# The USB Type-C™ Connector: A Brave New World for the PC Industry

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April 17, 2015

# Outline

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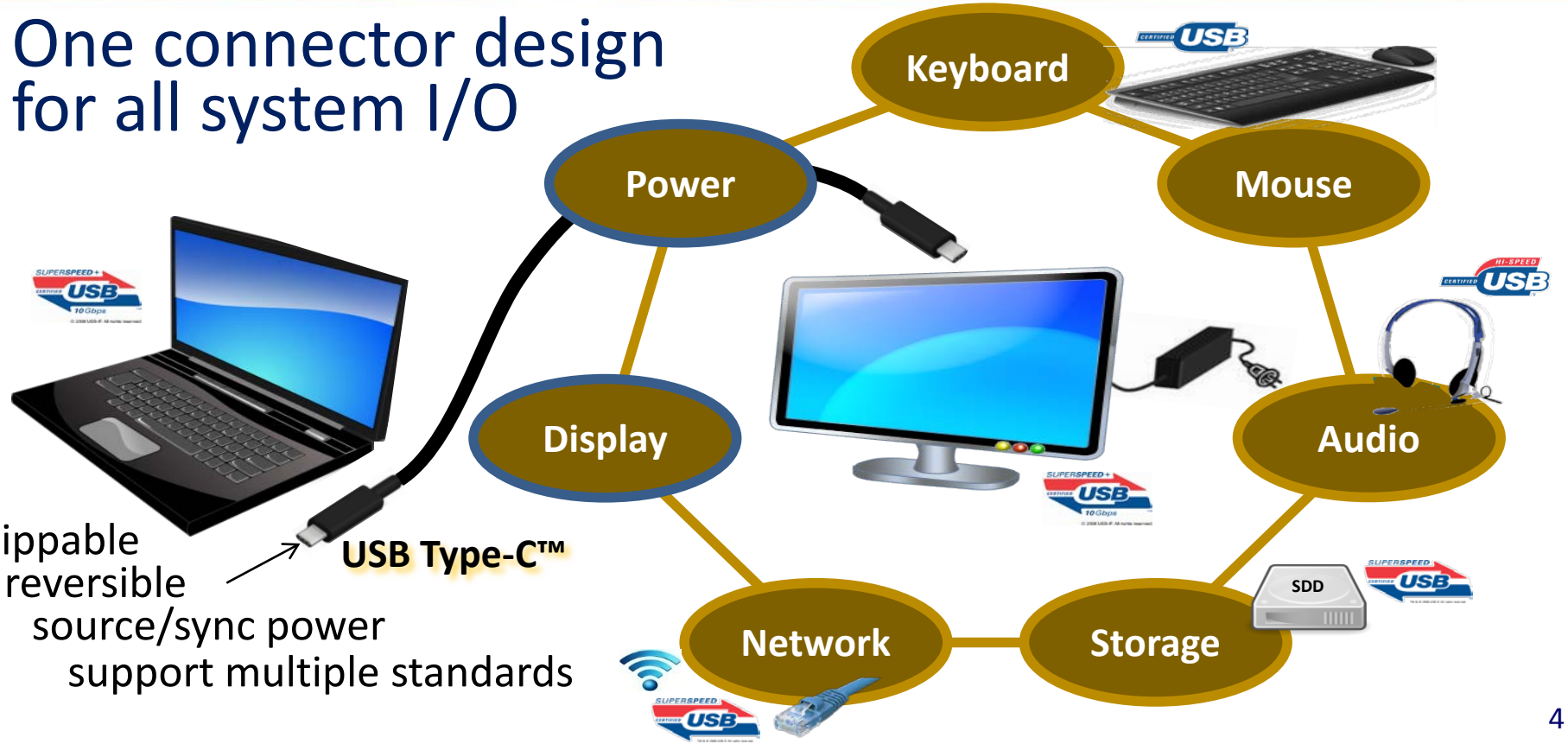
  - Key Design Aspects
  - Port Behaviors
  - User Experience Driven Challenges
- Challenges & Directions
  - Flippability
  - Symmetry
  - Power Delivery
  - 10G USB 3.1 Signaling
  - Alternate Mode Signaling
- Conclusion

# Introduction

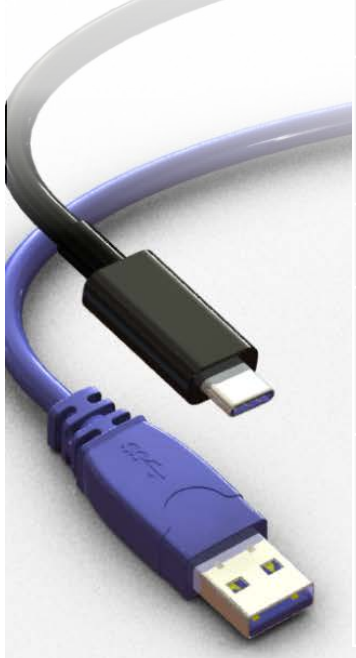
Start from the User Experience

# Vision

## One connector design for all system I/O



# USB Type-C Key Aspects



| | |
|---|---|
| **Thin & small** | 8.3mm x 2.5mm receptacle |
| **Easy to use** | Reversible plug orientation & cable direction |
| **Scalable** | >10 year lifespan |
| **Provides power** | Scalable power charging w/ source/sync negotiation |
| **Smooth Transition** | Legacy adapter cables defined & backward compatible with USB 2.0 |

# USB Type-C™ Port Behaviors

**Data roles**

- Downstream Facing Port (DFP): similar to Standard-A host or hub ports
- Upstream Facing Port (UFP): similar to Standard-B or Micro-B device ports

Type-C™ Ports can be host only, device only or dual-role.

**Power roles**

- Source: typical of standard-A host or hub ports
- Sink: typical of standard-B or micro-B device ports

Roles can be dynamically swapped using USB PD (data & power).

# Challenges

- Flippability
  - Automatic wire selection
- Symmetry
  - UFP/DFP negotiation
- Power Delivery
  - Source/sync & voltage/current negotiation
- 10G USB Signaling
  - 5G, USB 2.0 compatibility
  - Legacy connectors
- Alternate Mode Signaling
  - Automatic selection

Simplified user experience drives implementation complexity.

# Challenges & Directions

# Flippability

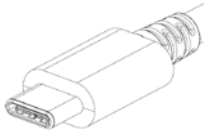
# USB Type-C™ Pin out

Looking into the product receptacle:

| 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 |

| Signal Group | Signal | Description |
|---|---|---|
| USB 3.1 | SSTXp1, SSTXn1<br>SSRXp1, SSRXn1<br>SSTXp2, SSTXn2<br>SSRXp2, SSRXn2 | SuperSpeed USB serial data interface: one transmit diff pair and one receive diff pair<br>Two pin sets to enable plug flipping |
| USB 2.0 | Dp1, Dn1<br>Dp2, Dn2 | USB 2.0 serial data interface<br>Two pin sets to enable plug flipping |
| Configuration | CC1, CC2 (receptacle)<br>CC (plug) | CC channel in the plug used for connection detect, interface configuration and VCONN |
| Auxiliary signals | SBU1, SBU2 | Sideband Use |
| Power | VBUS | USB cable bus power |
| | VCONN (plug) | USB plug power |
| | GND | USB cable return current path |

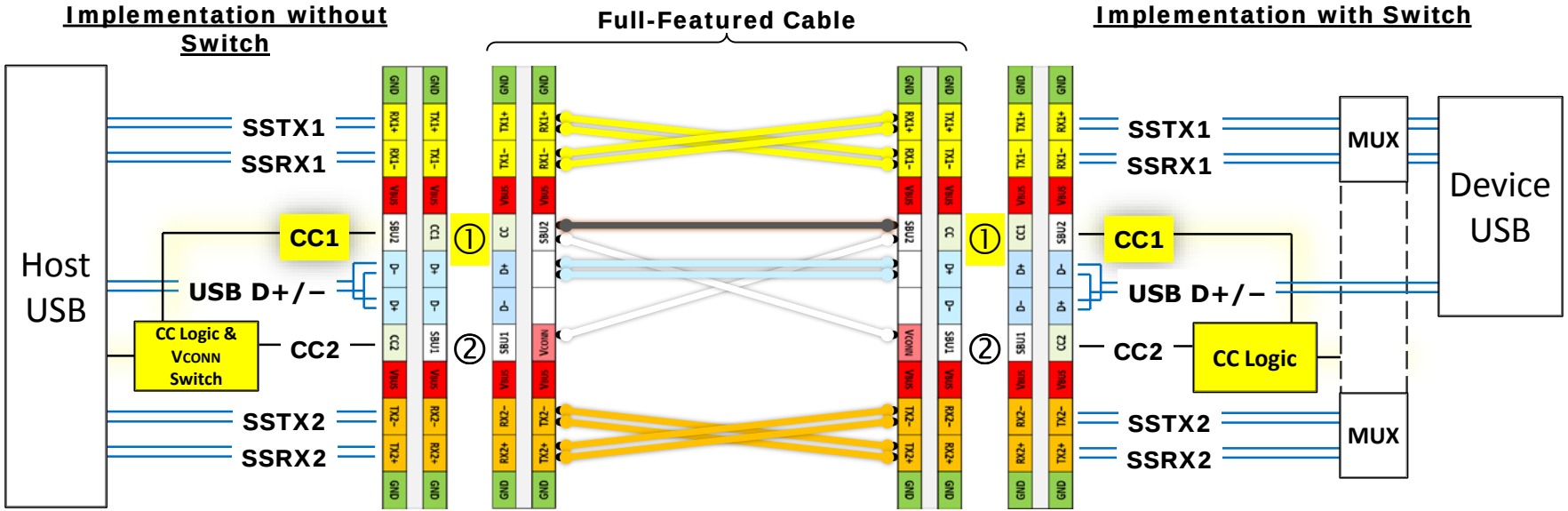
Looking into the cable or product plug:



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

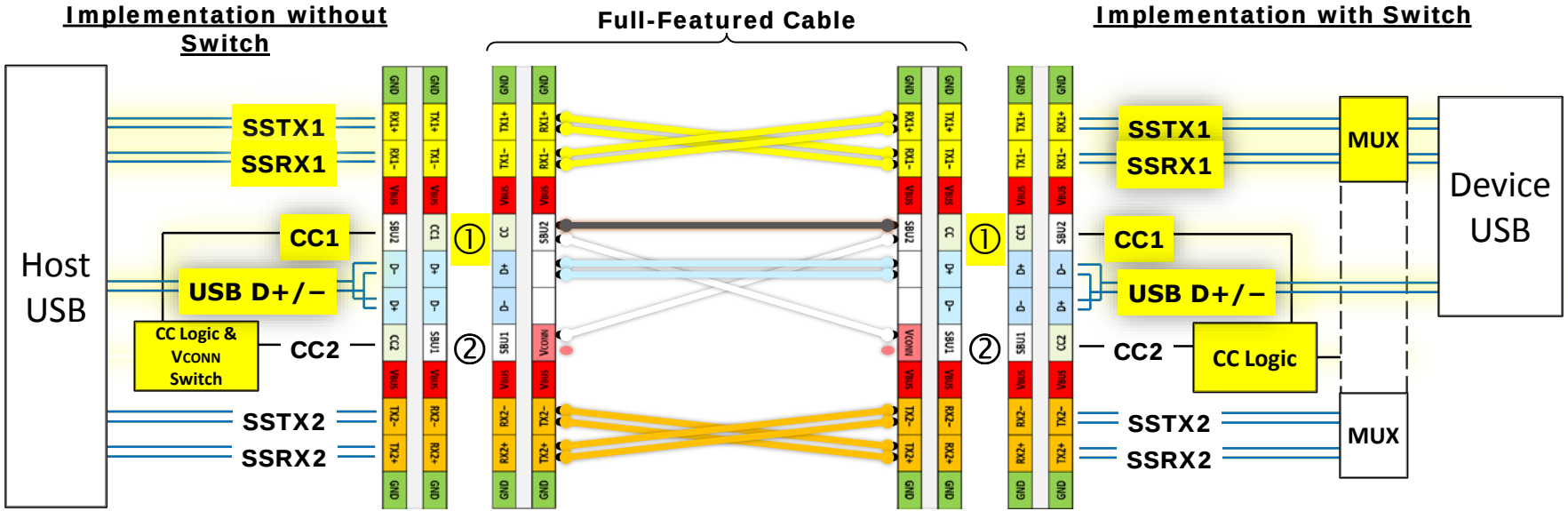
- The CC pin in the plug establishes signal orientation.
- SS Tx, SS Rx and SBU can be re-purposed for alternate protocol extensions.
- Type C can support up 2 USB ports, a DPx4 port, or a USB port and a DPx2 port.

# Functional Model



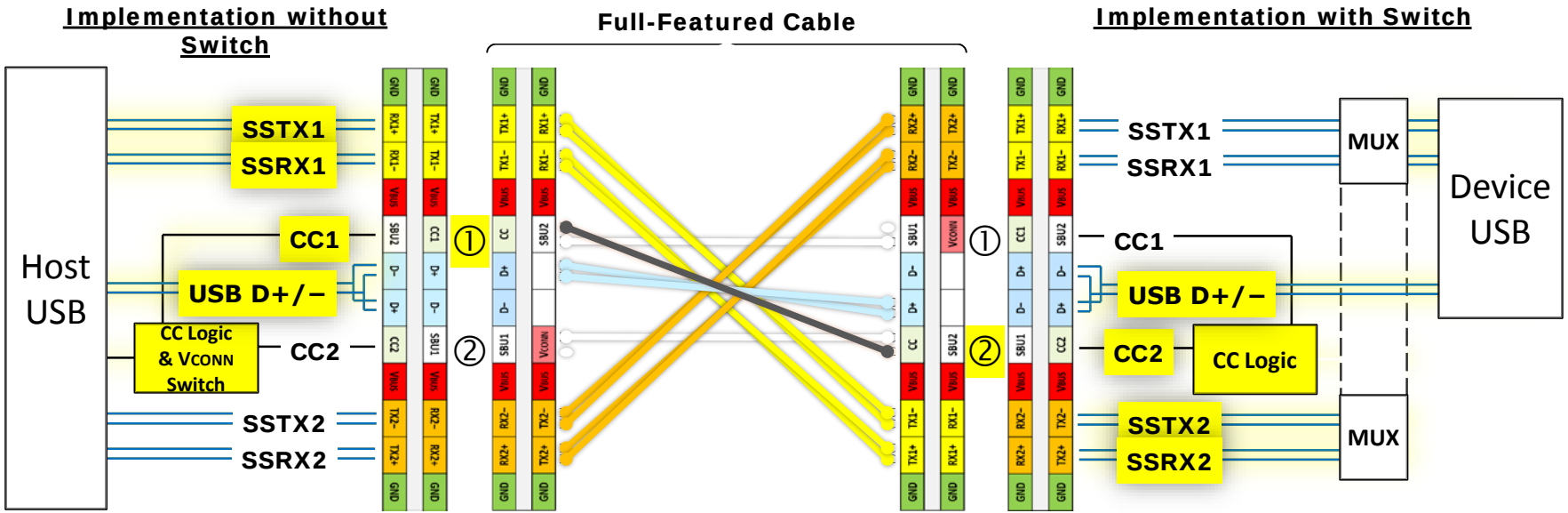

CC wire determines orientation through the cable

# Functional Model



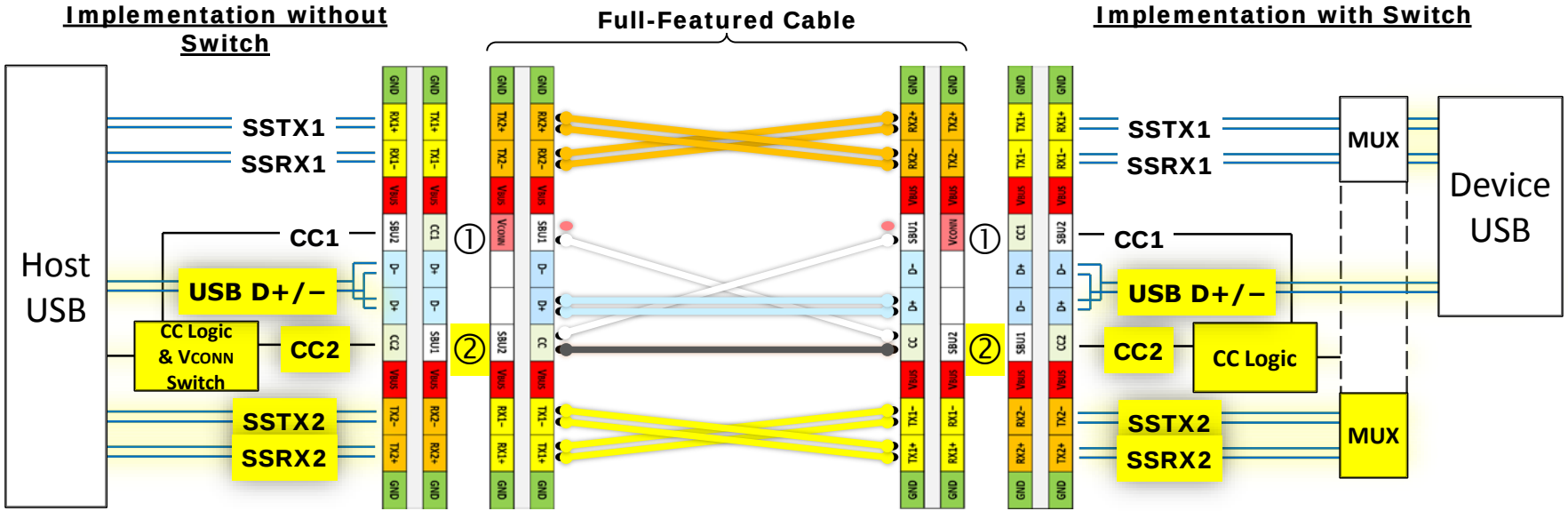

⇨ Un-flipped straight through – Position ① ⇔ Position ①

# Functional Model



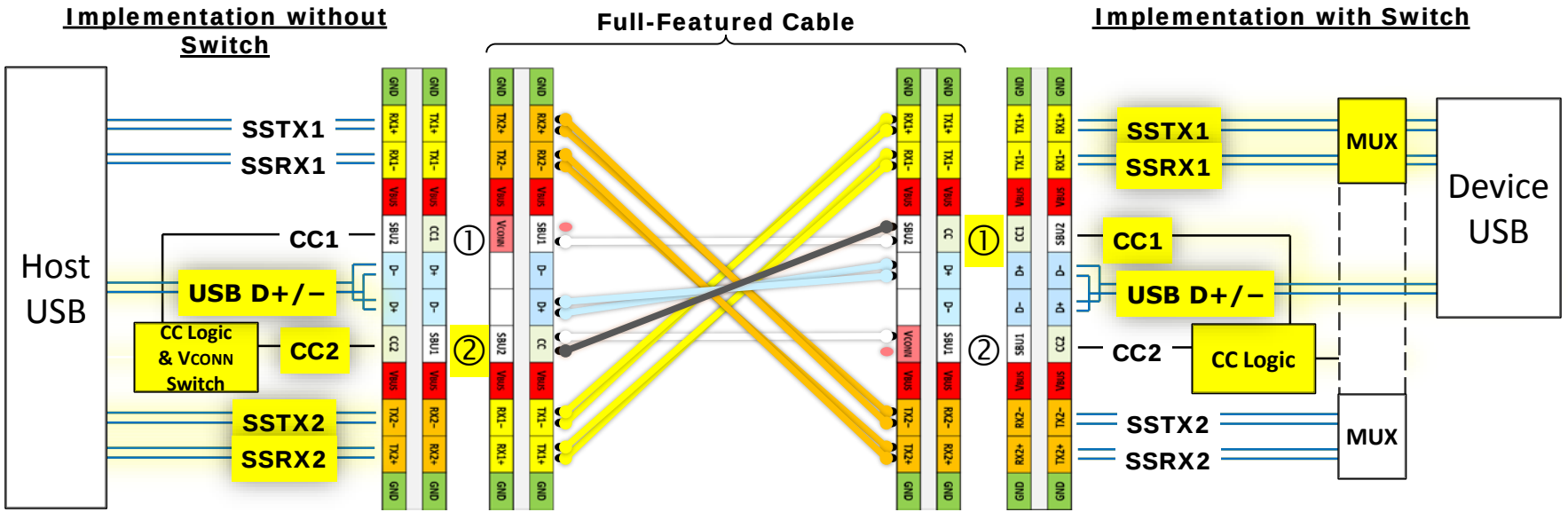

⇨ Un-flipped twisted through – Position ① ⇔ Position ②

# Functional Model



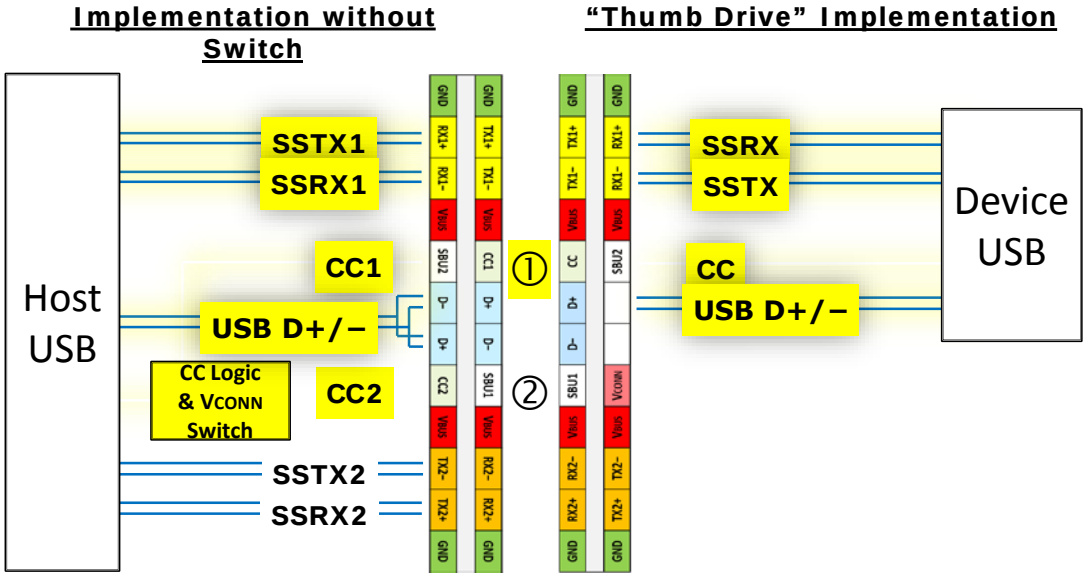

⇨ Flipped straight through – Position ② ⇔ Position ②

# Functional Model



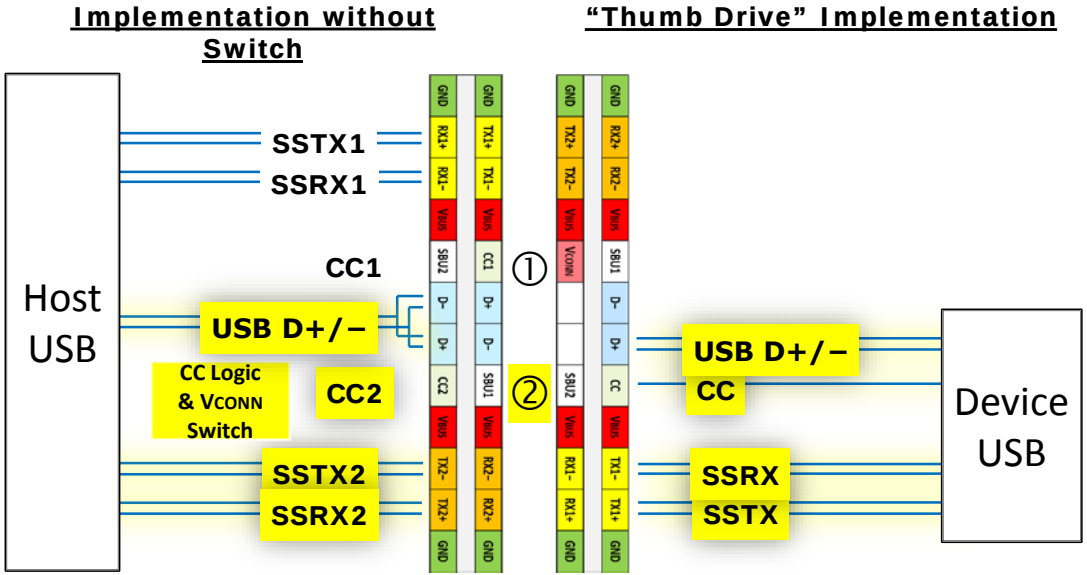

⇨ Flipped twisted through – Position ② ⇔ Position ①

# Direct Connect Functional Model




⇨ Un-flipped – Position ①

# Direct Connect Functional Model




⇨ Flipped – Position ②

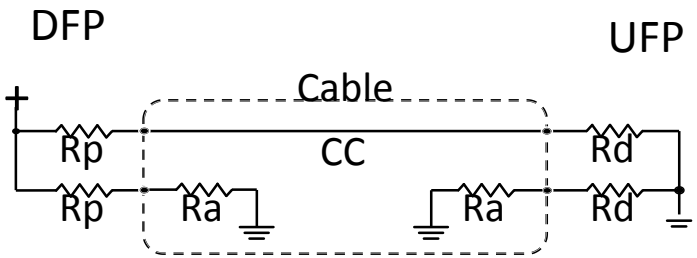
# Symmetry

# USB Type-C™ Port Data Roles

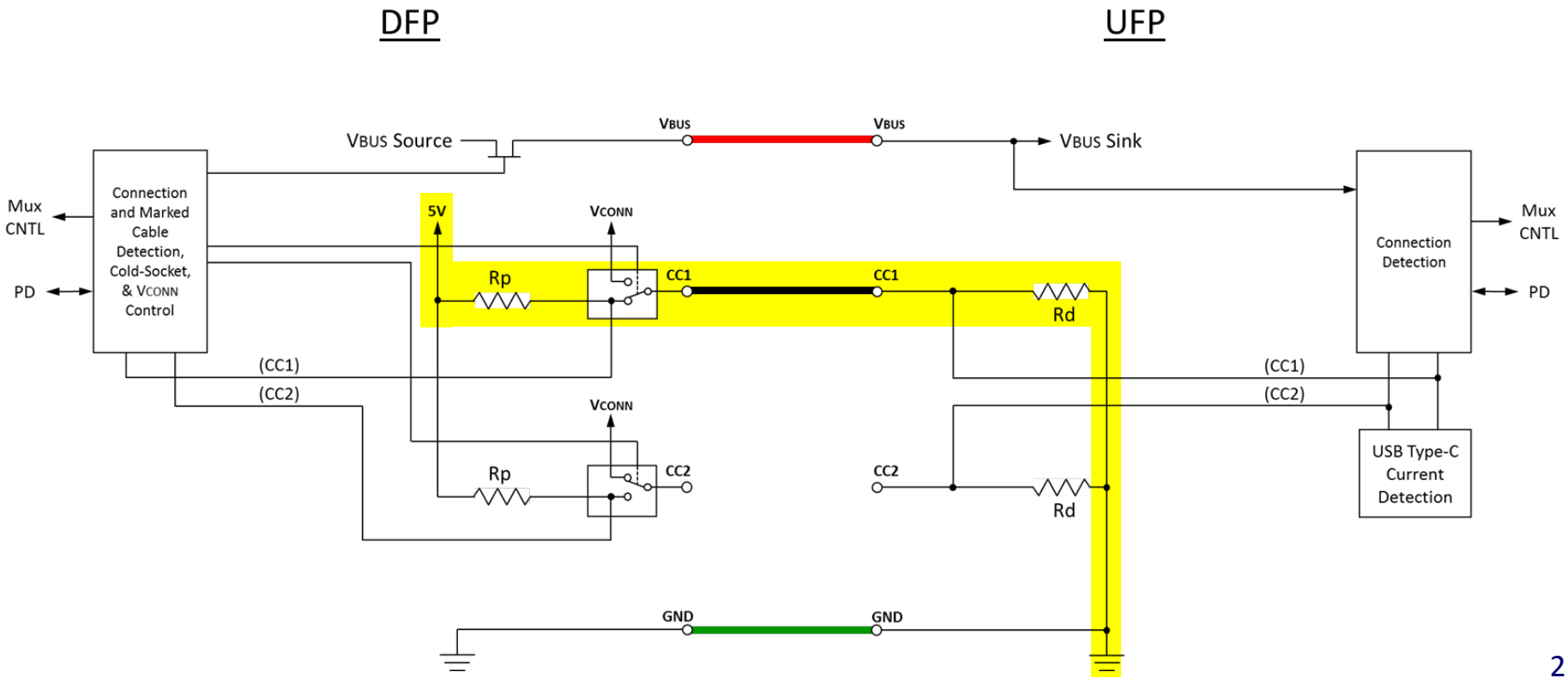
- Type-C™ ports can be host only, device only or dual-role.
  - Downstream Facing Port (DFP)
  - Upstream Facing Port (UFP)
  - Dual-role port (DRP) toggles between DFP and UFP states until resolved to the appropriate state based on what is attached to it.
- Roles can be dynamically swapped.

# USB Type-C Pull-Up/Pull-Down CC Model

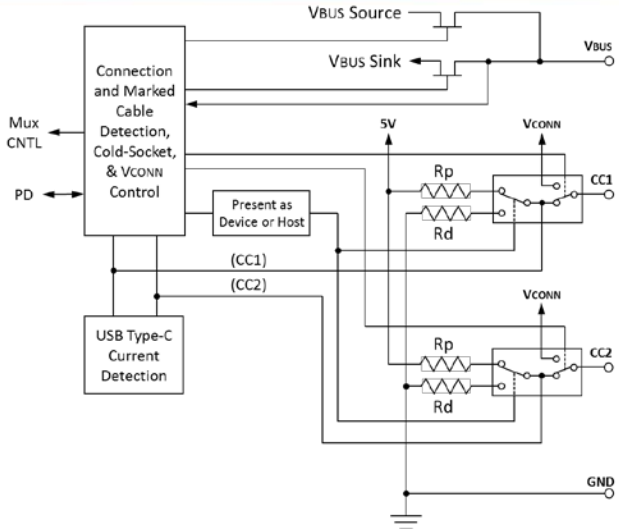
| | CC1 | CC2 | State | Position |
|---|---|---|---|---|
| Typical USB connections | Open | Open | Nothing connected | N/A |
| | Rd | Open | UFP connected | ① |
| | Open | Rd | UFP connected | ② |
| | Open | Ra | Powered Cable/No UFP connected | ① |
| | Ra | Open | Powered Cable/No UFP connected | ② |
| Powered Cables | Rd | Ra | Powered Cable/UFP connected | ① |
| | Ra | Rd | Powered Cable/UFP connected | ② |
| | Rd | Rd | Debug Accessory Mode connected (Appendix B) | N/A |
| | Ra | Ra | Audio Adapter Accessory Mode connected (Appendix A) | N/A |

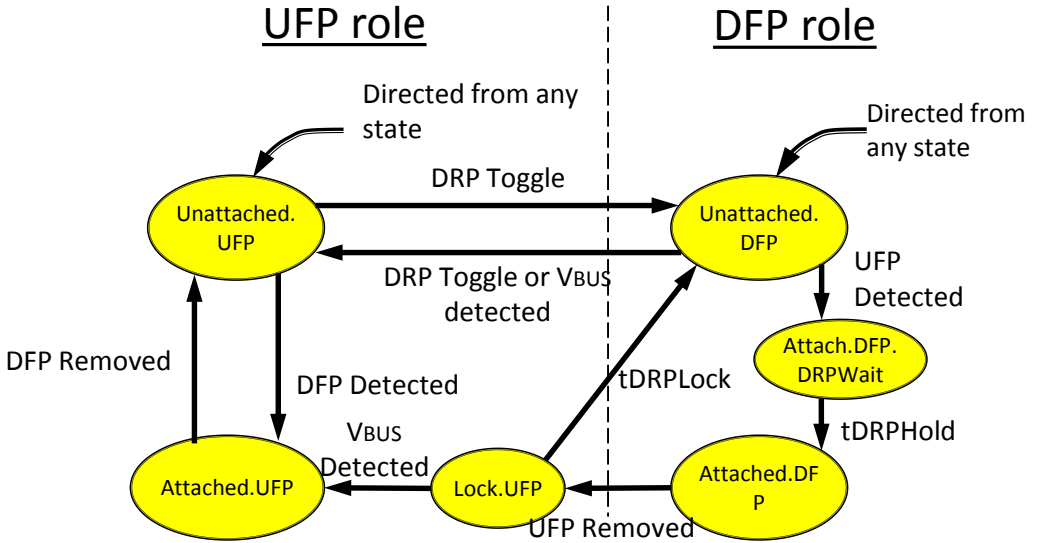


# Basic DFP meets Basic UFP



# Dual Role Port

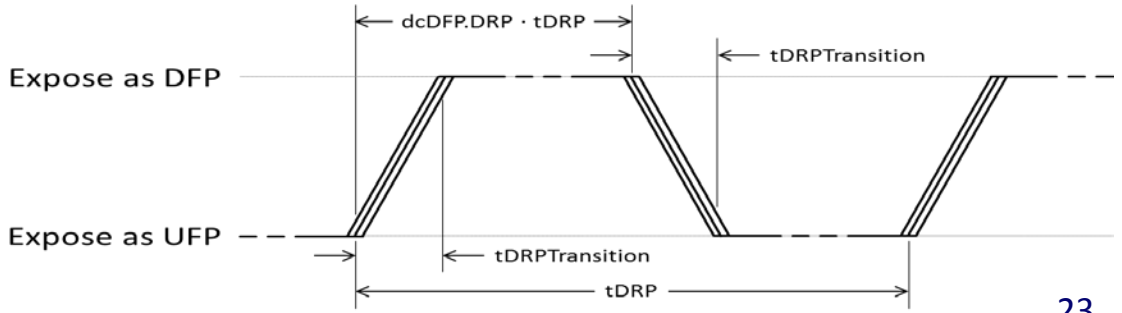


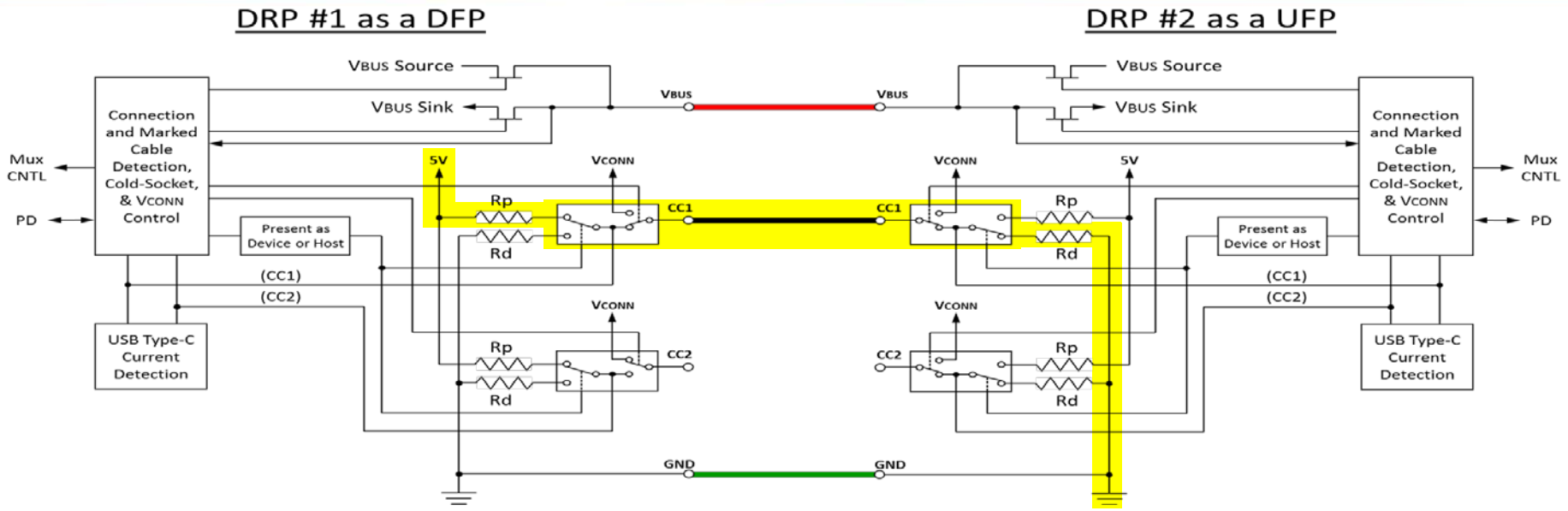

- DRP = DFP + UFP; selects role based on what is attached
- For discovery, DRP toggles between DFP & UFP

# DRP Behavior

- DRP meets DFP: DRP resolves to UFP
- DRP meets UFP: DRP resolves to DFP
- DRP meets DRP: final result depends on…
  - Randomness within toggle protocol
  - Product configuration
  - User preference



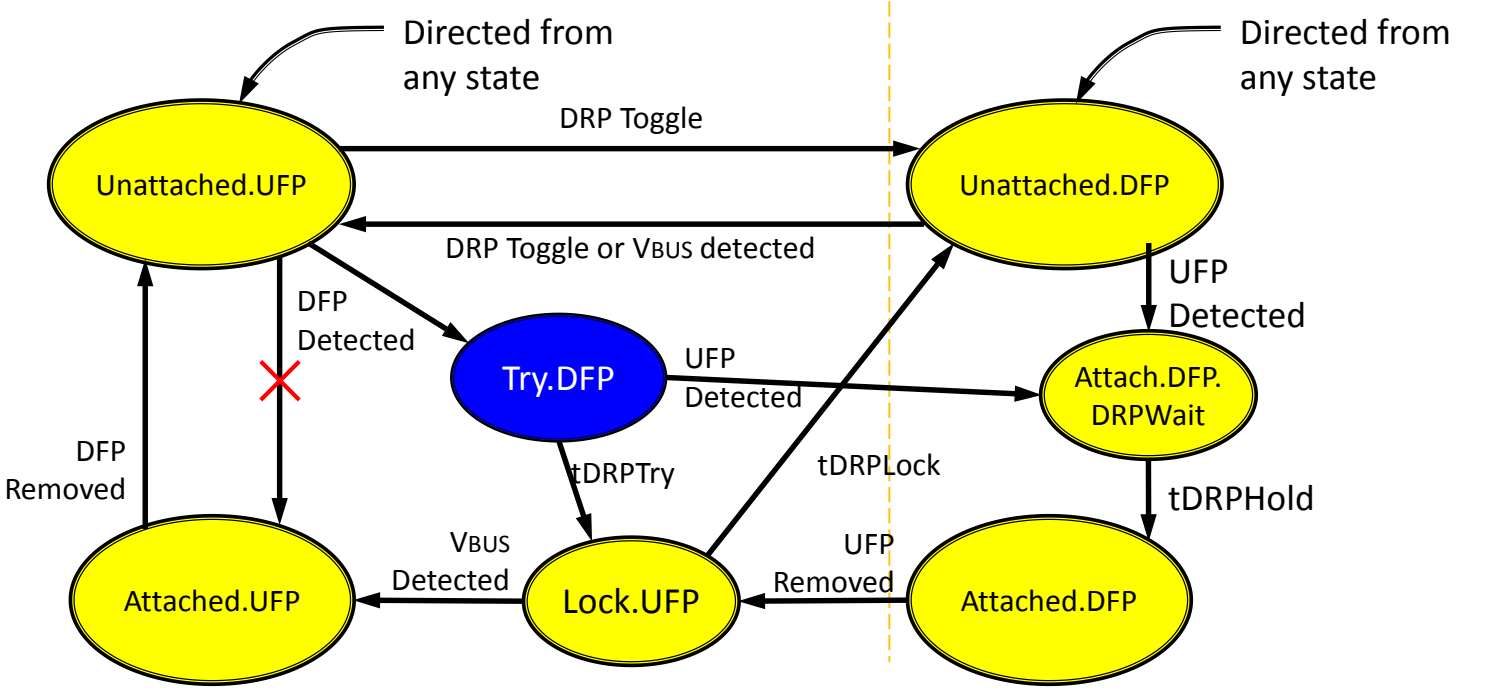
# DRP meets DRP




One DRP resolves to the DFP (host) role and the other resolves to the UFP (device) role.

# What if DRP #2 wants to be DFP?

The USB Type-C Connection State Machine allows a DRP that randomly detects a DFP to attempt to sway the connection to the opposite result



# Power Delivery

# USB Type-C Power Options

All solutions required to support Default USB Power appropriate to product – as defined by USB 2.0 and USB 3.1

| Precedence | Mode of Operation | | Nominal Voltage | Maximum Current |
|---|---|---|---|---|
| Highest | USB PD | | Configurable | 5 A |
| | USB Type-C Current @ 3.0 A | | 5 V | 3.0 A |
| | USB Type-C Current @ 1.5 A | | 5 V | 1.5 A |
| ↓ | USB BC 1.2 | | 5 V | Up to 1.5 A |
| | Default USB Power | USB 3.1 | 5 V | 900 mA |
| Lowest | | USB 2.0 | 5 V | 500 mA |

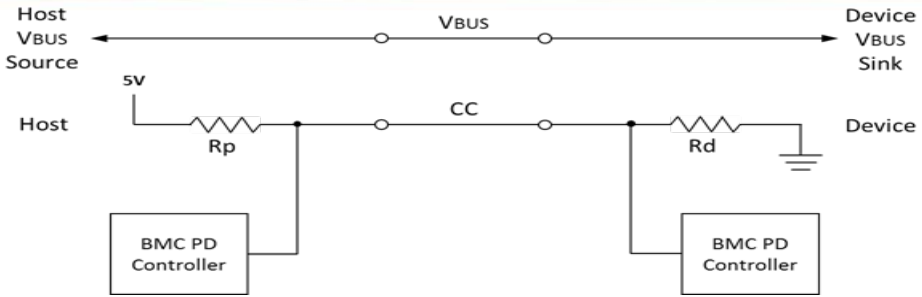
USB Type-C™ Current @ 1.5 A and 3.0 A – *preferred alternative to using BC 1.2 for mobile devices*

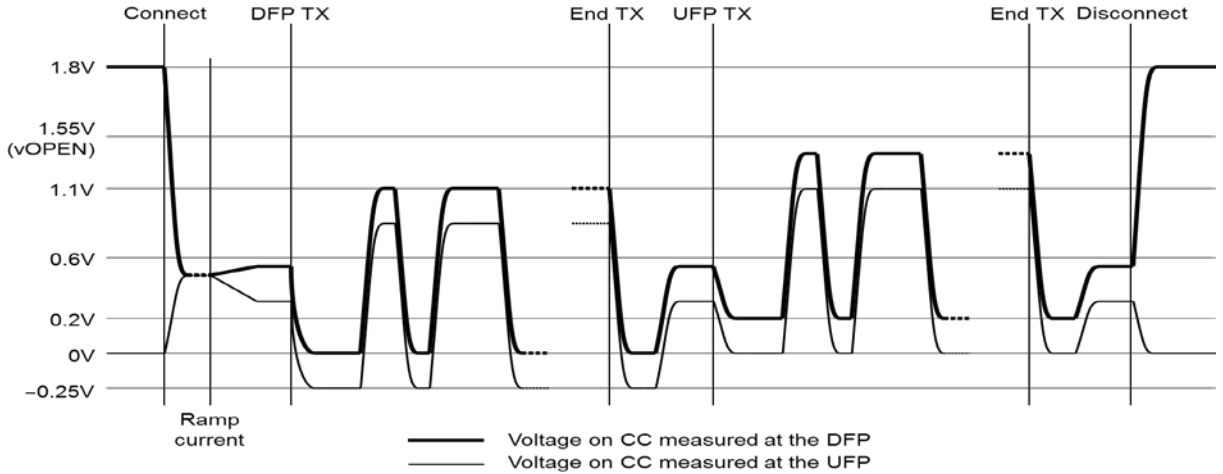
# Port PD Behaviors

- DFP: Normally presents Rp
  - If the DFP requires power to operate (e.g. dead battery case), present Rd and subsequently use USB PD to swap data roles.
- UFP: normally presents Rd
  - If the UFP is able to charge with dead battery, it periodically presents Rp.

# Power Delivery Configuration

USB PD 2.0 specifies DC-coupled Biphase Mark Coding (BMC) signal encoding for use over CC



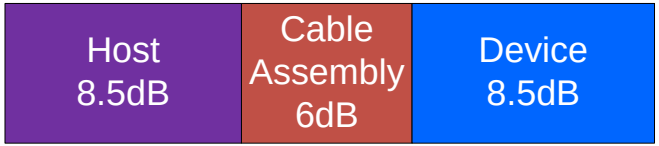
# 10G Signaling

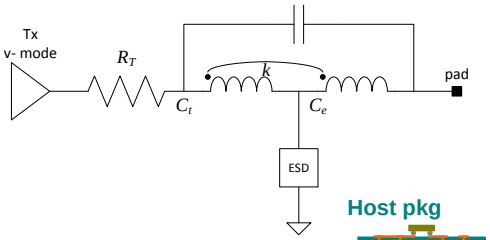
# USB3.1: SuperSpeed Plus

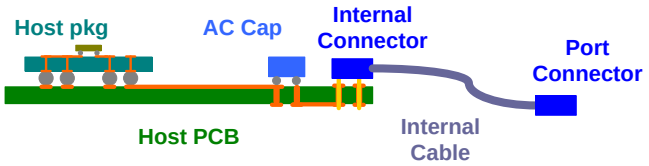
- Motivation: Enhanced USB experience thru higher BW
  - Gen1 speed = 5G with 8b10b encoding
  - Gen2 speed = 10G with 128/132 block coding
- Incremental Change over USB3.0
  - 10G with 128/132b line code (20% BW over 8b10b)
  - 1M passive cable
  - Configuration via LFPS based pulse modulation (LBPM)
  - Compatible w/ legacy connectors

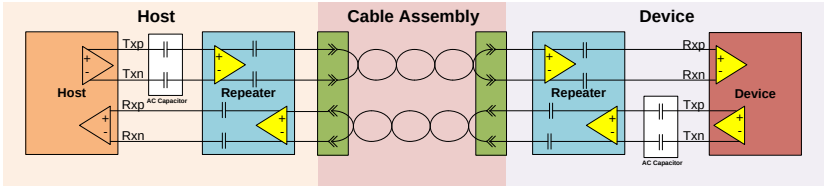
# 10G Challenges

- Limited PCB route length
  - 23dB max channel w/ symmetric loss budget
  - Muxing for flippability & alternate modes
- Mitigation directions
  - Mux integration
  - Pad cap reduction (e.g. Tcoils)
  - Low loss configurations
  - Repeaters



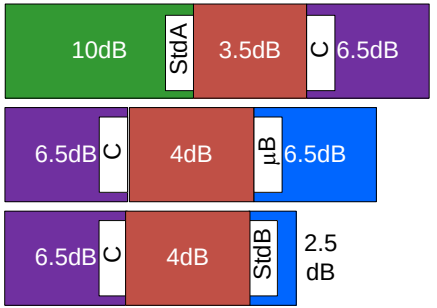
# Legacy Support

# Legacy Cable Assemblies and Adapters

## The most common cables:

| Plug 1 | Plug 2 | USB Version | Cable Length | Current Rating | |
|---|---|---|---|---|---|
| A | C | USB 2.0 | ≤ 4 m | 1.5 A | New devices with legacy host |
| A | C | USB 3.1 Gen2 | ≤ 1 m | 1.5 A | |
| C | B | USB 2.0 | ≤ 4 m | 1.5 A | Legacy peripherals with new host |
| C | B | USB 3.1 Gen2 | ≤ 1 m | 1.5 A | |
| C | Micro-B | USB 2.0 | ≤ 2 m | 1.5 A | |
| C | Micro-B | USB 3.1 Gen2 | ≤ 1 m | 1.5 A | |

### 5G Loss Budgets




## The only defined adapters:

| Plug | Receptacle | USB Version | Cable Length | Current Rating | |
|---|---|---|---|---|---|
| C | Micro-B | USB 2.0 | ≤ 0.15 m | 1.5 A | Legacy Micro-B chargers with new devices |
| C | A | USB 3.1 Gen1 | ≤ 0.15 m | 1.5 A | Legacy "thumb drives" with new hosts |

# Alternate Modes

# Challenges

Expect products to support multiple standards.①

- Automatic detection and configuration
  - Use USB PD protocol
  - Expect discrete solutions thru ~2016, eventual migration to integrated solution
- Multi-protocol repeaters

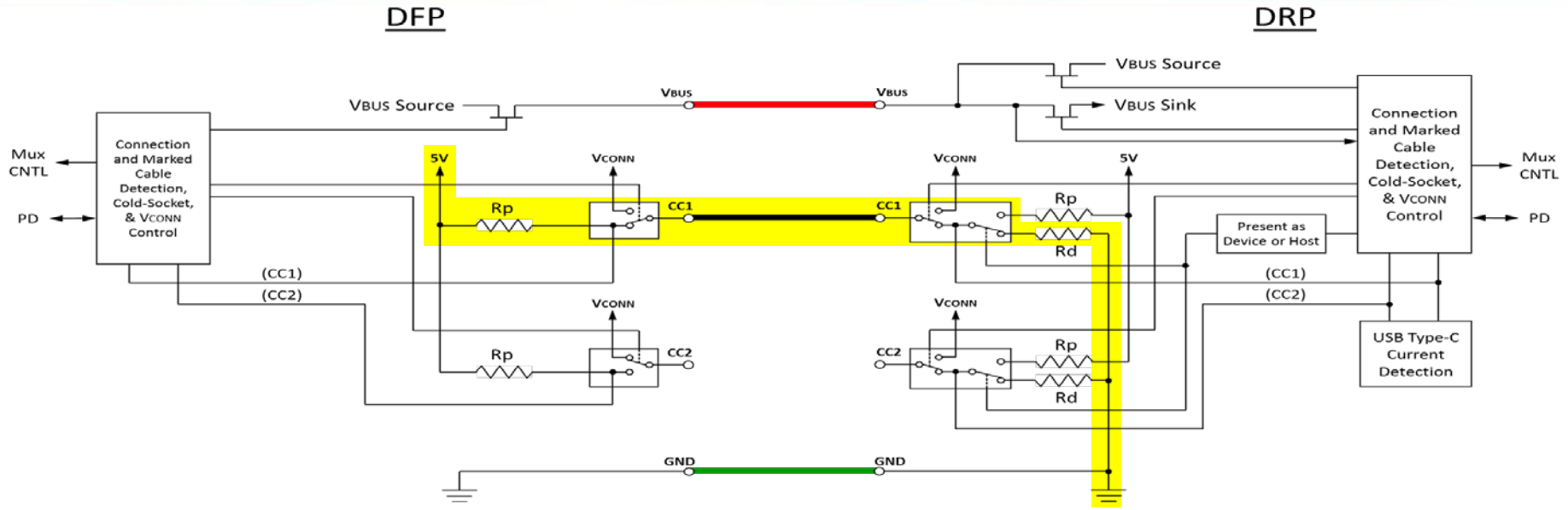
① VESA® Brings DisplayPort™ to New USB Type-C Connector, 09/22/2014, www.vesa.org.

# Summary

- USB Type-C™ promises a great user experience: Plug it in and it works.
  - Whatever: mouse, keyboard, SSD, display…
  - However: upside down/rightside up, either plug
- To realize that promise the industry must incorporate significant complexity into product designs while addressing multiple technical challenges.

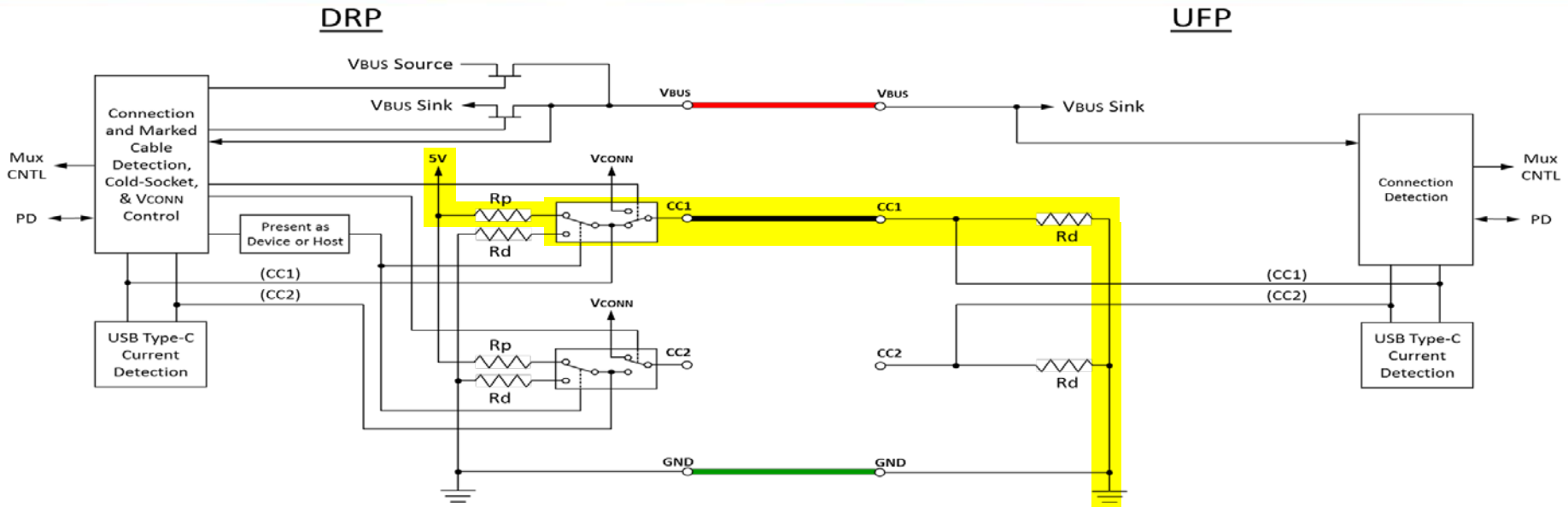
# Additional Details

# DFP meets DRP



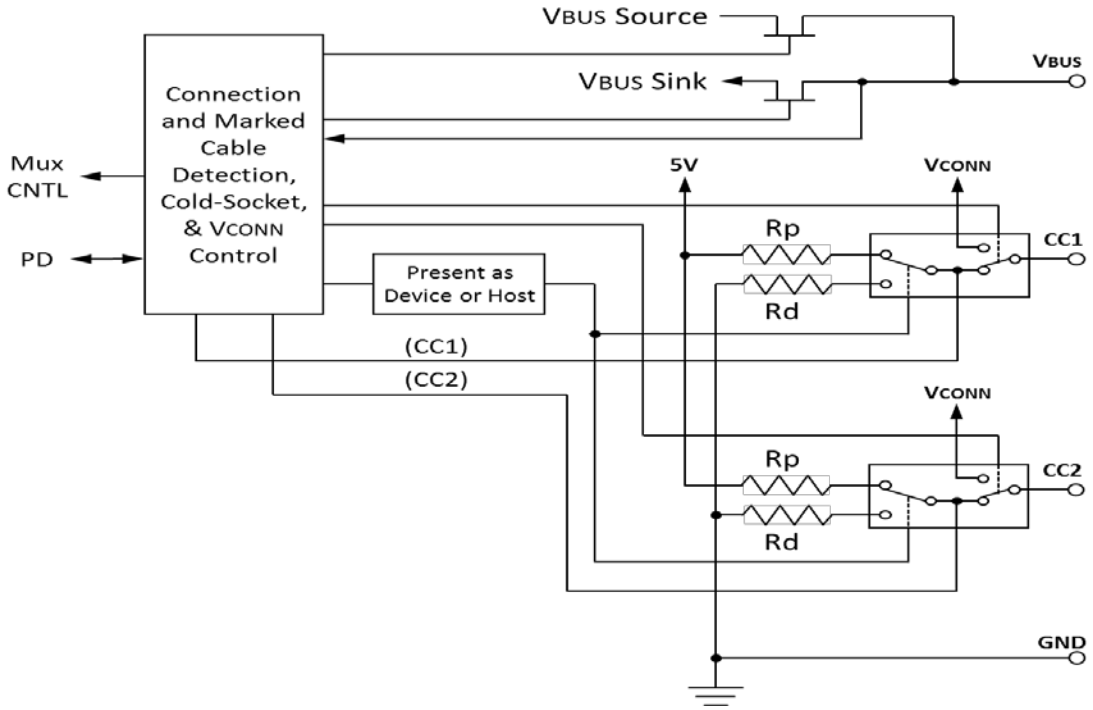

DRP resolves to the UFP (device) role

# DRP meets UFP




DRP resolves to the DFP (host) role

# DFP Supporting USB PD Provider/Consumer




- Supports USB PD data and power role swaps
- Normally Rp is presented
  - If the DFP requires power to operate (e.g. dead battery case), present Rd and subsequently use USB PD to swap data roles

# UFP Supporting USB PD Consumer/Provider

- Supports USB PD data and power role swaps
- Normally Rd is presented
  - If the UFP is able to charge with dead battery, it periodically presents Rp