Application Note

Implementing USB Type-C® Using TI's Portfolio

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ABSTRACT

This application note provides insight into redriver designs that TI has to offer in the USB Type-C° space. Block diagrams and descriptions of typical use cases are provided for each part.

Table of Contents

1 Introduction....2
1.1 What is USB?....2
1.2 What is USB Type-C and How is This Different From Previous USB Specifications?....3
1.3 What is DisplayPort?....3
1.4 What is DisplayPort Alt. Mode?....4
2 USB Type-C Part Selection Guide....4
2.1 Standard USB Type-C Application....4
2.2 DisplayPort Alt. Mode Source Applications:....6
2.3 DisplayPort Only Applications....9
3 Summary....10
4 References....10

Trademarks

1 Introduction

This application note includes the fundamentals of USB Type-C® and DisplayPort Alt. mode.

1.1 What is USB?

Universal Serial Bus, or USB is a serial protocol that allows for communication from a USB host to a USB device. This protocol was originally introduced in 1996, and today is one of the most popular communication protocols in the world. USB is used in applications ranging from mobile phones to electrical vehicles. Since 1996 there have been many updates and improvements to the protocol specification that led to popularity. As shown in Table 1-1, the major revisions of the USB in use today are USB 2.0, USB 3.2, and USB 4.

Table 1-1. Major USB Revisions and Data Communication Speeds Associated

USB Version	Symbol	Data Rate		
USB 2.0	LS	Low-Speed		1.5Mbps
	FS	Full-Speed		12Mbps
	HS	High-Speed		480Mbps
USB 3.2	Gen 1	SuperSpeed		5Gbps
	Gen 2	SuperSpeed 10Gbps		10Gbps
	Gen 2x2	SuperSpeed 20Gbps		20Gbps
USB 4				40Gbps

The latest revision of the USB is always backwards compatible with the previous iteration. This means a USB port supporting the newest revision, USB 4 with communication speeds of 40Gbps, is also required to support the oldest revision, USB 2.0 Low Speed with a communication speed of 1.5Mbps.

When USB transitioned from USB2 to USB3.x there was a major change in the physical characteristics of the USB port.

- In USB2.0 speeds all communication take place between a single DC-coupled differential pair utilizing half-duplex communication. (bidirectional communication across a single channel)
- In USB3.2 onwards the communication takes place across two AC-coupled differential pairs allowing for full duplex communication. (unidirectional communication across two channels)

The USB specification also defines standard connectors associated with the USB protocol. The following diagram highlights the different USB connectors and the footprints:

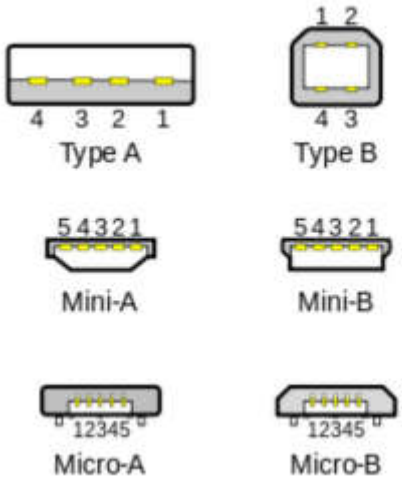

Figure 1-1. Typical USB 2.0 Connector Types

Here a link to the USB website for more details: *USB Document Library*

1.2 What is USB Type-C and How is This Different From Previous USB Specifications?

USB Type-C is a physical connector type that is symmetric across the x-axis and y-axis, meaning that there are two orientations of the cable that can be plugged into a receptacle. A USB device is required to function normally regardless of cable orientation; for this reason, the USB Type-C pinout includes a duplicate of each. The duplicate pins in a USB-C receptacle are shown in Figure 1-2.

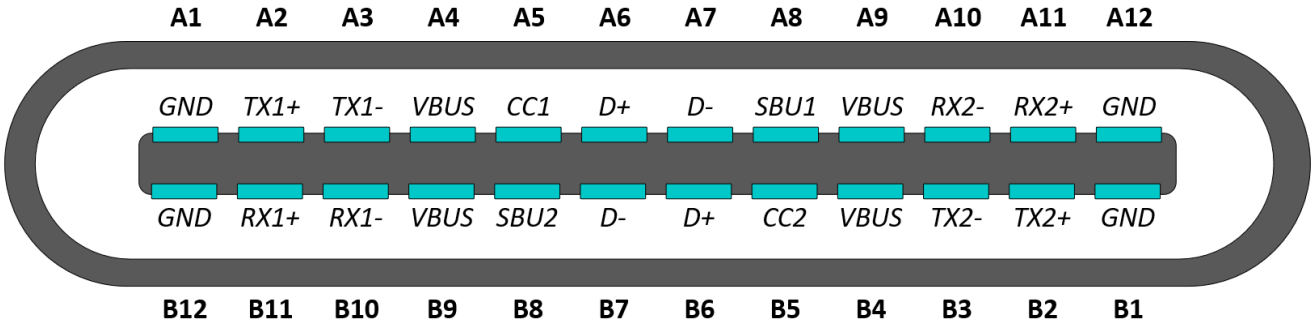

Figure 1-2. USB Type-C Pinout

Pins A5 and B5 of a Type-C receptacle are Configuration Channel (CC) pins. The USB Type-C specification implemented the CC channels on the connector to detect the orientation of the cable. After detecting the cable orientation, a mux is used to route the data signals to the appropriate pins.

1.3 What is DisplayPort?

DisplayPort or DP is a unidirectional video and audio transmission protocol. DisplayPort utilizes a state-of-the-art digital protocol and provides an expandable foundation to enable amazing digital display experiences. Designed for low power implementation and high performance, DisplayPort enables the next generation display technology while providing compatibility with existing equipment. DisplayPort is also designed specifically for usage in space-constrained applications like ultra-thin notebooks, netbooks and graphic cards where connector space is at a premium and where display performance really matters.

DisplayPort is an AC-coupled interface. The latest revision of DisplayPort (DP 2.1) is able to transmit up to 20Gbps per lane allowing for 80Gbps bandwidth. Additionally, much like USB, DisplayPort is designed to be backwards compatible back to DP 1.2 (5.4Gbps per lane).

1.4 What is DisplayPort Alt. Mode?

DisplayPort Alt mode is one of the alternate modes supported by USB Type-C. DisplayPort Alt. Mode allows for DisplayPort video and audio data to be sent through the USB Type-C connector. There are two modes of DisplayPort Alt. Mode that are very commonly used.

1. Full DP mode: In this mode all high speed differential pairs of the USB Type-C connector TX1, RX1, TX2, and RX2 output DisplayPort data. There is no USB3.x functionality as all the AC coupled differential pairs are used for DisplayPort transmission. However, the USB2.0 path is uninterrupted, so USB2.0 functionality remains in this mode.
2. DP x USB mode: In this mode both USB3.x and DisplayPort is functional. This mode uses one TX and RX pair for full-duplex USB3.x communication, and the second TX and RX pair is used to transmit DisplayPort video and audio data.

2 USB Type-C Part Selection Guide

TI offers many designs that enable USB Type-C as well as DisplayPort Alt. Mode. However, this can be difficult to select the correct chip for the correct application. The following charts can help streamline the process for selecting a signal conditioning chip for your USB Type-C applications.

Note

For all of the following diagrams, **RED** signal paths are outgoing and **BLUE** signal paths are incoming

2.1 Standard USB Type-C Application

The parts covered in this application cannot support DisplayPort Alt. Mode and are typically used to connect a single USB 3.2 TX/RX pair to a USB Type-C connector. All parts in this section have a signal conditioning component.

- **USB 3.2 Gen 1** (5Gbps)
  - TUSB542/ TUSB521-Q1

The TUSB542 and the automotive qualified version, TUSB521-Q1, are both active 2:1 MUXs designed for USB signals. An active MUX is an IC that is able to provide the functionality of a MUX and redriver in one chip. These parts can be used as a loss reducing component in standard USB3.2 Gen 1 systems. Additionally, the parts both are able to take a standard USB TX and RX pair and path these signals out to a USB Type-C connector.

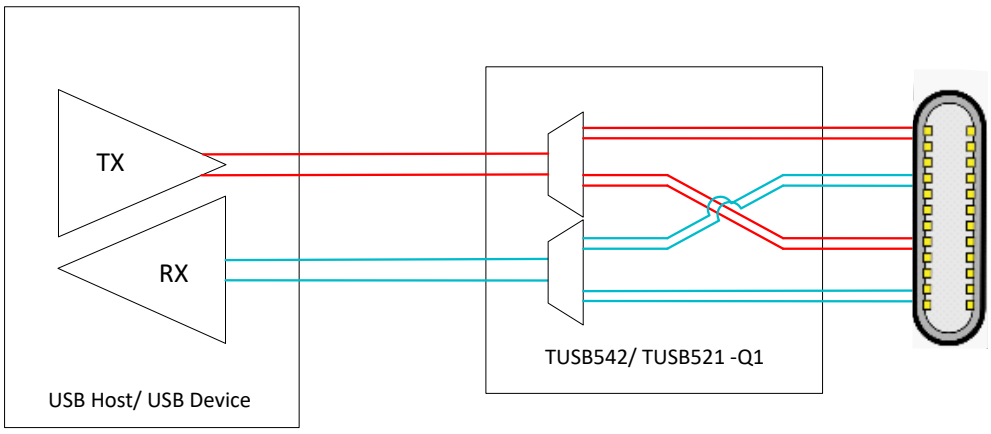

Figure 2-1. Typical USB Type-C Application for TUSB542 or TUSB521-Q1

- TUSB544

The TUSB544 is a 4-lane redriver that is able to provide equalization. This redriver is designed so part can also be used for DisplayPort Alt. Mode systems as well as standard USB Type-C systems. This part has directional control for equalization, so the part can be customized for various applications. For best results, place the TUSB544 after the USB Type-C MUX, and this is usually placed close to the USB Type-C connector.

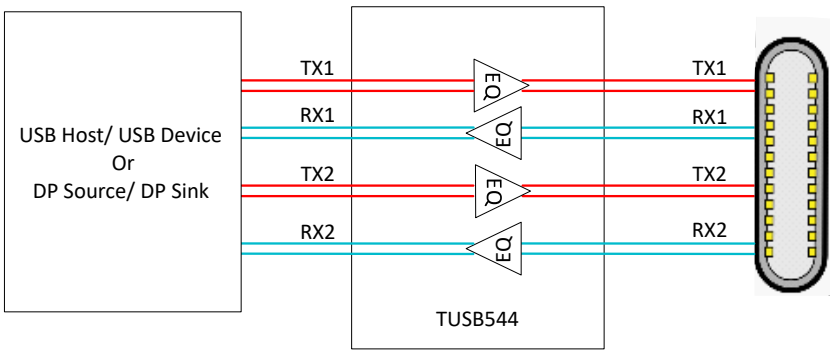

Figure 2-2. Typical USB Type-C Application for TUSB544

- **USB 3.2 Gen 2** (10Gbps)
  - TUSB1042/ TUSB1142/ TUSB1021-Q1

The TUSB1042 and the automotive qualified version, TUSB1021-Q1, are both active 2:1 MUXs designed for USB signals. An active MUX is an IC that is able to provide the functionality of a MUX and redriver in one chip. These parts can be used as a loss reducing component in standard USB3.2 Gen 1 systems. The TUSB1142 has the same functionality of the TUSB1042 and TUSB1021-Q1, but adds the convenience of adaptive EQ on the USB Type-C signals. This adaptive EQ automatically compensates the signal removing the need for EQ tuning. Additionally, all three are able to take a standard USB TX and RX pair and path these signals out to a USB Type-C connector.

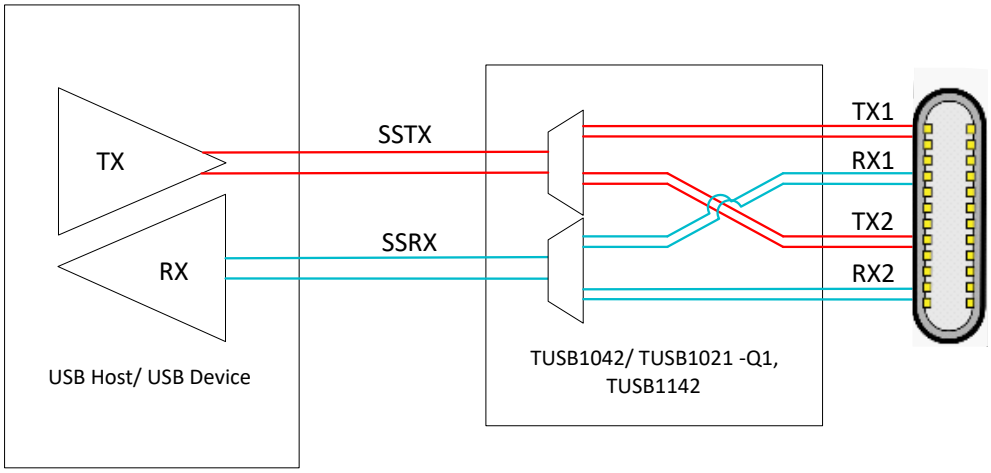

Figure 2-3. Typical USB Type-C Application for TUSB1042, TUSB1021-Q1, or TUSB1142

- TUSB1044/ TUSB1044A

The TUSB1044 and TUSB1044A are 4-lane redrivers that are able to provide equalization. These redrivers are designed to be used for DisplayPort Alt. Mode systems as well as standard USB Type-C systems. These parts have directional control for the parts equalization, so the parts can be customized for various applications. For best results, place the TUSB1044 and TUSB1044A after the USB Type-C MUX, and usually placed close to the USB Type-C connector.

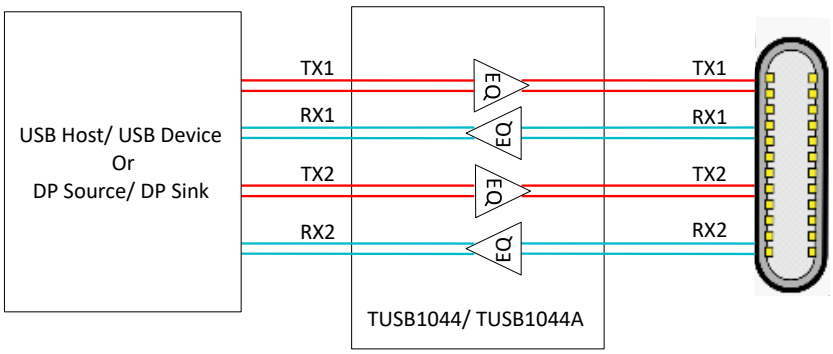

Figure 2-4. Typical USB Type-C Application for TUSB1044 and TUSB1044A

2.2 DisplayPort Alt. Mode Source Applications:

- **USB 3.2 Gen 1** (5Gbps)/ **DisplayPort 1.4** (8.1Gbps)
  - TUSB544

See description in **Standard USB Type-C Application** section.

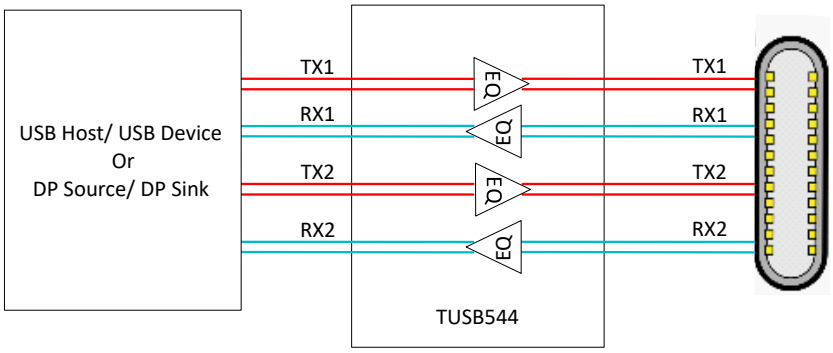

Figure 2-5. Typical DisplayPort Alt. Mode application for TUSB544

- – TUSB546/ TUSB5461-Q1

The TUSB546 and the automotive counterpart TUSB5461-Q1 are both designed to be cross bar MUXs allowing for standard USB Type-C communication as well as DisplayPort Alt. Mode. These parts are designed for DisplayPort source operation. The inputs for these parts are the 4-lanes of DisplayPort and the SSTX & SSRX pairs for USB communication. These 6 signals are routed to the 4 high speed lanes of the USB Type-C connector.

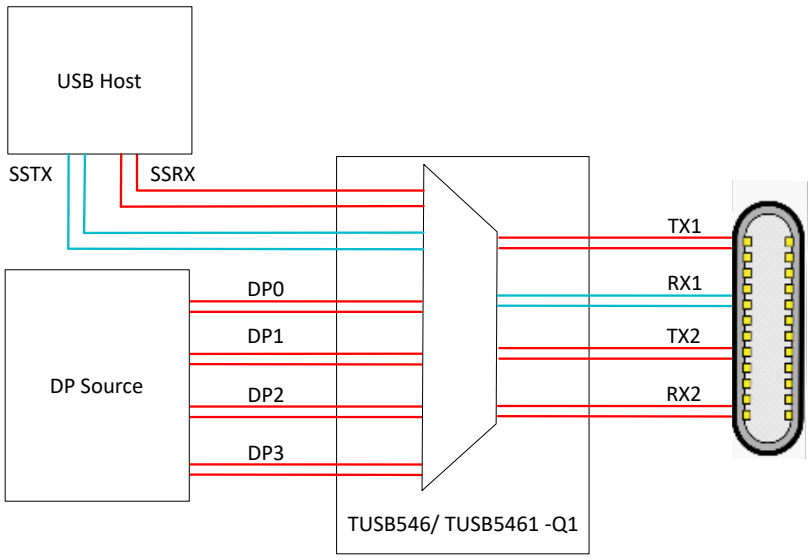

Figure 2-6. Typical DisplayPort Alt. Mode Application for TUSB546 and TUSB546-Q1

- **USB3.2 Gen2** (10Gbps)/ **DisplayPort 2.1** (10Gbps)
  - TUSB1044/ TUSB1044A

See description in **Standard USB Type-C Application** section.

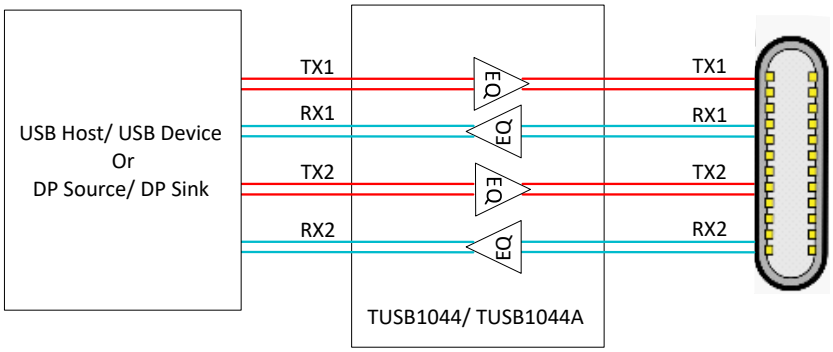

Figure 2-7. Typical DisplayPort Alt. Mode Application for TUSB1044 and TUSB1044A

- – TUSB1046/ TUSB1046A

The TUSB1046 and TUSB1046 are both designed to be cross bar MUXs allowing for standard USB Type-C communication as well as DisplayPort Alt. Mode. These parts are designed for DisplayPort source operation. The inputs for these parts are the 4-lanes of DisplayPort and the SSTX and SSRX pairs for USB communication. These 6 signals are routed to the 4 high speed lanes of the USB Type-C connector.

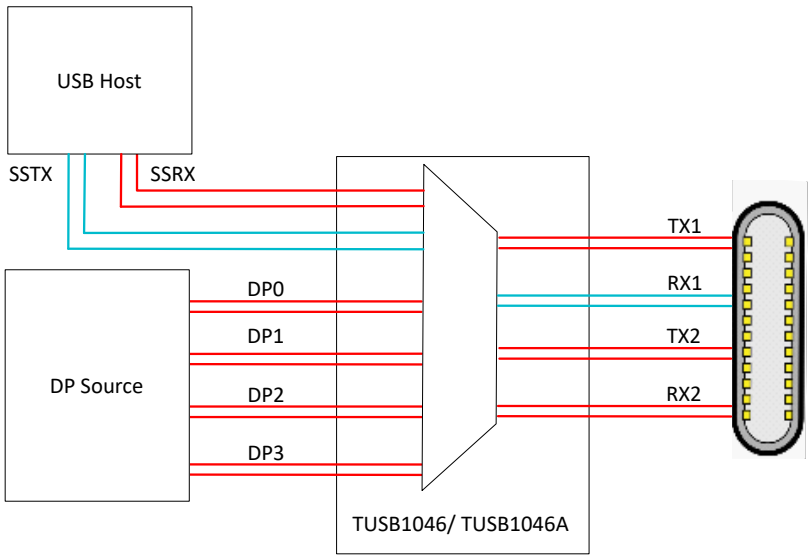

Figure 2-8. Typical DisplayPort Alt. Mode Application for TUSB1046 and TUSB1046A

- – TUSB1146/ TUSB1146-Q1

The TUSB1146 and the automotive counterpart TUSB1146-Q1 are designed to be crossbar MUXs allowing for standard USB Type-C communication as well as DisplayPort Alt. Mode. These parts are designed for DisplayPort source operation. The inputs for these parts are the 4-lanes of DisplayPort and the SSTX & SSRX pairs for USB communication. These 6 signals are routed to the 4 high speed lanes of the USB Type-C connector. These parts also have the additional functionality of adaptive equalization which allows for automatic equalization tuning on the USB Type-C connector side, making compliance testing much easier to pass.

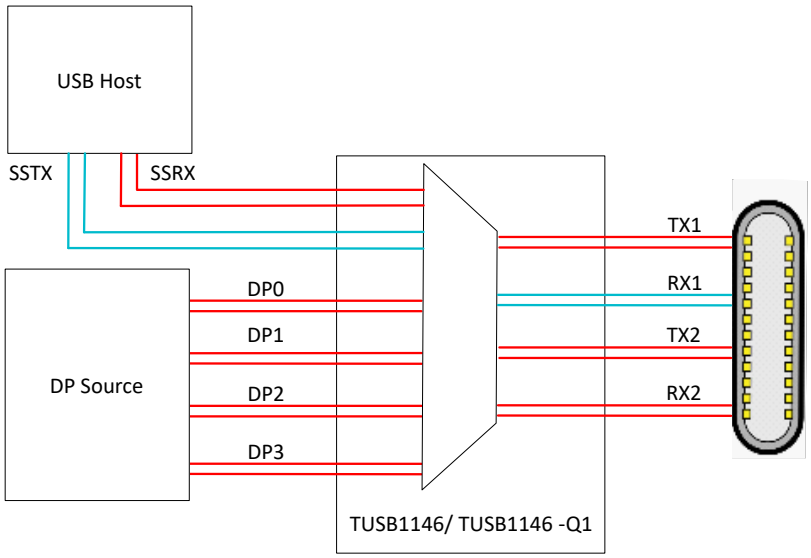

Figure 2-9. Typical DisplayPort Alt. Mode Application for TUSB1146 and TUSB1146A

DisplayPort Alt. Mode Sink Applications:

- **USB 3.2 Gen 1** (5Gbps)/ **DisplayPort 1.4** (8.1Gbps)
  - – TUSB564/ TUSB564-Q1

The TUSB564 and the automotive counterpart TUSB564-Q1 are both designed to be cross bar MUXs allowing for standard USB Type-C communication as well as DisplayPort Alt. Mode. These parts are designed for DisplayPort sink operation. The inputs for these parts are the 4 high speed lanes of the USB Type-C connector, and the outputs are the 4-lanes of DisplayPort and the SSTX & SSRX pairs for USB communication.

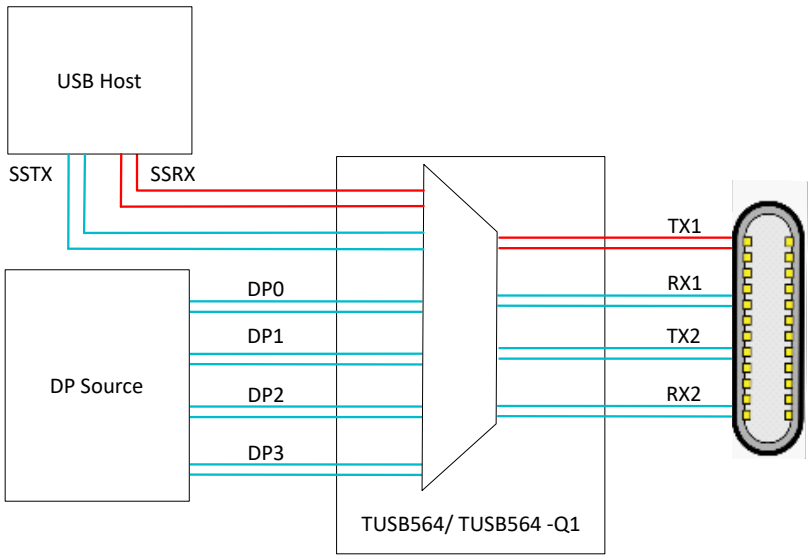

Figure 2-10. Typical DisplayPort Alt. Mode Application for TUSB564 and TUSB564-Q1

- **USB3.2 Gen2** (10Gbps)/ **DisplayPort 2.1** (10Gbps)
  - TUSB1064 and TUSB1064-Q1

The TUSB1064 and the automotive counterpart TUSB1064-Q1 are both designed to be cross bar MUXs allowing for standard USB Type-C communication as well as DisplayPort Alt. Mode. These parts are designed for DisplayPort sink operation. The inputs for these parts are the 4 high speed lanes of the USB Type-C connector, and the outputs are the 4-lanes of DisplayPort and the SSTX & SSRX pairs for USB communication.

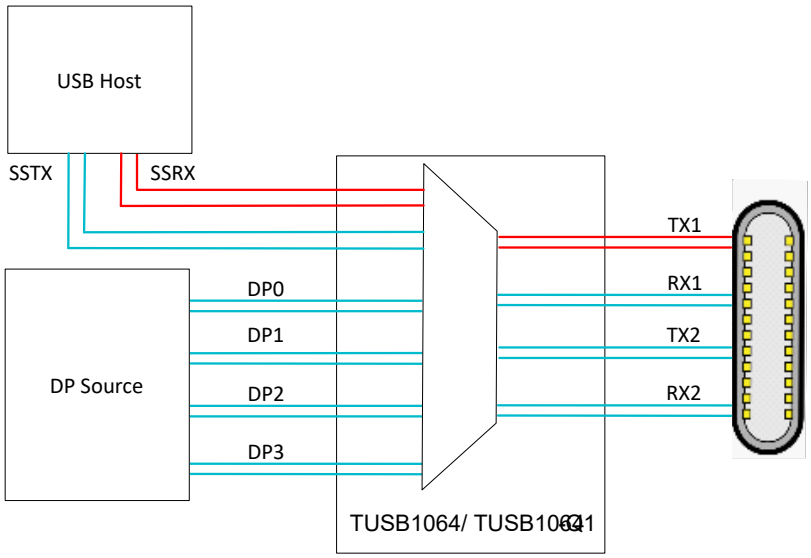

Figure 2-11. Typical DisplayPort Alt. Mode Application for TUSB1064 and TUSB1064-Q1

2.3 DisplayPort Only Applications

The parts covered in this section cannot support any USB communication and can only be used in the Full DP mode of the USB Type-C DisplayPort Alt. Mode.

- **DisplayPort 1.4** (8.1Gbps)
  - TDP142/ TDP142-Q1

The TDP142 and the automotive counterpart, TDP142-Q1, are both linear DisplayPort redrivers. We can use this redriver to connect to all 4 high speed data lanes of the USB Type-C connector. This configuration allows for DisplayPort Alt. Mode in full DP mode.

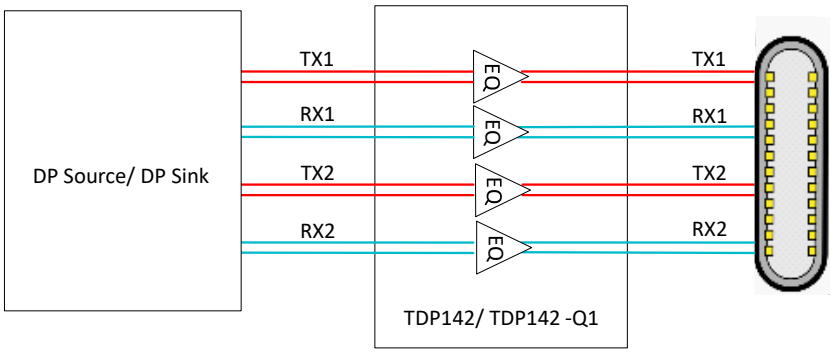

Figure 2-12. Typical USB Type-C Application for TDP142 and TDP142-Q1

- **DisplayPort 2.1** (20Gbps)
  - TDP2044

The TDP2044 is a linear DisplayPort redriver. We can use this redriver to connect to all 4 high speed data lanes of the USB Type-C connector. This configuration allows for DisplayPort Alt. Mode in full DP mode.

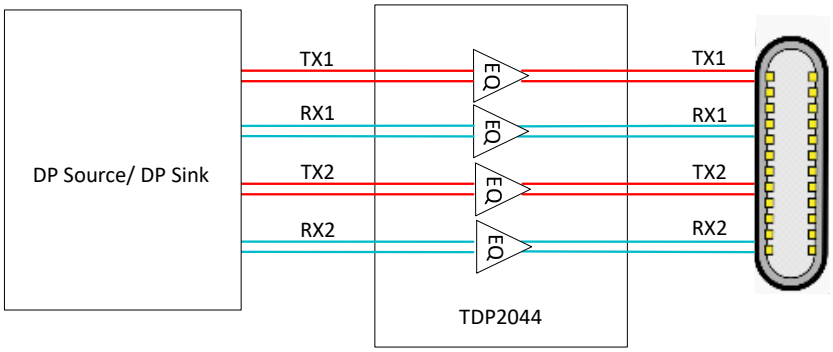

Figure 2-13. Typical USB Type-C Application for TDP2044

3 Summary

Texas Instruments provides a variety of designs that integrate in the USB Type-C space. Please use this application note to guide your part selection based off of the end application.

4 References

1. Texas Instruments, *An Engineer's Guide to USB Type-C®*
2. Vesa, *Why DisplayPort: Get the DisplayPort Overview Presentations*

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