Application Note

TUSB521-Q1 and TUSB1021-Q1 Configuration Guidelines

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ABSTRACT

The TUSB521-Q1 and TUSB1021-Q1 are automotive USB3.1 redrivers capable of multiplexing USB3 signals at data rates of 5Gbps and 10Gbps in respect to the devices as the redrivers are listed. In particular, these devices excel in applications which use a USB Type-C interface for communicating between host and device. USB signal amplitudes attenuate through a typical FR4 channel, placing limitations on system trace length at 5Gbps, 10Gbps, and even higher data rates. A longer channel with large attenuation results in signal integrity issues at a USB receiver. This document includes how using the TUSB521-Q1 and the TUSB1021-Q1 can be used at 5Gbps and 10Gbps respectively to help improve these signals to make sure the signals maintain integrity while still being able to pass standard compliance testing.

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Trademarks

1 Introduction

The TUSB521-Q1 and TUSB1021-Q1 are automotive USB3.1 redrivers capable of multiplexing USB3 signals at data rates of 5Gbps and 10Gbps in respect to the devices as the redrivers are listed. In particular, these devices excel in applications which use a USB Type-C interface for communicating between host and device. USB signal amplitudes attenuate through a typical FR4 channel, placing limitations on system trace length at 5Gbps, 10Gbps, and even higher data rates. A longer channel with large attenuation results in signal integrity issues at a USB receiver. The TUSB521-Q1 and TUSB1021-Q1 are used to eliminate or minimize the attenuation effects of the channel to produce a compatible eye at the device receiver. Attenuation is minimized by applying receiver equalization to compensate for cable and board loss due to intersymbol interference (ISI) and insertion loss. The TUSB521-Q1 and TUSB1021-Q1 are configurable with 16 receiver equalization settings for USB signals.

2 TUSB521-Q1 Equalization Selection

The TUSB521-Q1 used in a device application enables the system to pass USB 3.1 Gen 1 transmitter and receiver compliance. The TUSB521-Q1 recovers incoming data by applying equalization that compensates for channel loss, typical FR4 channel loss is provided in Table 2-1. The amount of equalization the TUSB521-Q1 is configured to provide to the signal needs to be set according to the amount of loss before the signal enters the device, also known as the pre-channel. The EQ settings for the TX and RX lanes of the USB3.1 signal can be set independently either through pin-strap or through I2C. For pin-strap, The equalization selection is configured through the EQ and SSEQ pins. The USB equalization values available for the TUSB521-Q1 are listed in Table 2-2.

Table 2-1. Example FR4 Trace Loss At 5GBps

FR4 PCB Trace Length (Inches)	Loss at 2.5GHz (dB)
1	0.5
2	1
3	1.5
4	2
5	2.5
6	2.9
7	3.4
8	3.9
9	4.4
10	4.9
11	5.4
12	5.9
13	6.4
14	6.9

Table 2-2. TUSB521-Q1 Receiver Equalization GPIO Control

EQUALIZATION SETTING #	RX1 and RX2 PORTS			SSTX PORT		
	EQ1 PIN LEVEL	EQ0 PIN LEVEL	EQ GAIN AT 2.5GHz (dB)	SSEQ1 PIN LEVEL	SSEQ0 PIN LEVEL	EQ GAIN AT 2.5GHz (dB)
0	0	0	–0.7	0	0	–0.9
1	0	R	1.8	0	R	0.2
2	0	F	2.7	0	F	1.1
3	0	1	3.7	0	1	2.2
4	R	0	4.6	R	0	3.0
5	R	R	5.5	R	R	4.0
6	R	F	6.3	R	F	4.8
7	R	1	7.0	R	1	5.6
8	F	0	7.8	F	0	6.4
9	F	R	8.5	F	R	7.0
10	F	F	9.1	F	F	7.6
11	F	1	9.7	F	1	8.2
12	1	0	10.1	1	0	8.7
13	1	R	10.7	1	R	9.2
14	1	F	11.1	1	F	9.7
15	1	1	11.6	1	1	10.2

3 TUSB1021-Q1 Equalization Selection

For the TUSB1021-Q1, the same means of selecting which EQ settings to use still applies, with differences being in how much loss to expect per inch at 10Gbps with USB3.1 Gen 2 in Table 3-1, and how much loss the TUSB1021-Q1 can compensate for with the EQ settings in Table 3-2.

Table 3-1. Example FR4 Trace Loss at 10Gbps

FR4 PCB Trace Length (Inches)	Loss at 5GHz (dB)
1	0.9
2	1.7
3	2.6
4	3.5
5	4.3
6	5.2
7	6.1
8	7
9	7.8
10	8.7
11	9.6
12	10.4
13	11.3
14	12.2

Table 3-2. TUSB1021-Q1 Receiver Equalization GPIO Control

EQUALIZATION SETTING #	RX1 and RX2 PORTS			SSTX PORT		
	EQ1 PIN LEVEL	EQ0 PIN LEVEL	EQ GAIN AT 5GHz (dB)	SSEQ1 PIN LEVEL	SSEQ0 PIN LEVEL	EQ GAIN AT 5GHz (dB)
0	0	0	0.4	0	0	–2.4
1	0	R	2.6	0	R	–0.2
2	0	F	4.2	0	F	1.3
3	0	1	5.7	0	1	2.8
4	R	0	6.7	R	0	3.8
5	R	R	7.9	R	R	4.9
6	R	F	8.7	R	F	5.8
7	R	1	9.5	R	1	6.6
8	F	0	10.2	F	0	7.3
9	F	R	10.9	F	R	7.9
10	F	F	11.4	F	F	8.4
11	F	1	11.9	F	1	8.9
12	1	0	12.2	1	0	9.3
13	1	R	12.6	1	R	9.7
14	1	F	12.9	1	F	10.0
15	1	1	13.3	1	1	10.5

4 TUSB521-Q1 Placement Example

Following the layout guidelines listed in this document enables the TUSB521-Q1 to recover a signal from a USB device up to a typical 14-inch FR4 trace. Keep in mind that the distance after the redriver to the USB-C connector, also known as the post-channel length, needs to be a maximum of 5 inches. These recommended maximum trace lengths assumes the device provides -3dB of de-emphasis and has a compliant receiver that recovers the 20dB loss budgeted by the USBIF for a Type-C cable and the host or device. By adjusting the equalization, de-emphasis, and VOD settings of a device, it is possible to extend the maximum trace lengths available in a system for extended usage. Vice verse, if the signal cannot be recovered with the 20dB loss budget given by the USBIF, then changes are needed to be made to meet this requirement, such as changing placement of the device or adjusting the settings of the device. Any of these changes to the device need to be made only after discussing with the device manufacturer to determine the correct settings.

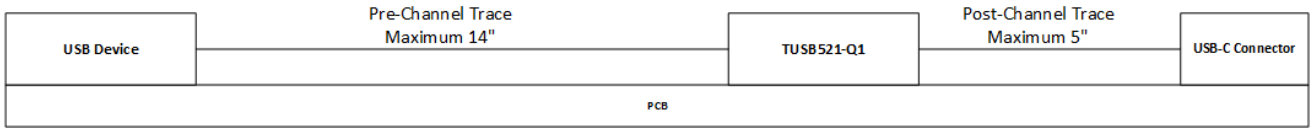

Figure 4-1. TUSB521-Q1 Placement Design Example

5 TUSB521-Q1 Configuration Example

Figure 5-1 provides an example configuration of a device system using a USB3.1 Gen 1 device operating at 5Gbps with the TUSB521-Q1.

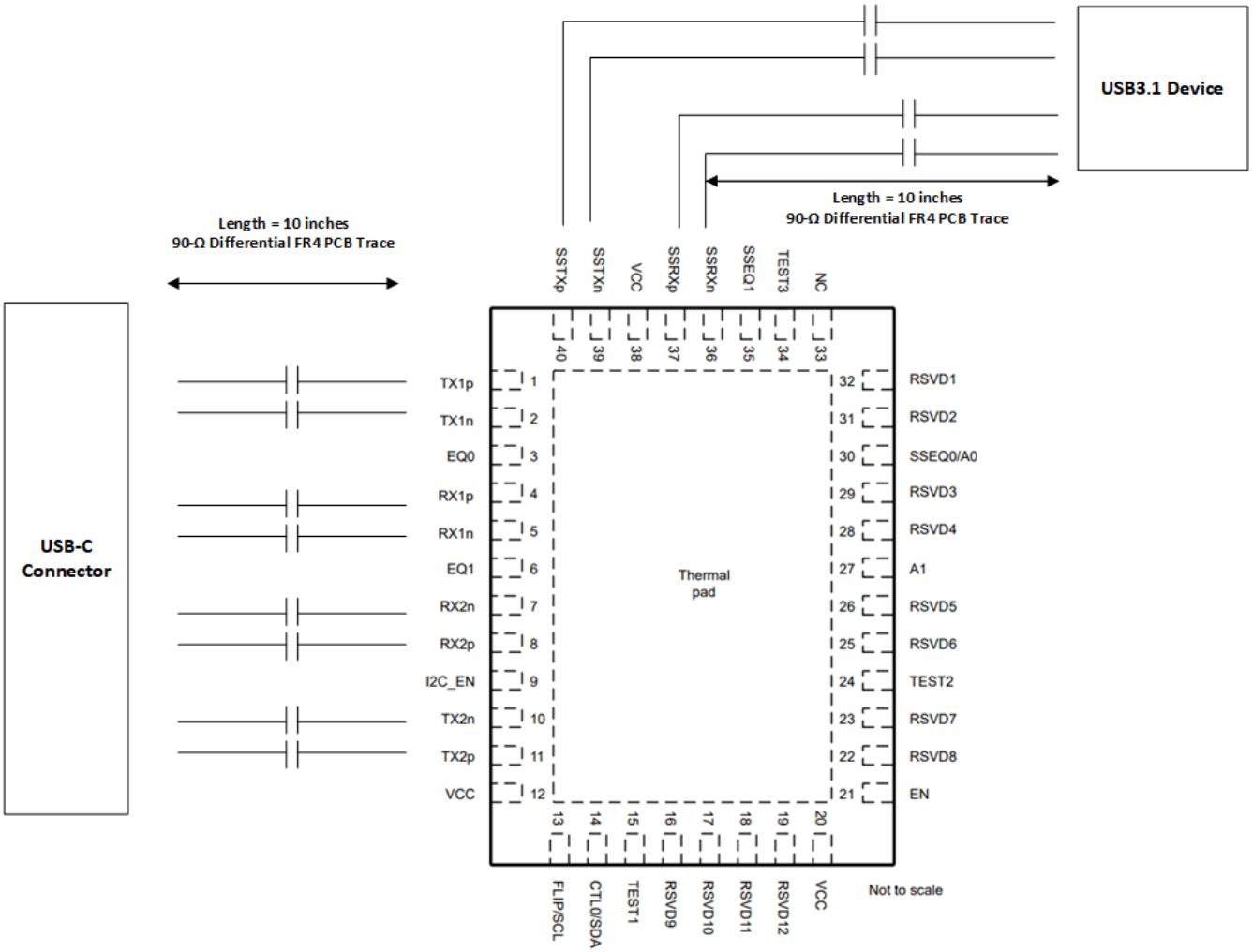

Figure 5-1. TUSB521-Q1 Example Implementation

Using the given trace lengths in this example, the method to select the equalization values for SSTX and RX1/2 is to select the closest EQ gain available to match the trace loss and additional loss through the connector, components, and device package:

- USB device to TUSB521-Q1 SSTX = 10 inches (-4.9dB) + typical loss in Device package + capacitor (-1.5dB) = total loss of -6.4dB. TUSB521-Q1 SSEQ setting used = Setting #8 (6.4dB).
- Type-C connector to TUSB521-Q1 RX1/RX2 = 5 inches (-2.5dB) + typical connector loss + component (-2dB) = total loss of -4.5dB. TUSB521-Q1 EQ setting used = Setting #4 (4.6dB).

Please note that other factors such as the layout quality, device transmitter and receiver quality require adjusting the EQ settings for best performance. Use the above method to select the initial configuration values based on system board trace lengths.

6 Layout Guidelines

Use the following layout guidelines in routing the high-speed USB signals to and from the TUSB521-Q1 and TUSB1021-Q1:

- Route the RXP/N and TXP/N pairs with a controlled 90Ω differential impedance (±15%).
- Keep differential pairs away from other high-speed signals.
- Keep intra-pair routing to within 2 mils.
- Locate the differential pair length matching near the mismatch.
- Separate each pair by at least 3 times the signal trace width.
- Minimize the use of bends in differential traces. When bends are used, make the number of left and right bends as equal as possible and the angle of the bend is ≥135º. Bending the trace this way minimizes any length mismatch caused by the bends and minimize the impact bends have on the EMI.
- Route all differential pairs on the same layer.
- Minimize the number of vias to two or less.
- Keep differential traces on layers adjacent to a ground plane.
- Do not route differential pairs over any split plane.
- If using a through-hole connector, route the high-speed signals on opposite side of the connector so that the connector pin does not create a stub in the transmission line.

6.1 Ground Stitching

The entirety of any high-speed signal trace must maintain the same GND reference plane from origination to termination. If the same GND reference plane is not maintained, via-stitch the GND planes together to establish continuous grounding and uniform impedance. Place these stitching vias symmetrically within 200-mils (center-to-center, closer is better) of the signal transition vias. See Figure 6-1 for an example of GND stitching via.

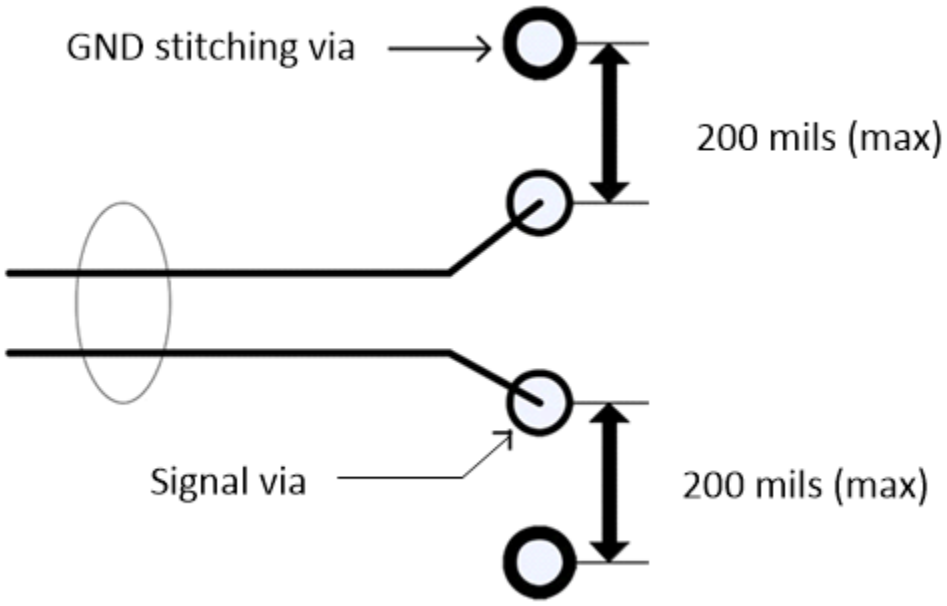

Figure 6-1. Ground Stitching Via Example

6.2 AC Coupling and Resistor Placement

When placing AC-Coupling capacitors, the maximum component size is 0402 . During layout, on the host or device channel, place the AC-Coupling capacitors equidistant to the device and the TUSB521-Q1/TUSB1021-Q1. On the connector to TUSB521-Q1/TUSB1021-Q1 channel, place the AC Coupling caps close to the TUSB521-Q1/TUSB1021-Q1 with symmetrical placement to establish top signal quality and to minimize reflections. Place the optional pull-down resistors so that the pad of the resistor shares the high-speed trace to minimize the presence of a stub. See Figure 6-2 for an example of the optimal AC Coupling capacitor layout symmetry.

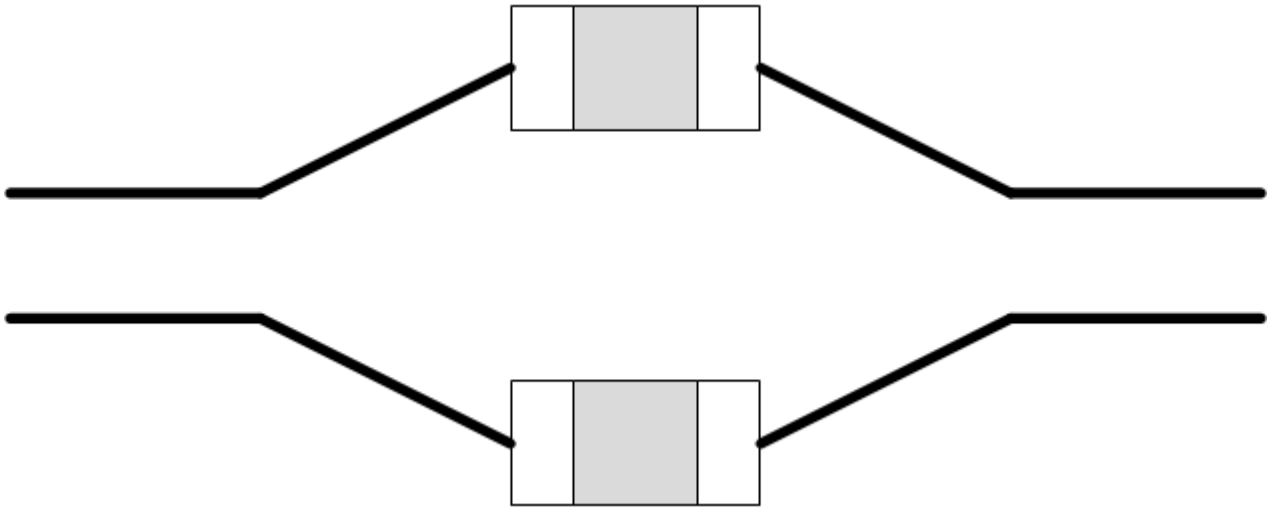

Figure 6-2. AC Coupling Capacitor Layout Example

7 Summary

Due to the higher data rates of USB3 and USB3.1 Gen 2, this is crucial to properly integrate a redriver into a system to make sure that the related signals are properly boosted and do not violate any of the conditions outlined by the USBIF. By following the above configuration guidelines for the TUSB521-Q1 and the TUSB1021-Q1, this can be easy to make sure that the system is able to properly boost the USB3.1 data signals without causing any over or under-compensation. Additionally, by following the layout guidelines here that are typically associated with a USB3.1 trace, designing a system around the harsher requirements of a USB3.1 needs to be much easier to understand.

8 References

1. Texas Instruments, *TUSB521-Q1 Automotive USB Type-C® 5Gbps Linear Redriver MUX and DeMUX*, data sheet.
2. Texas Instruments, *TUSB1021-Q1 Automotive USB Type-C® 10Gbps Linear Redriver MUX and DeMUX*, data sheet.

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