

USB探秘

张宇翔



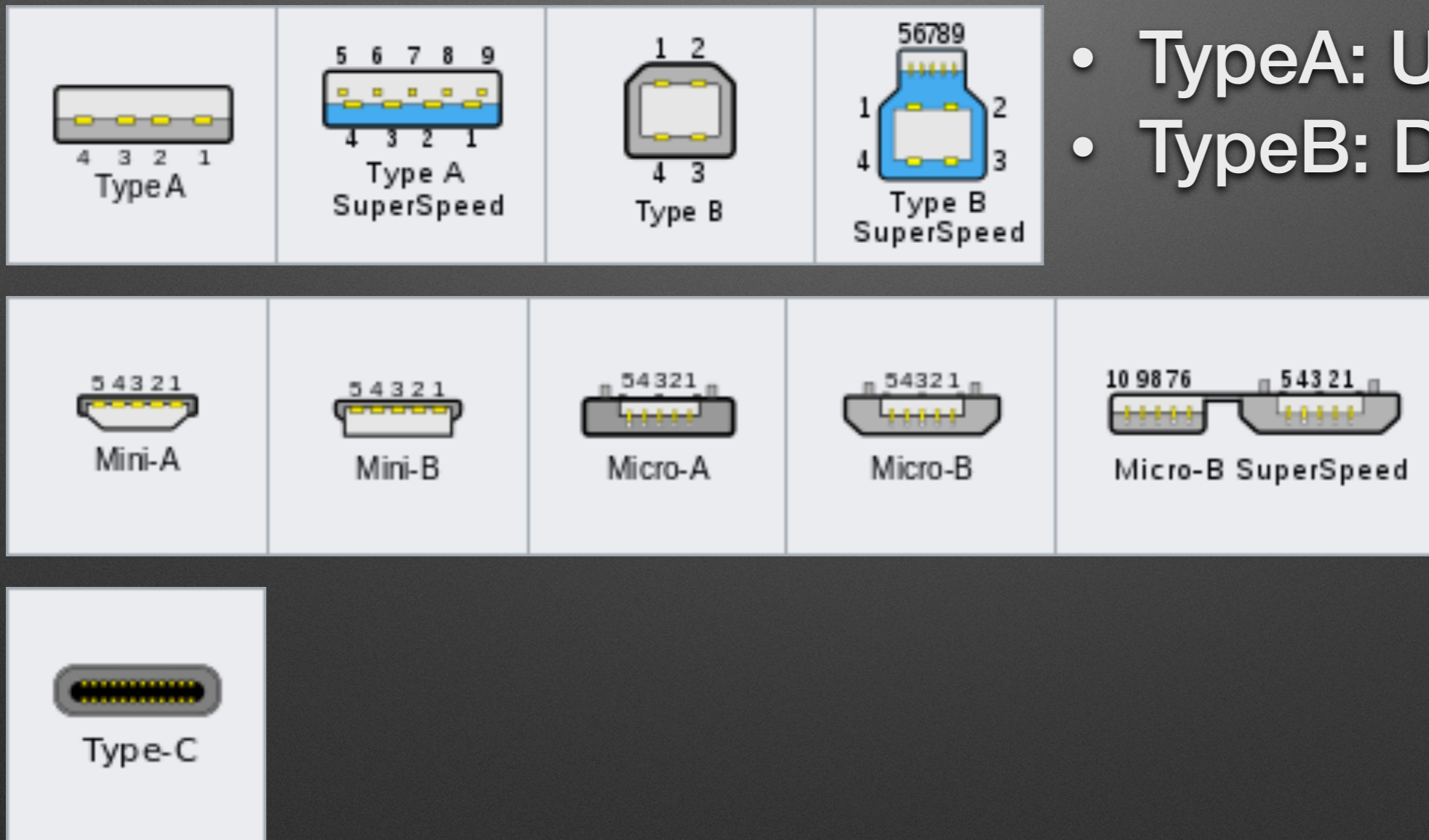
History

USB 1.0	January 1996	Low Speed (1.5 Mbit/s)
USB 1.1	August 1998	Full Speed (12 Mbit/s)
USB 2.0	April 2000	High Speed (480 Mbit/s)
USB 3.0 (3.1 Gen1)	November 2008	SuperSpeed (5 Gbit/s)
USB 3.1 (3.1 Gen2)	July 2013	SuperSpeed+ (10 Gbit/s)

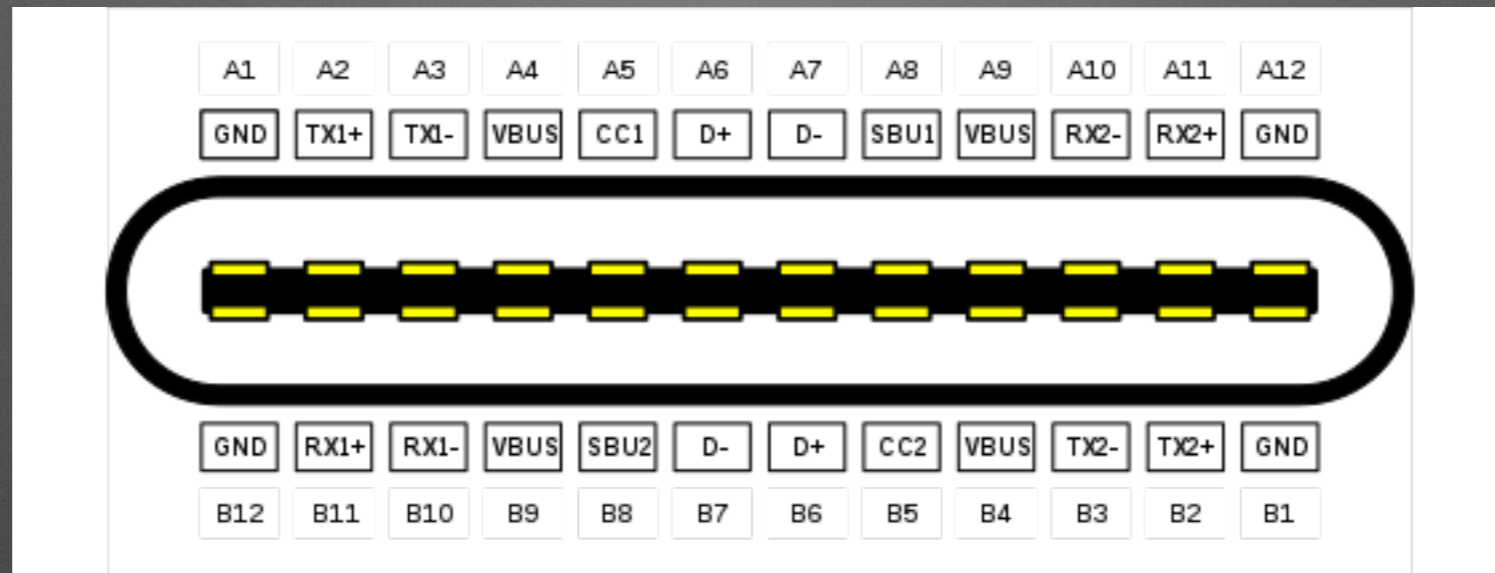


USB Plug

- Type A: Upstream
- Type B: Downstream

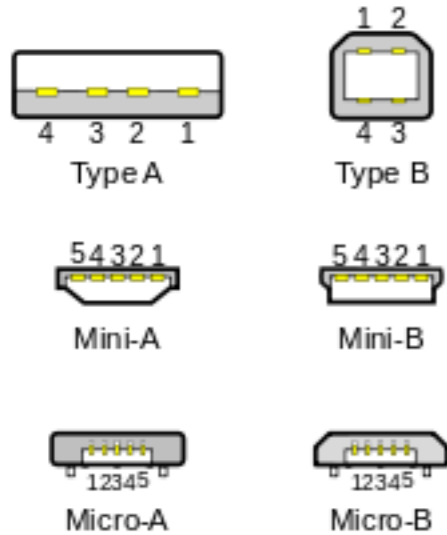


USB Type-C



- Alternate Mode (active cable required)
 - Thunderbolt, Displayport
- USB PD (active cable required)
 - up to 100W (20V 5A)

USB Pinouts

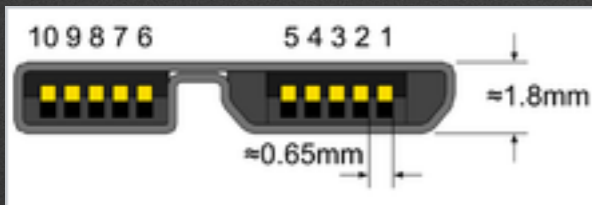


Type-A and -B pinout

Pin	Name	Wire color	Description
1	V _{BUS}	Red, or Orange	+5 V
2	D-	White, or Gold	Data-
3	D+	Green	Data+
4	GND	Black, or Blue	Ground

Mini/Micro-A and -B pinout

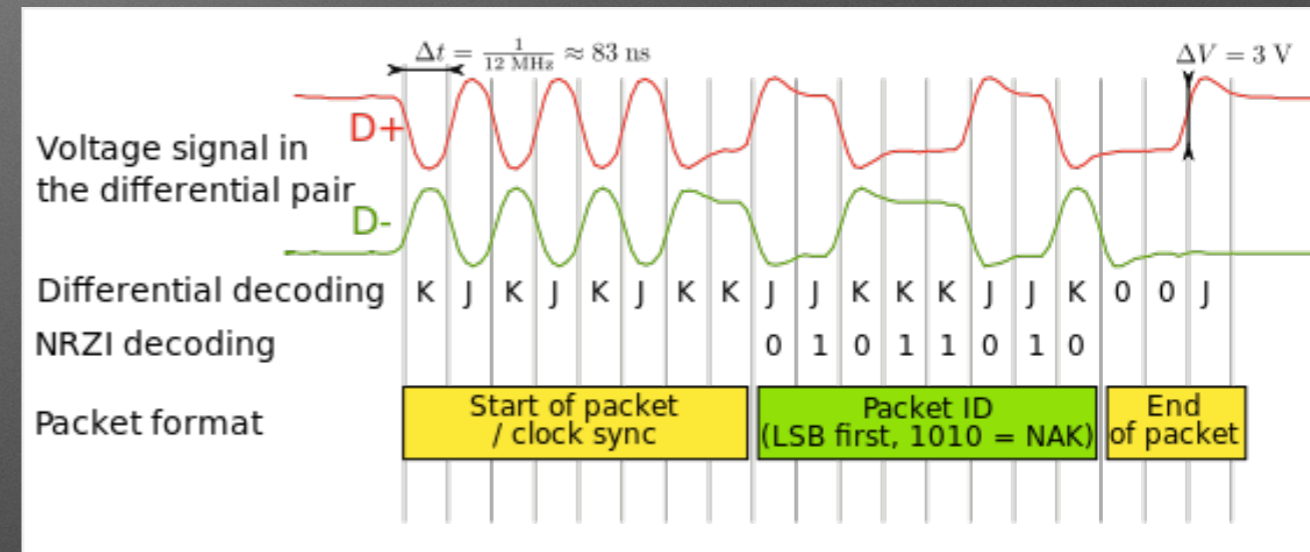
Pin	Name	Wire color	Description
1	V _{BUS}	Red	+5 V
2	D-	White	Data-
3	D+	Green	Data+
4	ID	No wire	On-The-Go ID distinguishes cable ends: <ul style="list-style-type: none"> "A" plug (host): connected to GND "B" plug (device): not connected
5	GND	Black	Signal ground



- Micro-B SuperSpeed plug**
1. Power (V_{BUS}, 5 V)
 2. Data- (D-)
 3. Data+ (D+)
 4. ID (On-The-Go)
 5. GND
 6. SuperSpeed transmit- (SSTx-)
 7. SuperSpeed transmit+ (SSTx+)
 8. GND
 9. SuperSpeed receive- (SSRx-)
 10. SuperSpeed receive+ (SSRx+)

USB Physical Layer

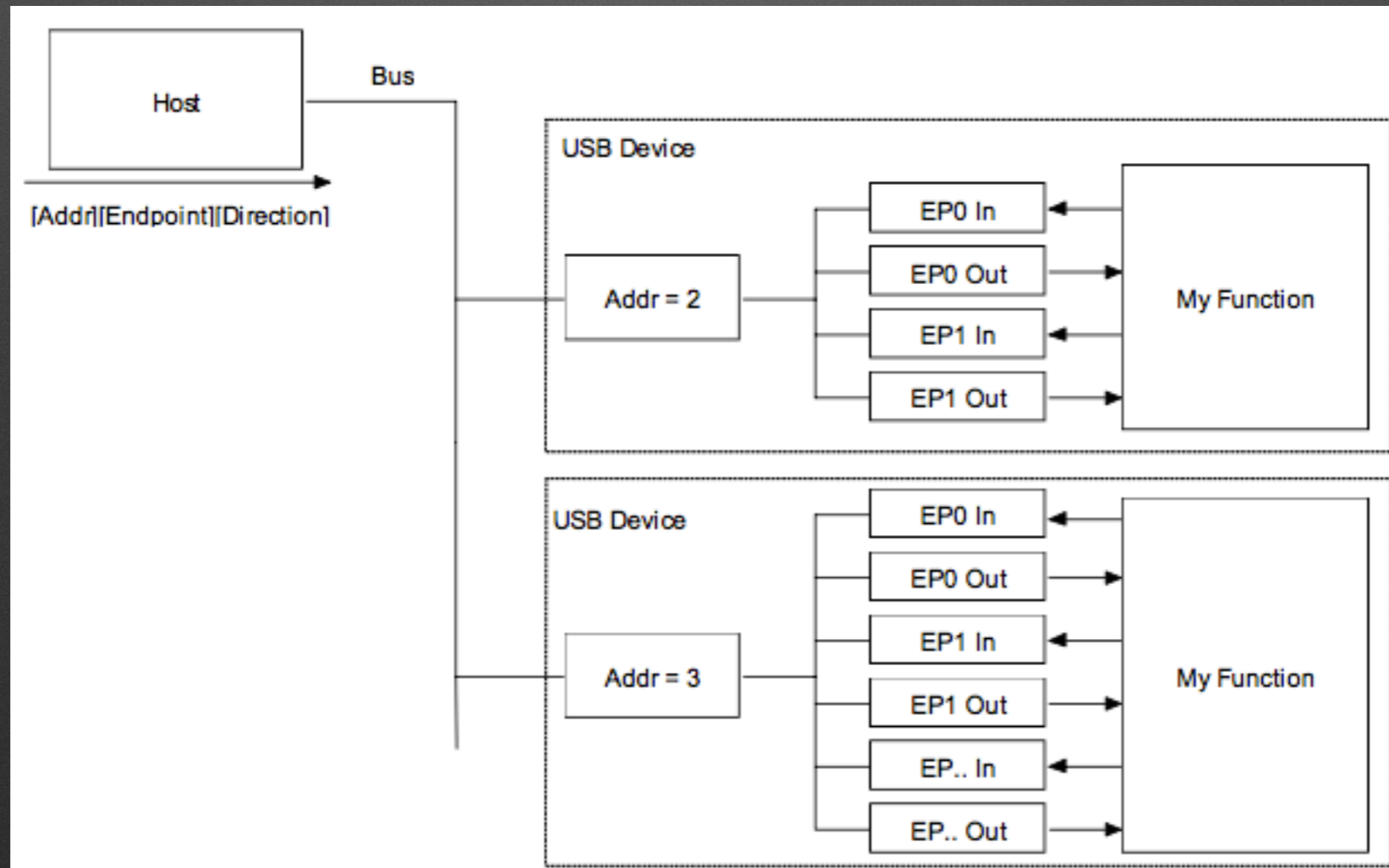
- High Speed signals (D+/D-)
 - 480Mbps, NRZI encoding
 - Half-Duplex



- Super Speed signals (SSTX+/SSTX-, SSRX+/SSRX-)
 - 5Gbps, 8b/10b encoding, actual data rate is 4Gbps
 - Full-Duplex

System Overview

- Up to 127 devices on a host controller
- Up to 16 IN/OUT endpoints per device
 - EP0 dedicated to device configure

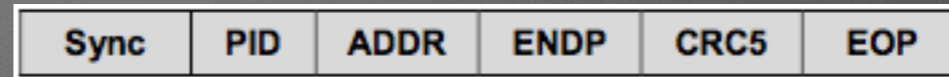


USB Protocols

- USB Packets
 - Token Packets, Data Packets, Handshake Packets, SOF Packets
- USB Transfers
 - Control Transfers, Interrupt Transfers, Isochronous Transfers, Bulk Transfers
- Devices Classes

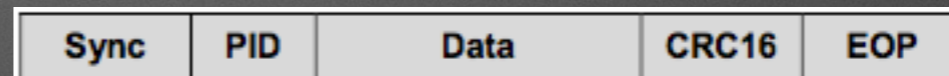
USB Packets

- Token Packets



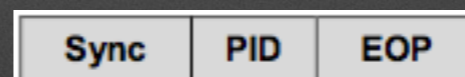
- In, Out, Setup

- Data Packets



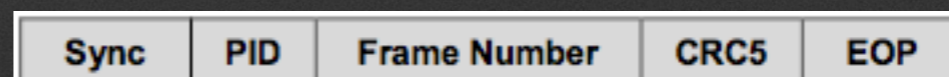
- Data0, Data1

- Handshake Packets



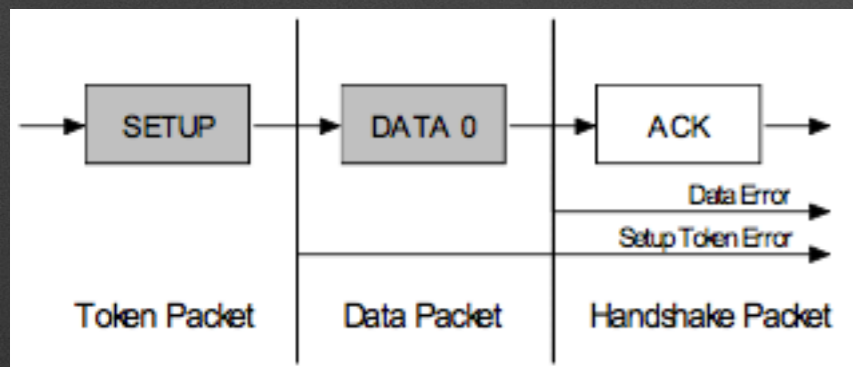
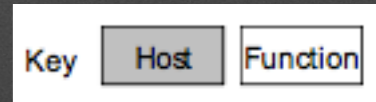
- ACK, NAK, STALL

- Start-of-Frame Packets

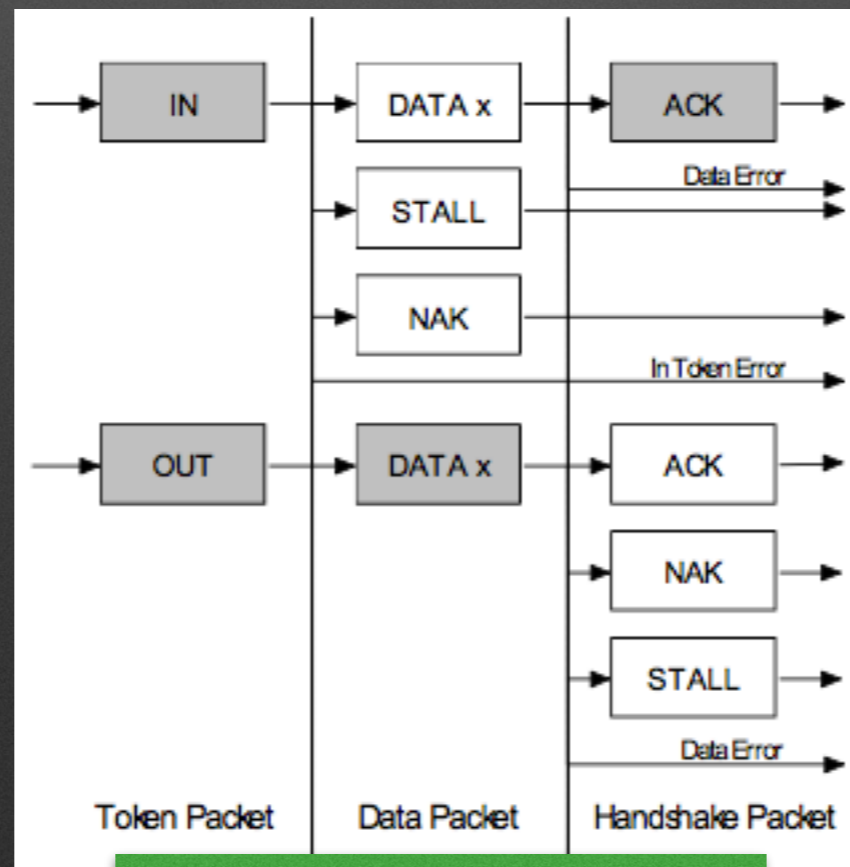


USB Transfers

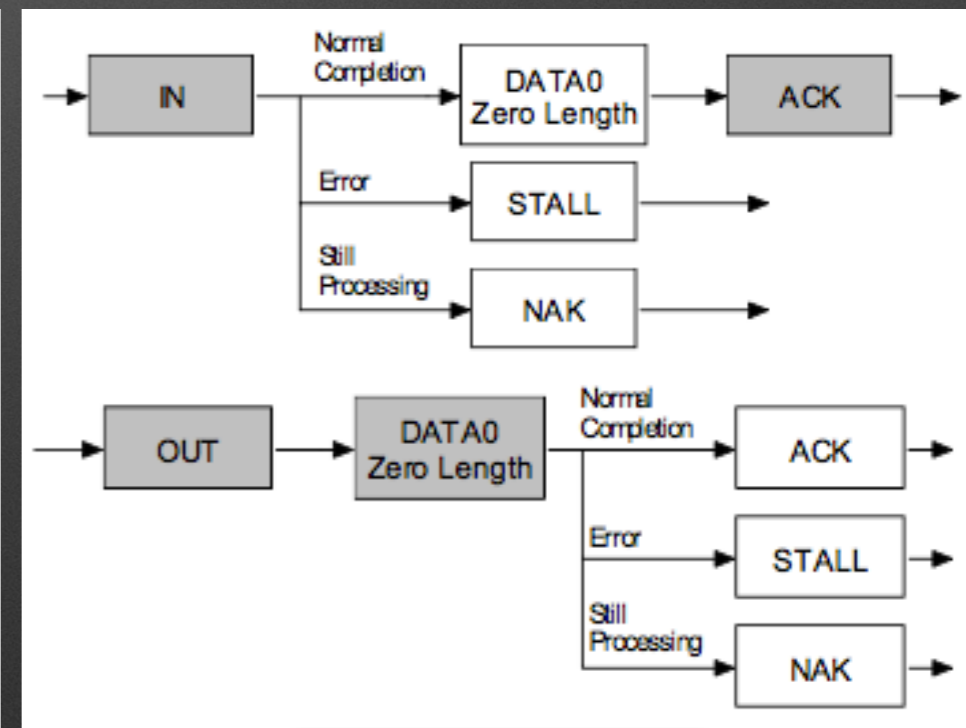
- Control Transfers
 - command and status operation
 - enumeration functions



Setup Stage



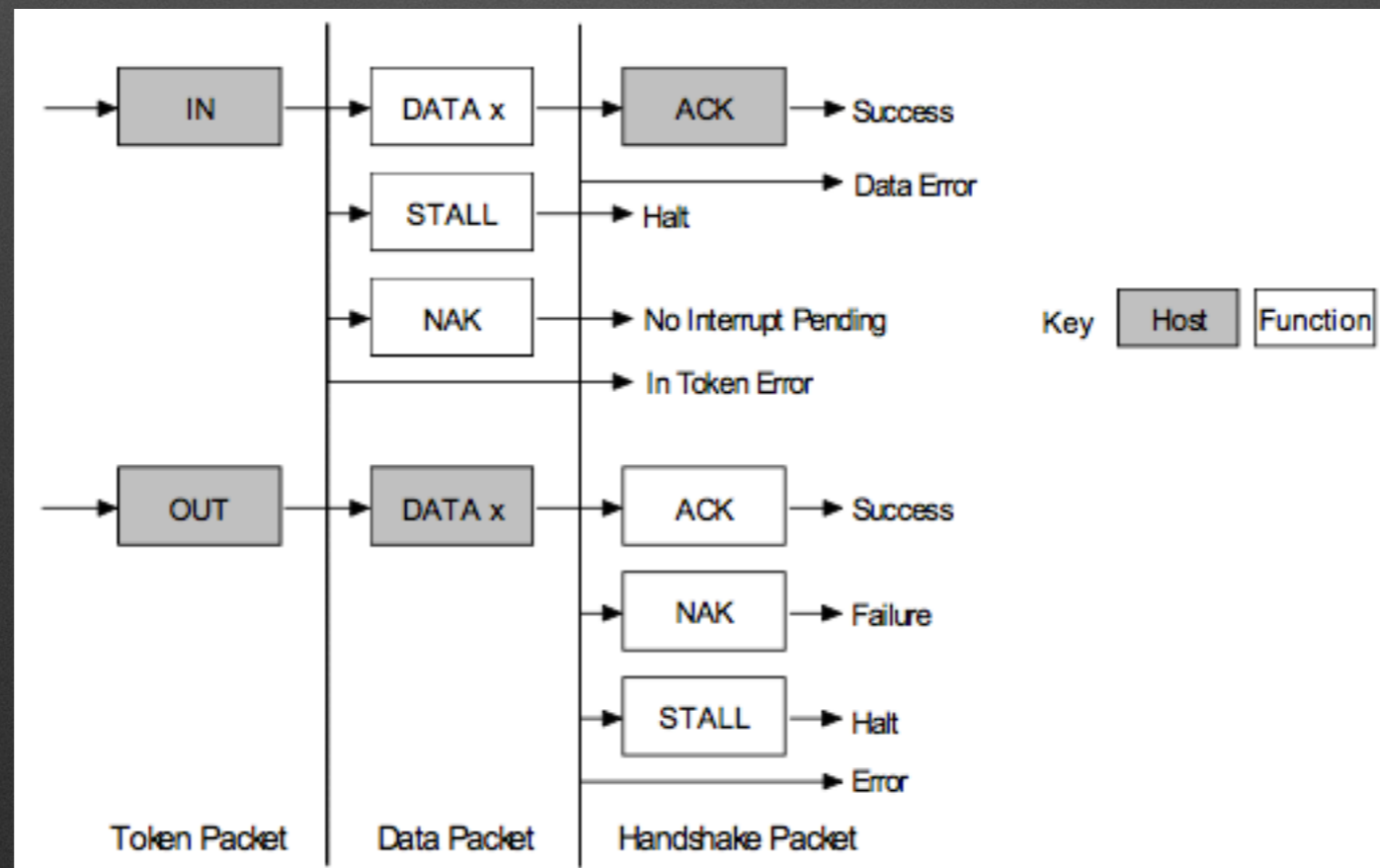
Data Stage(optional)



Status Stage

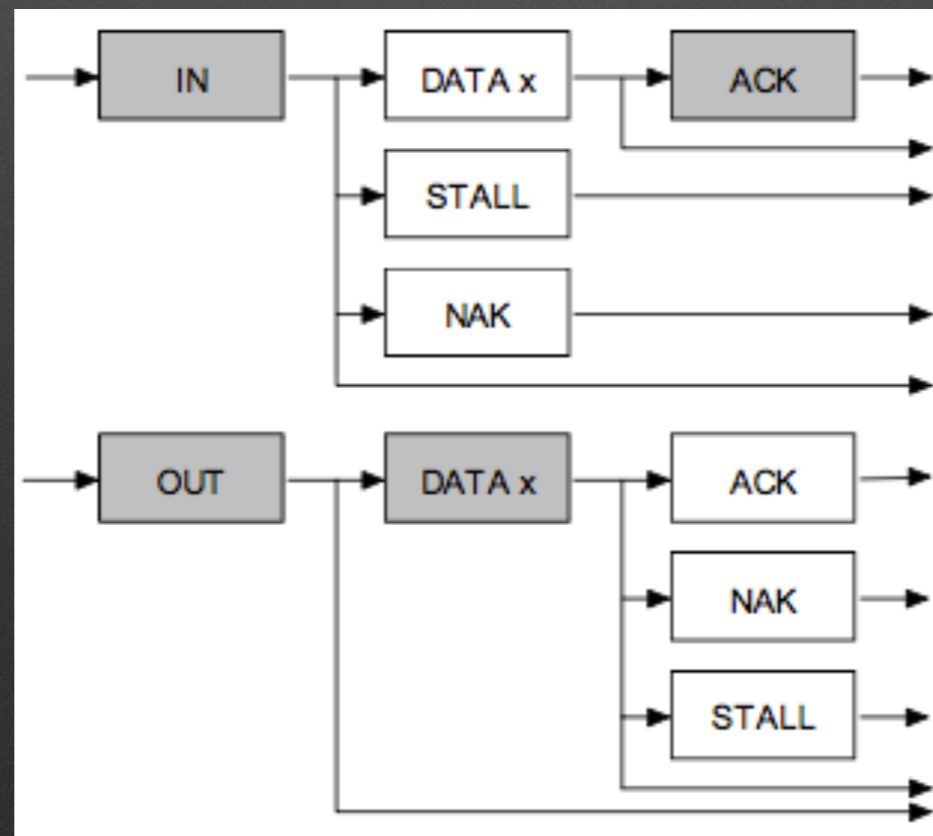
USB Transfers

- Interrupt Transfers
- guaranteed latency



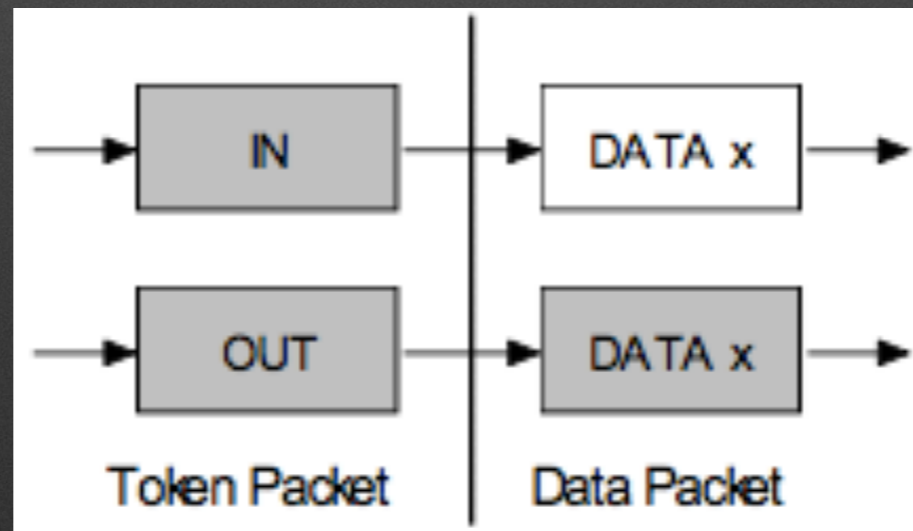
USB Transfers

- Bulk Transfers
 - used to transfer large bursty data
 - guarantee of delivery (error detection, re-transmission)
 - no guarantee of bandwidth or minimum latency



USB Transfers

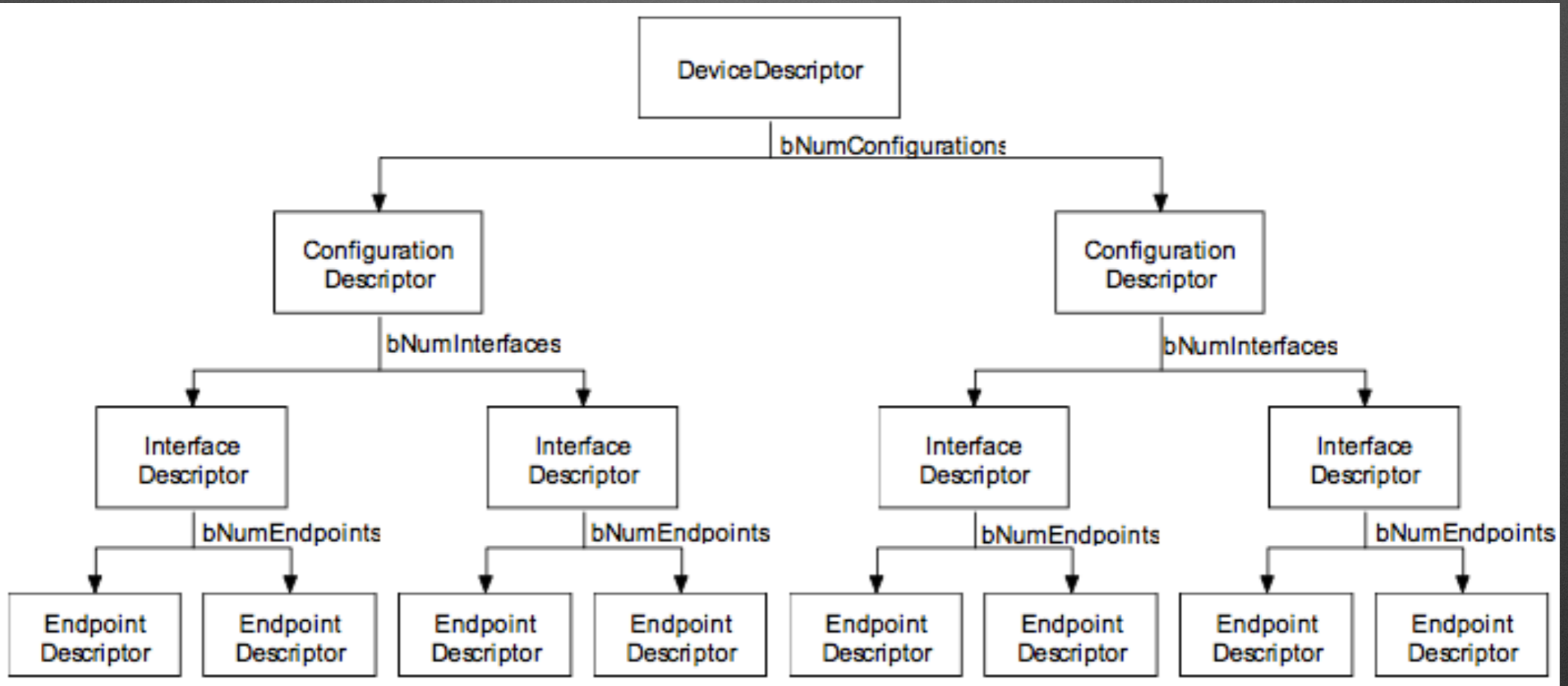
- Isochronous Transfers
 - guaranteed bandwidth and bounded latency
 - error detection, but no re-transmission



Device Classes

- MSC: Mass storage class
- HID: Human interface device
- CDC: Communications device class
 - ACM, ECM, etc.
- UVC: USB video class
- CCID: Chip card interface device
- Vendor-specific

USB Descriptors



USB Descriptors

- Device Descriptor
 - device info: VID/PID, name, serial number, ...
- Configuration Descriptors
 - number of interfaces, max power, ...
- Interface Descriptors
 - interface class/subclass/protocol
- Endpoint Descriptors
 - transfer type, max packet size, interval

Host Programming - libusb

- Host-side USB access library
- Cross-platform: Linux, macOS, Windows, Android
- User-mode: No kernel driver required (except Windows)
- Language bindings:
 - C/C++
 - Java/C#
 - Python/Ruby/Node.js

OTG



- OTG Device = Host + Device
- Monolithic USB Gadgets drivers in Linux
 - modprobe g_serial / g_ether / g_ffs
- ConfigFS based composite gadget
 - flexible!

REFERENCES

- <https://en.wikipedia.org/wiki/USB>
- *USB in a Nutshell*, www.beyondlogic.org
- *USB and the Real World*, Alan Ott, Embedded Linux Conference April 28, 2014
- *Kernel USB Gadget Configfs Interface*, Matt Porter