TI Webinar Series

USB Type-C™ and Power Delivery Technology Overview

Karl Fleischmann
Product Marketing Engineer
Universal Serial Bus (USB)
The interface of choice by billions

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<thead>
<tr>
<th>Year</th>
<th>USB</th>
<th>Hi-Speed USB</th>
<th>USB On-the-go</th>
<th>Superspeed USB</th>
<th>SuperSpeed+ USB 10 Gbps</th>
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<tbody>
<tr>
<td>2000</td>
<td>USB</td>
<td>USB2.0 LS/FS</td>
<td>USB2.0 HS</td>
<td>USB3.1 Gen1 LS/FS/HS/SS</td>
<td>USB3.1 Gen2 LS/FS/HS/SS/SS+</td>
</tr>
<tr>
<td>2000</td>
<td>Hi-Speed USB</td>
<td>USB2.0 HS</td>
<td>USB2.0 OTG Master/slave configurable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>USB On-the-go</td>
<td>USB2.0 HS</td>
<td></td>
<td>USB3.1 Gen1 LS/FS/HS/SS</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>Superspeed USB</td>
<td></td>
<td>USB3.1 Gen1 LS/FS/HS/SS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>SuperSpeed+ USB 10 Gbps</td>
<td></td>
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</tbody>
</table>

**USB Speeds**
- Low Speed (LS): 1.5Mbps
- Full Speed (FS): 12Mbps
- High Speed (HS): 480Mbps
- Super Speed (SSS): 5Gbps
- Super Speed+ (SSS+): 10Gbps

- Standard A, B, mini B, micro A, B connectors
- Has host side & device side - not reversible
- Data through USB2 and SS pairs
- Power through $V_{BUS}$ limited to 7.5W (using BC1.2)
- Non USB use case NOT allowed

**USB3.1**
- LS, FS & HS
- SuperSpeed(+)
  - SSTX+
  - SSTX-
  - SSRX+
  - SSRX-

**USB2.0**
- D+
- D-
- $V_{BUS}$
- GND

**USB2.0 w 2-wire bi-directional interface**

**SuperSpeed(+)**
- Adds a dual-simplex data path with revised USB protocol

**USB Cable**
- Not reversible – host side and device side
USB Type-C: One Connector for All

Supports data, video and power in a single connector

- USB Type-C or USB Type-C is a small form factor receptacle, plug, and cable standard
- Flippable connectors and reversible cable gives user friendly experience
- Type-C connector is compatible with existing USB protocols and expected to replace all Type-A and Type-B connectors
- Supports USB 3.1 (10Gbps)
- Native 15W (5V/3A) power support with option for up to 100W (20V/5A) using USB PD – faster charging
- Supports “Alternate Modes” such as Display Port Video through the same port
- USB Type-C removes the need for different plug/receptacle types for host and devices
USB Type-C is a Physical Interface
Supports USB 2.0 or USB 3.1 or DisplayPort video or other protocols

USB Type-C is a connector/cable interface, not a new speed
USB2, USB3.1 and Alt Mode function (DP video) can co-exist

USB Only Applications

Alt Mode Applications
USB Type-C for All Connectivity

*First connector supporting power in both ways*
USB Type-C Expected to Replace Legacy USB Connectors

Backward compatible with more features and flexibility

USB2.0
- Type-A
- Type-B
- Mini-B
- Micro-B

USB3.0
- Type-A
- Type-B
- Micro-B

One size for USB2.0, 3.1

USB2.0
- USB3.1
- DisplayPort
- Power Delivery

USB 2.0 (480Mb/s)
USB 3.1 (5Gb/s)
USB 3.1 (10Gb/s)

One Port Many Functions
USB Type-C Receptacle

**Power, USB 2.0, USB 3.1, & Alt Mode video (DP) coexist**

**Channel Configuration Pins (CC1/CC2)**
- Receptacle has two CC pins
- One CC wire pass through the cable
- Used for cable attach, orientation, role detection and current mode functions
- Unused CC pin is used for VCONN power

**Selecting Data Signals**
- Flippability of USB Type-C Plug requires appropriate selection of:
  - USB 3.1 SS signals
  - USB 2.0 HS signals
- Receptacles have two pairs of D+ and D- pins
  - If stub connected (D+ to D+ and D- to D-) no mux needed
  - OK at 480Mbps.
- USB 3.1 SS signals can not be stub connected due to signal integrity requiring selection mux.
Features:

- Single USB 2.0 Bus pair through the cable, D+ are connected internally, as are D-.
- USB 3.1 (Tx/Rx pair) high speed data buses for USB SS (+) or Alt Mode.
- CC1/CC2 in receptacle assume role of CC or \( V_{CONN} \):
  - CC is the configuration channel for the type-C interface.
  - \( V_{CONN} \) powers electronics in the USB Type-C plug once cable configuration is complete.
- \( V_{BUS} \) Buses enable power delivery up to 100W total.
- Two ‘SBU’ – “Sideband use” buses for Alt Mode.
USB Type-C Channel Configuration

**Simple way to accommodate flippable, symmetrical & reversible cable**

Simple resistor divider network between host and device
- DFP pulls-up the CC pin with $R_p$
- UFP pulls-down the CC pin with $R_d$
- DRD/P alternates between DFP and UFP

One CC wire in the cable
- DFP(UFP) can detect attachment of UFP (DFP) if active CC line has a $R_d$ ($R_p$) on the other side
- DFP/UFP can detect plug orientation by monitoring which CC line is active
- DFP uses different $R_p$ (or current source) values to advertise its current provider capability. USB default, 1.5A or 3A

**Data & power roles**
- By default DFP (host) is power source and UFP (device) is power sink
- USB PD can be used to change these roles

**VCONN power**
- DFP provides VCONN power (1W minimum) at the unused CC pin for electronics inside cable
- Cable installs pull-down resistor $R_a$ to request VCONN power

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**Type-C Data Roles:**
- **Downstream Facing Port (DFP)** - Host
- **Upstream Facing Port (UFP)** - Device
- **Dual Role Port (Dual role data DRD & Dual role power DRP)** - switch between DFP and UFP

**Type-C Power Roles:**
- **Source** - a provider of power when connected
- **Sink** - a consumer of power when connected
USB Type-C Connectors and Cables

Option for cheaper implementation and backward compatibility

- Two cable/plug options: Full-Featured (USB 3.1 & USB 2.0), and USB 2.0
- Cables supporting USB 3.1 or Alt Mode must be electronically marked
- Standard (full-featured & USB 2.0) cables support 3A current – electronically marked cable can support up to 5A

USB Type-C to Legacy Standard A/B, Mini/micro B cable options
- USB Type-C to USB 3.1 Standard-A
- USB Type-C to USB 2.0 Standard-A
- USB Type-C to USB 3.1 Standard-B
- USB Type-C to USB 2.0 Standard-B
- USB Type-C to USB 2.0 mini-B
- USB Type-C to USB 3.1 micro-B
- USB Type-C to USB 2.0 micro-B
USB Type-C Power Modes
Flexible and Modular Power Delivery Methods

USB Type-C can be used to deliver power via a number of different protocols:

<table>
<thead>
<tr>
<th>Precedence</th>
<th>Mode of Operation</th>
<th>Nominal Voltage</th>
<th>Maximum Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest</td>
<td>USB PD</td>
<td>Up to 20 V</td>
<td>Up to 5 A</td>
</tr>
<tr>
<td></td>
<td>USB Type-C current @ 3A</td>
<td>5 V</td>
<td>3 A</td>
</tr>
<tr>
<td></td>
<td>USB Type-C current @ 1.5A</td>
<td>5 V</td>
<td>1.5 A</td>
</tr>
<tr>
<td></td>
<td>USB BC1.2</td>
<td>5 V</td>
<td>Up to 1.5 A</td>
</tr>
<tr>
<td>Lowest</td>
<td>USB 3.1</td>
<td>900 mA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>USB 2.0</td>
<td></td>
<td>500 mA</td>
</tr>
</tbody>
</table>

Port Power Roles

Following the introduction of USB PD, port power roles are now defined separately from the port data roles.

- **Provider**: device can only provide power
- **Consumer**: device can only receive power
- **Consumer provider**: the device can act as either a consumer or provider. This is only possible for devices that support USB PD

Capable of delivering up to 100W over one USB Type-C port!
USB Type-C connector is same for all. Who provides power and who consumes?

<table>
<thead>
<tr>
<th>Power class</th>
<th>Example devices</th>
<th>Mode/Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always source</td>
<td>Charger</td>
<td>DFP/Source</td>
</tr>
<tr>
<td>Usually source</td>
<td>Laptop, battery bank</td>
<td>DFP/Source with optional Try.SRC</td>
</tr>
<tr>
<td>Dual</td>
<td>Tablet</td>
<td>DRP/dual</td>
</tr>
<tr>
<td>Usually sink</td>
<td>Phone</td>
<td>UFP/Sink with optional Try.SNK</td>
</tr>
<tr>
<td>Always sink</td>
<td>Portable drive, accessory</td>
<td>UFP/Sink</td>
</tr>
</tbody>
</table>
What is USB PD?
- USB PD is a single wire communication protocol over CC lines
- A negotiation method to extend USB Type-C interface capability for more power, alt mode and flexibility
- Both ends must support certain extended feature(s) for a successful PD contract

Why USB PD?
- **Extended Power**
  - USB Type-C provides up to 15W (5V/3A) power through VBUS with simple resistor divider network
  - USB PD must be used to extend the power delivery beyond 5V/3A
  - PD can negotiate power up to 100W (20V/5A) – faster charging
  - PD can also negotiate >1W of VCONN power up to 6W
- **Alternate Mode**
  - USB PD must be used for any Alt mode
  - Through PD Alt Mode negotiation USB Type-C interface can be used for non-USB use cases
  - SS differential pairs and SBU lines are available for Alt Mode use
  - USB2 must be preserved when in Alt Mode
- **Role Flexibility**
  - By default Host/DFP is power source and Device/UFP is power sink
  - USB PD must be used to decouple the data/power roles
USB PD Power Profiles

Ensures orderly inter-operability

The maximum current and power rails that a source shall support at each voltage for a given PDP

Source Power Rules
- Ensure the PD Power (PDP) of an adapter specified in watts explicitly defines the voltage and currents at each voltage the adapter supports
- Ensure that adapters with large PDP are always capable of providing the power to devices designed for use with adopters with smaller PDP
- Enable an ecosystem of adapters that are interoperable with the devices in the ecosystem

<table>
<thead>
<tr>
<th>PDP (W)</th>
<th>Current at 5 V(A)</th>
<th>Current at 9 V(A)</th>
<th>Current at 15 V(A)</th>
<th>Current at 20 V(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.5 \leq x \leq 15$</td>
<td>$x \div 5$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$15 &lt; x \leq 27$</td>
<td>3</td>
<td>$x \div 9$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$27 &lt; x \leq 45$</td>
<td>3</td>
<td>3</td>
<td>$x \div 15$</td>
<td></td>
</tr>
<tr>
<td>$45 &lt; x \leq 60$</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>$x \div 20$</td>
</tr>
<tr>
<td>$60 &lt; x \leq 100$</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>$x \div 20^1$</td>
</tr>
</tbody>
</table>

$^1$ Requires a 5A cable.
Electronically Marked Cable

*Making USB Type-C interface ubiquitous*

**What is E-marker?**
- Simple USB PD controller inside a cable
- Responds to USB PD commands from DFP/source
- Provide cable characteristics such as current carrying capability, performance, vendor identification etc.
- Typically powered by VCONN

**When E-marker is needed?**
- USB Type-C cable supporting more than 3A current
- USB Type-C full featured cable with USB 3.1 or alternate mode signaling
# Features through USB Type-C Interface

*Do we need PD?*

<table>
<thead>
<tr>
<th>Function</th>
<th>PD Needed?</th>
</tr>
</thead>
<tbody>
<tr>
<td>USB 2.0 data</td>
<td>No</td>
</tr>
<tr>
<td>USB 2.0 &amp; 3.1 data</td>
<td>No</td>
</tr>
<tr>
<td>&lt;15W power</td>
<td>No</td>
</tr>
<tr>
<td>BC 1.2 power</td>
<td>No</td>
</tr>
<tr>
<td>Analog Audio</td>
<td>No</td>
</tr>
<tr>
<td>&gt;15W power</td>
<td>Yes</td>
</tr>
<tr>
<td>Alt Mode (such as DP Video)</td>
<td>Yes</td>
</tr>
<tr>
<td>Power/data role swap</td>
<td>Yes</td>
</tr>
<tr>
<td>Cable identification</td>
<td>Yes</td>
</tr>
<tr>
<td>Active cable support</td>
<td>Yes</td>
</tr>
</tbody>
</table>
USB Type-C Alternate Mode

*Extends beyond USB data*

What is Alt Mode?

- Alternate use of USB Type-C interface for non-USB functions
- USB2 must be preserved
- USB PD must be used to negotiate an alternate mode

**Definition:** Operation defined by a vendor or standards organization that is associated with a SVID assigned by the USB-IF. Entry and exit into and from an Alternate Mode is controlled by the **USB PD** Structured VDM Enter Mode and Exit Mode commands

<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>
</tr>
</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>
<th>B3</th>
<th>B4</th>
<th>B5</th>
<th>B6</th>
<th>B7</th>
<th>B8</th>
<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>V_{CONN}</td>
<td>SBU2</td>
<td>VBUS</td>
<td>RX1-</td>
<td>RX1+</td>
<td>GND</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example of Alt Modes

- DisplayPort (DP)
- Thunderbolt
- PCI Express
- MHL
- HDMI (for dongle/adapters)

Can you create your own alternate mode?

- Option 1: create an official alternate mode approved by USB-IF (will be given a SID, standard ID)
- Option 2: Get a VID from USB-IF and create a non-official alternate mode (you must own both sides of the system for this to work)
USB PD Alternate Mode Negotiation

Scope Trace between a Dock and Notebook establishing a USB PD Contract

USB Power Delivery Analyzer with PD Controller Firmware
(A Dock acting as a DFP/Source & Notebook acting as the UFP/Sink)
DisplayPort as USB Type-C Alternate Mode

Bringing high resolution video

Need for signal Muxes

- Selection of active USB SS signals depending on plug orientation
- Merging of Alt Mode signals into SS signal pairs
- Flexibility of SS signal versus Alt Mode signals
- Signal Mux can be a physical device (most use case today) or done inside a processor (supporting both USB and Alt Mode through same pins)

DisplayPort as Alt Mode

- DisplayPort is most popular Alt mode today supporting high resolution video
- Signal mux allows following options for system depending on application need:
  - USB SS RX/TX only
  - USB SS RX/TX & 2 lanes of DP video
  - 4 lanes of DP video
- DP AUX signals use SBU1 and SBU2 signal pins
- DP HPD signal is embedded into USB PD message
USB Type-C and Power Delivery Ecosystem
Broad portfolio of TI’s USB Type-C™ & PD products

<table>
<thead>
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<th>Standard Type-C (15W max)</th>
<th>Type-C &amp; PD Power Provider</th>
<th>Type-C &amp; Full PD Power, Data, Video</th>
<th>Companion Products</th>
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<td><strong>Products</strong></td>
<td><strong>Products</strong></td>
<td><strong>Products</strong></td>
<td><strong>Products</strong></td>
</tr>
<tr>
<td>TUSB320/1/2</td>
<td>TPS2574x</td>
<td>TPS6598x</td>
<td>Battery</td>
</tr>
<tr>
<td>TPS25810</td>
<td></td>
<td>TUSB422</td>
<td>DC/DC</td>
</tr>
<tr>
<td>TPS25820/1</td>
<td></td>
<td>TPS25725</td>
<td>Protection</td>
</tr>
<tr>
<td><strong>Differentiation</strong></td>
<td><strong>Differentiation</strong></td>
<td><strong>Differentiation</strong></td>
<td><strong>Differentiation</strong></td>
</tr>
<tr>
<td>Turn key solution &amp; smallest solution size in DFP &lt;15W power provider (TPS25810)</td>
<td>Turn key solution &amp; smallest solution size in DFP power provider (TPS25740/1)</td>
<td>Turn key solution &amp; smallest solution size (TPS6598x)</td>
<td>Only company to offer full ecosystem for total solution</td>
</tr>
<tr>
<td>Turn key solution &amp; smallest solution size &amp; cost in DFP &lt;7.5W power provider (TPS25820/1)</td>
<td>Leverage existing MCU &amp; customer ownership of EC (TUSB421)</td>
<td>Leverage existing MCU &amp; customer ownership of EC (TPS6598x)</td>
<td>Wide range of TI-Designs cover many end applications</td>
</tr>
<tr>
<td>Smallest device size &amp; lowest device cost (TUSB320/1/2)</td>
<td>Smallest solution size w/o MCU (TPS25725)</td>
<td>Smallest solution size w/o MCU (TPS25725)</td>
<td></td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td><strong>Applications</strong></td>
<td><strong>Applications</strong></td>
<td><strong>Applications</strong></td>
</tr>
<tr>
<td>Handset</td>
<td>Wall Charger</td>
<td>Laptop/PC</td>
<td>Battery</td>
</tr>
<tr>
<td>Laptop/PC</td>
<td>Adapter</td>
<td>Monitor</td>
<td>DC/DC</td>
</tr>
<tr>
<td>Powerbank</td>
<td>Car charger</td>
<td>Tablet</td>
<td>Protection</td>
</tr>
<tr>
<td>Wall Charger</td>
<td>Powerbank</td>
<td>Dock/Dongle</td>
<td>FET</td>
</tr>
<tr>
<td>Car charger</td>
<td></td>
<td>Infotainment</td>
<td></td>
</tr>
</tbody>
</table>
Standard Type-C (15W max)

**TUSB321 / TUSB322**
Type-C CC Logic, Port Control and VCONN Switch

- Optimized for Mobile Applications and Compatible to USB Type-C Specification 1.1
- Mode configuration (DFP, UFP, DRP)
  - Host Only
  - Device Only
  - Dual Role Port
  - I2C (TUSB322 only) and GPIO for Configuration
- Channel Configuration (CC)
  - Attach of USB Port Detection
  - Cable Orientation Detection
  - Role Detection
  - Type-C Current Mode (Default, Mid, High)
- ID Emulation and VBUS detection
- VCONN support, Supply Voltage 4.5-5.5V
- Low Active Standby Current Consumption
- Industrial Temperature Range, 1.6x1.6mm QFN package

**USB Type-C™ Minidock Board With Video and Charging Support Evaluation Module**
Standard Type-C (15W max)

TPS25810 - USB Type-C Port Power Switch

- USB Type-C DFP Interface (15W)
- Connector Attach/Detach Detection
- STD/1.5A/3A Capability Advertisement on CC Line
- $V_{\text{BUS}}$ Application
- $V_{\text{CONN}}$ Application to Active Cable
- <0.7 μA (typ) Operating Current with Nothing Attached
- Dedicated Supply for Charging, VCONN and Device Power
- Integrated 34 mΩ (typ) High-Side MOSFET
- Selectable 3.34 A/1.67 A OUT Current Limit with +/- 7.5% Accuracy
- Load Detection to Enable Port Power Management
- CC1 and CC2 +/-8 kV Contact and +/-15 kV Air Discharge ESD Rating (IEC 61000-4-2)
- Offered in 3x4, 20-pin QFN Package

TPS25810
TPS25810evm-745

CISPR 25 Class 5 USB Type-C™ Port Reference Design with USB 3.0 Data Support
USB-C DFP 5V3A Car Charger Reference Design
Type-C & PD Power Provider

TPS25740/40A/40B - USB Type-C Port Power Switch with USB PD controller

- No external MCU need, No Firmware need, integrated DFP solution
- USB Type-C DFP Interface
  - PD 2.0 physical layer, policy engine, device policy manager
  - 12 pin-selectable peak power advertisements (15W – 100W)
- Advertises up to 3 voltages
  - 5V, 12V, 20V (TPS25740)
  - 5V, 9V, 15V (TPS25740A)
  - 5V, 9V, 15V, 20V (TPS25740B)
- Connector Attach/Detach Detection
- VBUS Application
  - Declares the system is not USB data capable
- <10 uA (typ) Operating Current with Nothing Attached
- Integrated N-ch MOSFET gate driver and discharge (ABS MAX 30V)
- No need for LDO where 3.3V/5V is not available
- CC1 and CC2 +/-8 kV Contact and +/-15 kV Air Discharge ESD Rating (IEC 61000-4-2)
- Offered in 4x4, 24pin QFN Package

TPS25740
TPS25740evm-741
USB Type-C PD DFP Charger 5V/12V3A Out Adapter Reference Design
Type-C & Full PD Power, Data, Video

TPS65983 - Thunderbolt™ 3 USB Type-C and USB-PD Port Controller

- USB Power Delivery (PD) Controller
  - Mode Configuration for Source (Host), Sink (Device), or Source-Sink.
  - USB Type-C Specification Compliant
    - Cable Orientation and Role Detection
  - Port Power Switch
    - Supports 100W (20V, 5A), 60W (20V, 3A), and 15W (5V, 3A) of power
    - Meets USB Type-C Slew Rate Control, Hard Reset Support requirements
  - Integrated VCONN
    - Overcurrent, overvoltage, reverse current, and thermal protection
- Port Data Multiplexer
  - Sideband Use Data for Alternate Mode Support
    - DisplayPort, Thunderbolt™, etc.
- Power Management
  - 3.3V LDO Output for Dead Battery Support
  - Supports 100W (20V, 5A) External Power Path
  - UL 2367 and IEC 6950 Certified
  - 6x6mm, 96 Pin BGA MicroStar Junior Package

TPS65983
TPS65983evm
USB Type-C™ and Power Delivery Minidock With Video and Charging Support Reference Design

TPS65986 - USB Type-C Port Power Switch with USB-PD Controller

• USB Power Delivery (PD) Controller
  • Mode Configuration for Source (Host), Sink (Device), or Source-Sink.
• USB Type-C Specification Compliant
  • Cable Orientation and Role Detection
• Port Power Switch
  • Supports 60W (20V, 3A), and 15W (5V, 3A) of power
  • Slew Rate Control
  • Overcurrent, overvoltage, reverse current, and thermal protection
  • Hard Reset Support
• Port Data Multiplexer
  • Sideband Use Data for Alternate Mode Support
    • DisplayPort, etc.
• Power Management
  • 3.3V LDO Output for Dead Battery Support
• UL 2367 and IEC 6950 Certified
• 6x6mm, 96 Pin BGA MicroStar Junior Package

TPS65986
TPS65986evm
Type-C & Full PD Power, Data, Video

TPS65981/I - USB Type-C Port Power Switch with USB-PD Controller & HS Mux

- Supports all Type-C High Current Modes
  - Integrated Port Power Switches up to 20V @ 3A
  - Supports bi-directional external power NMOS FETs
- Fully Compliant USB PD Basedband modem per USB PD 2.0
  - BMC encoder/decoder
  - Physical Layer with CRC
  - Policy Manager
- Performs all CC pin functions
  - Cable Detection and Cable Orientation
- Integrated HS Mux and USB 2.0 Endpoint
  - CC1/2, SBU1/2, USB TP/TN, USBPP/BN
  - Support for Guest Protocol
  - DisplayPort, User Alternate Mode
- Flexible System interfaces
  - 12C Slave/Master, SPI, Simple connection HD3SS460 SS Mux for DisplayPort/USB 3.0
- Easy to use 8x8mm 56pin QFN
- Commercial (-40 to 85) and Industrial (-40 to 105) temp ranges

TPS65981
TPS65981evm
Type-C & Full PD Power, Data, Video

**HD3SS460**

4 x 6 Channels USB Type-C Alternate Mode MUX

- Compatible to USB TypeC Specifications 1.0
- X-point mux for USB Type-C with Alt Mode
  - Switching between 2 Ln DP + USBSS or 4 Ln DP
  - Switching for SBU pins
- Low power with 2mW active, 20uW shutdown
- ~3dB BW of over 5GHz
- Excellent dynamic characteristics (at 2.5GHz)
  - Off isolation = –25dB
  - Insertion loss = –1.6dB
  - Return loss = –11dB
- Single supply VCC of 3.3V ±10%
- Available in both Commercial Industrial Temperature
- 28 pin QFN package 3.5x5.5mm & 0.5mm pitch

**HD3SS460evm-src**

USB Type-C™ and Power Delivery Minidock With Video and Charging Support Reference Design
Type-C & Full PD Power, Data, Video

TUSB1046 Measurements – USB Path USB3.1 Gen2 10Gbps

MP1800 BERT 10Gbps, 1Vpp PRBS7

1ft SMP-SMP cable
1ft SMA-SMP cable

Input PCB trace 14" FR-4 -11.8dB Loss

TUSB1046 SSTX -> TX1

Output PCB trace 1.7" FR-4 -1.5dB Loss

EQ = 6dB

1ft SMP-SMA cable

DCAX 35GHz BW PTB

Scale x 20.58ps/div & Y 150mV/div
Type-C & Full PD Power, Data, Video

**TUSB1046/546 Measurements – DP Path DP1.4 HBR3 8.1Gbps**

- **MP1800 BERT 8.1Gbps, 1Vpp PRBS7**
- **1ft SMP-SMP cable**
- **1ft SMA-SMP cable**
- **Input PCB trace 22” FR-4 -14.2dB Loss**
- **TUSB1046 DP -> TX2**
- **Output PCB trace 1.7” FR-4 -1.2dB Loss**
- **EQ = 10dB**
- **1ft SMP-SMA cable**
- **DCAX 35GHz BW PTB**

Scale x 20.58ps/div & Y 150mV/div
Type-C & Full PD Power, Data, Video

**TUSB1046/546**

**USB Type-C 4:6 Cross-Point Redriver MUX - Source**

- Compatible to USB Type-C and VESA DP Alt Mode on USB Type-C Specifications
- Protocol Agnostic Redriver X-Point /Cross-Bar Mux for Type-C with DP Alt Modes in Source Systems
  - USB3.1 SS, or 2 Lanes DP + USB3.1 SS, or 4 Lanes DP
  - Switching for SBU pins
- Supports USB 3.1 Gen1/2 SS Signals up to 10 or 5Gbps
- Supports DisplayPort Signals up to DP1.4 8.1Gbps (HBR3)
- Equalization up to 14.4dB @ 5GHz/2.5GHz
- Single Supply of 3.3V ±10%
- Available in both Commercial Industrial Temperature
- 40 pin QFN 4x6mm 0.4mm Pitch

**Specifications**

- Protocol Agnostic Redriver X-Point /Cross-Point /Bar Mux for Type-C with DP Alt Modes in Source Systems
- USB3.1 SS, or 2 Lanes DP + USB3.1 SS, or 4 Lanes DP
- Switching for SBU pins
- Supports USB 3.1 Gen1/2 SS Signals up to 10 or 5Gbps
- Supports DisplayPort Signals up to DP1.4 8.1Gbps (HBR3)
- Equalization up to 14.4dB @ 5GHz/2.5GHz
- Single Supply of 3.3V ±10%
- Available in both Commercial Industrial Temperature
- 40 pin QFN 4x6mm 0.4mm Pitch

**Models**

- TUSB546-DCI
- TUSB546evm
- TUSB1046-DCI
- TUSB1046evm
Potential Failure: Mechanical Twist

If the USB plug is removed at an angle, it might cause the VBUS pin to short with SBU or CC/Vconn pins.
Potential Failure: Debris or Water

Any debris or water that is conductive could short the SBU and CC pins to the 20V Vbus lines.
Potential Failure: Noncompliant Cables

- Even if your system is not using USB PD (you are charging at 5V, 500mA), there are non-compliant cables that output 20V without PD negotiation.
- If your system is not designed to handle 20V, then there would be a failure.

In a survey of USB Type-C cables available on Amazon, 28% of cables were not compliant to USB-IF specification. (Google Engineer Benson Leung: 20/71 cables out of specification)

- Despite Amazon’s ban there is still a risk of end user’s purchasing non-compliant USB Type-C cables from cable manufacturers.
USB Type-C Protection Companion Devices

TPD6S300 - USB Type-C CC, SBU, D+/D- protector for Short-to-VBUS & IEC ESD Events

- One-Chip protection solution for USB Type-C Ports CC, SBU, and D+/D- lines
- 4-Channels of Short-to-VBUS Over Voltage Protection (CC1, CC2, SBU1, SBU2): 30V Tolerant OVP FETs
- 6-Channels of IEC 61000-4-2 ESD Protection (CC1, CC2, SBU1, SBU2, DP, DM)
  - ±8kV Contact, ±15kV Air-Gap
- CC1, CC2 FETs 600mA capable for passing VCONN power
- CC Dead Battery Resistors Integrated
- 3mm x 3mm QFN Package Options
- 3.5mm x 3.5mm QFN Package Option for Q1 version

TPD6S300
TPD6S300evm
USB Type-C Protection Companion Devices

- One-Chip protection solution for USB Type-C Ports CC, SBU, and D+/D- lines
- 4-Channels of Short-to-VBUS Over Voltage Protection (CC1, CC2, SBU1, SBU2): 30V Tolerant OVP FETs
- 8-Channels of IEC 61000-4-2 ESD Protection (CC1, CC2, SBU1, SBU2, DP_T, DM_T, DP_B, DM_B)
  - ±8kV Contact, ±15kV Air-Gap
- CC1, CC2 FETs 600mA capable for passing VCONN power
- CC Dead Battery Resistors Integrated
- 3mm x 3mm QFN Package Options
- 3.5mm x 3.5mm QFN Package Option for Q1 version

TPD8S300 - USB Type-C CC, SBU, D+/D- protector for Short-to-VBUS & IEC ESD Events

TPD8S300
TPD8S300evm
TPS65981evm
Getting Started

- **TI’s USB Type-C and Power Delivery Repository**
  - Over 45 TI Reference Designs and Evaluation Modules to jump start your designs!
  - Over 20 Application notes, webinars and white papers
  - Design support through a [USB Type-C focused E2E forum](#)

![2in x 4in Dual-port PD Docking Design](image)
Reference solution for a USB Type-C™ and PD dock including audio, data, power, and video.

![Automotive media interface port design](image)
1in x 2.5in reference design for an automotive 15W USB Type-C™ port with USB 2.0 and 3.0 data.
Thanks!