Implementing USB Communication Device Class (CDC) on SiM3U1xx MCUs

1. Introduction

USB revolutionized the PC peripheral space by making a very simple plug-and-play interface for users. As a result, many modern computers no longer support RS-232 serial COM ports, opting for the slimmer USB alternative. This can be an issue for the developer who needs a COM port for communication between a peripheral and host PC. A subset of the USB Communication Device Class (CDC) can be used to emulate a serial port providing a virtual COM port UART interface. This allows developers to use legacy applications with new products using the same COM port interface as before, with few hardware and software modifications.

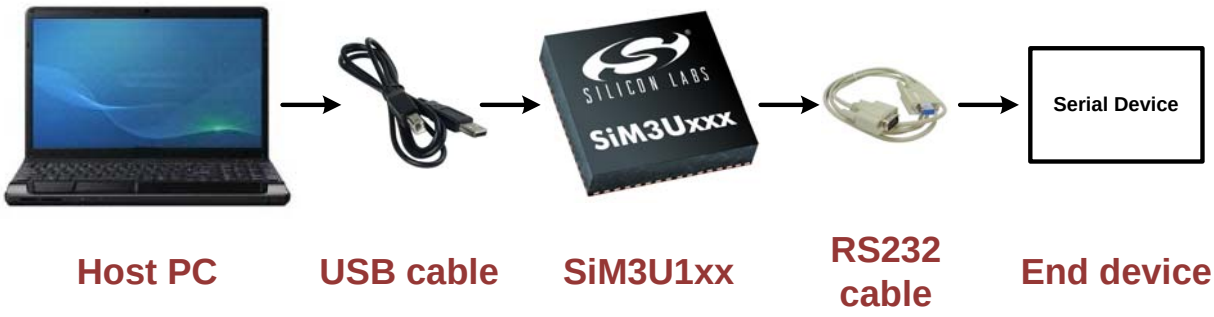


Figure 1. USB CDC Virtual COM Port System

This application note describes the USB communications device class driver (or USB CDC) in detail and includes an implementation example for the Silicon Labs SiM3U1xx MCU.

1.1. Assumptions

This document assumes the following:

- A working knowledge of the C programming language.
- Familiarity with the USB 2.0 specification and terms and abbreviations defined by the USB specification.
- Familiarity with Silicon Labs SiM3U1xx development environment.

1.2. Features and Limitations

The CDC firmware implemented with this application note includes the following features:

- Emulates a serial COM port on PC that supports the CDC Abstract Control Model (ACM).
- Provides an abstract communication interface for data transfers between the host and the device.
- Handles standard Chapter 9 USB device requests.
- Handles CDC-specific requests from USB host.
- Notifies the USB host of status using an interrupt endpoint.
- Provides data communication with the USB host using a bulk endpoint.
- The following baud rates are supported: 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200, 230400, 460800, and 921600 bps.

The example does not implement the following:

- No CTS/RTS control is performed, so flow control must be set to **none** in the terminal program.
- RTS/DTR control is not implemented.

2. Relevant Documentation

Precision32™ Application Notes are listed on the following website: www.silabs.com/32bit-appnotes.

- **AN667: Getting Started with the Silicon Labs Precision32™ IDE**—provides a description of the IDE features and environment.
- **AN670: Getting Started with the Silicon Labs Precision32™ AppBuilder**—provides a description of the AppBuilder features.

3. USB CDC Class

The USB communications device class (CDC) is a composite USB device class, and the class may include more than one interface. The CDC is used primarily for modems, but also for ISDN, fax machines, and telephony applications for performing regular voice calls.

The Abstract Control Model subclass of CDC and bridges the gap between legacy modem devices and USB devices, enabling the use of application programs designed for older modems.

3.1. Class Requests

The class requests and class notifications supported are listed in Table 1.

Table 1. Abstract Control Model Requests

Request	Code	Description
SET_LINE_CODING	20h	Configures baud rate, stop-bits, parity, and number-of-character bits.
GET_LINE_CODING	21h	Requests current DTE rate, stop-bits, parity, and number-of-character bits.
SET_CONTROL_LINE_STATE	22h	RS232 signal used to tell the DCE device the DTE device is now present.

These class-specific requests are used for device and call management.

3.1.1. Set Line Coding

This request allows the host to specify typical asynchronous line-character formatting properties.

bmRequestType	bRequest	wValue	wIndex	wLength	Data
00100001b	SET_LINE_CODING	0	interface	size of structure	line coding structure

Table 2 defines the line coding properties.

Table 2. Line Coding Format

Offset	Field	Size	Value	Description
0	dwDTERate	4	Number	Data terminal rate, in bits per second.
4	bCharFormat	1	Number	0: 1 Stop bit 1: 1.5 Stop bits 2: 2 Stop bits
5	bParityType	1	Number	Parity: 0:None 1: Odd 2: Even 3: Mark 4: Space
6	bDataBits	1	Number	Data bits (5, 6, 7, 8 or 16).

3.1.2. Get Line Coding

This request allows the host to find out the currently configured line coding. Table 2 defines the line coding properties.

bmRequestType	bRequest	wValue	wIndex	wLength	Data
10100001b	GET_LINE_CODING	0	interface	size of structure	line coding structure

3.1.3. Set Control Line State

This request generates RS-232/V.24 style control signals. Table 3 defines control signal bitmap.

bmRequestType	bRequest	wValue	wIndex	wLength	Data
00100001b	SET_LINE_CON-TROL_STATE	control signal bitmap	interface	0	none

Table 3. Control Signal Bitmap

Bit Position	Description
15:2	Reserved (Reset to zero).
1	Carrier control for half duplex modems. This signal corresponds to V.24 signal 105 and RS232 signal RTS. 0: Deactivate carrier. 1: Activate carrier. The device ignores the value of this bit when operating in full duplex mode.
0	Indicates to DCE if DTE is present or not. This signal corresponds to V.24 signal 108/2 and RS232 signal DTR. 0: DTE is not present. 1: DTE is present.

3.2. Class Notifications

Table 4 shows the class notifications supported by the Abstract Control Model.

Table 4. Abstract Control Model Notifications

Notification	Code	Description
SERIAL_STATE	20h	Returns the current state of the carrier detects, DSR, break, and ring signal.

3.2.1. Serial State

This notification sends an asynchronous message containing the current UART status.

bmRequestType	bRequest	wValue	wIndex	wLength	Data
10100001b	SERIAL_STATE	0	interface	2	UART state bitmap

The data field for this notification is a bitmapped value that contains the current state of detects transmission carrier, break, ring signal, and device overrun error. These signals are typically found on a UART and are used for communication status reporting. A state is considered enabled if its respective bit is set to 1.

Note: The firmware example included with this application does not currently support state change.

Table 5. UART State Bitmap

Bit Position	Field	Description
15:7		Reserved (future use).
6	bOverRun	Received data has been discarded due to overrun in the device.
5	bParity	A parity error occurred.
4	bFraming	A framing error occurred.
3	bRingSignal	State of ring signal detection of the device.
2	bBreak	State of break detection mechanism of the device.
1	bTxCarrier	State of transmission carrier. This signal corresponds to V.24 signal 106 and RS232 signal DSR.
0	bRxCarrier	State of receiver carrier detection mechanism of device. This signal corresponds to V.24 signal 109 and RS232 signal DCD.

3.3. Endpoint Configuration

Table 6 illustrates the endpoint configuration for the Abstract Control Model.

Table 6. UART State Bitmap

Endpoint	Direction	Type	Max Packet Size	Description
EP0	In/Out	Control	64	Standard requests, class requests.
EP1	In	Interrupt	16	State notification from device to host.
EP2	In	Bulk	64	Data transfer from device to host.
EP3	Out	Bulk	64	Data transfer from host to device.

Figure 2 shows a standard CDC communication flow.

Item	Device	Endpoint	Interface	Status	Sp...	Payload
Enter text here	Ent...	Enter text h...	Enter te...	Enter ...	E.	Enter text here
Class request IN (0x21)	5	0		OK	FS	7 bytes (00 C2 01 00 00 00 08)
Class request IN (0x21)	5	0		OK	FS	7 bytes (00 C2 01 00 00 00 08)
Class request OUT (0x20)	5	0		OK	FS	7 bytes (00 E1 00 00 00 00 08)
Class request IN (0x21)	5	0		OK	FS	7 bytes (00 E1 00 00 00 00 08)
Class request OUT (0x22)	5	0		OK	FS	No data
Class request OUT (0x20)	5	0		OK	FS	7 bytes (00 E1 00 00 00 00 08)
Class request IN (0x21)	5	0		OK	FS	7 bytes (00 E1 00 00 00 00 08)
Class request OUT (0x22)	5	0		OK	FS	No data
IN transaction	5	1		ACK	FS	10 bytes (A1 20 00 00 00 00 02 00 00 00)
IN transaction	5	1		ACK	FS	10 bytes (A1 20 00 00 00 00 02 00 00 00)
APPEND - New elements appen...						
OUT transaction	5	3		ACK	FS	1 byte (61)
IN transaction	5	2		ACK	FS	1 byte (62)

Figure 2. USB CDC Communication Flow

4. Firmware Example Overview

The firmware example included with this application note contains the driver, USB stack for the SiM3U1xx, and PC-side application layer code.

4.1. File Organization

The files included in the USB CDC example are as follows:

- **generated**—directory containing SiM3U1xx hardware initialization files
- **VirtualSerial**—directory containing the virtual COM demo files
  - **CDC_ACM.inf**—USB CDC INF file
  - **Descriptors.c**—Virtual COM USB descriptors
  - **LUFAConfig.h**—Project configuration
  - **VirtualSerial.c**—primary application file
- **LUFA**—SiM3L1xx USB stack firmware
  - **Common**—common header files
  - **Drivers**—USB driver files
    - **Misc**—miscellaneous files
    - **USB**—USB stack files
      - **Class**—USB class files
        - **Device**—USB device class files
          - **AudioClassDevice.***—USB audio class implementation
          - **CDCClassDevice.***—USB CDC class implementation
          - **HIDClassDevice.***—USB HID class implementation
          - **MassStorageClassDevice.***—USB mass storage class implementation
          - **MIDIClassDevice.***—USB MIDI class implementation
          - **RNDISClassDevice.***—USB RNDIS class implementation
        - **Host**—USB host class files, not implemented by the SiM3U1xx
        - **Common**—common driver files
      - **Core**—USB Chapter 9 handler files
        - **SiM3U**—SiM3U1xx USB hardware control firmware files
          - **Device_SIM3U.***—USB device definitions
          - **Endpoint_SIM3U.***—USB endpoint transition control
          - **EndpointStream_SIM3U.***—USB endpoint stream transition control
          - **USBController_SIM3U.***—USB controller definitions
          - **USBInterrupt_SIM3U.***—USB interrupt handler
      - **USB.h**—USB header file
- **main.c**

4.2. LUFA USB Stack

The USB CDC firmware example is based on the LUFA open-source project. LUFA is an open-source complete USB stack released under the permissive MIT License. It includes support for many USB classes, both for USB Hosts and USB Devices. For USB Devices, the LUFA stack includes support for Audio Class, CDC Class, HID Class, Mass Storage Class, MIDI Class, and RNDIS Class.

More information about the LUFA project can be found on the official website: http://www.fourwalledcubicle.com/LUFA.php.

5. Detailed List of Functions

This section discusses the detailed function declarations in the CDC USB stack firmware example.

5.1. CDC Functions

This section focuses on the functions found in the **CDCClassDevice.c** and **CDCClassDevice.h** files (**AN758_USB_CDC\src\LUFA\Drivers\USB\Class\Device** directory). This file implements the USB CDC device class.

5.1.1. CDC_Device_Process_ControlRequest

Handle USB CDC special class request.

Syntax

```
void CDC_Device_ProcessControlRequest(USB_ClassInfo_CDC_Device_t* const
CDCInterfaceInfo)
```

Parameters

`CDCInterfaceInfo`: Pointer to CDC Class state structure

Return Value

None

Description

This function parses the USB control request to handle different USB CDC special class request. Update CDCInterfaceInfo with data from USB host, or send data in CDCInterfaceInfo to USB host.

Example

```
USB_ClassInfo_CDC_Device_t VirtualSerial_CDC_Interface =
{
     .Config =
     {
          .ControlInterfaceNumber   = 0,
          .DataINEndpoint           =
          {
               .Address          = CDC_TX_EPADDR,
               .Size             = CDC_TXRX_EPSIZE,
               .Banks            = 1,
          },
          .DataOUTEndpoint =
          {
               .Address          = CDC_RX_EPADDR,
               .Size             = CDC_TXRX_EPSIZE,
               .Banks            = 1,
          },
          .NotificationEndpoint =
          {
               .Address          = CDC_NOTIFICATION_EPADDR,
               .Size             = CDC_NOTIFICATION_EPSIZE,
               .Banks            = 1,
          },
     },
};
CDC_Device_ProcessControlRequest(&VirtualSerial_CDC_Interface);
```

5.1.2. CDC_Device_ConfigureEndpoints

USB CDC device endpoint configuration.

Syntax

```
bool CDC_Device_ConfigureEndpoints(USB_ClassInfo_CDC_Device_t* const
CDCInterfaceInfo)
```

Parameters

```
CDCInterfaceInfo: Pointer to CDC Class state structure
```

Return Value

```
True: if configuration success
False: if configuration failure
```

Description

This functions set data in/out endpoint as bulk type, and set notification endpoint as interrupt type.

Example

```
bool ConfigSuccess = true;
ConfigSuccess &= CDC_Device_ConfigureEndpoints(&VirtualSerial_CDC_Interface);
```

5.1.3. CDC_Device_SendData

USB CDC sends data to USB IN FIFO.

Syntax

```
uint8_t CDC_Device_SendData(USB_ClassInfo_CDC_Device_t* const CDCInter-faceInfo,
const char* const Buffer,const uint16_t Length)
```

Parameters

```
CDCInterfaceInfo: Pointer to CDC Class state structure
Buffer: Pointer to data buffer
Length: Transmit length
```

Return Value

```
Error code: definition can be found in EndpointStream.h
ENDPOINT_RWSTREAM_NoError
ENDPOINT_RWSTREAM_EndpointStalled
ENDPOINT_RWSTREAM_DeviceDisconnected
ENDPOINT_RWSTREAM_BusSuspended
ENDPOINT_RWSTREAM_Timeout
ENDPOINT_RWSTREAM_IncompleteTransfer
```

Description

This function sends data to USB IN FIFO. Transmit data size specified in Length.

Note: `Endpoint_ClearIN()` must be called to send data to USB host, otherwise, the data will keep in USB device FIFO.

Example

```
uint32_t recv_count;
recv_count = uart_get_data(in_buff);
if(recv_count)
{
CDC_Device_SendData(&VirtualSerial_CDC_Interface, (char *)in_buff, recv_count);
Endpoint_ClearIN();
}
```

5.1.4. CDC_Device_SendByte

USB CDC sends one byte to USB IN FIFO.

Syntax

```
uint8_t CDC_Device_SendByte(USB_ClassInfo_CDC_Device_t* const CDCInterfaceInfo,
const uint8_t Data)
```

Parameters

```
CDCInterfaceInfo: Pointer to CDC Class state structure
Data: byte data to send
```

Return Value

```
Error code: definition can be found in EndpointStream.h
ENDPOINT_RWSTREAM_NoError
ENDPOINT_RWSTREAM_EndpointStalled
ENDPOINT_RWSTREAM_DeviceDisconnected
ENDPOINT_RWSTREAM_BusSuspended
ENDPOINT_RWSTREAM_Timeout
ENDPOINT_RWSTREAM_IncompleteTransfer
```

Description

This function sends one byte to USB IN FIFO.

Note: `Endpoint_ClearIN()` must be called to send data to USB host, otherwise, the data will keep in USB device FIFO.

Example

```
CDC_Device_SendByte(&VirtualSerial_CDC_Interface,0x55);
Endpoint_ClearIN();
```

5.1.5. CDC_Device_BytesReceived

USB CDC number of bytes received.

Syntax

```
uint16_t CDC_Device_BytesReceived(USB_ClassInfo_CDC_Device_t* const
CDCInterfaceInfo)
```

Parameters

```
CDCInterfaceInfo: Pointer to CDC Class state structure
```

Return Value

```
Bytes received in USB endpoint.
```

Description

This function check how many bytes received in USB data out endpoint

Example

```
uint32_t recv_count;
recv_count = CDC_Device_BytesReceived(&VirtualSerial_CDC_Interface);
```

5.1.6. CDC_Device_ReceiveByte

USB CDC receive one byte from USB OUT FIFO.

Syntax

```
int16_t CDC_Device_ReceiveByte(USB_ClassInfo_CDC_Device_t* const CDCInterfaceInfo)
```

Parameters

```
CDCInterfaceInfo: Pointer to CDC Class state structure
```

Return Value

```
-1: if no data received
Data: one byte from USB data out FIFO.
```

Description

This function receives one byte from USB data out FIFO. It returns -1 if no data received.

Example

```
uint32_t out_buff;
out_buff = CDC_Device_ReceiveByte(&VirtualSerial_CDC_Interface);
```

5.1.7. CDC_Device_SendControlLineStateChange

USB CDC notification.

Syntax

```
void CDC_Device_SendControlLineStateChange(USB_ClassInfo_CDC_Device_t* const
CDCInterfaceInfo)
```

Parameters

```
CDCInterfaceInfo: Pointer to CDC Class state structure
```

Return Value

None

Description

This function sends state data to notification endpoint.

Example

```
CDC_Device_SendControlLineStateChange(CDCInterfaceInfo);
```

5.2. UART Functions

This section details the functions found in the **gUART0.c** file (**AN758_USB_CDC\src\generated** directory). This file contains the hardware configuration for the SiM3U1xx device.

5.2.1. UART0_enter_default_mode_from_reset

UART0 hardware default configuration.

Syntax

```
void UART0_enter_default_mode_from_reset(void)
```

Parameters

None

Return Value

None

Description

This function set UART0 TX/RX default configuration as 115200 bps, 8-bit data width, 1 bit stop bit, no-parity

Example

```
UART0_enter_default_mode_from_reset();
```

5.2.2. uart_configuration

UART0 configuration setting.

Syntax

```
void uart_configuration(uint32_t baud_rate,uint8_t stop_bits,uint8_t parity,uint8_t
data_bits)
```

Parameters

```
baud_rate: baud rate
stop_bits: 0 - 1 stop bit; 1 - 1.5 stop bits; 2 - 2 stop bits
parity: 0 - none; 1 - odd; 2 - even; 3 - mark; 4 - space
data_bits: data bits(5,6,7,8 or 16)
```

Return Value

None

Description

This function set UART0 TX/RX baud rate, stop bits, parity and data bits.

Example

```
uart_configuration(115200,0,0,8);
```

5.2.3. uart_get_data

UART0 get data.

Syntax

```
uint32_t uart_get_data(uint8_t * data)
```

Parameters

```
data: pointer to receive data buffer
```

Return Value

```
The number of bytes received from UART
```

Description

This function gets data from UART FIFO to data buffer and return number of bytes received.

Example

```
uint32_t recv_count;
static uint8_t in_buff[64];
recv_count = uart_get_data(in_buff);
```

5.2.4. uart_send_data

UART0 send data.

Syntax

```
void uart_send_data(unsigned char *data, unsigned int count)
```

Parameters

```
data: pointer to send data buffer
count: Number of bytes to send
```

Return Value

```
None
```

Description

This function send data from data buffer to UART FIFO, transmit data bytes specified in count.

Example

```
uint32_t send_count = 4;
static uint8_t out_buff[64];
uart_send_data(out_buff,sendcount);
```

5.2.5. uart_send_byte

UART0 send one byte.

Syntax

```
void uart_send_byte(uint8_t data)
```

Parameters

```
data: Byte to send
```

Return Value

```
None
```

Description

This function sends one byte data to UART FIFO

Example

```
uint8_t out_byte = 0x55;
uart_send_byte(out_byte);
```

5.2.6. uart_get_byte

UART0 get one byte.

Syntax

```
uint8_t uart_get_byte()
```

Parameters

```
None
```

Return Value

```
Byte received
```

Description

This function gets one byte data from UART FIFO

Example

```
uint8_t in_byte;
In_byte = uart_get_byte();
```

5.3. Application Layer

The application layer for the USB CDC firmware example can be found in the **VirtualSerial.c** and **Descriptors.c** files in the **AN758_USB_CDC\src\VirtualSerial** directory.

5.3.1. vcp_main

Virtual COM port entry function.

Syntax

```
void vcp_main(void)
```

Parameters

```
None
```

Return Value

```
None
```

Description

This function initialize USB stack and execute Echo mode or Bridge mode in endless while loop.

Example

```
enter_default_mode_from_reset();
vcp_main();
```

5.3.2. VCOM_echo

It echo input character to USB virtual COM

Syntax

```
void VCOM_echo(void)
```

Parameters

```
None
```

Return Value

```
None
```

Description

This function get byte from USB virtual COM port and send back to virtual COM. User will see echo character in their serial com tool.

Example

```
VCOM_echo();
```

5.3.3. VCOM_bridge

It transfer data between USB virtual COM port and UART hardware COM port.

Syntax

```
void VCOM_bridge(void)
```

Parameters

```
None
```

Return Value

```
None
```

Description

This function acts as USB to UART bridge function.

Example

```
VCOM_bridge();
```

5.3.4. EVENT_USB_Device_ControlRequest

Event handler for control request.

Syntax

```
void EVENT_USB_Device_ControlRequest(void)
```

Parameters

None

Return Value

None

Description

This function is event handler for the library USB Control Request reception event. It handlers USB CDC special class request from USB host.

Example

```
if(Endpoint_IsSETUPReceived())
{
uint8_t* RequestHeader = (uint8_t*)&USB_ControlRequest;

for (uint8_t RequestHeaderByte = 0; RequestHeaderByte <
sizeof(USB_Request_Header_t); RequestHeaderByte++)
  *(RequestHeader++) = Endpoint_Read_8();
}
EVENT_USB_Device_ControlRequest();
```

5.3.5. EVENT_CDC_Device_LineEncodingChanged

Event handler for the CDC Class driver Line Encoding Changed event.

Syntax

```
void EVENT_CDC_Device_LineEncodingChanged(USB_ClassInfo_CDC_Device_t* const
CDCInterfaceInfo)
```

Parameters

```
CDCInterfaceInfo:Pointer to the CDC class interface configuration structure
```

Return Value

None

Description

This function change UART configuration according CDC class interface configuration.

Example

```
CDCInterfaceInfo->State.LineEncoding.BaudRateBPS = Endpoint_Read_32_LE();
CDCInterfaceInfo->State.LineEncoding.CharFormat  = Endpoint_Read_8();
CDCInterfaceInfo->State.LineEncoding.ParityType  = Endpoint_Read_8();
CDCInterfaceInfo->State.LineEncoding.DataBits    = Endpoint_Read_8();

Endpoint_ClearOUT();
Endpoint_ClearStatusStage();

EVENT_CDC_Device_LineEncodingChanged(CDCInterfaceInfo);
```

5.3.6. EVENT_USB_Device_ConfigurationChanged

Event handler for the library USB Configuration changed event.

Syntax

```
void EVENT_USB_Device_ConfigurationChanged(void)
```

Parameters

None

Return Value

None

Description

This function configures endpoint according USB CDC class interface configuration structure.

Example

```
EVENT_USB_Device_ConfigurationChanged();
```

5.3.7. CALLBACK_USB_GetDescriptor

Send back descriptor per Get Descriptor request.

Syntax

```
uint16_t CALLBACK_USB_GetDescriptor(const uint16_t wValue,
                                    const uint8_t wIndex,
                                    const void** const DescriptorAddress)
```

Parameters

None

Return Value

Descriptor size

Description

When the device receives a Get Descriptor request on the control endpoint, this function is called so that the descriptor details can be passed back and the appropriate descriptor sent back to the USB host.

Example

```
const void* DescriptorPointer;
uint16_t    DescriptorSize;

if ((DescriptorSize = CALLBACK_USB_GetDescriptor(USB_ControlRequest.wValue,
USB_ControlRequest.wIndex,&DescriptorPointer )) == NO_DESCRIPTOR)
{
     return;
}
Endpoint_ClearSETUP();
Endpoint_Write_Control_Stream_LE(DescriptorPointer, DescriptorSize);
```

5.3.8. Macros

```
#define ENDPOINT_DIR_IN     0x80
#define ENDPOINT_DIR_OUT    0x00

/** Endpoint address of the CDC device-to-host notification IN endpoint. */
#define CDC_NOTIFICATION_EPADDR        (ENDPOINT_DIR_IN | 1)
/** Endpoint address of the CDC device-to-host data IN endpoint. */
#define CDC_TX_EPADDR                  (ENDPOINT_DIR_IN | 2)
/** Endpoint address of the CDC host-to-device data OUT endpoint. */
#define CDC_RX_EPADDR                  (ENDPOINT_DIR_OUT | 3)
/* Size in bytes of the CDC device-to-host notification IN endpoint*/
#define CDC_NOTIFICATION_EPSIZE        16
/** Size in bytes of the CDC data IN and OUT endpoints. */
#define CDC_TXRX_EPSIZE                64
```

5.3.9. USB CDC Class Interface Structure

```
USB_ClassInfo_CDC_Device_t VirtualSerial_CDC_Interface =
{
     .Config =
     {
          .ControlInterfaceNumber   = 0,
          .DataINEndpoint           =
          {
               .Address          = CDC_TX_EPADDR,
               .Size             = CDC_TXRX_EPSIZE,
               .Banks            = 1,
          },
          .DataOUTEndpoint =
          {
               .Address          = CDC_RX_EPADDR,
               .Size             = CDC_TXRX_EPSIZE,
               .Banks            = 1,
          },
          .NotificationEndpoint =
          {
               .Address          = CDC_NOTIFICATION_EPADDR,
               .Size             = CDC_NOTIFICATION_EPSIZE,
               .Banks            = 1,
          },
     },
};
```

5.3.10. USB CDC Descriptors

Device descriptor structure, this descriptor, located in flash memory, describes the overall device characteristics, including the supported USB version, control endpoint size and the number of device configurations. The descriptor is read out by the USB host when the enumeration process begins.

```
const USB_Descriptor_Device_t PROGMEM DeviceDescriptor =
{
     .Header                 = {.Size = sizeof(USB_Descriptor_Device_t), .Type =
     DTYPE_Device},

     .USBSpecification       = VERSION_BCD(01.10),
     .Class                  = CDC_CSCP_CDCClass,
     .SubClass               = CDC_CSCP_NoSpecificSubclass,
     .Protocol               = CDC_CSCP_NoSpecificProtocol,

     .Endpoint0Size          = ENDPOINT_CONTROLEP_DEFAULT_SIZE,

     .VendorID               = 0x10C4,
     .ProductID              = 0xA003,
     .ReleaseNumber          = VERSION_BCD(00.01),

     .ManufacturerStrIndex   = 0x01,
     .ProductStrIndex        = 0x02,
     .SerialNumStrIndex      = USE_INTERNAL_SERIAL,

     .NumberOfConfigurations = 1
};
```

Type defines for the device configuration descriptor structure. As the configuration descriptor contains several sub-descriptors which vary between devices, and which describe the device's usage to the host. Detail definition can be found in Descriptors.c.

```
typedef struct
{
     USB_Descriptor_Configuration_Header_t    Config;

     // CDC Control Interface
     USB_Descriptor_Interface_t               CDC_CCI_Interface;
     USB_CDC_Descriptor_FunctionalHeader_t    CDC_Functional_Header;
     USB_CDC_Descriptor_FunctionalACM_t       CDC_Functional_ACM;
     USB_CDC_Descriptor_FunctionalUnion_t     CDC_Functional_Union;
     USB_Descriptor_Endpoint_t                CDC_NotificationEndpoint;

     // CDC Data Interface
     USB_Descriptor_Interface_t               CDC_DCI_Interface;
     USB_Descriptor_Endpoint_t                CDC_DataOutEndpoint;
     USB_Descriptor_Endpoint_t                CDC_DataInEndpoint;
} USB_Descriptor_Configuration_t;
```

Example:

```
const USB_Descriptor_Configuration_t ConfigurationDescriptor;
```

String Descriptors

```
#define STR0LEN 4
static uint8_t const String0Desc[STR0LEN] =
{
     STR0LEN, DTYPE_String, 0x09, 0x04
};
#define STR1LEN sizeof("SILICON LABORATORIES INC.")*2
static uint8_t const String1Desc[STR1LEN] ={...}
#define STR2LEN sizeof("SiM3U1xx CDC Class")*2
static uint8_t const String2Desc[STR2LEN] ={...}
```

5.4. USB Low-Level Functions

The USB hardware access layer functions are in the **AN758_USB_CDC\src\LUFA\Drivers\USB\Core\SIM3U** directory.

5.4.1. USB_Device_GetFrameNumber

Returns the current USB frame number.

Syntax

```
static inline uint16_t USB_Device_GetFrameNumber(void)
```

Parameters

None

Return Value

Current USB frame number from the USB controller

Description

This function returns the current USB frame number, when in device mode. Every millisecond the USB bus is active.

Example

```
uint16_t PreviousFrameNumber = USB_Device_GetFrameNumber();
```

5.4.2. USB_Device_SetLowSpeed

Set USB device as low speed.

Syntax

```
static inline void USB_Device_SetLowSpeed(void)
```

Parameters

None

Return Value

None

Description

This function set USB device as low speed.

Example

```
if (USB_Options & USB_DEVICE_OPT_LOWSPEED)
{
    USB_Device_SetLowSpeed();
}
else
{
    USB_Device_SetFullSpeed();
}
```

5.4.3. USB_Device_SetFullSpeed

Set USB device as full speed.

Syntax

```
static inline void USB_Device_SetFullSpeed(void)
```

Parameters

None

Return Value

None

Description

This function set USB device as Full speed.

Example

```
if (USB_Options & USB_DEVICE_OPT_LOWSPEED)
{
    USB_Device_SetLowSpeed();
}
else
{
    USB_Device_SetFullSpeed();
}
```

5.4.4. USB_Device_SetDeviceAddress

Set USB device address.

Syntax

```
static inline void USB_Device_SetDeviceAddress(const uint8_t Address)
```

Parameters

Address: USB address

Return Value

None

Description

This function set USB device address assigned from USB host .

Example

```
uint8_t    DeviceAddress = (USB_ControlRequest.wValue & 0x7F);
USB_Device_SetDeviceAddress(DeviceAddress);
```

5.4.5. USB_Device_IsAddressSet

Check USB device address assigned or not.

Syntax

```
static inline bool USB_Device_IsAddressSet(void)
```

Parameters

None

Return Value

USB device address

Description

This function USB device address assigned or not.

Example

```
USB_DeviceState = (USB_Device_IsAddressSet()) ? DEVICE_STATE_Configured :
DEVICE_STATE_Powered;
```

5.4.6. USB_Init

USB hardware initialization.

Syntax

```
void USB_Init(const uint8_t Options)
```

Parameters

```
Options: USB Device Mode Option
```

Return Value

```
None
```

Description

This function initializes USB hardware. Set full or low speed. Turn on USB 48 MHz oscillators. Enable USB interrupt. Configure Endpoint to default state. Enable internal pull up resistor to attach USB device.

Example

```
USB_Init(USB_DEVICE_OPT_FULLSPEED);
```

5.4.7. USB0_IRQHandler

USB interrupt handler.

Syntax

```
void USB0_IRQHandler(void)
```

Parameters

```
None
```

Return Value

```
None
```

Description

This function handles all enabled USB device interrupt. Clear interrupt flag. Execute handler function.

Example

When USB interrupt happened, PC will jump to vector table and then jump into this function.

5.4.8. USB0_ep0_handler

Handle endpoint 0 request.

Syntax

```
void USB0_ep0_handler(void)
```

Parameters

```
None
```

Return Value

```
None
```

Description

This function handles all endpoint 0 request.

Example

```
if (usbEpInterruptMask & SI32_USB_A_IOINT_EP0I_MASK)
{
    USB0_ep0_handler();
    return;
}
```

5.4.9. USB0_epn_handler

Handle endpoint n request.

Syntax

```
void USB0_epn_handler(void)
```

Parameters

```
None
```

Return Value

```
None
```

Description

This function handles all endpoint n request.

Example

```
if (usbEpInterruptMask & (SI32_USB_A_IOINT_IN1I_MASK | SI32_USB_A_IOINT_OUT1I_MASK))
{
    Endpoint_SelectEndpoint(1);
    USB0_epn_handler();
}
if (usbEpInterruptMask & (SI32_USB_A_IOINT_IN2I_MASK | SI32_USB_A_IOINT_OUT2I_MASK))
{
    Endpoint_SelectEndpoint(2);
    USB0_epn_handler();
}
```

5.4.10. Endpoint_WaitUntilReady

Wait for endpoint ready.

Syntax

```
uint8_t Endpoint_WaitUntilReady(void)
```

Parameters

```
None
```

Return Value

```
ENDPOINT_READYWAIT_NoError,
ENDPOINT_READYWAIT_EndpointStalled,
ENDPOINT_READYWAIT_DeviceDisconnected,
ENDPOINT_READYWAIT_BusSuspended,
ENDPOINT_READYWAIT_Timeout
```

Description

This function will check endpoint ready status. It set 100ms timeout with counting frame number.

Example

```
if ((ErrorCode = Endpoint_WaitUntilReady()) != ENDPOINT_READYWAIT_NoError)
  return ErrorCode;
```

5.4.11. Endpoint_ConfigureEndpointTable

Configure endpoint.

Syntax

```
bool Endpoint_ConfigureEndpointTable(
                      const USB_Endpoint_Table_t* const Table,
                    const uint8_t Entries)
```

Parameters

```
Table: pointer to endpoint table
Entries: no use in this software
```

Return Value

```
True: if configure successful.
False: if configure failure.
```

Description

This function configures endpoint.

Example

```
if (!(Endpoint_ConfigureEndpointTable(&CDCInterfaceInfo->Config.DataINEndpoint, 1)))
  return false;
```

5.4.12. Endpoint_Write_Control_Stream_LE

Write stream data to control endpoint

Syntax

```
uint8_t Endpoint_Write_Control_Stream_LE(const void* const Buffer,
         uint16_t Length)
```

Parameters

```
Buffer: pointer to data buffer
Length: Transmit length
```

Return Value

```
ENDPOINT_RWCSTREAM_NoError
```

Description

This function writes stream data to control endpoint.

Example

```
Endpoint_Write_Control_Stream_LE(DescriptorPointer, DescriptorSize);
```

5.4.13. Endpoint_Write_Stream_LE

Write stream data to correspond endpoint.

Syntax

```
uint8_t Endpoint_Write_Stream_LE(const void* const Buffer,
         uint16_t Length,
         uint16_t* const BytesProcessed)
```

Parameters

```
Buffer: pointer to data buffer
Length: Transmit length
```

Return Value

```
ENDPOINT_RWSTREAM_NoError,
ENDPOINT_READYWAIT_EndpointStalled,
ENDPOINT_READYWAIT_DeviceDisconnected,
ENDPOINT_READYWAIT_BusSuspended,
ENDPOINT_READYWAIT_Timeout
```

Description

This function writes stream data to correspond endpoint according usb_ep_selected.

Example

```
Endpoint_SelectEndpoint(CDCInterfaceInfo->Config.DataINEndpoint.Address);
return Endpoint_Write_Stream_LE(Buffer, Length, NULL);
```

5.4.14. Endpoint_ClearIN

Sends an IN packet to the host on the currently selected endpoint.

Syntax

```
static inline void Endpoint_ClearIN(void)
```

Parameters

```
None
```

Return Value

```
None
```

Description

This function Sends an IN packet to the host on the currently selected endpoint. It set IPRDYI = 1 to start USB IN transmits.

Example

```
CDC_Device_SendData(&VirtualSerial_CDC_Interface, (char *)in_buff, recv_count);
Endpoint_ClearIN();
```

5.4.15. Endpoint_ClearOUT

Acknowledges an OUT packet to the host on the currently selected endpoint

Syntax

```
static inline void Endpoint_ClearOUT(void)
```

Parameters

None

Return Value

None

Description

This function acknowledges an OUT packet to the host on the currently selected endpoint.

Example

```
CDCInterfaceInfo->State.LineEncoding.BaudRateBPS = Endpoint_Read_32_LE();
CDCInterfaceInfo->State.LineEncoding.CharFormat  = Endpoint_Read_8();
CDCInterfaceInfo->State.LineEncoding.ParityType  = Endpoint_Read_8();
CDCInterfaceInfo->State.LineEncoding.DataBits    = Endpoint_Read_8();

Endpoint_ClearOUT();
```

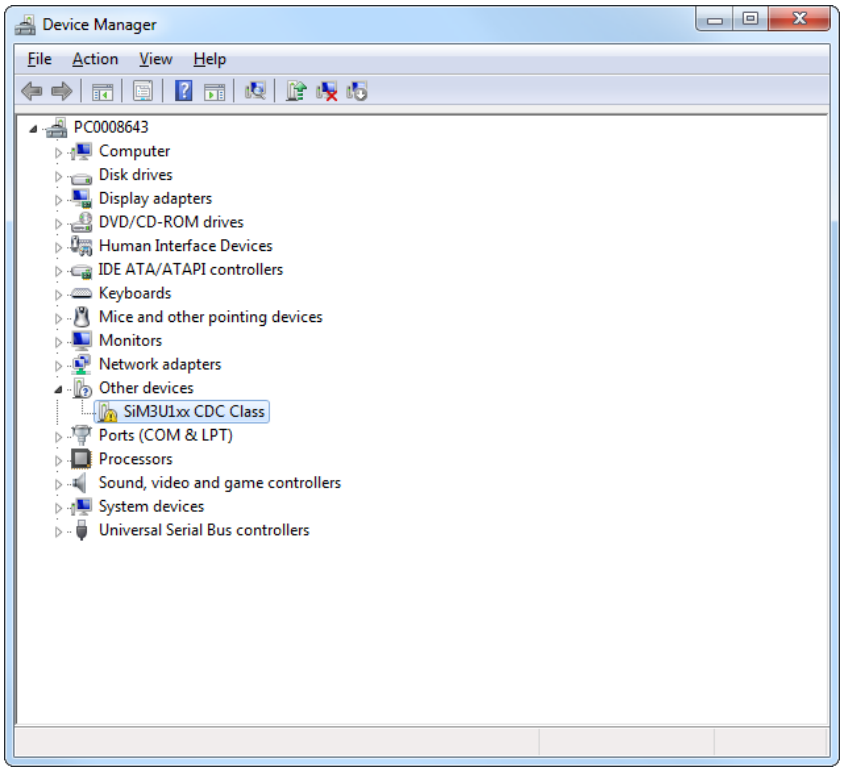
6. CDC Driver

The CDC class is implemented in all releases of Windows, and the operating system needs an INF file for the CDC driver. This INF file contains the Vendor ID and Product ID. If the VID/PID of the USB devices matches the INF file, Windows will load the driver described in the file. The **CDC_ACM** INF file can be found in the **AN758_USB_CDC\src\VirtualSerial** directory.

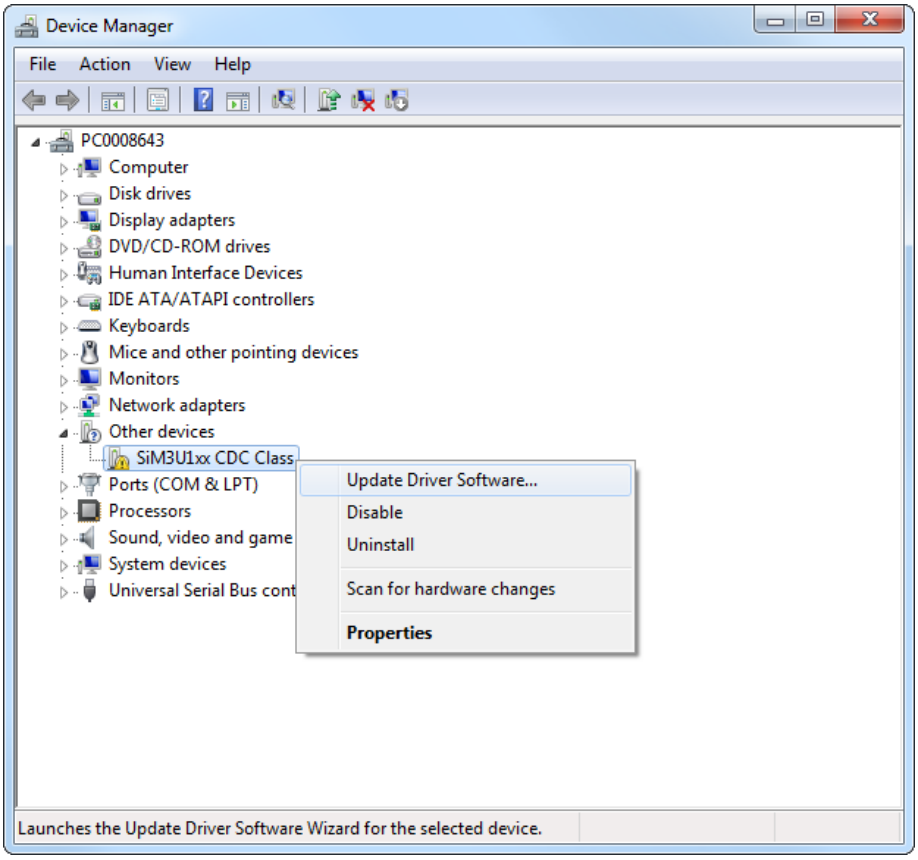
6.1. Installing the Driver

To install the driver on Windows 7:

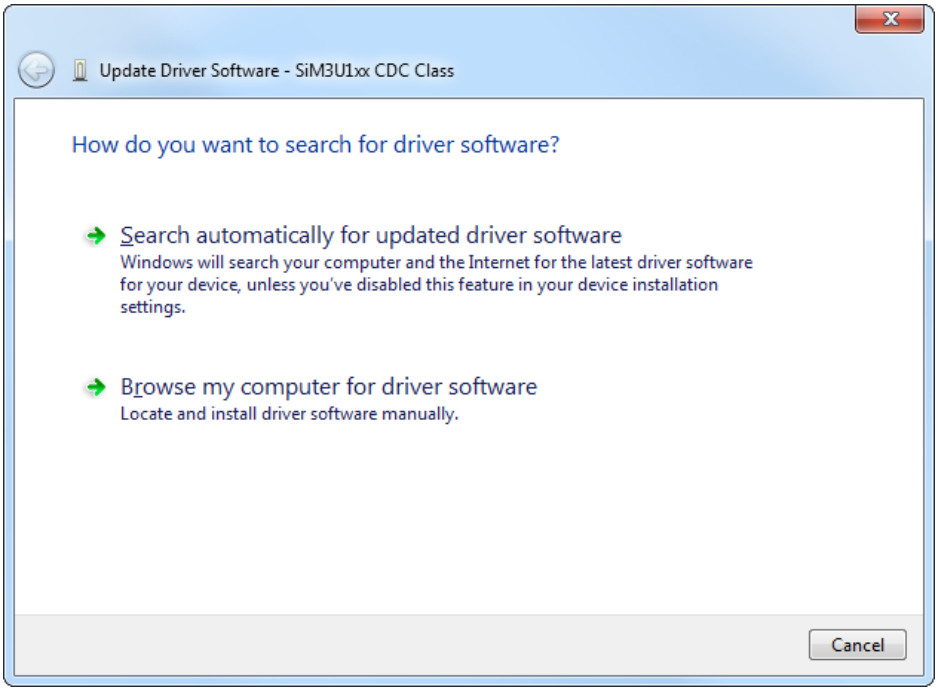
1. Build the project and download firmware to the SiM3U1xx MCU card.
2. Connect the USB cable between the Device USB connector (J13) and the PC.
3. Open Device Manager. The device will appear under **Other devices** as the **SiM3U1xx CDC Class** device.



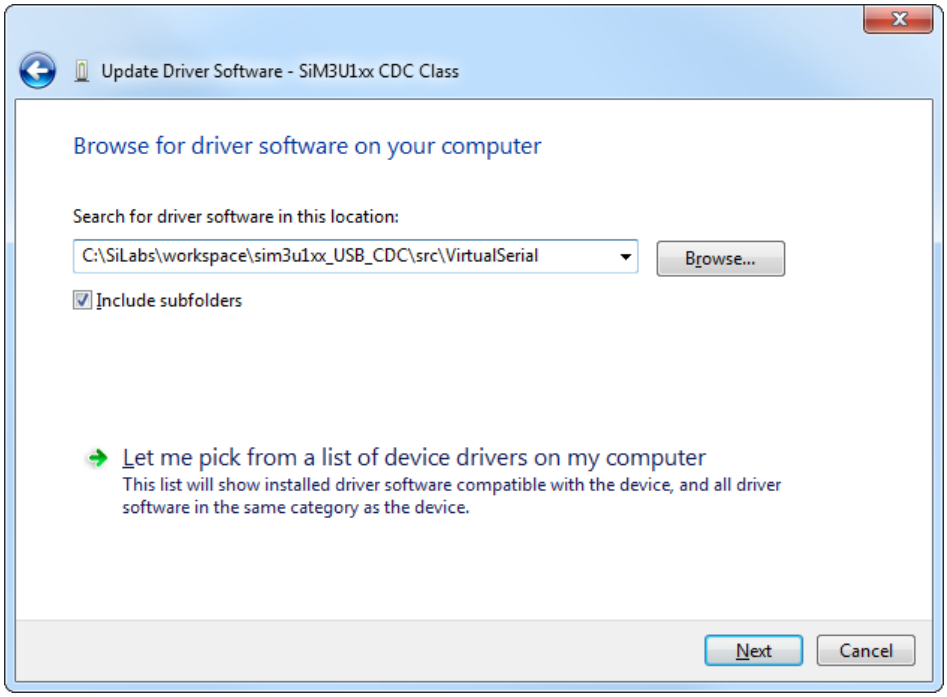
4. Right-click on the **SiM3U1xx CDC Class** device and select **Update Driver Software**.



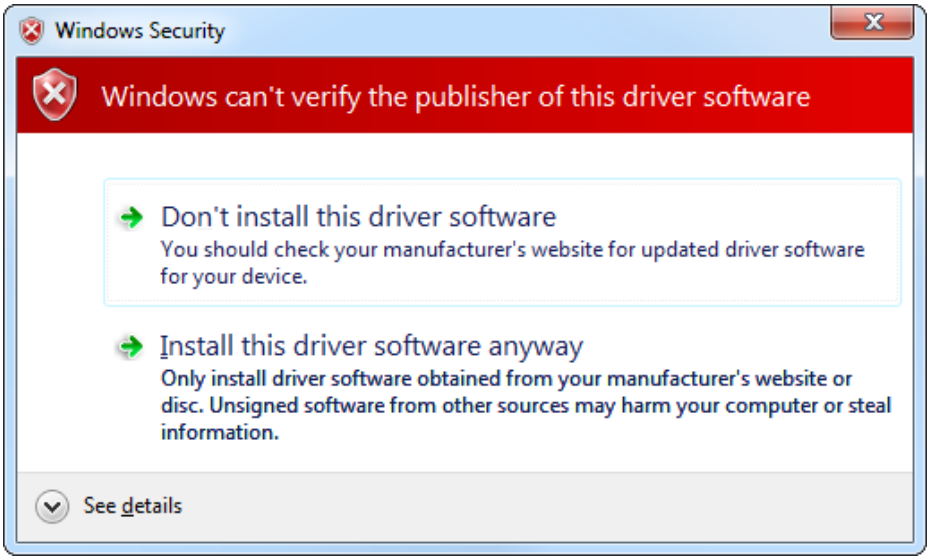
5. Select **Browse my computer for driver software**.



6. Enter the directory path of the **CDC_ACM.inf** file (**AN758_USB_CDC\src\VirtualSerial** directory). If the **Include subfolders** option is checked, entering the main **sim3u1xx_USB_CDC** directory in the workspace is sufficient.

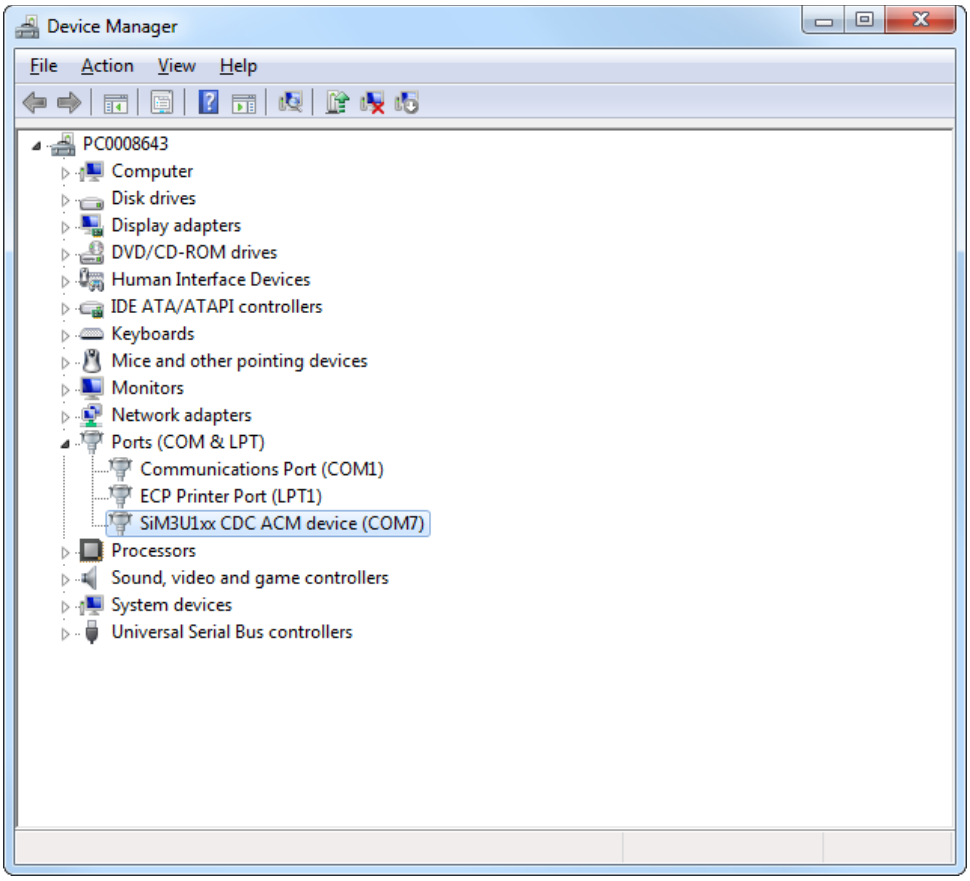


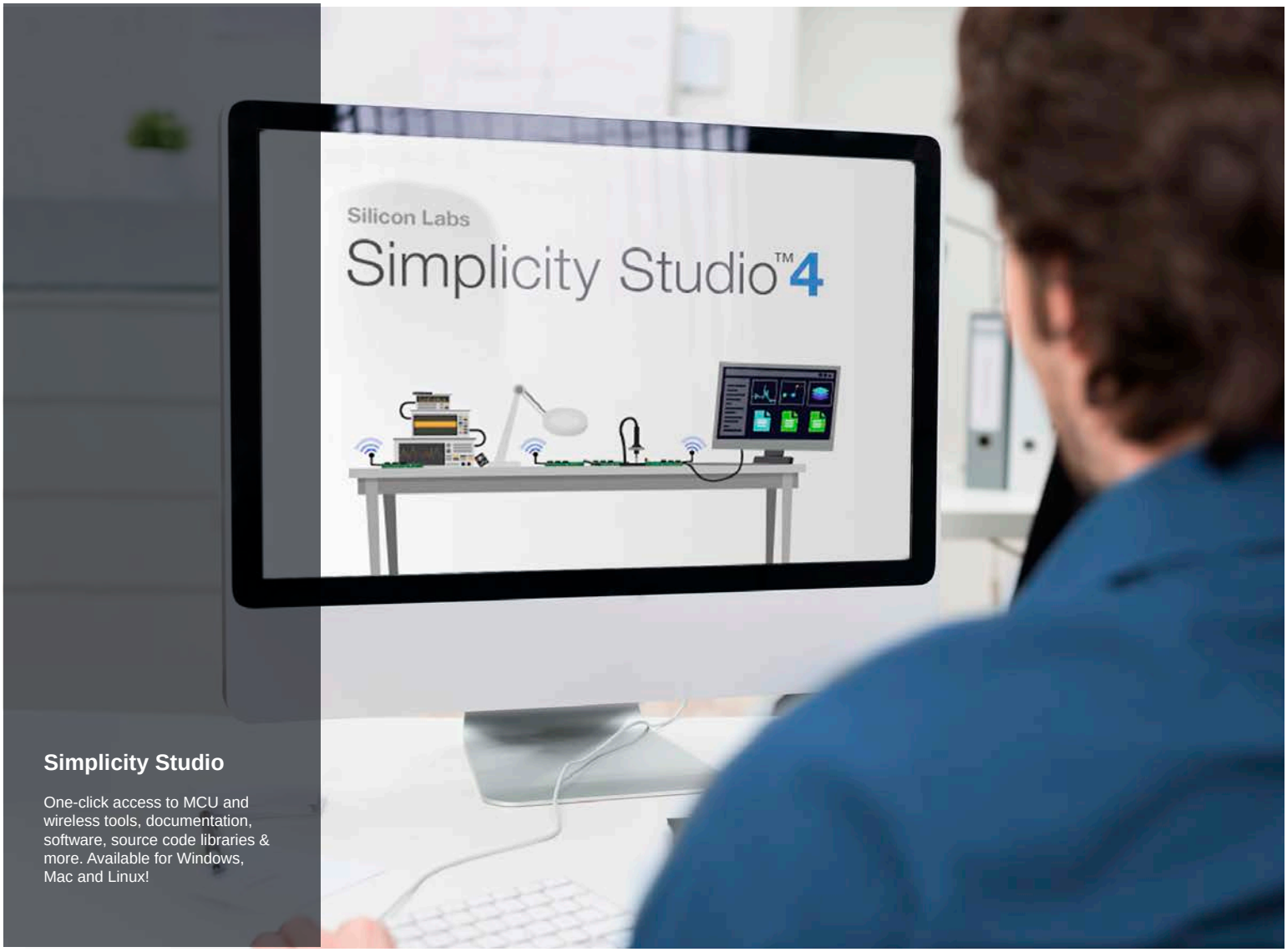
7. Windows will display a warning. Select **Install this driver software anyway**.



8. When the driver finishes installing, Windows will report the installation results.

9. Open Device Manager and observe the device. It will now appear under **Ports (COM & LPT)** with an assigned COM port number.





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