USB Type-C\textsuperscript{TM}, IEEE CSNV

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- Material in this presentation is taken from USB Type-C and USB PD2.0 Specs
  - Specs are available from USB-IF at http://www.usb.org and are subject to change. Usage restrictions are included in the spec.
  - If there are any deviations from spec in this material, the latest spec should be used as reference. User assumes all risk when using this material.
What is USB-C?

• One plug and one cable for:
  • High speed data transfer (USB2.0 & USB3.1G1 and G2)
  • High power charging (5 to 20V, up to 100W)
  • Display: up to 4 DP lanes
  • Powered dongles (device powers active cables)
  • Docking (combinations of above functions)
  • Debug: debug aux mode
  • and more....

• 24 Pin Reversible, Symmetric Cable
  • Either end can be plugged in either orientation
  • Each end is identical

Much more than “just USB!”
USB Type-C Plug and Socket

Figure 3-3  USB Full-Featured Type-C Plug Interface Dimensions

Figure 3-7  Reference Footprint for a USB Type-C Mid-Mount Dual-Row SMT Receptacle (Informative)
Roles and Cable Orientation

- USB-C endpoints (port partners) are either a DFP (downward facing port), a UFP (upward facing port) or a DRP (dual role port)
  - DFP = host, also typically the power source
  - UFP = device, also typically the power sink
  - DRP = host or device (think OTG)
- Until roles are determined, ALL signals except CC and Gnd are undriven
- CC lines used to determine roles, to determine cable orientation and to communicate between endpoints
- USB3 (SS) lanes live on one of two possible locations based on cable orientation: mux needed to select correct one
- Alternate modes (e.g., DisplayPort) repurpose SS lanes: mux needed to select different outputs to send to the USB3 socket
### Signal Group

<table>
<thead>
<tr>
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<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB 3.1</td>
<td>SSTXp1, SSTXn1, SSTRXp1, SSTRXn1</td>
<td>SuperSpeed USB serial data interface: one transmit diff pair and one receive diff pair</td>
</tr>
<tr>
<td></td>
<td>SSTXp2, SSTXn2, SSTRXp2, SSTRXn2</td>
<td>Two pin sets to enable plug flipping</td>
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<td>USB 2.0</td>
<td>Dp1, Dn1</td>
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<tr>
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<td>Configuration</td>
<td>CC1, CC2 (receptacle)</td>
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<td></td>
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<tr>
<td>Auxiliary signals</td>
<td>SBU1, SBU2</td>
<td>Sideband Use</td>
</tr>
<tr>
<td>Power</td>
<td>VBUS</td>
<td>USB cable bus power</td>
</tr>
<tr>
<td></td>
<td>VCONN (plug)</td>
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How does it work?

- Roles and cable orientation are determined by “CC” lines
  - Only 1 CC line is connected through the cable
  - DFP will provide a resistive pull-up (Rp) on both CC lines
    - Rp varies depending on current sourcing capability of DFP
    - 3 defined values: “default”, 1.5A and 3.0A
  - UFP will provide a resistive pull-down (Rd) on both CC lines
    - Rd is defined and fixed
- When a DFP is connected to a UFP, each will see one CC line at an intermediate voltage
  - Which CC line tells both the cable orientation
    - Cable orientation could be different at each end
    - DFP then knows to turn on “Vbus” to supply power to the UFP
    - UFP knows the current capabilities of the DFP by the voltage level on CC
• Cable/dongle can put a different resistive pulldown (Ra) on the second CC line
  • DFP needs to distinguish between Rd (CC line that goes through) and Ra (CC line that doesn’t go through)

• Ra tells the DFP that the cable/dongle needs power, independent of the Vbus power
  • Power called Vconn, supplied on the Ra CC line
  • DFP needs to provide 5v at up to 200mA for Vconn
    – Alternate modes can provide means for cable/dongle to ask for more than 200mA!
  • Vbus can vary from 5v to 20v, Vconn always remains at 5v
  • Used by an active cable, e.g., to power an integrated retimer
  • Used by a dongle, e.g., to power a DP to HDMI protocol converter
Many devices are sometimes DFPs and other times UFPs
  • A laptop is a DFP to a mouse but a UFP to a charger

When disconnected, DRP devices alternate Rp with Rd on the CC lines
  • 50ms or so switching rate
  • Specified to be inaccurate clocks to prevent synchronized switching between port partners

Devices can express a preference to be a UFP or a DFP
  • A phone might be a DRP to work with a thumbdrive
  • Always wants to be a power sink when connected with most other DRPs, e.g., laptops
• Once initial roles are established, USB-PD 2.0 can take over
  • USB-PD is optional
  • USB-PD signaled over the connected CC line once roles established
• USB-PD2.0 on Type-C uses Biphase Mark Coding (BMC) over the CC line
• Packets exchanged between port partners
Packets...

- **SOP, SOP’, SOP”**
  - “Start of Packet”
  - SOP are responded by port partner
  - SOP’ are responded by the near side connector
  - SOP” are responded by the far side connector
  - Device can poll cable for capabilities, e.g., current carrying ability

- **CRC**
  - Packets tested for integrity
  - Receiver must check packet integrity and respond within 1.1ms to avoid retransmit

- **Messages and Responses all have SOP*, CRC and EOP**
What Can You Do With PD?

• Get more power!
  • Without PD, power supply limited to 3A@5V
  • With PD, UFP asks for power modes DFP supports
    – DFP responds with up to 7 Power Data Objects (PDOs)
    – These indicate voltage/current capabilities of power supply
      – Must also factor in cable capabilities!
    – Up to 5A@20V
  • The UFP and DFP can then negotiate a new “power contract”
    – UFP selects one of the offered PDOs
• UFP and DFP can swap Vbus power roles, Vconn power roles or data roles
  • Why? Devices and docks both are usually DRPs
    – System is a power source (DFP) to a device, e.g., a mouse or a thumb drive
    – System is a power sink (UFP) to a charger
    – System is a power sink (UFP) but a data host (DFP) to a dock
    – System is a power sink (UFP) but a data host (DFP) to a monitor
• UFP and DFP can agree on alternate modes
  • USB3 lanes can be repurposed for other things, e.g., DisplayPort
And there is still more

- Aux modes are also supported
- Indicated by both CC lines pulled down to “Rd” or both lines pulled down to “Ra”
  - Cable orientation handled by alternate means
- Two are defined:
  - Analog audio aux mode
  - Debug aux mode
- Debug is interesting, analog audio less so
Implementations

- Something needs to run the state machines
  - Some implementations use a dedicated microcontroller
    - Embedded flash to eliminate external program store
    - Straightforward solution to meeting latencies
  - Other implementations use OS drivers or other CPU code
    - Needs to operate when system is “off”
    - Potentially problematic timing with system load

- Something needs to mux the signals
  - High speed mux for USB3 cable orientation or USB-to-alternate mode function muxing
  - Can use multiple USB3 ports for USB3 cable orientation

- Industry support on the fast track:
  - TI, Cypress, Lattice, Pericom, Rohm, Analogix, DIY, ...
What Could Possibly Go Wrong?

• Tiny power supplies charging large devices
  • The connector fits so why isn’t my laptop charging?
• Active cables and alternate modes
  • In the past, connectors defined cable capabilities...
• Asymmetric ports
  • Supporting all features on all ports adds incremental cost
  • One port may (will?) likely be used just for the power brick but
    – If one port is dedicated just for charging, how to you indicate
    – Different users might want to use different ports for charging
  • Similar arguments could be made for display
• User interface needs to help user understand behavior
  • Needs to help user understand USB “it just works” promise
Questions?