Application Note

TUSB564-Q1 Cable Length Analysis for USB and DisplayPort Data Over USB-C

TEXAS INSTRUMENTS

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ABSTRACT

The TUSB564-Q1 is a linear redriver and MUX design that supports USB Type-C® port signal conditioning at a data rate up to 5Gbps for USB and 8.1Gbps for DisplayPort™ (DP) protocols. TUSB564-Q1 is intended to be used in USB Type-C® sink-side applications that require a DisplayPort Alternate mode MUX to separate USB and video data. This application note shows the cable length extensions allowed by adding the TUSB564-Q1 into long channel applications.

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1 Introduction

This application note shows the cable length extensions allowed by using the TUSB564-Q1 redriver or MUX in a USB Type-C signal path.

USB signal quality measurements are taken on systems of differing channel lengths with the TUSB564-Q1 in the signal path. The data from these measurements demonstrate how a redriver or MUX like the TUSB564-Q1 can drive USB and DP signals across long cables.

For device (sink) applications, the TUSB564-Q1 enables a USB or DP compliant system to pass both USB or DP transmitter electrical compliance and USB receiver jitter tolerance tests.

2 USB Type-C With DisplayPort Alt-Mode

2.1 USB Type-C Basics

USB Type-C is an interface designed to transfer data, power, and video over a single connection. The versatility of a USB-C port can simplify the transfer of information between a source (host) and a sink (device). The most basic USB-C ports can pass USB2.0 data and 4.5 to 15W of power.

2.2 Adding USB3

When passing higher data rates through a USB-C port, the TX and RX SuperSpeed lines need to be used. USB-C ports have four differential channels dedicated to high speed data transfer. These channels are TX1, RX1, TX2, and RX2.

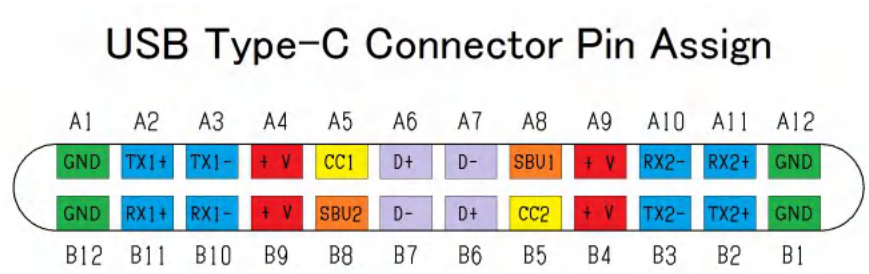

Figure 2-1. USB Type-C Pinout

A common use for the SuperSpeed lines is to pass USB3 data over one pair of TX and RX channels. When a USB-C connection is established, the cable orientation is used to select which pair of TX/RX channels ultimately pass data. TX1 and RX1 are used when the cable is not flipped, while TX2 and RX2 are used when the cable is flipped. These are referred to as the *normal orientation* and *flip orientation* respectively. A USB3 data MUX is required to select the right channel from the two orientations.

2.3 Adding DisplayPort Alt-mode

The SuperSpeed lines on a USB-C port can be re-purposed to pass video data as well as USB data. Passing DisplayPort data over a USB-C connection is known as DP alt-mode. DP alt-mode can support two lanes of DP and two lanes of USB simultaneously, or four lanes of dedicated DP operation. DP alt mode requires a specialized MUX to handle the split between USB and DisplayPort data lanes. The TUSB564-Q1 is one such MUX that can be used on the DisplayPort sink side of the USB-C connection.

3 USB 4-Meter System

As a starting point for testing, two 2 meter USB-C cables are used in the signal path. One cable is placed before the TUSB564-Q1, and the second cable is placed after the TUSB564-Q1. The bench board adds additional loss with the short pre and post-channel FR4 trace. A USB-C host is connected upstream, and measurements are taken at the end of the downstream USB cable.

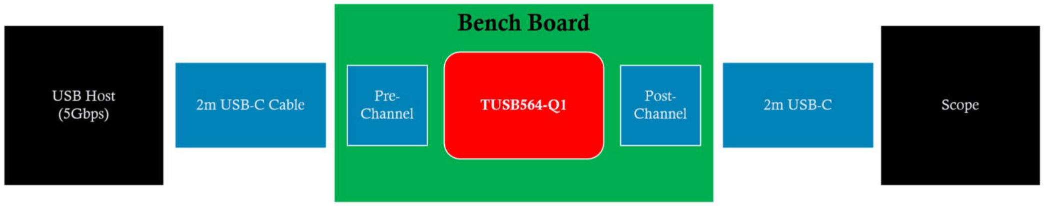

Figure 3-1. USB 4-Meter System Block Diagram

For this test, the equalization setting used on the TUSB564-Q1 is setting #3. This adds 2.2dB of gain on the downstream facing port. Figure 3-2 shows the results of a 5G far end USB compliance test taken at the downstream end of this system.

Test Name	Actual Value	Margin	Pass Limits
5G Random Jitter (CTLE ON)	640 fs		Information Only
5G Far End Maximum Deterministic Jitter (CTLE ON)	27.140 ps	68.4 %	VALUE <= 86.000 ps
5G Far End Total Jitter at BER-12 (CTLE ON)	36.150 ps	72.6 %	VALUE <= 132.000 ps
5G Far End Template Test (CTLE ON)	0.000	100.0 %	VALUE = 0.000
5G Far End Differential Output Voltage (CTLE ON)	249.6 mV	13.6 %	100.0 mV <= VALUE <= 1.2000 V

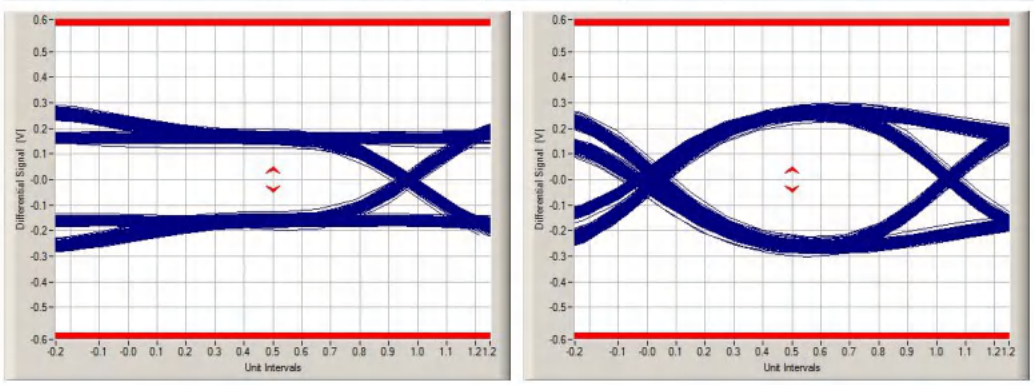

Figure 3-2. USB 4-Meter System Test Results

The 5G USB compliance test is able to pass with no issues in this configuration. The eye diagram shows a defined eye opening and transition area.

4 USB 9-Meter System

To simulate a long cable USB system, two 4.5-meter USB-C cables are used in the signal path. One cable is placed before the TUSB564-Q1, and the second cable is placed after the TUSB564-Q1. The bench board adds additional loss with it's short pre and post-channel FR4 trace. A USB-C host is connected upstream, and measurements are taken at the end of the downstream USB cable.

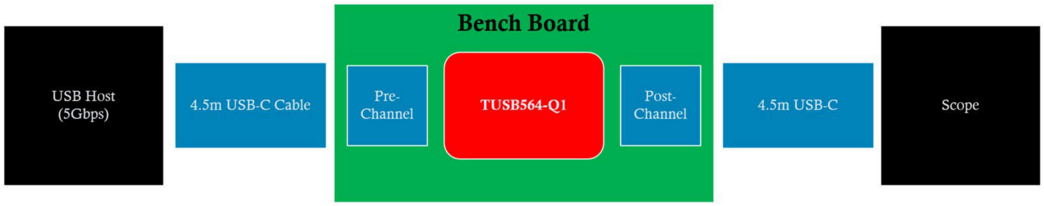

Figure 4-1. USB 9-Meter System Block Diagram

For this test, the equalization setting used on the TUSB564-Q1 is setting #9. This adds 7.0dB of gain on the downstream facing port. Figure 4-2 shows the results of a 5G far end USB compliance test taken at the downstream end of this system.

Test Name	Actual Value	Margin	Pass Limits
5G Random Jitter (CTLE ON)	775 fs		Information Only
5G Far End Maximum Deterministic Jitter (CTLE ON)	42.812 ps	50.2 %	VALUE <= 86.000 ps
5G Far End Total Jitter at BER-12 (CTLE ON)	53.709 ps	59.3 %	VALUE <= 132.000 ps
5G Far End Template Test (CTLE ON)	0.000	100.0 %	VALUE = 0.000
5G Far End Differential Output Voltage (CTLE ON)	134.9 mV	3.2 %	100.0 mV <= VALUE <= 1.2000 V

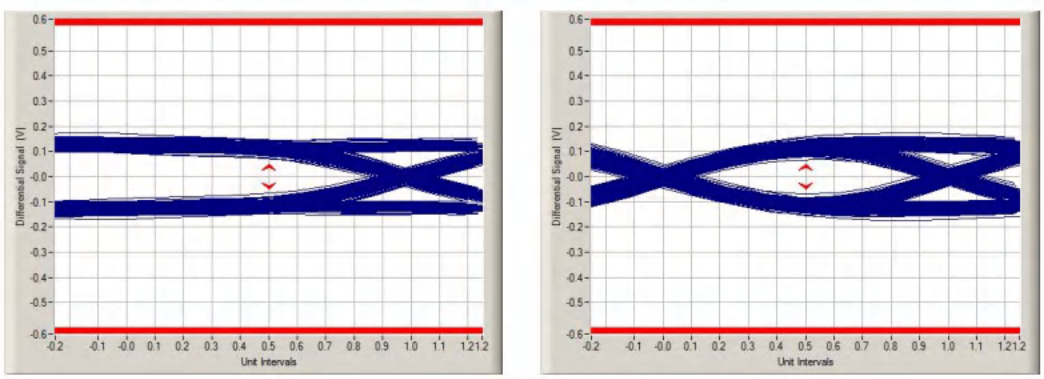

Figure 4-2. USB 9-Meter System Test Results

Once again, the 5G USB compliance test is able to pass in this configuration with no issues. The equalization from the TUSB564-Q1 is countering the added insertion loss from two 4.5-meter cables. This allows the eye to keep a defined shape as shown in the diagrams above. One thing to note is that there is a decrease in the differential output voltage between this test and the 4-meter system test. This is expected, as the TUSB564-Q1 is a linear re-driver which cannot alter the output swing of a signal. Tuning the output swing of the host can help to counter this if the application is expected to be long channel.

5 DisplayPort 4.6-Meter System

To begin testing an example DisplayPort system, one 4.6-meter DisplayPort cable is used in the signal path. This cable is placed before the TUSB564-Q1, and a oscilloscope is connected directly downstream from the TUSB564-Q1 bench board. The bench board adds additional loss with the short pre and post-channel FR4 trace. A DisplayPort source is connected upstream, and measurements are taken on the downstream oscilloscope.

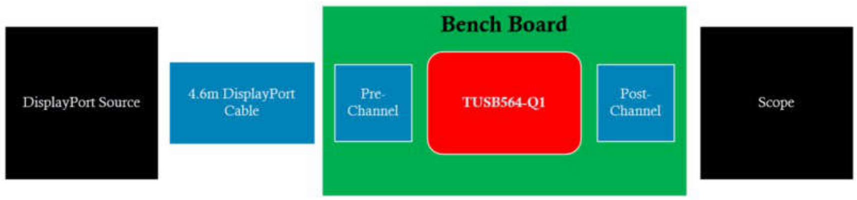

Figure 5-1. DisplayPort 4.6-Meter System Block Diagram

This test is run at both 5.4Gbps and 8.1Gbps to show the effect of data rate on the signal quality. A higher data rate signal is more sensitive to insertion loss and requires more equalization to recover after a lossy channel.

5.1 5.4Gbps

The equalization setting used on the TUSB564-Q1 is setting #0. This adds 1.0dB of gain on the DisplayPort lanes routing through the device. Following are the results of a 5.4Gbps DisplayPort compliance test taken at the downstream end of this system.

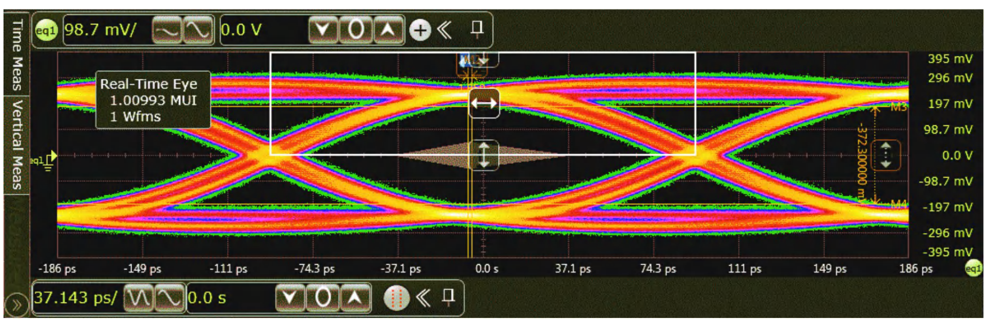

Figure 5-2. DisplayPort 4.6-Meter System Test Results at 5.4Gbps Lane 0

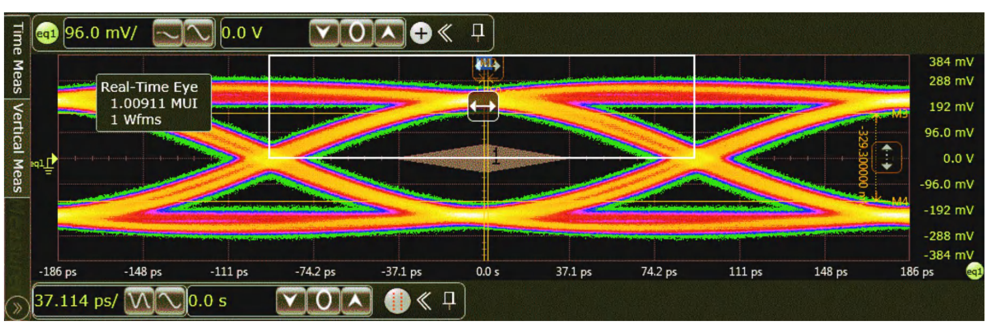

Figure 5-3. DisplayPort 4.6-Meter System Test Results at 5.4Gbps Lane 1

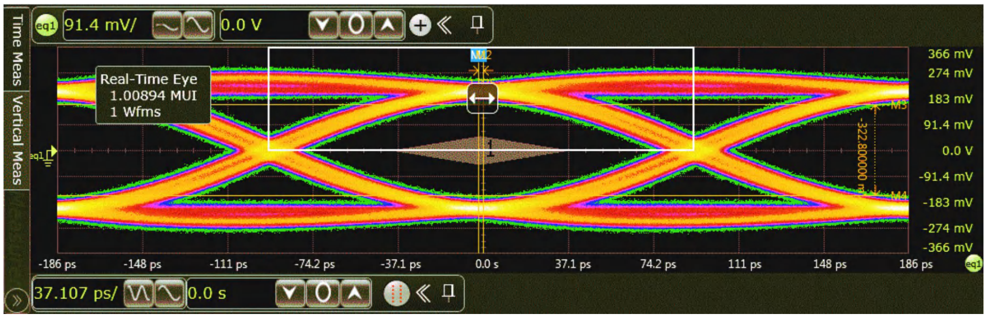

Figure 5-4. DisplayPort 4.6-Meter System Test Results at 5.4Gbps Lane 2

Figure 5-5. DisplayPort 4.6-Meter System Test Results at 5.4Gbps Lane 3

The compliance test is able to pass in this configuration with no issues. The eye diagram shows a defined eye opening and transition area.

5.2 8.1Gbps

The equalization setting used on the TUSB564-Q1 is setting #13. This adds 13.0dB of gain on the DisplayPort lanes routing through the device. Following are the results of an 8.1Gbps DisplayPort compliance test taken at the downstream end of this system.

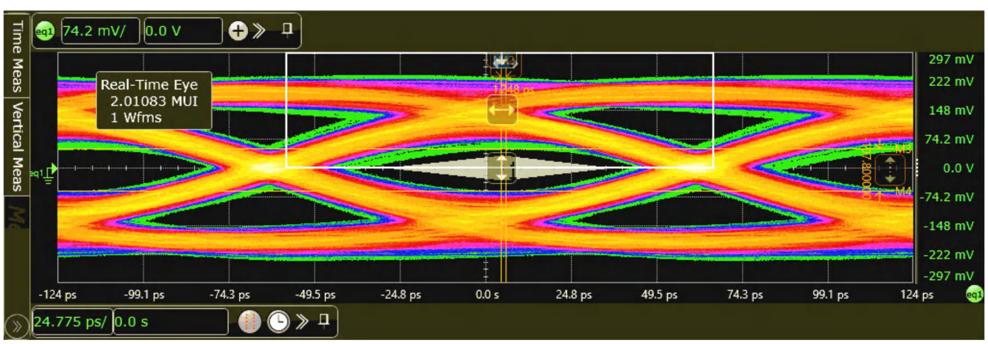

Figure 5-6. DisplayPort 4.6-Meter System Test Results at 8.1Gbps Lane 0

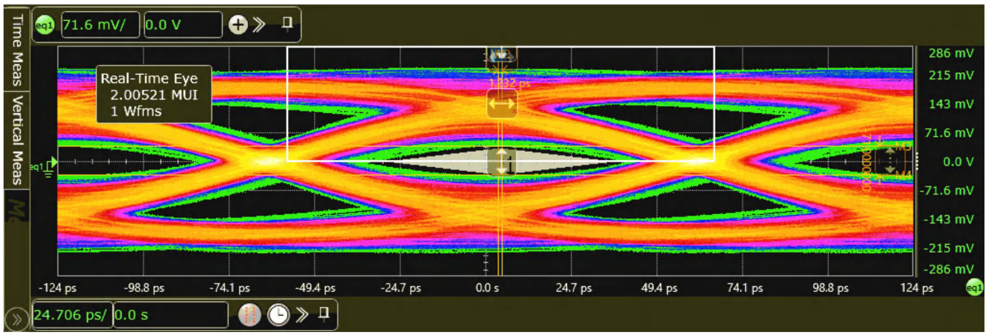

Figure 5-7. DisplayPort 4.6-Meter System Test Results at 8.1Gbps Lane 1

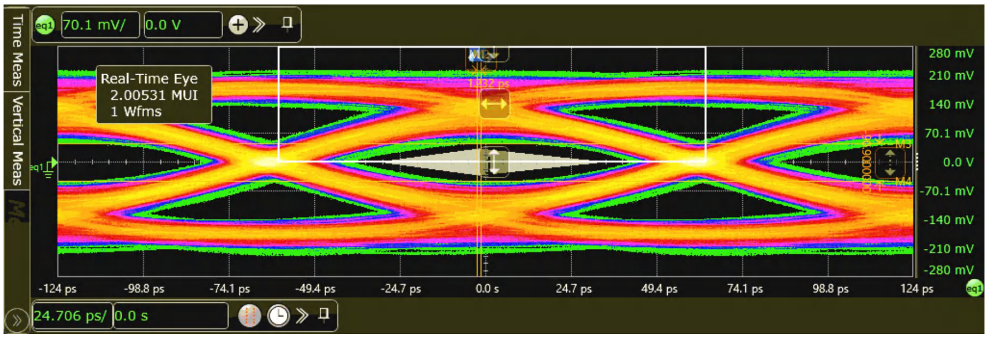

Figure 5-8. DisplayPort 4.6-Meter System Test Results at 8.1Gbps Lane 2

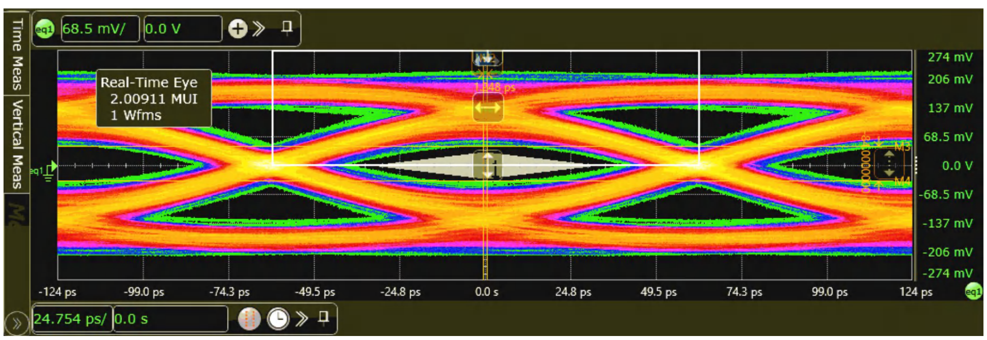

Figure 5-9. DisplayPort 4.6-Meter System Test Results at 8.1Gbps Lane 3

The compliance test is able to pass in this configuration with no issues. The eye diagram shows a defined eye opening and transition area. As seen from the eye diagram, attenuation is greater at 8.1Gbps than at 5.4Gbps, which is expected. This is the reason a greater equalization value is needed in this test compared with the previous 5.4Gbps DisplayPort test.

6 DisplayPort 9.2-Meter System

To simulate a long cable DisplayPort system, two 4.6-meter DisplayPort cables are used in the signal path. One cable is placed before the TUSB564-Q1, and the second cable is placed after the TUSB564-Q1. The bench board adds additional loss with it's short pre and post-channel FR4 trace. A DisplayPort source is connected upstream, and measurements are taken at the end of the downstream DisplayPort cable.

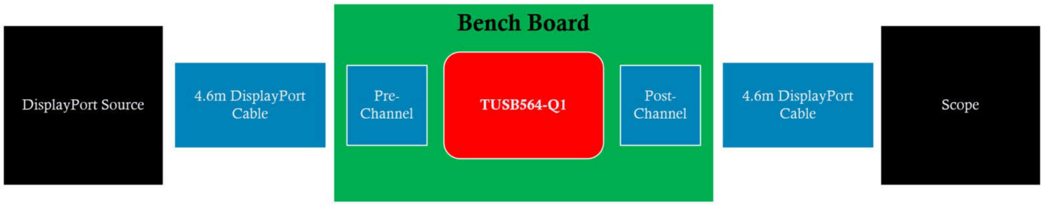

Figure 6-1. DisplayPort 9.2-Meter System Block Diagram

For this test, a 5.4Gbps DisplayPort signal is used. The equalization on the TUSB564-Q1 is set to #9. This adds 11.0dB of gain on the DisplayPort lanes routing through the device. Following are the results of a 5.4Gbps DisplayPort compliance test taken at the downstream end of this system.

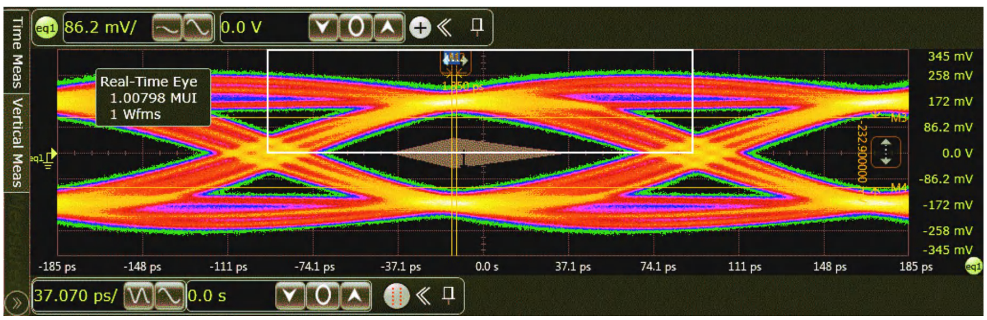

Figure 6-2. DisplayPort 9.2-Meter System Test Results Lane 0

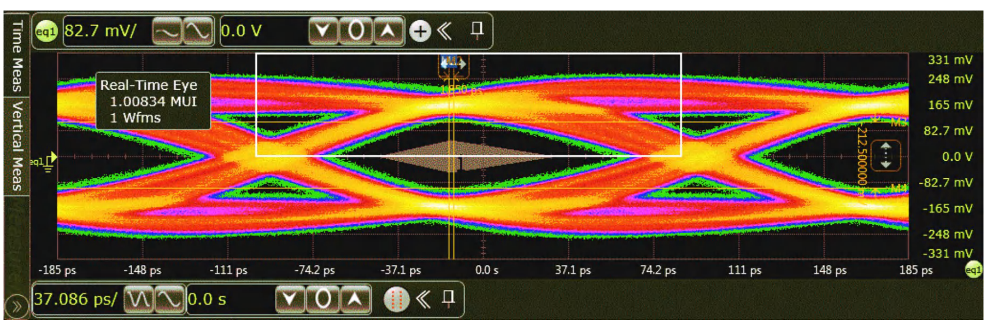

Figure 6-3. DisplayPort 9.2-Meter System Test Results Lane 1

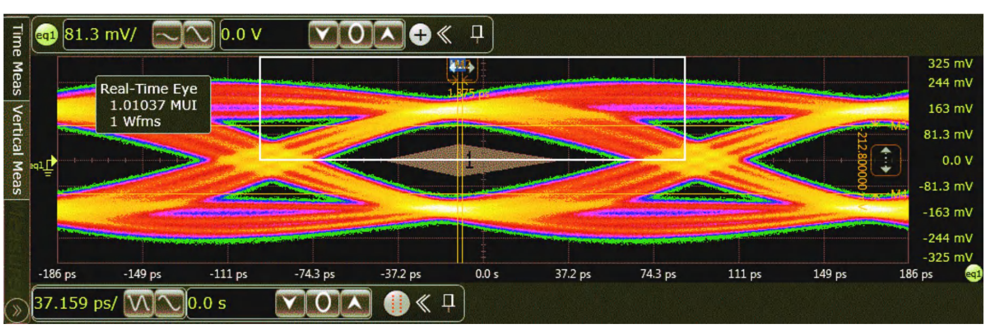

Figure 6-4. DisplayPort 9.2-Meter System Test Results Lane 2

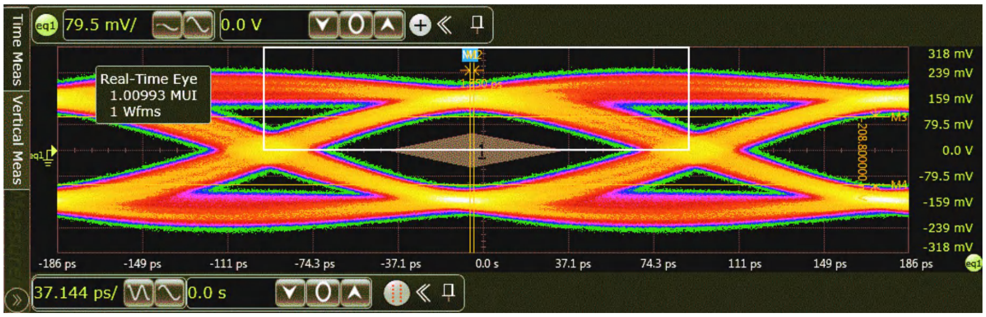

Figure 6-5. DisplayPort 9.2-Meter System Test Results Lane 3

The compliance test is able to pass in this configuration with no issues. The eye diagram shows a defined eye opening and transition area. At 5.4Gbps, the TUSB564-Q1 has enough compensation to drive a DisplayPort signal through 9.2 meters of cable with margin to spare.

7 Summary

The TUSB564-Q1 is designed to recover USB and DisplayPort signals that travel over long cable lengths or lossy channels. This is beneficial for applications which require high signal integrity across long distances. In the test systems used for this application note, the TUSB564-Q1 allows USB signals to pass over 9 meter cable lengths and DisplayPort signals to pass over 9.2 meter cable lengths. This device can be used in USB-C Alt mode systems to prevent attenuation and signal quality issues that stem from insertion loss. This document is intended to show the system-level impact of the TUSB564-Q1 when driving signals over a long channel.

8 References

- Texas Instruments, *TUSB564-Q1 Automotive USB Type-C® DP Alt Mode 8.1Gbps Sink-Side Linear Redriver Crosspoint Switch*, data sheet.

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