TPS65987D and TPS65988 BC1.2 Implementation Guideline

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ABSTRACT

With the introduction of USB Type-C, higher power charging is allowed over USB connection. USB Type-C connection allows up to 20 V 5 A to be carried over VBUS. However it is required for both ends of the connection support USB PD protocol or discovery process to allow for the higher VBUS charging. For higher power charging over USB Type-C to legacy USB connection, BC1.2 charging mechanism can be employed. In addition to USB Type-C and PD controller features, TPS65987D/TPS65988 has also integrated BC1.2 charging detection and advertisement features for backward compatibility with legacy USB sources and sinks that may use BC1.2 for charging. Using TPS65987D/88, all charging schemes allowed for USB Type-C systems including BC1.2 can be supported without an additional legacy component.

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1 What is BC1.2

The BC1.2 specification defines the mechanisms to permit USB devices to draw current higher than standard USB current: 500 mA for USB2.0, 900 mA for USB3.0. Through the mechanism defined in the BC1.2 spec, devices can draw up to 1.5 A of current. The detection and the advertisement of the higher current capable port are done through USB2.0 D+ and D- lines upon connection. There are three charging ports defined in the BC1.2 spec: Dedicated Charging Port (DCP), Charging Downstream Port (CDP) and Standard Downstream Port (SDP).

1.1 DCP

DCP is a charging only USB port without USB data support. A connected device that supports BC1.2 detection can draw up to 1.5 A of current. The D+ and D- lines are shorted through a resistor on DCP.

1.2 CDP

CDP is a charging USB port with USB data support. A connected device that supports BC1.2 detection can draw up to 1.5 A of current. The CDP advertising device should be able to source voltage 0.5 V to 0.7 V on D- for primary detection.

1.3 SDP

SDP is a standard USB port that can support max current up to 500 mA or 900 mA depending on the connection speed. BC1.2 mechanism is not supported.

1.4 BC1.2 Discovery Process Overview

When a BC1.2 charging capable device (a cell phone for example) is connected, it initiates a primary detection process to determine whether the connected downstream port is capable of BC1.2 higher current charging scheme: DCP or CDP. Upon detection of D+ >Vdat_ref (0.25 to 0.4 V), the CDP sources voltage Vdm_src (0.5 to 0.7 V) on D-. When a connected charging device detects D->Vdat_ref (0.25 to 0.4 V), it either starts drawing desired current up to 1.5 A or enters secondary detection process to determine whether the connected charging port is a DCP or CDP. If the primary detection fails then the connected port is SDP therefore the device is allowed only draw up to USB spec defined current up to 500 mA or 900 mA based upon the connection speed. Most cell phones with a micro B connector are allowed to draw up to 500 mA when connected to a SDP. Some portable devices that support USB3 connection are allowed to draw up to 900 mA when connected to a SDP. The connected charging device initiates the secondary detection process by driving D- to the Vdm_src (0.5 V to 0.7 V). If the device detects D+ voltage > Vdat_ref (0.25 to 0.4 V), then the connected port is deemed to be DCP. If D+ voltage remains below Vdat_ref, then the connected port is CDP. The enumeration process must start by pulling the D+ high within 1 second after VBUS becomes available. Only the portable devices not ready to be enumerated within 1 second of detecting VBUS are required to implement Secondary Detection.

Figure 1 shows the example transaction between a CDP and a charging device. The charging device skips the secondary detection as it is ready to enumerate within 1 second.

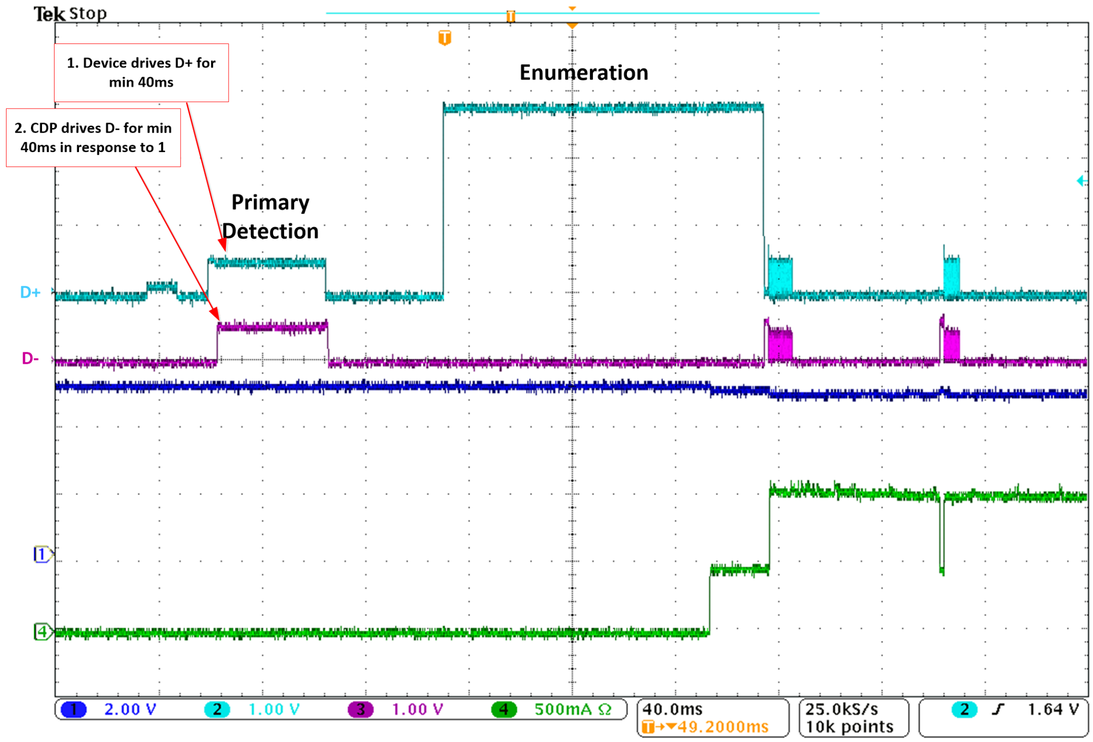

Figure 1. BC1.2 CDP Process Example

2 BC1.2 Charging Support Over USB Type-C using TPS65987D/88

The TPS65987D/88 supports both BC1.2 advertisement and detection features. The port can be configured to support BC1.2 DCP or CDP advertisement or detection through the host interface register 0x29 Port Control.

Table 1. 0x29 Port Control Register Definition for BC1.2 Charging

Bits	Name	Description	
Bytes 1-4:			
31:30	ChargerDetectEnable	00b	Charger Detect disable
		01b	BC1.2 detection enabled
		10b	Proprietary charger detection enabled
		11b	BC1.2 and proprietary detection enabled
29	USBDisable	0b	USB not disable
		1b	USB disable
28:26	ChargerAdvertiseEnable	000b	Charger advertise disable
		001b	BC 1.2 CDP advertisement only
		010b	BC 1.2 DCP advertisement only

The GPIOs are mapped as shown in Table 2 for BC1.2 D+ and D- communication.

Table 2. BC1.2 GPIO Mapping

GPIO	BC1.2 Port
GPIO18	BC1.2 Port 1 D+
GPIO19	BC1.2 Port 1 D-
GPIO20	BC1.2 Port 2 D+

Table 2. BC1.2 GPIO Mapping (continued)

GPIO	BC1.2 Port
GPIO21	BC1.2 Port 2 D-

The charging advertisement mode is entered only when the port is connected as source. The charging detection mode is entered only when the port is connected as sink. The port needs to enter Type-C connection state of Attached.SRC or Attached.SNK to advertise or detect BC1.2 mode.

2.1 BC1.2 Advertisement

The TPS65987D/88 can be programmed to advertise DCP or CDP through the Host Interface register. The bits [28:26] at address 0x29 Port Control Register can be configured accordingly based upon the system needs for legacy charging support. Table 3 below shows the Host Interface Specification definition for the BC12 Enable configuration with advertisement modes highlighted.

Table 3. 0x29 Port Control Register Definition for BC1.2 Charging

Bits	Name	Description	
Bytes 1-4:			
31:30	ChargerDetectEnable	00b	Charger Detect disable
		01b	BC1.2 detection enabled
		10b	Proprietary charger detection enabled
		11b	BC1.2 and proprietary detection enabled
29	USBDisable	0b	USB not disable
		1b	USB disable
28:26	ChargerAdvertiseEnable	000b	Charger advertise disable
		001b	BC 1.2 CDP advertisement only
		010b	BC 1.2 DCP advertisement only
		011b	DCP 1.2 V advertisement only
		100b	DCP Divider3 advertisement only
		101b	DCP auto mode 1 (Divider3, BC1.2 short)
		110b	DCP auto mode 1 (Divider3, 1.2 V, BC1.2 short)
		111b	Reserved
25	DCDEnable	0b	Data contact detect disabled
		1b	Data contact detect enabled
24	Resistor15kPresent	0b	15 kOhm resistor not present (USB2.0 Host Phy pulldowns not enabled)
		1b	15 kOhm resistor not present (USB2.0 Host Phy pulldowns enabled)

The register 0x29 needs to be programmed to 001b for CDP and 010b for DCP advertisement. Unlike legacy USB connectors, VBUS on an unconnected Type-Connector must remain at VBUS below VSafe0V. A Type-C devices capable of sourcing power over VBUS is to do so only after a Type-C sink connection has been detected via Type-C CC connection. (Refer to Type-C specification for full connection scheme).

The same requirement applies for Type-C to legacy connection. For a charger with a Type-C receptacle is to remain cold(no VBUS) until a sink connection is detected over CC line. A Type-C to legacy USB adapter is to present Rp pull-ups on CC lines which would enable Type-C sink detection as depicted in the block diagram below: Figure 2

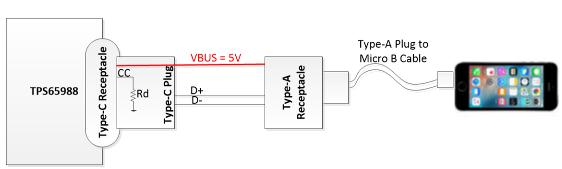

Figure 2. USB Device Connection Via Type-A to Type-C adapter

TPS65987D/88 enables BC1.2 advertisement only after Type-C sink detection has occurred. TPS65987D/88 starts the BC1.2 portable device detection process only after it has entered Attached.SRC state.

For applications without data communication capability such as USB Type-C chargers with a USB Type-C receptacle, BC1.2 DCP can be enabled for backward compatibility with legacy portable devices which support BC1.2 charging scheme. The scope capture below shows DCP advertisement connection process and its timing when TPS65987D/88 DCP configured port is connected to a BC1.2 portable device.

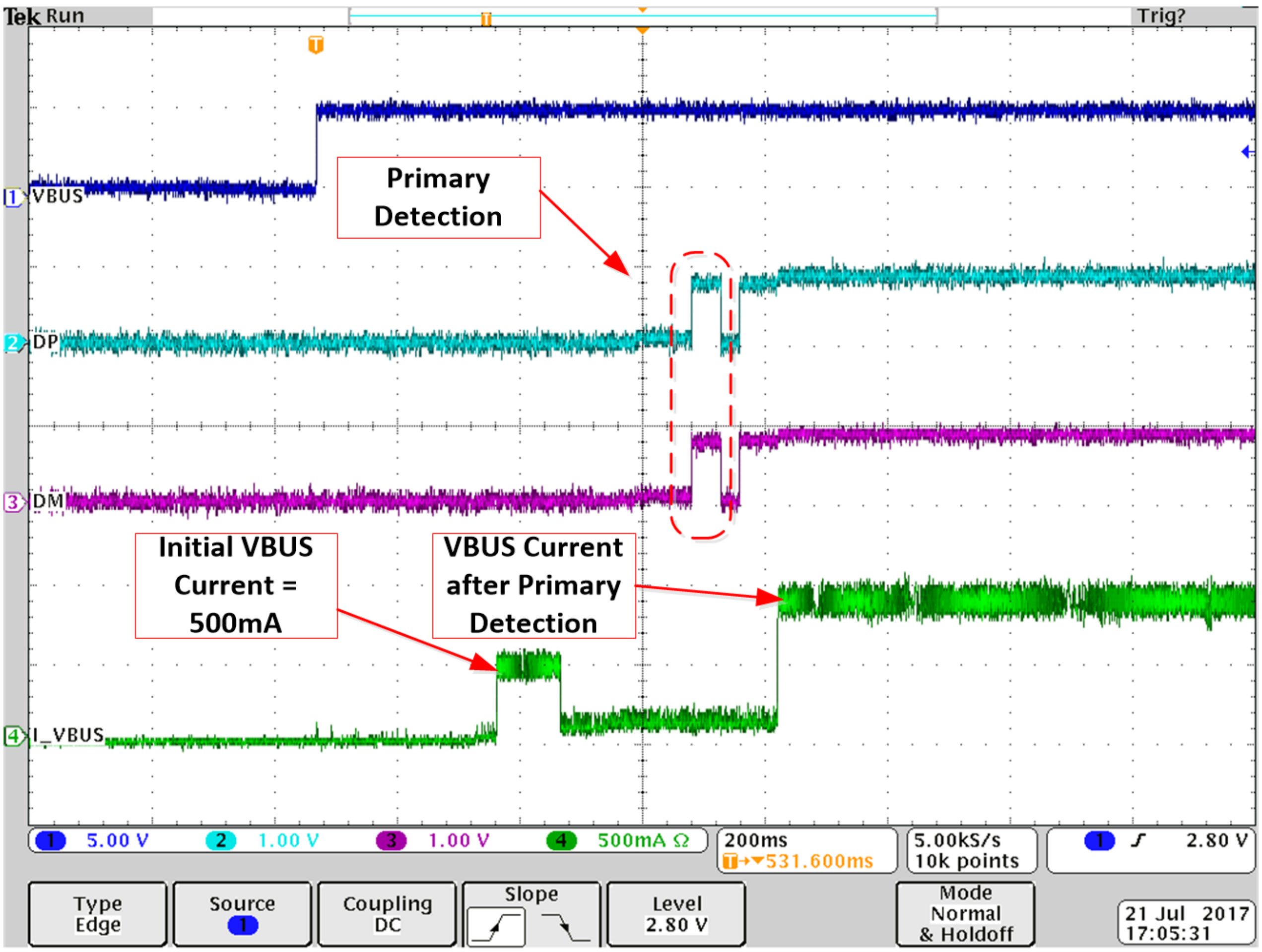

Figure 3. TPS65987D/88 DCP Advertisement Connection Process

Upon connection, the connected BC1.2 device starts driving D+. D- follows D+ as TPS65987D/88 DCP configured port has D+ and D- shorted per the BC1.2 specification definition. After the successful primary detection process, the connected BC1.2 device starts drawing higher current: ~1 A in this example.

For applications with a USB Type-C port capable of USB data communication (USB hub downstream port), BC1.2 CDP scheme can be implemented by enabling BC1.2 CDP advertisement in port control register(0x29). TPS65987D/88 enters or exits the BC1.2 charging mode automatically upon connection.

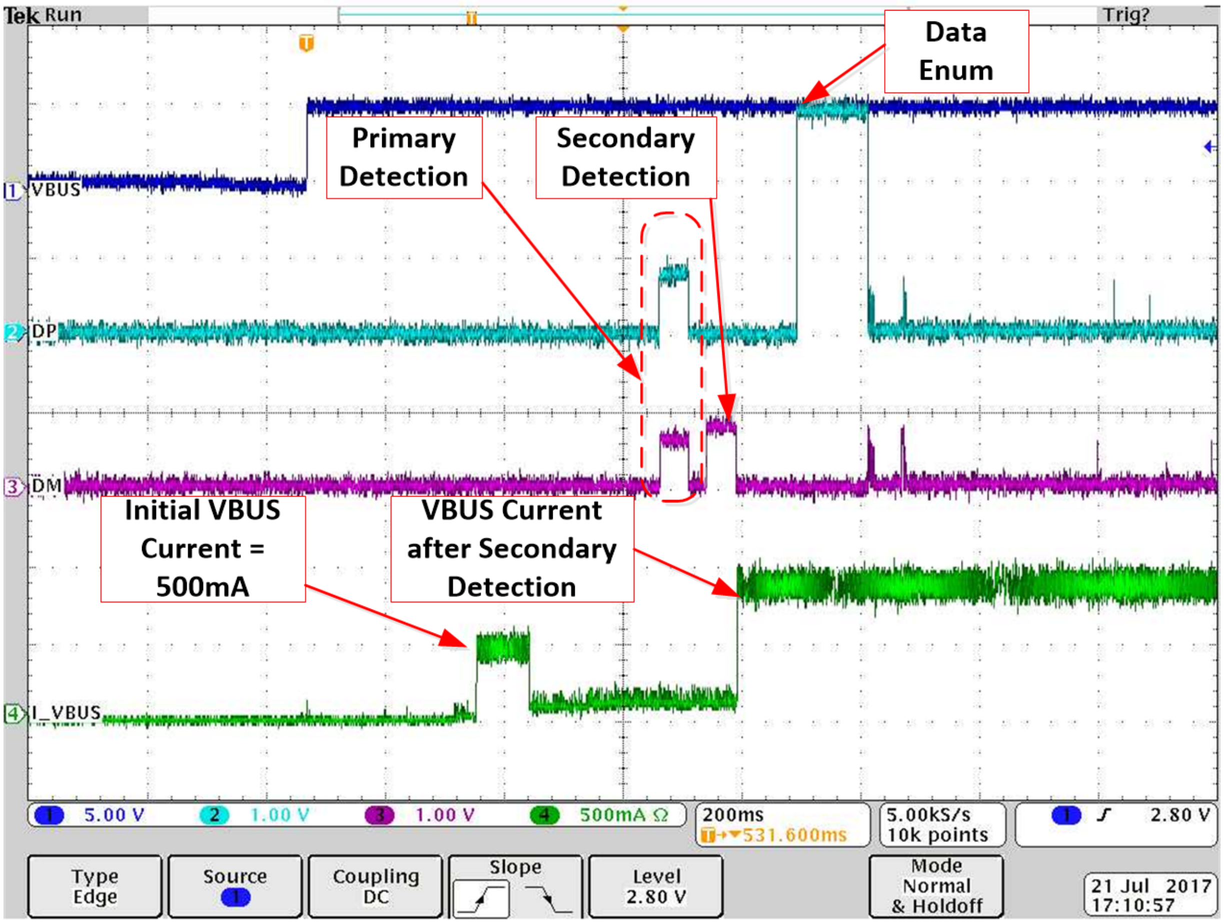

Figure 4. TPS65987D/88 CDP Advertisement Connection Process

Upon connection, the connected BC1.2 device starts driving D+. Upon detection of D+> Vdat_ref, D- is driven high (~0.7 V) by TPS65987D/88 CDP configured port. After the successful primary detection process, the connected BC1.2 device starts driving D- to determine whether the connected port is DCP or CDP. Upon the completion of the secondary detection process, the connected BC1.2 device starts drawing higher current: ~1 A in this example, followed by HS data numeration process.

2.2 BC1.2 Detection Implementation

The TPS65987D/88 can be programmed to support BC1.2 detection.

Table 4. 0x29 Port Control Register Definition for BC1.2 Charging

Bits	Name	Description	
Bytes 1-4:			
31:30	ChargerDetectEnable	00b	Charger Detect disable
		01b	BC1.2 detection enabled
		10b	Proprietary charger detection enabled
		11b	BC1.2 and proprietary detection enabled
29	USBDisable	0b	USB not disable
		1b	USB disable

Table 4. 0x29 Port Control Register Definition for BC1.2 Charging (continued)

Bits	Name	Description	
28:26	ChargerAdvertiseEnable	000b	Charger advertise disable
		001b	BC 1.2 CDP advertisement only
		010b	BC 1.2 DCP advertisement only

The detection mode can be enabled by programming BC12 Enable bits to 01b. With BC1.2 detection mode enabled, system can determine legacy connection status by reading Power Status register 0x3F bits 7:4 Charger Detect Status. It should be noted that the BC12 Status is valid only when ChargerDetectEnable = 1.

Table 5. 0x29 Port Control Register Definition for BC1.2 Charging

Bits	Name	Description	
Bytes 1-2:			
15:10	Reserved	Reserved (0)	
9:8	Charger Advertise Status	00b	Charger advertise disabled or not run
		01b	Charger advertisement in process
		10b	Charger advertisement complete
		11b	Reserved
7:4	Charger Detect Status[1]	0000b	Charger detection disabled or not run
		0001b	Charger detection in progress
		0010b	Charger detection complete, none detected
		0011b	Charger detection complete, SDP detected
		0100b	Charger detection complete, BC1.2 CDP detected
		0101b	Charger detection complete, BC1.2 DCP detected
		0110b	Charger detection complete, Divider1 DCP detected
		0111b	Charger detection complete, Divider2 DCP detected
		1000b	Charger detection complete, Divider3 DCP detected
		1001b	Charger detection complete, 1.2 V DCP detected
		1010b	Reserved
		1011b	Reserved
		1100b	Reserved
		1101b	Reserved
		1110b	Reserved
		1111b	Reserved
3:2	Type-C Current	00b	USB Default Current
		01b	1.5 A Current
		10b	3 A Current
		11b	PD contract negotiate (see other PD registers for more details).
1	SourceSink	0b	Connection requests power (PD Controller as source).
		1b	Connection provides power (PD Controller as sink).
0	PowerConnection	0b	No connection (rest of bits in this register are not valid).
		1b	Connection present (see other bits in register for more details).

(1) Rows highlighted in red a valid if ChargeDetect Enable = 1

Note that the BC12 Detection is active only when the device has detected a Type-C Source connection and has entered Attached.SNK state. Based upon the BC12 Status reading, system can determine the amount of current load. For example if BC12Status indicates CDP or DCP detected, it can draw up to 1.5 A over the legacy USB connection.

3 Charging Scheme Priority

A Type-C system can support multiple charging schemes: USB PD, USB Type-C and/or BC1.2. This means one or multiple charging schemes can be made available between connected systems. In case multiple charging schemes are available between port partners, the higher power contract would take priority over lower power schemes. A Type-C to Type-C system connection with a successful PD contract in place can support: USB PD High Voltage (5, 9, 12 or 20 V) charging up to 5 A, Type-C charging 5 V @ 3 A, and BC1.2 charging 5 V @ 1.5 A. The PD contract negotiated between the port partners would take the highest priority in this example. The Table 4-17 in USB Type-C specification defines the precedence of the power source usage as shown below. The precedence of the power negotiation rule must be followed per the USB Type-C spec definition.

Table 4-17 Precedence of power source usage

Precedence	Mode of Operation		Nominal Voltage	Maximum Current
Highest	*USB PD*		Configurable	5 A
	USB Type-C Current @ 3.0 A		5 V	3.0 A
↓	USB Type-C Current @ 1.5 A		5 V	1.5 A
	USB BC 1.2		5 V	Up to 1.5 A[1]
	Default USB Power	*USB 3.1*	5 V	See USB 3.1
Lowest		*USB 2.0*	5 V	See USB 2.0

Notes:

1. *USB BC 1.2* permits a power provider to be designed to support a level of power between 0.5 A and 1.5 A. If the *USB BC 1.2* power provider does not support 1.5 A, then it is required to follow power droop requirements. A *USB BC 1.2* power consumer may consume up to 1.5 A provided that the voltage does not drop below 2 V, which may occur at any level of power above 0.5 A.

Figure 5. Type-C Charging Priority Definition

The TPS65987D/88 would advertise or detect the legacy BC1.2 charging scheme with USB PD contract in place. The scope shot in Figure 6 below shows the connection between TPS65987D/88 and a device with multiple power mode support. The 20 V USB PD explicit contract supersedes all other power modes and VBUS steps up to 20 V at the end of the power negotiation

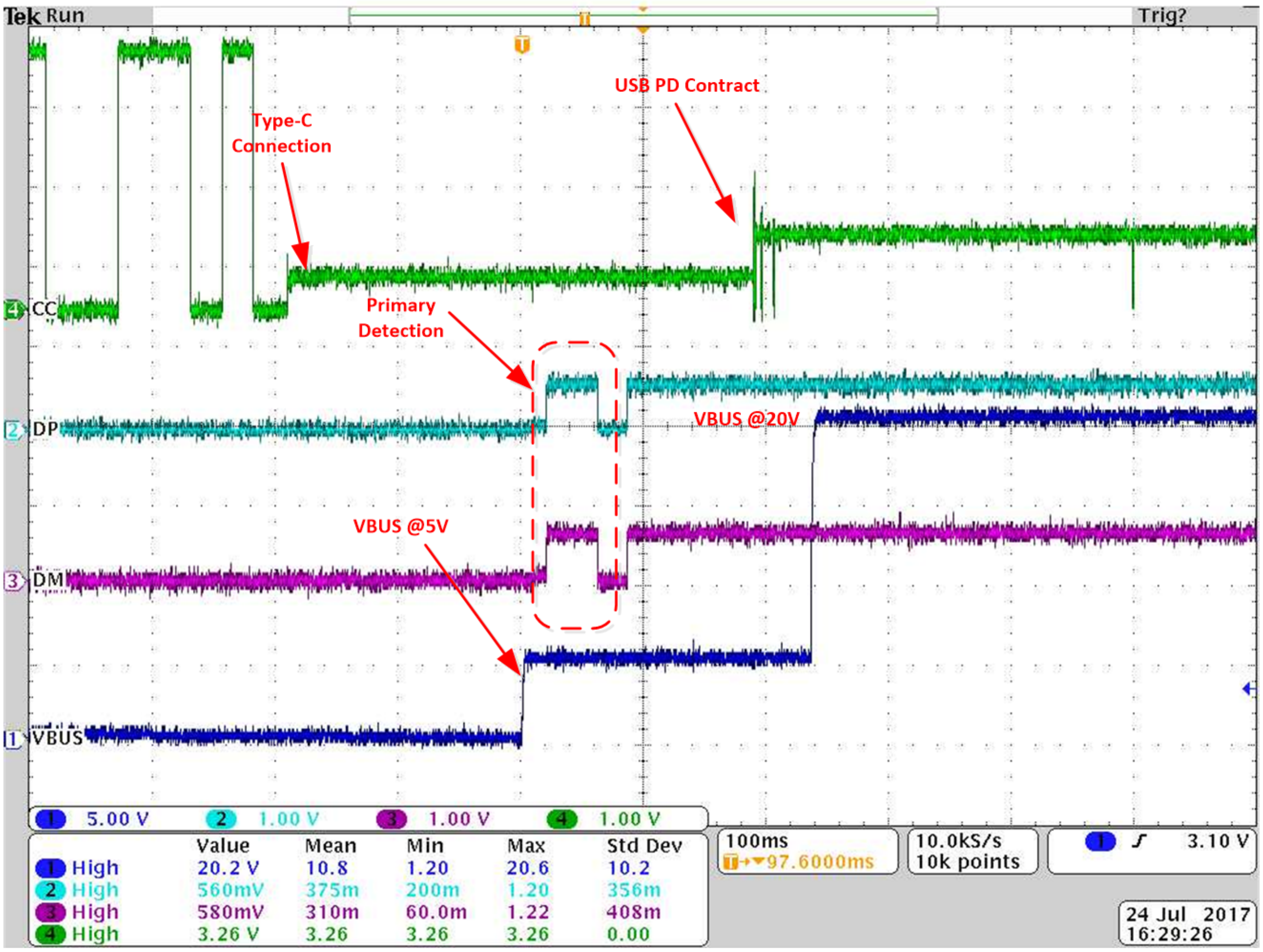

Figure 6. USB PD and BC1.2 Negotiation Priority Scheme

4 Type-C BC1.2 Requirements

TPS65987D/88 is designed to support all Type-C BC1.2 compliance requirements as specified in the USB Type-C spec.

4.1 USB Type-C BC1.2 Advertising Port Requirement

USB Type-C Spec requires a USB Type-C port with BC1.2 support to advertise at least 1.5 A current on its CC lines via Rp or current source. The CC lines need to reach the 1.5 A level within 275 ms of entering the Attached.SRC state. The USB Type-C port with BC1.2 support is also allowed to advertise 3 A of Type-C current on its CC lines.

4.2 USB Type-C BC1.2 Detection Port Requirement

USB Type-C Spec requires a USB Type-C port with BC1.2 support not to draw more than the Type-C current level detected upon its connection. If the port connects to a Source port with Rp at the default USB Power level, the port should not draw more than the default current until BC1.2 compliant source discovery is completed. If no BC1.2 compliant source is discovered, it should continue to limit its max current consumption to the default level. If BC1.2 compliance source is discovered, then it is allowed to draw up to 1.5 A.

5 USB2 Signal Routing Guideline on BC1.2 Capable Type-C Systems

For CDP applications, USB2 data lines D+ and D- need to be routed to a USB host or hub controller and TPS65987D/88. It is important that the data lines are routed with minimum stub for signal integrity purposes. See the example routing below in Figure 7

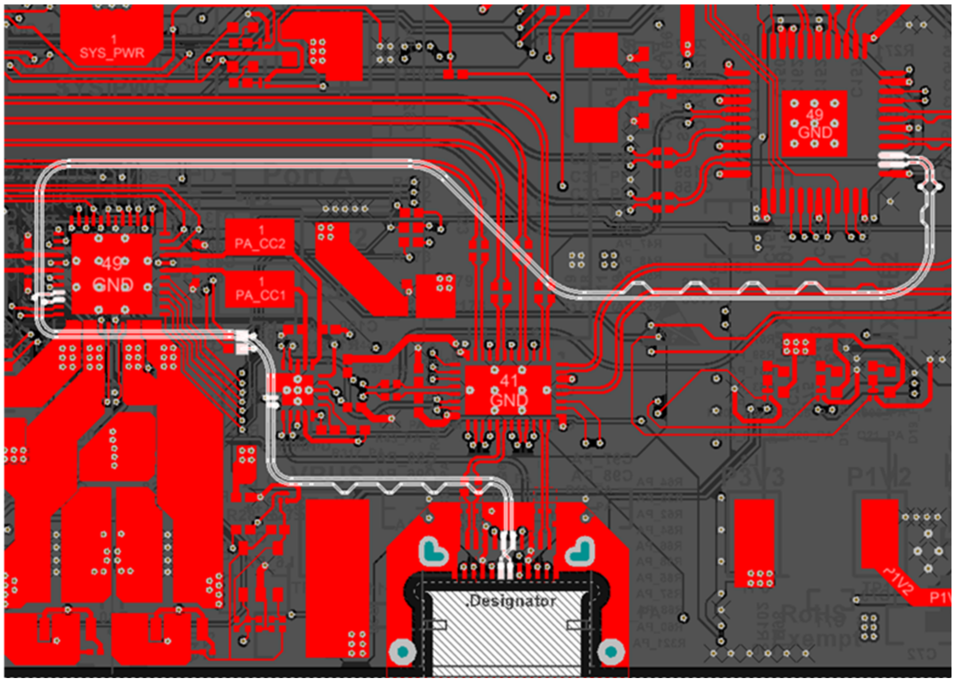

Figure 7. TPS65987D/88 D+/D- Routing Example with BC1.2 Support

Some host or hub controller downstream facing ports may already have BC1.2 support. Depending on the system configuration and its mode of operation, it needs to be decided which component the BC1.2 support needs to be enabled in: BC1.2 integrated in the DFP of the host or hub Vs. PD controller. The BC1.2 may not function correctly if it is enabled on both the hub and PD controller on the same port.

6 TPS65987D/88 BC1.2 Charging Test with Legacy Devices

This section summarizes test results on TPS65987D/88 BC1.2 charging tested with various legacy USB BC1.2 portable devices.

Table 6. TPS65987D/88 BC1.2 Charging Test Results

Manufacturer	Model #	TPS65987D/88 Port Advertisement Configuration					
		CDP			DCP		
		Power State	VBUS Current(mA)	Battery Stat	USB Enum	VBUS Current(mA)	Battery STat
Apple	Iphone5	On	1020	11%	Pass	950	10%
		Off	n/a	n/a	n/a	n/a	n/a
Samsung	GalaxyS5	On	790	92%	Pass	1160	92%
		Off	980	92%	n/a	860	92%
Samsung	GalaxyS3	On	1020	3%	Pass	1000	3%
		Off	1020	3%	n/a	1000	3%
Apple	IphoneSE	On	1320	94%	Pass	1010	94%
		Off	n/a	n/a	n/a	n/a	n/a
LG	G3	On	1040	89%	Pass	1020	89%

Table 6. TPS65987D/88 BC1.2 Charging Test Results (continued)

Manufacturer	Model #	TPS65987D/88 Port Advertisement Configuration					
		Off	470	90%	n/a	1010	89%
Apple	Iphone 6S-A1691	On	1500	86%	Pass	680	90%
		Off	n/a	n/a	n/a	n/a	n/a

7 References

- TPS65987D USB Type-C and USB PD Controller with Integrated Power Switches, Datasheet, Texas Instruments
- TPS65988 Dual Port USB Type-C and USB PD Controller with Integrated Power Switches, Datasheet, Texas Instruments
- Universal Serial Bus Type C Cable and Connector Specification, Revision 1.3
- Universal Serial Bus Power Delivery Specification, Revision 3.0
- Battery Charging Specification

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265