Atmel AVR4907: ASF - USB Device CDC Application

Features

- USB 2.0 compliance
  - Chapter 9 compliance
  - Full Speed (12Mbit/s), High Speed (480Mbit/s) data rates
- Basic USB CDC implementation
  - RX and TX streams
  - Data 8 or 9 bits
- Control available
  - DCD signal
  - DSR signal
  - Framing error
  - Parity error
  - Overrun
- Remote wakeup support
- USB bus powered support
- Real time (O.S. compliance, interrupt driven)
- Support 8-bit and 32-bit AVR®

1 Introduction

The aim of this document is to provide an easy way to integrate a USB CDC device application on a new or existing project.

Atmel Microcontrollers

Application Note

Rev. 8447A-AVR-11/11

2 Abbreviations

ASF:	AVR Software Framework
CD:	Composite Device: a USB device with more than one interface
CDC:	Communication Device Class
FS:	USB Full Speed
HS:	USB High Speed
UDC:	USB device Controller
UDD:	USB device Descriptor
UDI:	USB device Interface
USB:	Universal Serial Bus
SOF:	Start of Frame

3 Overview

This document includes four sections for all types of requirements when building a USB device CDC application:

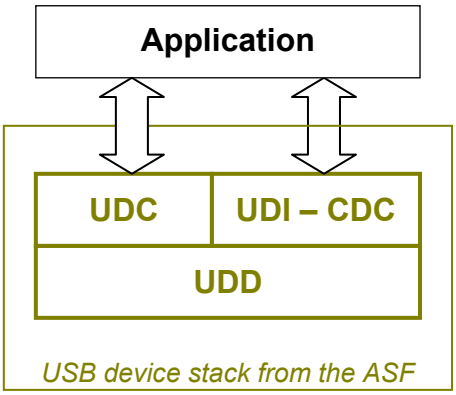
- **Quick start**
  Describes how to start a ready to use CDC device example
- **Example description**
  Describes a CDC device example
- **Building a USB device CDC**
  Describes how to add a USB device CDC interface in a project
- **Building a USB device CDC linked on standard I/O**
  Describes how to add a USB device CDC interface linked on standard I/O
  Standard I/O: stdio library, example printf()
- **CDC in a USB Composite Device**
  Describes how to integrate a CDC interface in a composite device project

For all these sections, it is recommended to know the main modules organization of a CDC application:

- User Application
- USB device Interface CDC (UDI-CDC)
- USB device Controller (UDC)
- USB device Driver (UDD)

For more advanced information concerning the USB stack implementation, please refer to the Atmel AVR4900 ASF USB Device stack application note.

Figure 3-1. USB device CDC architecture.

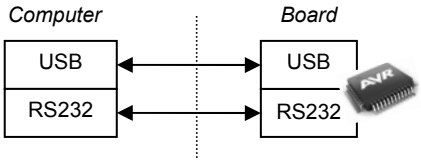


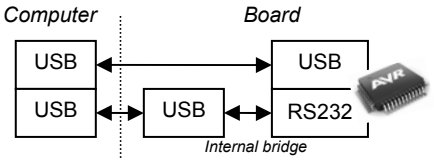
NOTE The USB device stack is available in the ASF in the common/services/usb directory.

4 Quick start

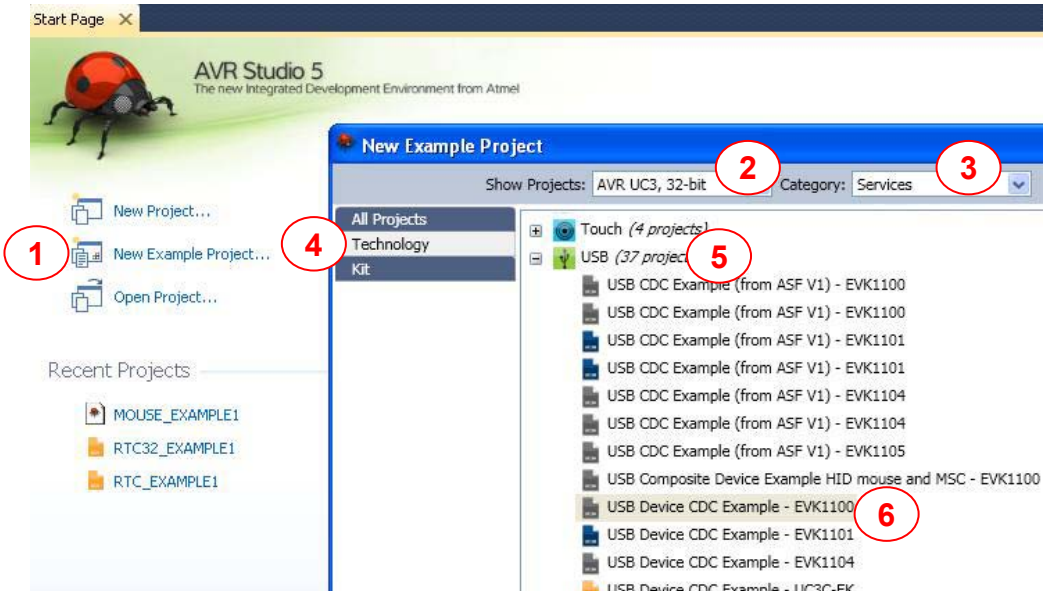
The USB device CDC examples are available in Atmel® AVR Studio® 5 and ASF. It is a bridge between an UART and the USB interface. It provides a Communication Port “COM” on USB Host which is a read/write access to a true UART of AVR product.

1. Power board, USB and UART connection.
   Connect a USB cable between board and USB Host, this cable powers the board. The UART connection RS232 can be done with a DB9 cable or by another USB cable if the board includes an internal UART bridge.



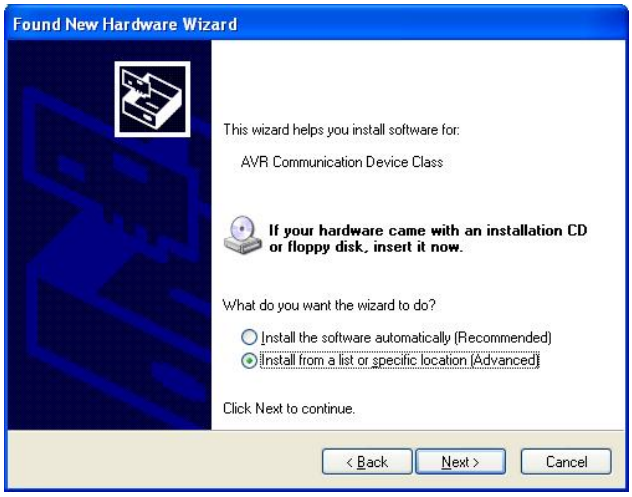


2. AVR Studio 5 allows the creation of a New Example Project.
   In the examples list, select a USB device CDC Example corresponding to the Atmel board used. Use the filter list to find quickly the example.

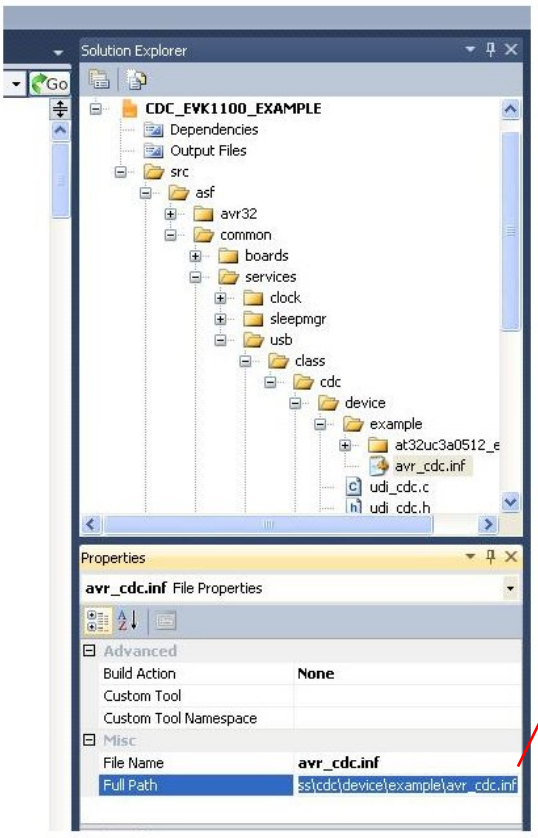


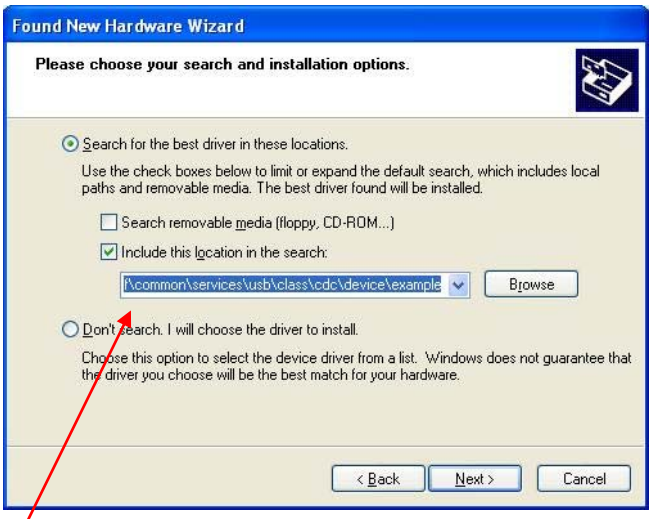
3. Compile, load and execute.
   The project does not require any modification and only needs to be compiled, loaded and run. Connect the Atmel debugger supported by the board and press F5.

4. Install the new CDC device on Windows®.
   For first use the new hardware wizard is popped up to install the driver. The mode Advance must be selected.



The `avr_cdc.inf` file available in example folder must be selected during Windows install.





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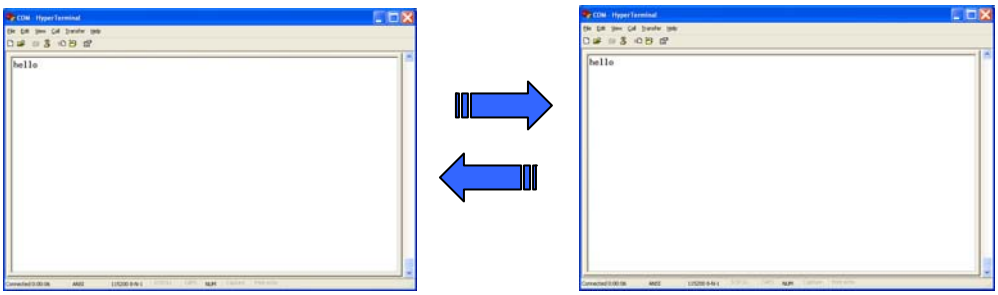
5. Open terminals.
   An RS232 terminal must be open for the both ports, UART and USB CDC. The port configuration (speed, data size, parity, stop bit) must be the same for both. The 115200baud without parity is supported by all AVR devices.

6. Send data.
   Now, tape a key in a terminal and the key is display in the other terminal.

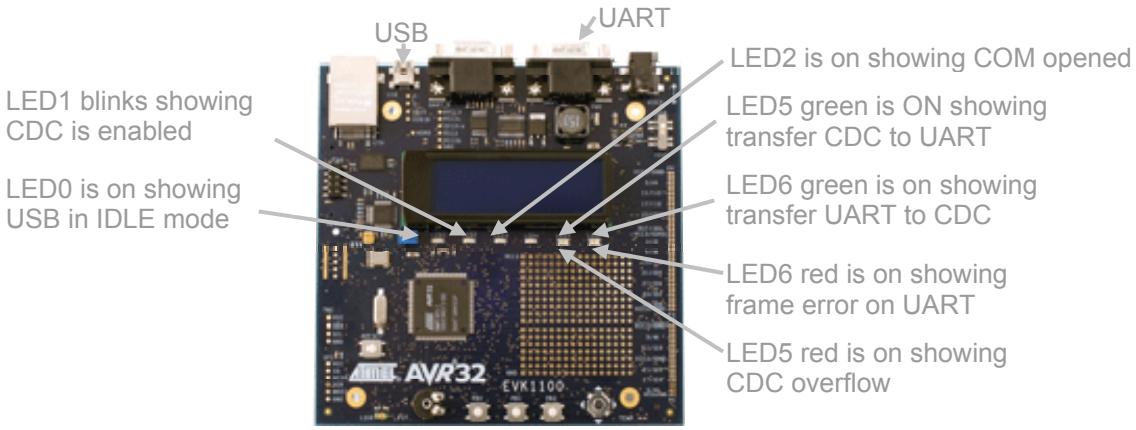


7. Flow control.

The user interface of the board can provide the following information:

- A LED is on when USB device is in IDLE mode and is off in SUSPEND mode
- A LED blinks showing that CDC interface is enabled by the USB Host
- A LED is on when the COM is open by USB Host
- A LED is on during data transfer
- A LED means an frame error on UART
- A LED means an CDC overflow

Figure 4-1. Example with the Atmel EVK1100 board.



The user interface description (specific to the board) is defined at the end of `ui.c` source file. This file is available within the project folder under “common/services/usb/class/cdc/device/example/part_boad/”.

5 Example description

5.1 Example content

The ASF provides a USB device CDC example for various Atmel AVR products. All these examples share common files and implement a UART bridge.

The Table 5-1 introduces a summary of the main files included in the USB device CDC example. These files are associated to the modules described in Figure 3-1.

Table 5-1. USB device CDC example files.

Modules	Files	ASF paths	Description

Application	`main.c`
	`ui.c`
	`uart_uc3.c`
	`uart_xmega.c`
	`conf_usb.h`
		Examples folder	Main loop
			Set up hardware switch and LEDs to show operations
			UC3 UART control and link to CDC interface
			XMEGA® UART control and link to CDC interface
			USB device configuration

UDI CDC	`udi_cdc.c/h`	common/services/usb/class/cdc/device/	CDC Class implementation
	`udi_cdc_desc.c` `udi_cdc_conf.h`	common/services/usb/class/cdc/device/	USB Descriptors for an USB device with CDC interface (not applicable for USB composite device)
	`usb_protocol_cdc.h`	common/services/usb/class/cdc/	CDC Protocol constants

UDC	`udc.c/h`
	`udc_desc.h`
	`udi.h`
	`udd.h`
		common/services/usb/udc/	USB device Core

	`usb_protocol.h` `usb_atmel.h`	common/services/usb/	USB Protocol constants

UDD	`usbb_device.c/h`
	`usbc_device.c/h`
	`usb_device.c/h`
		avr32/drivers/usbb/
		avr32/drivers/usbc/
		xmega/drivers/usb/
			USB Drivers

5.2 Example performance

On Atmel AVR UC3, the UART bridge mode can support easily the 115200 baud rate. Example, with a CPU frequency of 48MHz, the idle time is 86%.

On Atmel AVR XMEGA, the UART bridge mode can support the 115200 baud rate. Example, with a CPU frequency of 24MHz, the idle time is 65%.

The Atmel AVR4920: ASF – USB Device Stack – Compliance and Performance Figures application note is available and provides more information concerning CDC performance outside UART bridge mode.

5.3 Example behavior

The `main.c`, `ui.c`, `uart_xmega.c` and `uart_uc3.c` files implement the user interface and UART control of the CDC application. It is comprised of five steps:

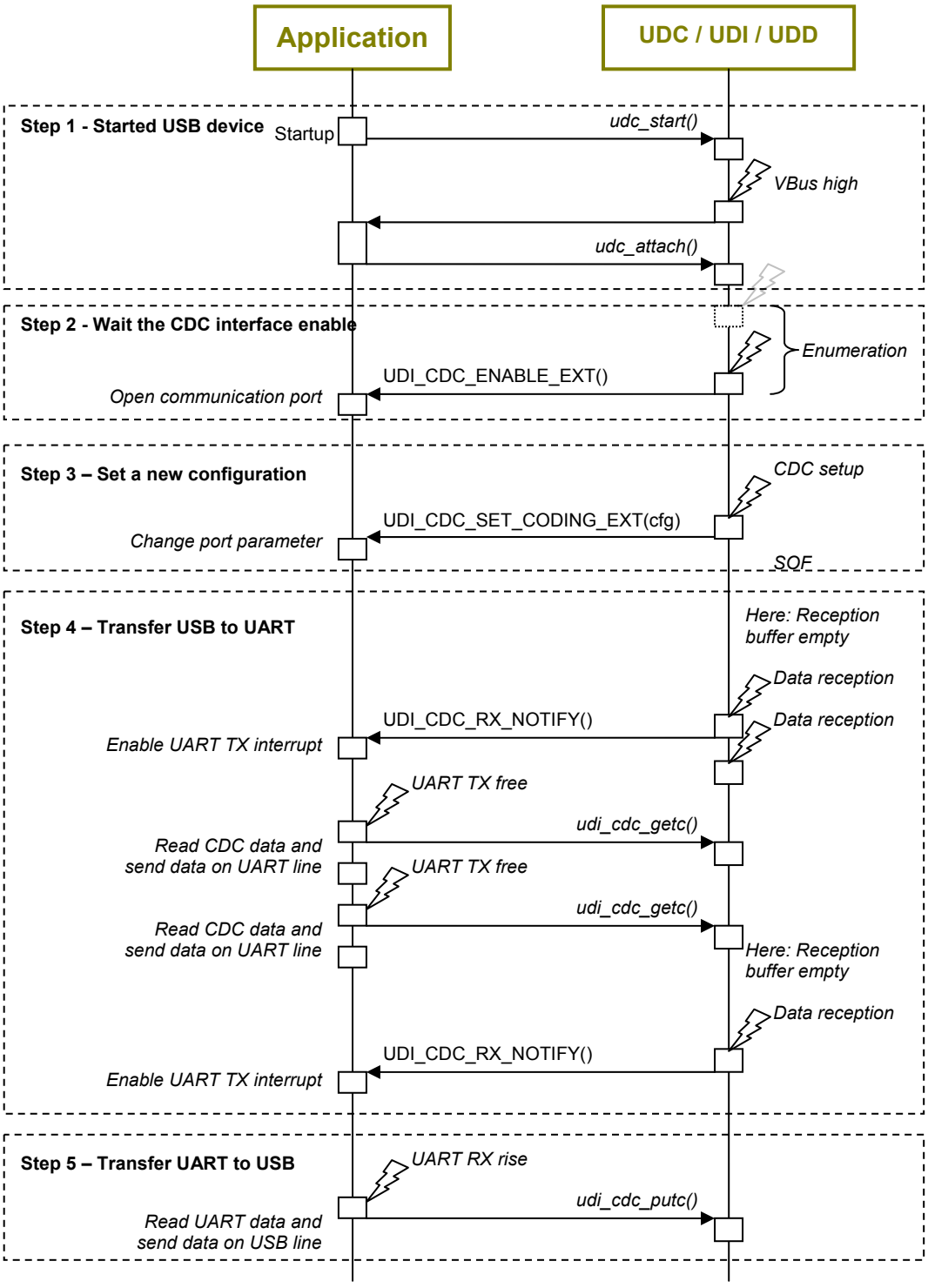
1. Start USB device.

```
udc_start();
udc_attach(); // Must be called when the USB cable is plugged
              // Cable plugged is detected via VBus events
```

2. Wait the enable of CDC interface via callback.
   ```
   UDI_CDC_ENABLE_EXT() // Authorize and open UART communication port
   ```
3. Set a new configuration of communication port.
   ```
   UDI_CDC_SET_CODING_EXT(cfg) // Configuration of UART communication port
   ```
4. Transfer data from USB bus.
   ```
   UDI_CDC_RX_NOTIFY()       // Notify that CDC reception buffer is not empty,
   then the UART TX interrupt is enabled

   udi_cdc_getc()     // Routine to read CDC buffer reception. It is a short
   function which can be called in UART TX interrupt routine
   ```
5. Transfer data to USB bus.
   ```
   udi_cdc_putc()     // Routine to put data to CDC buffer emission. It is a
   short function which can be called in UART RX interrupt routine
   ```

Figure 5-1. Example behavior sequence.



6 Building a USB device CDC

The USB device CDC modules provide a USB CDC interface which can be connected at any interface.

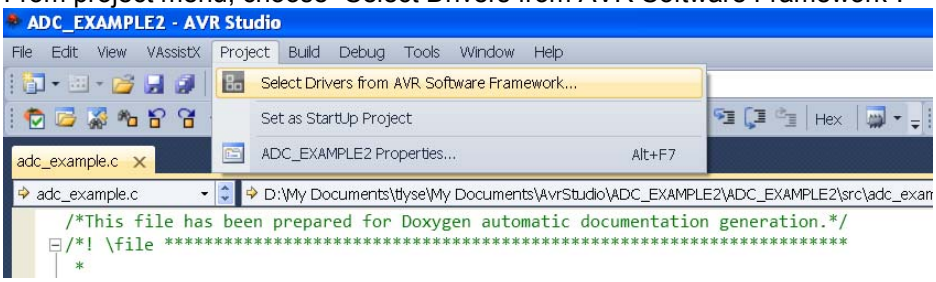
These modules are available in Atmel AVR Studio 5 and can be imported in an AVR Studio 5 project. This section describes how to add a USB device CDC in a project:

1. Import USB CDC module.
2. Configure personal USB parameters.
3. Call USB routines to run USB device.

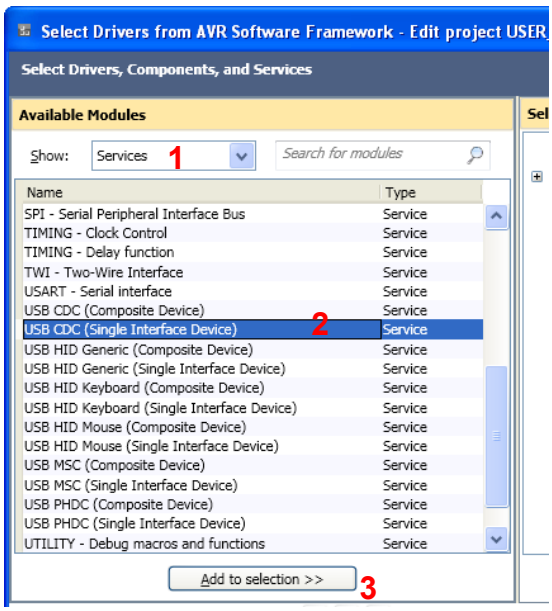
6.1 Import USB module

To import the USB CDC module, follow the instructions below:

1. Open or create your project:
2. From project menu, choose “Select Drivers from AVR Software Framework”.



3. Select Services (1), choose USB CDC (Single Interface Device) (2), and click on the “Add to selection” button (3).



6.2 USB configuration

All USB stack configurations are stored in the `conf_usb.h` file in the application module. These configurations are simple and do not require any specific USB knowledge.

There is one configuration section for each USB modules: UDC, UDI and UDD.

The UDC configuration possibilities are described in the Atmel AVR4900: ASF – USB Device Stack application note in the Section 7.1.1: USB device configuration".

The UDD configuration possibilities are described in the Atmel AVR4900: ASF – USB Device Stack application note in the Section 7.1.3: USB drivers' configuration".

The UDI which is the CDC interface require some configuration described in Table 6-1.

Table 6-1. UDI CDC - configuration.

Define name	Type	Description
UDI_CDC_LOW_RATE	Only defined (without value) to enable mode	Define it when the transfer CDC Device to Host is a low rate (<512000 bauds) to reduce CDC buffer sizes
UDI_CDC_DEFAULT_RATE	Word 32bits	Default communication rate at CDC start-up
UDI_CDC_DEFAULT_STOPBITS	CDC_STOP_BITS_1 CDC_STOP_BITS_1_5 CDC_STOP_BITS_2	Default stop bit configuration at CDC start-up
UDI_CDC_DEFAULT_PARITY	CDC_PAR_NONE CDC_PAR_ODD CDC_PAR_EVEN CDC_PAR_MARK CDC_PAR_SPACE	Default parity configuration at CDC start-up
UDI_CDC_DEFAULT_DATABITS	8 or 9	Default data bits configuration at CDC start-up

NOTE

It is important to verify the configuration defined in `conf_clock.h` file, because the USB hardware requires a specific clock frequency (see comment in `conf_clock.h` file).

6.3 USB implementation

This section describes source code to add to run a USB device CDC application.

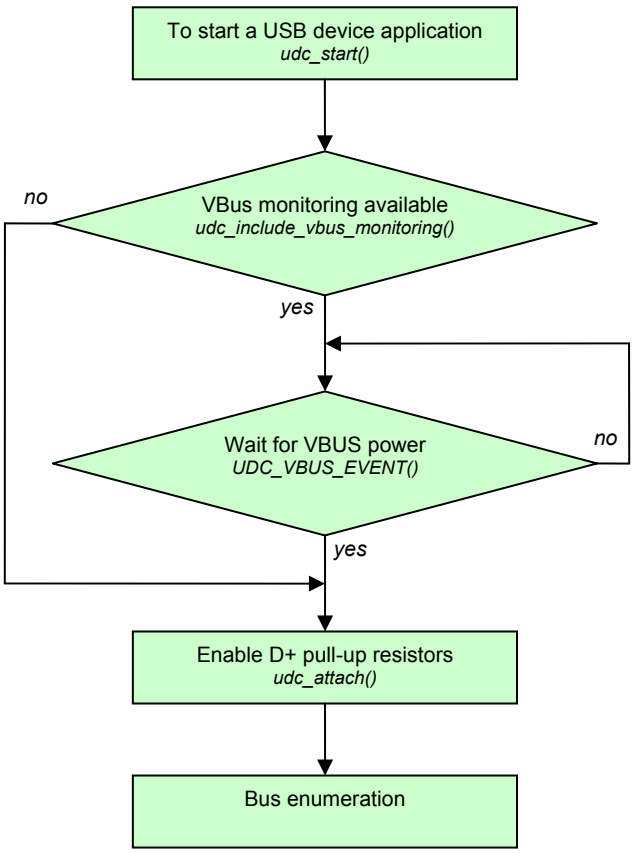
The implementation is made of three steps:

1. Start USB device.
2. Wait the enable of CDC interface by the Host.
3. Transfer data on USB bus.

6.3.1 USB device control

Only two function calls are needed to start a USB device application, see Figure 6-1.

Figure 6-1. USB device application sequence.



NOTE

In case of a new project, the USB stack requires to enable interrupts and to initialize the clock and sleepmgr services.

Example:

```
<conf_usb.h>
#define UDC_VBUS_EVENT(b_vbus_high) \
       vbus_event(b_vbus_high)

<main C file>:
main() {
   // Authorize interrupts
   irq_initialize_vectors();
   cpu_irq_enable();
   // Initialize the sleep manager service
   sleepmgr_init();
   // Initialize the clock service
   sysclk_init();
   // Enable USB Stack Device
   udc_start();
   if (!udc_include_vbus_monitoring()) {
       // VBUS monitoring is not available on this product
```

```
        // thereby VBUS has to be considered as present
        vbus_event (true);
    }
}

vbus_event(b_vbus_high) {
    if (b_vbus_high) {
        // Connect USB device
        udc_attach();
    }else{
        // Disconnect USB device
        udc_detach();
    }
}
```

6.3.2 USB interface control

After the device enumeration (detecting and identifying USB devices), the USB Host starts the device configuration. When the USB CDC interface from device is accepted by Host, the USB host enables this interface and the UDI_CDC_ENABLE_EXT() callback function is called.

When the USB device is unplugged or is reset by USB Host, the USB interface is disabled and the UDI_CDC_DISABLE_EXT() callback function is called.

Thus, it is recommended to enable/disable the communication port in these functions.

Example:

```
<conf_usb.h>
#define UDI_CDC_ENABLE_EXT() \
        cdc_enable()
#define UDI_CDC_DISABLE_EXT() \
        cdc_disable()

<main C file>:
cdc_enable() {
    // Open UART and enable UART transition interrupts
    …
    return true;
}
cdc_disable() {
    // Disable UART interrupts and close UART
    …
}
```

6.3.3 USB CDC control

The USB CDC functions described in Table 6-2 allow the application to send a notification. The functions in Table 6-3 allow to send or to receive data.

Table 6-2. UDI CDC – notification functions.

Declaration	Description
udi_cdc_ctrl_signal_dcd(bool b_set)	Send a notification concerning a state change of DCD signal
udi_cdc_ctrl_signal_dsr(bool b_set)	Send a notification concerning a state change of DSR signal
udi_cdc_signal_framing_error()	Send a notification concerning a framing error
udi_cdc_signal_parity_error()	Send a notification concerning a parity error
udi_cdc_signal_overrun()	Send a notification concerning an overrun

Table 6-3. UDI CDC – data functions.

Declaration	Description
udi_cdc_is_rx_ready()	This function checks if a character has been received on the CDC
int udi_cdc_getc()	Waits and gets a value on CDC
iram_size_t udi_cdc_read_buf(int* buf, iram_size_t size)	Waits and reads a RAM buffer on CDC
udi_cdc_is_tx_ready()	This function checks if a new character sent is possible
int udi_cdc_putc(int value)	Puts a byte on CDC
iram_size_t udi_cdc_write_buf(const int* buf, iram_size_t size)	Writes a RAM buffer on CDC

Example:

```
<UART C file>:
uart_process() {
   if (is_uart_framing_error())
       udi_cdc_signal_framing_error();
   if (is_data_reception()) {
       value = uart_getc();
       udi_cdc_putc(value);
   }
   if (udi_cdc_is_tx_ready())
       value = udi_cdc_getc();
       uart_putc(value);
   }
   ...
}
```

6.4 Create inf file for Windows O.S.

The Windows O.S. requires a *.inf file to install a new CDC device.

Here the inf file template to complete (see comment between < >):

```
; Windows 2000, XP & Vista setup File for AVR CDC Device
[Version]
Signature="$Windows NT$"
```

```
Class=Ports
ClassGuid={4D36E978-E325-11CE-BFC1-08002BE10318}
Provider=%ATMEL%        <Replace ATMEL by your manufacture name>
DriverVer=10/15/1999,5.0.2153.1

;-----------------------------------------------------------
; Targets
;-----------------------------------------------------------
[Manufacturer]
%ATMEL%=ATMEL, NTamd64  <Replace ATMEL by your manufacture name>
[ATMEL]
%ATMEL_CDC%=Reader, USB\VID_03EB&PID_2404
          <Replace 03EB by your VID, Replace 2404 by your PID>
[ATMEL.NTamd64]
%ATMEL_CDC%=DriverInstall, USB\VID_03EB&PID_2404
          <Replace 03EB by your VID, Replace 2404 by your PID>

;-----------------------------------------------------------
; Windows 2K, XP, and Vista32
;-----------------------------------------------------------
[Reader_Install.NTx86]
[DestinationDirs]
DefaultDestDir=12
Reader.NT.Copy=12
[Reader.NT]
include=mdmcpq.inf
CopyFiles=Reader.NT.Copy
AddReg=Reader.NT.AddReg
[Reader.NT.Copy]
usbser.sys
[Reader.NT.AddReg]
HKR,,DevLoader,,*ntkern
HKR,,NTMPDriver,,usbser.sys
HKR,,EnumPropPages32,,"MsPorts.dll,SerialPortPropPageProvider"
[Reader.NT.Services]
AddService = usbser, 0x00000002, Service_Inst
[Service_Inst]
DisplayName = %Serial.SvcDesc%
ServiceType = 1 ; SERVICE_KERNEL_DRIVER
StartType = 3 ; SERVICE_DEMAND_START
ErrorControl = 1 ; SERVICE_ERROR_NORMAL
ServiceBinary = %12%\usbser.sys
LoadOrderGroup = Base
```

```
;------------------------------------------------------------
; Vista64
;------------------------------------------------------------
[DriverInstall.NTamd64]
include=mdmcpq.inf
CopyFiles=DriverCopyFiles.NTamd64
AddReg=DriverInstall.NTamd64.AddReg
[DriverCopyFiles.NTamd64]
usbser.sys,,,0x20
[DriverInstall.NTamd64.AddReg]
HKR,,DevLoader,,*ntkern
HKR,,NTMPDriver,,usbser.sys
HKR,,EnumPropPages32,,"MsPorts.dll,SerialPortPropPageProvider"
[DriverInstall.NTamd64.Services]
AddService=usbser, 0x00000002, DriverService.NTamd64
[DriverService.NTamd64]
DisplayName=%Serial.SvcDesc%
ServiceType=1
StartType=3
ErrorControl=1
ServiceBinary=%12%\usbser.sys

;------------------------------------------------------------
; String
;------------------------------------------------------------
[Strings]
ATMEL = "ATMEL, Inc."    <Replace ATMEL by your manufacture name>
ATMEL_CDC = "AVR Communication Device Class"
                         <Write your device description>
Serial.SvcDesc = "USB Serial emulation driver"
```

NOTE An example of this *.inf file is provided in CDC example \common\services\usb\class\cdc\device\example\avr_cdc.inf

7 Building a USB device CDC connected to a standard I/O

The USB/CDC standard I/O module is provided to add quickly a link between the standard I/O library (example printf()) and a USB CDC interface.

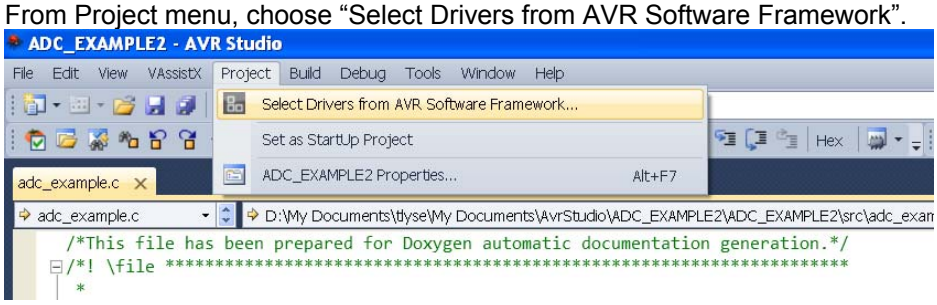
This module is available in Atmel AVR Studio 5 and can be imported in an AVR Studio 5 project. This section describes how to add a USB device CDC in a project:

1. Import USB/CDC Standard I/O (stdio) module.
2. Configure personal USB parameters.
3. Call USB routines to run USB device.
4. Create an inf file for Windows O.S. (not required on Linux®).

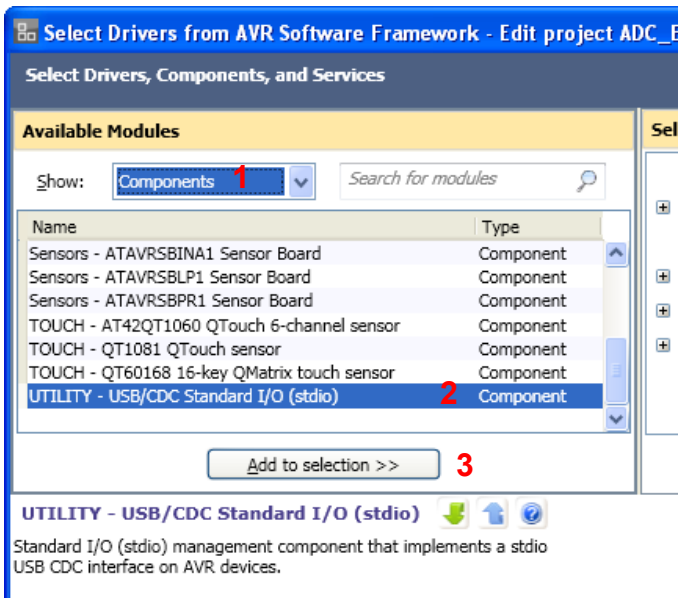
7.1 Import USB module

To import the USB/CDC Standard I/O module, follow the instructions below:

1. Open or create your project:
2. From Project menu, choose “Select Drivers from AVR Software Framework”.



3. Select Services (1), choose “UTILITY - USB/CDC Standard I/O (stdio)” (2), and click on the “Add to selection” button (3).



7.2 USB configuration

Follow the instruction described in Section 6.2.

7.3 USB implementation

Follow the instruction described in Section 6.3 except sections 6.3.2 and 6.3.3, which are already implemented in USB/CDC standard I/O module.

7.4 Create inf file for Windows O.S.

Follow the instruction described in Section 6.4.

8 CDC in a USB composite device

The information required to build a composite device is available in the Atmel AVR4902 ASF - USB Composite Device application note. A familiarity with this application note is mandatory.

This section introduced only the specific information required to build a composite device with a CDC interface.

8.1 USB configuration

In addition to the USB configuration described in Section 6.2, the following values must be defined in the `conf_usb.h` file:

USB_DEVICE_EP_CTRL_SIZE
Endpoint control size.

This must be:

- 8, 16, 32 or 64 for full speed device (8 is recommended to save RAM)
- 64 for a high speed device

UDI_CDC_DATA_EP_IN
IN bulk endpoint number used by the CDC interface to send data (TX).

UDI_CDC_DATA_EP_OUT
OUT bulk endpoint number used by the CDC interface to receive data (RX).

UDI_CDC_COMM_EP
IN interrupt endpoint number used by the CDC interface to send communication events.

UDI_CDC_COMM_IFACE_NUMBER
Interface number of the CDC communication interface.

UDI_CDC_DATA_IFACE_NUMBER
Interface number of the CDC data interface.

USB_DEVICE_MAX_EP
Total number of endpoints in the application. This must include three endpoints for CDC interface.

8.2 USB descriptor

The addition of CDC interfaces in device descriptors requires adding an Interface Association Descriptor (IAD) to associate the CDC communication interface descriptor with CDC data interface descriptor.

The USB device Descriptor of composite device, defined in `conf_usb.h` file, must include a CDC communication interface, a CDC data interface descriptor, and an interface Association Descriptor:

```
//! Define structure of composite interfaces descriptor
#define    UDI_COMPOSITE_DESC_T                    \
    usb_iad_desc_t udi_cdc_iad;                    \
    udi_cdc_comm_desc_t udi_cdc_comm;              \
    udi_cdc_data_desc_t udi_cdc_data;              \
    ...
```

```
//! Fill composite interfaces descriptor for Full Speed
#define    UDI_COMPOSITE_DESC_FS                    \
    .udi_cdc_iad               = UDI_CDC_IAD_DESC, \
    .udi_cdc_comm              = UDI_CDC_COMM_DESC, \
    .udi_cdc_data              = UDI_CDC_DATA_DESC, \
    ...

//! Fill composite interfaces descriptor for High Speed
#define    UDI_COMPOSITE_DESC_HS                    \
    .udi_cdc_iad               = UDI_CDC_IAD_DESC, \
    .udi_cdc_comm              = UDI_CDC_COMM_DESC, \
    .udi_cdc_data              = UDI_CDC_DATA_DESC, \
    ...

//! Fill Interface APIs corresponding at interfaces descriptor
#define    UDI_COMPOSITE_API  \
    &udi_api_cdc_comm,        \
    &udi_api_cdc_data,        \
    …
```

9 Table of contents

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