Introduction to USB Type-C™

Connectors and Cables

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Director of Application Engineering
Introduction to USB Type-C™

- Introduction

This document is intended to provide an overview of the next generation of USB connectors and cables. The USB Type-C cable is now considered the “universal” cable, as it has a reversible form factor, transfers USB3.1 SuperSpeed Plus data at 10Gbps and USB Power Delivery up to 100W of continuous power flow. The new Type-C plug and receptacle will not directly mate with existing USB connectors; however, the USB Type-C specification defines new Type-C to legacy cables and adapters that allow consumers to connect to existing products.
The Single Connector Platform Model
Key Features of USB 3.1

- Support attach of much higher performance peripherals
  - A/V Display beyond 1080p (uncompressed) and multi-displays
  - SSD, RAID HDD, or Hybrid HDD
- Blazing fast data sync
- Enable multi-function, single port connections
  - SuperSpeed Hubs with fatter system pipe supporting multiple SuperSpeed downstream devices
  - Display Dock enabling mix of SuperSpeed-based A/V, webcam, storage, etc. over a single connection
Comparison of USB connectors

The USB Type-C connector and cable specification defines a new receptacle, plug, cable and detection mechanisms that are compatible with existing USB interface electrical and functional specifications. Type-C is low profile, narrower, and more robust.

Type-C 24 Pin Receptacle

Type-C 22 Pin Plug

Standard-A, 9 pins

Micro-AB, 10 pins
PALCONN USB 2.0/3.1 Type-C Models

- USB 3.1 Type-C Top Mount Hybrid Receptacle with removable bezel clip, 24 pins
- USB 3.1 Type-C Mid-Mount Hybrid Receptacle with 18 SMT and 6 THT output pins
- USB 3.1 Type-C Top Mount Hybrid Receptacle with four mounting tabs, 24 pins
- USB 2.0 Type-C Top Mount SMT Receptacle with 16 pins
- USB 3.1 Full Featured Type-C Plug, 22 pins
- USB 2.0/3.1 Type-C Plug, Deep Drawn Shell
Key Features of the USB Type-C connector

- Entirely new design
  - Tailored for emerging product designs
  - Robust enough for laptops and tablets; slim enough for mobile phones
  - Similar to size of USB 2.0 Micro-B
- Usability enhancements
  - Both plug and cable orientation no longer keyed
  - Hosts and devices require logic to resolve their roles for proper USB bus operation
- Supports scalable power charging
- Future scalability
  - Designed to support future USB performance needs
- Two Power Sources
  - VBUS – definition expanded with USB Type-C Current
  - VCONN – a dedicated source for powering cable electronics, +5V pin powers circuits in the plug needed to implement Electronically Marked Cables. Vconn is independent of VBUS.
USB Type-C Receptacle Mechanical Features

• Type-C receptacle

• Receptacle Mechanical Features
  • Receptacle opening: 8.34mm X 2.56mm
  • Durability: 10,000 cycles
  • Improved EMC and RFI mitigation features
  • No exposed voltage pins

• Key Components
  • Shell
  • EMC Shield
  • Alignment
  • Tongue with mid-plate
    • 24 Signal contacts
    • Ground plane
    • Latching detents
    • Robustness

• Retention of the cable assembly in the receptacle is achieved by the side-latches in the plug and detent features on the sides of the receptacle tongue.
USB Type-C Plug Mechanical Features

- Type-C plug

  - Plug Mechanical Features
    - Plug front mating dimension: 8.25mm X 2.4mm
    - Durability: 10,000 cycles min
    - Mating force: 5 N to 20 N
    - Un-Mating force: 8 N to 20 N
    - Improved EMC and RFI mitigation features

- Key Components - Full-Feature and USB 2.0 only versions
  - Shell- laser weld or deep drawn styles
  - 22 Signal contact springs
  - Cable Electronic Marking (as required)
  - Latching springs
    - Provides positive feel for full insertion
    - Maintains mated condition
    - Eliminates holes in the shell, providing EMC reduction
    - Provides an additional GROUND return path
  - EMC springs
    - Full-Feature version has six springs while USB 2.0 version has four
    - EMC springs are critical to design to ensure the springs don’t short Vbus to GND
Type-C Electrical Performance

• Electrical Ratings
  ▪ Supports 3A for standard cables
  ▪ Supports 5A for connectors
  ▪ Supports voltages as high as +20V

• Contact Ratings
  ▪ contact resistance  40 mΩ
  ▪ connector contact current rating of 5A for (4) ganged VBUS pins
  ▪ contact construction requires new method for measuring temperature rise

• Impedance
  ▪ connector differential impedance  85 +/- 9 Ohms
    ▪ along interconnect path, determined by geometry, dielectric materials, stamped and formed contacts to match impedance
  ▪ raw cable differential impedance  90 +/- 5 Ohms
    ▪ chosen for lower loses
USB Type-C Configuration Channel (CC1/CC2)

The CC1 and CC2 pins are used to connect to either the CC or VCONN wire in a USB Type-C cable.

- Cable Attach and Removal Detection of USB Ports

- Resolve cable orientation and twist connections, current capability to establish USB data bus routing

- Establish “host” and “device” roles between two attached ports

- Discover and configure VBUS

- Configure VCONN, which is 5V, 1.0W power supply used to power circuits within the plug that are needed to implement E-Mark cables

- Discover and configure optional Alternate and Accessory modes
## USB Type-C Functional Pin-Out

<table>
<thead>
<tr>
<th>Receptacle</th>
<th>Plug</th>
</tr>
</thead>
</table>

### Receptacle

<table>
<thead>
<tr>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
<th>A7</th>
<th>A8</th>
<th>A9</th>
<th>A10</th>
<th>A11</th>
<th>A12</th>
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</thead>
<tbody>
<tr>
<td>GND</td>
<td>TX1+</td>
<td>TX1-</td>
<td>VBUS</td>
<td>CC1</td>
<td>D+</td>
<td>D-</td>
<td>SBU1</td>
<td>VBUS</td>
<td>RX2-</td>
<td>RX2+</td>
<td>GND</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B12</th>
<th>B11</th>
<th>B10</th>
<th>B9</th>
<th>B8</th>
<th>B7</th>
<th>B6</th>
<th>B5</th>
<th>B4</th>
<th>B3</th>
<th>B2</th>
<th>B1</th>
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<tbody>
<tr>
<td>GND</td>
<td>RX1+</td>
<td>RX1-</td>
<td>VBUS</td>
<td>SBU2</td>
<td>D-</td>
<td>D+</td>
<td>CC2</td>
<td>VBUS</td>
<td>TX2-</td>
<td>TX2+</td>
<td>GND</td>
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</table>

### Plug

<table>
<thead>
<tr>
<th>A12</th>
<th>A11</th>
<th>A10</th>
<th>A9</th>
<th>A8</th>
<th>A7</th>
<th>A6</th>
<th>A5</th>
<th>A4</th>
<th>A3</th>
<th>A2</th>
<th>A1</th>
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</thead>
<tbody>
<tr>
<td>GND</td>
<td>RX2+</td>
<td>RX2-</td>
<td>VBUS</td>
<td>SBU1</td>
<td>D-</td>
<td>D+</td>
<td>CC</td>
<td>VBUS</td>
<td>TX1-</td>
<td>TX1+</td>
<td>GND</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B1</th>
<th>B2</th>
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<th>B4</th>
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<th>B9</th>
<th>B10</th>
<th>B11</th>
<th>B12</th>
</tr>
</thead>
<tbody>
<tr>
<td>GND</td>
<td>TX2+</td>
<td>TX2-</td>
<td>VBUS</td>
<td>Vconn</td>
<td></td>
<td>SBU2</td>
<td>VBUS</td>
<td>RX1-</td>
<td>RX1+</td>
<td>GND</td>
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# USB Type-C Signal Summary

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

Implementation without Switch

This version of the model illustrates a traditional host to device

Implementation with Switch

Platform implementation impact varies based on capabilities chosen and level of integration
USB Type-C Functional Model

Implementation without Switch

Full-Featured Cable

Implementation with Switch

Host USB

USB D+/

CC Logic & VCONN Switch

SSTX1

SSRX1

SSTX2

SSRX2

Device USB

USB D+/

CC Logic

MUX

MUX

USB Type-C Plugs

CC wire determines orientation through the cable
## USB Type-C Power Options

<table>
<thead>
<tr>
<th>Mode of Operation</th>
<th>Nominal Voltage</th>
<th>Maximum Current</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB 2.0</td>
<td>5V</td>
<td>500mA</td>
<td>Default USB Power</td>
</tr>
<tr>
<td>USB 3.1</td>
<td>5V</td>
<td>900mA</td>
<td>Default USB Power</td>
</tr>
<tr>
<td>USB BC 1.2</td>
<td>5V</td>
<td>Up to 1.5A</td>
<td>Legacy charging</td>
</tr>
<tr>
<td>USB Type-C Current @ 1.5A</td>
<td>5V</td>
<td>1.5A</td>
<td>Supports higher power devices</td>
</tr>
<tr>
<td>USB Type-C Current @ 3.0A</td>
<td>5V</td>
<td>3A</td>
<td>Supports higher power devices</td>
</tr>
<tr>
<td>USB PD</td>
<td>Configurable up to 20V</td>
<td>Configurable up to 5A</td>
<td>Directional control and power level management</td>
</tr>
</tbody>
</table>
## USB Type-C Cable Length Summary

<table>
<thead>
<tr>
<th>USB Version</th>
<th>Cable Length</th>
<th>Current Rating</th>
<th>USB Power Delivery</th>
<th>Electronically Marked</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB2.0</td>
<td>≤ 4 Meters</td>
<td>3A 5A</td>
<td>Supported</td>
<td>Optional Required</td>
</tr>
<tr>
<td>USB3.0</td>
<td>≤ 2 Meters</td>
<td>3A 5A</td>
<td>Supported</td>
<td>Required Required</td>
</tr>
<tr>
<td>USB3.1</td>
<td>≤ 1 Meter</td>
<td>3A 5A</td>
<td>Supported</td>
<td>Required Required</td>
</tr>
</tbody>
</table>
Type-C Full Featured Cable Assembly
(Type-C Plug + Paddle Board + Cable, Top & Bottom Views)
Wire / Raw Cable

- No hard requirement on wire type. Expect both micro-coax and shielded twisted pairs to be used.
- Raw cable impedance for SuperSpeed pairs is recommended to be 90+/-5 ohms
  - 85 ohm cable would be better in matching impedance with the connector, but it will have more loss.
- Managing intra-pair skew is important to meet the mode conversion spec, particularly for micro-coax.
- Pay attention to wire bundle design to achieve impedance and crosstalk targets for the low speed (CC, SBU, Vbus, and USB 2.0).
# USB 3.1 Type-C Cable Assemblies
## Palconn Product Offering

<table>
<thead>
<tr>
<th>USB 3.1 Cable Assembly</th>
<th>P1</th>
<th>P2</th>
<th>Palconn Part Number</th>
<th>Cable Length</th>
<th>Signals</th>
<th>USB-IF Legacy Reference</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB 3.1 Type-C, Full Featured, E-Mark Cable</td>
<td>Type-C</td>
<td>Type-C</td>
<td>USB-UB-001-033</td>
<td>≤1M</td>
<td>All signals, with Vconn, E-Mark</td>
<td>n/a</td>
<td>ALL</td>
</tr>
<tr>
<td>USB 3.1 Type-C Standard Cable</td>
<td>Type-C</td>
<td>Type-C</td>
<td>USB-UB-001-082</td>
<td>≤1M</td>
<td>Standard cable, All signals, no Vconn</td>
<td>n/a</td>
<td>ALL</td>
</tr>
<tr>
<td>USB Type-C to 3.1 AM</td>
<td>Type-C</td>
<td>Type AM</td>
<td>USB-UB-001-043</td>
<td>≤1M</td>
<td>Vbus, Gnd, 3 pairs</td>
<td>AC3G2-5</td>
<td>DFP</td>
</tr>
<tr>
<td>USB Type-C to 3.1 BM</td>
<td>Type-C</td>
<td>Type BM</td>
<td>USB-UB-001-045</td>
<td>≤1M</td>
<td>Vbus, Gnd, 3 pairs</td>
<td>CB3G2-5</td>
<td>UFP</td>
</tr>
<tr>
<td>USB Type-C to 3.1 Micro BM</td>
<td>Type-C</td>
<td>Micro BM</td>
<td>USB-UB-001-046</td>
<td>≤1M</td>
<td>Vbus, Gnd, 3 pairs</td>
<td>CuB3G2-3</td>
<td>UFP</td>
</tr>
<tr>
<td>USB Type-C to USB 2.0 AM</td>
<td>Type-C</td>
<td>USB2.0 Type AM</td>
<td>USB-UB-001-047</td>
<td>≤2M ≤4M</td>
<td>Vbus, Gnd, 1 pair</td>
<td>AC2-5</td>
<td>DFP</td>
</tr>
<tr>
<td>USB Type-C to USB 2.0 BM</td>
<td>Type-C</td>
<td>USB2.0 Type BM</td>
<td>USB-UB-001-049</td>
<td>≤4M</td>
<td>Vbus, Gnd, 1 pair</td>
<td>CB2-5</td>
<td>UFP</td>
</tr>
<tr>
<td>USB Type-C to USB 2.0 Mini-B (1.5A MAX)</td>
<td>Type-C</td>
<td>USB2.0 Mini-BM</td>
<td>USB-UB-001-050</td>
<td>≤4M</td>
<td>Vbus, Gnd, 1 pair, ID</td>
<td>CmB2</td>
<td>UFP</td>
</tr>
<tr>
<td>USB Type-C to USB 2.0 Micro BM</td>
<td>Type-C</td>
<td>USB2.0 Micro BM</td>
<td>USB-UB-001-051</td>
<td>≤2M</td>
<td>Vbus, Gnd, 1 pair, ID</td>
<td>CuB2-3</td>
<td>UFP</td>
</tr>
<tr>
<td>USB Type-C to USB 2.0 Type-C</td>
<td>Type-C</td>
<td>Type-C</td>
<td>USB-UB-001-053</td>
<td>≤2M ≤4M</td>
<td>Vbus, Gnd, A5, 1 pair</td>
<td>n/a</td>
<td>ALL</td>
</tr>
<tr>
<td><strong>Adapters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USB Type-C to 3.1 AF</td>
<td>Type-C</td>
<td>USB 3.1 Type AF</td>
<td>USB-UB-001-054</td>
<td>≤0.15M</td>
<td>Vbus, Gnd, A5, 3 pair</td>
<td>n/a</td>
<td>UFP</td>
</tr>
<tr>
<td>USB Type-C to 2.0 Micro BF</td>
<td>Type-C</td>
<td>USB 2.0 Micro BF</td>
<td>USB-UB-001-055</td>
<td>≤0.15M</td>
<td>Vbus, Gnd, A5, 1 pair, ID</td>
<td>n/a</td>
<td>DFP</td>
</tr>
</tbody>
</table>

DFP = Downstream Facing Port = Host  
UFP = Upstream Facing Port = Device  
A5 = CC Line
Electronically Marked Cables

All USB Type-C Full-Featured cables and cables rated over 3 A require electronic marking
- Also required for USB Type-C to legacy cables implementing USB 3.1 Gen2

Electronic marking mechanism (SOP’) defined in USB PD 2.0
Electronically marked cable limited to drawing 70 mW from Vconn

[Diagram of electronically marked cable connections]
USB Type-C Legacy Cable Assemblies

USB Type-C to USB 3.1 Cable Assemblies:

- Standard-A
- Micro-B
- Standard-B

USB Type-C to USB 2.0 Cable Assemblies:

- Standard-A
- Standard-B
- Micro-B
- Mini-B

8 wires* 4 wires*
USB Type-C Legacy Adapters

Only two USB Type-C to legacy adapters are defined and allowed

USB Type-C to USB Standard-A Receptacle Adapter
- Intended for legacy “thumb drive” use with new host platforms

USB Type-C to USB 2.0 Micro-B Receptacle Adaptor
- Intended for adapting existing Micro-B chargers to new devices
USB Power Delivery 2.0 refers to a single wire protocol (on CC wire) created by the USB-IF

Key Features

- unlocks advanced capabilities of the USB Type-C cable
- PD messaging occurs independently of USB2.0, 3.0, or 3.1 data
- used for port-to-port negotiation of power roles:
  - VBUS voltage level configurable up to 20V
  - Current capability to match cable limits of 3A/5A
  - Power up to 100W
- Coexists with USB Battery Charging 1.2
- Swapping of power direction, data direction and source of VCONN
- Communication with USB Type-C Electronically Marked Cables
- Support for Alternate Modes of operation (DP, MHL, HDMI)
ALTERNATE MODES

Alternate Modes allow the USB Type-C cable to be reconfigured to support third party protocols.

Key Features

• Alternate Mode enabled only if both ports support USB PD protocol and are both compatible with the specific Alternate mode.
• Cable must support USB2.0 and Power Delivery connection.
• Alternate Mode negotiation is performed via USB PD protocol on a port-to-port basis.

Examples of USB Type-C Alternate Modes

• DisplayPort (supports)
  (2) Display Port lanes + (1) USB3.1 lane
  (4) Display Port lanes
• HDMI Alt Mode for USB Type-C
  • Allows HDMI sources with Type-C to connect directly to HDMI enabled displays
  • Uses simple USB Type-C to HDMI cable with no adapters
Type-C EMC Improvements

• Goal- Target radiation 15-20 dB lower than legacy USB 3.0 Standard-A

• Type-C plug
  ▪ no holes/cutouts in plug shell
  ▪ has ground contacts in front of shell to connect with ground bar in the back of receptacle
  ▪ Side latches-have electrical connection to receptacle mid-plate
  ▪ Low ESL bypass caps are required for VBUS lines on host and inside cable plug
  ▪ Sufficient connection points between the internal RFI spring and plug shell
  ▪ Cable external braid is physically connected to the plug metal shell as close to 360° as possible to control EMC

• Type-C receptacle
  ▪ Sufficient connection points between the internal EMC pad and the receptacle shell
  ▪ Receptacle mid-plate is directly connected to system PCB GND via solder tails
  ▪ External spring on receptacle shell is optional- internal EMC pad is not required if external springs are formed on the receptacle shell. May provide additional shielding
  ▪ Back-shield is critical- one of the main sources of leakages
USB Type-C Compliance Testing

• Signal integrity compliance testing is for USB Type-C to Type-C cable assembly
  ▪ There will be no signal integrity and EMC component-level compliance test for receptacles
  ▪ The receptacle is considered part of the host or device, and host/device makers are responsible for managing the receptacle performance
  ▪ Connector Mfg.'s can now apply for USB-IF TID approval after testing by an approved lab.

• There will be system level tests
  ▪ includes system Tx and Rx tests and RFI tests
  ▪ Host/device makers may request mated connector simulation or measure data from connector suppliers to verify the receptacle performance

• Test Fixtures for Compliance Testing
  ▪ USB Type-C workgroup has defined a common fixture design for Type-C cable assembly
  ▪ Can choose to fabricate your own, or buy from an approved fixture vendor
  ▪ The Compliance spec is posted on USB-IF website
Thank You