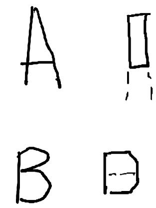
USB, Another synchronous LAN

USB cables matrix

One connector (not two side-by-side)

Plugs, each end	Type A	Mini-A	Micro-A	Type B	Mini-B	Micro-B	USB 3.0 micro-B	Type-C
Type A	Non-standard	Non-standard	Non-standard	Yes	Yes	Yes	Yes	Yes
Mini-A	Non-standard	No	No	Deprecated	Deprecated	Non-standard	No	No
Micro-A	Non-standard	No	No	Non-standard	Non-standard	Yes	No	No
Type B	Yes	Deprecated	Non-standard	No	No	No	No	Yes
Mini-B	Yes	Deprecated	Non-standard	No	Non-standard	No	No	Yes
Micro-B	Yes	Non-standard	Yes	No	No	No	No	Yes
3.0 micro-B	Yes	No	No	No	No	No	No	Yes
Type-C	Yes	No	No	Yes	Yes	Yes	Yes	Yes



"No" means you cannot find cables with this pairing of connectors on them.

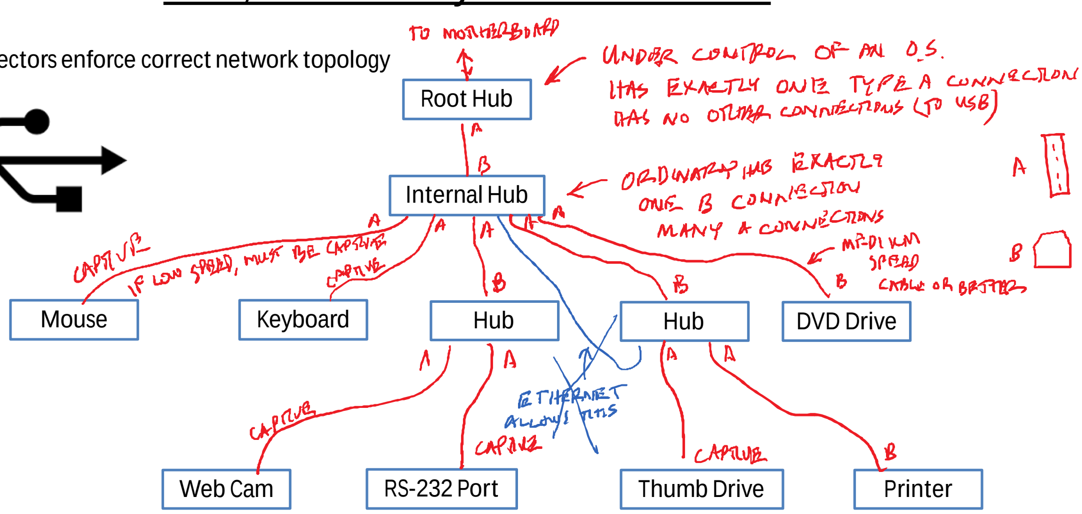
"Non-standard" means you can find them, but there is no assurance they will work.

This table is incomplete.

1

USB, Another synchronous LAN

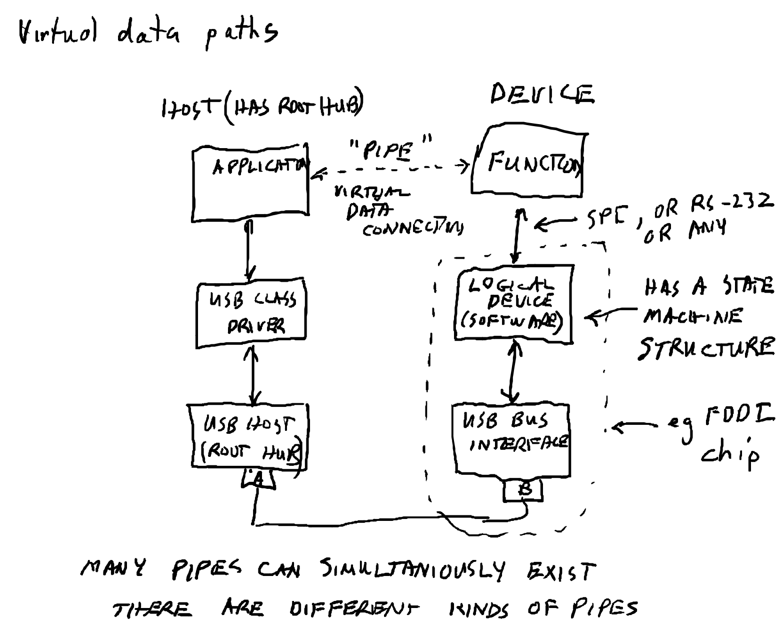
A-B connectors enforce correct network topology



Type C connectors are "active" meaning they have a chip in the handle of the plug.
The chip decides if the end is plugged into a device (takes role of type B) or a hub (takes role of type A).

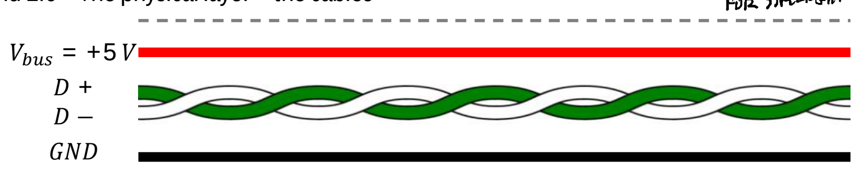
2

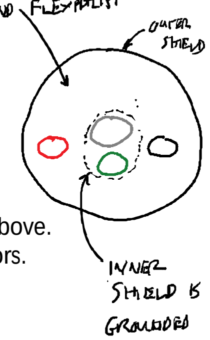
USB, Another synchronous LAN



3

USB 1.0 and 2.0—The physical layer—the cables





Each end of the cable has four conductors, color coded red, black, green, and white, as shown above.
A shield is required for all but low-speed mode, connected to the metallic shells of the connectors.
There is also an inner shield around the data wires only, connected to GND.
For the twisted pair, $Z_o = 90\ \Omega$, used for data. They use a type of differential signaling.
Connectors have 4 pins if full sized, but for mini and micro, they have 5 pins. Two pins are GND.
On the A end the two ground pins are connected together in the cable and to GND and inner shield.
On the B end one ground pin is connected to the GND wire and the other is open.
(The inner shield cannot be used as a conductor. The hub can detect a connection.)

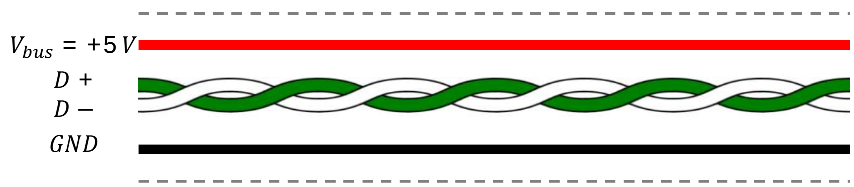
D+ carries true data, and at the same time D- carries false data (usually), half duplex
In a few cases D+ and D- carry separate signals—for packet boundary delimitation.
Data is logic-0 = 0 V, logic-1 = 5 V on D+
Data is logic-0 = 5 V, logic-1 = 0 V on D-
There is a common-mode signal of 2.5 V (The average of D+ and D- always equals 2.5 V.)
The receiver must use a differential amplifier with > 300 Ω input impedance to recover the signal.
The sender must drive the D+, D- pair with a 90 Ω differential driver with a 2.5 V common-mode signal.

SHIELDING & TWISTING AND IMPEDANCE ARE NOT REQ'D FOR 1.0 BUT THE CABLE MUST THEN BE CAPTIVE

Twisted pair illustration from http://www.cypress.com/file/134171/download

4

USB—The physical layer—the cables

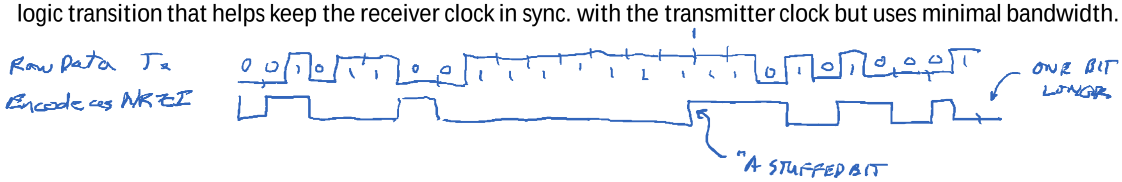


Clock is embedded in the data using NRZI plus bit stuffing after 7 logic-1 bits.

To send logic-0, change the data signals at the leading edge of the bit-time boundary.

To send logic-1, do not change the data signals at the leading edge of the bit-time boundary.

If there are ever seven logic-1 bits in a row, insert a logic-0 bit at the transmitter. The receiver will know to automatically strip this bit out since it will also get the seven logic-1 bits that preceded it. The stuffed bit causes a logic transition that helps keep the receiver clock in sync. with the transmitter clock but uses minimal bandwidth.



R-Pi uses USB as a main interface to the CPU. Example: Ethernet and Wi-Fi are just USB devices.

Twisted pair illustration from http://www.cypress.com/file/134171/download

5

USB—Device and Speed Detection

Pull-down resistors at the host or hub port cause D+ and D– to both default to logic-zero w.r.t. ground.
As long as both D+ and D– remain at ground, the port is considered open (nothing connected)
Device detection and Speed detection is done by pull-up resistors on data lines creating various non-zero voltages.

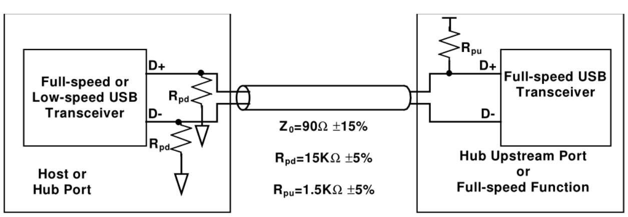


Figure 7-20. Full-speed Device Cable and Resistor Connections

All devices are initially detected as either full-speed or low-speed devices. A communication protocol in this initial mode subsequently elevates the speed to high speed or super-speed, if applicable.

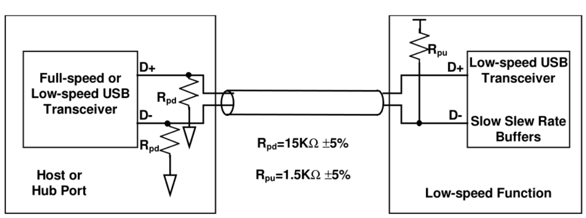


Figure 7-21. Low-speed Device Cable and Resistor Connections

Illustration from USB Specifications version 2.0, Section 7.1.5.1

6

USB—Power over USB

When a device is first detected +5 V power is applied with a current limit of 100 mA.
This is for safety. If a shorted cable or otherwise defective device is connected, at most 0.5 W is available.
Upon device detection the device may negotiate with the host for additional current and/or voltage.
- up to 0.5 A always at 5 V for USB 2.0 or 2.5 W
- up to 0.9 A always at 5 V for USB 3.0 or 4.5 W
- up to 3.0 A always at 5 V for USB 3.1 or 15 W
- up to 5.0 A at up to 20 V for USB 3.2, a.k.a. USB type-C, 100 W

7

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Charging via USB connectors

In 2006, the Chinese government dictum to apply to all smartphones after June 2007
Must be capable of being charged from a USB port
Motive: Reduce waste caused by discarding perfectly functional chargers along with obsolete/broken phones.
Many loopholes in this order, but it was significantly the first such order and was generally successful.
In 2009 the European Union passed their own dictum.
With USB-C now available there are efforts to standardize the charging of laptop computers to USB-C
Possibly smartphone charging will also move entirely over to USB-C
Most wall-warts that offer a USB connector DO NOT abide by the USB standards for negotiating current and voltage!
With USB 1.0 through 3.1 failure to comply to standard just prolongs the charge time.
With USB 3.2 or USB type-C the voltage issues are more complicated and my lead to future incompatibilities.

8

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There have been various computers built with connectors that accept USB but also feature proprietary extensions to the std.
There have been many USB cables and “extension cords” made that do not comply to the USB standard.

9

SUMMARY SLIDE

USB—Power over USB

When a device is first detected +5 V power is applied with a current limit of 100 mA.
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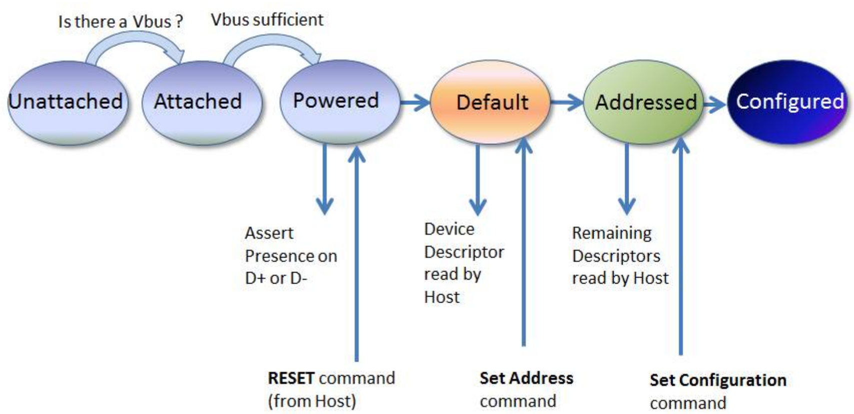
10

USB—Device Enumeration

When a device is first detected a process called enumeration begins to configure the device and give in an address.
Because USB is host controlled, when it is initially connected it is addressed by it's port on the USB hub.
The port addressing method is enough to fetch the device type, link it with an appropriate class driver, and. . .
provide address for all addressable registers in the device.



https://microchipdeveloper.com/usb:enumeration

11

USB—Device Class

Unlike Ethernet and many other interfaces, USB defines device class drivers.
Advantage: Plug it in and it works (sort of, usually).
Disadvantage: Hard for manufacturers to distinguish their products. (A mouse is a mouse is a mouse.)
Result: Custom class drivers can be installed to awaken new features in proprietary devices.
The table here shows pre-defined drivers
All USB devices must connect to one of these.

Example: HID is a mouse or keyboard or similar.

A "device class" is a driver that applies to the entire physical object. This object may have more than one purpose. Thus a "device" can subsequently connect itself to more than one "interface class" driver.

Example: printer/scanner
Base class 00h, interface classes 06h, 07h

Example: dDB's Wacom Bamboo tablet
Base class 00h, interface classes 03h, FFh
(Demo of Windows "Device Manager.")

Base Class Table

Base Class	Descriptor Usage	Description
00h	Device	Use class information in the Interface Descriptors
01h	Interface	Audio
02h	Both	Communications and CDC Control
03h	Interface	Human Interface Device (HID)
05h	Interface	Physical
06h	Interface	Image
07h	Interface	Printer
08h	Interface	Mass Storage (MSD)
09h	Device	8Hub
0Ah	Interface	CDC-Data
0Bh	Interface	Smart Card
0Dh	Interface	Content Security
0Eh	Interface	Video
0Fh	Interface	Personal Healthcare
10h	Interface	Audio/Video Devices
11h	Device	Billboard Device Class
DCh	Both	Diagnostic Device
0Eh	Interface	Wireless Controller
EFh	Both	Miscellaneous
FEh	Interface	Application Specific
FFh	Both	Vendor Specific

https://microchipdeveloper.com/usb:device-classes

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