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Basic USB Type-C™ Upstream Facing Port Implementation

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INTRODUCTION

The USB Type-C™ Specification was introduced in August 2014 and substantially expands the capabilities of USB. To take advantage of this expanded feature set, the cost of implementation per USB port can increase significantly. However, low-cost designs are still possible. This application note describes how to implement a basic USB Type-C Upstream Facing Port with a select few discrete components that will make the migration from legacy Type-B, mini B, micro B designs simple and low cost.

An upstream facing port (UFP) is a device-side port that may or may not be charged or be powered from VBUS. At minimum, a UFP must:

• Have a USB2.0 Device connection
• Provide Rd pull-down resistors on the CC pins

Optionally, the UFP may also:

• Detect cable insertion and orientation if not implementing USB3.0/3.1
• Detect current capability of the DFP if UFP only draws Legacy USB current load

Audience

This application note is targeted towards hardware designers looking to transition USB 2.0 and USB 3.0 designs over to the USB Type-C Cable. Some basic familiarity with the USB Type-C™ specification is also required.

References

The following documents should be referenced when using this application note. See your Microchip representative for availability.

• USB Type-C™ Cable and Connector Specification v1.0 Release (August 11, 2014)

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1.0   USB TYPE-C INTRODUCTION

The USB Type-C cable is a reversible 24-pin interconnect created by the USB-IF. The USB Type-C™ specification was first released in August 2014.

The USB Type-C cable is a universal cable that addresses the needs for a wide range of computing, display, and charging applications. The longterm objective of the USB Type-C cable is to replace all previous iterations of the USB cable while greatly expanding the overall capabilities. The recent introduction of the USB Power Delivery and Alternate Mode capabilities further expand the raw potential for even greater adoption of the USB standard in a wider range of applications.

The cost of implementing USB Power Delivery and Alternate Mode support is much higher than Legacy USB designs, and these capabilities are not required for all Applications. This document explains the requirements for implementing the low cost USB2.0 and USB3.0/3.1 devices using the USB Type-C receptacle.

1.1   USB Type-C Receptacle

FIGURE 1:   USB TYPE-C™ RECEPTACLE
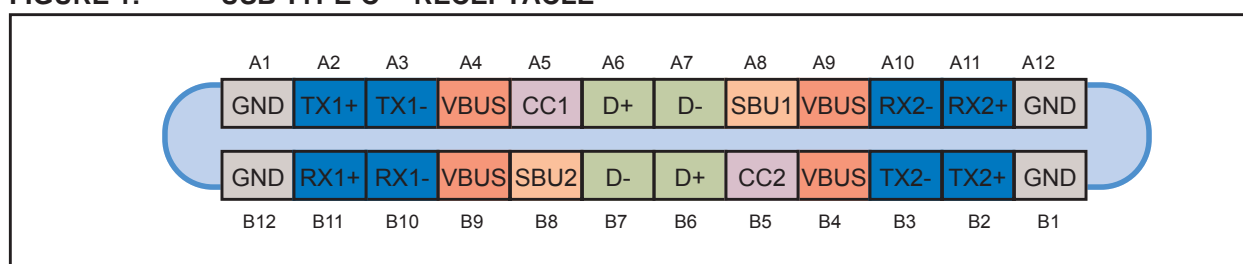
1.1.1   USB2.0 DIFFERENTIAL PAIRS

The 2 sets of USB2.0 differential pairs in the connector pinout only connect to a single differential pair in standard USB2.0 or Full Featured USB Type-C cables. In a typical design, the D+ and D- pins are simply shorted on the PCB so that a multiplexer or switch is not required.

The second set of pins (B6/B7) may only be re-purposed only in docking type applications where only 1 orientation is possible.

1.1.2   USB3.1 DIFFERENTIAL PAIRS

By default, only one set of TX/RX differential pairs are used for USB3.0/USB3.1 communication, depending on cable insertion orientation. Because of the cable reversibility, the USB3.0/USB3.1 lanes must be rerouted upon orientation connection. A typical application may use a 2:1 multiplexer to achieve this.

1.1.3   CC1/CC2 PINS

In a basic USB Type-C UFP application, the CC pins are used to detect cable orientation and USB Type-C current capability detection.

1.1.4   SBU1/SBU2

The SBU wires are lower speed signal wires that is allocated for Alternate Mode use only.

2.0 IMPLEMENTING AN UPSTREAM FACING PORT (UFP)

The most basic and lowest cost implementation of a USB Type-C UFP requires 3 components:

• A USB2.0 Device or Hub upstream port
• A USB Type-C Receptacle
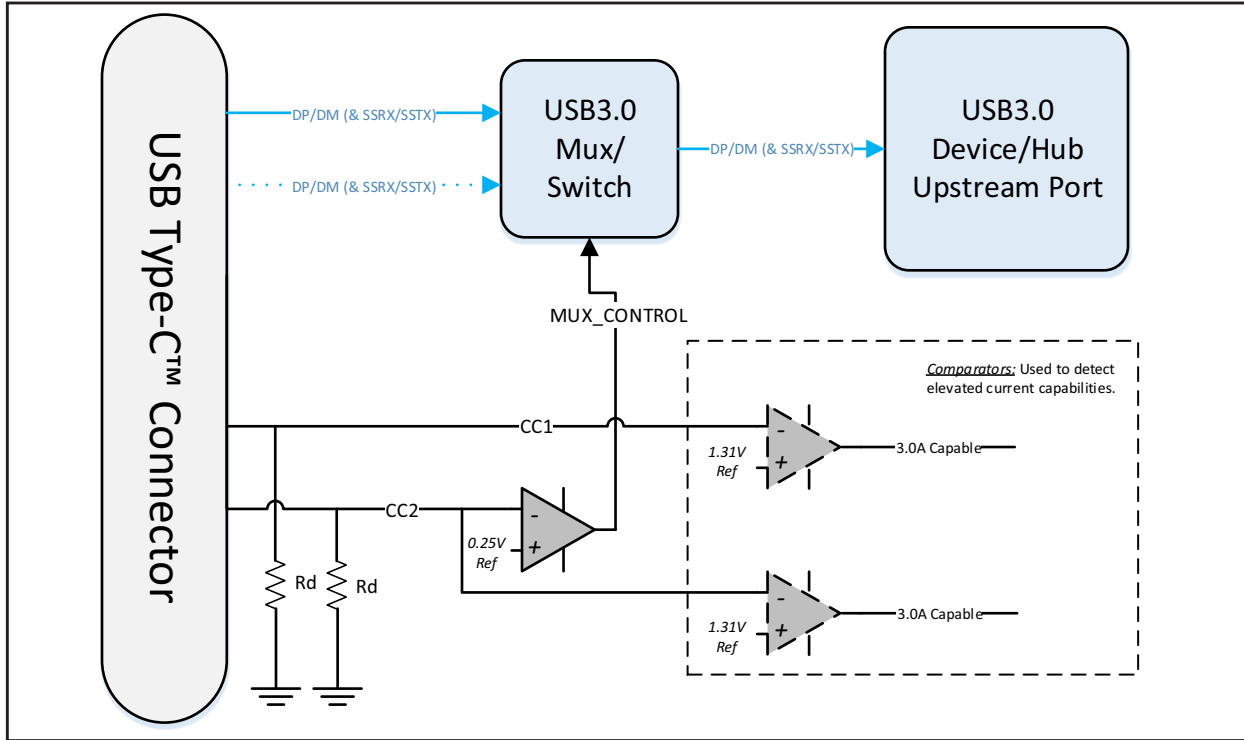• CC Pin Rd Pull-Down resistors

FIGURE 2: **LOWEST COST USB TYPE-C™ UFP IMPLEMENTATION**
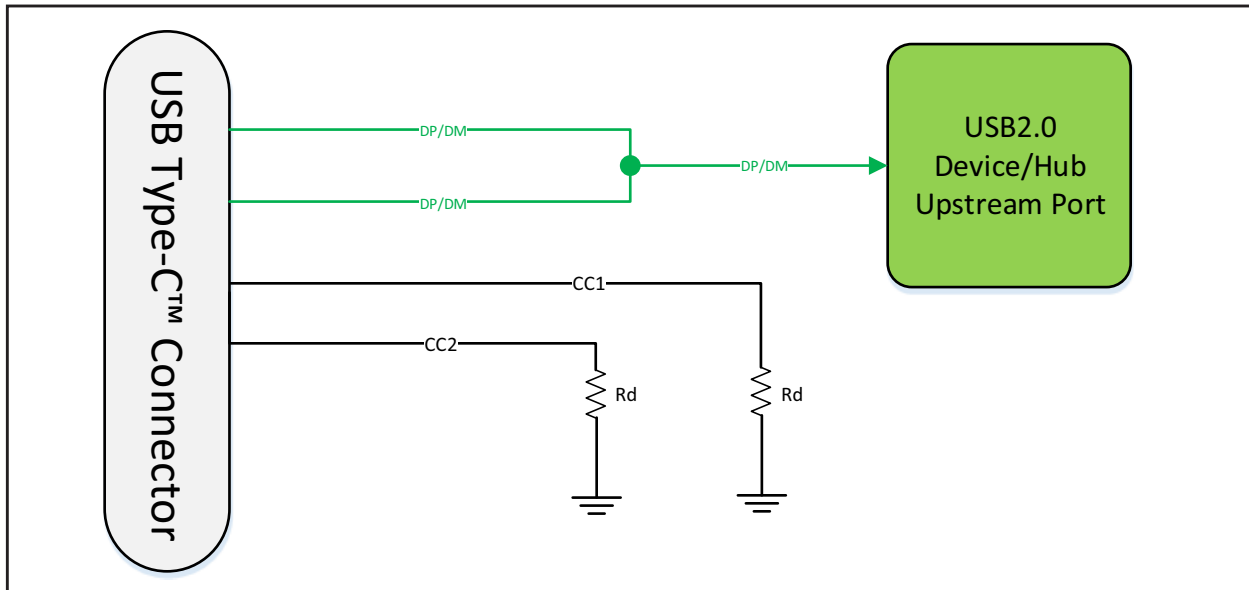
If you wish to implement a USB3.0/3.1 device/hub with USB Type-C current capability detection, the following components are required:

• A USB3.0/3.1 Device or Hub upstream port
• A USB Type-C Receptacle
• CC Pin Rd Pull-Down resistors
• USB3.0/3.1 2:1 Multiplexer
• CC Comparators:
  - Orientation Detection: Minimum 1 comparator for determining USB Type-C plug orientation and controlling USB3.0/3.1 2:1 multiplexer.
  - USB Type-C Current Capability Detection: 2 comparators for 1.5A detection, 2 comparators for 3.0A detection, 4 comparators for detecting both capabilities.

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FIGURE 3:   BASIC USB TYPE-C™ UFP USB3.0/3.1 SYSTEM WITH 3.0A CURRENT DETECTION

2.1   USB2.0 or USB3.0/3.1 Device or Hub Upstream Port

Any USB compliant USB 2.0 or USB3.0/3.1 device port or hub upstream port may be used.

2.2   USB Type-C Receptacle

Any standard 24-Pin USB Type-C Receptacle may be used.

2.3   CC Pin Circuitry

2.3.1   RD PULL-DOWN RESISTORS

A UFP is required to connect both CC pins to GND through a Rd resistor. A DFP must implement a Rp pull-up resistor to 5.0V or 3.3V. When a DFP to UFP connection is made, a resistor divider is formed, and the voltage at the CC pin can be measured to interpret the type of connection. Table 1 describes the possible values of the Rd pull-down resistor.

Note: A voltage clamp may be implemented instead of a pull-down resistor, but no power capability detection may be performed.

TABLE 1:   RD PULL-DOWN RESISTOR VALUES

Rd Implementation	Resistor Value	Detect Power Capability?	Max Pin Voltage
± 10% resistor to GND	5.1 kΩ	**Yes**	2.04V
± 20% resistor to GND	5.1 kΩ	No	2.18V
± 20% voltage clamp	1.1V	No	1.32V

2.3.2 COMPARATOR BANK

2.3.2.1 Orientation Detection

No microcontroller is required on a UFP, but voltages on the CC pins need to be monitored to detect the plug orientation and the current sourcing capability of the DFP (if sinking current above legacy USB levels is desired). Using comparators is a simple way to perform this detection.

A single comparator on the CC1 or CC2 pin with a 0.25V reference voltage can be used to detect the orientation of the cable. For example, if VBUS is supplied and the CC wire is connected to the CC1 pin then the output of the comparator will not be asserted and the UFP can conclude that a cable has been inserted in the "un-flipped" orientation. If VBUS is supplied and the CC wire is connected to the CC2 pin (and the voltage on CC2 exceeds 0.25V), then output of the comparator will be asserted and the UFP can conclude that a cable has been inserted in the "flipped" orientation.

2.3.2.2 USB Type-C Current Charging

If higher than Legacy USB current is required, additional comparators may be used to detect the current capability of the DFP. The USB Type-C™ specification defines the voltage ranges on the CC pin that communicate the current capability of the DFP. The voltage ranges are shown in Table 2 below.

TABLE 2: CC PIN VOLTAGE RANGES

CC Pin Voltage	
0.00V - 0.25V	No connection
0.25V - 0.70V	Legacy current (500mA for USB2.0, 900mA for USB3.0/3.1)
0.70V - 1.31V	1.5A capable
> 1.31V	3.0A capable

The measurement for charging current detection must be debounced by *tPDDebounce* before the DFP current advertisement can be qualified. After this detection is qualified, the UFP must adjust its load within *tSinkAdj*. See the most up-to-date version of the USB Type-C™ specification for these timing parameters.

2.4 USB Signal Multiplexer (Optional)

There are several options for connecting the USB signals to the USB Type-C receptacles. These options differ slightly between USB2.0 and USB3.0/3.1 applications.

2.4.1 USB2.0 UFP OPTION 1: HIGH-SPEED MULTIPLEXER/SWITCH

The most robust solution for USB2.0 applications is to use a USB High-Speed switch to control the routing of the USB signals. The Microchip USB3740 is a cost-effective solution for this purpose and offers several benefits:

- Extreme ESD: +- 15kV (IEC)
- Low Power: 5uA(on), 1uA (off)
- Off Isolation: less than -40dB
- High bandwidth: up to 1 GHz
- Preserves signal integrity
- Small Package: 1.3 x 1.8 mm – 10pin DFN (.4mm pitch)

FIGURE 4:   BLOCK DIAGRAM OF USB2.0 UFP OPTION 1: HIGH-SPEED SWITCH
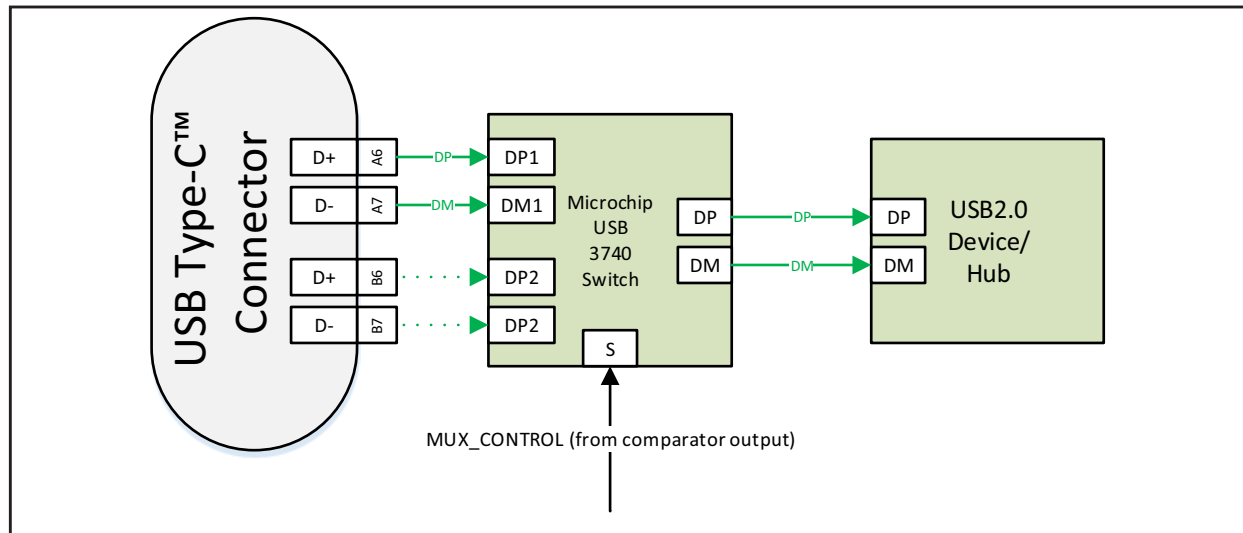

2.4.2   USB2.0 UFP OPTION 2: SHORT DP/DM PINS TOGETHER

The simplest solution is to short together the DP / DM pins at the receptacle. Only one DP / DM pair at the connector will be active at once.

Note: This implementation will negatively affect the integrity of the USB signals because of the creation of stubs on the USB traces.
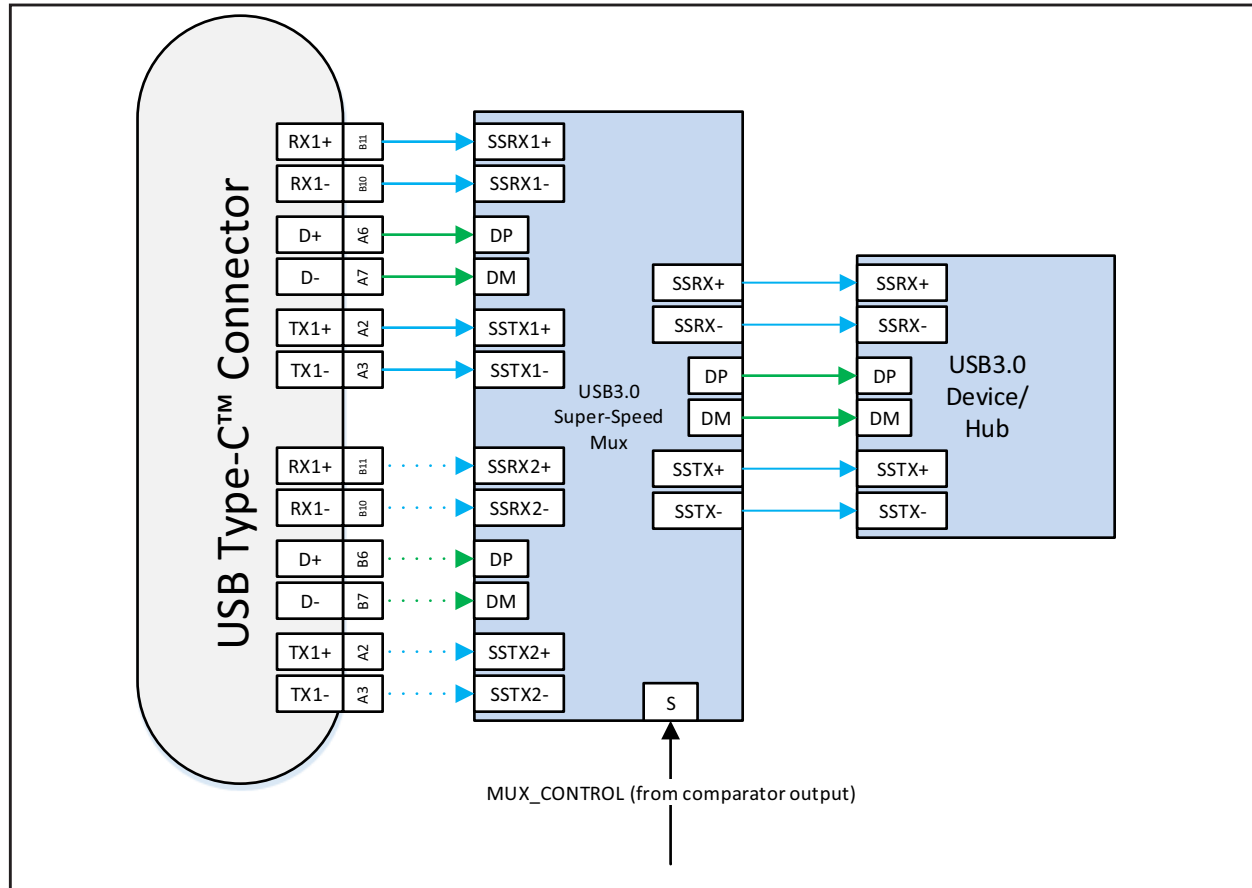
FIGURE 5:   BLOCK DIAGRAM OF USB2.0 OPTION 2: SHORT DP/DM PINS TOGETHER
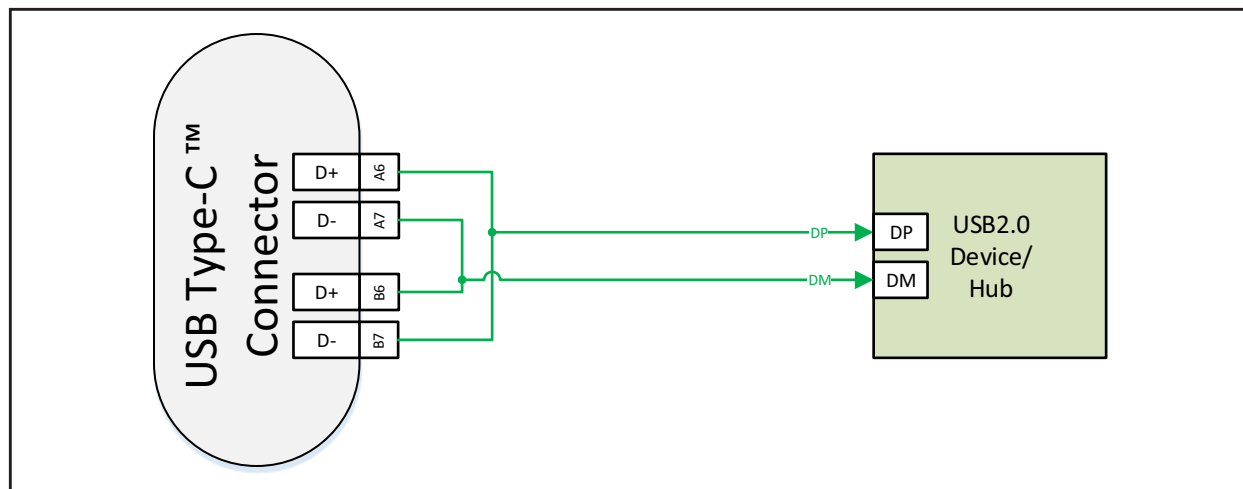
2.4.3   USB3.0/USB3.1 UFP: SUPER SPEED MULTIPLEXER/SWITCH

The only feasible option for a USB3.0/3.1 UFP is to implement a Super-Speed USB3.0/3.1 switch to control the routing of the USB signals.

FIGURE 6: **BLOCK DIAGRAM OF USB3.0/3.1 UFP: SUPER-SPEED MUX**

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APPENDIX A: APPLICATION NOTE REVISION HISTORY

TABLE A-1: REVISION HISTORY

Revision Level & Date	Section/Figure/Entry	Correction
Rev. A, May 2015	Initial release.	
Rev. B, September 2015	Throughout document	Fixed heading formats. Changed all instances of USB3.0 to USB3.0/3.1.
	Figure 2	Updated figure.
	Figure 3	Updated figure.
	Section 2.2	Updated first paragraph.
	Table 1	Updated table and title.
	Section 2.3.2.1	Fixed section numbering. Updated first paragraph.
	Section 2.3.2.2	Fixed section numbering.
	Section 2.4.1	Updated first bullet point.
	Figure 4	Updated figure and title.
	Section 2.4.2	Updated section title. Updated paragraph so last sentence becomes a note.
	Figure 5	Updated figure and title.
	Section 2.4.3	Updated section title.
	Figure 6	Updated figure and title.

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