Alternate Mode for USB Type-C™: Going beyond USB

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TI enables USB Type-C Alternate Mode with a 10G linear redriver switch solution capable of delivering high-quality 10G USB data and 8K video over a single interface.

Every year, billions of universal serial bus (USB) devices are sold around the world for applications ranging from personal electronics to computing, communication, automotive and industrial. As USB continues to evolve to USB Type-C, the unique capability of unifying data, video and power delivery (PD) over a single cable has captivated many innovative product ideas.

Type-C PD provides up to 100 W of power over a USB cable, as well as configures Alternate Mode (Alt Mode) over Type-C. This configuration enables other protocols such as DisplayPort (DP), high-definition multimedia interface (HDMI), Thunderbolt™, mobile high-definition link (MHL), and Peripheral Component Interconnect Express (PCIe), to name a few, to transfer over Type-C cables.

For example, DP over Type-C Alt Mode allows streaming video as well as USB data to transfer simultaneously through a common Type-C connector. This transfer has greatly simplified the device interface with a reduced footprint, making USB even more ubiquitous for multi-gigabit connectivity.

USB Type-C

Developed in the 1990s, USB has become the most successful computing interface yet. The throughput has improved from 1.5 Mbps to 10 Gbps through standards evolution (**Figure 1**).

As the computing platform is trending towards smaller and lighter form factors with less physical connectors, in 2014 the Type-C connector was introduced to unify all USB connectors with a smaller and flippable interface, as well as unify the data, video and power delivery of up to 100 W through a single interface. Type-C will enable even wider adoption for USB in power banks, computing, video streaming, mobile devices, appliances, automotive and industrial applications.

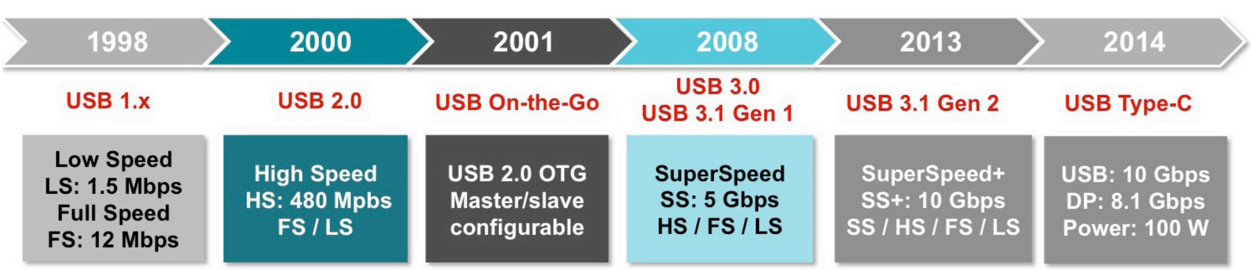


***Figure 1**. Evolution of the USB standard.*

USB Type-C is a flippable interface with a small form factor of less than 3 mm in height. The flip-ability of cable is enabled through dual redundancies of pins in the port/receptacle and plug. Direction through these pins is handled by multiplexing based on the cable orientation. Type-C port/receptacle pins, as shown in **Figure 2**, comprise of USB 2.0 D+/D– data bus, USB 3.1 transceiver/receiver (TX/RX) pairs, configuration channel (CC) for cable attach detection, cable orientation detection, role detection and current-mode detection.

One unused CC pin becomes the VCONN pin, which supplies the power to active cables or adaptors. The VBUS pin is used for the cable bus power and GND pin for the cable ground. Side band use (SBU) is not for USB, but is open for Alternate Mode, such as DisplayPort over Type-C.

There are three modes for Type-C, depending on whether it is on the host or the device side. Host-mode is used by a USB master. The port that supports host-mode is a downstream facing port (DFP). Device-mode is used by a USB slave. The port that supports device-mode is an upstream facing port (UFP). Dual-role mode can be master or slave. The port that supports dual-role mode is a dual-role port (DRP).

The Type-C Alt Mode Specification, allows for protocols other than USB to be transferred over a USB connection, such as DisplayPort, HDMI, MHL or Thunderbolt over the Type-C interface. Alternate Mode can be enabled only via a USB PD protocol handshake through structured vendor-defined messages (VDM) to discover, configure, and to enter or exit Alt Modes. It is highly flexible with multiple high-speed communication lanes and open SBU channels.

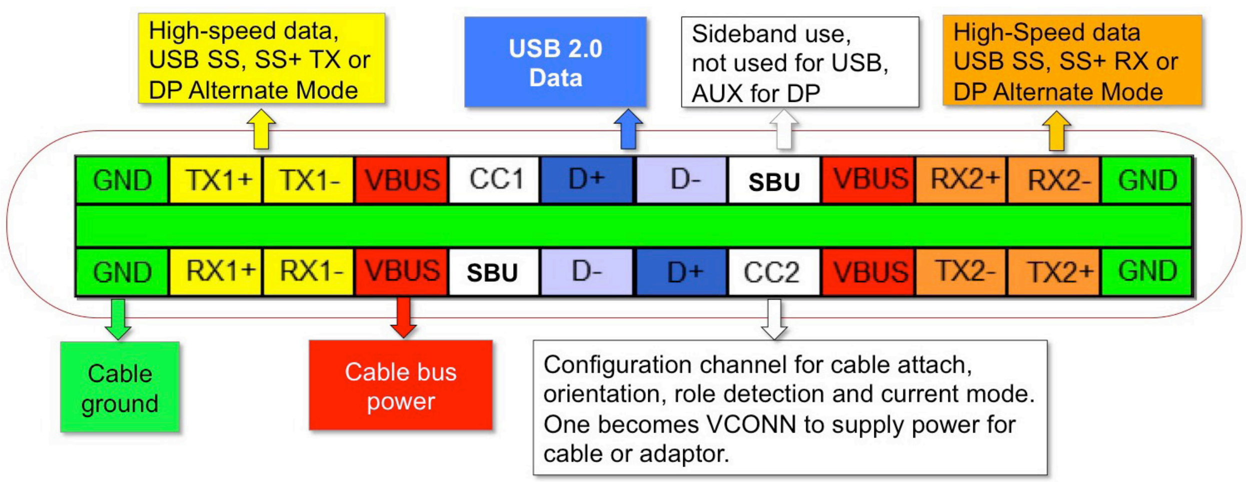


***Figure 2**. USB Type-C receptacle pin out.*

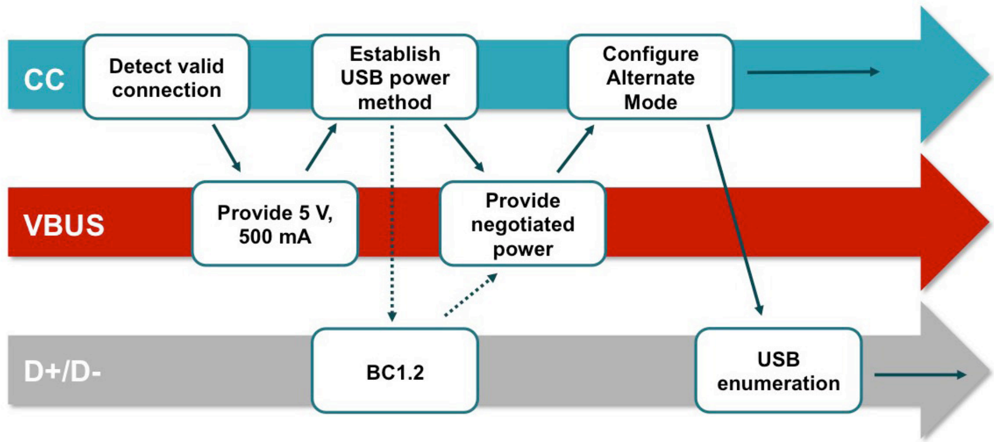


Figure 3. *Alt Mode configuration sequence.*

The steps in **Figure 3** show the Type-C Alt Mode configuration sequence:

1. USB connection is detected via a CC connection.
2. The default power of 5 V at 500 mA becomes available on the VBUS pin.
3. Either Battery Charging 1.2 (BC 1.2) or USB PD can be used to further negotiate the USB PD to the desired power over VBUS.
4. USB PD is needed to use structured vendor-defined messages (VDM) to negotiate the Alt Mode handshaking.
5. USB enumeration.
6. If DP Alt Mode negotiation is completed, proceed with the DP link training to establish the DP link.
7. USB and DP channels are ready for data and video transfer over Type-C.

Alt Mode requires multiplexers

Depending on the requirements of a particular Alt Mode standard, single or multiple protocols may reside over a single Type-C interface.

For example, the Video Electronics Standards Association (VESA) DisplayPort Alt Mode on Type-C standard enables four lanes of DisplayPort, as well as simultaneous USB 3.1 and DisplayPort. With multiple protocol support and a flippable aspect of Type-C, multiplexing between different protocols is needed in order to connect video and data source to the appropriate destination.

On the source side, the multiplexer (mux) takes USB and DP lanes and switches them to the appropriate high-speed lanes. On the sink side, the mux takes the four high-speed lanes from Type-C connector as input and then distributes the signal to the USB receiver or DP sink accordingly. **Figure 4** shows the high level Alt Mode communication data path from source-to-sink, and mux placement.

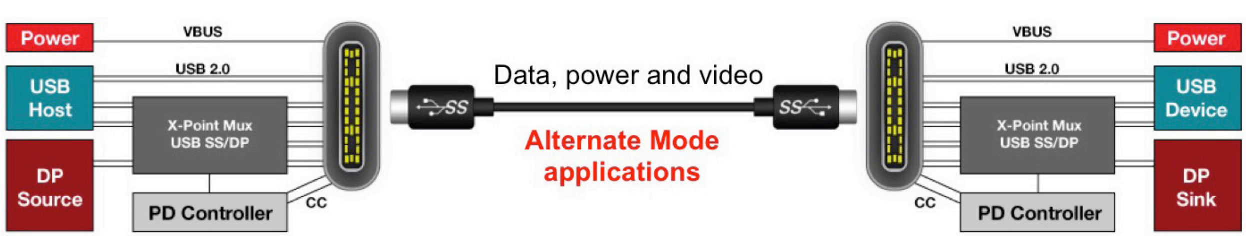


Figure 4. *USB Type-C Alt Mode end-to-end connections.*

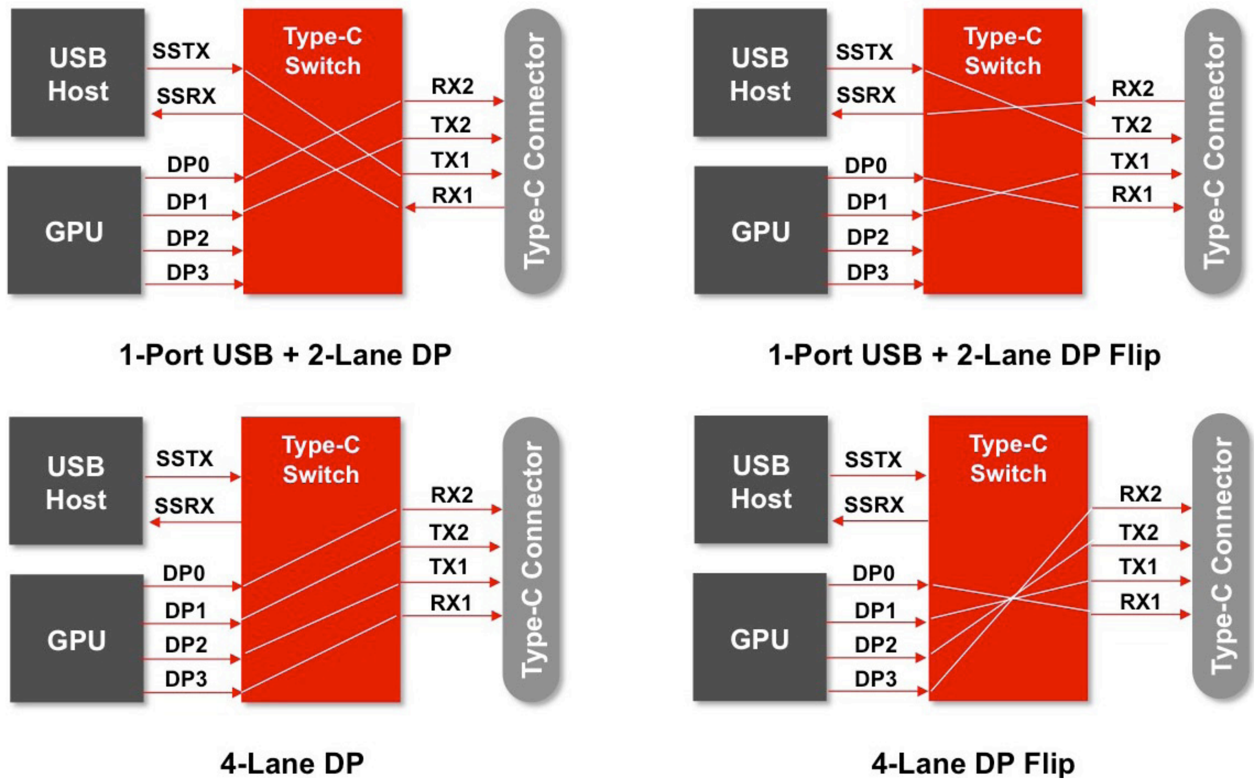


Figure 5. *Different Alt Mode connection map.*

DisplayPort as Alt Mode

DisplayPort is the most popular Alt Mode being used today that supports high-resolution video. A signal mux is required to support four different signal configuration use cases in order to meet different application needs and the flip-ability of the Type-C connectors:

- One-port USB plus a two-lane DP for simultaneous data and video transfer
- One-port USB plus a two-lane DP with Type-C connector flip orientation
- Four-lane DP-only application
- Four-lane DP-only with Type-C connector flip orientation

Additionally, DP auxiliary (AUX) signals use SBU1 and SBU2 signal pins, and the DP HPD signal is embedded into the USB PD message to enable full DP applications.

DisplayPort link training involves optimizing the link between a DisplayPort source and sink with the goal of a robust connection for streaming video. Device(s) in the DP signal path, for example signal conditioners such as redrivers and switches in the path not known to the system, could potentially hamper the link training process, resulting in non-robust source and sink settings. The outcome will be no video connection or dropped video frames, creating an unacceptable user experience.

A well-designed Alt Mode switch needs to be transparent and not interfere or break DP link training. This allows the Alt Mode to help establish the best DP communication channel between the source and sink.

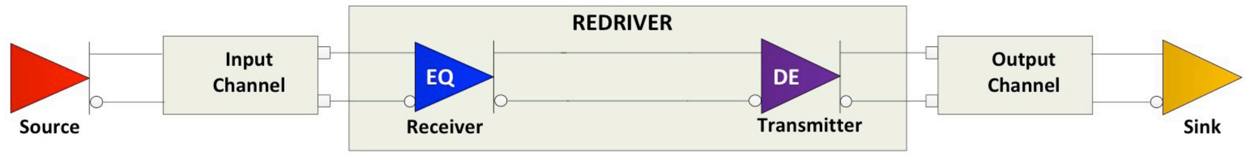


Figure 6. *Example of a redriver concept.*

The Type-C Alt Mode switch can be either a passive or redriver switch. A passive switch is bidirectional so that it can be placed on either the source or sink side. A redriver switch is unidirectional with the data-path direction determined by an external device like the PD controller.

As USB speed evolves to 10 Gbps per the USB 3.1 Gen 2 specification, and DP is reaching 8.1 Gbps in DP1.3 and DP1.4, those multi-gigabit signals will easily suffer signal degradation while they travel through printed circuit board (PCB) traces, switches, connectors and cables. Often it is necessary to embed a signal conditioner inside the active switch to compensate for channel loss.

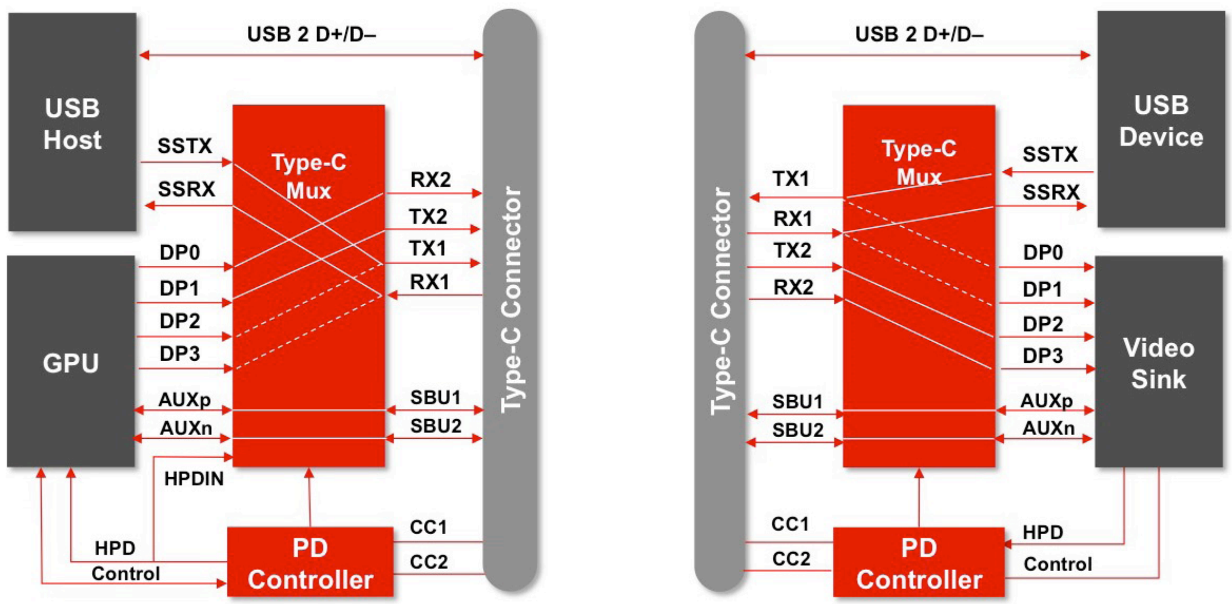
Linear versus limiting redriver

A redriver, as shown in **Figure 6**, has a receiver and a transmitter. On the receiver side, it performs signal conditioning through its equalizer (EQ) function. Essentially, the redriver provides compensation for input channel loss which, if not equalized, leads to extra deterministic jitter. The equalized signal is then driven out by the transmitter. The transmitter also can have the option of de-emphasis (DE) or pre-emphasis (PE). DE is essentially the attenuation of the signal's low-frequency components, PE is the boosting up of the signal's high-frequency components. Both techniques pre-compensate for the loss of the output channel connected to the redriver's transmitter side.

A redriver can further be classified as linear or limiting. If the redriver's output signal amplitude is a linear function of the signal amplitude at its input for a certain range of input and output amplitudes, then the redriver is termed linear in that input and output amplitude range, otherwise it is limiting.

When a signal goes through a passive medium such as a PCB trace, it is attenuated linearly. That is, the trace attenuates the signal by a certain ratio, regardless of the signal's amplitude at the trace's input. A perfect redriver should do the exact opposite. The redriver should amplify the signal by the same ratio, regardless of the signal's amplitude at its input. A redriver that does this is a linear redriver. The effect of such a redriver is the same as removing the PCB trace or shortening it. In this way, a linear redriver is ideal for protocols such as DisplayPort that include source and sink link training. A Type-C Alt Mode active switch can have a linear redriver inside to provide channel equalization with better signal quality. A redriver is directional, it can drive the signal in only one direction, thus, separate Type-C Alt Mode redrivers/switches are required on the source and sink sides.

Figure 7 shows source versus sink redriver use cases:



Source-side Alternate Mode Redriver

Sink-side Alternate Mode Redriver

***Figure 7**. Alternate Mode redriver mux in source and sink side.*

To reduce the pin out, some processors mux the DP and USB lanes inside the processor, resulting in four high-speed lanes to the Type-C connector. This brings challenges when redriving these four lanes in both directions where each lane can be configured as either DP or USB. Additional measures need to be put in place to handle this bi-directional, multi-protocol redriving capability.

Another example of this bidirectional use case is using the redriver inside the Type-C cable to provide better signal integrity output of the cable. For linear redrivers, the placement of the redriver is not confined. Two redrivers can be placed inside the cable – one on each end to boost the signal quality even more.

Conclusion

Convergence of video and data through Alternate Mode in USB Type-C will bring much-needed convenience to the consumers with small form factor devices, lighter and universal multi-purpose cables, as well as higher speed for faster data transfer and high definition video streaming for improved user experience. Texas Instruments has been in the forefront of the technology enablement with TUSB546 and TUSB1046, the industry's first USB Type-C DP Alt Mode, 10G linear redriver cross-point switch that supports DP1.4 at 8.1 Gbps and USB 3.1 Gen2 at 10 Gbps. TUSB1046 can redrive both DP and USB signals, while providing up to 14.4 dB equalization gain to compensate for channel loss, ultimately enabling better Alt Mode signal quality over USB Type-C channels.

Reference

- Download these datasheets: TUSB1046, TUSB546

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