Application Report
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Enabling HDMI over USB Type-C using TUSB546A-DCI

Mike Campbell

ABSTRACT

The TUSB546A-DCI is a linear redriver that supports both USB3.1 Gen1 and DisplayPort 1.4 over a USB Type-C interface. Even though the TUSB546A-DCI was released for the DisplayPort Alternate mode, the TUSB546A-DCI can also be used as a redriver in a USB-C HDMI Alternate mode source application. This document is intended to describe how to use the TUSB546A-DCI in a HDMI Type-C source application. The information in this document can also be applied to the TUSB546-DCI, TUSB1046-DCI, and TUSB1046A-DCI. For the remainder of the document TUSBx46 is used to describe all of these parts.

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1 Introduction

With the release of the HDMI Alt Mode specification in September of 2016, a need as arisen for a signal conditioner which can support HDMI 1.4 and HDMI 2.0 datarates. The TUSBx46 is a Type-C linear redriver mux intended for Type-C source applications. The TUSBx46 multiplexes between four DP1.4 lanes and USB3.1 to a single Type-C receptacle. Even though TUSBx46 was released to address the DisplayPort alternate mode application, it can also be used in HDMI Alternate mode. This document details the requirements for using the TUSBx46 in a HDMI Alternate Mode source.

2 DisplayPort Alt Mode and HDMI Alt Mode

The TUSBx46 was designed for the USB-C DisplayPort alternate mode specification but can also be used for USB-C HDMI Alternate mode. There are some key differences between these two standards which must be taken into account when using the TUSBx46. These differences are summarized in Table 1 through Table 3. The most important difference is the polarity inversion on TMDS_D0 and TMDS_CLK. Unlike USB3.1, neither HDMI nor DisplayPort support polarity inversion correction. For this reason, polarity inversion must be corrected at the TUSBx46 DP input. The proper connection is detailed in Table 4.

Table 1. Summary of Key Differences

Function or Feature	HDMI Alternate Mode	DisplayPort Alternate Mode
Polarity match Type-C receptacle pins	Inversion on TMDS_D0 and TMDS_CLK	Yes
HPD	Both USB PD and SBU1	Only over USB PD
SBU1 and SBU2 pins	HPD/HEAC- and HEAC+	AUXP and AUXN

Table 2. USB-C Receptacle DisplayPort Alternate Mode DFP_D Map

NORMAL ORIENTATION											
A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
GND	DP_D2P (TXP1)	DP_D2P (TXN1)	V_{BUS}	CC1	Dp1	Dn1	AUXP (SBU1)	V_{BUS}	DP_D0N (RXN2)	DP_D0P (RXP2)	GND
GND	DP_D3P (RXP1)	DP_D3P (RXN1)	V_{BUS}	AUXN (SBU2)	Dn2	Dp2	VCONN	V_{BUS}	DP_D1N (TXN2)	DP_D1P (TXP2)	GND
B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1

Table 3. USB-C Receptacle HDMI Alternate Mode Map

NORMAL ORIENTATION											
A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
GND	TMDS Data1+ (TXP1)	TMDS Data1- (TXN1)	V_{BUS}	CC1	Dp1	Dn1	HPD / HEAC- (SBU1)	V_{BUS}	TMDS Data0+ (RXN2)	TMDS Data0- (RXP2)	GND
GND	TMDS Data2+ (RXP1)	TMDS Data2- (RXN1)	V_{BUS}	Utility / HEAC+ (SBU2)	Dn2	Dp2	VCONN	V_{BUS}	TMDS Clock+ (TXN2)	TMDS Clock- (TXP2)	GND
B12	B11	B10	B9	B8	B7	B6	B5	B4	B3	B2	B1

3 HDMI TX to the TUSBx46 DisplayPort Input

The HDMI 1.4b and HDMI2.0 standards define a DC-coupled 3.3 V common mode interface while DisplayPort standard defines an AC-coupled interface. Because TUSBx46 implements a DisplayPort receiver, the TUSBx46 DP[3:0] pins must be AC-coupled to the HDMI transmitter as depicted in Figure 1.

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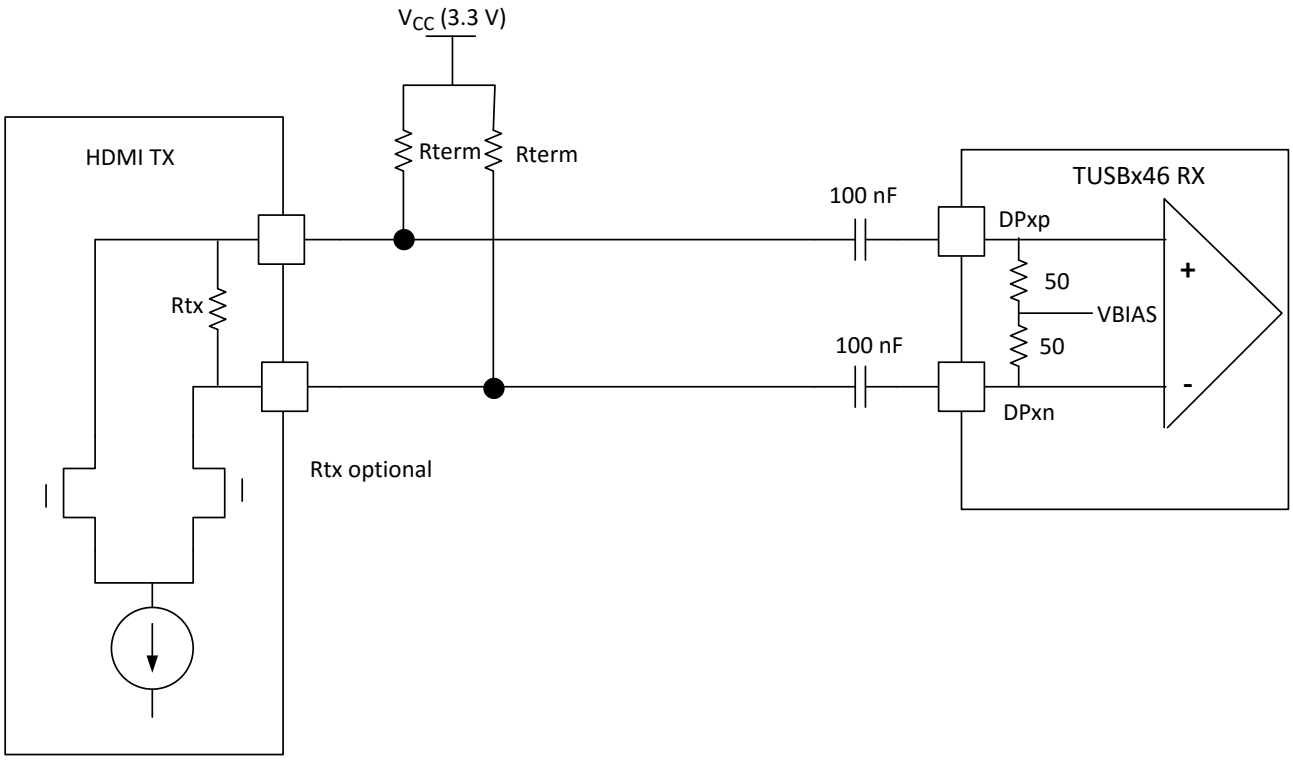

Figure 1. HDMI TX to TUSBx46 DP AC-coupled Receiver

The external Rterm along with TUSBx46 internal termination produces double termination and therefore will reduce the signal into TUSBx46 input. With TUSBx46 being a linear redriver, the reduced input swing is propagated to the USB-C receptacle. A Rterm value of 50-Ω works with all HDMI TX, but also cuts in half the signal into TUSBx46. If 50-Ω is used, then HDMI transmitter's voltage swing must be increased to compensate for the double termination. A larger Rterm will minimize the impact of double termination. The maximum value used for Rterm will depend on the HDMI TX capabilities. Consult HDMI TX vendor to find out the maximum allowed Rterm.

The high-speed signals from the HDMI source must be connected to the TUSBx46 DisplayPort inputs based on Table 4:

Table 4. HDMI to TUSBx46 DP Input Map

HDMI TMDS SIGNAL NAME	TUSBx46 DISPLAYPORT INPUT SIGNAL NAME	TUSBx46 DISPLAYPORT INPUT PIN NUMBER	COMMENT
TMDS_D0N	DP0P	9	This polarity inversion is required in order for TUSBx46 to route to the correct Type-C pin.
TMDS_D0P	DP0N	10	This polarity inversion is required in order for TUSBx46 to route to the correct Type-C pin.
TMDS_D1N	DP2N	16	
TMDS_D1P	DP2P	15	
TMDS_D2N	DP3N	19	
TMDS_D2P	DP3P	18	
TMDS_CLKN	DP1P	12	This polarity inversion is not required. A HDMI monitor should not care about the HDMI clock polarity.
TMDS_CLKP	DP1N	13	This polarity inversion is not required. A HDMI monitor should not care about the HDMI clock polarity.

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4 HDMI HEAC

The USB-C HDMI Alternate mode spec defines that HEAC+ and HEAC- signals are routed over the Type-C SBU1/2 pins. The HEAC signals are 5-V signaling levels; and therefore, must not be connected to the TUSBx46 SBU1/2 pins. The TUSBx46 SBU1/2 pins are not 5-V tolerant and therefore can be damaged if HEAC signals are directly connected. It is recommended to use an external mux or PD controller which can support these levels.

5 AUX Implementation

The TUSBx46 snoops AUX transactions in order to enable and disable DisplayPort lanes to save power. This snoop feature is enabled by default. Because AUX is not used in HDMI, the AUX snoop feature must be disabled whenever HDMI Alternate mode is enabled.

Table 5. AUX Snoop Enable Control

TUSBx46 GPIO or I2C MODE	AUX SNOOP ENABLED	AUX SNOOP DISABLED
GPIO Mode (pin I2C_EN = 0)	CAD_SNK (pin 29) = Low	CAD_SNK (pin 29) = HIGH
I2C Mode (pin I2C_EN != 0)	Clear bit 7 Reg13h	Set bit 7 Reg13h

6 HPD Implementation

The TUSBx46 uses the HPDIN to enable and disable DisplayPort path functionality to save power. The HPD signal from PD controller should be routed to either pin 23 or pin 32 based on the TUSBx46 GPIO/I2C Mode.

NOTE: TUSBx46 HPDIN pins (pin 23 or 32) are not 5-V tolerant. Therefore, HPDIN signal must be connected to a PD controller which drives HPD at 3.3 V LVCMOS level.

Table 6. HPD Connection Options

TUSBx46 GPIO or I2C MODE	HPD
GPIO Mode (pin I2C_EN = 0)	Pin 32
I2C Mode (pin I2C_EN != 0)	Pin 23

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7 Example Software

TUSBx46 in I2C mode must be configured for DisplayPort only when using HDMI mode. The Aardvark script below shows how to configure TUSBx46 for DisplayPort only mode and disable AUX snoop. This script uses an arbitrary equalization value for each lane receiver. Each receiver has 16 possible equalization settings. The actual value used should be based on the channel insertion loss for each DisplayPort or HDMI lane. The script slave address is set to 0x0F which corresponds to both DPEQ0/A1 and SSEQ0/A0 pins being at a '1' level. This slave address should be changed to match DPEQ0/A1 and SSEQ0/A0 pins value in the user's system.

```
<aardvark>

          <configure i2c="1" spi="1" gpio="0" tpower="0" pullups="0"/> <i2c_bitrate
          khz="400"/>
===DP only and EQ override set====

          <i2c_write addr="0x0F" count="1" radix="16"> 0A 12 </i2c_write> />
===Disable AUX Snoop and enable all DP lanes====

          <i2c_write addr="0x0F" count="1" radix="16"> 13 80 </i2c_write> />
===DP Lanes 0 and 1 EQ setting. 16 possible settings.====

          ===Lane 0 EQ: 0 Setting =====

          ===Lane 1 EQ: 1 Setting =====

          <i2c_write addr="0x0F" count="1" radix="16"> 10 10 </i2c_write> />
===DP Lanes 2 and 3 EQ Settings. 16 possible settings.====

          ===Lane 2 EQ: 0 Setting =====

          ===Lane 3 EQ: 1 Setting =====

          <i2c_write addr="0x0F" count="1" radix="16"> 11 10 </i2c_write> />
 </aardvark>
```


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8 USB-C HDMI Implementation Examples

8.1 HDMI and USB3.1 support

This example implementation shows how to implement TUSBx46 in I2C mode (I2C_EN != '0') with a APU that supports both HDMI and USB 3.1. If GPIO mode (I2C_EN = '0') is the desired implementation instead of I2C mode, the PD controller must control TUSBx56's CAD_SNK, CTL0, CLT1, and FLIP pins. For an application which does not need to support USB3.1, the TUSBx46 SSRXP/N and SSTXP/N pins can be left unconnected.

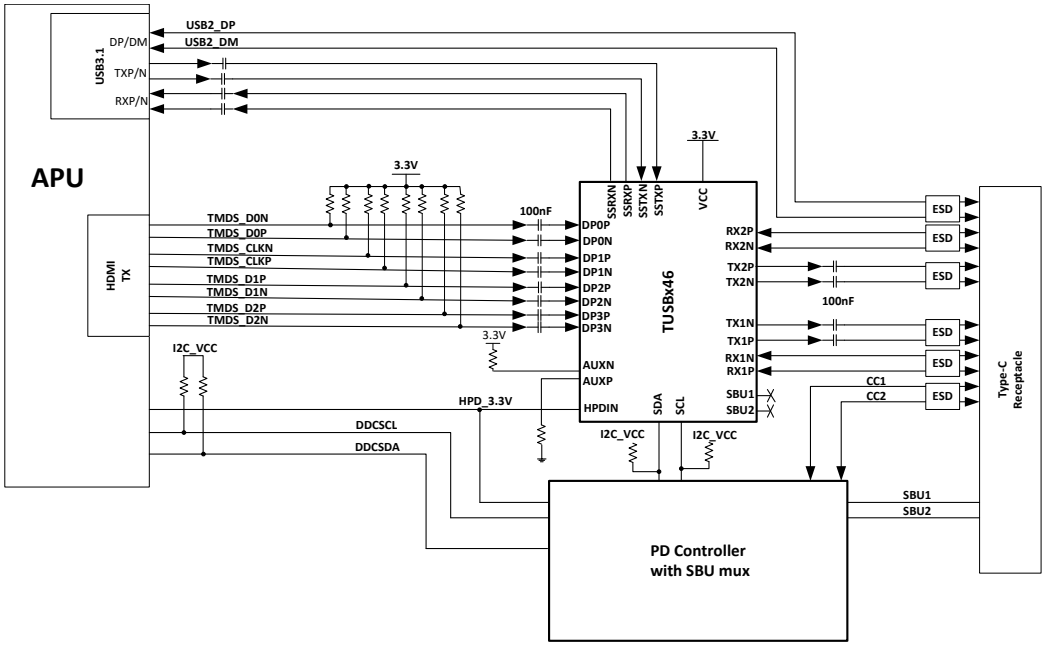

Figure 2. HDMI and USB3.1 using TUSBx46 in I2C Mode

8.2 HDMI, DisplayPort and USB3.1

Implementing both USB-C HDMI and DisplayPort alternate modes may require an 2:1 passive switch like the Texas Instruments HD3SS215. A 2:1 passive switch is needed if a single DisplayPort++ (DP++) transmitter is unable to perform the necessary muxing of HDMI TMDS lanes and DisplayPort lanes.

In this example the two DP++ TX ports (such as a two Intel DDI ports) are DC-coupled to HD3SS215's DA[3:0] and DB[3:0]. HD3SS215's DC[3:0] pins are connected to the TUSBx46 DP[3:0] through ac coupling capacitors. As shown in Figure 3, the DP++ TX TMDS lanes are routed to the appropriate DB[3:0] pins on the HD3SS215 so as to meet the requirements detailed in Table 4.

Unlike an HDMI transmitter, a DP++ transmitter implements DisplayPort electrical characteristics. Therefore; the Rterm depicted in Figure 1 is no longer needed.

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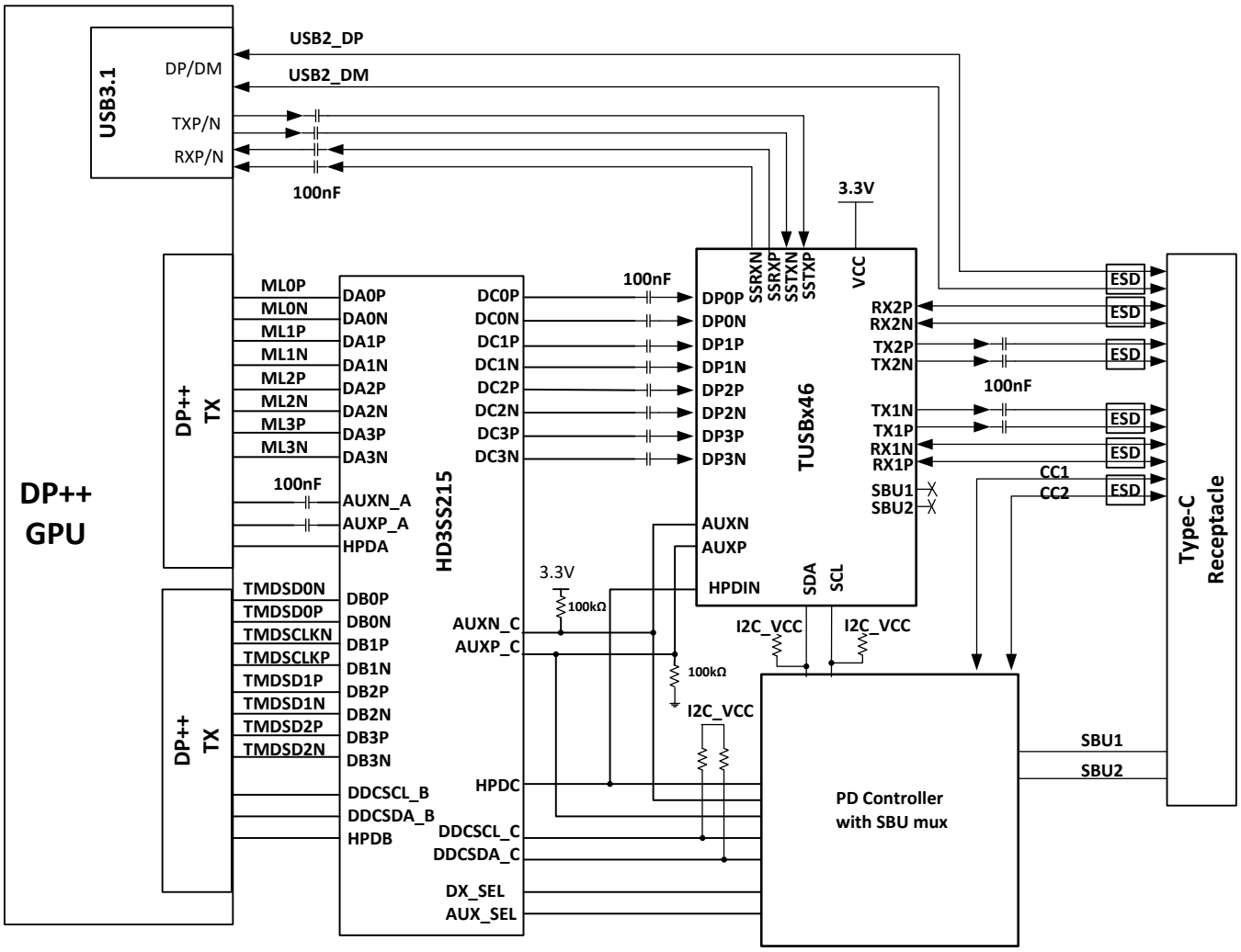

Figure 3. HDMI, DisplayPort, and USB3.1 using TUSBx46 and HD3SS215

9 References

- Datasheet: TUSB546A-DCI USB Type-C DP Alt Mode Linear Redriver Crosspoint Switch, SLLSF14.
- HDMI 1.4b Alt Mode on USB Type-C Specification, Version 1.0a, January 17, 2017
- VESA DisplayPort Alt Mode on USB Type-C Standard, Version 1.0a, August 5, 2015

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