USB Type-C™ and Power Delivery DisplayPort Alternate Mode

Introduction

The USB Type-C and Power Delivery specifications allow platforms equipped with USB Type-C ports to negotiate power levels up to 3 A at 5 V, 9 V and 15 V, and up to 5 A at 20 V, for a maximum 100 W power delivery.

Besides power negotiation, the specifications introduce Alternate Modes so USB Type-C hosts and devices can add functionality like carrying high-speed data signals over USB Type-C connectors and cables; one of these modes manages the DisplayPort video protocol.

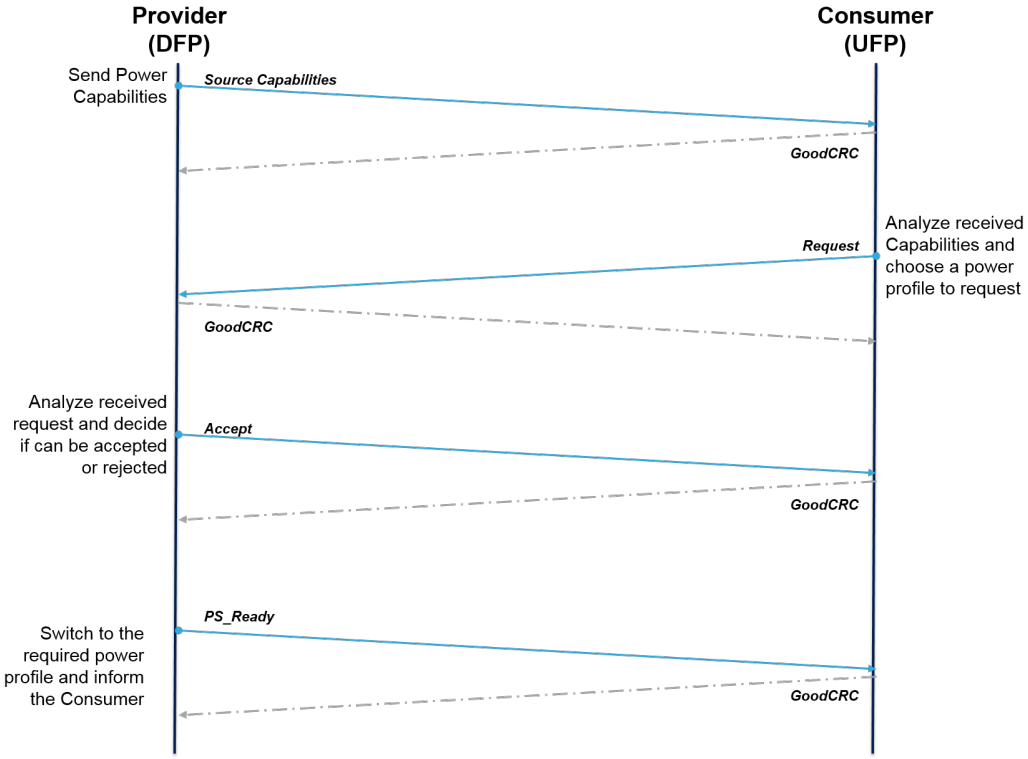
The Video Electronics Standards Association (VESA®) and USB-IF released the “DisplayPort Alternate Mode on USB Type-C Connector Standard” for devices equipped with Type-C connectors and compliant with USB Power Delivery specifications. It defines how USB Type-C connectors and cables carry video signals in up to 4K resolution along SuperSpeed data lines and other signals required by the DisplayPort protocol through secondary channels.

Figure 1. USB Type-C to DisplayPort adapter board by STMicroelectronics

1 Power Delivery negotiation

In the USB Type-C and Power Delivery specifications, power negotiation is accomplished between a power source (provider) and a power sink (consumer) via message exchange.

Figure 2. PD Message exchange between a provider and a consumer during power negotiation



Initially the source dispatches a `Source_Capabilities` message with its available power profiles. The sink analyzes the message and sends a `Request` for a profile that best matches its requirements. The source may accept or reject this request according to its power commitments at the time. If the source can accept the request, it switches to the required power profile and sends a `PS_Ready` message to the sink.

Whenever a source or a sink receives a message, they validate the message with a cyclic redundancy check (CRC) and send a `GoodCRC` confirmation message if the check passes. If the check does not pass, the message is ignored. If the communication error persists, a soft reset message resets the protocol parameters to re-establish communication. If the error still persists, the system performs a hard reset.

2 DisplayPort Alternate Mode roles and negotiation

The VESA DisplayPort Alternate Mode and USB Type-C Connector Standard specifications describe the interactions between a video data source and a video data sink for entering or exiting Alternate Mode, as well as the commands and rules to guarantee communication consistency between the two entities.

Alternate Mode negotiation cannot begin before the two partners (source and sink) reach an explicit contract through the Power Delivery protocol, also defining the data role. Initially, the power source is the DFP (or host) and the power sink is the UFP (or device).

The VESA Standard clearly describes data roles on the basis of port characteristics:

- DFP_U: Downstream Facing Port (referred to as “DFP” in USB Type-C r1.3). Usually the ports on a host or the ports on a hub to which devices are connected.
- UFP_U: Upstream Facing Port (referred to as “UFP” in USB Type-C r1.3). The port on a device or a hub that connects to a host or the DFP_U of a hub.
- DFP_D: Downstream Facing Port (referred to “DFP” in DP Alt Mode standard v1.0a). Generally associated with a DisplayPort source device, but may also be associated with a DisplayPort Branch device.
- UFP_D: Upstream Facing Port (referred to “UFP” in DP Alt Mode standard v1.0a). Generally associated with a DisplayPort sink device, but may also be associated with a DisplayPort Branch device.

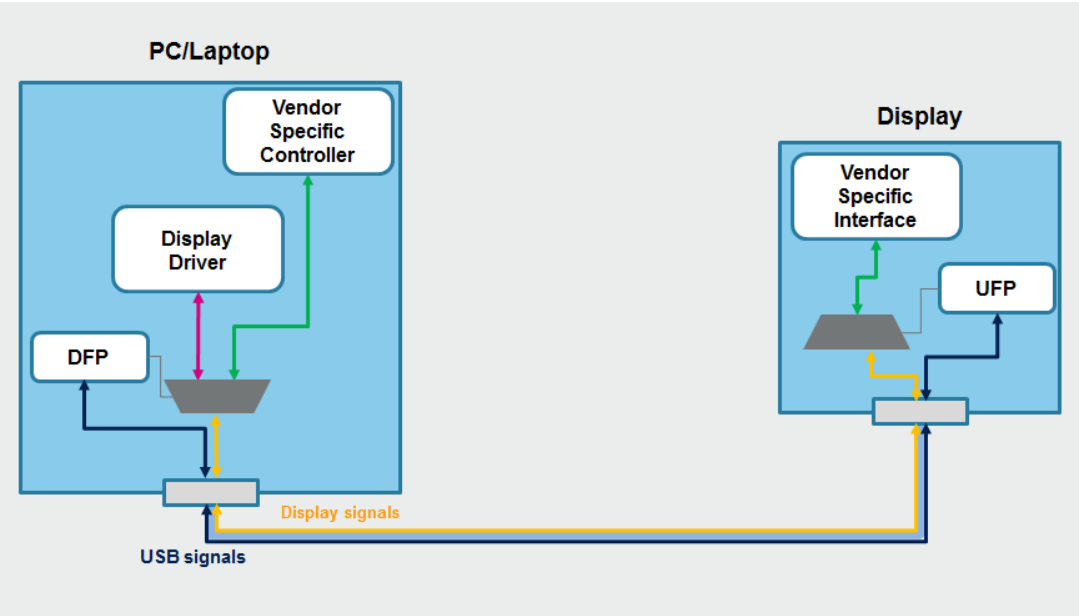
The data roles (DFP_D and UFP_D) cannot change once the roles have been identified and the DisplayPort protocol is running.

After the DFP and UFP are connected, the Type-C to DisplayPort Alternate Mode configuration sequence begins:

1. The DFP (Source) detects the “Attach” event occurred of a UFP (Sink) on its Type-C connector, provides the default voltage (5V) on its VBUS pin, and starts the power negotiation. The UFP selects one of the offered Source Capabilities and reaches the explicit contract with the DFP.
2. The DFP requires for the list of supported modes to the UFP, using the structured vendor-defined messages (VDM), and the UFP replies with the available modes supported by itself.
3. Once the DFP selects the DP mode and then orders the UFP to reconfigure the pins of its type-C connector to enter in the selected alternate mode, now the two entities respectively become DFP_D and UFP_D.

If your monitor has a Type-C interface and supports DisplayPort Alternate Mode, you can connect it directly to any computer that supports alternate modes and has a Type-C receptacle (DFP) with a simple Type-C cable. If your monitor only has a DisplayPort receptacle, you can use a Type-C to DP adapter that complies with the VESA standard, and a standard DP cable.

Figure 3. Typical scenario using Alternate Mode to drive a display



3 Type-C signaling configuration and functions description

Alternate Mode reconfigures certain pins on a Type-C connector to support other protocols, like USB Type-C connector pins assignment for the DisplayPort Alternate Mode. The different solutions supporting DP over USB Type-C with specific connector pinouts and electrical wiring are listed in the VESA specification.

The 24-pin USB Type-C connector can be divided into seven functional types:

- VBUS: four power pins allowing up to 20 V
- CCx: two configuration channels for protocol communication
- VCONN: supplies the cable configuration IC (on the receptacle, it is one of the CC pins)
- SuperSpeed Lane1: with RX differential pair RX1p, RX1n and TX differential pair TX1p, TX1n
- SuperSpeed Lane2: with RX differential pair RX2p, RX2n and TX differential pair TX2p, TX2n
- SBU1,2: side band lines for alternate modes
- Dp, Dn: USB 2.0 high speed signals
- GND: four ground pins

Figure 4. USB Type-C plug pinout

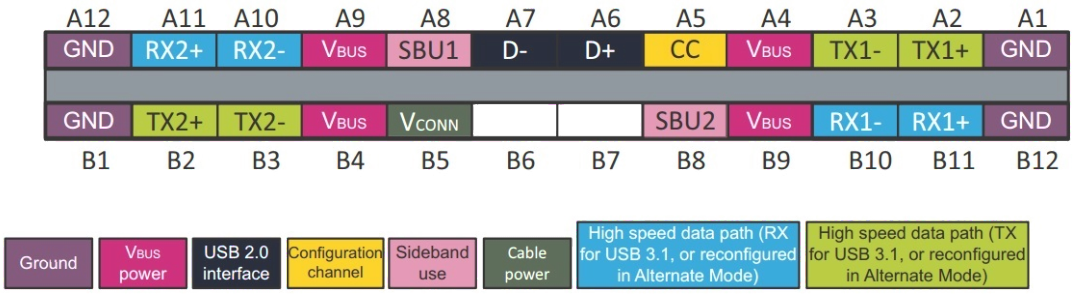
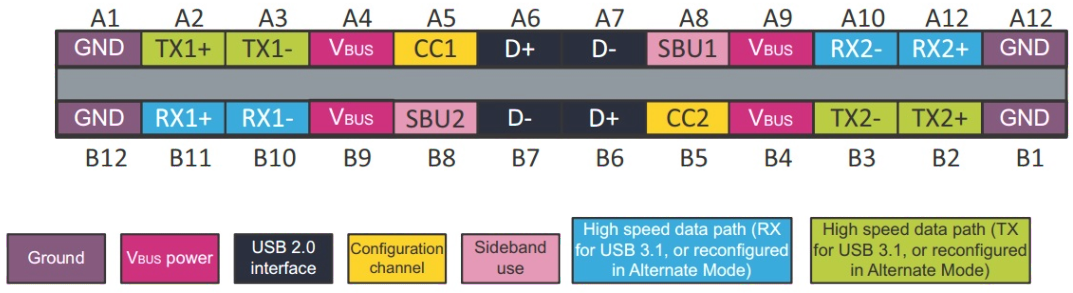


Figure 5. USB Type-C receptacle pinout



VBUS pins carry power to and from the platform, while the VCONN pin on the plug supplies 5 V (up to 1 W) to the IC via the electronically-marked Type-C cable.

The configuration channel (CC) pins are used to exchange messages according to the USB PD specification.

DisplayPort Alternate Mode uses the SuperSpeed lanes to implement the DisplayPort protocol: the four sets of SuperSpeed USB3.1 Lanes with eight pins for high-speed data transfer (green TX1+, TX1-, TX2+ and TX2- pins and blue RX1+, RX1-, RX2+ and RX2- pins) establish the connection between the four DP links and the four sets of high-speed data cables.

In the type-C connector, the SBU or Secondary Bus pins are data paths for the DisplayPort AUX channel and hot plug detection (HPD). DisplayPort source and sink devices use the AUX Channel for device linking and management, while DP sink devices implement HPD with vendor-defined messages (VDM) to signal their presence or to request the attention of the DP source.

The Type-C connector pins D+ and D- support legacy USB2.0 peripherals. These pins are not configurable, and are used to manage the USB2.0 data bandwidths. These pins can be used to set the USB Enumeration in the hosting platform for serial communication, or for the DFU feature.

3.1 Pin assignments

When USB Type-C behaves as a display source (DFP_D), pins assignments A, B, C, D, E and F are configured for the USB Type-C connector pins A2-A3, A8, A10-A11 and B2-B3, B8, B10-B11.

Pins assignments A, B, C, and D are used with USB Type-C to USB Type-C cables and with adapters from USB Type-C to other video standards such as VGA, DVI and HDMI. Pin assignments E and F are used with USB Type-C to DisplayPort adapter plugs or receptacles.

DisplayPort can use either two or four of the USB-C differential high speed lanes ML0, ML1, ML2 and ML3 for payload data transmission, and the DisplayPort AUX Channel is routed using the USB-C Sideband (SBU) signal pins A8 and B8.

Table 1. DFP_D Type-C receptacle pin assignments – normal plug orientation

Pin Assignments		A	B	C	D	E	F
Device Category		USB Type-C to USB Type-C or Protocol Converter		USB Type-C to USB Type-C or Protocol Converter		USB Type-C to DisplayPort (DP)	
DisplayPort Signaling		GEN2_BR	GEN2_BR	DP_BR	DP_BR	DP_BR	DP_BR
Receptacle Pin Number	A11-A10	Open/ ML2	Open/ ML1	ML0	ML0	ML0	ML0
	A2-A3	ML1	SSTX	ML2	SSTX	ML2	SSTX
	B11-B10	Open/ ML3	SSRX	ML3	SSRX	ML3	SSRX
	B2-B3	ML0	ML0	ML1	ML1	ML1	ML1
	A8	AUX_CH_P	AUX_CH_P	AUX_CH_P	AUX_CH_P	AUX_CH_P	AUX_CH_P
	B8	AUX_CH_N	AUX_CH_N	AUX_CH_N	AUX_CH_N	AUX_CH_N	AUX_CH_N

Table 2. DFP_D Type-C Receptacle Pin Assignments – Flipped Plug Orientation

Pin Assignments		A	B	C	D	E	F
Device Category		USB Type-C to USB Type-C or Protocol Converter		USB Type-C to USB Type-C or Protocol Converter		USB Type-C to DisplayPort (DP)	
DisplayPort Signaling		GEN2_BR	GEN2_BR	DP_BR	DP_BR	DP_BR	DP_BR
Receptacle Pin Number	A11-A10	Open/ ML3	SSRX	ML3	SSRX	ML3	SSRX
	A2-A3	ML0	ML0	ML1	ML1	ML1	ML1
	B11-B10	Open/ ML2	Open/ ML1	ML0	ML0	ML0	ML0
	B2-B3	ML1	SSTX	ML2	SSTX	ML2	SSTX
	A8	AUX_CH_N	AUX_CH_N	AUX_CH_N	AUX_CH_N	AUX_CH_N	AUX_CH_N
	B8	AUX_CH_P	AUX_CH_P	AUX_CH_P	AUX_CH_P	AUX_CH_P	AUX_CH_P

When USB Type-C behaves as a display sink (UFP_D), pin assignments A, B, C, D and E are configured for USB Type-C.

Table 3. UFP_D Type-C Receptacle Pin Assignments – Normal Plug Orientation

Pin Assignments		A	B	C	D	E
Device Category		USB Type-C to USB Type-C or Protocol Converter		USB Type-C to USB Type-C or Protocol Converter		USB Type-C to DisplayPort (DP)
DisplayPort Signaling		GEN2_BR	GEN2_BR	DP_BR	DP_BR	DP_BR
Receptacle Pin Number	A11-A10	ML0	ML0	ML1	ML1	ML3
	A2-A3	Open/ ML3	SSTX	ML3	SSTX	ML1
	B11-B10	ML1	SSRX	ML2	SSRX	ML0
	B2-B3	ML0	ML1	ML0	ML0	ML2
	A8	AUX_CH_N	AUX_CH_N	AUX_CH_N	AUX_CH_N	AUX_CH_P
	B8	AUX_CH_P	AUX_CH_P	AUX_CH_P	AUX_CH_P	AUX_CH_N

Table 4. UFP_D Type-C Receptacle Pin Assignments – Flipped Plug Orientation

Pin Assignments		A	B	C	D	E
Device Category		USB Type-C to USB Type-C or Protocol Converter		USB Type-C to USB Type-C or Protocol Converter		USB Type-C to DisplayPort (DP)
DisplayPort Signaling		GEN2_BR	GEN2_BR	DP_BR	DP_BR	DP_BR
Receptacle Pin Number	A11-A10	ML1	SSRX	ML2	SSRX	ML0
	A2-A3	Open/ ML2	Open/ ML1	ML0	ML0	ML2
	B11-B10	ML0	ML0	ML1	ML1	ML3
	B2-B3	Open/ML3	SSTX	ML3	SSTX	ML1
	A8	AUX_CH_P	AUX_CH_P	AUX_CH_P	AUX_CH_P	AUX_CH_N
	B8	AUX_CH_N	AUX_CH_N	AUX_CH_N	AUX_CH_N	AUX_CH_P

In both cases (DFP and UFP), the video data rate changes depending on the configuration.

A USB Type-C receptacle that supports DFP_D functionality (the receptacle can behave as a DisplayPort Source device or as a DFP_D on a DisplayPort Branch device) shall support one or more DFP_D pin assignments. Likewise, a USB Type-C Receptacle that supports UFP_D (the receptacle can behave as a DisplayPort Sink device or as the UFP_D on a DisplayPort Branch device) shall support one or more UFP_D pin assignments.

3.2 AUX signal

When operating in DisplayPort Mode, the USB Type-C connector must support the AUX channel through differential signaling on receptacle pins A8 and B8. These pins remain unconnected until the DisplayPort Mode connection is activated and the configuration is selected; a high-speed switch can connect the SBU pins on the type C connector with the AUX channel of the DisplayPort.

The DisplayPort specification defines the pull-up and pull-down resistors for the AUX_CH_P/AUX_CH_N signal pair at both DFP_D and UFP_D. This implementation allows a UFP_D to determine when a DFP_D has connected.

Table 5. **Pull-up and pull-down resistors for AUX_CH_P/AUX_CH_N**

Signal	DisplayPort DFP_D	DisplayPort UFP_D	Logic value when connected
AUX_CH_P	100kΩ to GND	1MΩ to 3.3V	0
AUX_CH_N	100kΩ to 3.3V	1MΩ to GND	1

3.3 Hot plug detection

The hot plug detection (HPD) mechanism provides display (UFP_U) status information to the DFP_U hosting the video GPU. This mechanism is deployed in the following ways:

- With the IRQ_HPD interrupt signal that, switching from low to high, indicates a Display (UFP_U) is connected to the video source (DFP_U).
- With an HPD_High or HPD_Low state bit-field value in a `DisplayPort Status Update` message.

The two methods are connected because the logical state of HPD remains high while receiving an IRQ_HPD, and low while HPD is being de-bounced on a new mechanical connection.

4 DisplayPort Alternate Mode commands and flow

Once the DFP_U and UFP_U have completed negotiation, the DP Alternate Mode procedure implements a combination of the command flow described in the DisplayPort specification and vendor defined messages (VDM) defined in the USB PD specification.

The complete sequence for a DFP_U and a UFP_U to enter and configure DisplayPort Alternate Mode involves six main exchanges. Each exchange has a request command and corresponding `GoodCRC` response (when accepted), plus an update command like `ACK`, `NACK` or `BUSY`. The DisplayPort-specific requests are `Discover`, `Enter`, `Status Update`, `Configure`, `Exit` and `Attention`.

4.1 Structured vendor defined messages

Structured VDM bit-fields represent the commands and data necessary for DFP_U and UFP_U to enter and exit Display Port Alternate Mode.

Table 6. VDM header structure

Bits(s)	Description	Values
4:0	Command	0h = RESERVED, not used 1h = Discover Identity 2h = Discover SVIDs 3h = Discover Modes 4h = Enter Mode 5h = Exit Mode 6h = Attention 7h – Fh = RESERVED, not used 10h = DisplayPort Status Update 11h = DisplayPort Configure 12h – 1Fh = RESERVED for DP_SID use
5	RESERVED	RESERVED (always 0)
7:6	Command Type Initiator shall clear to 0.	00 = Initiator 01 = Responder ACK 10 = Responder NAK 11 = Responder BUSY
10:8	Object Position	000 = RESERVED 001 – 110 = Index into the list of Vendor Defined Objects (VDOs) to identify the desired Mode VDO. 111 = Exit all Modes (equivalent of a power-on reset). Shall not be used with the Enter Mode command.
12:11	RESERVED	RESERVED (always 0)
14:13	Structured VDM Version	00 = Version 1.0 All other values are RESERVED
15	VDM Type	1 = Structured VDM
31:16	Standard or Vendor ID	Base SID (for Discover SVIDs command) or DP_SID, a 16-bit unsigned integer, assigned by the USB-IF.

Bits 4:0 of the VDM header contain the main commands exchanged by the DFP and UFP: `Discover`, `Enter`, `Status Update`, `Configure`, `Exit` and `Attention`.
Bits 7:6 identify the command types for the initiator and the responder. Only a DFP supporting DisplayPort may be an initiator, while the responder may be both the DFP and the UFP. For example, if the UFP_U response to an `Enter Mode` VDM is `NAK`, the procedure stops and DP Alt Mode is not entered (and the UFP_U will expose its USB Billboard Device Class). The `BUSY` command is not available for the UFP_U.
Bits 10:8 refer to the vendor defined objects (VDOs) for the desired Mode. The DFP_U and UFP_U must be aligned on the same offset (indexed from 1) as the object position to correctly decode the `Enter Mode`, `DisplayPort Configure`, `DisplayPort Status Update`, `Attention`, and `Exit Mode` commands.
Bits 15:13 are for VDM versions and types (Structured VDM are required to negotiate Alt Mode).
Bits 31:16 are for the specific vendor ID (SVID). Every vendor may generate and insert an SVID in the VDMs to identify the specific Alternate Mode supported and to access to it once the ID correspondence between DFP and UFP devices has been verified. The USB Standard 16-bit ID assigned by USB-IF for DisplayPort is 0xFF01 (Mode #1 is the DisplayPort).

4.2 Discover command

The `Discover` command starts the procedure and exposes the Alternate Mode feature when supporting devices are connected. The initial Discovery phase is a sequence of three commands to identify the entering conditions of the devices:

- `Discover Identity` exposes the presence of a connected device
- `Discover SVIDs` identifies the alternate modes supported by the connected product
- `Discover Mode` detects the specific alternate modes supported by the product for a given SVID.

The UFP_U sends a Responder `Discover Modes` VDM to indicate its DisplayPort capabilities in the relative VDO.

Table 7. DisplayPort Capabilities (VDO in Responder Discover Modes VDM)

Bits(s)	Description	Values
1:0	Port Capability	00 = RESERVED. 01 = UFP_D-capable (including Branch device). 10 = DFP_D-capable (including Branch device). 11 = Both DFP_D and UFP_D-capable.
5:2	Signalling for Transport of DisplayPort Protocol	xxx1 = Supports DP v1.3 signaling rates and electrical specification (shall always be set apart from diagnostic purposes). xx1x = Supports USB Gen 2 signaling rate and electrical specification. x1xx = RESERVED. 1xxx = RESERVED.
6	Receptacle Indication	0 = DisplayPort interface is presented on a USB Type-C Plug. 1 = DisplayPort interface is presented on a USB Type-C Receptacle.
7	USB r2.0 Signalling Not Used	0 = USB r2.0 signaling may be required on A6 – A7 or B6 – B7 while in DisplayPort Configuration. 1 = USB r2.0 signaling is not required on A6 – A7 or B6 – B7 while in DisplayPort Configuration.

Bits(s)	Description	Values
15:8	DFP_D Pin Assignments Supported (reported by a DFP_D receptacle or UFP_D (direct attachment) plug)	00000000 = DFP_D pin assignments are not supported. xxxxxxx1 = Pin Assignment A is supported. xxxxxx1x = Pin Assignment B is supported. xxxxx1xx = Pin Assignment C is supported. xxxx1xxx = Pin Assignment D is supported. xxx1xxxx = Pin Assignment E is supported. xx1xxxxx = Pin Assignment F is supported. x1xxxxxx = RESERVED. 1xxxxxxx = RESERVED.
23:16	UFP_D Pin Assignments Supported (reported by a UFP_D receptacle or DFP_D (direct attachment) plug)	00000000 = UFP_D pin assignments are not supported. xxxxxxx1 = Pin Assignment A is supported. xxxxxx1x = Pin Assignment B is supported. xxxxx1xx = Pin Assignment C is supported. xxxx1xxx = Pin Assignment D is supported. xxx1xxxx = Pin Assignment E is supported. xx1xxxxx = RESERVED. x1xxxxxx = RESERVED. 1xxxxxxx = RESERVED.
31:24	RESERVED	RESERVED (always 0).

4.3 Enter and Exit commands

The `Enter Mode` and `Exit Mode` commands start and stop communication for a definite sequence of DisplayPort Mode-specific commands that may only be issued when DisplayPort Mode is established.

Enter Mode is triggered when the DFP_U sends the command to the UFP_U and receives the Responder `ACK`. The DFP_U then sends a `DisplayPort Status Update` command to the UFP_U.

After DisplayPort Mode is entered and the procedure is accomplished, the DFP_U and UFP_U shall remain in Alt Mode until one of the following events occurs: an `Exit Mode` command, a hard reset on PD, or the Device is disconnected. The DFP_U sends the `Exit Mode` command for the UFP_U to exit DisplayPort Mode; this command is only issued when the port is in USB configuration.

When, during DisplayPort Configuration, the UFP_U receives an `Exit Mode` command, it must switch to USB Configuration and then continue with the other actions. After the DFP_U receives the Responder `ACK`, the DFP_U exits to a new connection state.

4.4 Status Update command

The `Status Update` command is part of the `Enter Mode` command sequence (after receiving the Responder `ACK`) but can also be sent by the DFP_U whenever a UFP_U status update is required.

The DFP_U sends the `DisplayPort Status Update` command with latest status in its VDO, and the UFP_U replies by returning its `DisplayPort Status` in the VDO. Following this, the DFP_U and UFP_U proceed with the next steps in configuring the port.

Table 8. **DisplayPort Status**

Bits(s)	Description	Values
1:0	DFP_D/UFP_D Connected	00 = Neither DFP_D nor UFP_D is connected, or Adapter is disabled. 01 = DFP_D is connected. 10 = UFP_D is connected.(1) 11 = Both DFP_D and UFP_D are connected.
2(2)	Power Low	0 = Adapter is functioning normally or is disabled. 1 = Adapter has detected low power and disabled DisplayPort support.
3(2)	Enabled	0 = Adapter DisplayPort functionality is disabled. 1 = Adapter DisplayPort functionality is enabled and operational.
4(2)	Multi-function Preferred	0 = No preference for Multi-function. 1 = Multi-function preferred.
5(2)	USB Configuration Request	0 = Maintain current configuration. 1 = Request switch to USB Configuration (if in DisplayPort Configuration).
6(2)	Exit DisplayPort Mode Request	0 = Maintain current mode. 1 = Request exit from DisplayPort Mode (if in DisplayPort Mode).
7(3)	HPD State	0 = HPD_Low. 1 = HPD_High.(4)
8(3)	IRQ_HPD	0 = No IRQ_HPD since last status message. 1 = IRQ_HPD.(5)
31:9	RESERVED	RESERVED (always 0).

Notes from VESA specification:

1. An adapter that contains a DisplayPort Branch device with its DisplayPort receiver connected to the USB Type-C Plug shall report UFP_D connected, regardless of whether the Branch device has DFP_D connected.
2. These status bits apply only to DisplayPort Status sent by a UFP_U to a DFP_U. When sending DisplayPort Status, the DFP_U shall clear these bits. When receiving DisplayPort Status, the UFP_U shall ignore these bits.
3. These status bits apply only to DisplayPort Status sent by a UFP_D to a DFP_D. When sending DisplayPort Status, the DFP_D shall clear these bits. When receiving DisplayPort Status, the UFP_D shall ignore these bits.
4. HPD state is reported after glitch filtering, IRQ_HPD filtering (HPD state is maintained high when reporting an IRQ_HPD) and de-bouncing, when applied.
5. IRQ_HPD may be generated only when the HPD state is HPD_High.

4.5 Configure command

The `Configure` command is required to switch to the DisplayPort mode signalling on the Type-C connector as its VDO contains the details of the requested pin assignment.

A DFP_U may transmit a `DisplayPort Configure` command at any time when it is in DisplayPort Mode. When two products are compatible, the DFP_U sends a `Configure` command to the UFP_U to configure and prepare both ports for video data. The UFP_U may enable DisplayPort signaling as soon at it receives this command, and then respond with an `ACK` after it reconfigures the pins connected to DisplayPort.

The DFP_U may also change the number of connected DisplayPort lanes during reconfiguration. In this case, as well as placing any additional USB Type-C pins into Safe mode before sending the `DisplayPort Configure` command, the DFP_U must ensure that the HPD state is taken low and then isolate the SBU pins. The DFP_U

does not reconnect the SBU pins until after receiving the Responder ACK and then reconnecting the reconfigured High-Speed pins.

Finally the DFP_U must keep HPD_Low for a minimum of 3 ms to ensure that its DisplayPort transmitter correctly recognizes an HPD disconnection event.

Table 9. DisplayPort Configurations

Bits(s)	Description	Values
1:0	Select Configuration	00 = Set configuration for USB.(1) 01 = Set configuration for UFP_U as DFP_D.(1) 10 = Set configuration for UFP_U as UFP_D.(1) 11 = RESERVED
5:2	Signaling for Transport of DisplayPort Protocol	0000 = Signaling unspecified (used only when Select Configuration field is set for USB Configuration). 0001 = Select DP v1.3 signaling rates and electrical settings. 0010 = Select Gen 2 signaling rates and electrical specifications. All other values are RESERVED.
7:6	RESERVED	RESERVED (always 0).
15:8	Configure UFP_U Pin Assignment	00000000 = De-select pin assignment. 00000001 = Select Pin Assignment A. 00000010 = Select Pin Assignment B. 00000100 = Select Pin Assignment C. 00001000 = Select Pin Assignment D. 00010000 = Select Pin Assignment E. 00100000 = Select Pin Assignment F. All other values are RESERVED.
31:9	RESERVED	RESERVED (always 0).

Notes from VESA specification:

1. Selecting configuration for USB results in selecting USB Configuration. Either selecting UFP_U as DFP_D or selecting UFP_U as UFP_D results in selecting DisplayPort Configuration.

4.6 Attention command

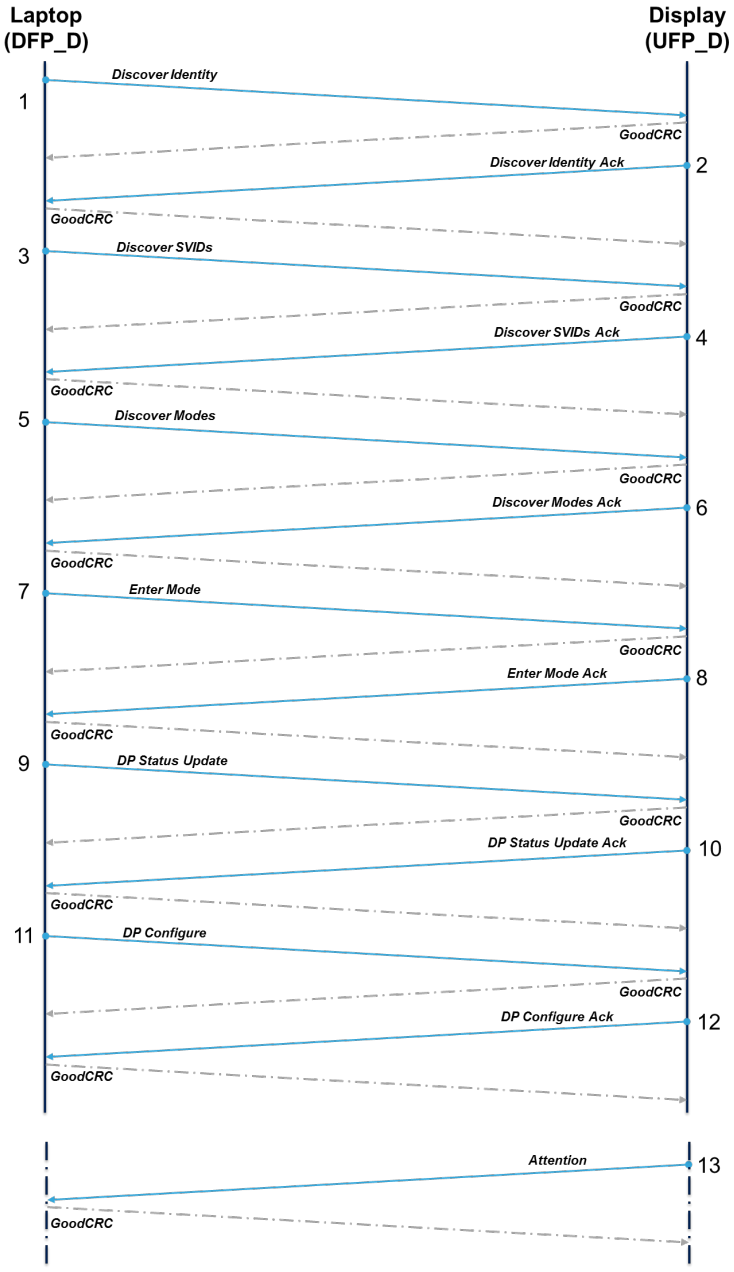
The `Attention` message is used by a UFP_U to advise the DFP_U with a specific VDO to inform it that its status has changed since the last reported message.

An `Attention` message with IRQ set to 1 marks the end of USB PD DP Alternate Mode communication and the beginning of standard DP operation, when all the DP signals are mapped to the Type-C connections.

4.7 USB PD and VESA DP Alternate Mode flow

The procedure for a DFP and a UFP to successfully enter and configure DisplayPort Alternate Mode involves six main steps, each with a specific PD message, and subsequent `GoodCRC` and `ACK` confirmations.

Figure 6. **DisplayPort Alternate Mode command flow**



The following procedure is performed after a USB PD explicit contract is achieved:

1. The DFP sends a `Discover Identity` command to discover the UFP connected via cable, and the UFP confirms with a `Discover Identity ACK`.
2. The DFP sends the `Discover SVIDs` command to retrieve all the alternate modes supported by UFP, which replies with a `Discover SVIDs ACK` and a list of all the SVIDs of its alternate modes.
3. The DFP sends the `Discover Modes` command to identify the alternate modes supported by the UFP for a given SVID, and the UFP responds with the `Discover Modes ACK` and a list of the alternate modes enabled in the device.
4. The DFP sends the `Enter Mode` command, merging the SVID and Mode number along with any payload data defined by the vendor for that SVID-Mode combination. An `Enter Mode ACK` is returned by the UFP; this message contains the payload data established by the vendor for that SVID-Mode.

At this step, the DFP and the UFP have entered the selected DisplayPort Alternate Mode, and have respectively become DFP_D and UFP_D. While the previous steps generically referred to all the alternate modes supported by the USB PD specification, the following steps address the VESA DisplayPort specification for configuring the DP Alternate Mode.

5. A `DP Capabilities` message is sent by the DFP_D to determine the capabilities of the connected UFP_D. The UFP_D responds with a `DP Capabilities ACK` and the payload that confirms the DP Alternate Mode for the VESA specification.
6. After checking the DP capabilities sent by the UFP_D, the DFP_D selects the configuration that matches both products.
   a. If the two products are compatible, the DFP_D sends a `DP Configure` command message to configure the UFP_D and prepare both products for DP video data. This implies that a pin assignment mode has been selected on the type-C connector and the SuperSpeed lanes, as well as the other relevant pins are redirected to support the communication wiring. Normally, the DFP_D selects a pin assignment for its USB Type-C Receptacle and configures the port partner with the same pin assignment.
   b. If the products are not compatible, the DFP_D sends the `Exit Mode` command to the UFP_D and the two entities resume the normal DFP and UFP data roles.

      Finally, the UFP_D returns the `DP Configure ACK` message with the related payload as per VESA DP Alternate Mode specification.
7. Whenever the UFP_D status changes, the UFP_D can send an `Attention` message to advise the DFP_D with status updates so the DFP_D can react accordingly.

5 USB Billboard Device Class

The USB Billboard Device Class is a mechanism defined by the USB-IF to signal that the Alternate Mode procedure supported by Device Container has failed. According to USB Type-C and Power Delivery specifications, if a device fails to enter the Alternate Mode within 1000 ms, the USB Billboard Device Class definition implies that the device should at least expose a USB 2.0 interface, and must be powered by VBUS.

By identifying the device type from the USB Billboard Device Class information, the connecting host reports that the attached device does not support Alternate Mode. Therefore, USB Billboard must be implemented on any USB Type-C device embedding Alternate-Mode implementation.

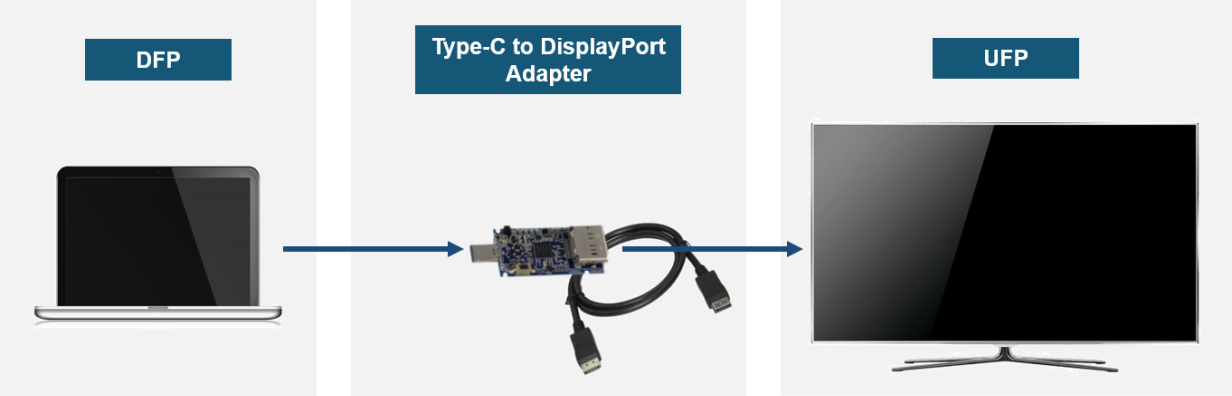
6 Type-C to DisplayPort adapter

Type-C to DisplayPort adapters are typical implementations that can carry DisplayPort protocol data stream from a host device to a DP-compliant monitor over an established Type-C and PD connection.

A Type-C to DisplayPort Adapter generally consists of a Type-C plug (or captive cable) and a DisplayPort Receptacle. To use an adapter like this, the host device must be compliant with the DisplayPort Alternate Mode standard. The host device must:

- have a USB Type-C port
- be compliant with the Power Delivery specification
- be able to manage DisplayPort Alternate Mode functionality

Figure 7. Type-C to DisplayPort adapter between DFP and UFP



The host and the adapter must identify themselves with a DP_SID code that confirms DisplayPort Alternate Mode support and establishes commands from the DisplayPort Alternate Mode standard.

Once the host identifies the attached device as a Type-C to DisplayPort Video adapter, it finalizes the DisplayPort Alternate Mode procedure to allow video streaming over the established connection. In case of failure, the connection is redirected to a USB Billboard Device Class.

6.1 Detection mechanism for adapters

The SBU isolation switch (high speed switch) manages the continuity of SBU signals on the Type-C plug and the AUX channels on the DisplayPort receptacle.

When an adapter is attached to a DFP Type-C receptacle, it must set its HPD driving pin to a high-impedance state and the SBU isolation switch open. A logic 1 on AUX_CH_P or HPD indicates a connected DisplayPort UFP_D.

A DisplayPort monitor (UFP_D) usually exposes a weak pull-up resistor on AUX_CH_P. Displays that don't provide this pull-up resistor assert HPD without DisplayPort DFP_D detection.

When an adapter detects a DisplayPort UFP_D, it reports the event to the USB Type-C system via PD. If the Type-C system returns a `DisplayPort Configure` command, the adapter switches to DisplayPort DFP_D configuration and closes the SBU switch to connect the AUX signals on the DisplayPort connector to the DisplayPort UFP_D.

When the SBU isolation switch is closed, the pull-down resistor on AUX_CH_P in the DFP_D at the USB Type-C receptacle sets AUX_CH_P to logic 0 (and the pull-up resistor on AUX_CH_N sets AUX_CH_N to logic 1). This condition forms the basis for the completion of the DisplayPort Alternate Mode procedure.

If the UFP_D is subsequently disconnected from the DisplayPort connector, the HPD state passes to logic 0. The adapter reports the disconnected state to the DFP_D via USB PD messaging, and the DFP_D calls for the isolation of the SBU connections.

The following table describes the possible HPD, AUX_CH_P, and AUX_CH_N states when there is no connection on the DisplayPort connector or the Adapter is in DFP_D Configuration (connected to a UFP_D at the DisplayPort connector).

Table 10. DisplayPort Connector HPD and AUX States When Disconnected

HPD	AUX_CH_P	AUX_CH_N	Interpretation
0	0	0	Nothing is connected, or a powered-down device is connected.
0	0	1	An external DisplayPort DFP_D has been connected.
0	1	0	An external DisplayPort UFP_D has been connected and is waiting to detect the presence of the DisplayPort DFP_D (i.e., waiting for the 100 kΩ resistors to be connected). Presence of DisplayPort UFP_D is reported.
0	1	1	Invalid.
1	0	0	An external DisplayPort UFP_D has been connected (one that does not implement the 1 MΩ resistors, but directly asserts HPD).
1	0	1	DisplayPort UFP_D is connected. The Adapter has already closed the SBU isolation switches, connecting the 100 kΩ resistors from the DFP_D. This state is maintained until the DisplayPort UFP_D is disconnected.
1	1	0	Invalid (possible transitory state between 0 1 0 and 1 0 1 if the DisplayPort UFP_D detects a connection resulting from the Adapter's weak pull-down resistor).
1	1	1	Invalid (this state may occur if the connected device is a DisplayPort DFP_D side DP++ Adapter with DisplayPort Dual-Mode Adapter with Display Data Channel (DDC) pull-up resistors, as specified in DP++ v1.1).

6.2 VCONN and VBUS on Type-C to DisplayPort adapters

An adapter supporting DisplayPort on a USB Type-C Plug must be able to be supplied by VBUS or operate as a VCONN-powered accessory.

To support DisplayPort, a DFP_U Type-C receptacle must be able to supply a maximum 1.5 W between 2.7 and 5.5 V in addition to the VCONN power consumption requirements of the USB Type-C specification.

A Type-C to DisplayPort adapter may also operate as a VCONN-powered accessory if it does not provide power on VBUS and does not need VBUS (except to power the presentation of USB Billboard Device class, when required).

Revision history

Table 11. **Document revision history**

Date	Revision	Changes
10-Feb-2018	1	Initial release

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References

1. USB Type-C™ Cable and Connector Specification, Release 1.3, July 12, 2017.
2. USB Power Delivery Specification Revision 3.0, Version 1.1, January 12, 2017.
3. VESA DisplayPort Alternate Mode on USB Type-C Standard, Version 1.0a, August 05, 2015.
4. USB Device Class Definition for Billboard Devices, Revision 1.21, September 8, 2016.

Glossary

Cyclic redundancy check Error-detecting scheme commonly used in digital networks and storage devices to detect accidental changes to raw data

DisplayPort Alternate Mode

the MUX system which repurposes USB Type-C RX/TX and SBU lines for compatability with DisplayPort signal requirements

reference design

fully tested and functional solutions with accompanying documentation, intended for direct duplication or further modification

SuperSpeed USB

the SSRX and SSTX USB connector pins reserved for elevated data exchange rates (5 Gbps for USB 3.0)

USB Implementers Forum A non-profit corporation founded by the group of companies that developed the Universal Serial Bus specification

USB Power Delivery

the logic and technology through which devices connected via USB negotiate their respective power roles (source or sink) and corresponding power level

vendor-defined message

standard data packets sent and received along USB configuration channel lines to negotiate Power Delivery and Alt Mode agreements between the device and the host

VESA

A technical standards organization for computer display standards.

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