1 Introduction

With the continued success of the USB interface, there exists a need to adapt USB technology to serve newer computing platforms and devices as they trend toward smaller, thinner and lighter form-factors. Many of these newer platforms and devices are reaching a point where existing USB receptacles and plugs are inhibiting innovation, especially given the relatively large size and internal volume constraints of the Standard-A and Standard-B versions of USB connectors. Additionally, as platform usage models have evolved, usability and robustness requirements have advanced and the existing set of USB connectors were not originally designed for some of these newer requirements. This specification is to establish a new USB connector ecosystem that addresses the evolving needs of platforms and devices while retaining all of the functional benefits of USB that form the basis for this most popular of computing device interconnects.

1.1 Purpose

This specification defines the USB Type-C receptacles, plug and cables.

The USB Type-C Cable and Connector Specification is guided by the following principles:

- Enable new and exciting host and device form-factors where size, industrial design and style are important parameters
- Work seamlessly with existing USB host and device silicon solutions
- Enhance ease of use for connecting USB devices with a focus on minimizing user confusion for plug and cable orientation

The USB Type-C Cable and Connector Specification defines a new receptacle, plug, cable and detection mechanisms that are compatible with existing USB interface electrical and functional specifications. This specification covers the following aspects that are needed to produce and use this new USB cable/connector solution in newer platforms and devices, and that interoperate with existing platforms and devices:

- USB Type-C receptacles, including electro-mechanical definition and performance requirements
- USB Type-C plugs and cable assemblies, including electro-mechanical definition and performance requirements
- USB Type-C to legacy cable assemblies and adapters
- USB Type-C-based device detection and interface configuration, including support for legacy connections
- USB Power Delivery optimized for the USB Type-C connector

The USB Type-C Cable and Connector Specification defines a standardized mechanism that supports Alternate Modes, such as repurposing the connector for docking-specific applications.

1.2 Scope

This specification is intended as a supplement to the existing *USB 2.0*, *USB 3.1* and *USB Power Delivery* specifications. It addresses only the elements required to implement and support the USB Type-C receptacles, plugs and cables.

Normative information is provided to allow interoperability of components designed to this specification. Informative information, when provided, may illustrate possible design implementations.

1.3 Related Documents

USB 2.0 *Universal Serial Bus Revision 2.0 Specification*
This includes the entire document release package.
http://www.usb.org/developers/docs

USB 3.1 *Universal Serial Bus Revision 3.1 Specification*
This includes the entire document release package.
http://www.usb.org/developers/docs

USB PD *USB Power Delivery Specification, Revision 2.0, August 11, 2014*
http://www.usb.org/developers/docs

USB BB *USB Billboard Device Class Specification, Revision 1.0, August 11, 2014*
http://www.usb.org/developers/docs

USB BC *Battery Charging Specification, Revision 1.2 (including errata and ECNs through March 15, 2012), March 15, 2012*
http://www.usb.org/developers/docs

1.4 Conventions

1.4.1 Precedence

If there is a conflict between text, figures, and tables, the precedence shall be tables, figures, and then text.

1.4.2 Keywords

The following keywords differentiate between the levels of requirements and options.

1.4.2.1 Informative

Informative is a keyword that describes information with this specification that intends to discuss and clarify requirements and features as opposed to mandating them.

1.4.2.2 May

May is a keyword that indicates a choice with no implied preference.

1.4.2.3 N/A

N/A is a keyword that indicates that a field or value is not applicable and has no defined value and shall not be checked or used by the recipient.

1.4.2.4 Normative

Normative is a keyword that describes features that are mandated by this specification.

1.4.2.5 Optional

Optional is a keyword that describes features not mandated by this specification. However, if an optional feature is implemented, the feature shall be implemented as defined by this specification (optional normative).

1.4.2.6 Reserved

Reserved is a keyword indicating reserved bits, bytes, words, fields, and code values that are set-aside for future standardization. Their use and interpretation may be specified by future extensions to this specification and, unless otherwise stated, shall not be utilized or adapted by vendor implementation. A reserved bit, byte, word, or field shall be set to zero by the sender and shall be ignored by the receiver. Reserved field values shall not be sent by the sender and, if received, shall be ignored by the receiver.

1.4.2.7 Shall

Shall is a keyword indicating a mandatory (normative) requirement. Designers are mandated to implement all such requirements to ensure interoperability with other compliant Devices.

1.4.2.8 Should

Should is a keyword indicating flexibility of choice with a preferred alternative. Equivalent to the phrase "it is recommended that".

1.4.3 Numbering

Numbers that are immediately followed by a lowercase "b" (e.g., 01b) are binary values. Numbers that are immediately followed by an uppercase "B" are byte values. Numbers that are immediately followed by a lowercase "h" (e.g., 3Ah) are hexadecimal values. Numbers not immediately followed by either a "b", "B", or "h" are decimal values.

1.5 Terms and Abbreviations

Term	Description
Accessory Mode	A reconfiguration of the connector based on the presence of Rd/Rd or Ra/Ra on CC1/CC2, respectively.
Active cable	An Electronically Marked Cable with additional electronics to condition the data path signals.
Alternate Mode	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.
Audio Adapter Accessory Mode	The Accessory Mode defined by the presence of Ra/Ra on CC1/CC2, respectively. See Appendix A.
BFSK	Binary Frequency Shift Keying used for *USB PD* communication over VBUS.
BMC	Biphase Mark Coding used for *USB PD* communication over the CC wire.
Captive cable	A cable that is terminated on one end with a USB Type-C plug and has a vendor-specific connect means (hardwired or custom detachable) on the opposite end.
CC	Configuration Channel (CC) used in the discovery, configuration and management of connections across a USB Type-C cable.
Debug Accessory Mode	The Accessory Mode defined by the presence of Rd/Rd on CC1/CC2, respectively. See Appendix B.
Default VBUS	VBUS voltage as defined by the *USB 2.0* and *USB 3.1* specifications. Note: where used, 5 V connotes the same meaning.

Term	Description
DFP	Downstream Facing Port, specifically associated with the flow of data in a USB connection. Typically the ports on a host or the ports on a hub to which devices are connected. In its initial state, the DFP sources VBUS and VCONN, and supports data. A charge-only DFP port only sources VBUS.
Direct connect	The host's DFP is connected directly with no USB hub in between, either via a cable or without (e.g., thumb drive), to the device's UFP.
DRP	The acronym used in this specification to refer to a USB data port that can operate as either a DFP or a UFP. The role that the port offers may be fixed to either a DFP or UFP or may alternate between the two port states. The port's role may be changed dynamically. Note: this term is not to be confused with the terminology in the USB Power Delivery specification where "dual-role port" refers to power roles.
DR_Swap	*USB PD* Data Role Swap.
Electronically Marked Cable	A USB Type-C cable that uses *USB PD* to provide the cable's characteristics.
Initiator	The port initiating a Vendor Defined Message. It is independent of the port's PD role (e.g., Provider, Consumer, Provider/Consumer, or Consumer/Provider). In most cases, the Initiator will be a host.
Passive cable	A cable that does not incorporate any electronics to condition the data path signals. A passive cable may or may not be electronically marked.
Port Partner	Refers to the port (device or host) a port is attached to.
Powered cable	A cable with electronics in the plug that requires VCONN indicated by the presence of Ra between the VCONN pin and ground.
PR_Swap	*USB PD* Power Role Swap.
Responder	The port responding to the Initiator of a Vendor Defined Message (VDM). It is independent of the port's PD role (e.g., Provider, Consumer, Provider/Consumer, or Consumer/Provider). In most cases, the Responder will be a device.
SBU	Sideband Use.
SID	A Standard ID (SID) is a unique 16-bit value assigned by the USB-IF to identify an industry standard.
Sink	Port asserting Rd on CC and consuming power from VBUS; most commonly a Device.
Source	Port asserting Rp on CC and providing power over VBUS; most commonly a Host or Hub DFP.
SVID	General reference to either a SID or a VID. Used by *USB PD* Structured VDMs when requesting SIDs and VIDs from a device.
Type-A	A general reference to all versions of USB "A" plugs and receptacles.
Type-B	A general reference to all versions of USB "B" plugs and receptacles.

Term	Description
Type-C Plug	A USB plug conforming to the mechanical and electrical requirements in this specification.
Type-C Port	The USB port associated to a USB Type-C receptacle. This includes the USB signaling, CC logic, multiplexers and other associated logic.
Type-C Receptacle	A USB receptacle conforming to the mechanical and electrical requirements of this specification.
UFP	Upstream Facing Port, specifically associated with the flow of data in a USB connection. The port on a device or a hub that connects to a host or the DFP of a hub. In its initial state, the UFP sinks VBUS and supports data.
USB 2.0 Type-C Cable	A USB Type-C to Type-C cable that only supports USB 2.0 data operation. This cable does not include USB 3.1 or SBU wires.
USB 2.0 Type-C Plug	A USB Type-C plug specifically designed to implement the USB 2.0 Type-C cable.
USB Full-Featured Type-C Cable	A USB Type-C to Type-C cable that supports USB 2.0 and USB 3.1 data operation. This cable includes SBU wires.
USB Full-Featured Type-C Plug	A USB Type-C plug specifically designed to implement the USB Full-Featured Type-C cable.
VCONN-powered accessory	An accessory that is powered from VCONN to operate in an Alternate Mode.
VCONN_Swap	*USB PD* VCONN Swap.
VDM	Vendor Defined Message as defined by the *USB PD* specification.
VID	A Vendor ID (VID) is a unique 16-bit value assigned by the USB-IF to identify a vendor.

4 Functional

This chapter covers the functional requirements for the signaling across the USB Type-C cables and connectors. This includes functional signal definition, discovery and configuration processes, and power delivery.

For purposes of this description, a USB port operating as a host is referred to as the Downstream Facing Port (DFP) and a USB port operating as a device is referred to as the Upstream Facing Port (UFP).

Chapter 5 defines functional extensions that are optional.

4.1 Signal Summary

Table 4-1 summarizes the list of signals used on the USB Type-C connectors.

Table 4-1 USB Type-C List of Signals

Signal Group	Signal	Description
USB 3.1	**SSTXp1, SSTXn1** **SSRXp1, SSRXn1** **SSTXp2, SSTXn2** **SSRXp2, SSRXn2**	SuperSpeed USB serial data interface defines 1 differential transmit pair and 1 differential receive pair. On a USB Type-C receptacle, two sets of SuperSpeed USB signal pins are defined to enable plug flipping feature
USB 2.0	**Dp1, Dn1** **Dp2, Dn2**	USB 2.0 serial data interface defines a differential pair. On a USB Type-C receptacle, two set of USB 2.0 signal pins are defined to enable plug flipping feature
Configuration	**CC1, CC2** (receptacle) **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

4.2 Signal Pin Descriptions

4.2.1 SuperSpeed USB Pins

SSTXp1, SSTXn1 (SSTXp2, SSTXn2)

These pins are required to implement the system's transmit path of a USB 3.1 SuperSpeed interface. The transmitter differential pair in a port are routed to the receiver differential pair in the port at the opposite end of the path. The USB 3.1 Specification defines all electrical characteristics, enumeration, protocol, and management features for this interface.

Two pairs of pins are defined to enable the plug flipping feature – see Section 4.5.1.1 for further definition.

SSRXp1, SSRXn1 (SSRXp2, SSRXn2)

These pins are required to implement the system's receive path of a USB 3.1 SuperSpeed interface. The receiver differential pair in a port are routed to the transmitter differential pair in the port at the opposite end of the path. The USB 3.1 Specification defines all electrical characteristics, enumeration, protocol, and management features for this interface.

Two pairs of pins are defined to enable the plug flipping feature – see Section 4.5.1.1 for further definition.

4.2.2 USB 2.0 Pins

Dp1, Dn1 (Dp2, Dn2) These pins are required to implement *USB 2.0* functionality. *USB 2.0* in all three modes (LS, FS, and HS) is supported. The *USB 2.0 Specification* defines all electrical characteristics, enumeration, and bus protocol and bus management features for this interface.

Two pairs of pins are defined to enable the plug flipping feature – see Section 4.5.1.1 for further definition.

4.2.3 Auxiliary Signal Pins

SBU1, SBU2 These pins are assigned to sideband use. Refer to Section 4.3 for the functional requirements.

4.2.4 Power and Ground Pins

VBUS These pins are for USB cable bus power as defined by the USB specifications. This source is only present when a DFP-to-UFP connection across the CC channel is present – see Section 4.5.1.2.1. Refer to Section 4.4.2 for the functional requirements for VBUS.

VCONN VCONN is applied to the unused CC pin to supply power to the local plug. Refer to Section 4.4.3 for the functional requirements for VCONN.

GND Return current path.

4.2.5 Configuration Pins

CC1, CC2, CC These pins are used to detect connections and configure the interface across the USB Type-C cables and connectors. Refer to Section 4.5 for the functional definition. Once a connection is established, CC1 or CC2 will be reassigned for providing power over the VCONN pin of the plug – see Section 4.5.1.2.1.

4.3 Sideband Use (SBU)

The Sideband Use pins (SBU1 and SBU2) are limited to the uses as defined by this specification and additional functionality will be defined in future versions of the USB specifications. See Section 5.1 and Appendix A for use of the SBU pins in Alternate Modes and Audio Adapter Accessory Mode.

The SBU pins on a port shall either be open circuit or have a weak pull-down to ground no stronger than zSBUTermination.

These pins are pre-wired in the standard USB Full-Featured Type-C cable as individual single-ended wires (SBU_A and SBU_B). Note that SBU1 and SBU2 are cross-connected in the cable.

4.4 Power and Ground

4.4.1 IR Drop

The maximum allowable cable IR drop for ground shall be 250 mV and for VBUS shall be 500 mV through the cable to the cable's maximum rated VBUS current capacity. When VCONN is being sourced, the IR drop for the ground shall still be met considering any additional VCONN return current.

Figure 4-1 illustrates what parameters contribute to the IR drop and where it shall be measured. The IR drop includes the contact resistance of the mated plug and receptacles at each end.

Figure 4-1 Cable IR Drop

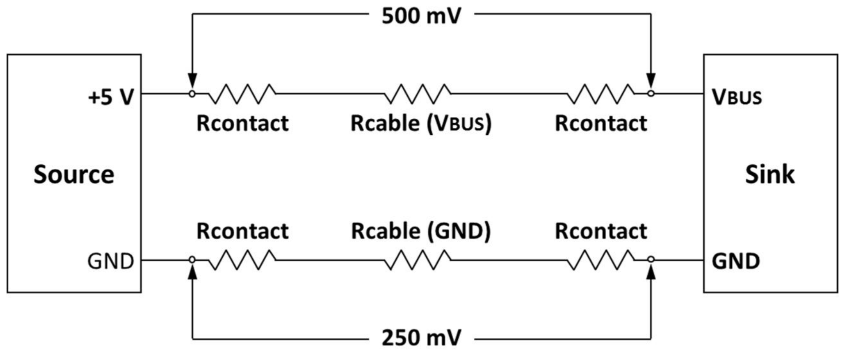
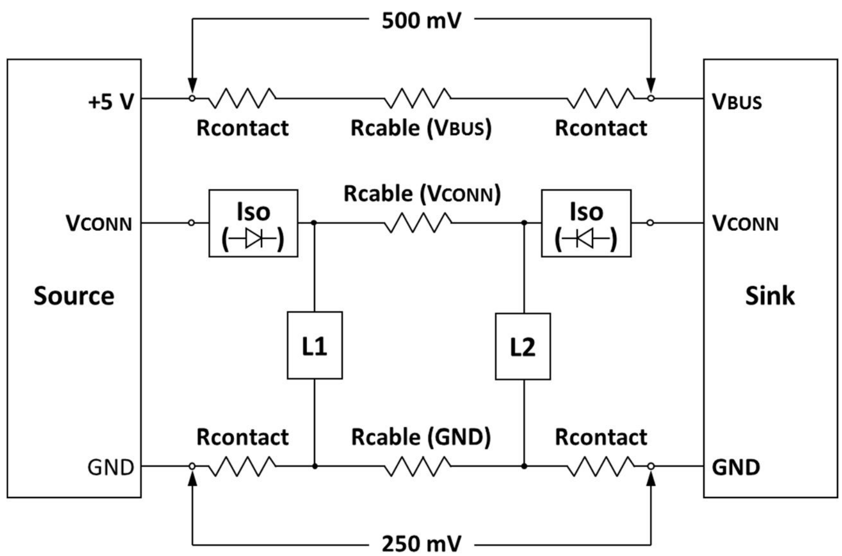


Figure 4-2 illustrates what parameters contribute to the IR drop for a powered cable and where it shall be measured. Note that the powered cable includes isolation elements (Iso) and loads (L1 and L2) for the functions in the powered cable such as *USB PD* controllers. The IR drop shall remain below 250 mV in all cases.

Figure 4-2 Cable IR Drop for powered cables



4.4.2 VBUS

The allowable default range for VBUS as measured at the DFP receptacle shall be as defined by the *USB 2.0 Specification* and *USB 3.1 Specification*. Note that due to higher currents allowed, legacy devices may experience a higher voltage (up to 5.5V maximum) at light loads.

The DFP's USB Type-C receptacle VBUS pin shall remain unpowered until a UFP is attached. The VBUS pin shall return to the unpowered state when the UFP is detached. See Table 4-18 for VBUS timing values. Legacy hosts/chargers that by default source VBUS when connected using any legacy USB connector (Standard-A, Micro-B, etc.) to USB Type-C cable or adapter are exempted from these two requirements.

A DRP or DFP or UFP with Accessory Support implementing an Rp pull-up as its method of connection detection shall provide an impedance between VBUS and GND on its receptacle pins as specified in Table 4-2 when not sourcing power on VBUS (i.e., when in states Unattached.SRC or Unattached.Accessory).

Table 4-2 VBUS Leakage

	Minimum	Maximum	Notes
VBUS Leakage Impedance	72.4 kΩ		Leakage between VBUS pins and GND pins on receptacle when VBUS is not being Sourced.

4.4.3 VCONN

VCONN is provided by the DFP to power cables with electronics in the plug. VCONN is provided over the CC pin that is determined not to be connected to the CC wire of the cable.

Initially, VCONN shall be sourced on all DFP USB Type-C receptacles that utilize the SSTX and SSRX pins during specific connection states as described in Section 4.5.2.2. VCONN may be sourced on DFP USB Type-C receptacles that do not utilize the SSTX and SSRX pins as described in Section 4.5.2.2. *USB PD* VCONN_Swap command also provides the DFP a means to request that the attached UFP source VCONN.

Table 4-3 provides the voltage and power requirements that shall be met for VCONN. See Section 4.9 for more details about Electronically Marked Cables. See Section 4.10 for a wider VCONN voltage operating range for VCONN-powered accessories. See Section 5.1 regarding optional support for an increased VCONN power range in Alternate Modes.

Table 4-3 VCONN Source Characteristics

	Minimum	Maximum	Notes
Voltage	4.75 V	5.5 V	Ports that support VCONN-powered accessories are allowed to supply at a lower minimum of 2.7 V when operating in the PoweredAccessory state.
Power	1.0 W		Source may latch-off VCONN if excessive power is drawn beyond the specified inrush and mode wattage.
Bulk Capacitance	10 μF	220 μF	The VCONN source shall disconnect the bulk capacitance from the receptacle when VCONN is powered off.

To aid in reducing the power associated with supplying VCONN, a DFP is allowed to either not source VCONN or turn off Vconn under any of the following conditions:

- Ra is not detected on the CC pin that is not connected to the CC wire
- After completing the *USB PD* Discover Identity process and determining that VCONN is not needed
- If there is no response to *USB PD* Discover Identity messages

Table 4-4 provides the requirements that shall be met for cables that consume VCONN power.

Table 4-4 VCONN Sink Characteristics

	Minimum	Maximum	Notes
Inrush Capacitance		10 µF	A cable shall not present more than the equivalent inrush capacitance to the VCONN source. The active cable is responsible for discharging its capacitance.
Power for Electronically Marked Cables		70 mW	See Section 4.9.
Power for Active Cables		1.0 W	See Section 5.2.
tVCONNDischarge		250 ms	The time from the point that the cable is detached until vVCONNDischarge shall be met.
vVCONNDischarge		150 mV	The VCONN voltage following cable detach and self-discharge.

The cable may remove or weaken Ra when VCONN is above 1.0 V as long as the other requirements are met. See Section 4.5.1.2.1.

4.5 Configuration Channel (CC)

4.5.1 Architectural Overview

For the USB Type-C solution, two pins on the connector, CC1 and CC2, are used to establish and manage the DFP-to-UFP connection. Note that in this section, "direct connect" is used to refer to a device connected directly to a host (e.g., a thumb drive). When the device is connected through a hub, the connection between a UFP on the hub and the host port and the connection between the device port and a DFP on the hub, are treated as separate connections. Functionally, the configuration channel is used to serve the following purposes.

- Detect attach of USB ports, e.g. a DFP to a UFP
- Resolve cable orientation and twist connections to establish USB data bus routing
- Establish DFP and UFP roles between two attached ports
- Discover and configure VBUS: USB Type-C Current modes or *USB Power Delivery*
- Configure VCONN
- Discover and configure optional Alternate and Accessory modes

4.5.1.1 USB Data Bus Interface and USB Type-C Plug Flip-ability

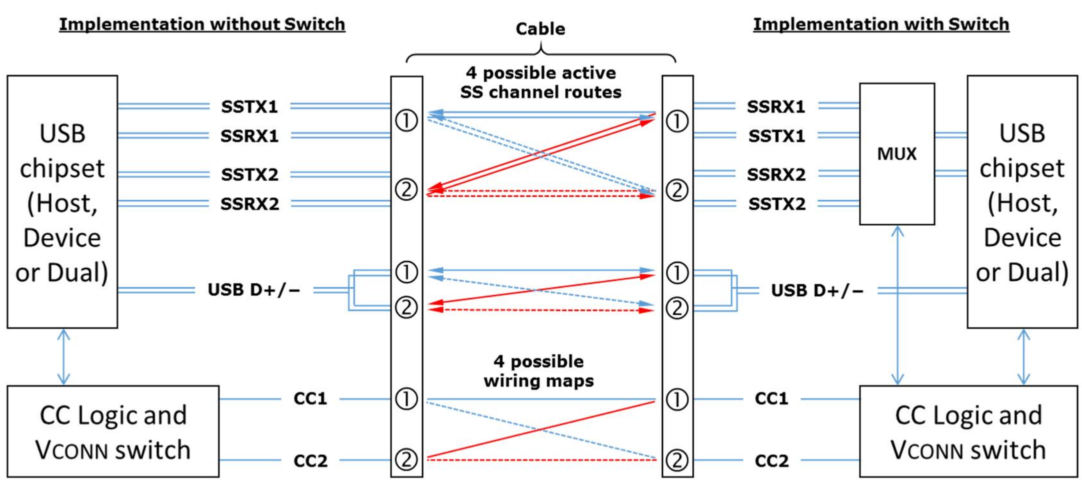
Since the USB Type-C plug can be inserted in either right-side-up or upside-down position, the hosts and devices that support USB data bus functionality must operate on the signal pins that are actually connected end-to-end. In the case of USB 2.0, this is done by shorting together the two D+ signal pins and the two D− signal pins in the DFP and UFP receptacles. In the case of USB SuperSpeed signals, it requires the functional equivalent of a switch in both the DFP and UFP to appropriately route the SuperSpeed TX and RX signal pairs to the connected path through the cable.

Figure 4-3 illustrates the logical data bus model for a USB Type-C-based DFP connected to a USB Type-C-based UFP. The USB cable that sits between a DFP and UFP can be in one of four possible connected states when viewed by the DFP:

- Un-flipped straight through – Position ① ⇔ Position ①
- Un-flipped twisted through – Position ① ⇔ Position ②
- Flipped straight through – Position ② ⇔ Position ②
- Flipped twisted through – Position ② ⇔ Position ①

To establish the proper routing of the active USB data bus from DFP to UFP, the standard USB Type-C cable is wired such that a single CC wire is position aligned with the first USB SuperSpeed signal pairs (SSTXp1/SSTXn1 and SSRXp1/SSRXn1) – in this way, the CC wire and USB SuperSpeed data bus wires that are used for signaling within the cable track with regard to the orientation and twist of the cable. By being able to detect which of the CC pins (CC1 or CC2) at the receptacle is terminated by the UFP, the DFP is able to determine which SuperSpeed USB signals are to be used for the connection and the DFP can use this to control the functional switch for routing the SuperSpeed USB signal pairs. Similarly in the UFP, detecting which of the CC pins at the receptacle is terminated by the DFP allows the UFP to control the functional switch that routes its SuperSpeed USB signal pairs.

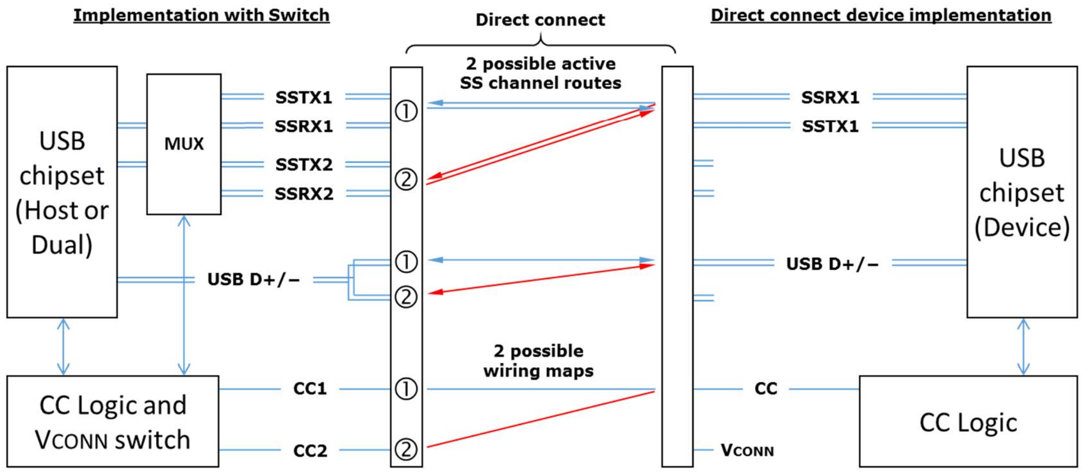
Figure 4-3 Logical Model for Data Bus Routing across USB Type-C-based Ports



While Figure 4-3 illustrates the functional model as a DFP connected to a UFP, this model equally applies to a USB hub's DFPs as well.

Figure 4-4 illustrates the logical data bus model for a USB Type-C-based UFP (implemented with a USB Type-C plug either physically incorporated into the device or permanently attached as a captive cable) connected directly to a USB Type-C-based DFP. For the UFP, the location of the USB SuperSpeed data bus, USB 2.0 data bus, CC and VCONN pins are fixed by design. Given that the UFP pin locations are fixed, only two possible connected states exist when viewed by the DFP.

Figure 4-4 Logical Model for USB Type-C-based Ports for the Direct Connect Device



The functional requirements for implementing SuperSpeed USB data bus routing for the USB Type-C receptacle are not included in the scope of this specification. There are multiple host, device and hub architectures that can be used to accomplish this which could include either discrete or integrated switching, and could include merging this functionality with other USB 3.1 design elements, e.g. a bus repeater.

4.5.1.2 Connecting DFPs and UFPs

Given that the USB Type-C receptacle and plug no longer differentiate host and device roles based on connector shape, e.g., as was the case with USB Type-A and Type-B connectors, any two ports that have USB Type-C receptacles can be connected together with a standard USB Type-C cable. Table 4-5 summarizes the expected results when interconnecting DFP, UFP and DRP ports.

Table 4-5 USB Type-C-based Port Interoperability

	DFP	UFP	DRP
DFP	Non-functional	Functional	Functional
UFP	Functional	Non-functional	Functional
DRP	Functional	Functional	Functional*

* Resolution of roles may be automatic or manually driven

In the cases where no function results, neither port shall be harmed by this connection. The user has to independently realize the invalid combination and take appropriate action to resolve. While these two invalid combinations mimic traditional USB where DFP-to-DFP and UFP-to-UFP connections are not intended to work, the non-keyed USB Type-C solution does not prevent the user from attempting such interconnects. VBUS and VCONN shall not be applied by a DFP in these cases.

The typical flow for the configuration of the interface in the general USB case of a DFP to a UFP is as follows:

1. Detect a valid connection between the ports (including determining cable orientation and DFP/UFP relationship)
2. Optionally discover the cable's capabilities
3. Optionally establish alternatives to traditional USB power (See Section 4.6.2)
    a. *USB PD* communication over CC for advanced power delivery negotiation
    b. USB Type-C Current modes
    c. USB BC 1.2
4. USB Device Enumeration

For cases of DRPs connecting to either DFP, UFP or another DRP, the process is essentially the same except that during the detecting a valid connection step, the DRP alternates between operating as a DFP for detecting an attached UFP and presenting as a UFP to be detected by an attached DFP. Ultimately this results in a DFP-to-UFP connection.

4.5.1.2.1 Detecting a Valid DFP-to-UFP Connection

The general concept for setting up a valid connection between a DFP and UFP is based on being able to detect terminations residing in the product being attached.

To aid in defining the functional behavior of CC, a pull-up (Rp) and pull-down (Rd) termination model is used – actual implementation in hosts and devices may vary, for example, the pull-up termination could be replaced by a current source. Figure 4-5 and Figure 4-6 illustrates two models, the first based on a pull-up resistor in the DFP and the second replacing this with a current source.

Figure 4-5 Pull-Up/Pull-Down CC Model

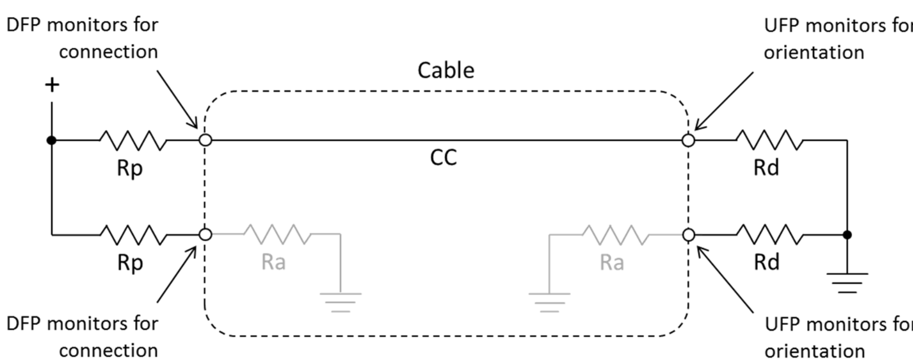
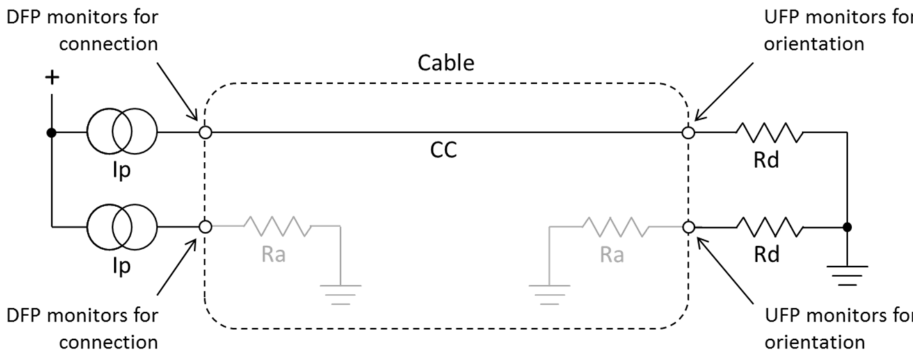


Figure 4-6 Current Source/Pull-Down CC Model



Initially, a DFP exposes Rp terminations on its CC pins and a UFP exposes Rd terminations on its CC pins, the DFP-to-UFP combination of this circuit configuration represents a valid connection. To detect this, the DFP monitors both CC pins for a voltage lower than its unterminated voltage – the choice of Rp is a function of the pull-up termination voltage and the DFP's detection circuit. This indicates that either a UFP, a powered cable, or a UFP connected via a powered cable has been attached.

Prior to application of VCONN, a powered cable exposes Ra on its VCONN pin. Ra represents the load on VCONN plus any resistive elements to ground. In some cable plugs it might be a pure resistance and in others it may be simply the load.

The DFP has to be able to differentiate between the presence of Rd and Ra to know whether there is a UFP attached and where to apply VCONN. The DFP is not required to source VCONN unless Ra is detected.

Two special termination combinations on the CC pins as seen by a DFP are defined for directly attached Accessory Modes: Ra/Ra for Audio Adapter Accessory Mode (Appendix A) and Rd/Rd for Debug Accessory Mode (Appendix B).

The DFP uses de-bounce timers to reliably detect states on the CC pins to de-bounce the connection (tCCDebounce), and hide *USB PD* BMC communications (tPDDebounce).

Table 4-6 summarizes the port state from the DFP's perspective.

Table 4-6 Source Perspective

CC1	CC2	State	Position
Open	**Open**	Nothing attached	N/A
Rd	**Open**	Sink attached	①
Open	**Rd**		②
Open	**Ra**	Powered cable without Sink attached	①
Ra	**Open**		②
Rd	**Ra**	Powered cable withSink or VCONN-powered Accessory attached	①
Ra	**Rd**		②
Rd	**Rd**	Debug Accessory Mode attached (Appendix B)	N/A
Ra	**Ra**	Audio Adapter Accessory Mode attached (Appendix A)	N/A

When the UFP senses VBUS, the UFP monitors both CC pins for a voltage greater than its local ground. The CC pin that is at a higher voltage (i.e. pulled up by Rp in the DFP) indicates the orientation of the plug.

Table 4-7 summarizes the typical behaviors for simple DFPs and UFPs for each state in Table 4-6.

Table 4-7 Source and Sink Behaviors by State

State	Source Behavior	Sink Behavior
Nothing attached	• Sense CC pins for attach • Do not apply VBUS or VCONN	• Sense VBUS for attach
Sink attached	• Sense CC for orientation • Sense CC for detach • Apply VBUS and VCONN	• Sense CC pins for orientation • Sense loss of VBUS for detach
Powered cable without Sink attached	• Sense CC pins for attach • Do not apply VBUS or VCONN	• Sense VBUS for attach
Powered cablewithSink or VCONN-powered Accessory attached	• Sense CC for orientation • Sense CC for detach • Apply VBUS and VCONN	• If accessories are supported, see Source Behavior with exception that VBUS is not applied., otherwise, N/A.
Debug Accessory Mode attached	• Sense CC pins for detach • Reconfigure for debug	• If accessories are supported, see Source Behavior, otherwise, N/A
Audio Adapter Accessory Mode attached	• Sense CC pins for detach • Reconfigure for analog audio	• If accessories are supported, see Source Behavior, otherwise, N/A

Figure 4-3 shows how the inserted plug orientation is detected at the DFP's receptacle by noting on which of the two CC pins in the receptacle an Rd termination is sensed. Now that the DFP has recognized that a UFP is attached and the plug orientation is determined, it configures the SuperSpeed USB data bus routing to the receptacle.

The DFP then turns on VBUS. For the CC pin that does not connect DFP-to-UFP through the cable, the DFP supplies VCONN and may remove the termination. With the UFP now powered, it configures the USB data path. This completes the DFP-to-UFP connection.

The DFP monitors the CC wire for the loss of pull-down termination to detect detach. If the UFP is removed, the DFP port removes any voltage applied to VBUS and VCONN, resets its interface configuration and resumes looking for a new UFP attach.

Once a valid DFP-to-UFP connection is established, alternatives to traditional USB power (VBUS as defined by either *USB 2.0* or *USB 3.1* specifications) may be available depending on the capabilities of the host and device. These include USB Type-C Current, USB Power Delivery, and *USB Battery Charging 1.2*.

In the case where *USB PD* PR_Swap is used to swap the source and sink of VBUS, the source of VCONN remains unchanged during and after the VBUS power swap. The new source monitors the CC wire and the new sink monitors VBUS to detect detach. When a detach event is detected, any voltages applied to VBUS and VCONN are removed, each port resets its interface configuration and resumes looking for an attach event.

In the case where *USB PD* DR_Swap is used to swap the DFP and UFP, the new UFP maintains sourcing VCONN during and after the data role swap.

In the case where USB PD VCONN_Swap is used to swap the VCONN source, the VBUS source/sink and DFP/UFP roles are maintained during and after the VCONN swap.

The last step in the normal USB Type-C connect process is for the USB device to be attached and enumerated per standard USB 2.0 and USB 3.1 processes.

4.5.1.3 Configuration Channel Functional Models

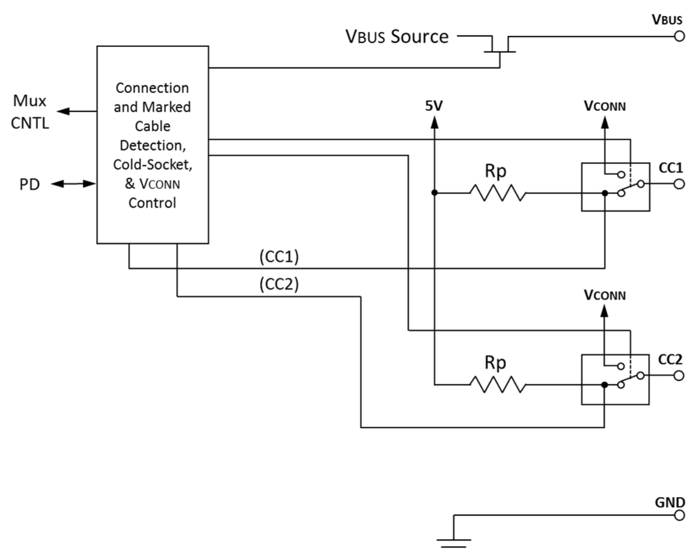
The functional models for the configuration channel behavior based on the CC1 and CC2 pins are described in this section for each port type: DFP, UFP and DRP.

The figures in the following sections illustrate the CC1 and CC2 routing after the CC detection process is complete. In these figures, VBUS and VCONN may or may not actually be available.

4.5.1.3.1 DFP Configuration Channel Functional Model

Figure 4-7 illustrates the functional model for CC1 and CC2 for a DFP prior to attach. This illustration includes consideration for the USB PD Provider.

Figure 4-7 DFP Functional Model for CC1 and CC2



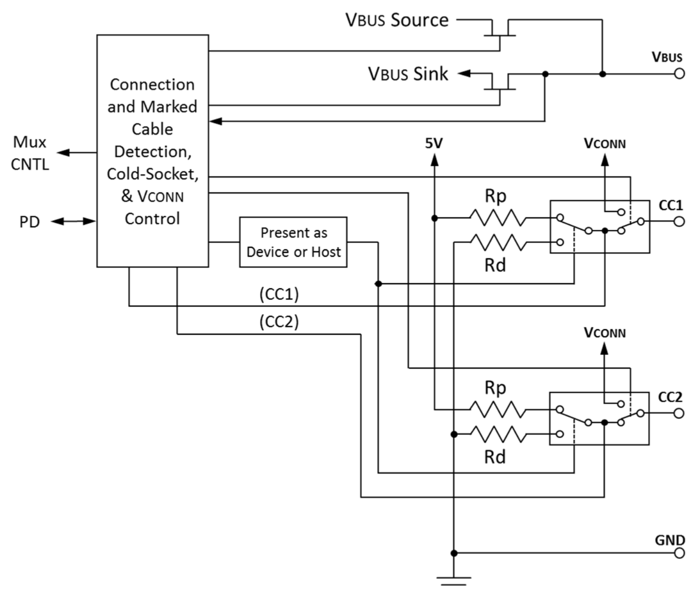
Referring to Figure 4-7, a port that behaves as a DFP has the following functional characteristics:

1. The DFP uses a FET to enable/disable power delivery across VBUS and initially the DFP has VBUS disabled.
2. The DFP supplies pull-up resistors (Rp) on CC1 and CC2 and monitors both CC pins to detect a UFP – the presence of an Rd pull-down resistor on either pin indicates that a UFP is being attached. The value of Rp indicates the initial USB Type-C Current level supported by the host.
3. The DFP uses the CC pin pull-down characteristic to detect and establish the correct routing for the USB SuperSpeed data path and determine which CC pin is intended for supplying VCONN.
4. Once a UFP is detected, the DFP enables VBUS and VCONN.

5. The DFP can dynamically adjust the value of Rp to indicate a change in available USB Type-C Current to a UFP.
6. The DFP monitors the continued presence of Rd to detect UFP detach. When a detach event is detected, the DFP removes VBUS and VCONN, and returns to step 2.
7. If the DFP supports advanced functions (USB Power Delivery and/or Alternate Modes), *USB PD* communication is required.

Figure 4-8 illustrates the functional model for CC1 and CC2 for a DFP that is a *USB PD* Provider/Consumer (e.g., supports *USB PD* PR_Swap) prior to attach.

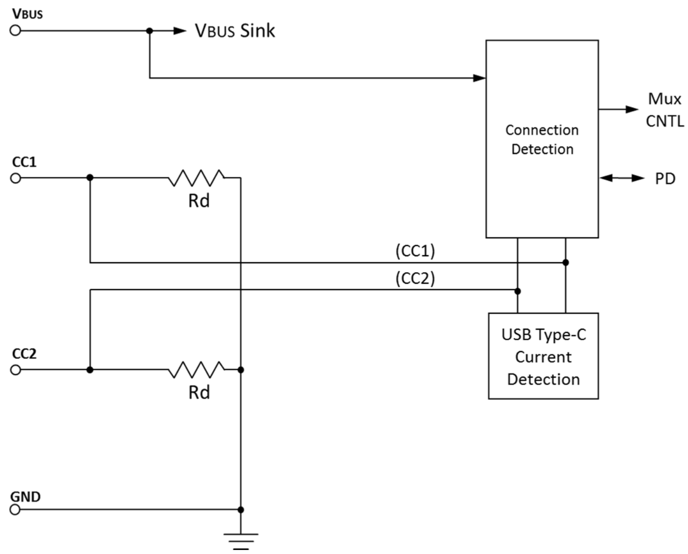
Figure 4-8 DFP Functional Model Supporting USB PD Provider/Consumer



4.5.1.3.2 UFP Configuration Channel Functional Model

Figure 4-9 illustrates the functional model for CC1 and CC2 for a UFP. This illustration includes consideration for both USB Type-C Current and *USB PD* Consumer.

Figure 4-9 UFP Functional Model for CC1 and CC2

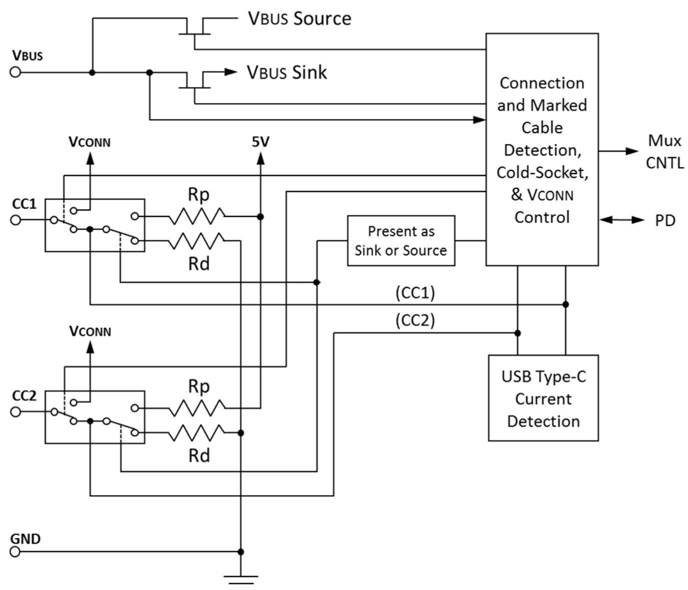


Referring to Figure 4-9, a port that behaves as a UFP has the following functional characteristics:

1. The UFP terminates both CC1 and CC2 to GND using pull-down resistors.
2. The UFP determines that a DFP is attached by the presence of power on VBUS.
3. The UFP uses the CC pin pull-up characteristic to detect and establish the correct routing for the USB SuperSpeed data path.
4. The UFP can optionally monitor CC to detect an available higher USB Type-C Current from the DFP. The UFP shall manage its load to stay within the detected DFP current limit.
5. If the UFP supports advanced functions (USB Power Delivery and/or Alternate Modes), *USB PD* communication is required.

Figure 4-10 illustrates the functional model for CC1 and CC2 for a UFP that is a *USB PD* Consumer/Provider (e.g., supports *USB PD* PR_Swap) and supports *USB PD* VCONN_Swap prior to attach.

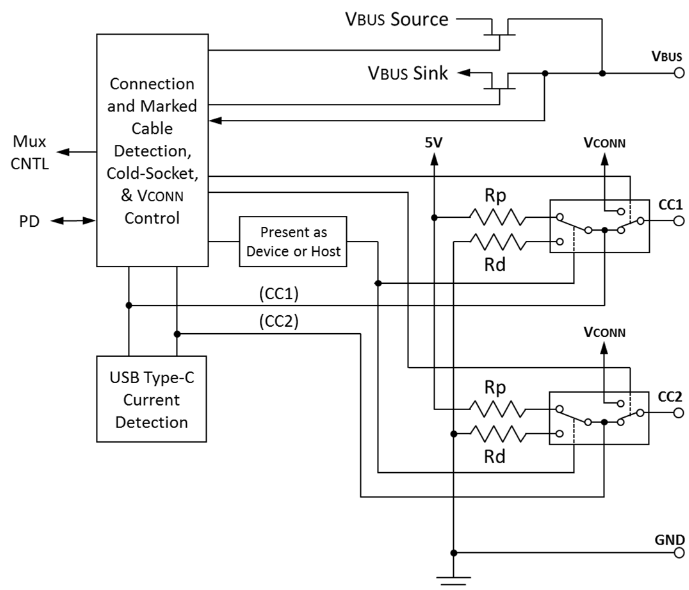
Figure 4-10 UFP Functional Model Supporting USB PD Consumer/Provider and VCONN_Swap



4.5.1.3.3 DRP Configuration Channel Functional Model

Figure 4-11 illustrates the functional model for CC1 and CC2 for a DRP presenting as a DFP prior to attach. This illustration includes consideration for both the USB Type-C Current and the *USB PD* features.

Figure 4-11 DRP Functional Model for CC1 and CC2



Referring to Figure 4-11, a port that can alternate between DFP and UFP behaviors has the following functional characteristics:

1. The DRP uses a FET to enable/disable power delivery across VBUS and initially when in DFP mode has VBUS disabled.
2. The DRP uses switches for presenting as a DFP or UFP.
3. The DRP has logic used during initial attach to toggle between DFP and UFP operation:
    a. Until a specific stable state is established, the DRP alternates between exposing itself as a DFP and UFP. The timing of this process is dictated by a period (tDRP), percentage of time that a DRP exposes Rp (dcSRC.DRP) and role transition time (tDRPTransition).
    b. When the DRP is presenting as a DFP, it follows DFP operation to detect an attached UFP – if a UFP is detected, it applies VBUS, VCONN, and continues to operate as a DFP for a minimum of tDRPHold (e.g., cease alternating).
    c. When the DRP is presenting as a UFP, it monitors VBUS to detect that it is attached to a DFP – if a DFP is detected, it continues to operate as a UFP (cease alternating).
4. If the DRP supports advanced functions (USB Power Delivery and/or Alternate Modes), *USB PD* communication is required.
    a. If a DRP supports *USB PD*, initially the *USB PD* role follows the port role, i.e., when operating as a DFP, the *USB PD* operates as a Provider/Consumer and when operating as a UFP, the *USB PD* operates as a Consumer/Provider.

4.5.1.4 USB PD-based Power Role, Data Role and VCONN Swapping

Table 4-8 summarizes the behaviors of a port in response to the three *USB PD* swap commands.

Table 4-8 USB PD Swapping Port Behavior Summary

	Host/Device Data Roles	Rp/Rd	VBUS Source/Sink	VCONN Source
PR_Swap	Unchanged	Swapped	Swapped	Unchanged
DR_Swap	Swapped	Unchanged	Unchanged	Unchanged
VCONN_Swap	Unchanged	Unchanged	Unchanged	Swapped*

* Swapping of VCONN source port

4.5.2 CC Functional and Behavioral Requirements

This section provides the functional and behavioral requirements for implementing CC. The first sub-section provides connection state diagrams that are the basis for the remaining sub-sections.

The terms Source (SRC) and Sink (SNK) used in this section refer to the port's power role while the terms DFP and UFP refer to the port's data role. A DRP (Dual Role Port) is capable of acting as either a Source or Sink. Typically DFPs are found on hosts and source VBUS while a UFP is found on a device and sinks power from VBUS. When a connection is initially made, the port's initial power state and data role are established. USB PD introduces three swap commands that may alter a port's power or data role:

- The PR_Swap command changes the port's power state as reflected in the following state machines. PR_Swap does not change the port sourcing VCONN.
- The DR_Swap command has no effect on the following state machines or VCONN as it only changes the port's data role.
- VCONN_Swap command changes the port sourcing VCONN. The PR_Swap command and DR_Swap command have no effect on the port sourcing VCONN.

The connection state diagrams and CC behavior descriptions in this section describe the behavior of receptacle-based ports. The plug on a direct connect device or a device with a captive cable shall behave as a plug on a cable that is attached at its other end in normal orientation to a receptacle, These devices shall apply and sense CC voltage levels on pin A5 only and pin B5 shall have an impedance above zOPEN, unless it is a Powered Accessory, in which case B5 shall have an impedance Ra.

4.5.2.1 Connection State Diagrams

This section provides reference connection state diagrams for CC-based behaviors.

Refer to Section 4.5.2.2 for the specific state transition requirements related to each state shown in the diagrams.

Refer to Section 4.5.2.4 for a description of which states are mandatory for each port type, and a list of states where *USB PD* communication is permitted.

Figure 4-12 illustrates a connection state diagram for a Source (Host/Hub DFP).

Figure 4-12 Connection State Diagram: Source

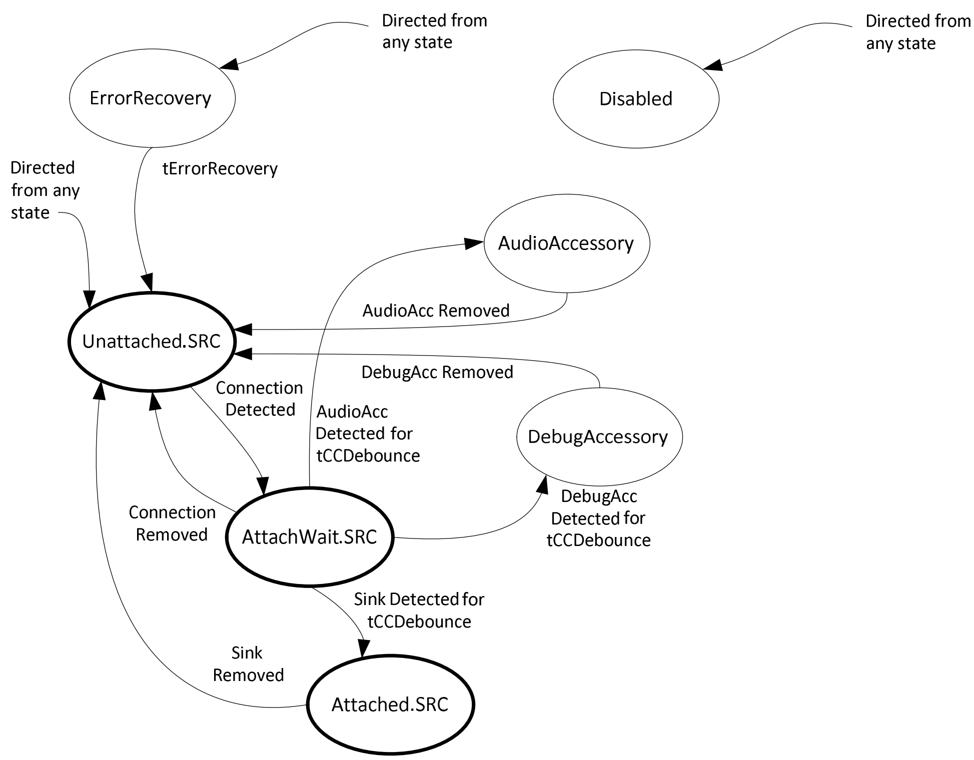


Figure 4-13 illustrates a connection state diagram for a simple Sink (Device UFP).

Figure 4-13 Connection State Diagram: Sink

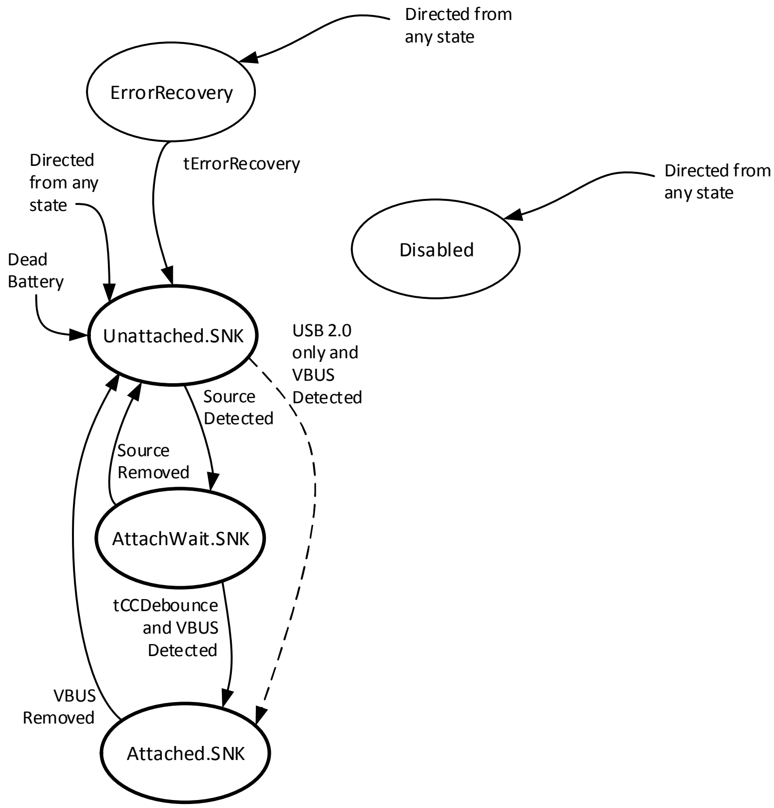


Figure 4-14 illustrates a connection state diagram for a Sink that supports Accessory Modes.

Figure 4-14 Connection State Diagram: Sink with Accessory Support

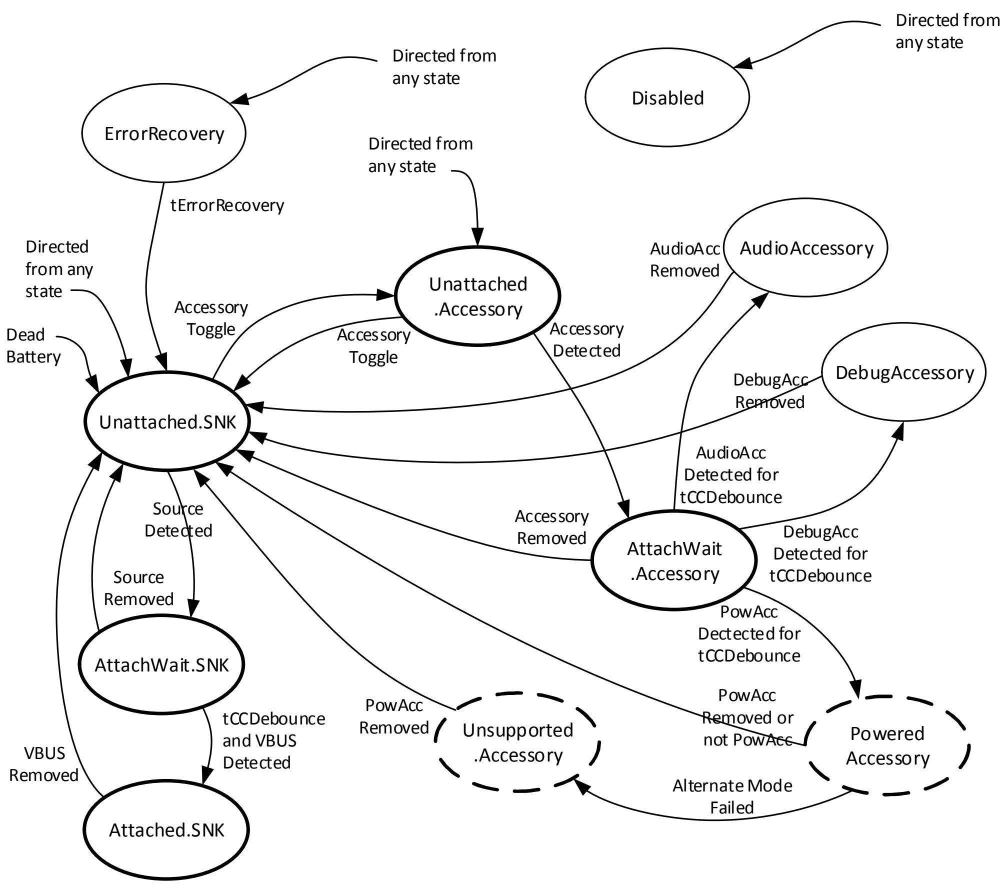


Figure 4-15 illustrates a connection state diagram for a simple DRP.

Figure 4-15 Connection State Diagram: DRP

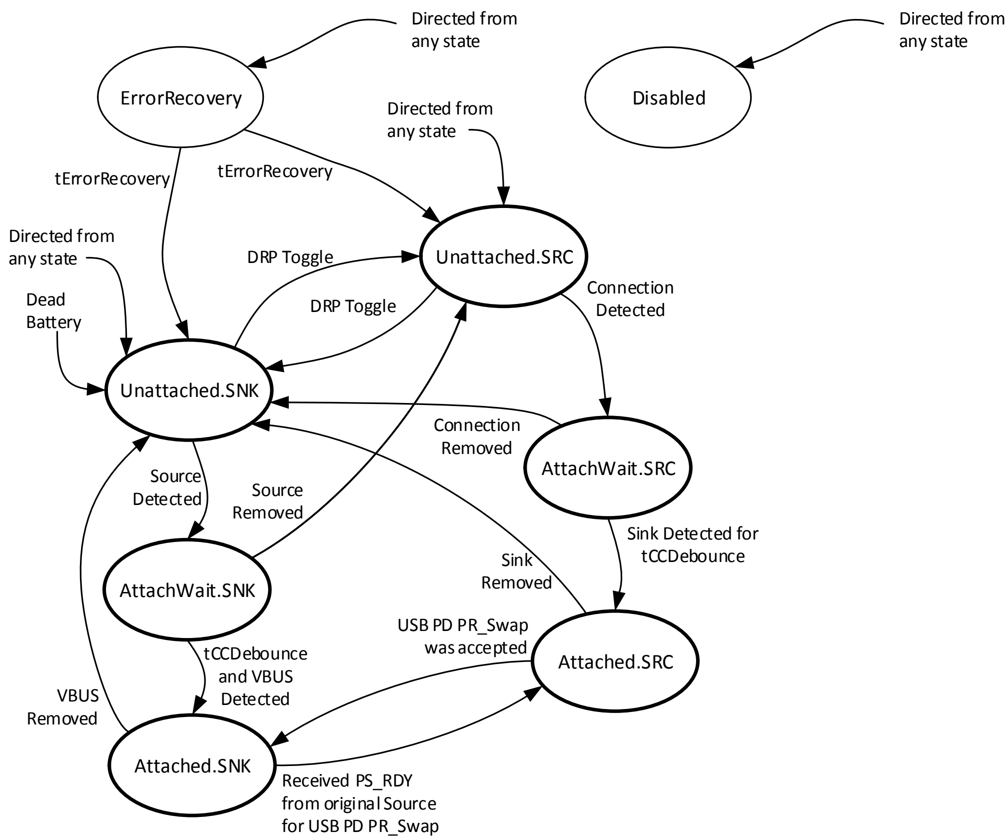
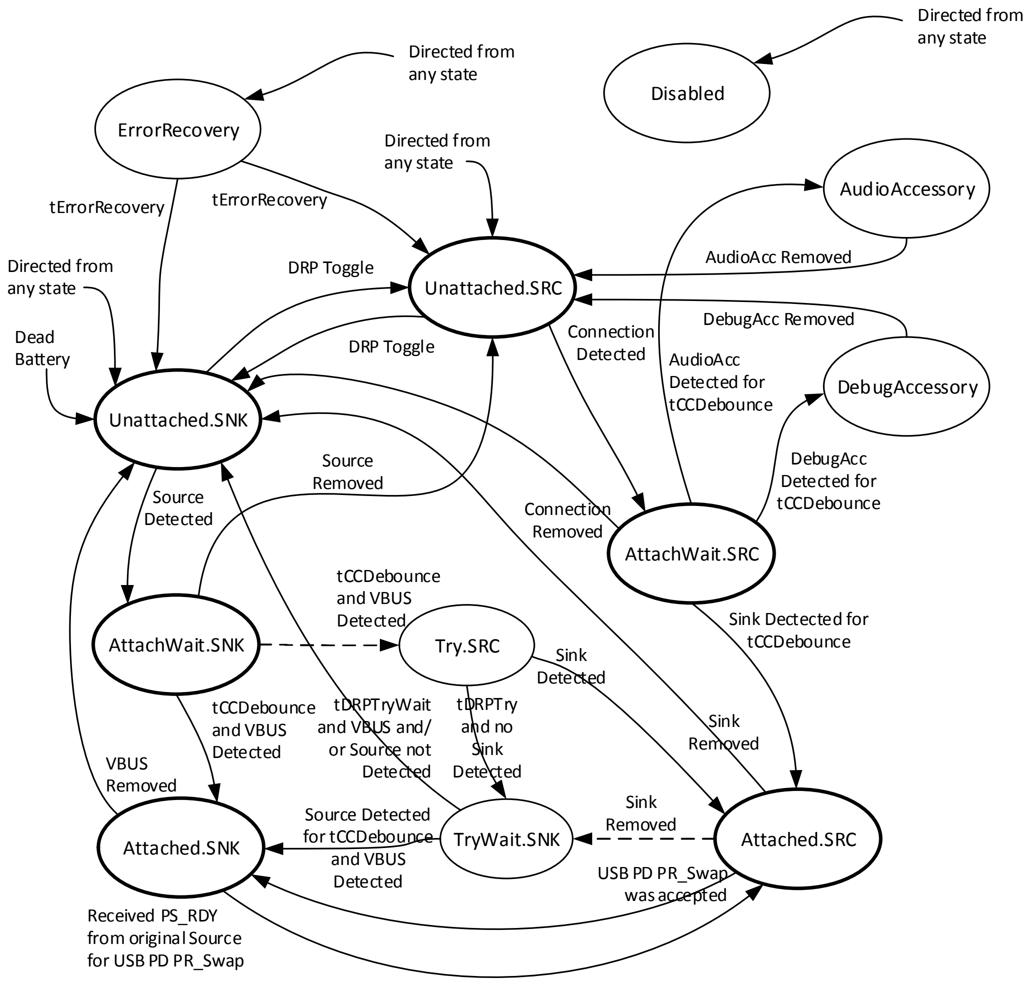


Figure 4-16 illustrates a connection state diagram for a DRP that supports all possible states including Accessory Modes and Try.SRC.

Figure 4-16 Connection State Diagram: DRP with Accessory and Try.SRC Support



4.5.2.2 Connection State Machine Requirements

Entry into any unattached state when "directed from any state" shall not be used to override tDRP toggle.

A DRP or a Sink may consume default power from VBUS in any state where it is not required to provide VBUS.

The following two tables define the electrical states for a CC pin in both a Source and a Sink. Every port has two CC pins, each with its own individual CC pin state. The combination of a port's two CC pin states are be used to define the conditions under which a port transitions from one state to another.

Table 4-9 Source Port CC Pin State

CC Pin State	Port partner CC Termination	Voltage Detected on CC when port asserts Rp
SRC.Open	**Open, Rp**	Above vOPEN
SRC.Rd	**Rd**	Within the vRd range (i.e., between minimum vRd and maximum vRd)
SRC.Ra	**Ra**	Below maximum vRa

Table 4-10 Sink Port CC Pin State

CC Pin State	Port partner CC Termination	Voltage Detected on CC when port asserts Rd
SNK.Rp	**Rp**	Above minimum vRd-Connect
SNK.Open	**Open, Ra, Rd**	Below maximum vRa

4.5.2.2.1 Disabled State

This state appears in Figure 4-12, Figure 4-13, Figure 4-14, Figure 4-15 and Figure 4-16.

The Disabled state is where the port prevents connection from occurring by removing all terminations from the CC pins.

The port should transition to the Disabled state from any other state when directed.

A port may choose not to support the Disabled state. If the Disabled state is not supported, the port shall be directed to either the Unattached.SNK or Unattached.SRC states after power-on.

4.5.2.2.1.1 Disabled State Requirements

The port shall not drive VBUS or VCONN, and shall present a high-impedance to ground (above zOPEN) on its CC pins.

4.5.2.2.1.2 Exiting From Disabled State

A Sink shall transition to Unattached.SNK when directed.

A Source shall transition to Unattached.SRC when directed.

A DRP shall transition to either Unattached.SNK or Unattached.SRC when directed.

4.5.2.2.2 ErrorRecovery State

This state appears in Figure 4-12, Figure 4-13, Figure 4-14, Figure 4-15 and Figure 4-16.

The ErrorRecovery state is where the port cycles its connection by removing all terminations from the CC pins for tErrorRecovery followed by transitioning to the appropriate Unattached.SNK or Unattached.SRC state based on port type.

The port should transition to the ErrorRecovery state from any other state when directed.

A port may choose not to support the ErrorRecovery state. If the ErrorRecovery state is not supported, the port shall be directed to the Disabled state if supported. If the Disabled state is not supported, the port shall be directed to either the Unattached.SNK or Unattached.SRC states.

4.5.2.2.2.1 ErrorRecovery State Requirements

The port shall not drive VBUS or VCONN, and shall present a high-impedance to ground (above zOPEN) on its CC pins.

4.5.2.2.2.2 Exiting From ErrorRecovery State

A Sink shall transition to Unattached.SNK after tErrorRecovery.

A Source shall transition to Unattached.SRC after tErrorRecovery.

A DRP shall transition to either Unattached.SNK or Unattached.SRC after tErrorRecovery.

4.5.2.2.3 Unattached.SNK State

This state appears in Figure 4-13, Figure 4-14, Figure 4-15 and Figure 4-16.

When in the Unattached.SNK state, the port is waiting to detect the presence of a Source.

A port with a dead battery shall enter this state while unpowered.

4.5.2.2.3.1 Unattached.SNK Requirements

The port shall not drive VBUS or VCONN.

Both CC pins shall be independently terminated to ground through Rd.

4.5.2.2.3.2 Exiting from Unattached.SNK State

The port shall transition to AttachWait.SNK when a Source connection is detected, as indicated by the SNK.Rp state on one of its CC pins.

A USB 2.0 only Sink without Accessory support that is self-powered or requires only default power and does not support *USB PD* may transition directly to Attached.SNK when VBUS is detected.

A DRP shall transition to Unattached.SRC within tDRPTransition after the state of both CC pins is SNK.Open for tDRP − dcSRC.DRP · tDRP, or if directed.

A Sink with Accessory support shall transition to Unattached.Accessory within tDRPTransition after the state of both CC pins is SNK.Open for tDRP − dcSRC.DRP · tDRP, or if directed.

4.5.2.2.4 AttachWait.SNK State

This state appears in Figure 4-13, Figure 4-14, Figure 4-15 and Figure 4-16.

When in the AttachWait.SNK state, the port has detected the SNK.Rp state on one CC pin and is waiting for VBUS.

4.5.2.2.4.1 AttachWait.SNK Requirements

The port shall not drive VBUS or VCONN.

Both CC pins shall be independently terminated to ground through Rd.

It is strongly recommended that a USB 3.1 SuperSpeed device hold off VBUS detection to the device controller until the Attached.SNK state is reached. Otherwise, it may connect as USB 2.0 when attached to a legacy host or hub's DFP.

4.5.2.2.4.2 Exiting from AttachWait.SNK State

A Sink shall transition to Unattached.SNK when the state of both CC pins is SNK.Open for at least tPDDebounce.

A DRP shall transition to Unattached.SRC when the state of both CC pins is SNK.Open for at least tPDDebounce.

The port shall transition to Attached.SNK if the state of exactly one CC pin has been SNK.Open for at least tCCDebounce and VBUS is detected. Note the Source may initiate *USB PD* communications which will cause brief periods of the SNK.Open state on both CC pins, but this event will not exceed tPDDebounce.

A DRP that strongly prefers the Source role may optionally transition to Try.SRC instead of Attached.SNK when the state of one CC pin has been SNK.Rp for at least tCCDebounce and VBUS is detected.

4.5.2.2.5 Attached.SNK State

This state appears in Figure 4-13, Figure 4-14, Figure 4-15 and Figure 4-16.

When in the Attached.SNK state, the port is attached and operating as a Sink. When the port initially enters this state it is also operating as a UFP. The power and data roles can be changed using *USB PD* commands.

A port that entered this state directly from Unattached.SNK due to detecting VBUS shall not determine orientation or availability of higher than Default USB Power and shall not use *USB PD*.

4.5.2.2.5.1 Attached.SNK Requirements

If the port needs to determine the orientation of the connector, it shall do so only upon entry to this state by detecting which CC pin is connected through the cable (i.e., the CC pin that is in the SNK.Rp state).

If the port supports signaling on USB SuperSpeed pairs, it shall functionally connect the USB SuperSpeed pairs and maintain the connection during and after a *USB PD* PR_Swap.

If the port has entered the Attached.SNK state from the AttachWait.SNK or TryWait.SNK states, only one CC pin will be in the SNK.Rp state. The port shall continue to terminate this CC pin to ground through Rd.

If the port has entered the Attached.SNK state from the Attached.SRC state following a *USB PD* PR_Swap, the port shall terminate the connected CC pin to ground through Rd.

The port shall meet the Sink Power Sub-State requirements specified in Section 4.5.2.3.

The port may negotiate a *USB PD* PR_Swap, DR_Swap or VCONN_Swap.

By default, upon entry from AttachWait.SNK or Unattached.SNK, VCONN shall not be supplied in the Attached.SNK state. If Attached.SNK is entered from Attached.SRC as a result of a *USB PD* PR_Swap, it shall maintain VCONN supply state, whether on or off, and its data role/connections. A *USB PD* DR_Swap has no effect on which port sources VCONN.

The port may negotiate a *USB PD* VCONN_Swap. When the port successfully executes *USB PD* VCONN_Swap operation and was not sourcing VCONN, it shall start sourcing VCONN within tVCONNON. When the port successfully executes *USB PD* VCONN_Swap operation and was sourcing VCONN, it shall stop sourcing VCONN within tVCONNOFF.

4.5.2.2.5.2 Exiting from Attached.SNK State

A port that is not in the process of a *USB PD* PR_Swap or a *USB PD* Hard Reset shall transition to Unattached.SNK when VBUS is no longer present. If supplying VCONN, the port shall cease to supply it within tVCONNOFF of exiting Attached.SNK.

After receiving a *USB PD* PS_RDY from the original Source during a *USB PD* PR_Swap, the port shall transition directly to the Attached.SRC state (i.e., remove Rd from CC, assert Rp on CC and supply VBUS), but shall maintain its VCONN supply state, whether off or on, and its data role/connections.

4.5.2.2.6 Unattached.SRC State

This state appears in Figure 4-12, Figure 4-15 and Figure 4-16.

When in the Unattached.SRC state, the port is waiting to detect the presence of a Sink or an Accessory.

4.5.2.2.6.1 Unattached.SRC Requirements

The port shall not drive VBUS or VCONN.

The port shall source current on both CC pins independently.

The port shall provide an Rp as specified in Table 4-13.

4.5.2.2.6.2 Exiting from Unattached.SRC State

The port shall transition to AttachWait.SRC when:

- The SRC.Rd state is detected on at least one CC pin or
- The SRC.Ra state is detected on both CC pins.

Note: A cable without an attached device can be detected, when the SRC.Ra state is detected on one CC pin and the SRC.Open state is detected on the other CC pin. However in this case, the port shall not transition to AttachWait.SRC.

A DRP shall transition to Unattached.SNK within tDRPTransition after dcSRC.DRP · tDRP, or if directed.

4.5.2.2.7 AttachWait.SRC State

This state appears in Figure 4-12, Figure 4-15 and Figure 4-16.

The AttachWait.SRC state is used to ensure that the state of both of the CC pins is stable after a Sink is connected.

4.5.2.2.7.1 AttachWait.SRC Requirements

The requirements for this state are identical to Unattached.SRC.

4.5.2.2.7.2 Exiting from AttachWait.SRC State

The port shall transition to Attached.SRC when the SRC.Rd state is detected on exactly one of the CC pins for at least tCCDebounce.

If the port supports Audio Adapter Accessory Mode, it shall transition to AudioAccessory when the SRC.Ra state is detected on both CC pins for at least tCCDebounce.

If the port supports Debug Accessory Mode, it shall transition to DebugAccessory when the SRC.Rd state is detected on both CC pins for at least tCCDebounce

A Source shall transition to Unattached.SRC and a DRP to Unattached.SNK when the SRC.Open state is detected on both CC pins.

A Source shall transition to Unattached.SRC and a DRP to Unattached.SNK when the SRC.Open state is detected on one CC pin and the SRC.Ra state is detected on the other CC pin.

4.5.2.2.8 Attached.SRC State

This state appears in Figure 4-12, Figure 4-15 and Figure 4-16.

When in the Attached.SRC state, the port is attached and operating as a Source. When the port initially enters this state it is also operating as a DFP. Subsequently, the initial power and data roles can be changed using *USB PD* commands.

4.5.2.2.8.1 Attached.SRC Requirements

If the port needs to determine the orientation of the connector, it shall do so only upon entry to the Attached.SRC state by detecting which CC pin is connected through the cable (i.e., which CC pin is in the SRC.Rd state).

If the port has entered this state from the AttachWait.SRC state or the Try.SRC state, the SRC.Rd state will be on only one CC pin. The port shall source current on this CC pin and monitor its state.

If the port has entered this state from the Attached.SNK state as the result of a *USB PD* PR_Swap, the port shall source current on the connected CC pin and monitor its state.

The port shall provide an Rp as specified in Table 4-13.

The port shall supply VBUS current at the level it advertises on Rp.

The port shall supply VBUS within tVBUSON of entering this state, and for as long as it is operating as a power source.

The port shall not initiate any *USB PD* communications until VBUS reaches vSafe5V.

If the port supports signaling on USB SuperSpeed pairs, it shall:

- Functionally connect the USB SuperSpeed pairs
- For VCONN, do one of two things:
    - Apply VCONN unconditionally to the CC pin not in the SRC.Rd state, or
    - Apply VCONN to the CC pin in the SRC.Ra state.

A port that does not support signaling on USB SuperSpeed pairs may supply VCONN in the same manner described above.

The port may negotiate a *USB PD* PR_Swap, DR_Swap or VCONN_Swap.

If the port supplies VCONN, it shall do so within tVCONNON.

The port shall not supply VCONN if it has entered this state as a result of a *USB PD* PR_Swap and was not previously supplying VCONN. A *USB PD* DR_Swap has no effect on which port sources VCONN.

The port may negotiate a *USB PD* VCONN_Swap. When the port successfully executes *USB PD* VCONN_Swap operation and was sourcing VCONN, it shall stop sourcing VCONN within tVCONNOFF. When the port successfully executes *USB PD* VCONN_Swap operation and was not sourcing VCONN, it shall start sourcing VCONN within tVCONNON.

4.5.2.2.8.2 Exiting from Attached.SRC State

A Source shall transition to Unattached.SRC when the SRC.Open state is detected on the monitored CC pin.

When the SRC.Open state is detected on the monitored CC pin, a DRP shall transition to Unattached.SNK unless it strongly prefers the Source role. In that case, it shall transition to TryWait.SNK. This transition to TryWait.SNK is needed so that two devices that both prefer the Source role do not loop endlessly between Source and Sink. In other words, a DRP that would enter Try.SRC from AttachWait.SNK shall enter TryWait.SNK for a Sink detach from Attached.SRC.

A port shall cease to supply VBUS within tVBUSOFF of exiting Attached.SRC.

A port that is supplying VCONN shall cease to supply it within tVCONNOFF of exiting Attached.SRC, unless it is exiting as a result of a *USB PD* PR_Swap.

After a *USB PD* PR_Swap is accepted (i.e., either an Accept message is received or acknowledged), a DRP shall transition directly to the Attached.SNK state (i.e., remove Rp from CC, assert Rd on CC and stop supplying VBUS) and maintain its current data role, connection and VCONN supply state.

4.5.2.2.9 Try.SRC State

This state appears in Figure 4-16.

When in the Try.SRC state, the port is querying to determine if the port partner supports the Sink role.

4.5.2.2.9.1 Try.SRC Requirements

The port shall not drive VBUS or VCONN.

The port shall source current on both CC pins independently.

The port shall provide an Rp as specified in Table 4-13.

4.5.2.2.9.2 Exiting from Try.SRC State

The port shall transition to Attached.SRC when the SRC.Rd state is detected on exactly one of the CC pins for at least tPDDebounce.

The port shall transition to TryWait.SNK after tDRPTry and the SRC.Rd state has not been detected.

4.5.2.2.10 TryWait.SNK State

This state appears in Figure 4-16.

When in the TryWait.SNK state, the port has failed to become a Source and is waiting to attach as a Sink. Alternatively the port is responding to Sink being removed while in the Attached.SRC state.

4.5.2.2.10.1 TryWait.SNK Requirements

The port shall not drive VBUS or VCONN.

Both CC pins shall be independently terminated to ground through Rd.

4.5.2.2.10.2 Exiting from TryWait.SNK State

The port shall transition to Attached.SNK if the state of exactly one CC pin has been SNK.Open for at least tCCDebounce and VBUS is detected. Note the Source may initiate *USB PD* communications which will cause brief periods of the SNK.Open state on both CC pins, but this event will not exceed tPDDebounce.

The port shall transition to Unattached.SNK after tDRPTryWait if either VBUS is not detected or the state of both of the CC pins is SNK.Open.

4.5.2.2.11 Unattached.Accessory State

This state appears in Figure 4-14.

The Unattached.Accessory state allows accessory-supporting Sinks to connect to accessories.

This state is functionally equivalent to the Unattached.SRC state in a DRP, except that Attached.SRC is not supported.

4.5.2.2.11.1 Unattached.Accessory Requirements

The port shall not drive VBUS or VCONN.

The port shall source current on both CC pins independently.

The port shall provide an Rp as specified in Table 4-13.

4.5.2.2.11.2 Exiting from Unattached.Accessory State

The port shall transition to AttachWait.Accessory when the state of neither of the CC pins is SRC.Open.

The port shall transition to Unattached.SNK within tDRPTransition after dcSRC.DRP · tDRP, and the state of at least one CC pin is SRC.Open or if directed.

4.5.2.2.12 AttachWait.Accessory State

This state appears in Figure 4-14.

The AttachWait.Accessory state is used to ensure that the state of both of the CC pins is stable after a cable is plugged in.

4.5.2.2.12.1 AttachWait.Accessory Requirements

The requirements for this state are identical to Unattached.Accessory.

4.5.2.2.12.2 Exiting from AttachWait.Accessory State

If the port supports Audio Adapter Accessory Mode, it shall transition to AudioAccessory when the state of both CC pins is SRC.Ra for at least tCCDebounce.

If the port supports Debug Accessory Mode, it shall transition to DebugAccessory when the state of both CC pins is SRC.Rd for at least tCCDebounce.

The port shall transition to Unattached.SNK when the state of either CC pin is SRC.Open for at least tCCDebounce.

If the port supports VCONN-powered accessories, it shall transition to PoweredAccessory state if the state of one of its CC pins is SRC.Rd and the state of the other CC pin is SRC.Ra concurrently for at least tCCDebounce.

4.5.2.2.13 AudioAccessory State

This state appears in Figure 4-12, Figure 4-14 and Figure 4-16.

The AudioAccessory state is used for the Audio Adapter Accessory Mode specified in Appendix A.

4.5.2.2.13.1 AudioAccessory Requirements

The port shall reconfigure its pins as detailed in Appendix A.

The port shall not drive VBUS or VCONN. A port that sinks current from the audio accessory over VBUS shall not draw more than 500 mA.

The port shall provide an Rp as specified in Table 4-13.

The port shall source current on at least one of the CC pins and monitor to detect when the CC pin state is no longer SRC.Ra. If the port sources and monitors only one CC pin, then it shall ensure that the termination on the unmonitored CC pin does not affect the monitored signal when the port is connected to an Audio Accessory that may short both CC pins together.

4.5.2.2.13.2 Exiting from AudioAccessory State

If the port is a Sink or DRP, the port shall transition to Unattached.SNK when the state of the monitored CC pin(s) is SRC.Open for at least tCCDebounce and VBUS is not being supplied from the accessory.

If the port is a Source, the port shall transition to Unattached.SRC when the state of the monitored CC pin(s) is SRC.Open for at least tCCDebounce.

4.5.2.2.14 DebugAccessory

This state appears in Figure 4-12, Figure 4-14 and Figure 4-16.

The DebugAccessory state is used for the Debug Accessory Mode specified in Appendix B.

4.5.2.2.14.1 DebugAccessory Requirements

This mode is for debug only and shall not be used for communicating with commercial products.

The port shall not drive VBUS or VCONN.

The port shall provide an Rp as specified in Table 4-13.

The port shall source current on at least one of the CC pins and monitor to detect when the CC pin state is no longer SRC.Rd. If the port monitors only one CC pin, it shall source current on the monitored pin and may source current or not on the unmonitored pin.

4.5.2.2.14.2 Exiting from DebugAccessory State

If the port is a Sink or DRP, the port shall transition to Unattached.SNK when the SRC.Open state is detected on the monitored CC pin(s) and VBUS is not being supplied from the accessory.

If the port is a Source, the port shall transition to Unattached.SRC when the SRC.Open state is detected on the monitored CC pin(s).

4.5.2.2.15 PoweredAccessory State

This state appears in Figure 4-14.

When in the PoweredAccessory state, the port is powering a VCONN–Powered Accessory.

4.5.2.2.15.1 PoweredAccessory Requirements

If the port needs to determine the orientation of the connector, it shall do so only upon entry to the PoweredAccessory state by detecting which CC pin is connected through the cable (i.e., which CC pin is in the SRC.Rd state).

The SRC.Rd state is detected on only one CC pin. The port shall advertise Default USB Power (see Table 4-13) on this CC pin and monitor its state.

The port shall supply VCONN (2.7 V minimum) on the unused CC pin within tVconnON-PA of entering the PoweredAccessory state.

The port shall not drive VBUS.

When the port initially enters the PoweredAccessory state it shall operate as a DFP.

The port shall use *USB Power Delivery* Structured Vendor Defined Messages (Structured VDMs) to identify the accessory and enter an Alternate Mode.

4.5.2.2.15.2 Exiting from PoweredAccessory State

The port shall transition to Unattached.SNK when the SRC.Open state is detected on the monitored CC pin.

The port shall transition to Unattached.SNK if the attached device is not a VCONN–Powered Accessory. For example, the attached device does not support *USB PD* or does not respond to *USB PD* commands required for a VCONN–Powered Accessory (e.g., Discover SVIDs, Discover Modes, etc.).

The port shall transition to Unsupported.Accessory if it does not successfully enter an Alternate Mode within tAMETimeout (see Section 5.1).

The port shall cease to supply VCONN within tVCONNOFF of exiting the PoweredAccessory state.

4.5.2.2.16 Unsupported.Accessory State

This state appears in Figure 4-14.

If a VCONN–powered accessory does not enter an Alternate Mode, the Unsupported.Accessory state is used to wait until the accessory is unplugged before continuing.

4.5.2.2.16.1 Unsupported.Accessory Requirements

Only one CC pin shall be in the SRC.Rd state. The port shall advertise Default USB Power (see Table 4-13) on this CC pin and monitor its voltage.

The port shall not drive VBUS or VCONN.

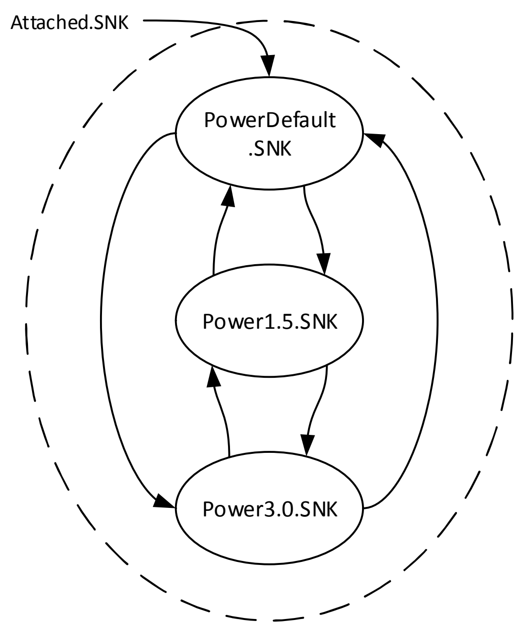
4.5.2.2.16.2 Exiting from Unsupported.Accessory

The port shall transition to Unattached.SNK when the SRC.Open state is detected on the monitored CC pin.

4.5.2.3 Sink Power Sub-State Requirements

When in the Attached.SNK state and the Source is supplying default VBUS, the port shall operate in one of the sub-states shown in Figure 4-17. The initial Sink Power Sub-State is PowerDefault.SNK. Subsequently, the Sink Power Sub-State is determined by Source's USB Type-C current advertisement. The port in Attached.SNK shall remain within the Sink Power Sub-States until either VBUS is removed or a *USB PD* contract is established with the Source.

Figure 4-17 Source Power Sub-States



The Sink is only required to implement Sink Power Sub-State transitions if the Sink wants to consume more than default USB current.

4.5.2.3.1 PowerDefault.SNK Sub-State

This sub-state supports Sinks consuming current within the lowest range (default) of Source-supplied current.

4.5.2.3.1.1 PowerDefault.SNK Requirements

The port shall draw no more than the default USB power from VBUS. See Section 4.6.2.1.

If the port wants to consume more than the default USB power, it shall monitor vRd to determine if more current is available from the Source.

4.5.2.3.1.2 Exiting from PowerDefault.SNK

For any change on CC indicating a change in allowable power, the port shall not transition until the new vRd on CC has been stable for at least tPDDebounce.

For a vRd in the vRd-1.5 range, the port shall transition to the Power1.5.SNK Sub-State.

For a vRd in the vRd-3.0 range, the port shall transition to the Power3.0.SNK Sub-State.

4.5.2.3.2 Power1.5.SNK Sub-State

This sub-state supports Sinks consuming current within the two lower ranges (default and 1.5 A) of Source-supplied current.

4.5.2.3.2.1 Power1.5.SNK Requirements

The port shall draw no more than 1.5 A from VBUS.

The port shall monitor vRd while it is in this sub-state.

4.5.2.3.2.2 Exiting from Power1.5.SNK

For any change on CC indicating a change in allowable power, the port shall not transition until the new vRd on CC has been stable for at least tPDDebounce.

For a vRd in the vRd-USB range, the port shall transition to the PowerDefault.SNK Sub-State and reduce its power consumption to the new range within tSinkAdj.

For a vRd in the vRd-3.0 range, the port shall transition to the Power3.0.SNK Sub-State.

4.5.2.3.3 Power3.0.SNK Sub-State

This sub-state supports Sinks consuming current within all three ranges (default, 1.5 A and 3.0 A) of Source-supplied current.

4.5.2.3.3.1 Power3.0.SNK Requirements

The port shall draw no more than 3.0 A from VBUS.

The port shall monitor vRd while it is in this sub-state.

4.5.2.3.3.2 Exiting from Power3.0.SNK

For any change on CC indicating a change in allowable power, the port shall not transition until the new vRd on CC has been stable for at least tPDDebounce.

For a vRd in the vRd-USB range, the port shall transition to the PowerDefault.SNK Sub-State and reduce its power consumption to the new range within tSinkAdj.

For a vRd in the vRd-1.5 range, the port shall transition to the Power1.5.SNK Sub-State and reduce its power consumption to the new range within tSinkAdj.

4.5.2.4 Connection States Summary

Table 4-11 defines the mandatory and optional states for each type of port.

Table 4-11 Mandatory and Optional States

	SOURCE	SINK	DRP	USB PD Communication
Disabled	Optional	Optional	Optional	Not Permitted
ErrorRecovery	Optional	Optional	Optional	Not Permitted
Unattached.SNK	N/A	Mandatory	Mandatory	Not Permitted
AttachWait.SNK	N/A	Mandatory[1]	Mandatory	Not Permitted
Attached.SNK	N/A	Mandatory	Mandatory	Permitted
Unattached.SRC	Mandatory	N/A	Mandatory	Not Permitted
AttachWait.SRC	Mandatory	N/A	Mandatory	Not Permitted
Attached.SRC	Mandatory	N/A	Mandatory	Permitted
Try.SRC	N/A	N/A	Optional	Not Permitted
TryWait.SNK[2]	N/A	N/A	Optional	Not Permitted
Accessory.Present	N/A	Optional	Optional	Not Permitted
AudioAccessory	Optional	Optional	Optional	Not Permitted
DebugAccessory	Optional	Optional	Optional	Permitted
Unattached.Accessory	N/A	Optional	N/A	Not Permitted
AttachWait.Accessory	N/A	Optional	N/A	Not Permitted
PoweredAccessory	N/A	Optional	N/A	Permitted
Unsupported.Accessory[3]	N/A	Optional	N/A	Not Permitted
PowerDefault.SNK	N/A	Mandatory	Mandatory	Permitted
Power1.5.SNK	N/A	Optional	Optional	Permitted
Power3.0.SNK	N/A	Optional	Optional	Permitted

Note:

1. Optional for UFP applications that are USB 2.0-only, consume USB Default Power and do not support *USB PD* or accessories.
2. TryWait.SNK is mandatory when Try.SRC is supported.
3. Unsupported.Accessory is mandatory when PoweredAccessory is supported.

4.5.3 USB Port Interoperability Behavior

This section describes interoperability behavior between USB Type-C to USB Type-C ports and between USB Type-C to legacy USB ports.

4.5.3.1 USB Type-C Port to USB Type-C Port Interoperability Behaviors

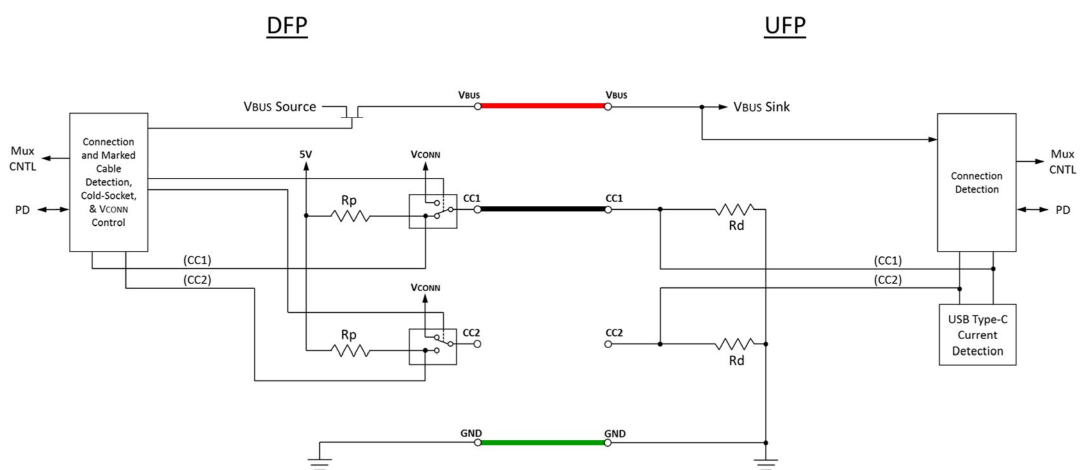
The following sub-sections describe typical port-to-port interoperability behaviors for the various combinations of USB Type-C DFP, UFP and DRPs as presented in Table 4-5. In all of the described behaviors, the impact of *USB PD*-based swaps (PR_Swap, DR_Swap or VCONN_Swap) are not considered.

The figures in the following sections illustrate the CC1 and CC2 routing after the CC detection process is complete.

4.5.3.1.1 DFP to UFP Behavior

Figure 4-18 illustrates the functional model for a DFP connected to a UFP. The single CC wire that is in a standard cable is only shown in one of the four possible connection routes, CC1 to CC1.

Figure 4-18 DFP to UFP Functional Model



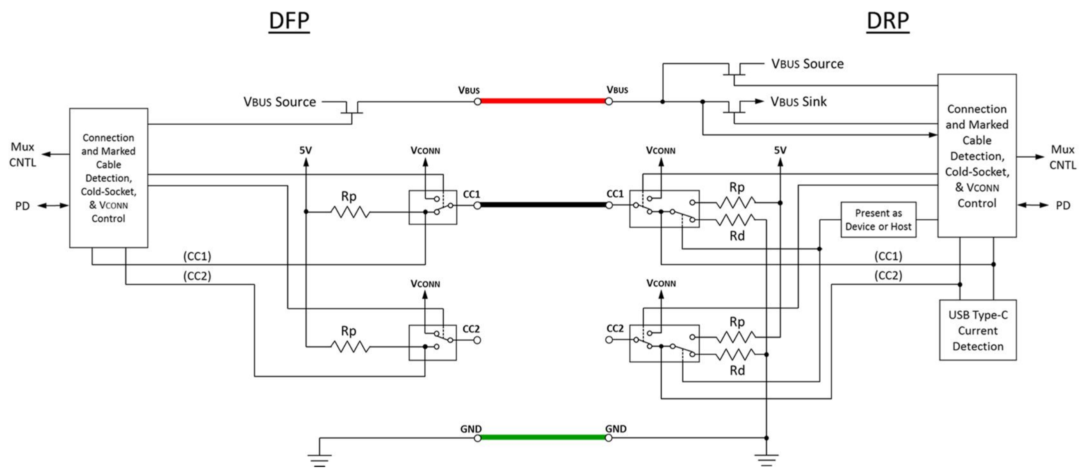
The following describes the behavior when a DFP is connected to a UFP.

1. DFP and UFP in the unattached state
2. DFP transitions from Unattached.SRC to Attached.SRC through AttachWait.SRC
   - DFP detects the UFP's pull-down on CC and enters Attached.SRC through AttachWait.SRC
   - DFP turns on VBUS and VCONN
3. UFP transitions from Unattached.SNK to Attached.SNK through AttachWait.SNK. UFP may skip AttachWait.SNK if it is USB 2.0 only and does not support accessories.
   - UFP detects VBUS and enters Attached.SNK through AttachWait.SNK
4. While the DFP and UFP are in the attached state:
   - DFP adjusts Rp as needed to limit the current the UFP may draw
   - UFP detects and monitors vRd for available current on VBUS
   - DFP monitors CC for detach and when detected, enters Unattached.SRC
   - UFP monitors VBUS for detach and when detected, enters Unattached.SNK

4.5.3.1.2 DFP to DRP Behavior

Figure 4-19 illustrates the functional model for a DFP connected to a DRP. The single CC wire that is in a standard cable is only shown in one of the four possible connection routes, CC1 to CC1.

Figure 4-19 DFP to DRP Functional Model



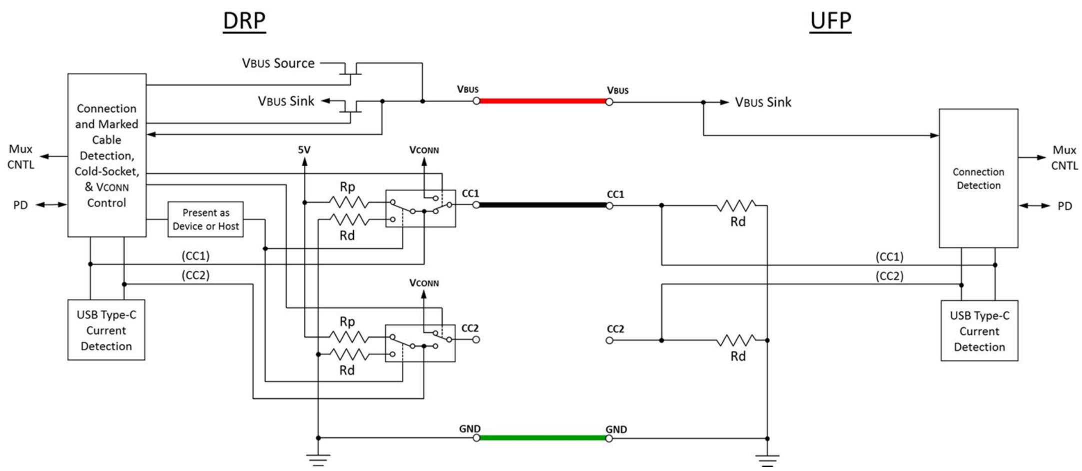
The following describes the behavior when a DFP is connected to a DRP.

1. DFP and DRP in the unattached state
   - DRP alternates between Unattached.SRC and Unattached.SNK
2. DFP transitions from Unattached.SRC to Attached.SRC through AttachWait.SRC
   - DFP detects the DRP's pull-down on CC and enters AttachWait.SRC. After tCCDebounce it then enters Attached.SRC.
   - DFP turns on VBUS and VCONN
3. DRP transitions from Unattached.SNK to Attached.SNK through AttachWait.SNK
   - DRP in Unattached.SNK detects pull up on CC and enters AttachWait.SNK. After that state persists for tCCDebounce and it detects VBUS, it enters Attached.SNK.
4. While the DFP and DRP are in their respective attached states:
   - DFP adjusts Rp as needed to limit the current the UFP may draw
   - DRP detects and monitors vRd for available current on VBUS
   - DFP monitors CC for detach and when detected, enters Unattached.SRC
   - DRP monitors VBUS for detach and when detected, enters Unattached.SNK (and resumes toggling between Unattached.SNK and Unattached.SRC)

4.5.3.1.3 DRP to UFP Behavior

Figure 4-20 illustrates the functional model for a DRP connected to a UFP. The single CC wire that is in a standard cable is only shown in one of the four possible connection routes, CC1 to CC1.

Figure 4-20 DRP to UFP Functional Model



The following describes the behavior when a DRP is connected to a UFP.

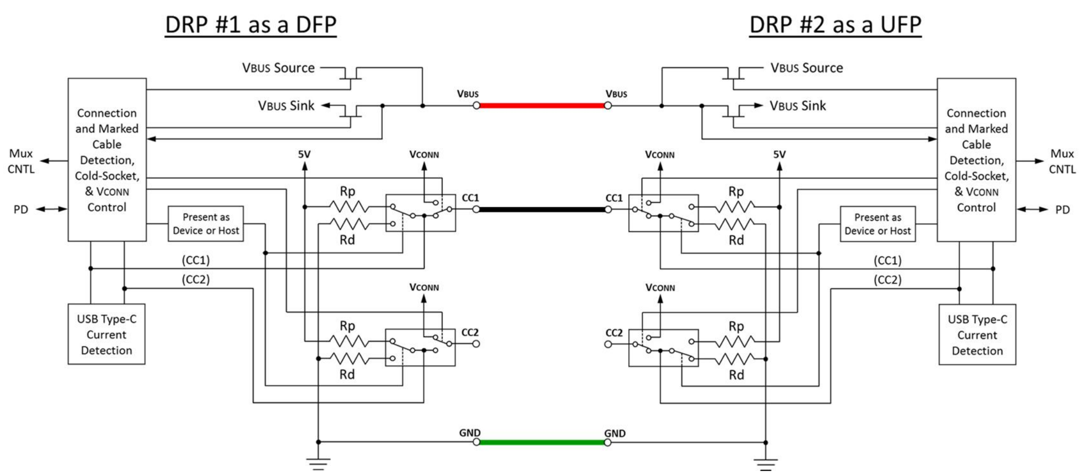
1. DRP and UFP in the unattached state
   - DRP alternates between Unattached.SRC and Unattached.SNK
2. DRP transitions from Unattached.SRC to AttachWait.SRC
   - DRP in Unattached.SRC detects one of the CC pull-downs of UFP which is in Unattached.SNK and DRP enters AttachWait.SRC
   - DRP in AttachWait.SRC detects that pull down on CC persists for tCCDebounce. It then enters Attached.SRC and turns on VBUS and VCONN
3. UFP transitions from Unattached.SNK to Attached.SNK through AttachWait.SNK if required.
   - UFP detects VBUS and enters Attached.SNK
4. DRP transitions from AttachWait.SRC to Attached.SRC
   - DRP in AttachWait.SRC times out (tDRPHold) and transitions to Attached.SRC
5. While the DRP and UFP are in their respective attached states:
   - DRP adjusts Rp as needed to limit the current the UFP may draw
   - UFP detects and monitors vRd for available current on VBUS
   - DRP monitors CC for detach and when detected, enters Unattached.SNK (and resumes toggling between Unattached.SNK and Unattached.SRC)
   - UFP monitors VBUS for detach and when detected, enters Unattached.SNK

4.5.3.1.4 DRP to DRP Behavior

Two behavior descriptions based on the connection state diagrams are provided below. In the first case, the two DRPs accept the resulting DFP-to-UFP relationship achieved randomly whereas in the second case the DRP #2 chooses to drive the random result to the opposite result using the Try.SRC mechanism.

Figure 4-21 illustrates the functional model for a DRP connected to a DRP in the first case described. The single CC wire that is in a standard cable is only shown in one of the four possible connection routes, CC1 to CC1. Port numbers have been arbitrarily assigned in the diagram to assist the reader to understand the process description.

Figure 4-21 DRP to DRP Functional Model – CASE 1

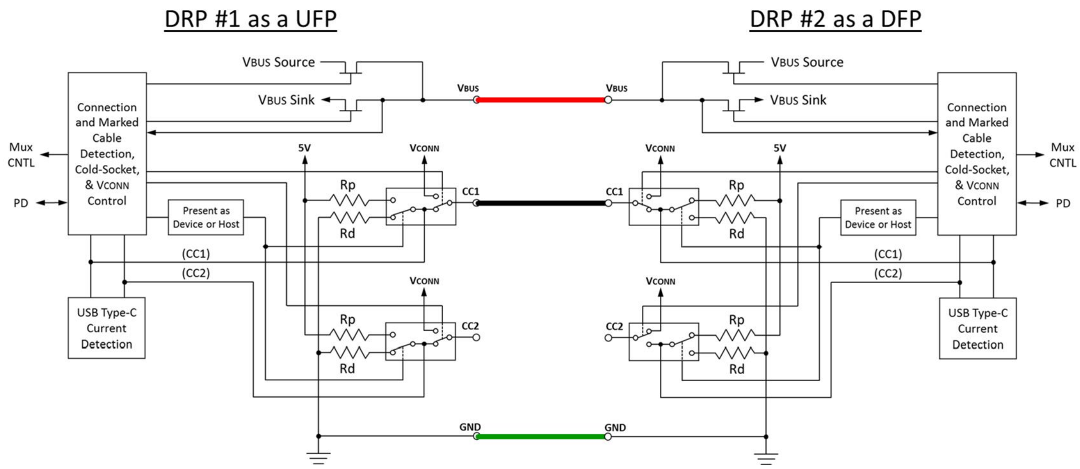


CASE 1: The following describes the behavior when a DRP is connected to another DRP. In this flow, the two DRPs accept the resulting DFP-to-UFP relationship achieved randomly.

1. Both DRPs in the unattached state
   - DRP #1 and DRP #2 alternate between Unattached.SRC and Unattached.SNK
2. DRP #1 transitions from Unattached.SRC to AttachWait.SRC
   - DRP #1 in Unattached.SRC detects a CC pull down of DRP #2 in Unattached.SNK and enters AttachWait.SRC
3. DRP #2 transitions from Unattached.SNK to AttachWait.SNK
   - DRP #2 in Unattached.SNK detects pull up on a CC and enters AttachWait.SNK
4. DRP #1 transitions from AttachWait.SRC to Attached.SRC
   - DRP #1 in AttachWait.SRC continues to see CC pull down of DRP #2 for tCCDebounce, enters Attached.SRC and turns on VBUS and VCONN
5. DRP #2 transitions from AttachWait.SNK to Attached.SNK.
   - DRP #2 after having been in AttachWait.SNK for tCCDebounce and having detected VBUS, enters Attached.SNK
6. While the DRPs are in their respective attached states:
   - DRP #1 adjusts Rp as needed to limit the current DRP #2 may draw
   - DRP #2 detects and monitors vRd for available current on VBUS
   - DRP #1 monitors CC for detach and when detected, enters Unattached.SNK (and resumes toggling between Unattached.SNK and Unattached.SRC)
   - DRP #2 monitors VBUS for detach and when detected, enters Unattached.SNK (and resumes toggling between Unattached.SNK and Unattached.SRC)

Figure 4-22 illustrates the functional model for a DRP connected to a DRP in the second case described.

Figure 4-22 DRP to DRP Functional Model – CASE 2



CASE 2: The following describes the behavior when a DRP is connected to another DRP. In this flow, the DRP #2 chooses to drive the random result to the opposite result using the Try.SRC mechanism.

1. Both DRPs in the unattached state
   - DRP #1 and DRP #2 alternate between Unattached.SRC and Unattached.SNK
2. DRP #1 transitions from Unattached.SRC to AttachWait.SRC
   - DRP #1 in Unattached.SRC detects a CC pull down of DRP #2 in Unattached.SNK and enters AttachWait.SRC
3. DRP #2 transitions from Unattached.SNK to AttachWait.SNK
   - DRP #2 in Unattached.SNK detects pull up on a CC and enters AttachWait.SNK
4. DRP #1 transitions from AttachWait.SRC to Attached.SRC
   - DRP #1 in AttachWait.SRC continues to see CC pull down of DRP #2 for tCCDebounce, enters Attached.SRC and turns on VBUS and VCONN
5. DRP #2 transitions from AttachWait.SNK to Try.SRC.
   - DRP #2 in AttachWait.SNK has been in this state for tCCDebounce and detects VBUS but strongly prefers the Source role, so transitions to Try.SRC
   - DRP #2 in Try.SRC asserts a pull-up on CC and waits
6. DRP #1 transitions from Attached.SRC to Unattached.SNK to AttachWait.SNK
   - DRP #1 in Attached.SRC no longer detects DRP #2's pull-down on CC and transitions to Unattached.SNK.
   - DRP #1 in Unattached.SNK turns off VBUS and VCONN and applies a pull-down on CC
   - DRP #2 in Unattached.SNK detects pull up on a CC and enters AttachWait.SNK
7. DRP #2 transitions from Try.SRC to Attached.SRC via AttachWait.SRC

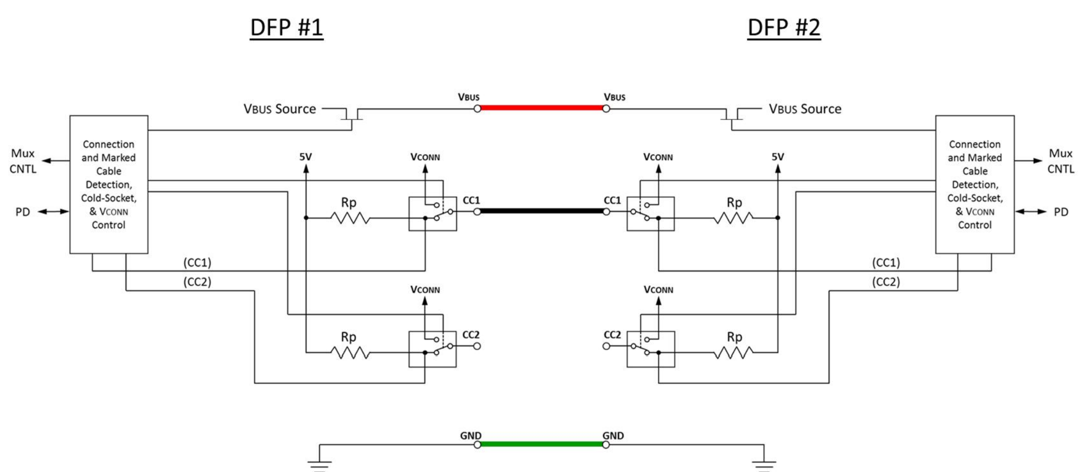
- DRP #2 in Try.SRC detects the DRP #1 in Unattached.SNK's pull-down on CC and enters AttachWait.SRC
- DRP #2 in AttachWait.SRC times out (tCCDebounce) and transitions to Attached.SRC
- DRP #2 in Attached.SRC turns on VBUS and VCONN

8. DRP #1 transitions from AttachWait.SNK to Attached.SNK
   - DRP #1 in AttachWait.SNK after tCCDebounce and detecting VBUS, enters Attached.SNK
9. While the DRPs are in their respective attached states:
   - DRP #2 adjusts Rp as needed to limit the current DRP #1 may draw
   - DRP #1 detects and monitors vRd for available current on VBUS
   - DRP #2 monitors CC for detach and when detected, enters Unattached.SRC (and resumes toggling between Unattached.SNK and Unattached.SRC)
   - DRP #1 monitors VBUS for detach and when detected, enters Unattached.SNK (and resumes toggling between Unattached.SNK and Unattached.SRC)

4.5.3.1.5 DFP to DFP Behavior

Figure 4-23 illustrates the functional model for a DFP connected to a DFP. The single CC wire that is in a standard cable is only shown in one of the four possible connection routes, CC1 to CC1. Port numbers have been arbitrarily assigned in the diagram to assist the reader to understand the process description.

Figure 4-23 DFP to DFP Functional Model



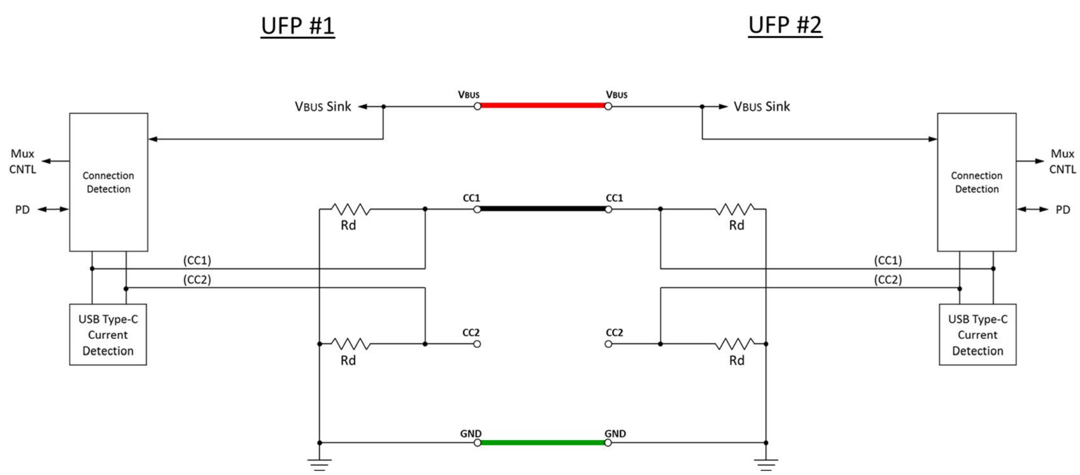
The following describes the behavior when a DFP is connected to another DFP.

1. Both DFPs in the unattached state
   - DFP #1 fails to detect a UFP's pull-down on CC and remains in Unattached.SRC
   - DFP #2 fails to detect a UFP's pull-down on CC and remains in Unattached.SRC

4.5.3.1.6 UFP to UFP Behavior

Figure 4-24 illustrates the functional model for a UFP connected to a UFP. The single CC wire that is in a standard cable is only shown in one of the four possible connection routes, CC1 to CC1. Port numbers have been arbitrarily assigned in the diagram to assist the reader to understand the process description.

Figure 4-24 UFP to UFP Functional Model



The following describes the behavior when a UFP is connected to another UFP.

1. Both UFPs in the unattached state
   - UFP #1 fails to detect pull up on CC or VBUS supplied by a DFP and remains in Unattached.SNK
   - UFP #2 fails to detect pull up on CC or VBUS supplied by a DFP and remains in Unattached.SNK

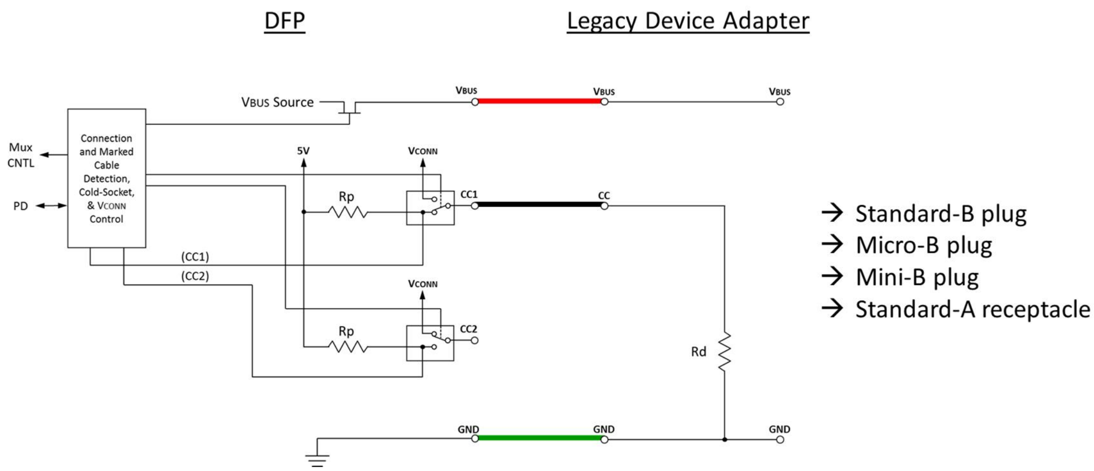
4.5.3.2 USB Type-C port to Legacy Port Interoperability Behaviors

The following sub-sections describe port-to-port interoperability behaviors for the various combinations of USB Type-C DFP, UFP and DRPs and legacy USB ports.

4.5.3.2.1 DFP to Legacy Device Port Behavior

Figure 4-25 illustrates the functional model for a DFP connected to a legacy device port. This model is based on having an adapter present as a UFP to the DFP. This adapter has a USB Type-C plug on one end plugged into the DFP and either a USB Standard-B plug, USB Micro-B plug, USB Mini-B plug, or a USB Standard-A receptacle on the other end.

Figure 4-25 DFP to Legacy Device Port Functional Model



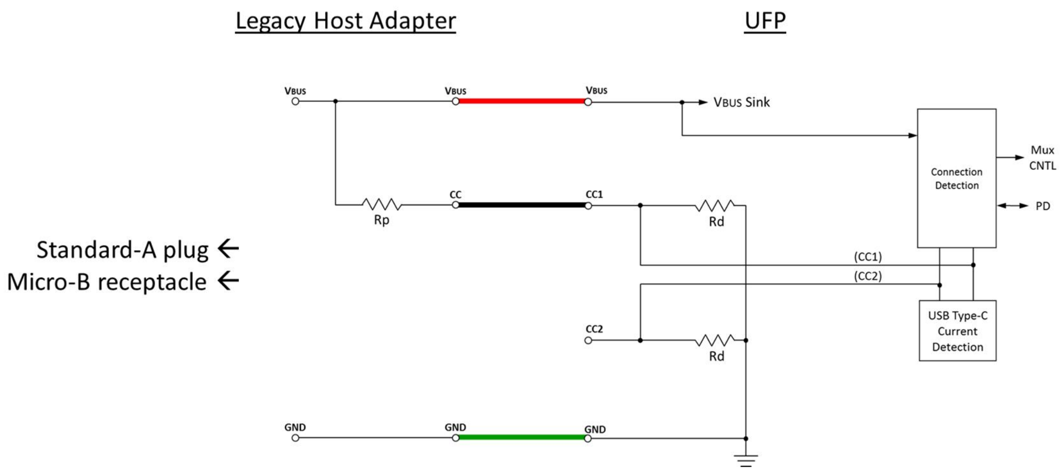
The following describes the behavior when a DFP is connected to a legacy device adapter that has an Rd to ground so as to mimic the behavior of a UFP.

1. DFP in the unattached state
2. DFP transitions from Unattached.SRC to Attached.SRC through AttachWait.SRC
   - DFP detects the UFP's pull-down on CC and enters AttachWait.SRC. After tCCDebounce, it enters Attached.SRC.
   - DFP turns on VBUS and VCONN
3. While the DFP is in the attached state:
   - DFP monitors CC for detach and when detected, enters Unattached.SRC

4.5.3.2.2 Legacy Host Port to UFP Behavior

Figure 4-26 illustrates the functional model for a legacy host port connected to a UFP. This model is based on having an adapter that presents itself as a host to the UFP, this adapter is either a USB Standard-A legacy plug or a USB Micro-B legacy receptacle on one end and the USB Type-C plug on the other end plugged into a UFP.

Figure 4-26 Legacy Host Port to UFP Functional Model



The following describes the behavior when a legacy host adapter that has an Rp to VBUS so as to mimic the behavior of a DFP that is connected to a UFP. The value of Rp shall indicate an advertisement of Default USB Power (See Table 4-13), even though the cable itself can carry 3 A. This is because the cable has no knowledge of the capabilities of the power source, and any higher current is negotiated via *USB BC 1.2* or by proprietary means.

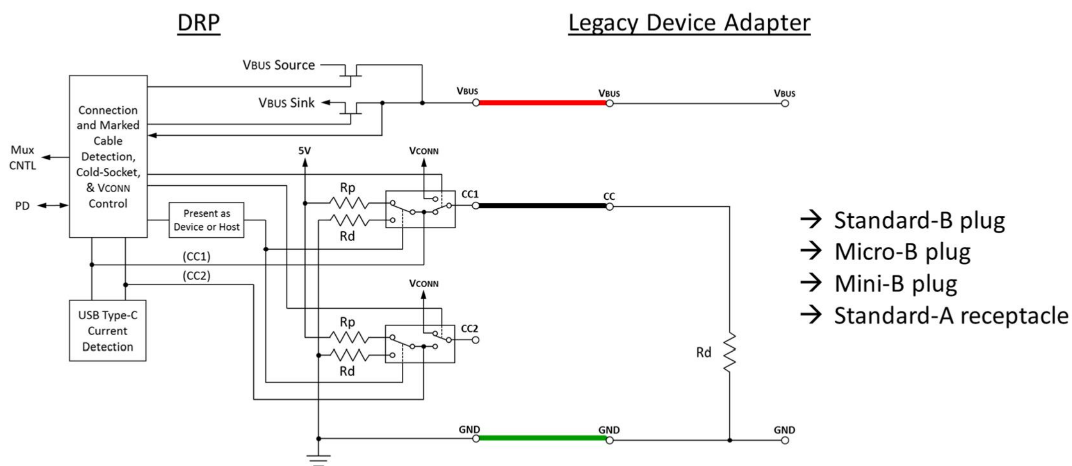
1. UFP in the unattached state
2. UFP transitions from Unattached.SNK to Attached.SNK through AttachWait.SNK if needed.
   - While in Unattached.SNK, if device is not USB 2.0 only, supports accessories or requires more than default power, it enters AttachWait.SNK when it detects a pull up on CC and ignores VBUS. Otherwise, it may enter Attached.SNK directly when VBUS is detected.
   - UFP detects VBUS and enters Attached.SNK
3. While the UFP is in the attached state:
   - UFP monitors VBUS for detach and when detected, enters Unattached.SNK

USB Type-C-based products that support *USB PD* BFSK are responsible for protecting the CC inputs from voltages greater than 5 V – see Section 4.6.2.4.

4.5.3.2.3 DRP to Legacy Device Port Behavior

Figure 4-27 illustrates the functional model for a DRP connected to a legacy device port. This model is based on having an adapter present as a UFP to the DRP. This adapter has a USB Type-C plug on one end plugged into a DRP and either a USB Standard-B plug, USB Micro-B plug, USB Mini-B plug, or a USB Standard-A receptacle on the other end.

Figure 4-27 DRP to Legacy Device Port Functional Model



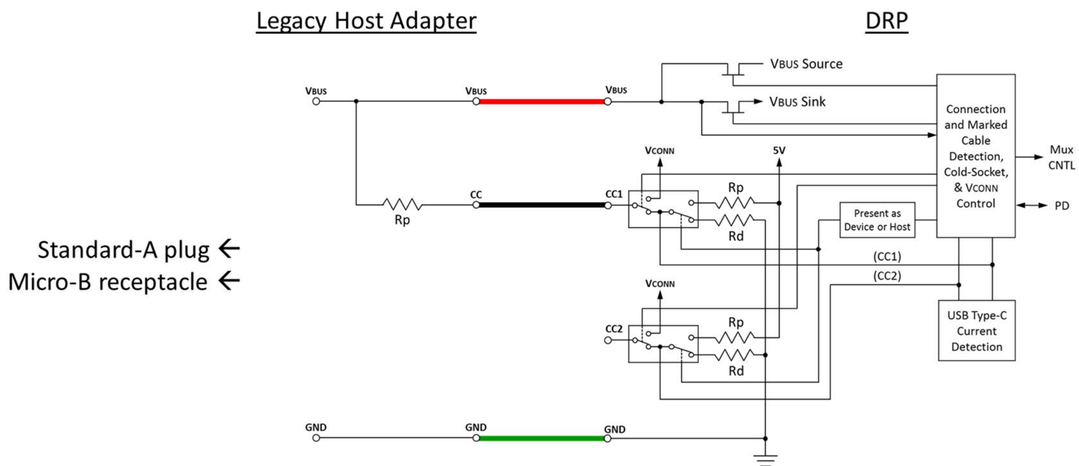
The following describes the behavior when a DRP is connected to a legacy device adapter that has an Rd to ground so as to mimic the behavior of a UFP.

1. DRP in the unattached state
   - DRP alternates between Unattached.SRC and Unattached.SNK
2. DRP transitions from Unattached.SRC to Attached.SRC
   - DRP in Unattached.SRC detects the adapter's pull-down on CC and enters AttachWait.SRC
   - DRP in AttachWait.SRC times out (tCCDebounce) and transitions to Attached.SRC
   - DRP in Attached.SRC turns on VBUS and VCONN
3. While the DRP is in the attached state:
   - DRP monitors CC for detach and when detected, enters Unattached.SRC (and resumes toggling between Unattached.SNK and Unattached.SRC)

4.5.3.2.4 Legacy Host Port to DRP Behavior

Figure 4-28 illustrates the functional model for a legacy host port connected to a DRP operating as a UFP. This model is based on having an adapter that presents itself as a host to the DRP operating as a UFP, this adapter is either a USB Standard-A legacy plug or a USB Micro-B legacy receptacle on one end and the USB Type-C plug on the other end plugged into a DRP.

Figure 4-28 Legacy Host Port to DRP Functional Model



The following describes the behavior when a legacy host adapter that has an Rp to VBUS so as to mimic the behavior of a DFP is connected to a DRP. The value of Rp shall indicate an advertisement of Default USB Power (See Table 4-13), even though the cable itself can carry 3 A. This is because the cable has no knowledge of the capabilities of the power source, and any higher current is negotiated via *USB BC 1.2* or by proprietary means.

1. DRP in the unattached state
   - DRP alternates between Unattached.SRC and Unattached.SNK
2. DRP transitions from Unattached.SNK to AttachWait.SNK to Attached.SNK
   - DRP in Unattached.SNK detects pull up on CC and enters AttachWait.SNK.
   - DRP in AttachWait.SNK detects VBUS and enters Attached.SNK
   - DRP in AttachWait.SNK may support Try.SRC and if so, may transition through Try.SRC and TryWait.SNK prior to entering Attached.SNK
3. While the DRP is in the attached state:
   - DRP monitors VBUS for detach and when detected, enters Unattached.SNK (and resumes toggling between Unattached.SNK and Unattached.SRC)

USB Type-C-based products that support *USB PD* BFSK are responsible for protecting the CC inputs from voltages greater than 5 V – see Section 4.6.2.4.

4.6 Power

Power delivery over the USB Type-C connector takes advantage of the existing USB methods as defined by: the *USB 2.0* and *USB 3.1* specifications, the *USB BC 1.2* specification and the *USB Power Delivery* specification. The USB Type-C Current mechanism allows the DFP to offer more current than defined by the *USB BC 1.2* specification.

All USB Type-C-based devices shall support USB Type-C Current and may support other USB-defined methods for power. The following order of precedence of power negotiation shall be followed: *USB BC 1.2* supersedes the *USB 2.0* and *USB 3.1* specifications, USB Type-C Current at 1.5 A and 3.0 A supersedes *USB BC 1.2*, and *USB Power Delivery* supersedes USB Type-C Current. Table 4-12 summarizes this order of precedence of power source usage.

Table 4-12 Precedence of power source usage

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

For example, once the PD mode (e.g. a power contract has been negotiated) has been entered, the device shall abide by that power contract ignoring any other previously made or offered by the USB Type-C Current, *USB BC 1.2* or *USB 2.0* and *USB 3.1* specifications. When the PD mode is exited, the device shall fallback in order to the USB Type-C Current, *USB BC 1.2* or *USB 2.0* and *USB 3.1* specification power levels.

All USB Type-C ports shall tolerate being connected to USB power source supplying default USB power, e.g. a host being connected to a legacy USB charger that always supplies VBUS.

4.6.1 Power Requirements during USB Suspend

USB Type-C implementations with USB Type-C Current, *USB PD* and VCONN, along with active cables, requires the need to expand the traditional USB suspend definition.

4.6.1.1 VBUS Requirements during USB Suspend

The *USB 2.0* and *USB 3.1* specifications define the amount of current a UFP is allowed to consume during suspend.

USB suspend power rules shall apply when the USB Type-C Current is at the Default USB Power level or when *USB PD* is being used and the Suspend bit is set appropriately.

When USB Type-C Current is set at 1.5 A or 3.0 A, the UFP is allowed to continue to draw current from VBUS during USB suspend. During USB suspend, the UFP's requirement to track and meet the USB Type-C Current advertisement remains in force (See Section 4.5.2.3).

USB PD provides a method for the source to communicate to the sink whether or not the sink has to follow the USB power rules for suspend.

4.6.1.2 VCONN Requirements during USB Suspend

If the DFP supplies VBUS power during USB suspend, it shall also supply at least 7.5 mA to VCONN.

Electronically marked cables shall draw no more than 7.5 mA from VCONN during USB suspend.

4.6.2 VBUS Power Provided Over a USB Type-C Cable

The minimum requirement for VBUS power supplied over the USB Type-C cable matches the existing requirement for VBUS supplied over existing legacy USB cables. *USB Power Delivery* is an optional capability that is intended to work over un-modified USB Type-C to USB Type-C cables, therefore any USB Type-C cable assembly that incorporates electronics that gets it power from VBUS shall be tolerant up to 20 V.

4.6.2.1 USB Type-C Current

Default USB voltage and current are defined by the *USB 2.0* and *USB 3.1* specifications. All USB Type-C current advertisements are at the USB VBUS voltage defined by these specifications.

The USB Type-C Current feature provides the following extensions:

- Higher current than defined by the *USB 2.0*, the *USB 3.1* or the *BC 1.2* specifications
- Allows the power source to manage the current it provides

The USB Type-C connector uses CC pins for configuration including an ability for a DFP to advertise to its port partner (UFP) the amount of current it can supply:

- Default values defined by the USB Specification
- 1.5 A
- 3.0 A

A UFP that takes advantage of the additional current offered (e.g., 1.5 A or 3.0 A) shall monitor the CC pins and shall adjust its current consumption within tSinkAdj to remain within the value advertised by the DFP. While a *USB PD* contract is in place, a UFP is not required to monitor USB Type-C current advertisements and shall not respond to USB Type-C current advertisements.

The DFP shall source VBUS to the UFP within tVBUSON. VBUS shall be in the specified voltage range at the advertised current.

A port sourcing VBUS shall protect itself from a sink that draws current in excess of the port's USB Type-C Current advertisement.

The DFP adjusts Rp (or current source) to advertise which of the three current levels it supports. See Table 4-13 for the termination requirements for the DFP to advertise currents.

The value of Rp establishes a voltage (vRd) on CC that is used by the UFP to determine the maximum current it may draw.

Table 4-24 defines the CC voltage range observed by the UFP that only support default USB current.

If the UFP wants to consume more than the default USB current, it shall track vRd to determine the maximum current it may draw. See Table 4-25.

Figure 4-29 and Figure 4-30 illustrate where the UFP monitors CC for vRd to detect if the host advertises more than the default USB current.

Figure 4-29 UFP Monitoring for Current in Pull-Up/Pull-Down CC Model

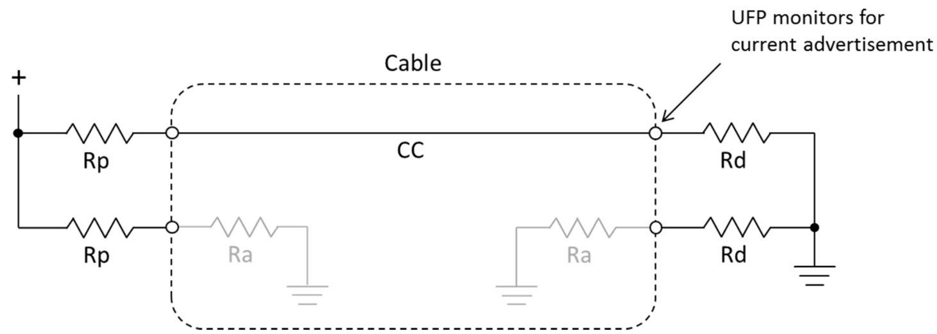
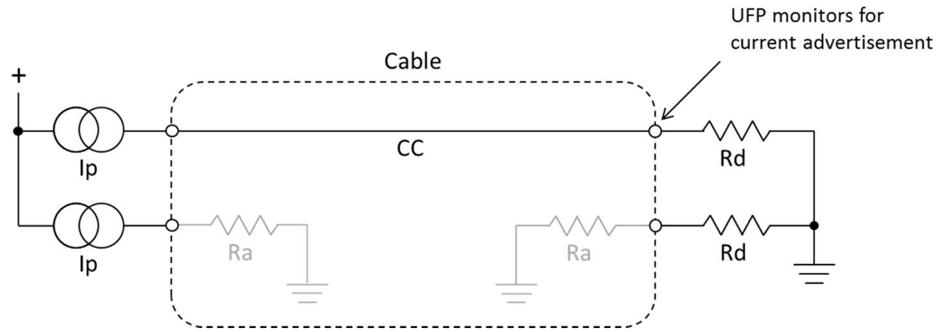


Figure 4-30 UFP Monitoring for Current in Current Source/Pull-Down CC Model



4.6.2.2 USB Battery Charging 1.2

USB Battery Charging Specification, Revision 1.2 defines a method that uses the USB 2.0 D+ and D− pins to advertise VBUS can supply up to 1.5 A. Support for *USB BC 1.2* charging is optional.

USB Type-C-based *BC 1.2* chargers that are capable of supplying at least 1.5 A shall advertise USB Type-C Current at the 1.5 A level, otherwise the charger shall advertise USB Type-C Current at the Default USB Power level. A USB Type-C-based *BC 1.2* charger that also supports USB Type-C Current at 3.0 A may advertise USB Type-C Current at 3.0 A.

4.6.2.3 Proprietary Power Source

A proprietary power source (i.e., battery charger) with a USB Type-C-captive cable or a USB Type-C receptacle that is capable of supplying at least 1.5 A and less than 3.0 A shall advertise USB Type-C Current at least at the 1.5 A level.

A proprietary power source with a USB Type-C-captive cable or a USB Type-C receptacle that is capable of supplying at least 3.0 A shall advertise USB Type-C Current at least at the 3.0 A level.

4.6.2.4 USB Power Delivery

USB Power Delivery is a feature on the USB Type-C connector. When *USB PD* is implemented, *USB PD* Bi-phase Mark Coded (BMC) carried on the CC wire shall be used for *USB PD* communications between USB Type-C ports.

At attach, VBUS shall be operationally stable prior to initiating *USB PD* communications.

Figure 4-31 illustrates how the USB PD BMC signaling is carried over the USB Type-C cable's CC wire.

Figure 4-31 USB PD over CC Pins

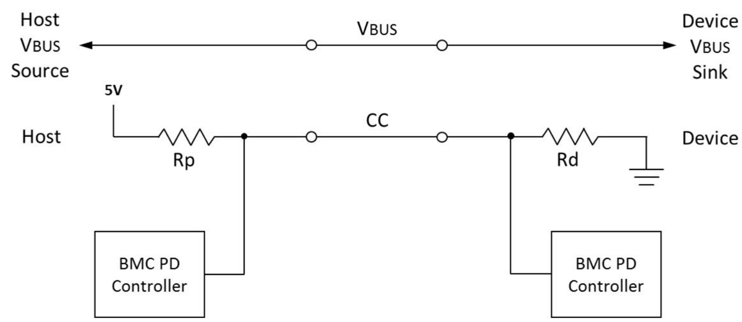
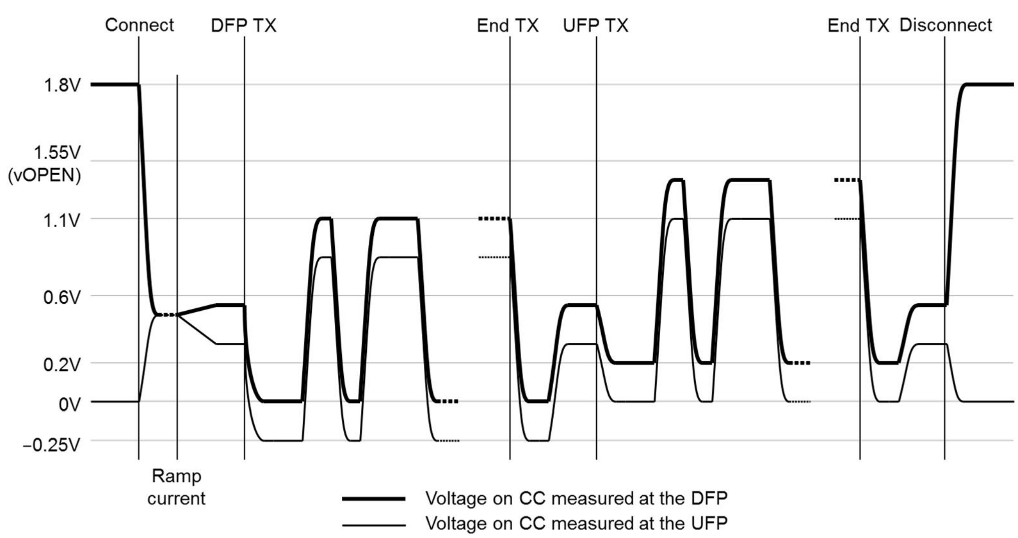


Figure 4-32 illustrates USB PD BMC signaling as seen on CC from both the perspective of the DFP and UFP. The breaks in the signaling are intended to represent the passage of time.

Figure 4-32 USB PD BMC Signaling over CC



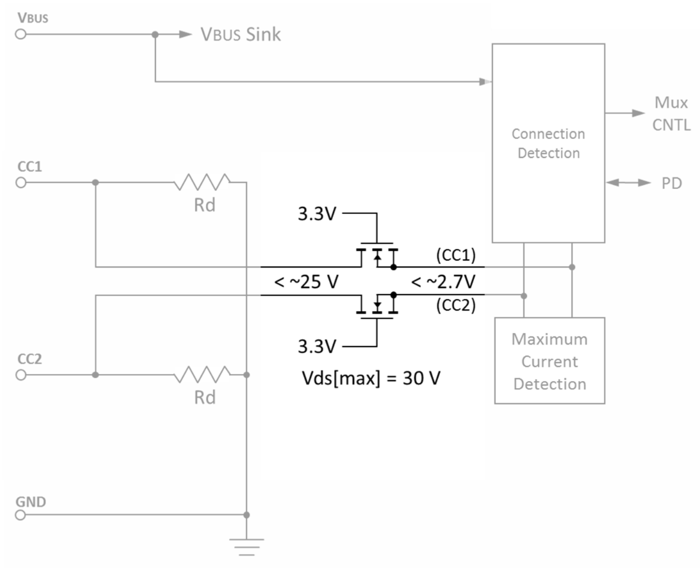
While a USB PD contract is in place, the provider shall advertise a USB Type-C Current of either 1.5 A or 3.0 A.

4.6.3 Supporting USB PD BFSK in Addition to USB PD BMC

For USB Type-C to legacy cables and adapters, two situations exist where USB PD BFSK may be used to negotiate greater than 5 V: USB Type-C to USB Standard-A PD cable and USB Type-C to USB Micro-B receptacle adapter. In both of these cases, Rp may be pulled up to a value higher than 5 V because VBUS may range up to 20 V for a USB PD negotiated contract. USB Type-C-based products that support USB PD BFSK and request a voltage greater than 5 V shall protect the CC inputs from termination voltages higher than 5 V as some adapters may present an Rp pulled up to VBUS that may be as high as 20 V.

Figure 4-33 illustrates an example of protecting the CC input from a higher voltage and does so in a manner that does not interfere with USB PD BMC communication.

Figure 4-33 Example implementation of CC input protection in a UFP



The *USB PD* Binary Frequency Shift Keying (BFSK) on VBUS may in addition be used to communicate with legacy *USB PD* products. *USB PD* BFSK shall only be used if *USB PD* BMC fails to establish PD communication, i.e. fails to receive a *USB PD* GoodCRC message in response to a *USB PD* Capabilities message following two hard resets. USB Type-C-based UFPs that support *USB PD* BFSK and want to request more than 1.5 A shall supply VCONN and confirm that the cable is electronically marked and capable of the desired current level (see Section 5.2.2).

4.7 USB Hubs

USB hubs are defined by the *USB 2.0* and *USB 3.1* specifications. USB hubs implemented with one or more USB Type-C connectors shall comply with the *USB 3.1 Specification*.

USB hubs shall have one UFP that may be a Charging UFP (See Section 4.8.3). The hub shall clearly identify to the user its UFP. This may be accomplished by physical isolation, labeling or a combination of both.

USB hub's DFPs shall not have DRP capability.

CC pins are used for port-to-port connections and shall be supported on all USB Type-C connections on the hub.

USB hub ports shall not implement or pass-through Alternate or Accessory Modes. SBU pins shall not be connected (zSBUTermination) on any USB hub port.

The USB hub's DFPs shall support power source requirements for a DFP. See Section 4.8.1.

4.8 Chargers

4.8.1 DFP as a Power Source

DFPs (e.g. battery chargers, hub DFPs and hosts) may all be used for battery charging. When a charger with a USB Type-C receptacle or a USB Type-C captive cable, it shall follow all the applicable requirements.

- A DFP shall expose its power capabilities using the USB Type-C Current method and it may additionally support other USB-standard methods (*USB BC 1.2* or *USB-PD*).
- A DFP may also expose its identity and/or power capabilities using a proprietary (e.g. non-USB-standard) method. A proprietary method may source up to 5 A if it has a captive cable capable of carrying that level of current. See Section 4.6.2.3 for additional requirements.
- A USB Type-C power provider advertising its current capability using *USB BC 1.2* shall meet the requirements in Section 4.6.2.2 regarding USB Type-C Current advertisement.
- A USB Type-C power provider that has negotiated a *USB-PD* contract shall meet the requirements in Section 4.6.2.4 regarding USB Type-C Current advertisement.
- If a USB Type-C power provider is capable of supplying a voltage greater than default VBUS, it shall fully conform to the *USB-PD* specification, and shall negotiate its power contracts using only *USB-PD*.
- If a USB Type-C power provider is capable of reversing source and sink power roles, it shall fully conform to the *USB-PD* specification, and shall negotiate its power contracts using only *USB-PD*.
- If a USB Type-C power provider is capable of supplying a current greater than 3.0 A, it shall use the *USB-PD* Discovery Identity to determine the current carrying capacity of the cable.

4.8.1.1 Chargers with USB Type-C Receptacles

- A charger with a USB Type-C receptacle (DFP) shall only apply power to VBUS when it detects a UFP is attached and shall remove power from VBUS when it detects the UFP is detached (vOPEN).
- A charger with a USB Type-C receptacle shall not advertise current exceeding 3.0 A except when it uses the *USB-PD* Discover Identity mechanism to determine the cable's actual current carrying capability and then it shall limit the advertised current accordingly.

4.8.1.2 Chargers with USB Type-C Captive Cables

- A charger with a USB Type-C captive cable may supply VBUS at any time. It is recommended that such a charger only apply power to VBUS when it detects a UFP is present and remove power from VBUS when it detects the UFP is not present (vOPEN).
- A charger with a USB Type-C captive cable shall limit its current advertisement so as not to exceed the current capability of the cable (up to 5 A).

4.8.2 Non-USB Charging Methods

A charger with a USB Type-C connector may employ additional proprietary charging methods to source power beyond what is allowed by the USB defined methods. When implemented, proprietary methods must meet the following requirements:

- The method shall only be used to establish identity and/or a current level at default VBUS voltage in a manner not defined by the USB methods
- The method shall only define the current level and shall not change the voltage delivered on VBUS
- The method shall not alter the DFP's role to source VBUS or the UFP's role to sink VBUS

- See Section 4.6.2.3 for additional requirements regarding USB Type-C Current advertisement.

A product with a USB Type-C connector that sinks power may support proprietary charging methods, these products shall not support methods that redefine VBUS voltage beyond what is defined by the USB 2.0 and USB 3.1 specifications.

4.8.3 Charging UFP

A Charging UFP is a special sub-class of a DRP that is capable of supplying power, but not capable of acting as a host. For example a hub's UFP or a monitor's UFP that operates as a device but not as a host.

The Charging UFP shall follow the rules for a DRP (See Section 4.5.1.4 and Figure 4-15). It shall also follow the requirements for the DFP as Power Source (See Section 4.8.1). The Charging UFP shall support *USB PD* and shall support the DR_Swap command.

4.8.4 Charging a System with a Dead Battery

A system that supports being charged by USB whose battery is dead shall apply Rd to both CC1 and CC2 and follow all UFP rules. When it is connected to a DFP or Charging UFP, the system will receive the default VBUS. It may use any allowed method to increase the amount of power it can use to charge its battery.

Circuitry to present Rd in a dead battery case only needs to guarantee the voltage on CC is pulled within the same range as the voltage clamp implementation of Rd in order for a DFP to recognize the UFP and provide VBUS. For example, a 20% resistor of value Rd in series with a FET with VGTH(max) < VCLAMP(max) with the gate weakly pulled to CC would guarantee detection and be removable upon power up.

When the system with a dead battery has sufficient charge, it may use the *USB PD* DR_Swap message to become the DFP.

4.9 Electronically Marked Cables

All USB Full-Featured Type-C cables shall be electronically marked. USB 2.0 Type-C cables may be electronically marked.

Electronically marked cables shall support *USB Power Delivery* Structured VDM Discover Identity command directed to SOP'. This provides a method to determine the characteristics of the cable, e.g. its current carrying capability, its performance, vendor identification, etc. This may be referred to as the USB Type-C Cable ID function.

Prior to an explicit *USB PD* contract, a Charging UFP is allowed to use SOP' to discover the cable's identity. After an explicit *USB PD* contract has been negotiated, only the DFP shall communicate with SOP'.

An electronically marked cable incorporates electronics that require VCONN, although VBUS or another source may be used. Electronically marked cables that do not incorporate data bus signal conditioning circuits shall consume no more than 70 mW from VCONN. During USB suspend, electronically marked cables shall not draw more than 7.5 mA from VCONN, see Section 4.6.1.2.

Figure 4-34 illustrates a typical electronically marked cable. The isolation elements (Iso) shall prevent VCONN from traversing end-to-end through the cable. Ra is required in the cable to allow the DFP to determine that VCONN is needed.

Figure 4-34 Electronically Marked Cable with VCONN connected through the cable

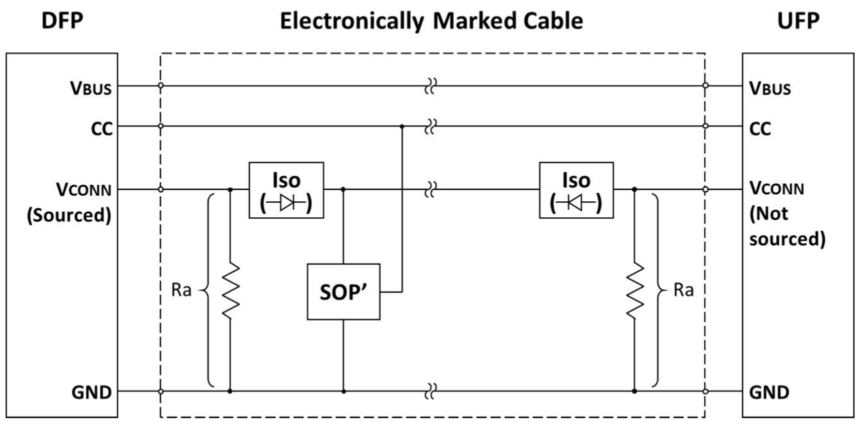
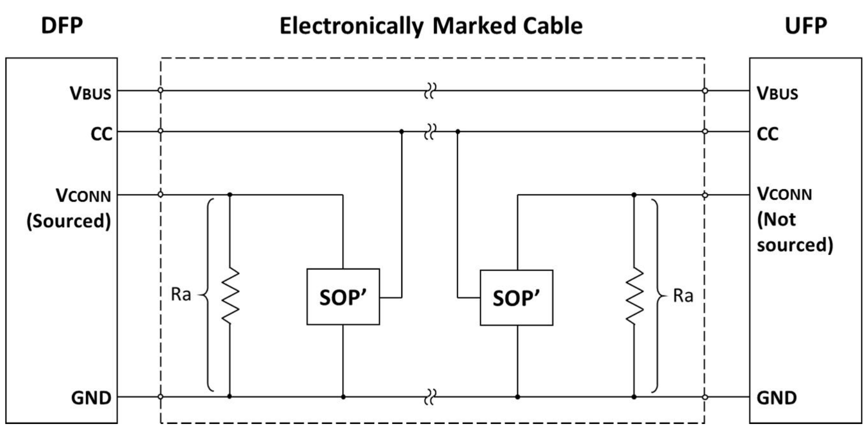


Figure 4-35 illustrates an electronically marked cable where the VCONN wire does not extend through the cable, therefore an SOP' element is required at each end of the cable. In this case, no isolation elements are needed.

Figure 4-35 Electronically Marked Cable with SOP' at both ends



For cables that only respond to SOP', the location of the responder is not relevant.

An active cable is an electronically marked cable that incorporates data bus signal conditioning circuits, for example to allow for implementing longer cables. Active cables shall not draw more than 1 W from VCONN, see Section 4.4.3.

Active cables may or may not require configuration management. Requirements for active cables that require configuration management are provided in Section 5.2.

Refer to Section 4.4.3 for the requirements of a DFP to supply VCONN. When VCONN is not present, a powered cable shall not interfere with normal CC operation including UFP detection, current advertisement and *USB PD* operation.

4.10 VCONN-Powered Accessories

A VCONN-powered accessory is a direct-attach UFP that implements an Alternate Mode (See Section 5.1) and can operate with just VCONN.

The VCONN-powered accessory exposes a maximum impedance to ground of Ra on the VCONN pin and Rd on the CC pin.

When operating in the UFP role and when VBUS is not present, VCONN-powered accessories shall treat the application of VCONN as an attach signal, and shall respond to *USB Power Delivery* messages.

When powered by only VCONN, a VCONN-powered accessory shall negotiate an Alternate Mode. If it fails to negotiate an Alternate Mode within tAMETimeout, its port partner removes VCONN.

VCONN-powered accessories shall be able to operate over a range of 2.7 V to 5.5 V on VCONN.

The removal of VCONN when VBUS is not present shall be treated as a detach event.

When VBUS is supplied, a VCONN-powered accessory is subject to all of the requirements for UFPs, including presenting a *USB Billboard Device Class* interface if negotiation for an Alternate Mode fails.

4.11 Parameter Values

4.11.1 Termination Parameters

Table 4-13 provides the values that shall be used for the DFP's Rp or current source. Other pull-up voltages shall be allowed if they remain less than 5.5 V and fall within the correct voltage ranges on the UFP side – see Table 4-21, Table 4-22 and Table 4-23. Note: when two DFPs are connected together, they may use different termination methods which could result in unexpected current flow.

Table 4-13 DFP CC Termination (Rp) Requirements

DFP Advertisement	Current Source to 1.7 – 5.5 V	Resistor pull-up to 4.75 – 5.5 V	Resistor pull-up to 3.3 V ± 5%
Default USB Power	80 μA ± 20%	56 kΩ ± 20% (Note 1)	36 kΩ ± 20%
1.5 A @ 5 V	180 μA ± 8%	22 kΩ ± 5%	12 kΩ ± 5%
3.0 A @ 5 V	330 μA ± 8%	10 kΩ ± 5%	4.7 kΩ ± 5%

Notes:

1. For Rp when implemented in the USB Type-C plug on a USB Type-C to *USB 3.1* Standard-A Cable Assembly, a USB Type-C to *USB 2.0* Standard-A Cable Assembly, a USB Type-C to *USB 2.0* Micro-B Receptacle Adapter Assembly or a USB Type-C captive cable connected to a USB host, a value of 56 kΩ ± 5% shall be used, in order to provide tolerance to IR drop on VBUS and GND in the cable assembly.

The UFP may find it convenient to implement Rd in multiple ways simultaneously (a wide range Rd when unpowered and a trimmed Rd when powered). Transitions between Rd implementations that do not exceed tCCDebounce shall not be interpreted as exceeding the wider Rd range. Table 4-14 provides the methods and values that shall be used for the UFP's Rd implementation.

Table 4-14 UFP CC Termination (Rd) Requirements

Rd Implementation	Nominal value	Can detect power capability?	Max voltage on pin
± 20% voltage clamp[1]	1.1 V	No	1.32 V
± 20% resistor to GND	5.1 kΩ	No	2.18 V
± 10% resistor to GND	5.1 kΩ	Yes	2.04 V

Note:
1. The clamp implementation inhibits *USB PD* communication although the system can start with the clamp and transition to the resistor once it is able to do *USB PD*.

Table 4-15 provides the impedance value to ground on VCONN in powered cables.

Table 4-15 Powered Cable Termination Requirements

	Minimum Impedance	Maximum Impedance
Ra	800 Ω[1]	1.2 kΩ

Note:
1. The minimum impedance may be less when powering active circuitry.

Table 4-16 provides the minimum impedance value to ground on CC for a self-powered device (UFP) or a device that supports the Disabled state or ErrorRecovery state to be undetected by a DFP.

Table 4-16 UFP CC Termination Requirements

	Minimum Impedance to GND
zOPEN	126 kΩ

Table 4-17 provides the impedance value for an SBU to appear open.

Table 4-17 SBU Termination Requirements

	Termination	Notes
zSBUTermination	≥ 950 kΩ	Functional equivalent to an open circuit

4.11.2 Timing Parameters

Table 4-18 provides the timing values that shall be met for delivering power over VBUS and VCONN.

Table 4-18 VBUS and VCONN Timing Parameters

	Minimum	Maximum	Description
tVBUSON	0 ms	275 ms	From the time the Sink is attached until the Source supplies VBUS.
tVBUSOFF	0 ms	650 ms	From the time the Sink is detached until the Source removes VBUS and reaches vSafe0V (See *USB PD*).
tVCONNON	0 ms	10 ms	From the time the Source supplied VBUS in the Attached.SRC state.
tVCONNON-PA	0 ms	100 ms	From the time a Sink with accessory support enters the PoweredAccessory state until the Sink sources VCONN.
tVCONNOFF	0 ms	35 ms	From the time that a Sink is detached or as directed until the VCONN supply is disconnected and bulk capacitance is removed.
tSinkAdj	tPDDebounce	60 ms	Response time for a Sink to adjust its current consumption to be in the specified range due to a change in USB Type-C Current advertisement

Figure 4-36 illustrates the timing parameters associated with the DRP toggling process. The tDRP parameter represents the overall period for a single cycle during which the port is exposed as both a Source and a Sink. The portion of the period where the DRP is exposed as a Source is established by dcSRC.DRP and the maximum transition time between the exposed states is dictated by tDRPTransition.

Figure 4-36 DRP Timing

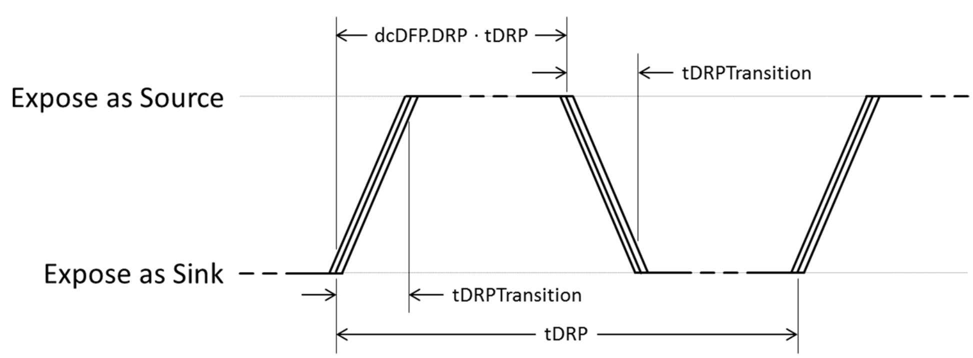


Table 4-19 provides the timing values that shall be met for DRPs. The clock used to control DRP swap should not be derived from a precision timing source such as a crystal, ceramic resonator, etc. to help minimize the probability of two DRP devices indefinitely failing to resolve into a Source to Sink relationship. Similarly, the percentage of time that a DRP spends advertising Source not be derived from a precision timing source.

Table 4-19 DRP Timing Parameters

	Minimum	Maximum	Description
tDRP	50 ms	100 ms	The period a DRP shall complete a Source to Sink and back advertisement
dcSRC.DRP	30%	70%	The percent of time that a DRP shall advertise Source during tDRP
tDRPTransition	0 ms	1 ms	The time a DRP shall complete transitions between Source and Sink roles during role resolution
tDRPTry	75 ms	150 ms	Wait time associated with the Try.SRC state.
tDRPTryWait	400 ms	800 ms	Wait time associated with the TryWait.SNK state

Table 4-20 provides the timing requirement for CC connection behaviors.

Table 4-20 CC Timing

	Minimum	Maximum	Description
tCCDebounce	100 ms	200 ms	Time a port shall wait before it can determine it is attached
tPDDebounce	10 ms	20 ms	Time a port shall wait before it can determine it is either detached or a change in USB Type-C current due to the potential for *USB PD* BMC signaling on CC
tErrorRecovery	25 ms		Time a self-powered port shall remain in the ErrorRecovery state.

4.11.3 Voltage Parameters

Table 4-21, Table 4-22 and Table 4-23 provide the CC voltage values that a Source shall use to detect what is attached based on the USB Type-C Current advertisement (Default USB, 1.5 A @ 5 V, or 3.0 A @ 5 V) that the Source is offering.

Table 4-21 CC Voltages on Source Side – Default USB

	Minimum Voltage	Maximum Voltage	Threshold
Powered cable/adapter (vRa)	0.00 V	0.15 V	0.20 V
Sink (vRd)	0.25 V	1.50 V	1.60 V
No connect (vOPEN)	1.65 V		

Table 4-22 CC Voltages on Source Side – 1.5 A @ 5 V

	Minimum Voltage	Maximum Voltage	Threshold
Powered cable/adapter (vRa)	0.00 V	0.35 V	0.40 V
Sink (vRd)	0.45 V	1.50 V	1.60 V
No connect (vOPEN)	1.65 V		

Table 4-23 CC Voltages on Source Side – 3.0 A @ 5 V

	Minimum Voltage	Maximum Voltage	Threshold
Powered cable/adapter (vRa)	0.00 V	0.75 V	0.80 V
Sink (vRd)	0.85 V	2.45 V	2.60 V
No connect (vOPEN)	2.75 V		

Table 4-24 provides the CC voltage values that shall be detected across a Sink's Rd for a Sink that does not support higher than default USB Type-C Current Source advertisements.

Table 4-24 Voltage on Sink CC Pins (Default USB Type-C Current only)

Detection	Min voltage	Max voltage	Threshold
vRa	−0.25 V	0.15 V	0.2 V
vRd-Connect	0.25 V	2.18 V	

Table 4-25 provides the CC voltage values that shall be detected across a Sink's Rd for a Sink that implements detection of higher than default USB Type-C Current Source advertisements. This table includes consideration for the effect that the IR drop across the cable GND has on the voltage across the Sink's Rd.

Table 4-25 Voltage on Sink CC pins (Multiple Source Current Advertisements)

Detection	Min voltage	Max voltage	Threshold
vRa	−0.25 V	0.15 V	0.2 V
vRd-Connect	0.25 V	2.04 V	
vRd-USB	0.25 V	0.61 V	0.66 V
vRd-1.5	0.70 V	1.16 V	1.23 V
vRd-3.0	1.31 V	2.04 V	

4.12 Summary of Ports by Product Type

The USB Type-C ports can exist in any one of 16 possible states. These states are characterized by:

- DFP (host-mode) or UFP (device-mode)
- Sourcing (Rp) or sinking (Rd) VBUS
- Data capable or not
- Sourcing VCONN

Table 4-26 summarizes all of the port states as differentiated by these four characteristics. This informative table may be helpful in understanding where a port starts (as indicated by bold ✓ marks) and the states the port traverses to get to an end condition for a particular type of host, hub or device.

It should be noted that some products are shown to have multiple possible starting states, these port types include DRPs, DFPs that default to UFPs in dead battery conditions, or UFPs that support upstream charging of dead battery hosts.

If applicable, the two primary *USB PD*-based swapping mechanisms are listed in the table for each product port types:

- Power Swap (PS) using *USB PD* PR_Swap : swaps VBUS source (Rp) and sink (Rd)
- Data Swap (DS) using *USB PD* DR_Swap : swaps DFP (host-mode) and UFP (device-mode) roles

For product port types that support *USB PD*, a third *USB PD*-based swapping mechanism may be supported:

- VCONN Swap using *USB PD* VCONN_Swap : swaps which end sources of VCONN

Subscripts highlight which of these three swapping mechanisms may be used in the transition from one port state to another. For example, for a Host DFP that supports PR_Swap under normal conditions, the initial port state would be 1 (DFP, Source, Yes, On) but would transition to 2 (DFP, Sink, Yes, On) with a *USB-PD* PR_Swap. For a DRP-based product, port transitions are dependent on the order that swaps are applied from the initial port state.

Table 4-26 Summary of Ports and Behaviors by Product Type

	DFP/UFP	DFP	DFP	DFP	DFP	DFP	DFP	DFP	DFP	UFP	UFP	UFP	UFP	UFP	UFP	UFP	UFP
	VBUS	Source	Sink	Source	Sink	Source	Sink	Source	Sink	Source	Sink	Source	Sink	Source	Sink	Source	Sink
	Data	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes	No	No
	VCONN	On	On	On	On	Off	Off	Off	Off	On	On	On	On	Off	Off	Off	Off
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Host	**DFP**	✓				✓											
	DFP with PS	✓	✓[1]			✓	✓[1,3]										✓[4]
Host/ Device	**DRP**	✓				✓									✓		
	DRP with PS	✓	✓[1]			✓	✓[1,3]			✓[1,3]				✓[1]	✓		✓[4]
	DRP with DS	✓				✓				✓[2,3]				✓[2]	✓		
	DRP with PS/DS	✓	✓[1]			✓	✓[1,3]			✓[1,2,3]				✓[1,2]	✓		✓[4]
Device	**UFP**										✓[3]				✓		
	UFP with PS									✓[1,3]	✓[3]			✓[1]	✓		
Hub (UFP)	**Hub UFP**										✓[3]				✓		
	Charging UFP			✓[4]				✓[4]		✓[1,3]	✓[3]			✓[1]	✓		
Hub (DFP)	**Hub DFP**	✓				✓											
	DFP with PS	✓	✓[1]			✓	✓[1,3]										
Power supply/Charger				✓				✓									
Power sucking device																	✓

Notes: 1 = PR_Swap (PS) used; 2 = DR_Swap (DS) used; 3 = VCONN_Swap used; 4 = Dead battery state/support