Introduction to USB Type-C™

Connectors and Cables

By Ed Green
**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.

Type-C Receptacle
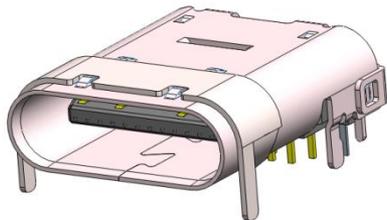
Type-C Plug
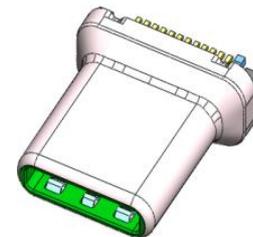
The Single Connector Platform Model

USB Type-C

Keyboard · Power · Mouse · Display · Audio · Network · Storage
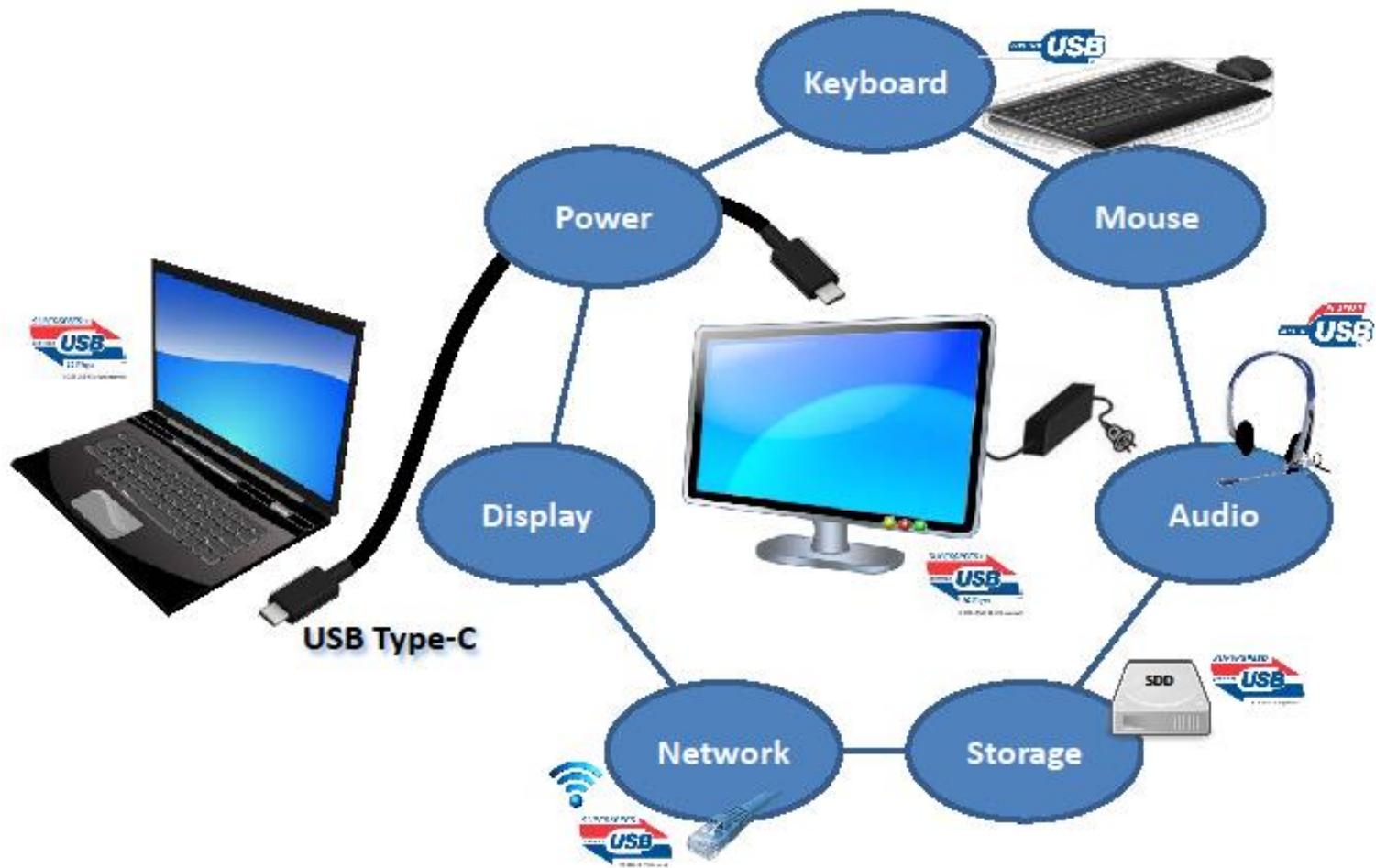
Key Features of USB 3.1

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

2.56

8.34

Standard-A, 9 pins

12.50

5.12
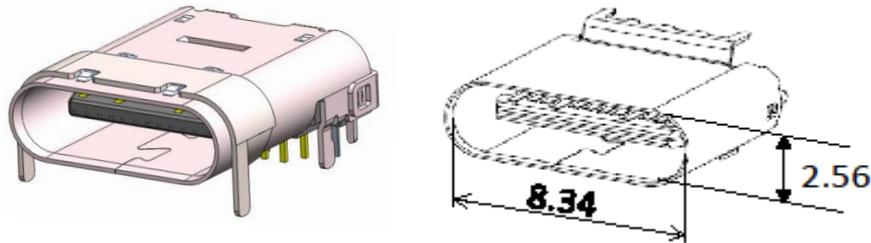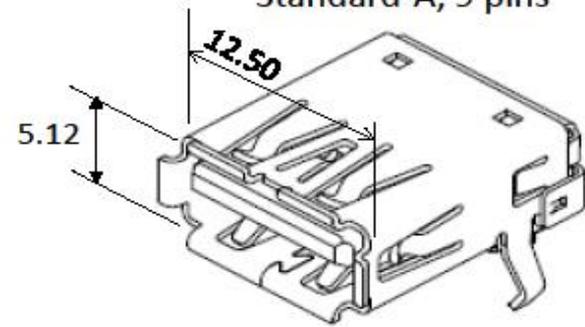
Type-C 22 Pin Plug

Micro-AB, 10 pins

12.25

1.85
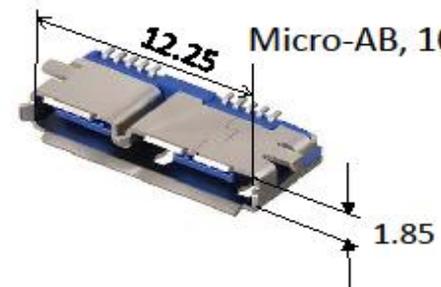
PALCONN USB 2.0/3.1 Type-C Models

- 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
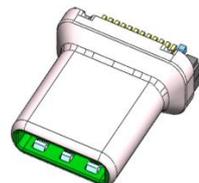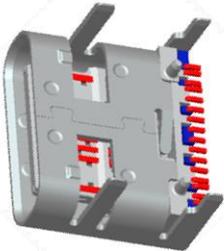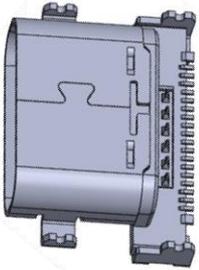
Key Features of the USB Type-C connector

- **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**
    - **V$_{BUS}$ – definition expanded with USB Type-C Current**
    - **V$_{CONN}$ – a dedicated source for powering cable electronics, +5V pin powers circuits in the plug needed to implement Electronically Marked Cables. Vconn is independent of V$_{BUS}$.**
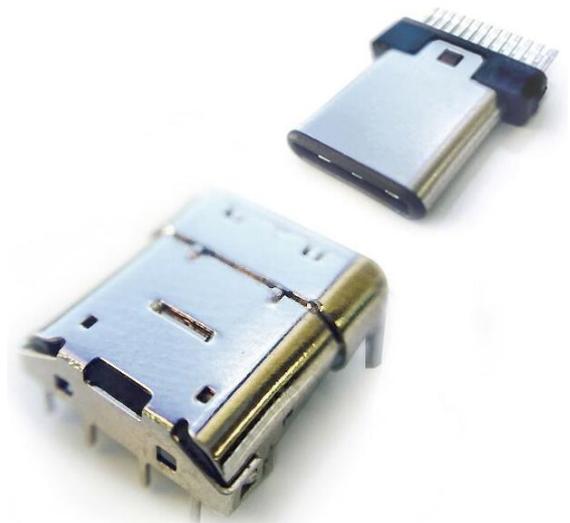
USB Type-C Receptacle Mechanical Features

- **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.**
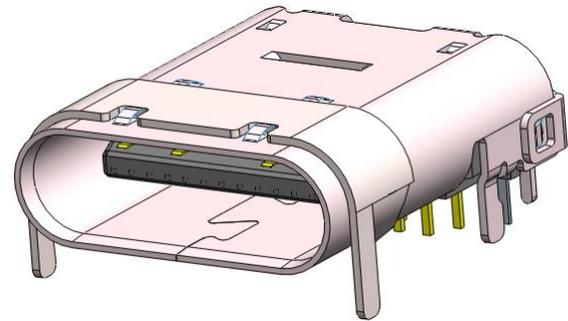
USB Type-C Plug Mechanical Features

- **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**
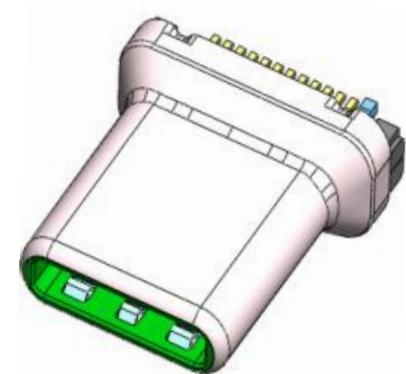
Type-C Electrical Performance

- **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

Receptacle
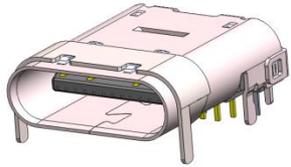
A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
GND	TX1+	TX1-	VBUS	CC1	D+	D-	SBU1	VBUS	RX2-	RX2+	GND

GND	RX1+	RX1-	VBUS	SBU2	D-	D+	CC2	VBUS	TX2-	TX2+	GND
B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1

Plug
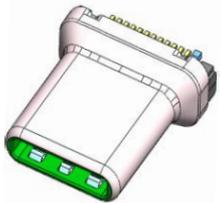
A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
GND	RX2+	RX2-	VBUS	SBU1	D-	D+	CC	VBUS	TX1-	TX1+	GND

GND	TX2+	TX2-	VBUS	Vconn			SBU2	VBUS	RX1-	RX1+	GND
B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12

USB Type-C Signal Summary

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

USB Type-C Functional Model
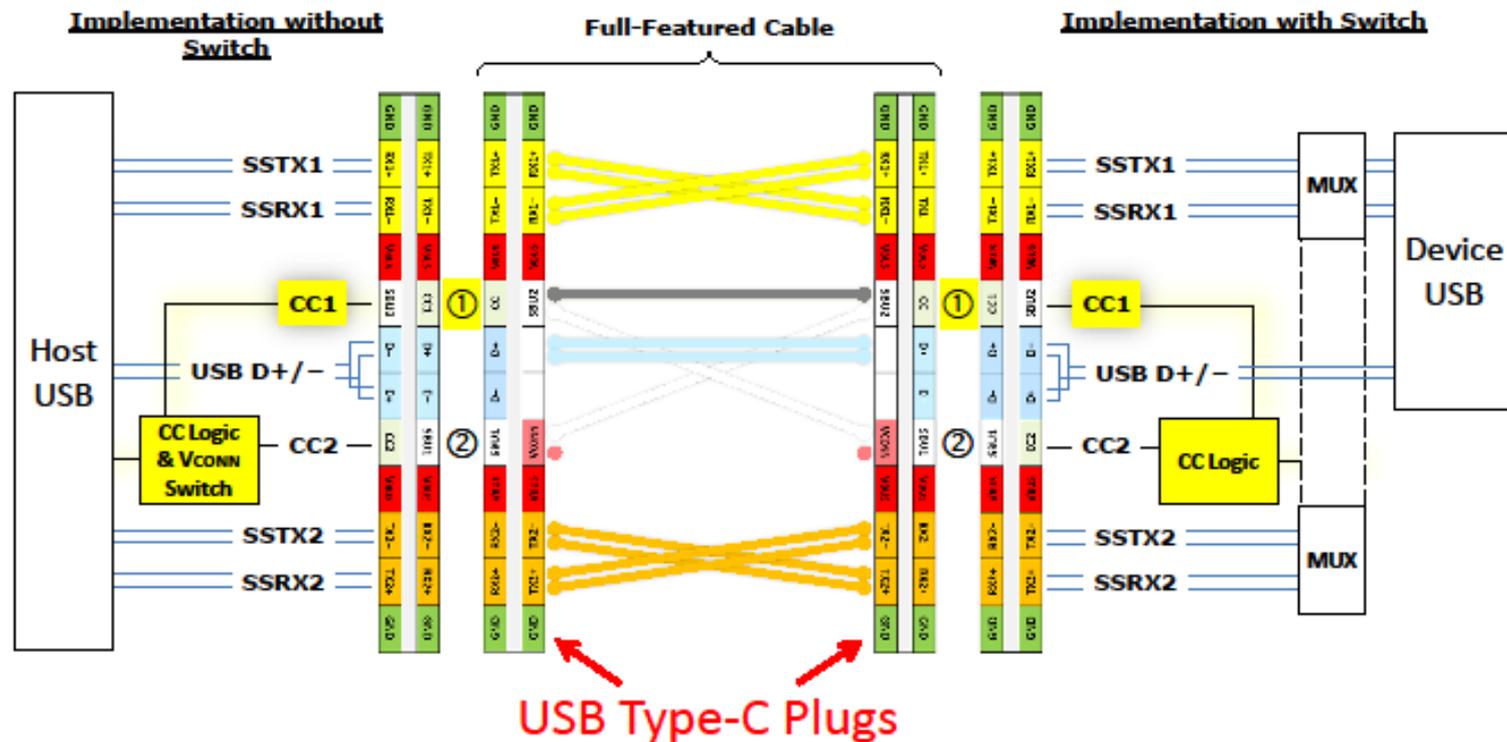
CC wire determines orientation through the cable

USB Type-C Power Options

Mode of Operation	Nominal Voltage	Maximum Current	Notes
USB 2.0	5V	500mA	Default USB Power
USB 3.1	5V	900mA	Default USB Power
USB BC 1.2	5V	Up to 1.5A	Legacy charging
USB Type-C Current @ 1.5A	5V	1.5A	Supports higher power devices
USB Type-C Current @ 3.0A	5V	3A	Supports higher power devices
USB PD	Configurable up to 20V	Configurable up to 5A	Directional control and power level management

USB Type-C Cable Length Summary

| USB Version	Cable Length	Current Rating	USB Power Delivery	Electronically Marked
USB2.0	≤ 4 Meters	3A 5A	Supported Supported	Optional Required
USB3.0	≤ 2 Meters	3A 5A	Supported Supported	Required Required
USB3.1	≤ 1 Meter	3A 5A	Supported Supported	Required Required

Type-C Full Featured Cable Assembly
(Type-C Plug + Paddle Board + Cable, Top & Bottom Views)
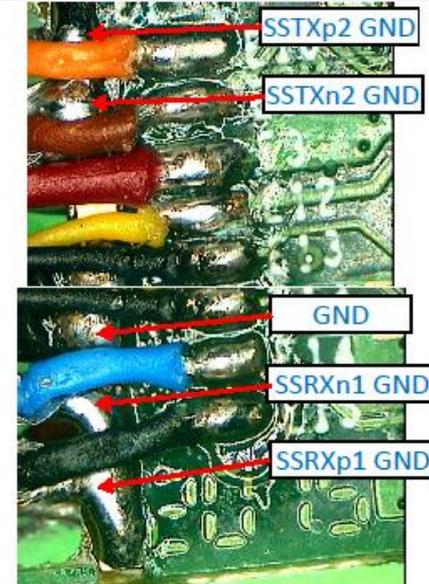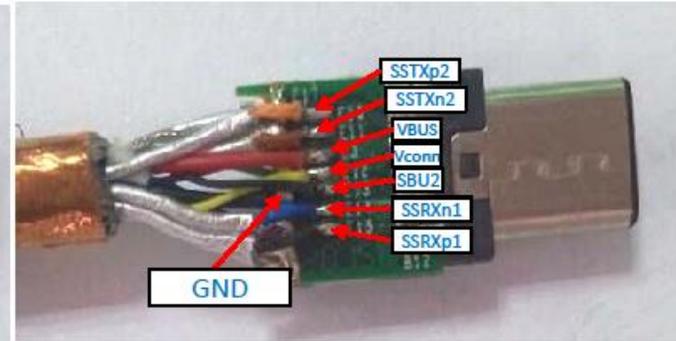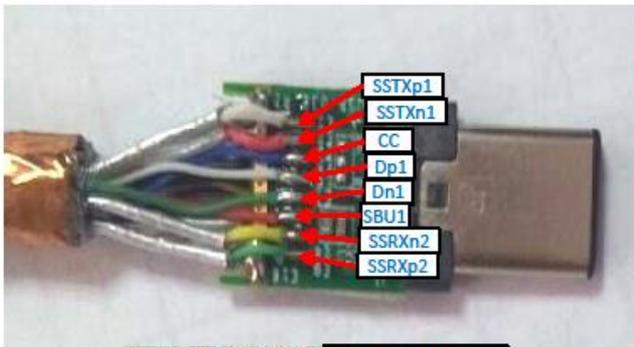
Wire / Raw Cable

- 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)
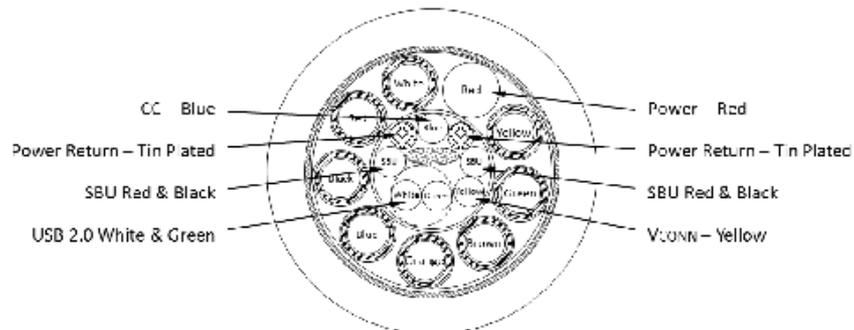
USB 3.1 Type-C Cable Assemblies
Palconn Product Offering

USB 3.1 Cable Assembly	P1	P2	Palconn Part Number	Cable Length	Signals	USB-IF Legacy Reference	Usage
USB3.1 Type-C, Full Featured, E-Mark Cable	Type-C	Type-C	USB-UB-001-033	≤1M	All signals, with Vconn, E-Mark	n/a	ALL
USB 3.1 Type-C Standard Cable	Type-C	Type-C	USB-UB-001-082	≤1M	Standard cable All signals, no Vconn	n/a	ALL
USB Type-C to 3.1 AM	Type-C	Type AM	USB-UB-001-043	≤1M	Vbus, Gnd, 3 pairs	AC3G2-5	DFP
USB Type-C to 3.1 BM	Type-C	Type BM	USB-UB-001-045	≤1M	Vbus, Gnd, 3 pairs	CB3G2-5	UFP
USB Type-C to 3.1 Micro BM	Type-C	Micro BM	USB-UB-001-046	≤1M	Vbus, Gnd, 3 pairs	CuB3G2-3	UFP
USB Type-C to USB 2.0 AM	Type-C	USB2.0 Type AM	USB-UB-001-047	≤2M ≤4M	Vbus, Gnd, 1 pair	AC2-5	DFP
USB Type-C to USB2.0 BM	Type-C	USB2.0 Type BM	USB-UB-001-049	≤4M	Vbus, Gnd, 1 pair	CB2-5	UFP
USB Type-C to USB 2.0 Mini-B M (1.5A MAX)	Type-C	USB2.0 Mini-BM	USB-UB-001-050	≤4M	Vbus, Gnd, 1 pair, ID	CmB2	UFP
USB Type-C to USB 2.0 Micro B M	Type-C	USB2.0 Micro BM	USB-UB-001-051	≤2M	Vbus, Gnd, 1 pair, ID	CuB2-3	UFP
USB Type-C to USB 2.0 Type-C	Type-C	Type-C	USB-UB-001-053	≤2M ≤4M	Vbus, Gnd, A5, 1 pair	n/a	ALL
Adapters							
USB Type-C to 3.1 AF	Type-C	USB 3.1 Type AF	USB-UB-001-054	≤0.15M	Vbus, Gnd, A5, 3 pair	n/a	UFP
USB Type-C to 2.0 Micro BF	Type-C	USB 2.0 Micro BF	USB-UB-001-055	≤0.15M	Vbus, Gnd, A5, 1 pair, ID	n/a	DFP

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
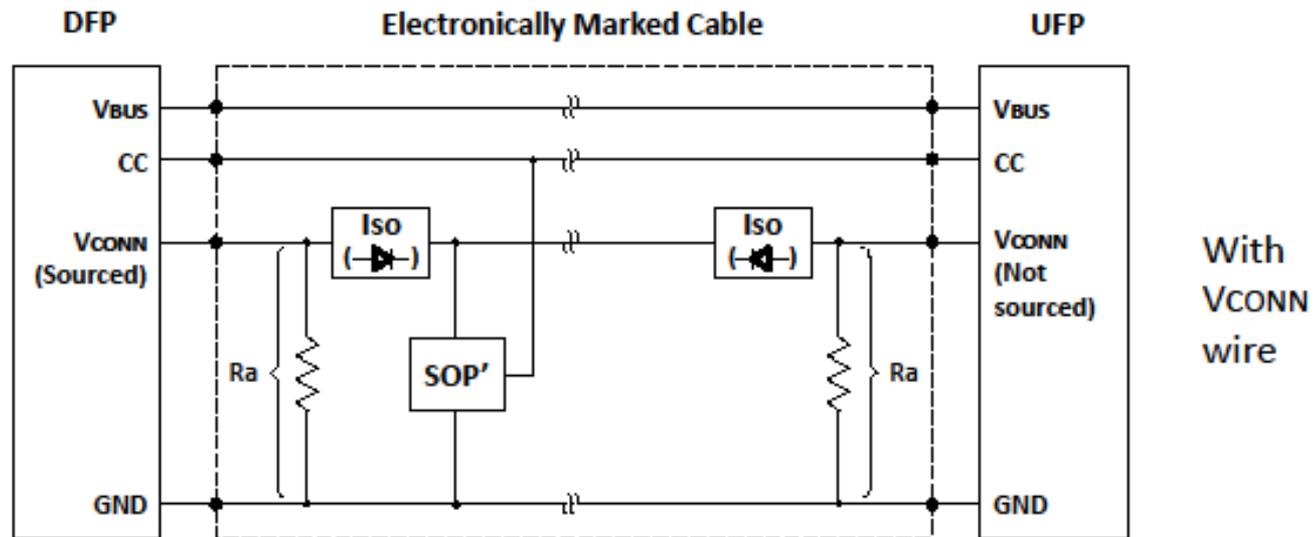
# USB Type-C Legacy Cable Assemblies

USB Type-C to USB 3.1 Cable Assemblies:

Standard-A

Micro-B
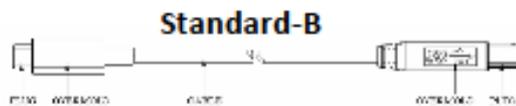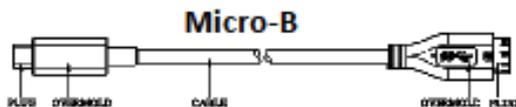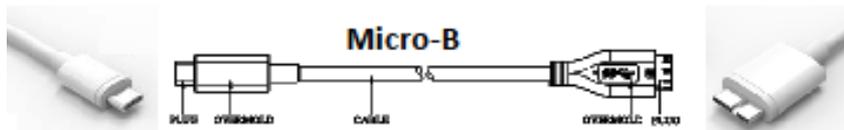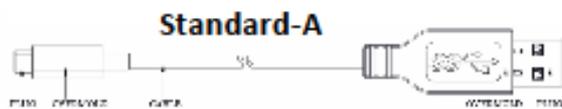
Standard-B

8 wires*

USB Type-C to USB 2.0 Cable Assemblies:

Standard-A

Standard-B

Micro-B

Mini-B
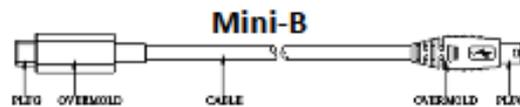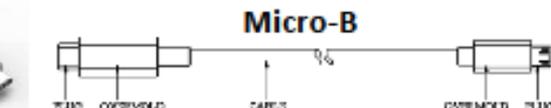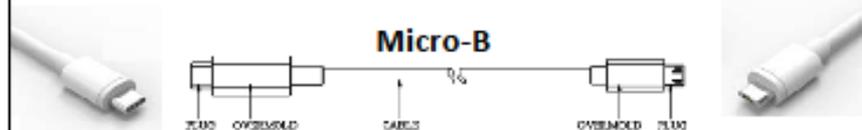
4 wires*

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

8 wires*

Intended for legacy "thumb drive" use with new host platforms

USB Type-C to USB 2.0 Micro-B Receptacle Adaptor

4 wires*

Intended for adapting existing Micro-B chargers to new devices

USB POWER DELIVERY 2.0

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 360⁰ 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