClass */
0, /* bFunctionProtocol */
0x06, /* iFunction (Index of string
/* Interface 1, Alternate Setting 0, Communication class interface
USB_INTERFACE_DESC_SIZE, /* bLength */
USB_INTERFACE_DESCRIPTOR_TYPE, /* bDescriptorType */
USB_CDC_CIF_NUM, /* bInterfaceNumber: Number 0:
```

Fig 7. IAD in HID+CDC example

bDescriptorType is 0x11 to indicate an Interface Association Descriptor.

bFirstInterface is the Interface Number of the first interface that is associated with this function.

bInterfaceCount is the Number of contiguous interfaces that are associated with this function.

Note: only contiguously numbered interfaces can be associated. Also note that this IAD descriptor must be positioned just before the interfaces it references.

For more details about IAD, please refer to http://www.usb.org/developers/whitepapers/iadclasscode_r10.pdf

3.3.2 Interface descriptor of DFU

[Fig 8](#) shows the DFU interface descriptor on run-time mode.

Offset	Field	Size	Value	Description
0	<i>bLength</i>	1	09h	Size of this descriptor, in bytes.
1	<i>bDescriptorType</i>	1	04h	INTERFACE descriptor type.
2	<i>bInterfaceNumber</i>	1	Number	Number of this interface.
3	<i>bAlternateSetting</i>	1	00h	Alternate setting. Must be zero.
4	<i>bNumEndpoints</i>	1	00h	Only the control pipe is used.
5	<i>bInterfaceClass</i>	1	FEh	Application Specific Class Code
6	<i>bInterfaceSubClass</i>	1	01h	Device Firmware Upgrade Code
7	<i>bInterfaceProtocol</i>	1	01h	Runtime protocol.
8	<i>iInterface</i>	1	Index	Index of string descriptor for this interface.

Fig 8. DFU interface descriptor on Run-time mode

Fig 9 shows the DFU interface descriptor on DFU mode.

Offset	Field	Size	Value	Description
0	<i>bLength</i>	1	09h	Size of this descriptor, in bytes.
1	<i>bDescriptorType</i>	1	04h	INTERFACE descriptor type.
2	<i>bInterfaceNumber</i>	1	00h	Number of this interface.
3	<i>bAlternateSetting</i>	1	Number	Alternate setting. *
4	<i>bNumEndpoints</i>	1	00h	Only the control pipe is used.
5	<i>bInterfaceClass</i>	1	FEh	Application Specific Class Code
6	<i>bInterfaceSubClass</i>	1	01h	Device Firmware Upgrade Code
7	<i>bInterfaceProtocol</i>	1	02h	DFU mode protocol.

Fig 9. DFU interface descriptor on DFU mode

3.4 Endpoint descriptor

All the endpoint descriptors are the same as their definitions in a single USB device.

Note: DFU function only use default control endpoint (EP0) to transfer data.

4. Composite device examples

The composite device examples include: HID+MSC, HID+CDC, MSC+CDC, HID+MSC+CDC, DFU+HID, DFU+CDC, DFU+MSC, DFU+HID+MSC.

All the examples on tested on Keil MCB11U00 evaluation board (LPC11U14/201, Rev. A). For more details about this board, please refer to <http://www.keil.com/mcb1000/>

For simplicity, only HID+MSC+CDC and DFU+HID+MSC are described here.

Note: To avoid the malfunction of USB devices with the same VID&PID (Windows loads the device driver based on the VID&PID), each application example here uses a different PID (VID stays unchanged).

4.1 HID+MSC+CDC

The USB configuration for this example can be found in **usbcfg.h** as shown in [Fig 10](#).

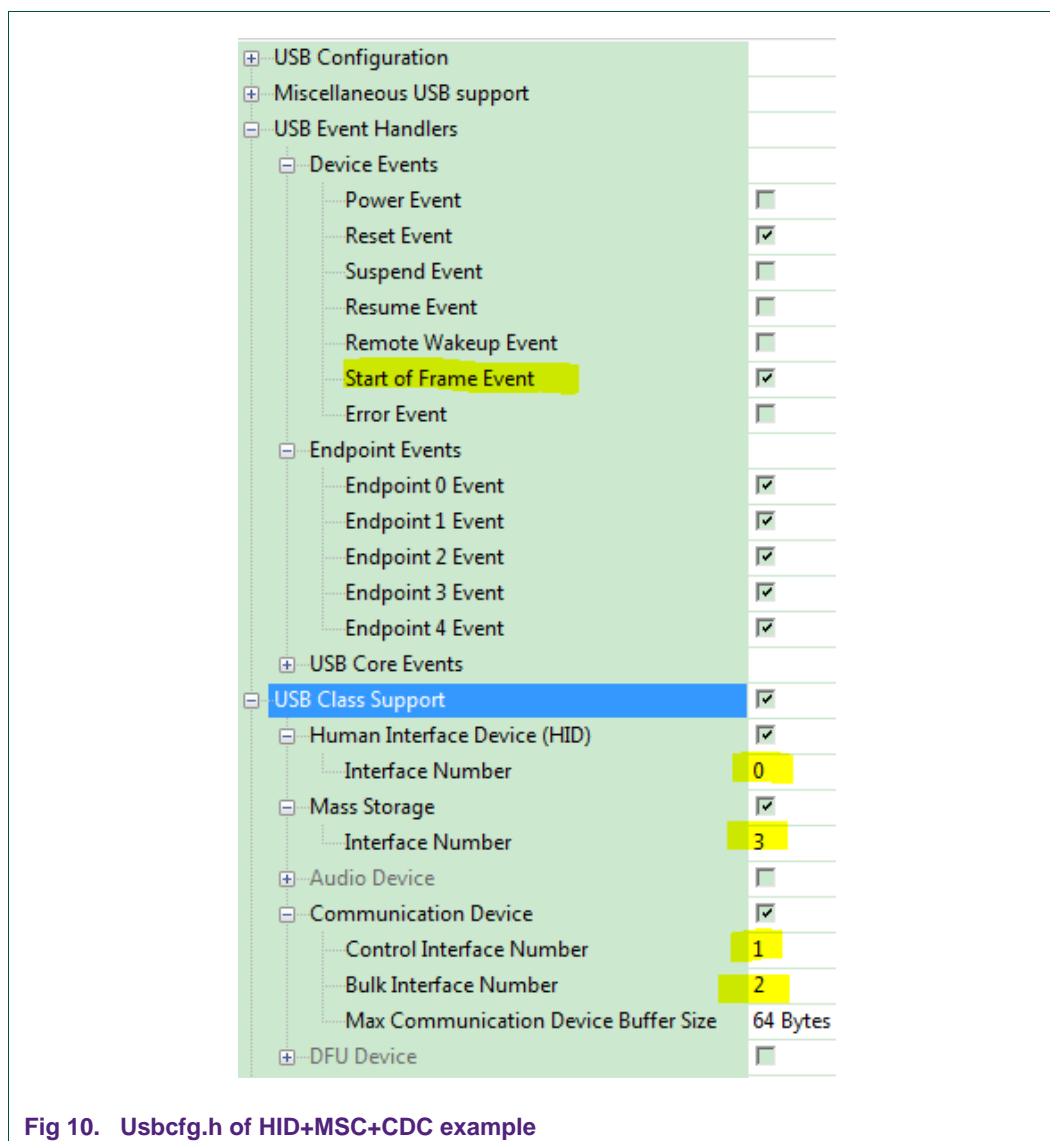
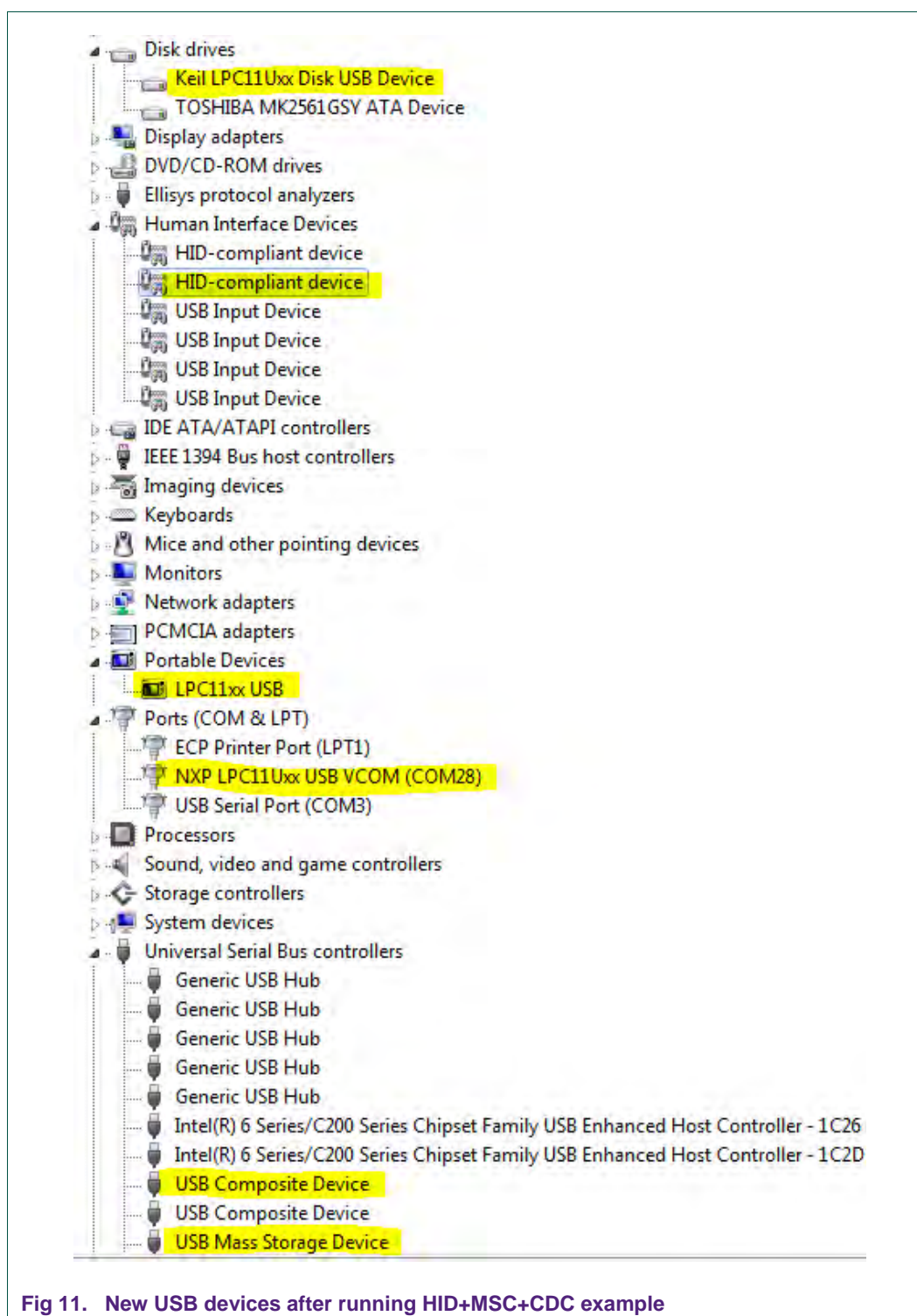


Fig 10. Usbcfg.h of HID+MSC+CDC example

The Start of Frame Event is necessary for CDC Virtual COM-port and should be enabled.

The implementation of a handler for each event and non-control endpoint can be found on **usbuser.c**.

After successful enumeration, Windows will request to install the driver for Virtual COM-port using an INF file which is located in \USBClass\CDC\Driver. After installation, the composite device will present three functions which can be viewed in the device manager. Windows system will load the generic HID and MSC driver automatically. Refer to [Fig 11](#).



Next, check if these three devices work.

For HID, run the HID Client utility **HIDClient.exe** (\USBClass\HID\Utility\). Refer to [Fig 12](#).



Fig 12. HID client utility (the HID device has been detected and selected)

The HID device works if:

- “LPC11Uxx HID” can be found and selected.
- Bit[1..0] of the Input Report can correctly reflect the status of Buttons S4 and S3 respectively on Keil MCB11U00 board.
- Bit[7..0] of the Output Report can correctly control the eight LEDs on the Keil MCB11U00 board.

The MSC device works if:

- A removable storage disk appeared with the label of “LPC11Uxx USB”.
- There is one file (**README.TXT**) in this disk.

To verify the virtual COM-port functionality, you need to open two Tera Term programs. One is for the virtual COM-port, the other is for the local RS-232 port or USB-to-RS232 port. The virtual COM-port works if the content typed in one Tera Term windows can be echoed in another window. Refer to [Fig 13](#).

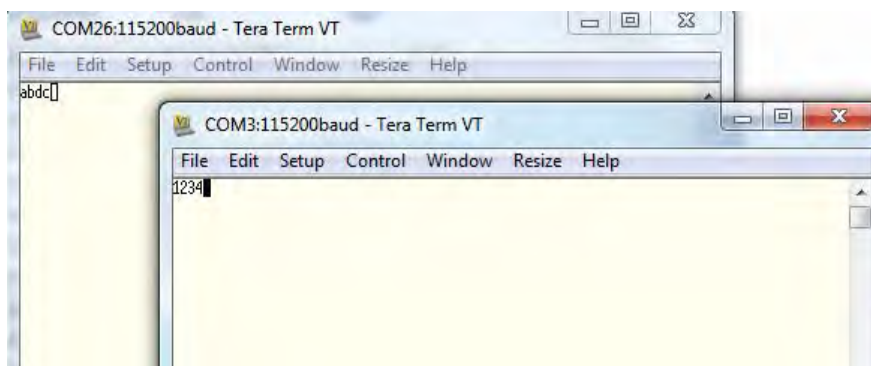


Fig 13. Verify virtual COM-port functionality (Note: The content typed in its own window is not displayed)

4.2 DFU+HID+MSC

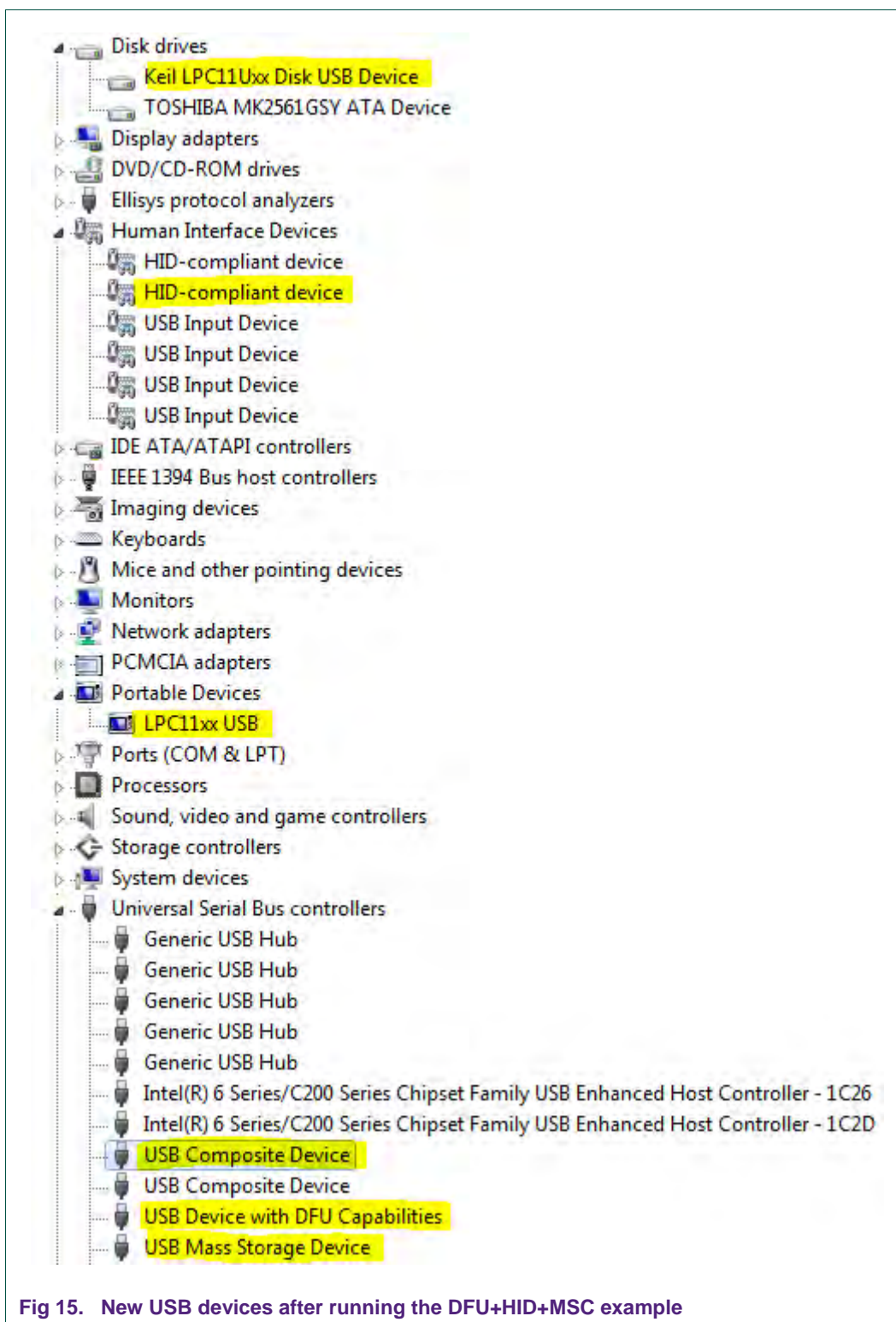
The USB configuration for this example can be found in `usbcfg.h` as shown in [Fig 14](#).

Option	Value
USB Configuration	
Miscellaneous USB support	
USB Event Handlers	
Device Events	
Power Event	<input type="checkbox"/>
Reset Event	<input checked="" type="checkbox"/>
Suspend Event	<input type="checkbox"/>
Resume Event	<input type="checkbox"/>
Remote Wakeup Event	<input type="checkbox"/>
Start of Frame Event	<input type="checkbox"/>
Error Event	<input type="checkbox"/>
Endpoint Events	
Endpoint 0 Event	<input checked="" type="checkbox"/>
Endpoint 1 Event	<input checked="" type="checkbox"/>
Endpoint 2 Event	<input checked="" type="checkbox"/>
Endpoint 3 Event	<input type="checkbox"/>
Endpoint 4 Event	<input type="checkbox"/>
USB Core Events	
USB Class Support	<input checked="" type="checkbox"/>
Human Interface Device (HID)	<input checked="" type="checkbox"/>
Interface Number	1
Mass Storage	<input checked="" type="checkbox"/>
Interface Number	2
Audio Device	<input type="checkbox"/>
Communication Device	<input type="checkbox"/>
DFU Device	<input checked="" type="checkbox"/>
Interface Number	0
Max Transfer Buffer Size	64 Bytes

Fig 14. Usbcfg.h of DFU+HID+MSC example

Note: The interface index of the DFU device in the examples is set to 0.

After successful enumeration, Windows requests installation of the driver for the DFU device located in `\USBClass\DFU\Driver`. After installation, the composite device presents three functions which can be viewed in the device manager. Windows loads the generic HID and MSC driver automatically. Refer to [Fig 15](#).



The verification of the HID and MSC device is the same with the HID+MSC+CDC example mentioned above.

For verification of a DFU device, run **DFUAPP.exe** (\\USBClass\\DFU\\Utility\\) and the correct information should be displayed. Refer to [Fig 16](#).

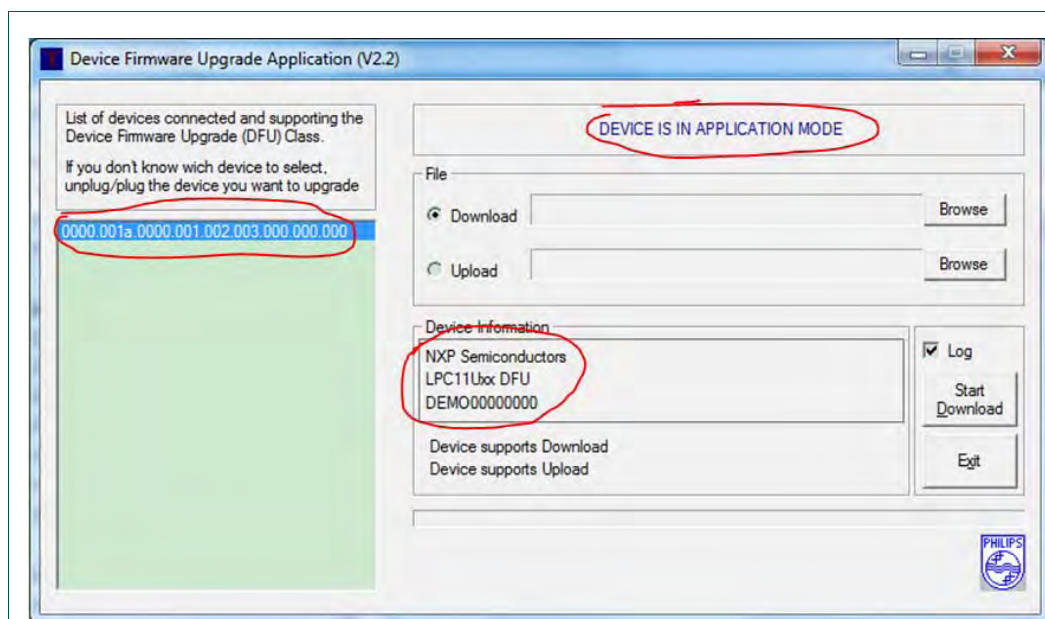


Fig 16. View of DFUAPP.EXE after it is opened

Next, select an image file and press “Start Download” to download to flash. The device switches from run-time mode to DFU mode and starts to transfer the data and program to internal flash on the specified address. Refer to [Fig 17](#) and [Fig 18](#).

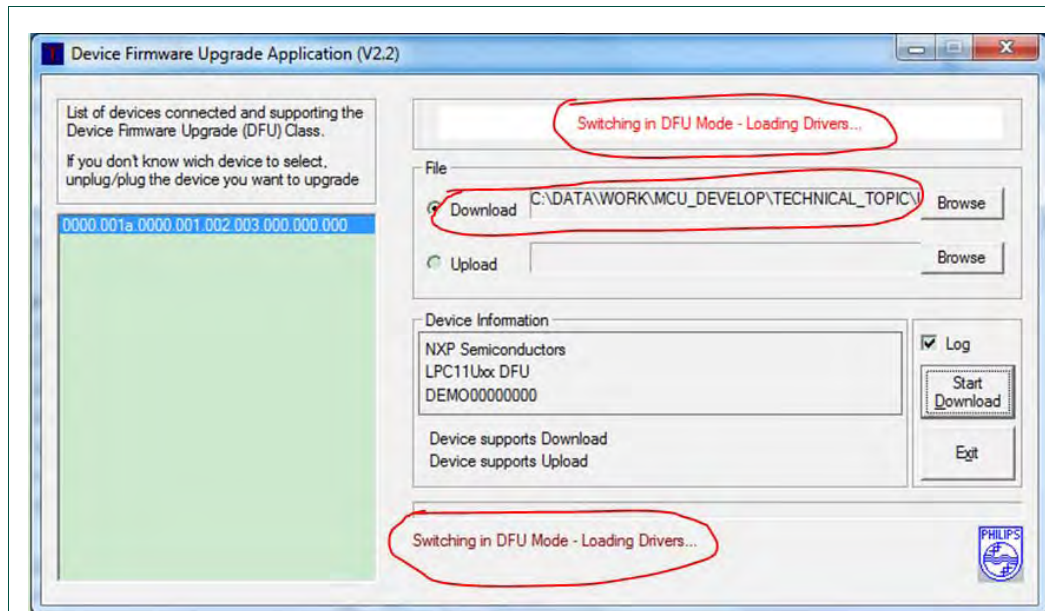
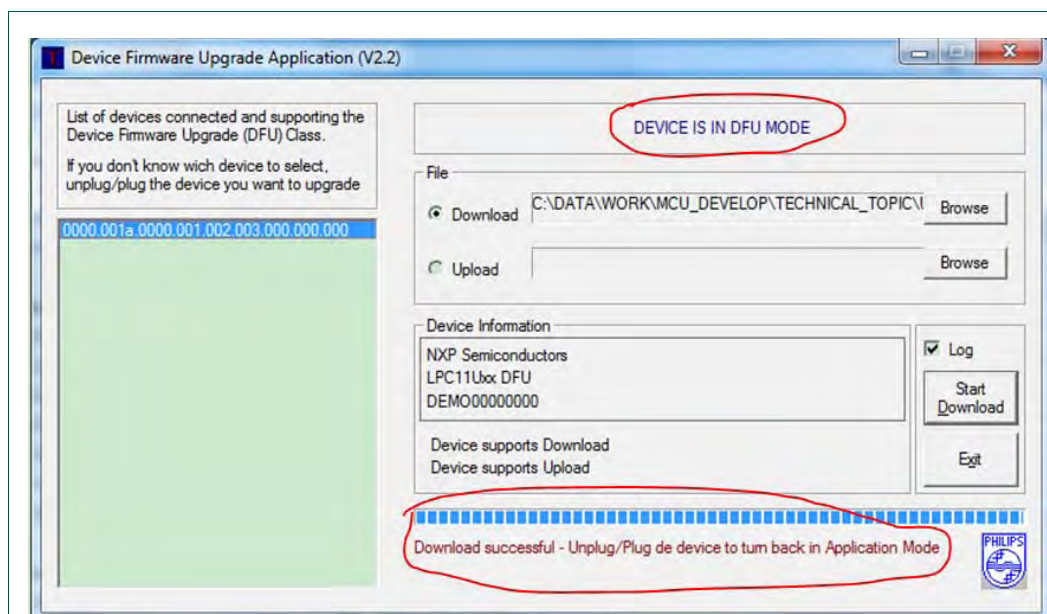
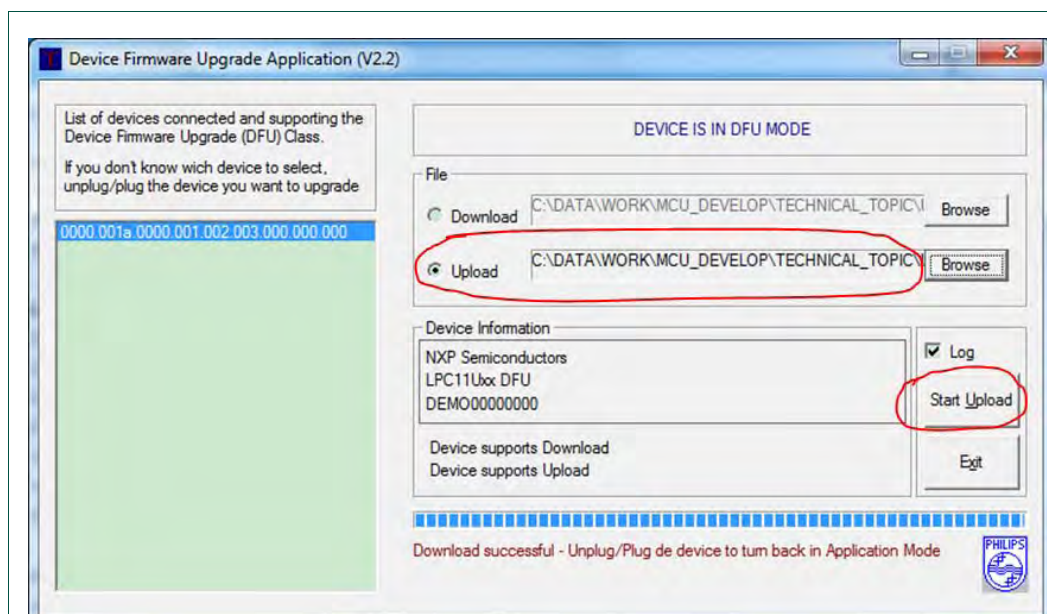


Fig 17. Start to download an image file

**Fig 18. Successful download**

Next, upload the content at the specified address in internal flash to an image file. Select an image file and press the “Start to Upload” button. Refer to [Fig 19](#) and [Fig 20](#).

**Fig 19. Select an image file to upload**

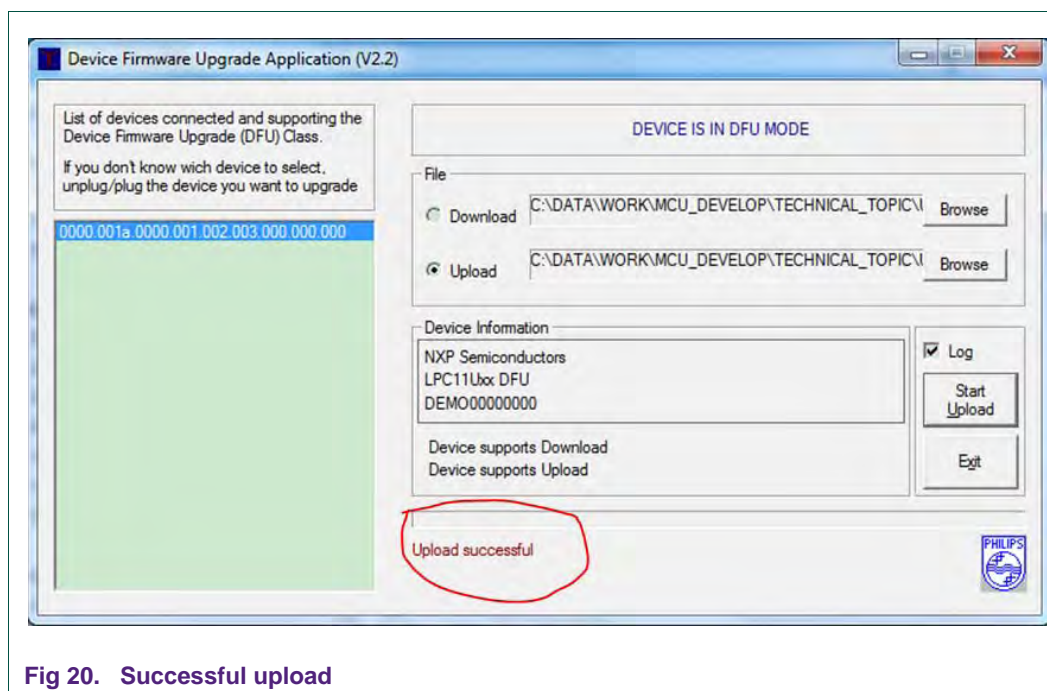


Fig 20. Successful upload

Note: the device will stay in DFU mode after download or upload operation. A reset or a power cycle is needed to make it return to run-time mode.

5. References

- [1] [LPC11Uxx User Manual UM10462 \(Rev. 2.1\)](#), NXP Semiconductors, Jan. 13, 2012
- [2] [AN11018: USB composite device on the LPC134x](#), NXP Semiconductors, Dec. 17, 2010
- [3] [Universal Serial Bus Revision 2.0 specification](#)
- [4] [Interface Association Descriptors \(USB ENGINEERING CHANGE NOTICE\)](#)
- [5] [USB Interface Association Descriptor, Device Class Code and Use Model](#), Rev 1.0
- [6] [Device Class Definition for Human Interface Devices \(HID\)](#), Version 1.11, June 27, 2001
- [7] [Universal Serial Bus Mass Storage Class Specification Overview](#), Revision 1.4, February 19, 2010
- [8] [Universal Serial Bus Mass Storage Class Bulk-Only Transport](#), Revision 1.0, September 31, 1999
- [9] [Communications Device Class](#), Revision 1.2
- [10] [Universal Serial Bus Device Class Specification for Device Firmware Upgrade](#), Version 1.1, Aug 5, 2004

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