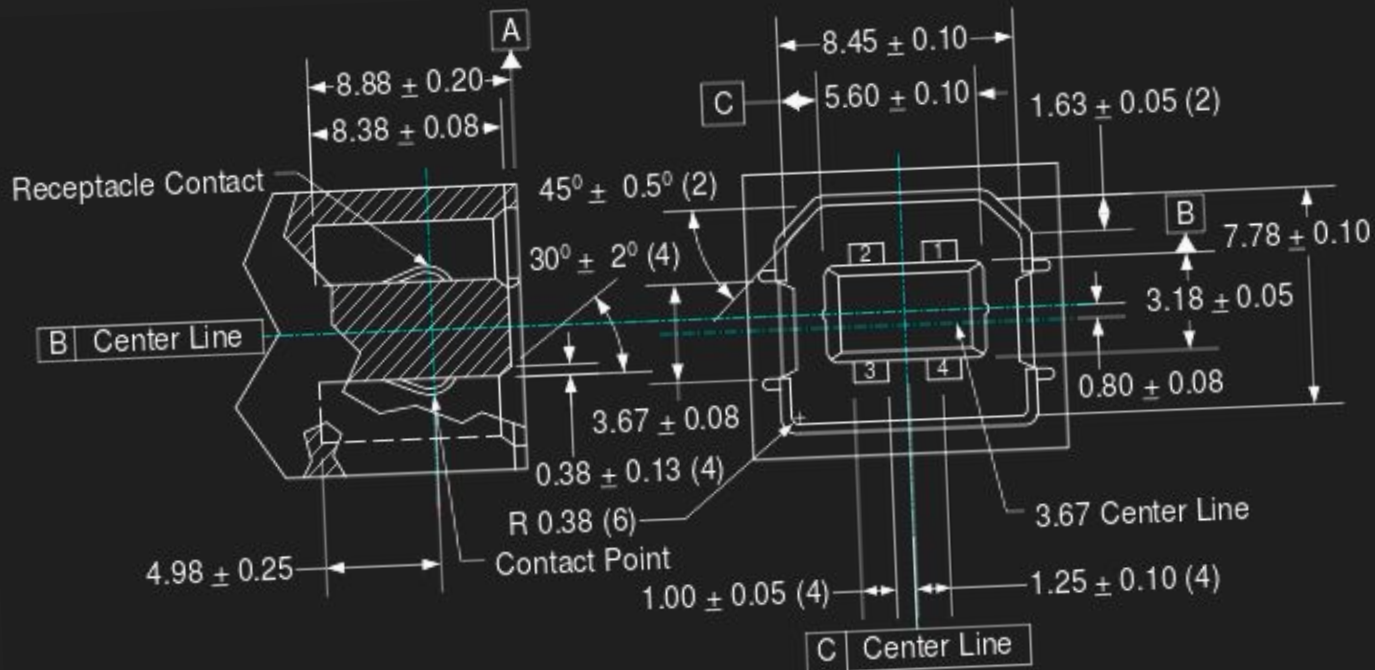


Build a USB 2.0 device from scratch

Friday 15, July 2016
Philémon `PhilGekni` Gardet
<phil@lse.epita.fr>

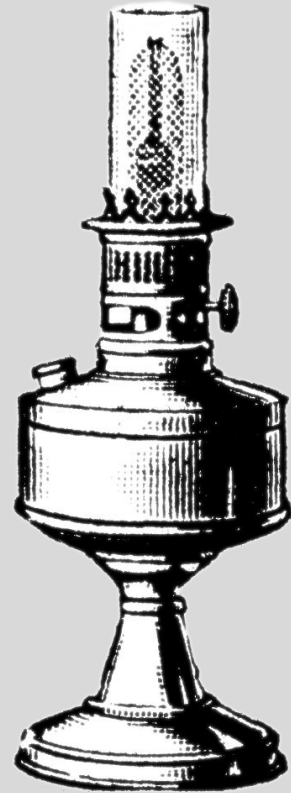


Plan

- The Overview
- The Protocol layers
- Implementation considerations



The Overview



Topology

Host

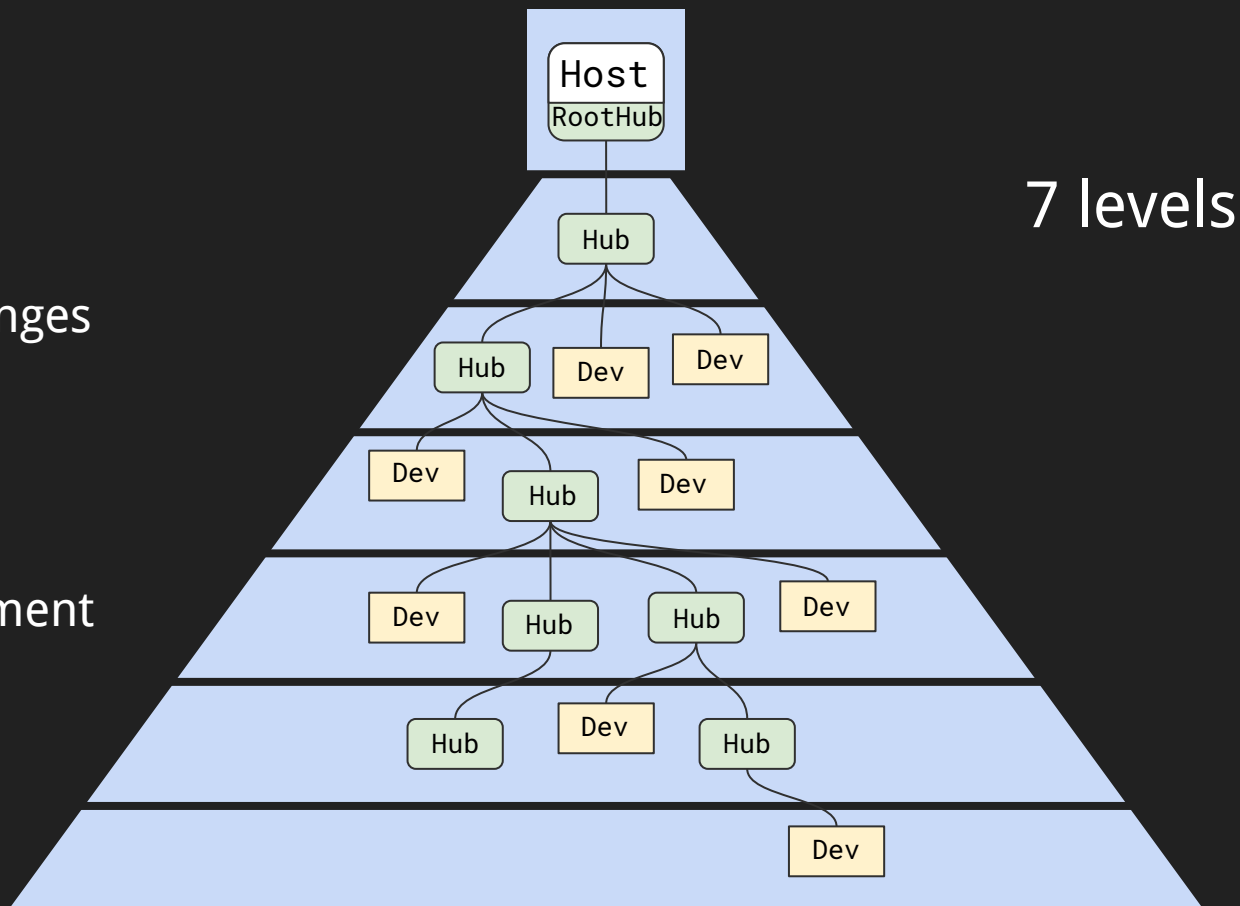
- Manages exchanges

Hubs

- Plug / Unplug notifications
- Power management

Devices

- Offer functions



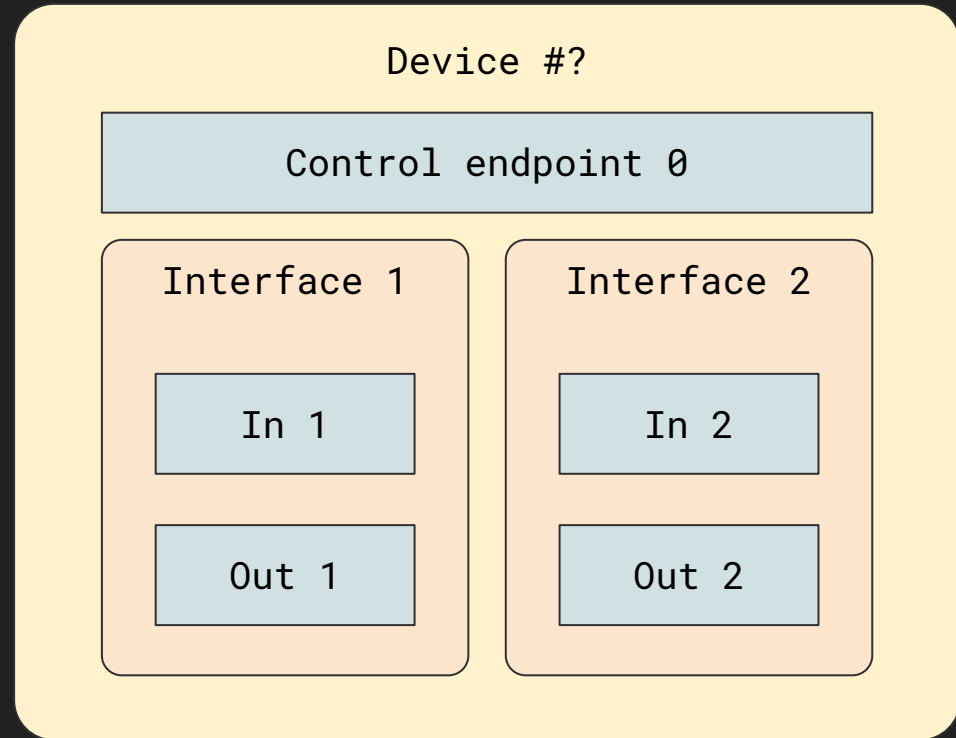
Endpoints and pipes device

Basic types

- Input
- Output
- Control

Full-speed

- 1 Control endpoint 0
- 15 in endpoints max
- 15 out endpoints min



Access by device + endpoint address

Endpoints/pipes types

Interrupt transfer (≤ 64 Bytes)

Regular queries

Isochronous transfer (≤ 64 Bytes)

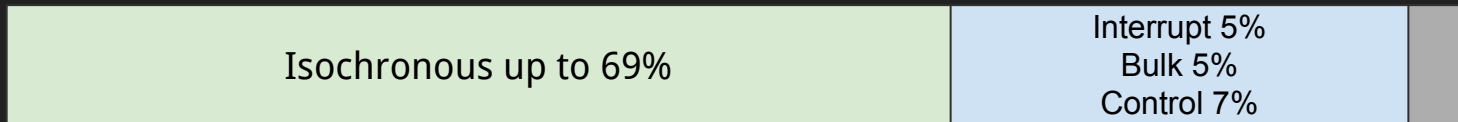
Constant bandwidth

Bulk transfer (≤ 1023 Bytes)

Large packet

Control transfers (≤ 64 Bytes)

Device setup / Hubs management / Status



Full-speed bandwidth

Device Class

- Base Class
- Subclass
- Protocol

Class Base ID	Descriptor Usage	Description
00h	Device	<i>Refer to Interfaces</i>
01h	Interface	Audio
02h	Both	Communication and CDC
09h	Device	Hub
EFh	Both	Miscellaneous
FEh	Interface	Application Specific
FFh	Both	<i>Vendor specific</i>

Vendor ID / Product ID

Device signature

vid:pid

Vendor ID

Delivered by the USB-IF

Product ID

Chosen by vendor

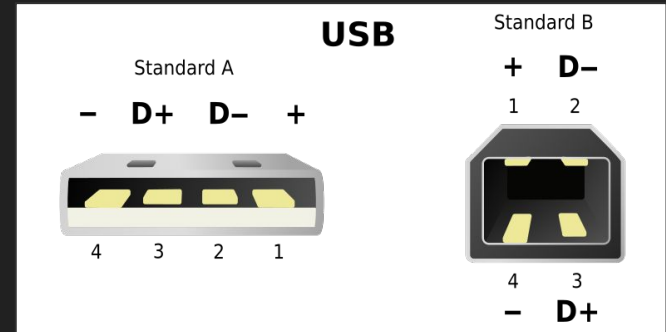
```
12d2 LINE TECH INDUSTRIAL CO., LTD.
12d6 EMS Dr. Thomas Wuensche
      0444 CPC-USB/ARM7
      0888 CPC-USB/M16C
12d7 BETTER WIRE FACTORY CO., LTD.
12d8 Araneus Information Systems Oy
      0001 Alea I True Random Number Generator
12e6 Waldorf Music GmbH
      0013 Blofeld
12ef Tapwave, Inc.
      0100 Tapwave Handheld [Tapwave Zodiac]
12f5 Dynamic System Electronics Corp.
12f7 Memorex Products, Inc.
      1a00 TD Classic 003B
      1e23 TravelDrive 2007 Flash Drive
12fd AIN Comm. Technology Co., Ltd
      1001 AWU2000b 802.11b Stick
12ff Fascinating Electronics, Inc.
      0101 Advanced RC Servo Controller
1307 Transcend Information, Inc.
      0163 256MB/512MB/1GB Flash Drive
      0165 2GB/4GB/8GB Flash Drive
      0190 Ut190 8 GB Flash Drive with MicroSD reader
      0310 SD/MicroSD CardReader [hama]
      0330 63-in-1 Multi-Card Reader/Writer
      0361 CR-75: 51-in-1 Card Reader/Writer [Sakar]
      1169 TS2GJF210 JetFlash 210 2GB
      1171 Fingerprint Reader
1308 Shuttle, Inc.
      0003 VFD Module
      c001 eHome Infrared Transceiver
1310 Roper
      0001 Class 1 Bluetooth Dongle
1312 ICS Electronics
1313 ThorLabs
      0010 LC1 Linear Camera (Jungo)
      0011 SP1 Spectrometer (Jungo)
      0012 SP2 Spectrometer (Jungo)
      0110 LC1 Linear Camera (VISA)
      0111 SP1 Spectrometer (VISA)
```

The Protocol layers

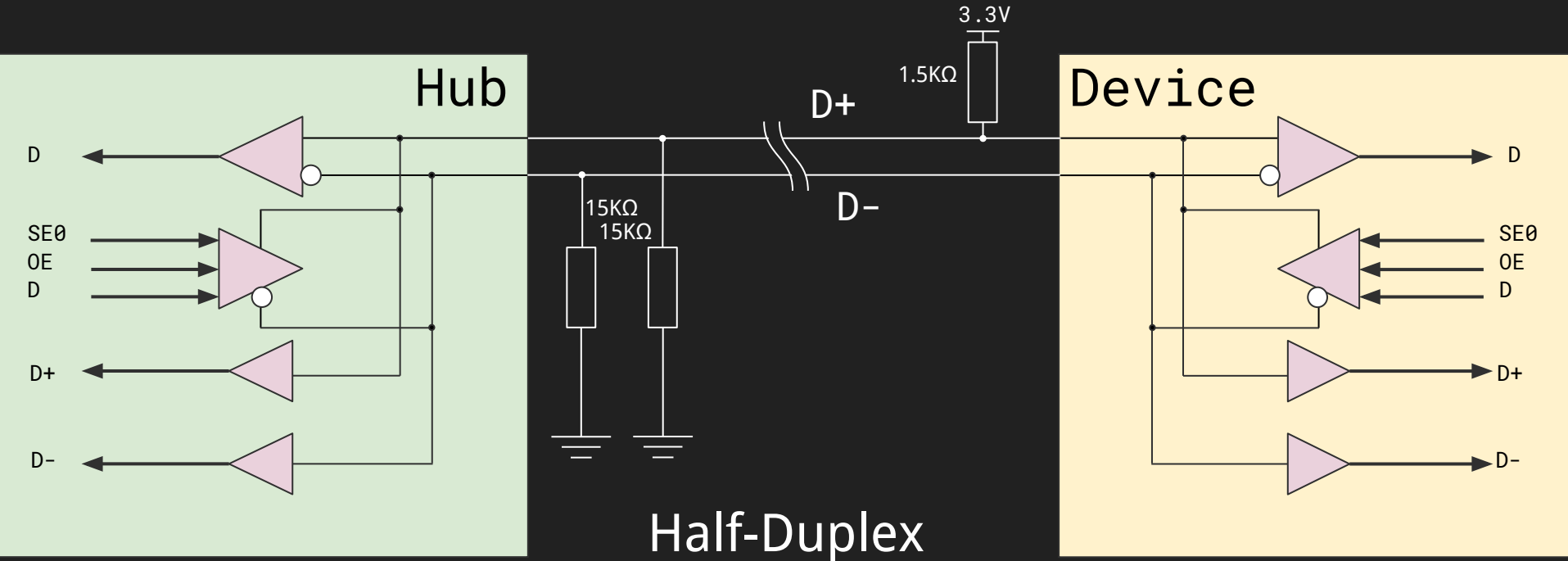


Signals - The connector

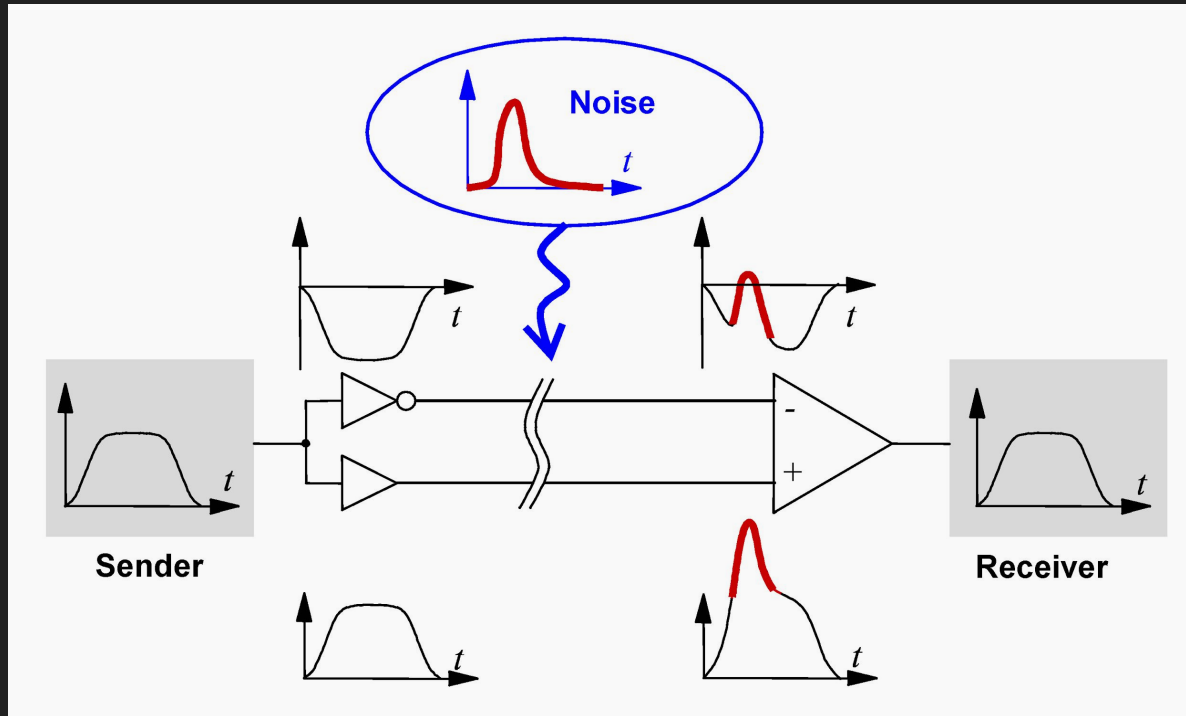
Name	Voltage Domain
Vcc	5 V
D+	3.3/0 V
D-	3.3/0 V
GND	Ground



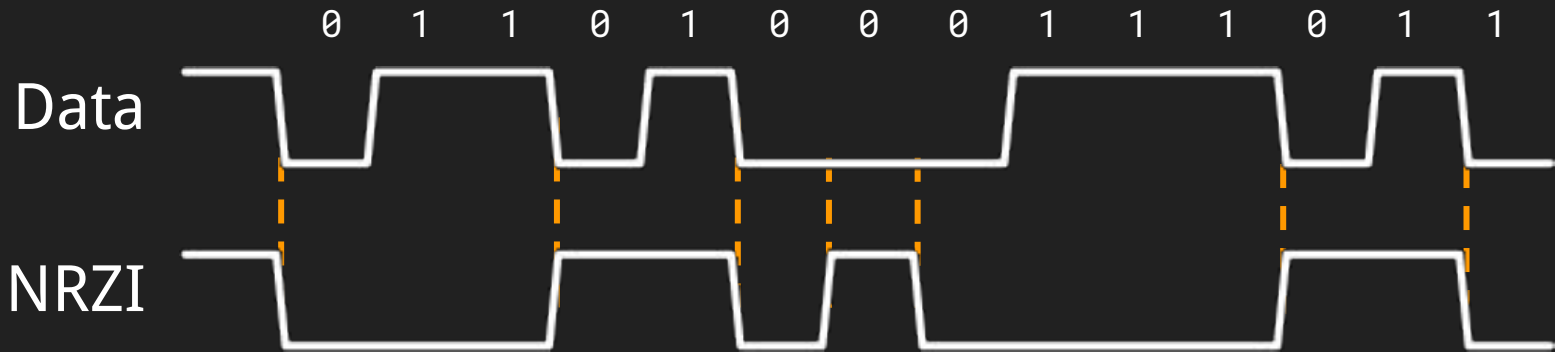
Signals - The link between a hub and a device



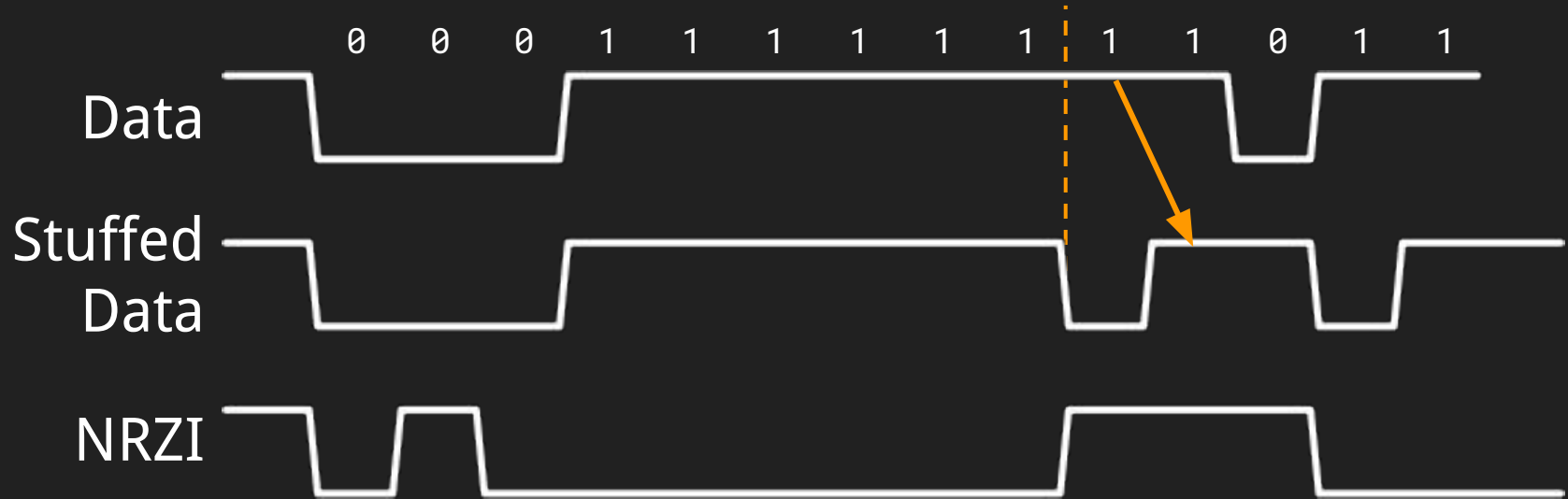
Signals - Decoding them - Differential level



Signals - Decoding them - NRZI encoding



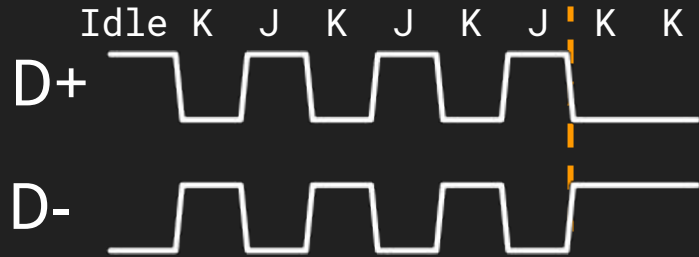
Signals - Decoding them - Bit stuffing



Signals - Patterns

Sync / SOP

Start of packet



Full-speed: J=1 and K=0

EOP

End of packet



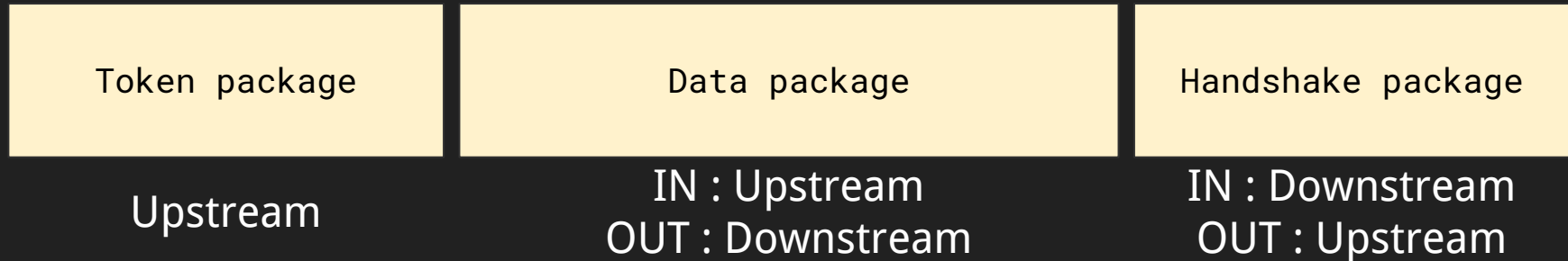
2 bits

Reset



10-20 mS

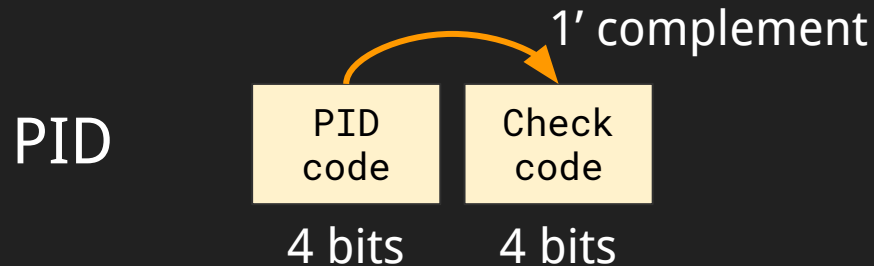
Packets - A classical exchange



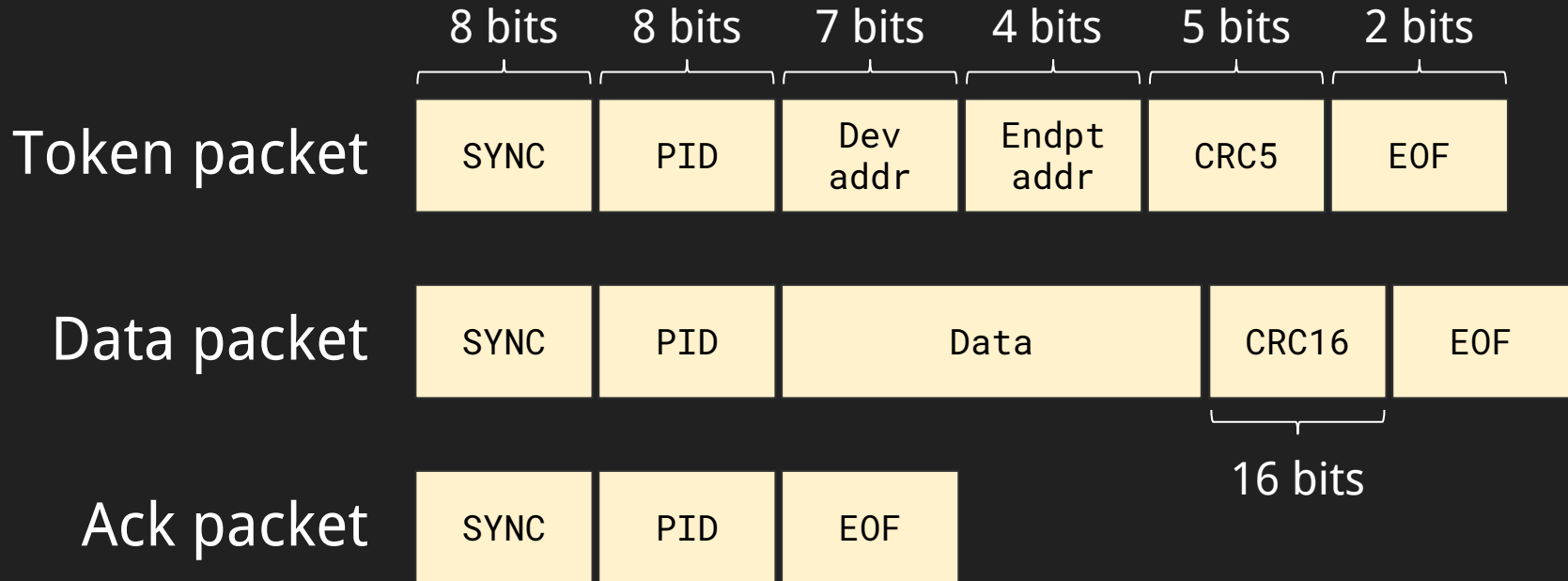
Timeout : 6.5 - 7.5 bit times
(total window : 16 bit times)

Packets - PID/Types

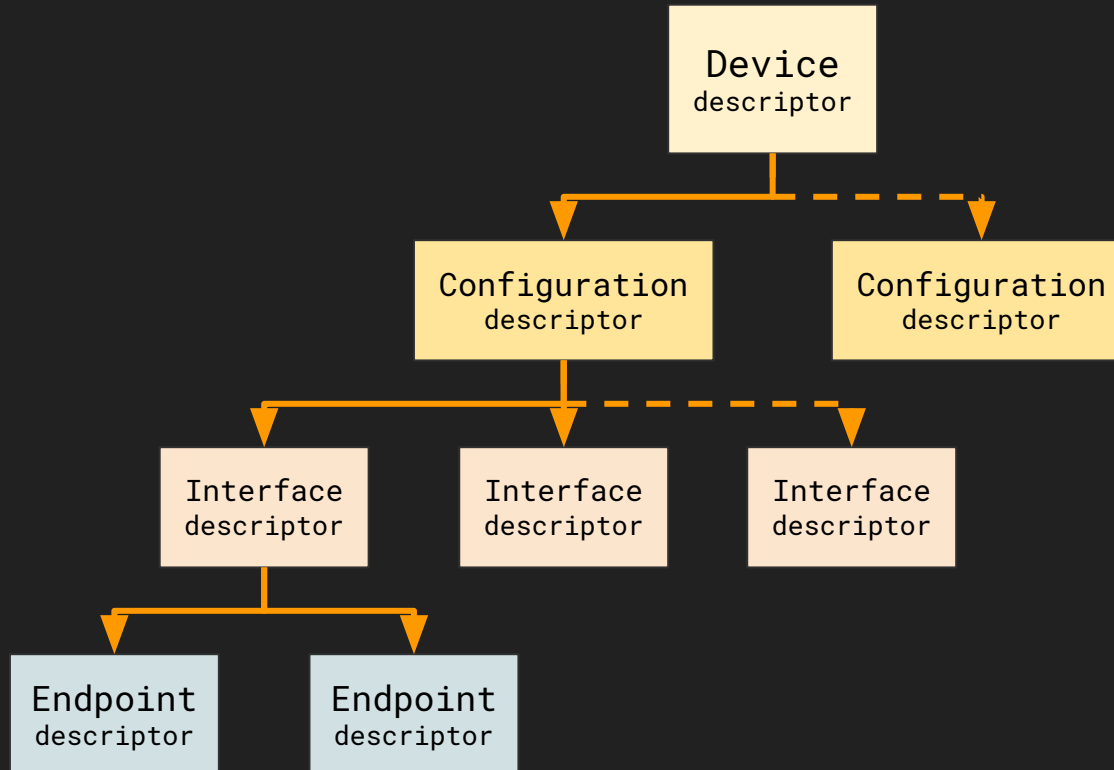
Token	Data	Handshake
OUT IN SETUP	DATA0 DATA1	ACK NAK STALL



Packets - The formats



Configuration - Descriptors



Configuration - Descriptors data

Device
descriptor

Class - Subclass - Protocol - VID - PID
Max packet size endpoint 0

Configuration
descriptor

Power attributes - Max power

Interface
descriptor

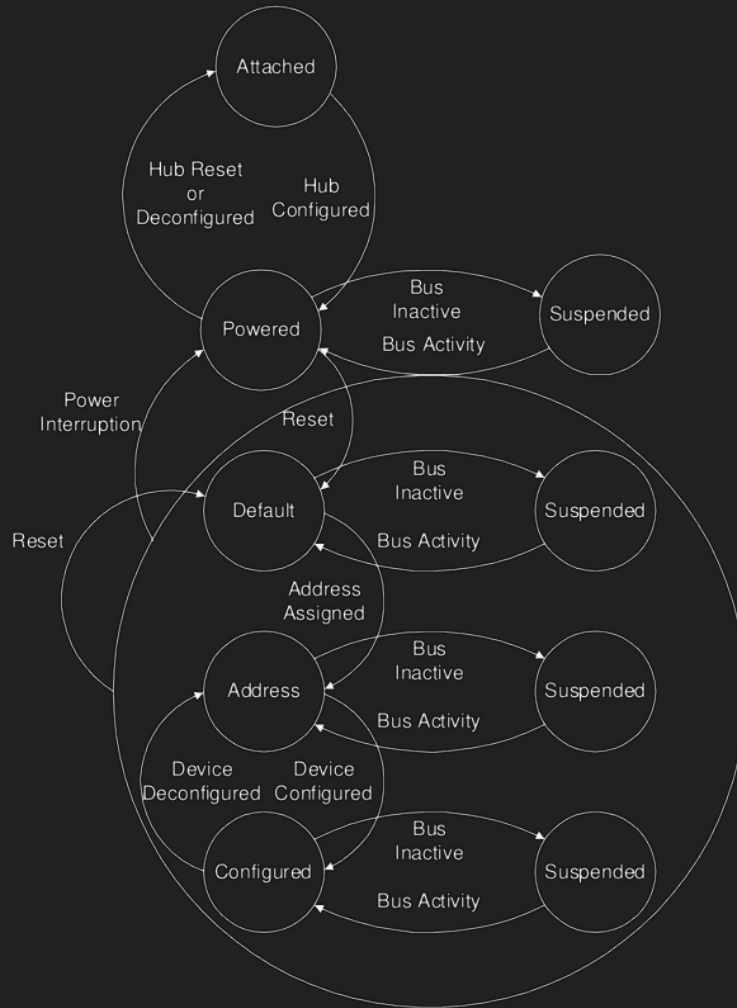
Class - Subclass - Protocol
Alternative setting

Endpoint
descriptor

Endpoint address - Endpoint type

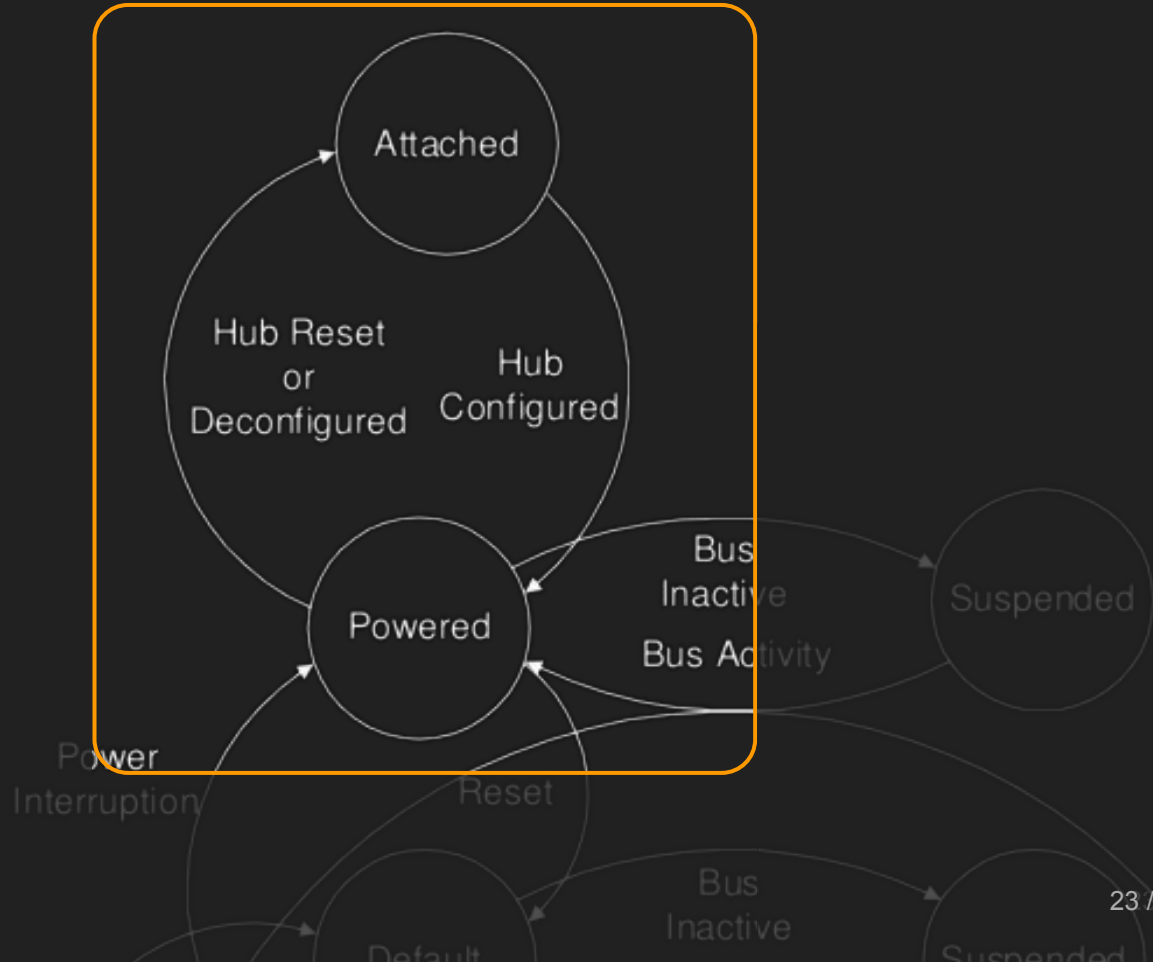
Configuration - Device status

- Attached
- Powered
- Default
- Address
- Configured



Configuration - Hub configured

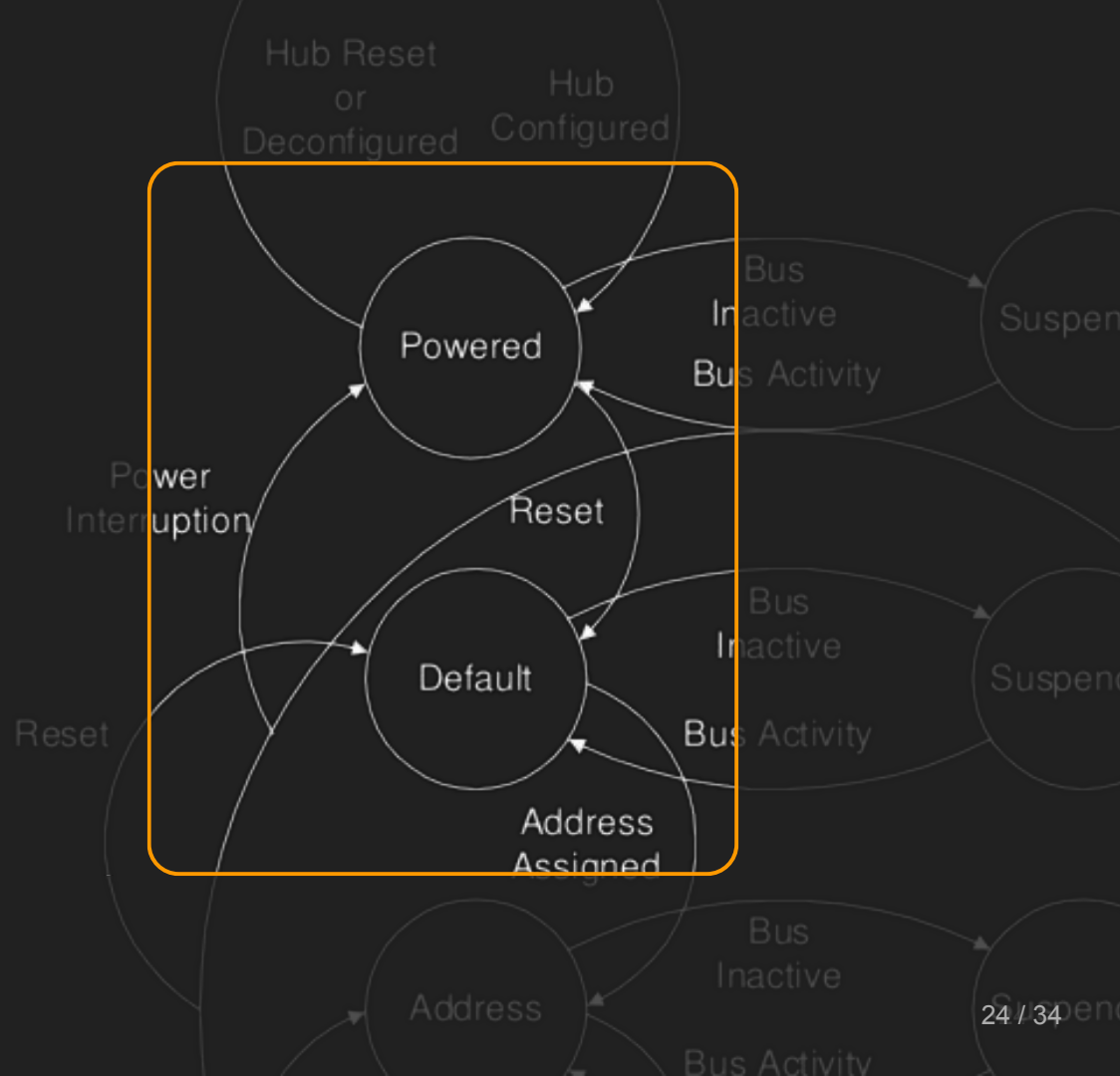
Internal hub
registers updating



Configuration

- Reset

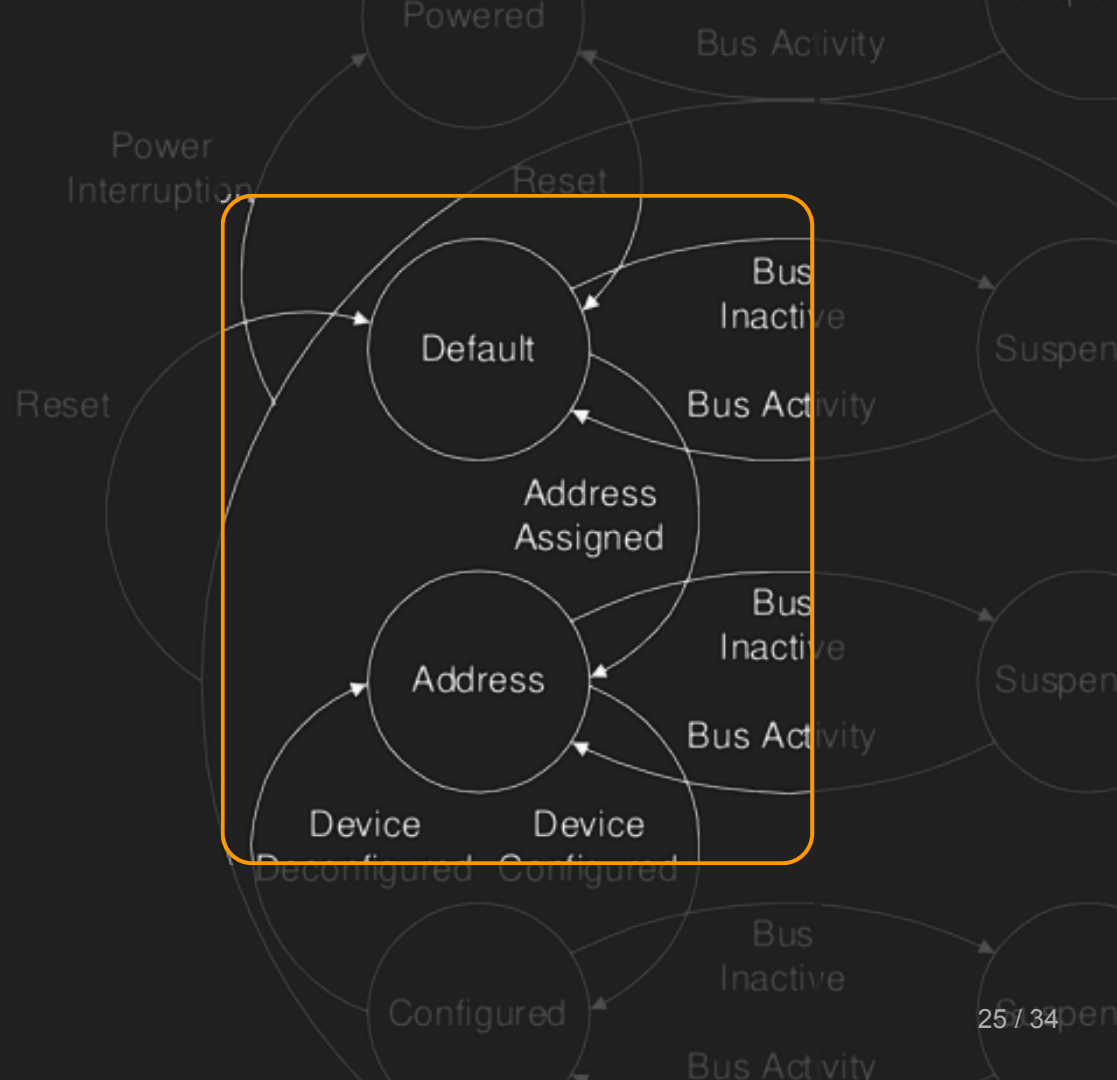
- Only one device
- Adresse set to 0



Configuration

- Set address

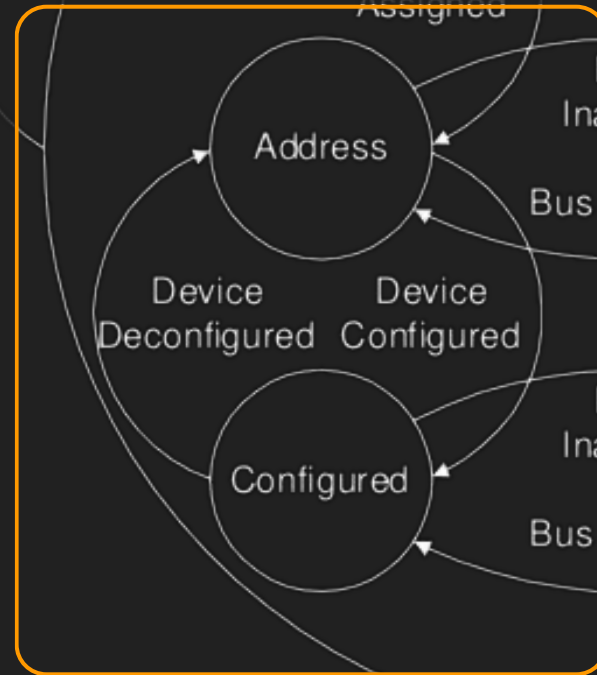
- Only one device with 0 address
- Host -> Endpoint 0



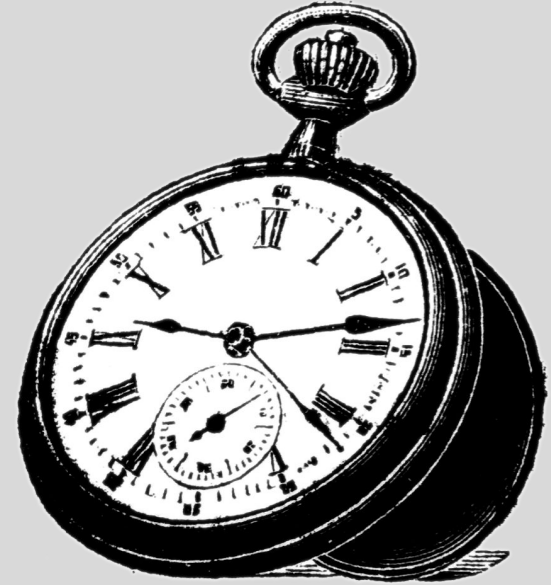
Configuration

- Configure device

- Gets Descriptors
- Choses descriptors



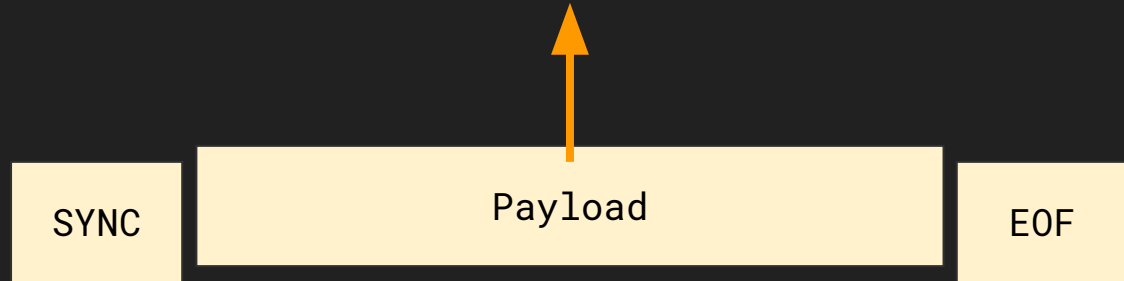
Implementation considerations



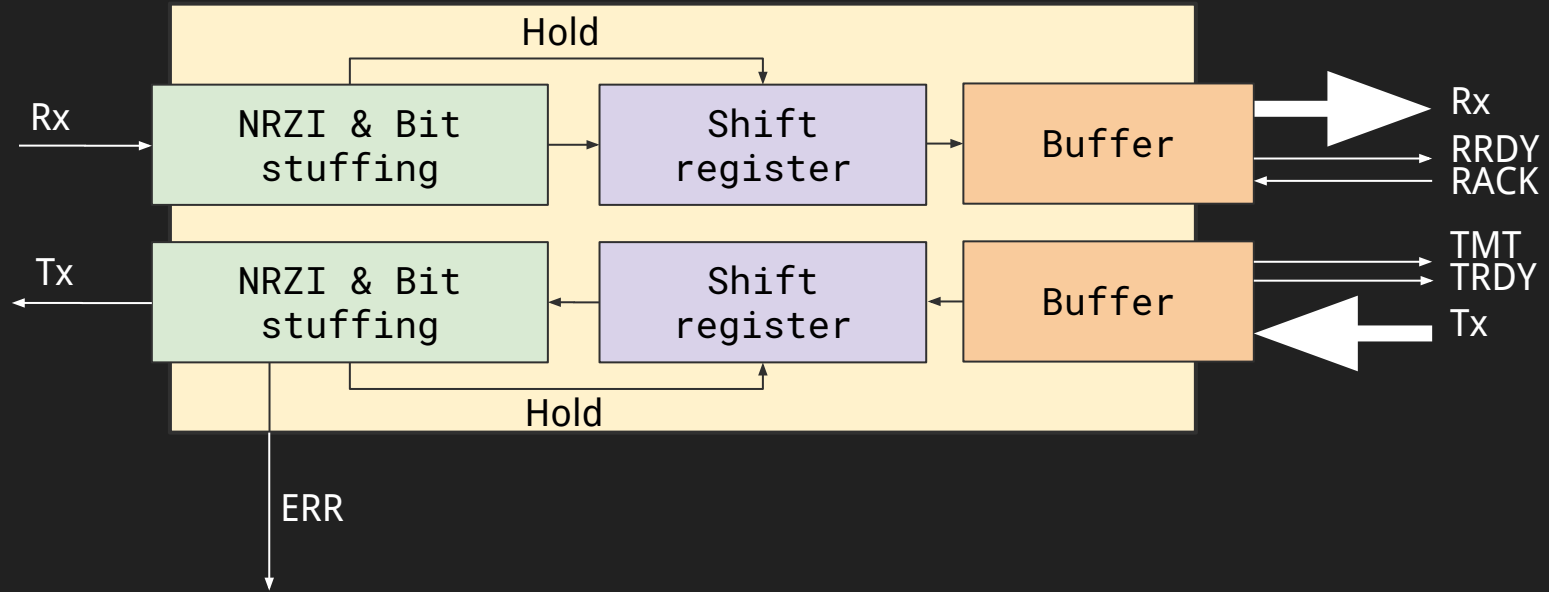
Hardware role

- Differential level
- NRZI
- Bit stuffing

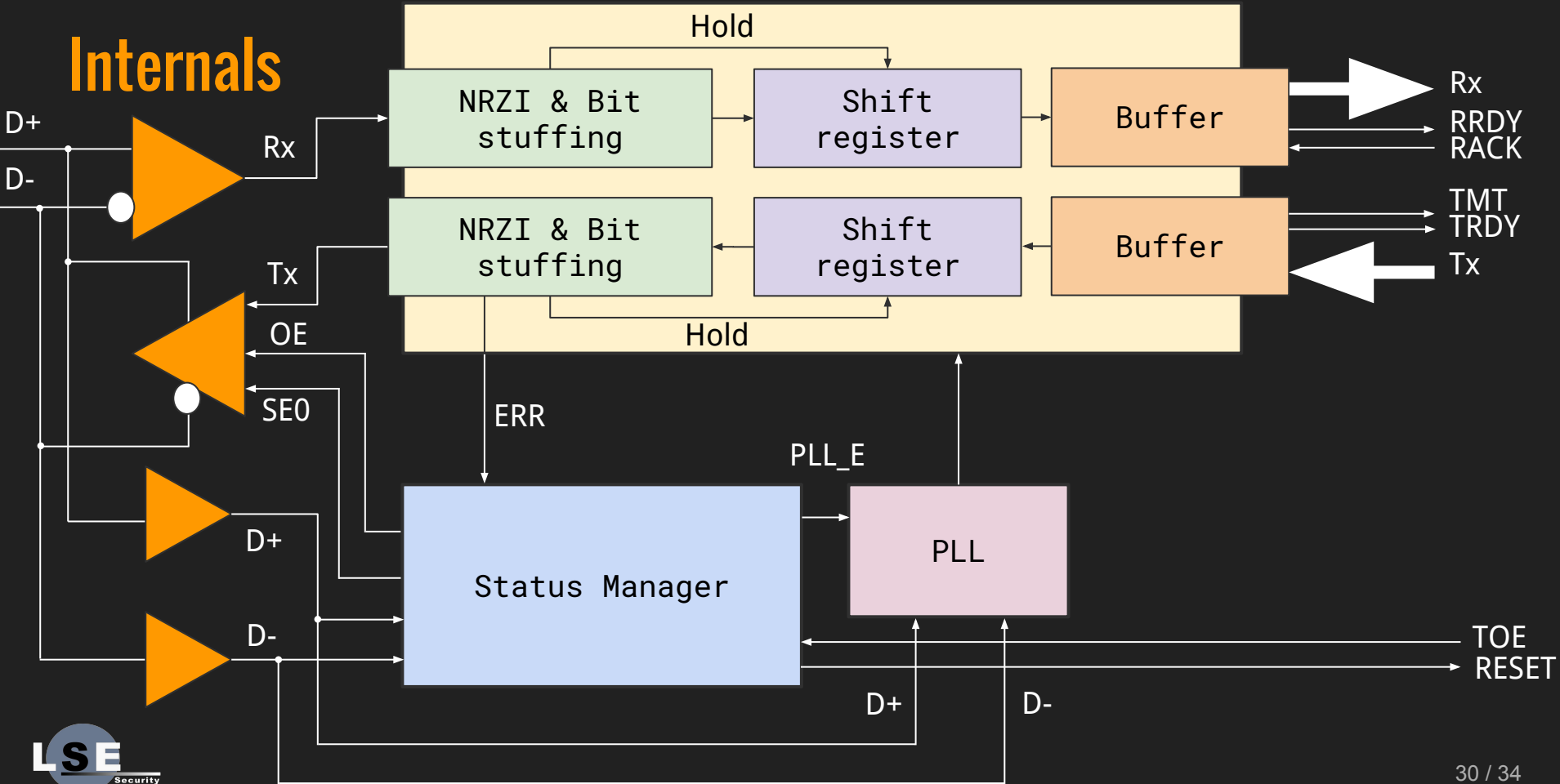
- Bit stuffing error detection



Internals



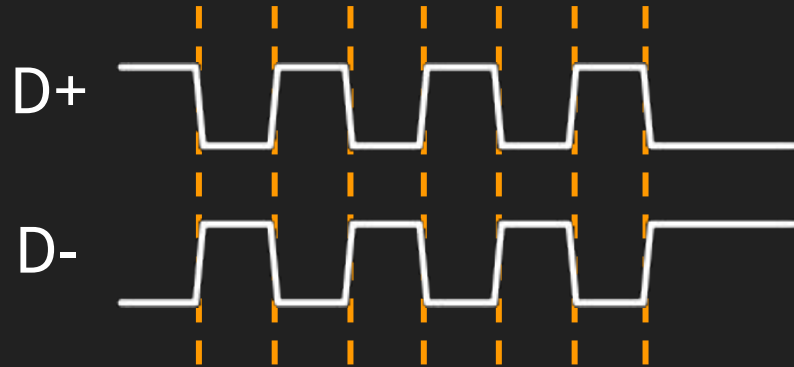
Internals



PLL and resynchronization

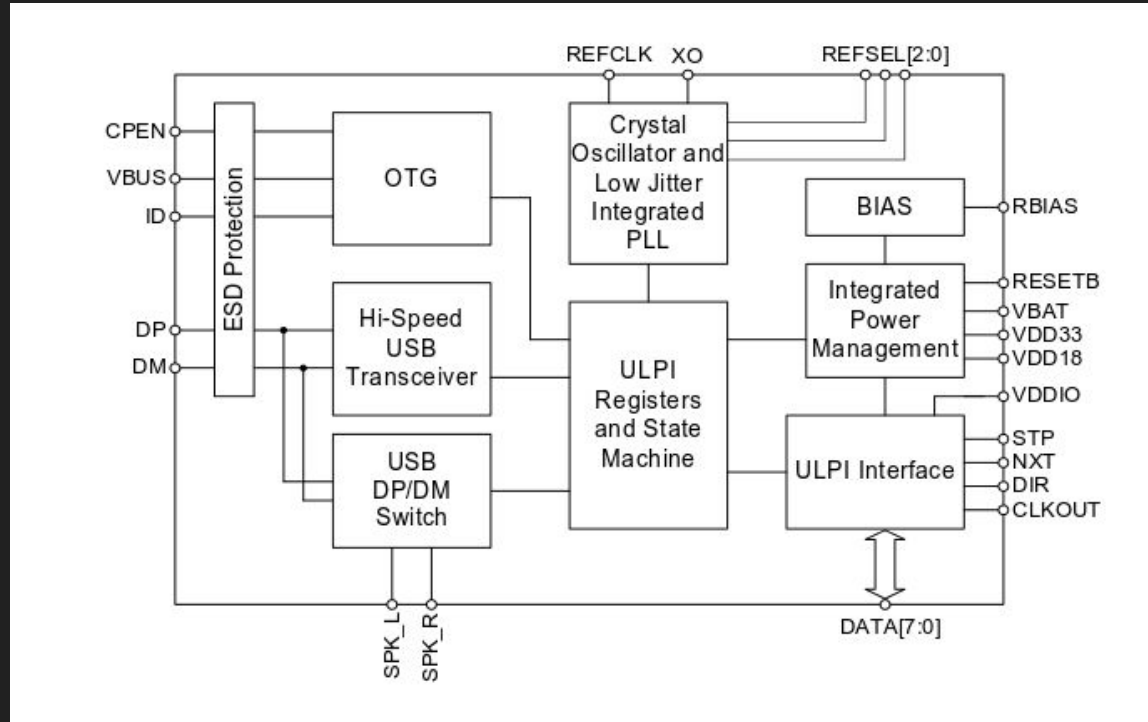
- ALTPLL
- ALTPLL_RECONFIG

“ Dynamic adjustment of the charge-pump current and loop-filter components to facilitate **dynamic reconfiguration** of the PLL bandwidth. This feature is **available only** in *Arria GX, HardCopy II, Stratix II, Stratix II GX, Stratix III, and Stratix IV* devices. ”



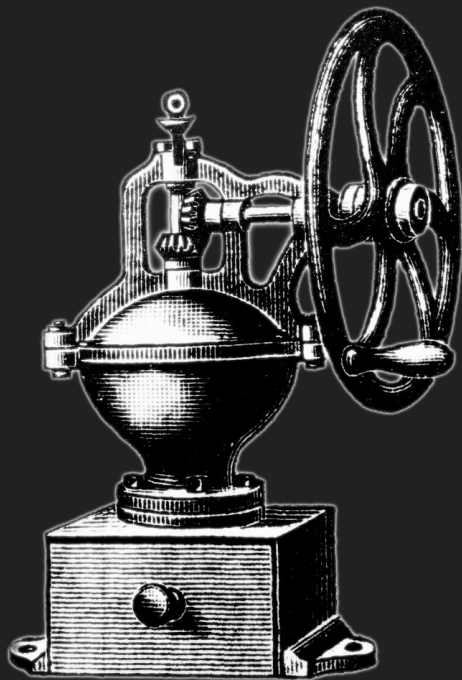
Sync pattern

Deviation : PHY USB



Conclusion





Bibliography & links

- Universal Serial Bus Revision 2.0 specification
- Universal Serial Bus System Architecture
ANDERSON Don, DZATKO Dave. Addison-Wesley, 2001
- USB in a NutShell
<http://www.beyondlogic.org/usbnutshell>
- USB class specifications
http://www.usb.org/developers/docs/devclass_docs
- Open Sources PID/VID
<http://pid.codes/>