USB Type-C demystified

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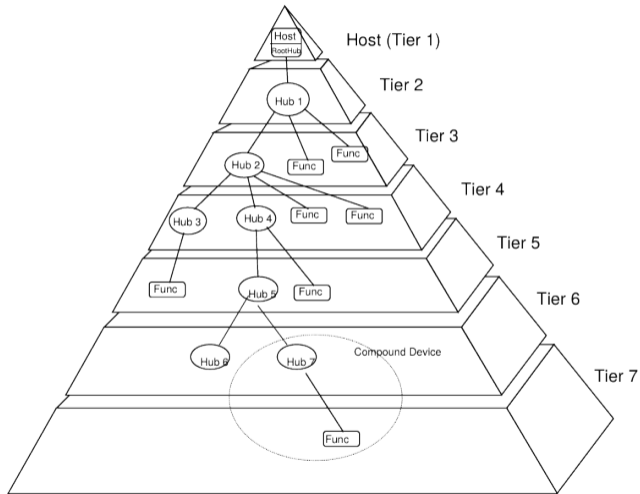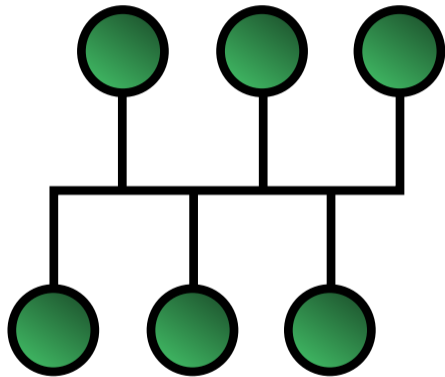# Universal Serial **Bus**? Not really.

Figure 4-1. Bus Topology

USB topology

- tiered star
- just one *host*
- up to 127 *devices*
    - *hubs* connecting other *devices*
    - *functions*, the actual peripherals
    - *compound devices* combining a *hub* and *functions*
- at most 4 *hubs* cascaded
- half-duplex transmission controlled by the *host*

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The speeds of USB 2.0

- Low-speed - 1,5 Mbps
  - simple cable
  - only *captive* cables allowed
- Full-speed - 12 Mbps
- High-speed - 480 Mbps (USB 2.0)

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USB 3.x

- new speed: SuperSpeed – 5 Gbps (USB 3.0, 3.1 Gen 1)
- two *extra* pairs for duplex transfer
- backwards interopable sockets and **A-type** plugs
- coexists with USB 2.0, which is **unchanged**
  - uses former half-duplex pair D-, D+
  - total capacity for High- a Full-Speed devices is still 480 Mbps
- USB 3.1 Gen 2 introduced SuperSpeed+ (10 Gbps)
- USB 3.2 Gen $n{\times}k$ uses k lanes $k = \{1, 2\}$

Connectors
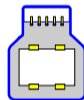

USB 1.1 – 2.0

A B

Mini-A Mini-B

Micro-A Micro-B

USB 3.0

A

B

Micro-B

Author: Milos.bmx, Wikimedia Commons CC-BY-SA

Avoiding problematic connections

- oriented cables A -> B
- very different connectors

Forbidden (passive) cable assemblies

- USB extension cords
  - can overcome the cable lenhth limit
- same connector on both sides of the cable
  - can be dangerous for two hosts connected together

USB Type-C connector

- new universal connector for *hosts* and *devices*
- four SuperSpeed pairs
- one USB 2.0 pair
- VBUS current up to 5 Amps
- Configuration Channel for cable attachment and polarity detection
- supports non-USB alternate modes
- elektronically marked cables

Type-C contacts

High Speed Data Path (TX for USB, or for DP Alt Mode)
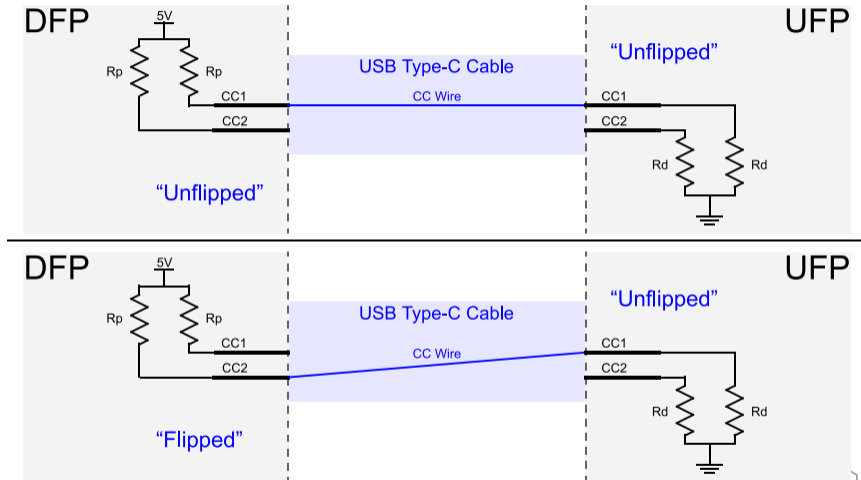
USB 2.0 Interface

High Speed Data Path (RX for USB, or TX for DP Alt Mode)

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

Cable Ground

Cable Bus Power

For Sideband Use (not used for USB)

Plug Configuration Detection
- One becomes V_{CONN}, for cable or adaptor power
- CC is used for USB-PD communication

Source: Benson Leung

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Cable orientation detection

Source: Microchip AN 1953

Type-C powering

- no voltage in the socket before a *device* is connected
- three power levels according to Rp:
  - USB default (5 V, 500/900 mA)
  - 5 V, 1 500 mA
  - 5 V, 3 000 mA
- more options with USB Power Delivery 2.0+

USB Power Delivery

- using Biphase Mark Code over configuration channel
- up to 20 V, 5 A = 100 W
- can change current direction (ie. device to host)
- can switch non-USB alternate modes

Type-C cables and adaptors
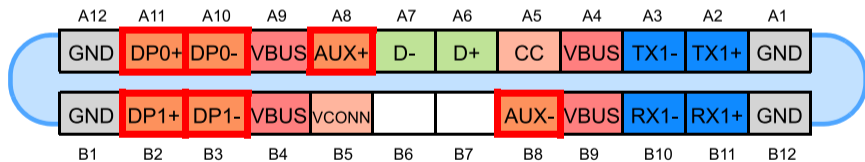
Basic Type-C cable types

- High-speed, 3A (most common, no marker chip)
- High-speed, 5A (charging cable)
- SuperSpeed, 3A (3 subtypes according to USB revision)
- SuperSpeed, 5A (3 subtypes according to USB revision)

Forbidden with Type-C

- proprietary charging protocols that change VBUS to more than 5 Volts
- passive adaptors with Type-C sockets

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DisplayPort Alternate Mode

- the most common display attachment alternate mode
- uses SuperSpeed pairs for DisplayPort
- **coexists with USB and PD** in one cable
- SuperSpeed USB will not fit with 4K DisplayPort

A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
GND	DP0+	DP0-	VBUS	AUX+	D-	D+	CC	VBUS	TX1-	TX1+	GND

GND	DP1+	DP1-	VBUS	VCONN			AUX-	VBUS	RX1-	RX1+	GND
B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12

Source: Microchip AN 1953

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Thunderbolt 3

- proprietary interface with up to 40 Gbps speed
- uses USB Type-C connectors
- keeps using USB *Power Delivery*
- allows **link capacity sharing** by multiple devices
- can connect multiple displays, USB devices or PCIe cards
- **authentication and authorization** of devices
- all TB3 hosts support SuperSpeed USB with DP-alt mode
- TB3 peripherals cannot work with USB at all
- the standard **has been opened** and became **USB4** in 2019
    - requires using Type-C connectors
    - defines only tunnelling of USB 3.2, PCIe and DP
    - legacy USB devices are supported via tunneled USB 3.2

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Further reading

- Benson Leung on Medium.com and people.kernel.org
- Microchip AN 1953

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Thank you!

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The slides are already published on my website.