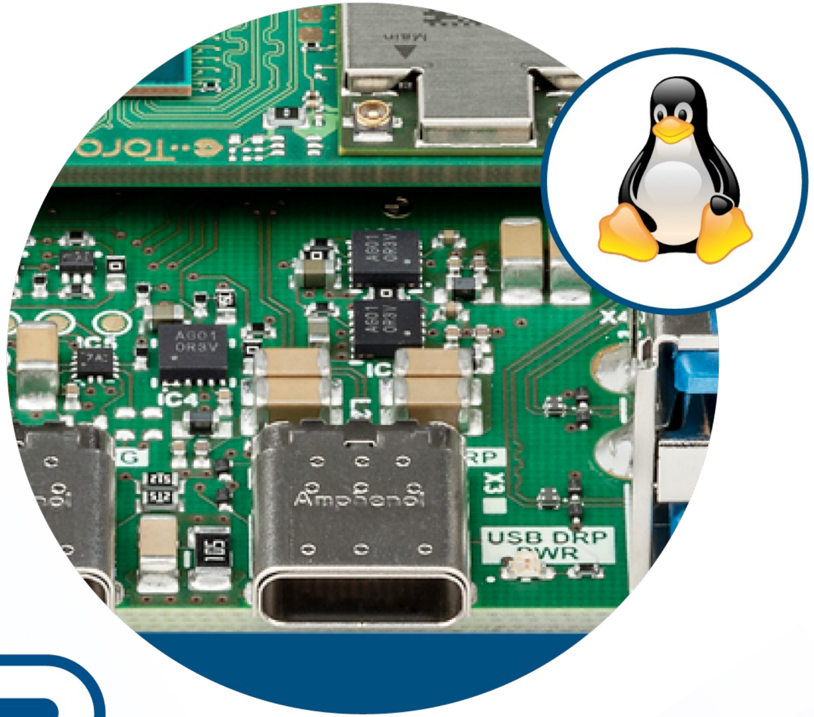
Toradex
Swiss. Embedded. Computing.

EOSS EMBEDDED OPEN SOURCE SUMMIT

USB on Embedded Linux Systems Deep Dive



USB

Presented by
Toradex

WITH YOU TODAY…

- Joined Toradex 2011
- Spearheaded Embedded Linux Adoption
- Introduced Upstream First Policy
- Top 10 U-Boot Contributor
- Top 10 Linux Kernel Arm SoC Contributor
- Industrial Embedded Linux Platform Torizon Fully Based on Mainline Technology
  - Mainline U-Boot with Distroboot
  - KMS/DRM Graphics with Etnaviv & Nouveau
  - OTA with OSTree
  - Docker resp. Podman

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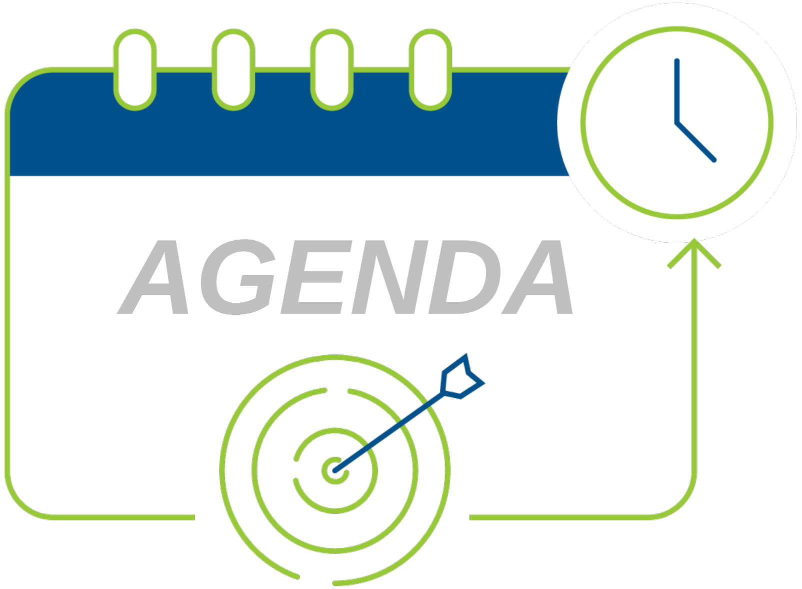
Software Team Lead - Embedded Linux BSP

Toradex

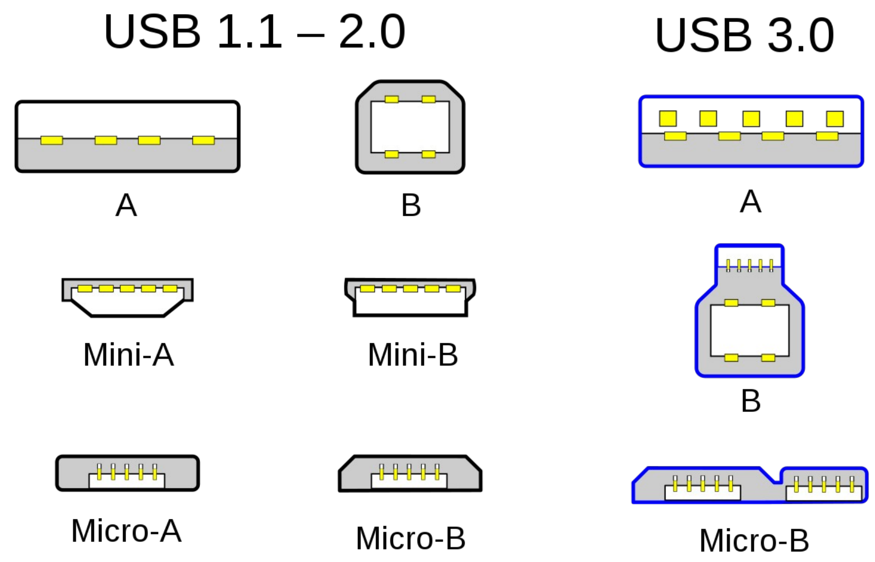
WHAT WE’LL COVER TODAY…

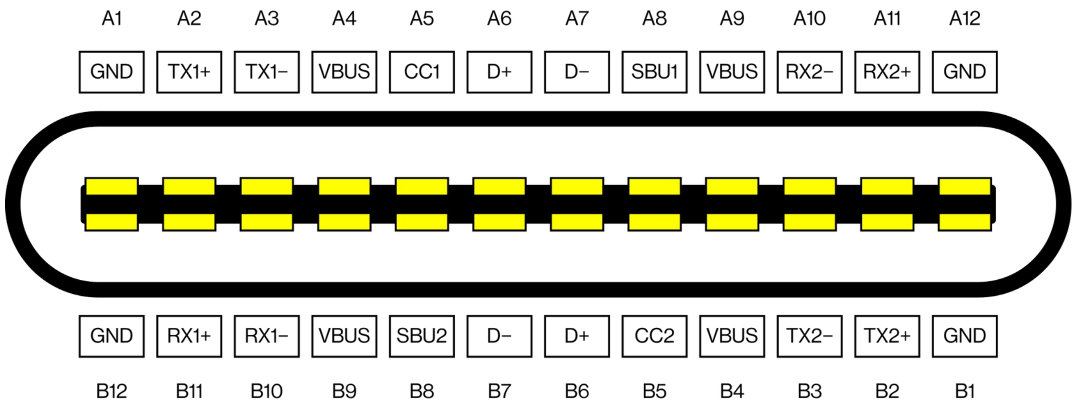
- Introduction to the USB Specification
- USB in Embedded Systems
- USB Recovery Mode
- USB in U-Boot
- USB in the Linux Kernel
- USB from Userspace
- USB Tooling
- USB Role Switching
- USB Debugging
- Live Demonstration



Introduction to the USB Specification

- Connectors
  - USB-A: USB 2.0 and 3.0 variants
  - USB-B: Fullsize, mini, micro and USB 3.0 variants
  - USB-C: One size fits all, right?
- USB transfer speed
  - Low-speed: up to 1.5 Mbps
    - Since USB 1.0
  - Full-speed: up to 12 Mbps
    - Since USB 1.1
  - High-speed: up to 480 Mbps
    - Since USB 2.0
  - SuperSpeed: up to 5 Gbps
    - Since USB 3.0
  - ...





A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
GND	TX1+	TX1−	VBUS	CC1	D+	D−	SBU1	VBUS	RX2−	RX2+	GND
GND	RX1+	RX1−	VBUS	SBU2	D−	D+	CC2	VBUS	TX2−	TX2+	GND
B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1

Introduction to the USB Specification (cont.)

- USB protocol
  - Device: Entity connected to the bus
  - Configuration: State of a device
    - Initialisation, standby, active
    - Bundles a bunch of interfaces
  - Interface: Logical device
    - Each interface encapsulates a single high-level function (e.g. webcam: video stream, audio stream, buttons)
    - One driver is needed for each interface!
    - Alternate settings: Each USB interface may have different parameter settings (e.g. for different bandwidth)
    - The initial state is always in the first setting (number 0)
    - Alternate settings often used for isochronous endpoints (endpoints use different amounts of reserved bandwidth)

Introduction to the USB Specification (cont.)

- Endpoint: Unidirectional communication pipe
  - Control endpoints
    - For configuration, get information, send commands, and retrieve status information
    - Simple, small data transfers
    - Every device has a control endpoint (endpoint 0)
    - USB protocol guarantees corresponding data transfers will always have enough (reserved) bandwidth
  - Interrupt endpoints
    - Transfer small amounts of data at a fixed rate
    - Guaranteed, reserved bandwidth
    - For devices requiring guaranteed response time, such as USB human interface devices (HID) e.g. mice and keyboards
    - Note: Different from hardware interrupts, really requires constant polling from the host

Introduction to the USB Specification (cont.)

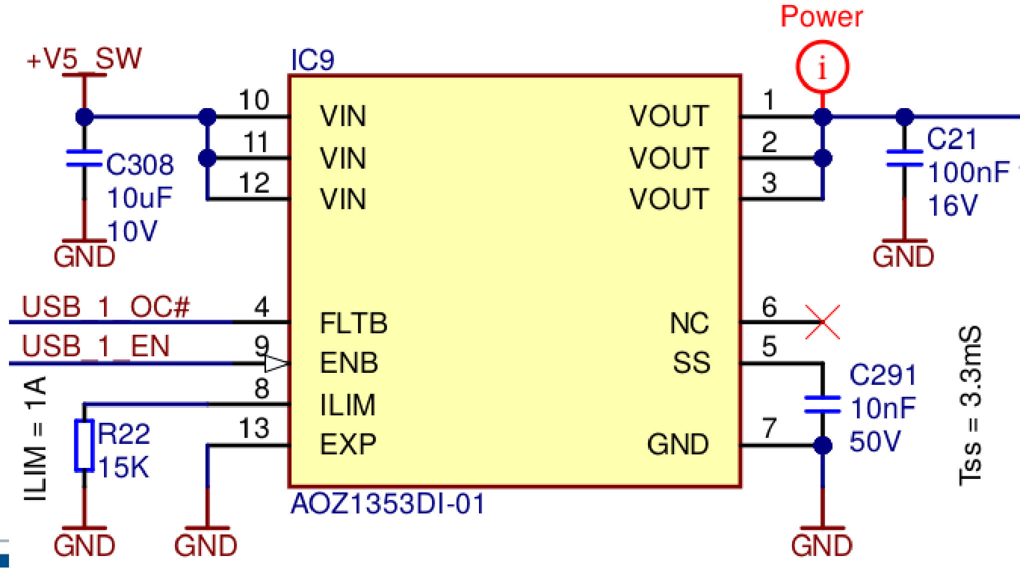
- Endpoints: Unidirectional communication pipes (cont.)
  - Bulk endpoints
    - Large sporadic data transfers
    - Using all remaining available bandwidth
    - However, no guarantee on bandwidth or latency
    - Only guarantee that no data is lost
    - Typically used when there is no quality of service requirement (Network, printer, storage devices et al.)
  - Isochronous endpoints
    - Also for large amounts of data
    - Guaranteed speed (often but not necessarily as fast as possible).
    - No guarantee that all data makes it through
    - Used by real-time data transfers (typically for audio and video devices with quality of service requirements)

Introduction to the USB Specification (cont.)

- USB request blocks (URBs)
  - Communication between host and device done asynchronously using URBs
  - Similar to packets in network communication
  - Every endpoint can handle a queue of URBs
  - Every URB has a completion handler
  - A driver may allocate many URBs for a single endpoint or reuse same URB for different endpoints
  - See Documentation/usb/URB.txt in kernel sources
- URB scheduling interval
  - For interrupt and isochronous transfers
  - Low-speed and full-speed devices: The interval unit is frames (ms)
  - Hi-speed devices: The interval unit is microframes (1/8 ms)

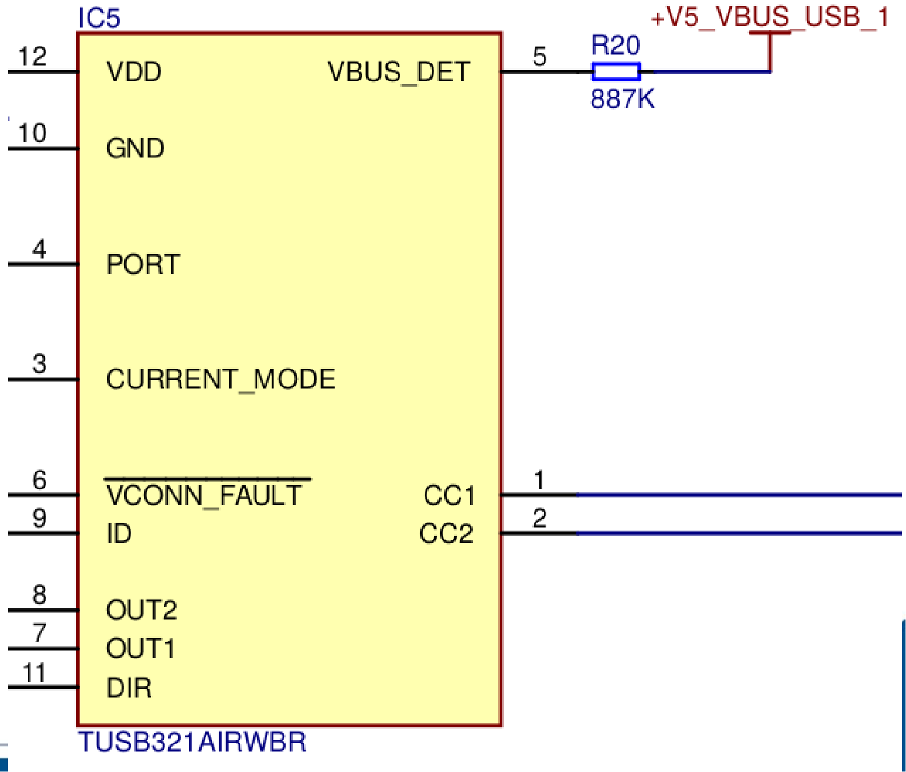
USB in Embedded Systems

- Most modern SoCs feature at least one USB port often with accompanying PHY
- Dedicated differential signals
  - D+/D- for up to USB 2.0 low/full/high-speed
  - SSRX+/SSRX- and SSTX+/SSTX- for SuperSpeed beginning with USB 3.0
- Supporting signals
  - May be dedicated or realised by regular GPIOs
  - ID: usually low for host and not connected (pulled-up) for device
  - OverCurrent: device draws too much VBUS current (output from USB power switch chips)
  - VBUS
    - Input in device role
    - May influence connection/suspend state
    - Often not 5 volt tolerant requiring a voltage divider
  - VBUS enable
    - Output in host role (enable for USB power switch chips)

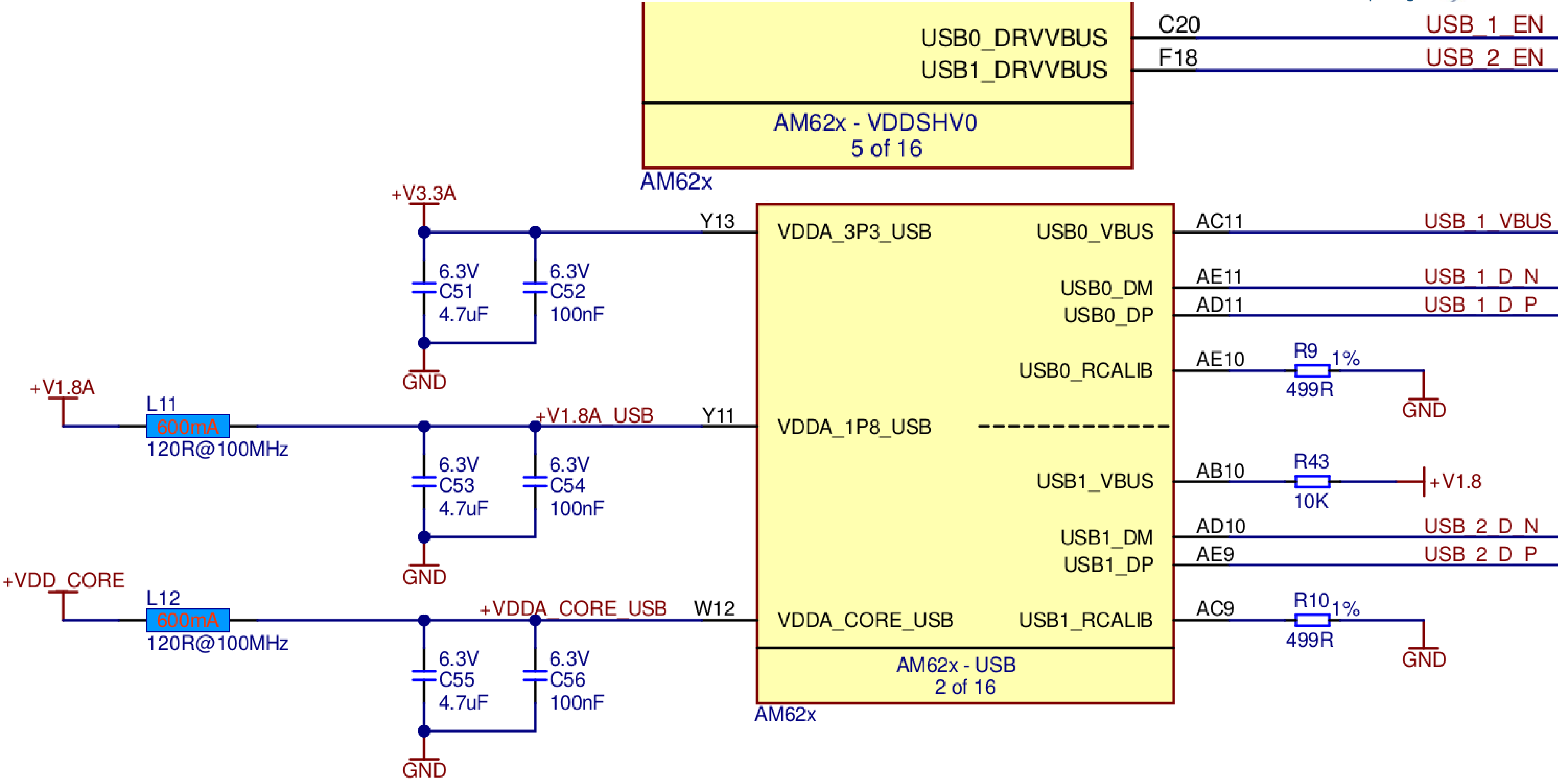


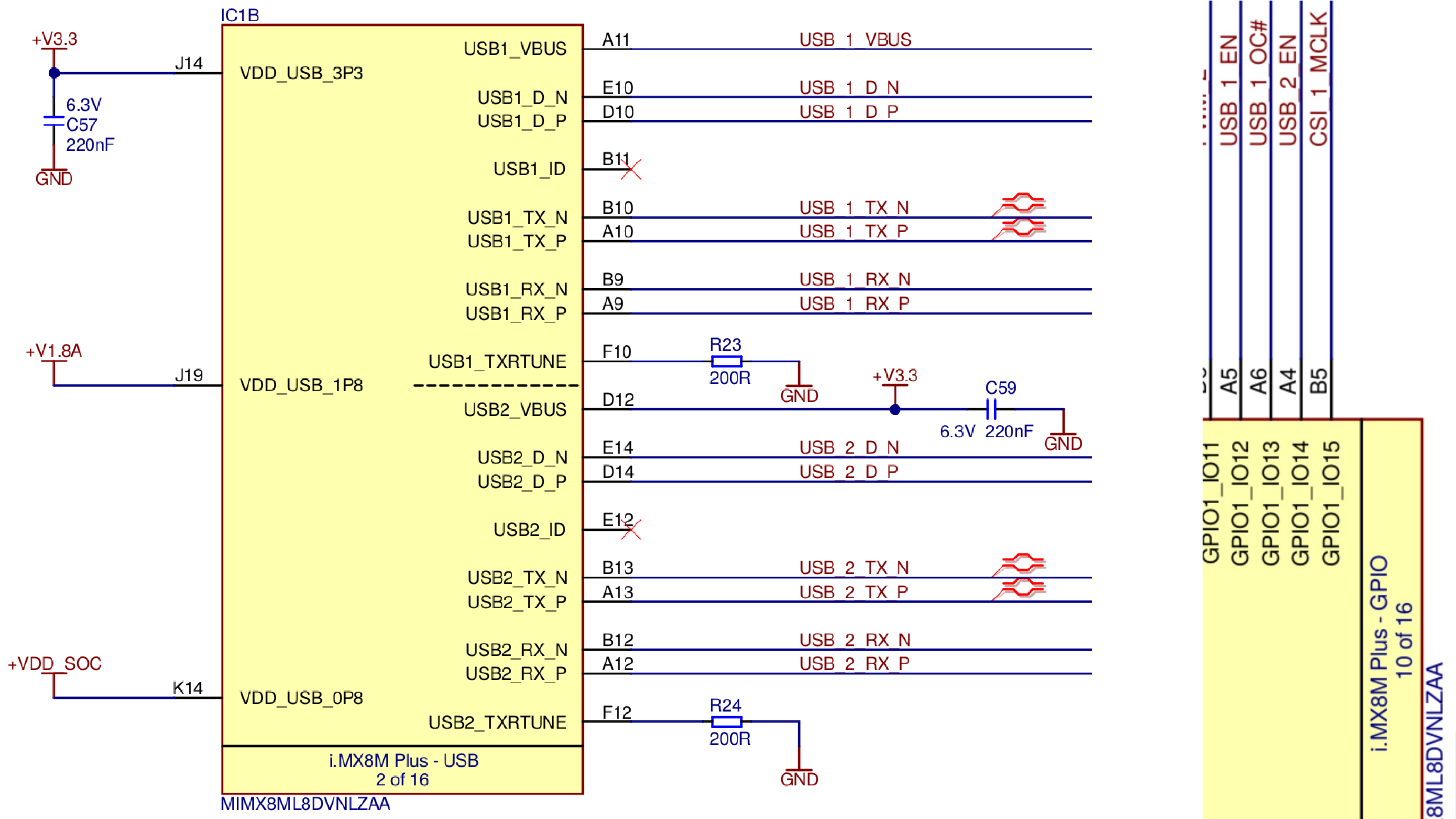
USB in Embedded Systems (cont.)

- External hub and/or PHY chips
- Designed-in chips
  - USB-to-Ethernet bridges
  - USB-to-serial adapters
  - ...
- USB-C
  - Special companion chips taking care of signalling details
  - Either compatible to legacy signalling (e.g. ID and VBUS)
  - Or using out-of-band signalling
    (e.g. I2C or SPI) mandating special driver
  - May further take care of power delivery requirements
  - Blog posts and webinars from Toradex about the topic (see references)



USB in Embedded Systems (cont.)




IC1B
+V3.3
J14
VDD_USB_3P3
6.3V
C57
220nF
GND
USB1_VBUS
A11
USB_1_VBUS
USB1_D_N
E10
USB_1_D_N
USB1_D_P
D10
USB_1_D_P
USB1_ID
B11
USB1_TX_N
B10
USB_1_TX_N
USB1_TX_P
A10
USB_1_TX_P
USB1_RX_N
B9
USB_1_RX_N
USB1_RX_P
A9
USB_1_RX_P
+V1.8A
J19
VDD_USB_1P8
USB1_TXRTUNE
F10
R23
200R
GND
+V3.3
USB2_VBUS
D12
C59
6.3V
220nF
GND
USB2_D_N
E14
USB_2_D_N
USB2_D_P
D14
USB_2_D_P
USB2_ID
E12
USB2_TX_N
B13
USB_2_TX_N
USB2_TX_P
A13
USB_2_TX_P
USB2_RX_N
B12
USB_2_RX_N
USB2_RX_P
A12
USB_2_RX_P
+VDD_SOC
K14
VDD_USB_0P8
USB2_TXRTUNE
F12
R24
200R
GND
i.MX8M Plus - USB
2 of 16
MIMX8ML8DVNLZAA
USB_1_EN
USB_1_OC#
USB_2_EN
CSI_1_MCLK
A5
A6
A4
B5
GPIO1_IO11
GPIO1_IO12
GPIO1_IO13
GPIO1_IO14
GPIO1_IO15
i.MX8M Plus - GPIO
10 of 16
8ML8DVNLZAA

USB Recovery Mode

- Most modern SoCs allow multiple so-called “boot modes”
- Selected by either strapping pins or fusing (done during production)
- Functionality of the Boot ROM aka initial program loader (IPL)
- Once initial “stage” is loaded/executed other mechanisms may be used to load/execute later “stages”
- NXP i.MX 6/7/8 and Vybrid support USB serial download protocol (SDP)
  - Basically former serial aka UART download protocol encapsulated in USB
  - Two implementations thereof exist:
    - imx_loader aka imx_usb
    - mfgtools 3.0 aka universal update utility (uuu)

USB Recovery Mode (cont.)

- TI AM62x Sitara support USB device firmware upgrade (DFU)
  - Official USB device class
  - Relatively low transfer speed for large files
  - Imposed utilization of only EP0 for transfer
  - Host side implementation: dfu-util
- For convenience further configuration/scripting may be required
  - What USB vendor/product ID to act upon
  - What binaries to use for what “stages”
- Toradex easy installer uses those mechanisms to allow loading full fledged Linux/Qt based installer

USB in U-Boot

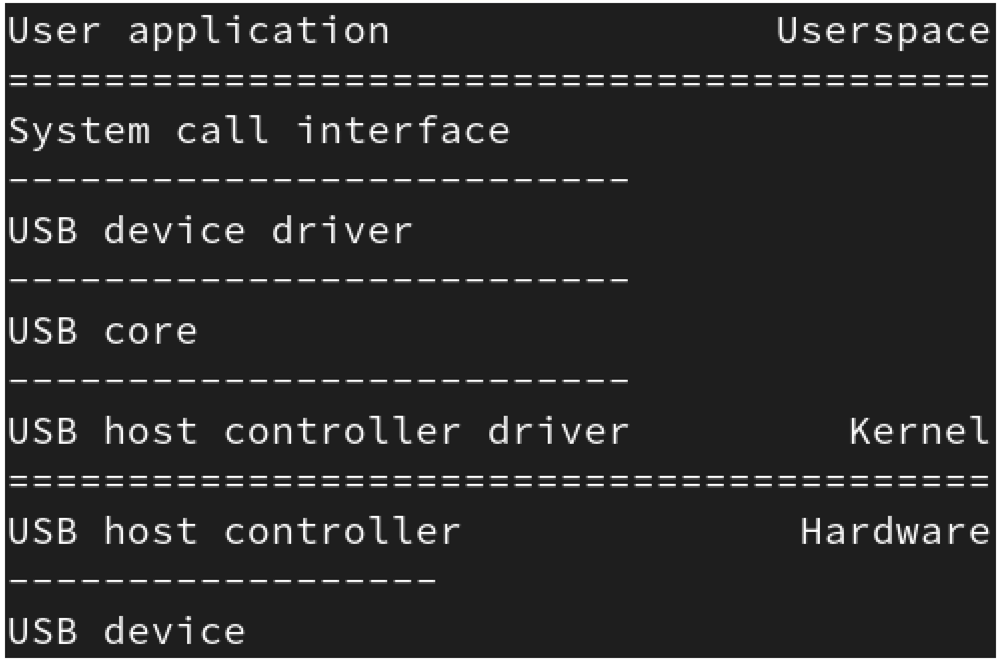
- Device side aka gadget
  - Manually start one functionality at a time: DFU, Fastboot, UMS
  - Device Firmware Upgrade (DFU)
    - CONFIG_DFU and CONFIG_CMD_DFU plus at least one backend like CONFIG_DFU_RAM
    - Environment variable
      dfu_alt_info_ram=tispl.bin ram 0x80080000 0x200000;u-boot.img ram 0x81000000 0x400000;loadaddr ram 0x88200000 0x80000;scriptaddr ram 0x90280000 0x80000;ramdisk_addr_r ram 0x90300000 0x8000000
    - dfu <USB_controller> [<interface> <dev>] [<timeout>]
  - Android Fastboot
    - CONFIG_USB_FUNCTION_FASTBOOT depends on CONFIG_USB_GADGET_DOWNLOAD, CONFIG_USB_GADGET_VENDOR_NUM, CONFIG_USB_GADGET_PRODUCT_NUM and CONFIG_USB_GADGET_MANUFACTURER
    - Requires large memory buffer via CONFIG_FASTBOOT_BUF_ADDR and CONFIG_FASTBOOT_BUF_SIZE
    - Further configuration like partition aliases, raw partition descriptors and variable overrides possible
    - fastboot usb 0

USB in U-Boot (cont.)

- Device side aka gadget (cont.)
  - USB mass storage class (ums): shares a U-Boot block device via USB
    - CONFIG_CMD_USB_MASS_STORAGE depends on CONFIG_USB_USB_GADGET and CONFIG_BLK
    - ums <dev> [<interface>] <devnum[:partnum]>
    - Where <dev> is the USB gadget device number (usually zero unless multiple device controller instances)
    - Further arguments are specific to the block device
- Host side
  - CONFIG_CMD_USB depends on a low-level host controller driver
  - USB is NOT automatically started during start-up due to potential interference with OS e.g. Linux kernel boot
  - Therefore requires manually starting it with “usb start” and stopping with “usb stop”
  - Enumeration is also rather slow due to timeouts
  - “usb tree” shows all USB devices in a tree like display
  - Supports keyboards, storage as well as USB-to-Ethernet adapters (with their resp. configs)

USB in the Linux Kernel

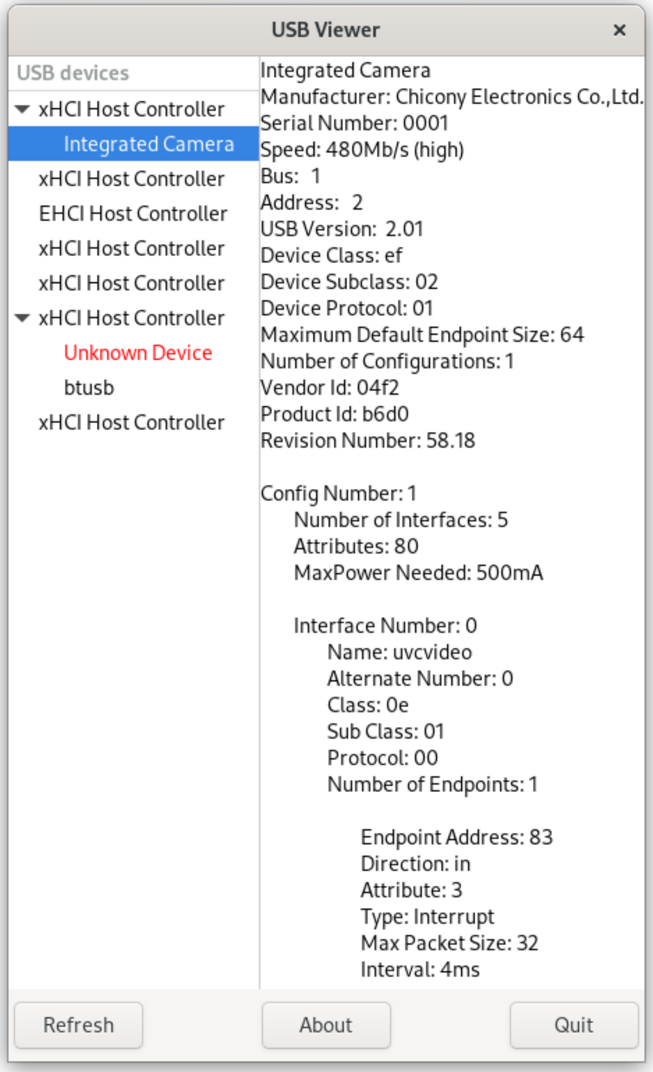
- USB core: Implements the USB bus specification
  - Architecture independent kernel subsystem
- USB host controller drivers
  - Architecture and platform dependent
  - Different driver depending on USB host controller hardware (OHCI/UHCI, EHCI, xHCI et al.)
- USB device drivers
  - Platform independent
  - Drivers for specific peripheral on the USB bus
- USB device controller (UDC) drivers
  - Architecture and platform dependent
  - Different driver depending on USB device controller hardware
- USB gadget drivers
  - Platform independent
  - Different driver depending on peripheral functionality to provide (Ethernet, serial, storage et al.)



```
User application                Userspace
=========================================
System call interface
--------------------------
USB device driver
--------------------------
USB core
--------------------------
USB host controller driver         Kernel
=========================================
USB host controller             Hardware
------------------
USB device
```

USB from Userspace

- /proc/bus/usb/devices
- usbutils: Utilities for inspecting devices connected to a USB bus
  - lsusb: List USB devices, tree like view with -t resp. --tree
  - usb-devices: Print USB device details
  - usbhid-dump: Dump USB HID device report descriptors and streams
- usbview: Display information on USB devices
  - GTK+ 3.x graphical application



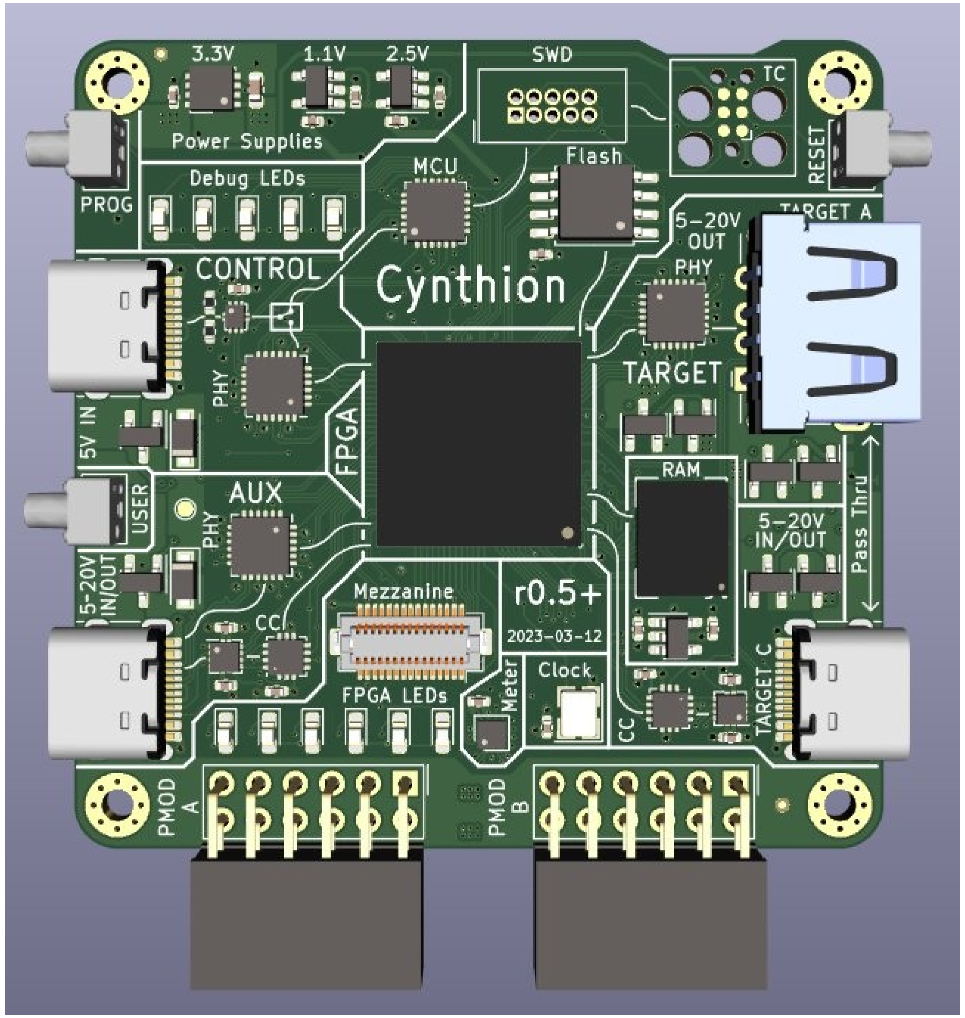
```
Integrated Camera
Manufacturer: Chicony Electronics Co.,Ltd.
Serial Number: 0001
Speed: 480Mb/s (high)
Bus:   1
Address:   2
USB Version:  2.01
Device Class: ef
Device Subclass: 02
Device Protocol: 01
Maximum Default Endpoint Size: 64
Number of Configurations: 1
Vendor Id: 04f2
Product Id: b6d0
Revision Number: 58.18

Config Number: 1
    Number of Interfaces: 5
    Attributes: 80
    MaxPower Needed: 500mA

    Interface Number: 0
        Name: uvcvideo
        Alternate Number: 0
        Class: 0e
        Sub Class: 01
        Protocol: 00
        Number of Endpoints: 1

            Endpoint Address: 83
            Direction: in
            Attribute: 3
            Type: Interrupt
            Max Packet Size: 32
            Interval: 4ms
```

USB from Userspace (cont.)

- libusb: A cross-platform user library to access USB devices
  - C library providing generic access to USB devices
  - Intended to be used by developers to facilitate the production of applications that communicate with USB hardware
  - Portable: Using a single cross-platform API on Android, Linux, macOS, Windows, etc.
  - User-mode: No special privilege or elevation is required for the application to communicate with a device
- uhubctl: USB hub per-port power control
  - Utility to control USB power per-port on smart USB hubs
  - Smart hub defined as one that implements per-port power switching

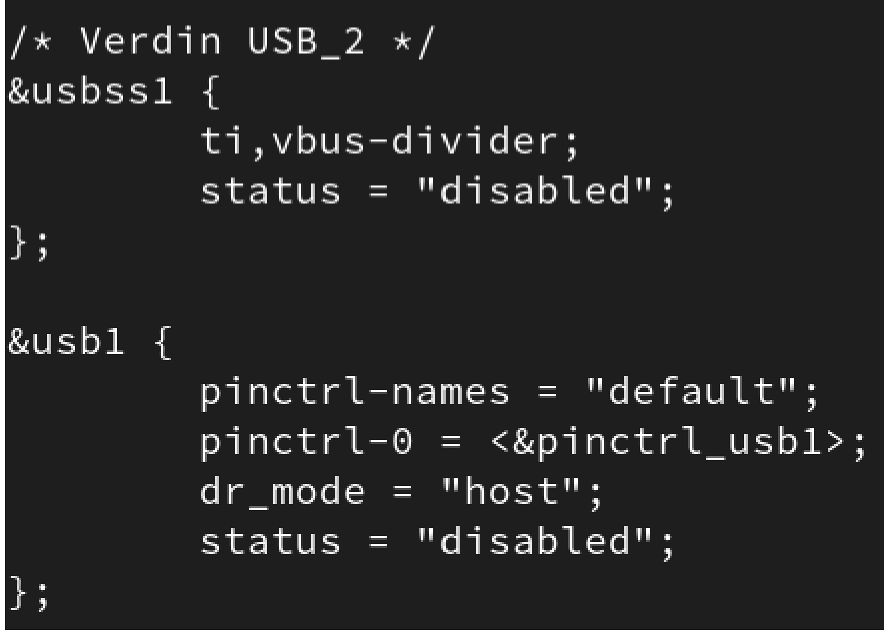
USB Tooling

- FTDI USB-to-serial aka UART adapters
- USB analyzer
  - BEAGLE
  - Cynthion (formerly Luna)
    - A multi-tool for building, analyzing, and hacking USB devices
    - Completely open source hardware and software
- USB CAN analyzer
- USB logic analyzer
  - DreamSourceLab DSLogic
  - Saleae Logic
- USB oscilloscope
  - DreamSourceLab DSCope

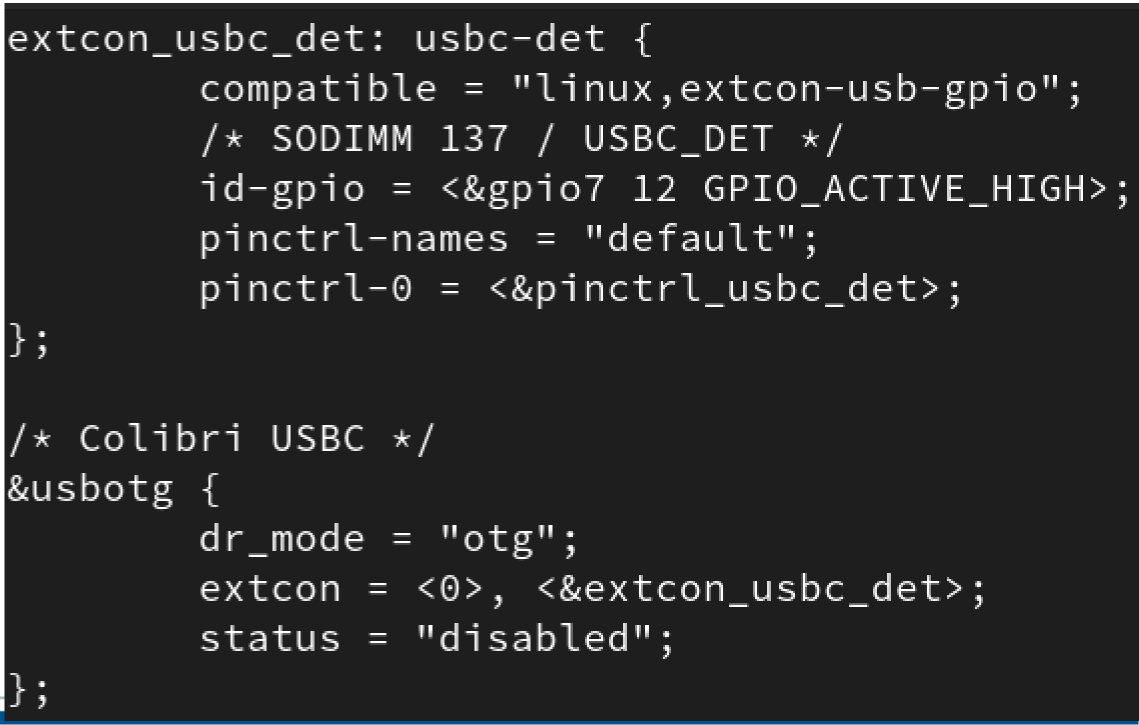


USB Role Switching

- Device/host resp. on-the-go (OTG) or dual role device (DRD) switching
- Fixed in device tree
  - dr_mode property
    - May be host, otg (usually defaults to peripheral) or peripheral
- USB GPIO extcon device driver (e.g. as used on Colibri iMX6/7)
  - Documentation/devicetree/bindings/extcon/extcon-usb-gpio.txt
  - Virtual device used to generate USB cable states from USB ID pin connected to a GPIO pin (obsolete)
  - CONFIG_EXTCON_USB_GPIO
  - drivers/extcon/extcon-usb-gpio.c
  - compatible = "linux,extcon-usb-gpio";
  - id-gpio and/or vbus-gpio
  - Reference it in actual USB node
  - Here zero means no VBUS detection capability, ID pin aka device/host only



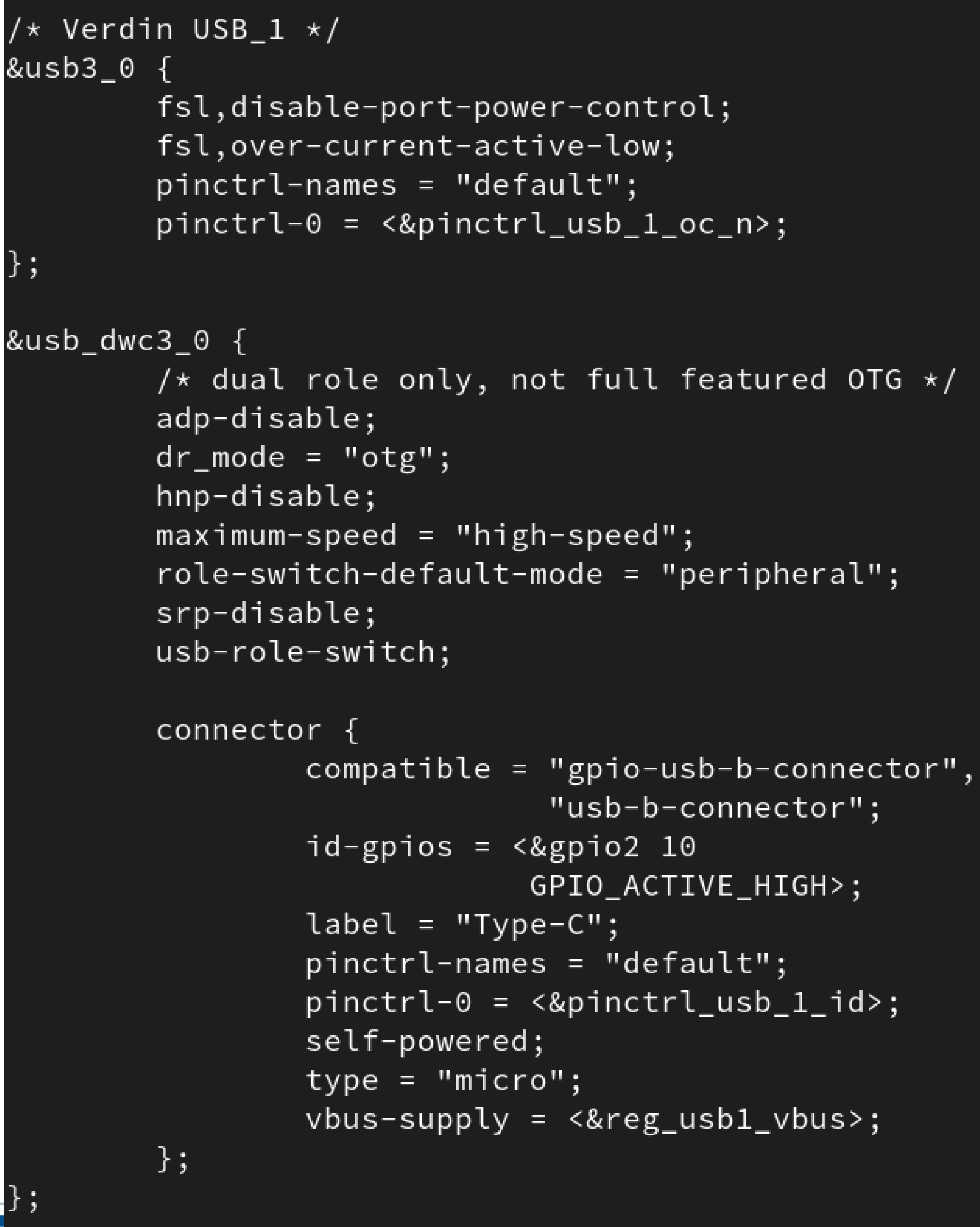
```
/* Verdin USB_2 */
&usbss1 {
        ti,vbus-divider;
        status = "disabled";
};

&usb1 {
        pinctrl-names = "default";
        pinctrl-0 = <&pinctrl_usb1>;
        dr_mode = "host";
        status = "disabled";
};
```



```
extcon_usbc_det: usbc-det {
        compatible = "linux,extcon-usb-gpio";
        /* SODIMM 137 / USBC_DET */
        id-gpio = <&gpio7 12 GPIO_ACTIVE_HIGH>;
        pinctrl-names = "default";
        pinctrl-0 = <&pinctrl_usbc_det>;
};

/* Colibri USBC */
&usbotg {
        dr_mode = "otg";
        extcon = <0>, <&extcon_usbc_det>;
        status = "disabled";
};
```

USB Role Switching (cont.)

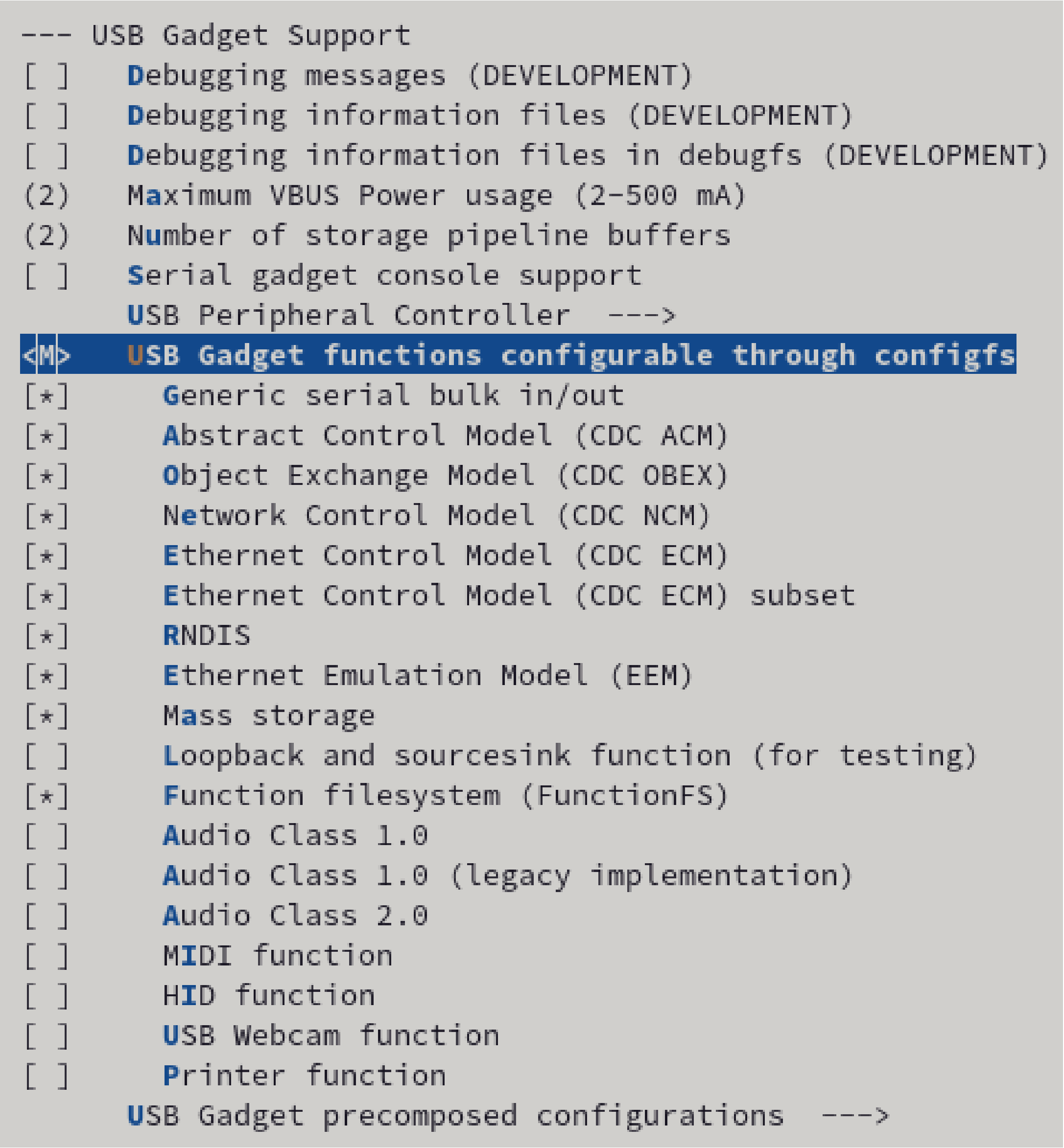
- USB connector subsystem (e.g. as used on Verdin iMX8M Plus)
- Documentation/devicetree/bindings/connector/usb-connector.yaml
- USB GPIO based connection detection driver
  - CONFIG_USB_CONN_GPIO
  - drivers/usb/common/usb-conn-gpio.c
- Simple GPIO VBUS sensing driver for B peripheral devices
  - CONFIG_USB_GPIO_VBUS
  - drivers/usb/phy/phy-gpio-vbus-usb.c
- compatible = "gpio-usb-b-connector", "usb-b-connector";
- label = "Type-C";
- type: mini/micro in case of non-fullsize connector
- self-powered and more optional power related properties
- id-gpio and/or vbus-gpio
- vbus-supply



```
/* Verdin USB_1 */
&usb3_0 {
        fsl,disable-port-power-control;
        fsl,over-current-active-low;
        pinctrl-names = "default";
        pinctrl-0 = <&pinctrl_usb_1_oc_n>;
};

&usb_dwc3_0 {
        /* dual role only, not full featured OTG */
        adp-disable;
        dr_mode = "otg";
        hnp-disable;
        maximum-speed = "high-speed";
        role-switch-default-mode = "peripheral";
        srp-disable;
        usb-role-switch;

        connector {
                compatible = "gpio-usb-b-connector",
                             "usb-b-connector";
                id-gpios = <&gpio2 10
                            GPIO_ACTIVE_HIGH>;
                label = "Type-C";
                pinctrl-names = "default";
                pinctrl-0 = <&pinctrl_usb_1_id>;
                self-powered;
                type = "micro";
                vbus-supply = <&reg_usb1_vbus>;
        };
};
```

USB Device Functionality

- USB gadget functions configurable through configfs



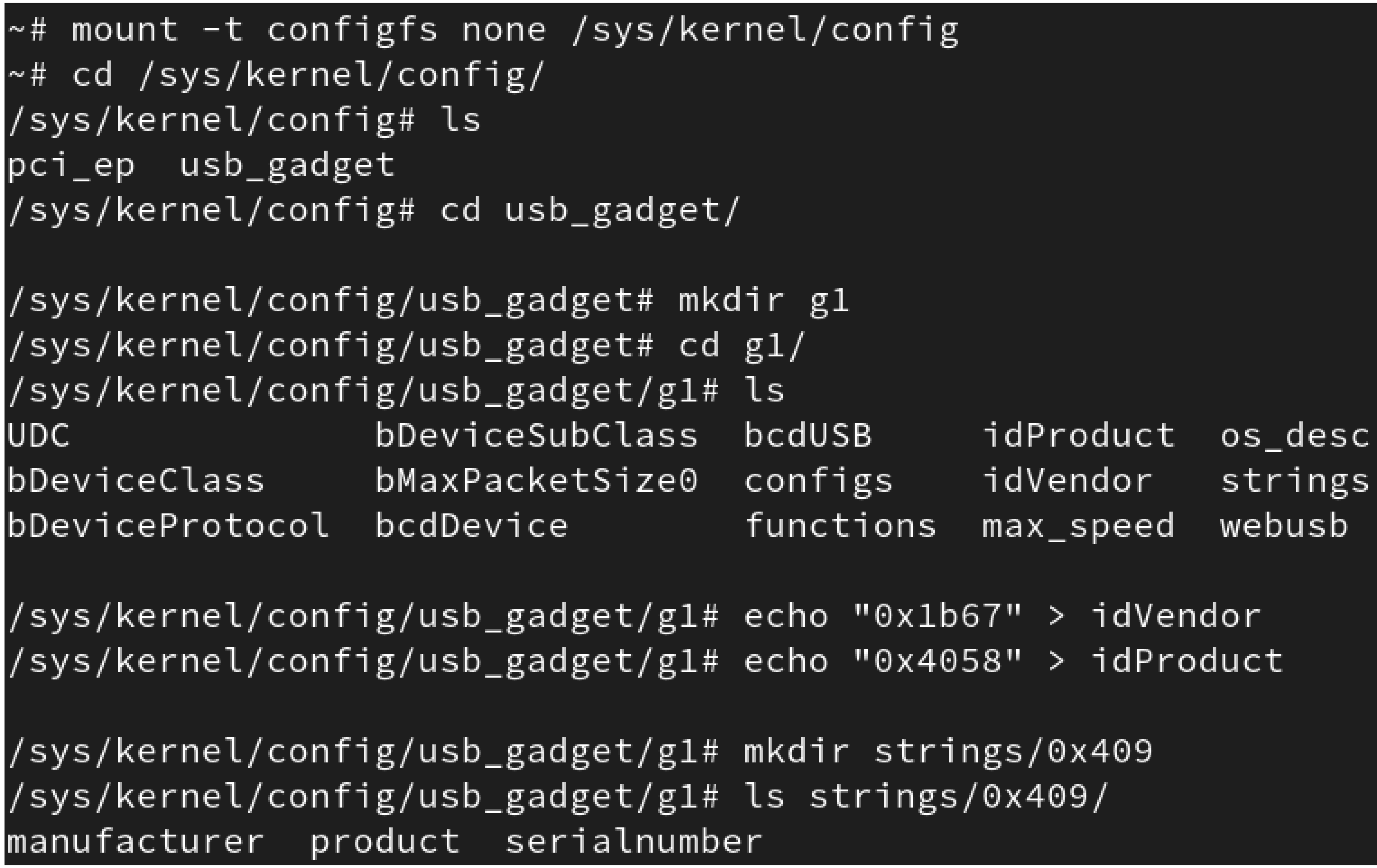
```
--- USB Gadget Support
[ ]   Debugging messages (DEVELOPMENT)
[ ]   Debugging information files (DEVELOPMENT)
[ ]   Debugging information files in debugfs (DEVELOPMENT)
(2)   Maximum VBUS Power usage (2-500 mA)
(2)   Number of storage pipeline buffers
[ ]   Serial gadget console support
      USB Peripheral Controller  --->
<M>   USB Gadget functions configurable through configfs
[*]     Generic serial bulk in/out
[*]     Abstract Control Model (CDC ACM)
[*]     Object Exchange Model (CDC OBEX)
[*]     Network Control Model (CDC NCM)
[*]     Ethernet Control Model (CDC ECM)
[*]     Ethernet Control Model (CDC ECM) subset
[*]     RNDIS
[*]     Ethernet Emulation Model (EEM)
[*]     Mass storage
[ ]     Loopback and sourcesink function (for testing)
[*]     Function filesystem (FunctionFS)
[ ]     Audio Class 1.0
[ ]     Audio Class 1.0 (legacy implementation)
[ ]     Audio Class 2.0
[ ]     MIDI function
[ ]     HID function
[ ]     USB Webcam function
[ ]     Printer function
      USB Gadget precomposed configurations  --->
```

configfs

- Userspace-driven kernel object configuration
- Ram-based filesystem that provides the converse of sysfs's functionality
- Where sysfs is a filesystem-based view of kernel objects, configfs is a filesystem which allows userspace instantiation of kernel objects, or config_items
- Two types of configfs attributes
  - Normal attributes: Small ASCII text files
  - Binary attributes
- USB Gadget ConfigFS: Interface that allows definition of arbitrary functions and configurations to define an application specific USB composite device from userspace
  - Create gadget device and bind to a UDC driver from userspace

configfs (cont.)

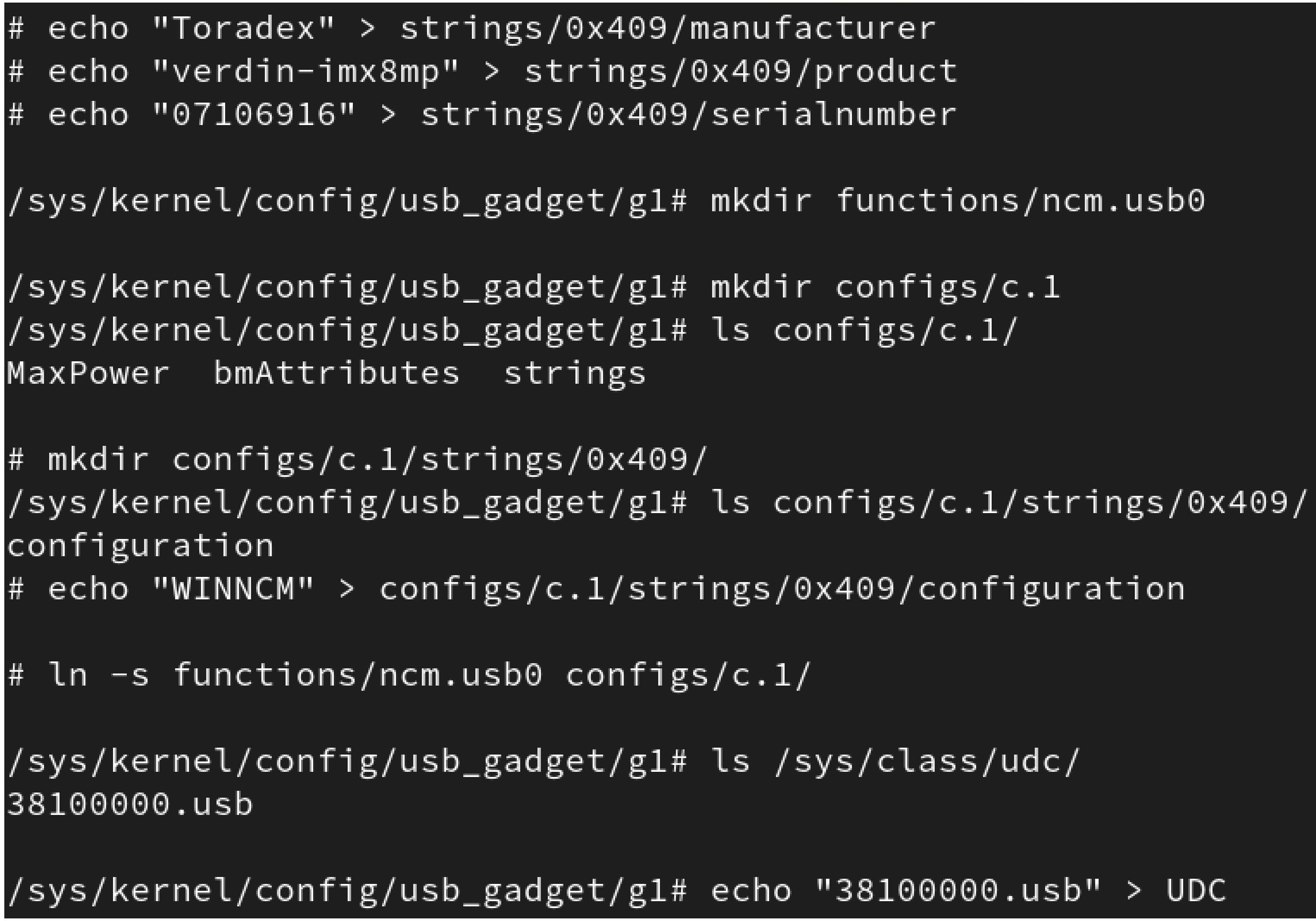
- First needs to be mounted
- If USB gadget configfs support enabled usb_gadget subdirectory present
- By creating the g1 directory instantiated new gadget device filled by template
- Write our vendor/product IDs
- Instantiate English language strings



```
~# mount -t configfs none /sys/kernel/config
~# cd /sys/kernel/config/
/sys/kernel/config# ls
pci_ep  usb_gadget
/sys/kernel/config# cd usb_gadget/

/sys/kernel/config/usb_gadget# mkdir g1
/sys/kernel/config/usb_gadget# cd g1/
/sys/kernel/config/usb_gadget/g1# ls
UDC              bDeviceSubClass  bcdUSB     idProduct  os_desc
bDeviceClass     bMaxPacketSize0  configs    idVendor   strings
bDeviceProtocol  bcdDevice        functions  max_speed  webusb

/sys/kernel/config/usb_gadget/g1# echo "0x1b67" > idVendor
/sys/kernel/config/usb_gadget/g1# echo "0x4058" > idProduct

/sys/kernel/config/usb_gadget/g1# mkdir strings/0x409
/sys/kernel/config/usb_gadget/g1# ls strings/0x409/
manufacturer  product  serialnumber
```

configfs (cont.)

- Write our manufacturer, product and serialnumber descriptor strings
- Create function instances
- Note: Multiple function instances of the same type must have a unique extension
- Create configuration instance
- Create English language strings and write description for this device configuration
- Bind each of our function instances to this configuration
- Check which UDC instances available
- Attach created gadget device to desired UDC



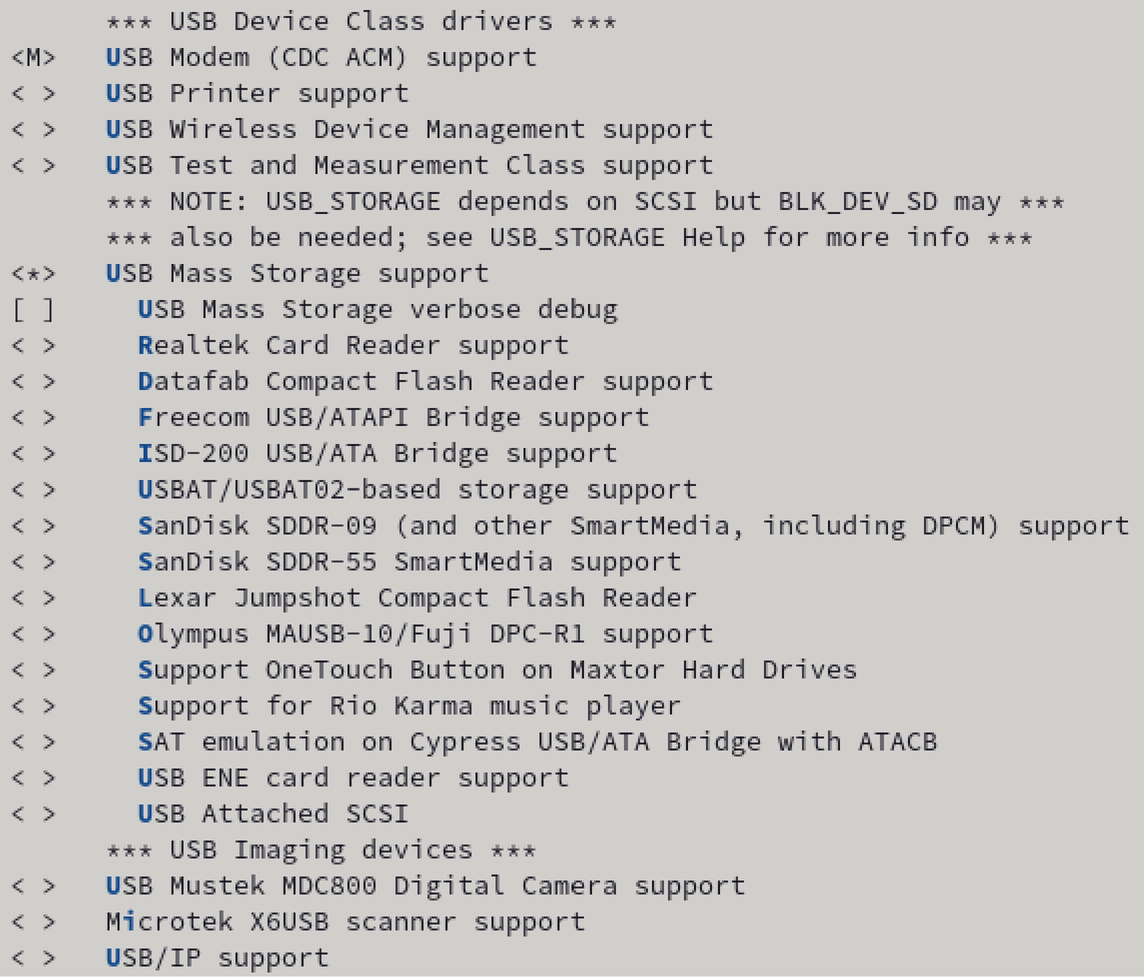
```
# echo "Toradex" > strings/0x409/manufacturer
# echo "verdin-imx8mp" > strings/0x409/product
# echo "07106916" > strings/0x409/serialnumber

/sys/kernel/config/usb_gadget/g1# mkdir functions/ncm.usb0

/sys/kernel/config/usb_gadget/g1# mkdir configs/c.1
/sys/kernel/config/usb_gadget/g1# ls configs/c.1/
MaxPower  bmAttributes  strings

# mkdir configs/c.1/strings/0x409/
/sys/kernel/config/usb_gadget/g1# ls configs/c.1/strings/0x409/
configuration
# echo "WINNCM" > configs/c.1/strings/0x409/configuration

# ln -s functions/ncm.usb0 configs/c.1/

/sys/kernel/config/usb_gadget/g1# ls /sys/class/udc/
38100000.usb

/sys/kernel/config/usb_gadget/g1# echo "38100000.usb" > UDC
```

configfs (cont.)

- libusbgx
- Library providing C API to USB gadget configfs
- Basically programmatic way to go about creation and removal of gadgets

USB Host Functionality

- USB device class drivers

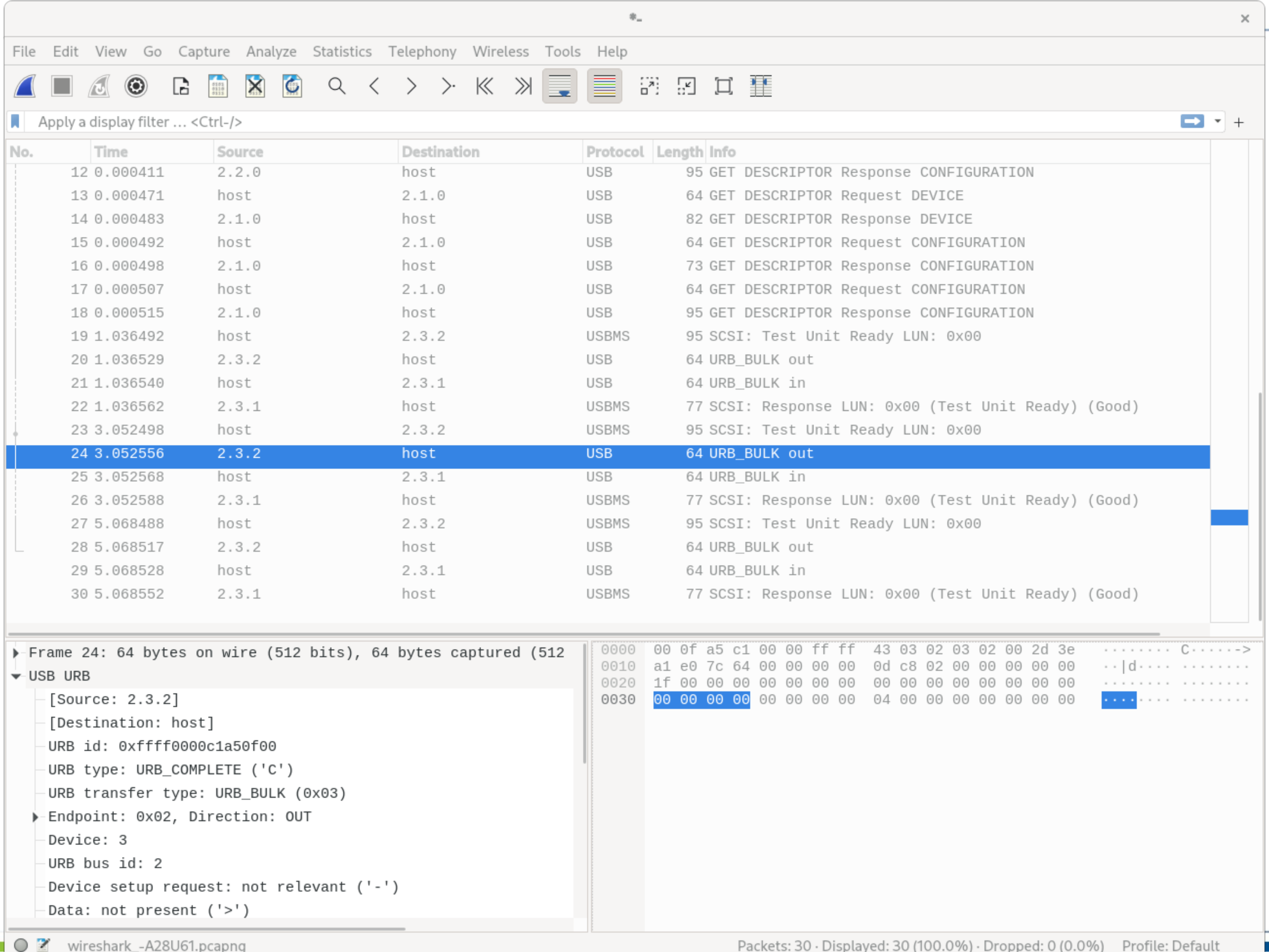


```
      *** USB Device Class drivers ***
<M>   USB Modem (CDC ACM) support
< >   USB Printer support
< >   USB Wireless Device Management support
< >   USB Test and Measurement Class support
      *** NOTE: USB_STORAGE depends on SCSI but BLK_DEV_SD may ***
      *** also be needed; see USB_STORAGE Help for more info ***
<*>   USB Mass Storage support
[ ]     USB Mass Storage verbose debug
< >     Realtek Card Reader support
< >     Datafab Compact Flash Reader support
< >     Freecom USB/ATAPI Bridge support
< >     ISD-200 USB/ATA Bridge support
< >     USBAT/USBAT02-based storage support
< >     SanDisk SDDR-09 (and other SmartMedia, including DPCM) support
< >     SanDisk SDDR-55 SmartMedia support
< >     Lexar Jumpshot Compact Flash Reader
< >     Olympus MAUSB-10/Fuji DPC-R1 support
< >     Support OneTouch Button on Maxtor Hard Drives
< >     Support for Rio Karma music player
< >     SAT emulation on Cypress USB/ATA Bridge with ATACB
< >     USB ENE card reader support
< >     USB Attached SCSI
      *** USB Imaging devices ***
< >   USB Mustek MDC800 Digital Camera support
< >   Microtek X6USB scanner support
< >   USB/IP support
```

Debugging USB

- usbmon
  - Linux kernel facility used to collect traces of I/O on the USB bus
  - May be compiled as built-in or Linux kernel module requiring separate loading
  - Analogous to packet socket used by network monitoring tools such as tcpdump
  - As a matter of fact tcpdump comes with support for usbmon: tcpdump --list-interfaces
- Virtual USB Analyzer
  - Tool for visualizing logs of USB packets from hardware or software USB sniffer tools
  - Developed at VMware
  - Python 2.7 PyGTK based
  - Probably abandoned rather obsolete project
- Wireshark
  - Has built-in USB analysis functionality
  - But how to do that on an Embedded device?
  - ssh <target> “tcpcump -i usbmon2 -U -w -” | flatpak run --filesystem=host --file-forwarding=host --share=network org.wireshark.Wireshark -k -i -

Debugging USB (cont.)



```
No.  Time      Source  Destination Protocol Length Info
  12 0.000411  2.2.0   host        USB       95 GET DESCRIPTOR Response CONFIGURATION
  13 0.000471  host    2.1.0       USB       64 GET DESCRIPTOR Request DEVICE
  14 0.000483  2.1.0   host        USB       82 GET DESCRIPTOR Response DEVICE
  15 0.000492  host    2.1.0       USB       64 GET DESCRIPTOR Request CONFIGURATION
  16 0.000498  2.1.0   host        USB       73 GET DESCRIPTOR Response CONFIGURATION
  17 0.000507  host    2.1.0       USB       64 GET DESCRIPTOR Request CONFIGURATION
  18 0.000515  2.1.0   host        USB       95 GET DESCRIPTOR Response CONFIGURATION
  19 1.036492  host    2.3.2       USBMS     95 SCSI: Test Unit Ready LUN: 0x00
  20 1.036529  2.3.2   host        USB       64 URB_BULK out
  21 1.036540  host    2.3.1       USB       64 URB_BULK in
  22 1.036562  2.3.1   host        USBMS     77 SCSI: Response LUN: 0x00 (Test Unit Ready) (Good)
  23 3.052498  host    2.3.2       USBMS     95 SCSI: Test Unit Ready LUN: 0x00
  24 3.052556  2.3.2   host        USB       64 URB_BULK out
  25 3.052568  host    2.3.1       USB       64 URB_BULK in
  26 3.052588  2.3.1   host        USBMS     77 SCSI: Response LUN: 0x00 (Test Unit Ready) (Good)
  27 5.068488  host    2.3.2       USBMS     95 SCSI: Test Unit Ready LUN: 0x00
  28 5.068517  2.3.2   host        USB       64 URB_BULK out
  29 5.068528  host    2.3.1       USB       64 URB_BULK in
  30 5.068552  2.3.1   host        USBMS     77 SCSI: Response LUN: 0x00 (Test Unit Ready) (Good)
```

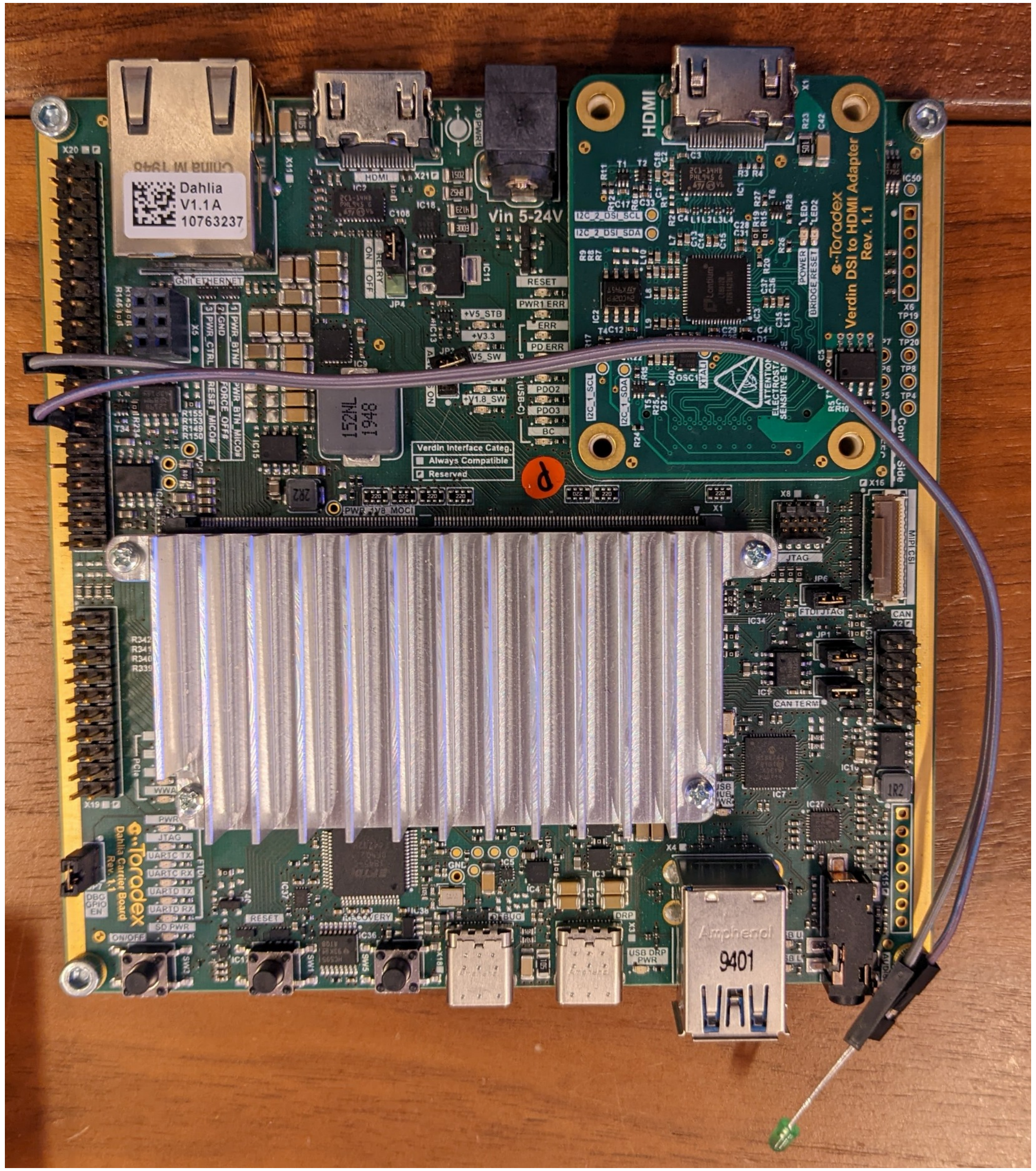
```
▸ Frame 24: 64 bytes on wire (512 bits), 64 bytes captured (512
▾ USB URB
    [Source: 2.3.2]
    [Destination: host]
    URB id: 0xffff0000c1a50f00
    URB type: URB_COMPLETE ('C')
    URB transfer type: URB_BULK (0x03)
  ▸ Endpoint: 0x02, Direction: OUT
    Device: 3
    URB bus id: 2
    Device setup request: not relevant ('-')
    Data: not present ('>')
```

```
0000  00 0f a5 c1 00 00 ff ff  43 03 02 03 02 00 2d 3e   ········ C·····->
0010  a1 e0 7c 64 00 00 00 00  0d c8 02 00 00 00 00 00   ··|d···· ········
0020  1f 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00   ········ ········
0030  00 00 00 00 00 00 00 00  04 00 00 00 00 00 00 00   ········ ········
```

wireshark_-A28U61.pcapng   Packets: 30 · Displayed: 30 (100.0%) · Dropped: 0 (0.0%)   Profile: Default

Live Demonstration

- Nothing fancy, just a regular Toradex board in the wild running upstream Linux (;-p)



Q&A

References

- USB Specification
  https://www.usb.org/documents
- USB-C
  https://www.toradex.com/blog/add-usb-c-to-your-next-carrier-board-design-1
  https://www.toradex.com/blog/add-usb-c-to-your-next-carrier-board-design-2
  https://www.toradex.com/webinars/add-usb-c-to-your-next-carrier-board-design
- imx_loader
  https://github.com/boundarydevices/imx_usb_loader
- uuu
  https://github.com/nxp-imx/mfgtools
- dfu-util
  https://dfu-util.sourceforge.net
- Toradex Easy Installer
  https://www.toradex.com/tools-libraries/toradex-easy-installer
- usbview
  http://www.kroah.com/linux-usb

References (cont.)

- libusb
  https://libusb.info
- uhubctl
  https://github.com/mvp/uhubctl
- Virtual USB Analyzer
  https://vusb-analyzer.sourceforge.net
- Wireshark
  https://wiki.wireshark.org/CaptureSetup/USB
- usbmon
  https://docs.kernel.org/usb/usbmon.html

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