USB Type-C ENGINEERING CHANGE NOTICE

Title: CC Voltage Thresholds
Applied to: USB Type-C Specification Release 2.3, Oct 2023

Brief description of the functional changes proposed:

The USB Type-C specification specifies impedance on source side, impedance on sink side but also absolute voltages. All are currently defined as mandatory and shouldn't be. Having defined voltages mandatory, on top of impedances gives no room for design implementation. It appears also that some table numbers do not fit with calculation based on impedances/current sources.

Benefits as a result of the proposed changes:

Provide room for design implementation to define thresholds based on their DUT impedance dispersion.

An assessment of the impact to the existing revision and systems that currently conform to the USB specification:

Should have no impact. All designs based on previous values still fall into the calculated ranges.
The ECN is a clarification of threshold calculations, but all designs based on previous specifications still fit the requirement.

An analysis of the hardware implications:

Makes design easier by allowing for the thresholds in design to be based on that designs actual variance.

An analysis of the software implications:

None

An analysis of the compliance testing implications:

No impact

Actual Change Requested

(a). Section 4.11.3 Voltage Parameters

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4.11.3 Voltage Parameters

Table 4-35, Table 4-36 and Table 4-37 provide the CC voltage values that a Source ***shall*** use to detect what is attached based on the ***USB Type-C Current*** advertisement (Default USB, 1.5 A @ 5 V, or 3.0 A @ 5 V) that the Source is offering.

Table 4-35 CC Voltages on Source Side – Default USB

	Minimum Voltage	Maximum Voltage	Threshold
Powered cable/adapter (*vRa*)	0.00 V	0.15 V	0.20 V
Sink (*vRd*)	0.25 V	1.50 V	1.60 V
No connect (*vOPEN*)	1.65 V		

Table 4-36 CC Voltages on Source Side – 1.5 A @ 5 V

	Minimum Voltage	Maximum Voltage	Threshold
Powered cable/adapter (*vRa*)	0.00 V	0.35 V	0.40 V
Sink (*vRd*)	0.45 V	1.50 V	1.60 V
No connect (*vOPEN*)	1.65 V		

Table 4-37 CC Voltages on Source Side – 3.0 A @ 5 V

	Minimum Voltage	Maximum Voltage	Threshold
Powered cable/adapter (*vRa*)	0.00 V	0.75 V	0.80 V
Sink (*vRd*)	0.85 V	2.45 V	2.60 V
No connect (*vOPEN*)	2.75 V		

Table 4-38 provides the CC voltage values that ***shall*** be detected across a Sink's ***Rd*** for a Sink that does not support higher than default ***USB Type-C Current*** Source advertisements.

Table 4-38 Voltages on Sink CC Pins – Default USB Type-C Current Only

Detection	Minimum Voltage	Maximum Voltage	Threshold
vRa	−0.25 V	0.15 V	0.2 V
vRd-Connect	0.25 V	2.18 V	

Table 4-39 provides the CC voltage values that ***shall*** be detected across a Sink's ***Rd*** for a Sink that implements detection of higher than default ***USB Type-C Current*** Source advertisements. This table includes consideration for the effect that the IR drop across the cable GND has on the voltage across the Sink's ***Rd***.

Table 4-39 Voltages on Sink CC Pins – Multiple Source Current Advertisements

Detection	Minimum Voltage	Maximum Voltage	Threshold
vRa	−0.25 V	0.15 V	0.2 V
vRd-Connect	0.25 V	2.04 V	
vRd-USB	0.25 V	0.61 V	0.66 V
vRd-1.5	0.70 V	1.16 V	1.23 V
vRd-3.0	1.31 V	2.04 V	

Table 4-40 provides the clamping voltage that any port (Source, Sink or DRP) ***may*** clamp its CC pin to protect from damage. The inclusion of clamping ***shall not*** impact the functionality when the CC pin is functioning as VCONN Source or Sink.

Table 4-40 CC Pin Clamping Voltage

	Minimum Voltage
vCC-Clamp	2.9 V

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4.11.3 Voltage Parameters

This section provides voltage calculations to be used by a Source to detect an attach and a Sink to detect the ***USB Type-C Current*** advertisement (Default USB, 1.5 A, or 3.0 A) with some numeric examples. This allows calculations for thresholds of specific implementations to be based on the parameter variances of the implementation.

4.11.3.1 Threshold calculation

For calculating threshold settings to detect an Attach by a Source and the Source ***USB Type-C Current*** advertisement by a Sink, the equations in this section are used. The cable CC wire resistance is considered negligible compared to the Source R_p and Sink R_d and is not included. Each equation calculates the CC pin voltage as seen from the Sink or the Source. Figure 4-X and Figure 4-Y illustrate the two models used to determine these equations, the first based on a pull-up resistor in the Source and the second replacing this with a current source.

Figure 4-X Pull-Up/Pull-Down Voltage Detection Model

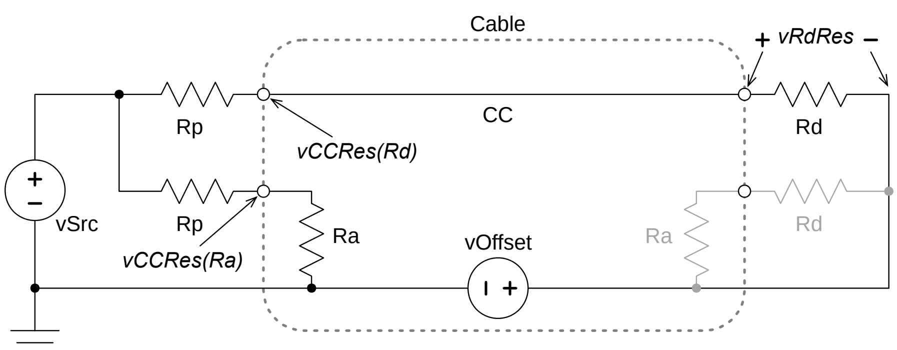
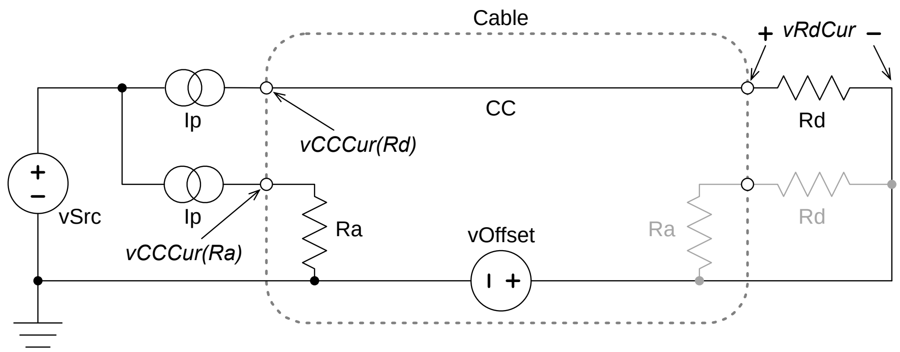


Figure 4-Y Current Source/Pull-Down CC Model



4.11.3.1.1 Voltage on Sink CC pins

The CC pin voltage seen by the Sink is the voltage across the Sink Rd pull-down resistor. For the following calculations, it is assumed that:

- vSrc = voltage supply of the Source pull-up resistor,
- Rp = Source pull-up resistor,
- Ip = Source pull-up current,
- R_d = Sink pull-down resistor,
- vOffset = the ground offset due to the cable IR drop when current is drawn by the Sink,
- vRdRes = voltage across the Sink Rd for a Source pull-up to vSrc through the resistor R_p,
- $vRdCur$ = voltage across the Sink Rd for a Source pull-up current of Ip.

$$vRdRes(min) = (vSrc(min) - vOffset(max))\frac{R_d(min)}{R_d(min) + R_p(max)}$$

$$vRdRes(max) = vSrc(max)\frac{R_d(max)}{R_d(max) + R_p(min)}$$

$$vRdCur(\mathrm{min}) = Ip(min) \cdot R_d(min)$$

$$vRdCur(\mathrm{max}) = Ip(max) \cdot R_d(max)$$

$$vRd(min) = \min\left(vRdRes(min), vRdCur(\mathrm{min})\right)$$

$$vRd(max) = \max\left(vRdRes(max), vRdCur(\mathrm{max})\right)$$

A Sink is not aware of the Source advertising method with either a current source or a resistive pull-up. The vRd for both a Source advertisement with a current source and a resistance must be calculated and the minimum and maximum taken. From the Sink perspective, the maximum variance for each parameter in the Source is the maximum for each source implementation, from Table 4-27. The vOffset(max) can depend on the maximum current drawn by the Sink, whether the connection is a direct attach, or assume the maximum 250mV for a cable. The variance of Rd can be smaller than the maximum in Table 4-28. Thus, the Sink can use these equations to determine the optimum minimum and maximum thresholds for detecting the Source current advertisements.

4.11.3.1.2 Voltage on Source CC pins

The Source equations are used to determine when either an attach or detach occurs with a Sink (R_d) or a cable/accessory (R_a). For the following calculations, it is assumed that:

- *vSrc* = voltage supply of the source pull-up resistor,
- *Rp* = Source pull-up resistor,
- *Ip* = Source pull-up current,
- $R_{d|a}$ = either a device pull-down resistor R_d or a cable/accessory pull-down resistor R_a,
- *vOffset* = the ground offset due to the cable IR drop when current is drawn by a sink,
- *vCCRes* = Source CC pin voltage for a Source pull-up to vSrc through the resistor R_p,
- *vCCCur* = Source CC pin voltage for a Source pull-up current of Ip.

The CC pin voltage seen by the source is given by the following equations.

$$vCCRes = (vSrc - vOffset)\frac{R_{d|a}}{R_{d|a} + R_p} + vOffset$$

$$vCCCur = Ip \cdot R_{d|a} + vOffset$$

To determine the minimum and maximum values, these equations become,

$$vCCRes(min) = vSrc(min)\frac{R_d(min)}{R_d(min) + R_p(max)}$$

$$vCCRes(max) = (vSrc(max) - vOffset(max))\frac{R_{d|a}(max)}{R_{d|a}(max) + R_p(min)} + vOffset(max)$$

$$vCCCur(\mathrm{min}) = Min(\ Ip(min) \cdot R_d(min)\ \ , vRdclamp(\mathrm{min}))$$

$$vCCCur(\mathrm{max}) = Max(\ ip(max) \cdot R_{d|a}(max) + vOffset(max)\ , vRdclamp(max))$$

vOffset is 0V at initial connect as the current drawn is negligible (no Vbus), therefore vOffset is included in determining the disconnect threshold only. Note, the connect and disconnect thresholds can be the same in a design and in this case the higher value including the vOffset(max) is used.

A Source is aware of whether it is advertising with a current source or a resistive pull-up and will use only the equations associated with its specific method. From the Source perspective, the sink voltage calculation must assume the maximum 20% variance of R_d or the clamp voltage as shown in Table 4-28. The vOffset(max) may depend on the max current the Source is capable of offering or the maximum 250mV may be assumed. The variance of R_p and Ip can be smaller than the maximum in Table 4-27.

4.11.3.2 Threshold examples

The following show calculations using the previous equations for determining threshold settings based on example designs.

4.11.3.2.1 Example of Voltage on Sink CC pin – Among all source advertisement (Rd +/- 20%)

Table 4-T1 shows the range of the Sink CC pin voltage (vRd) for a Rd with a variance of +/- 20% and clamp voltage variation of +/- 20%. If a Sink implementation used the CC pin voltage as connect detection, then a threshold above the maximum from this table would be required.

Table 4-T1. Sink CC pin voltages for connect detection for Rd and clamp voltage +/- 20%

	Minimum Voltage(V)	Maximum voltage(V)
vRd-connect	0.249	2.181

4.11.3.2.2 Example of Voltage on Sink CC pins – Multiple Source Current Advertisements (Rd +/-10%)

Table 4-T2 shows the range of the Sink CC pin voltage and resulting thresholds for detecting a connect/disconnect and/or the ***USB Type-C Current*** advertisement from the Source.

Table 4-T2. Sink CC pin voltages for connect and current advertisement detection for Rd +-10%

	Minimum Voltage(V)	Maximum voltage(V)
vRd-USB	0.277	0.612
vRd-1.5	0.746	1.164
vRd-3.0	1.369	2.042
Threshold between vRd-USB and vRd-1.5	0.613	0.745
Threshold between vRd-1.5 and vRd-3.0	1.165	1.368
Disconnect/connect threshold	2.043	

4.11.3.2.3 Example of Voltage on Source CC pins – Current source (variance as per table4-27)

Table 4-T3 shows the range of the Source CC pin voltage for the three different current advertisements when using a pull-up current for the advertisement. These voltages are based on the variance found in Table 4-27.

Table 4-T3. Source CC pin voltages for all current advertisements using a pull-up current with variance found in Table 4-27.

	Minimum Voltage(V)	Maximum voltage(V)
Connect threshold vCCCur-Rd-USB	0.261	1.32(2)
Disconnect threshold² – Rd-USB	1.321	
Connect threshold vCCCur-Rd-1.5	0.676	1.32(2)
Disconnect threshold¹ – Rd-1.5	1.441	
Connect threshold vCCCur-Rd-3.0	0.88(2)	2.181
Disconnect threshold¹– Rd-3.0	2.432	
vCCCur-Ra-USB	0(3)	0.115
vCCCur-Ra-1.5	0(3)	0.233
vCCCur-Ra-3.0	0(3)	0.428
Threshold between vCCCur-Rd-USB and vCCCur-Ra-USB	0.116	0.260
Threshold between vCCCur-Rd-1.5 and vCCCur-Ra-1.5	0.234	0.675
Threshold between vCCCur-Rd-3.0 and vCCCur-Ra-3.0	0.429	0.879

Note 1: Disconnect threshold should take vOffset into account. vOffset=0.25V is assumed here.
Note 2: Result is from the voltage clamp variance
Note 3: Per Note 1 of Table 4-29, Ra minimum impedance may be less then $Ra_{(min)}$ when Vconn is *not* applied

4.11.3.2.4 Example of Voltage on Source CC pins –Rp @5V (variance as per table 4-27)

Table 4-T4 shows the range of the Source CC pin voltage for a pull-up resistance to 5V using the variance from Table 4-27.

Table 4-T4. Source CC pin voltages for pull-up resistance to 5V with variance found in Table 4-27.

	Minimum Voltage(V)	Maximum voltage(V)
Connect threshold vCCRes-Rd-USB	0.272	1.32(2)
Disconnect threshold² – Rd-USB	1.321	2.93(4)
Connect threshold vCCRes-Rd-1.5	0.713	1.32(2)
Disconnect threshold¹ – Rd-1.5	1.440	2.44(4)
Connect threshold vCCRes-Rd-3.0	0.88(2)	2.155
Disconnect threshold¹– Rd-3.0	2.308	2.66(4)
vCCRes-Ra-USB	0(3)	0.143
vCCRes-Ra-1.5	0(3)	0.299
vCCRes-Ra-3.0	0(3)	0.617
Threshold between vCCRes-Rd-USB and vCCRes-Ra-USB	0.144	0.271
Threshold between vCCRes-Rd-1.5 and vCCRes-Ra-1.5	0.300	0.712
Threshold between vCCRes-Rd-3.0 and vCCRes-Ra-3.0	0.618	0.879

Note 1: Disconnect threshold should take vOffset into account. vOffset=0.25V is assumed here.
Note 2: Result is from the voltage clamp variance
Note 3: Per Note 1 of Table 4-29, Ra minimum impedance may be less then $Ra_{(min)}$ when Vconn is *not* applied
Note 4: Considers zOPEN minimum.

4.11.3.2.5 Example of Voltage on Source CC pins –Rp @3.3V (tolerance as per table4-27)

Table 4-T5 shows the range of the Source CC pin voltage for a pull-up resistance to 3.3V using the variance from Table 4-27.

Table 4-T5. Source CC pin voltages for pull-up resistance to 3.3V with variance found in Table 4-27.

	Minimum Voltage(V)	Maximum voltage(V)
Connect threshold vCCRes-Rd-USB	0.271	1.32(2)
Disconnect threshold– Rd-USB	1.321(2)	2.15(4)
Connect threshold vCCRes-Rd-1.5	0.767	1.32(2)
Disconnect threshold[1] – Rd-1.5	1.374	2.62(4)
Connect threshold vCCRes-Rd-3.0	0.88(2)	2.003
Disconnect threshold[1]– Rd-3.0	2.110	2.77(4)
vCCRes-Ra-USB	0(3)	0.139
vCCRes-Ra-1.5	0(3)	0.330
vCCRes-Ra-3.0	0(3)	0.734
Threshold between vCCRes-Rd-USB and vCCRes-Ra-USB	0.140	0.270
Threshold between vCCRes-Rd-1.5 and vCCRes-Ra-1.5	0.331	0.766
Threshold between vCCRes-Rd-3.0 and vCCRes-Ra-3.0	0.735	0.879

Note 1: Disconnect threshold should take vOffset into account. vOffset=0.25V is assumed here.
Note 2: Result is from the voltage clamp variance
Note 3: Per Note 1 of Table 4-29, Ra minimum impedance may be less then $Ra_{(min)}$ when Vconn is *not* applied
Note 4: Considers zOPEN minimum.

4.11.3.3 CC clamp voltage

Table 4-40 provides the clamping voltage that any port (Source, Sink or DRP) ***may*** clamp its CC pin to protect from damage. The inclusion of clamping ***shall not*** impact the functionality when the CC pin is functioning as VCONN Source or Sink.

Table 4-40 CC Pin Clamping Voltage

	Minimum Voltage
vCC-Clamp	2.9 V

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Table 4-27 Source CC Termination (Rp) Requirements

Source Advertisement	Current Source to 1.7 – 5.5 V	Resistor pull-up to 4.75 – 5.5 V	Resistor pull-up to 3.3 V ± 5%
Default USB Power	80 µA ± 20%	56 kΩ ± 20% (Note 1)	36 kΩ ± 20%
1.5 A @ 5 V	180 µA ± 8%	22 kΩ ± 5%	12 kΩ ± 5%
3.0 A @ 5 V	330 µA ± 8%	10 kΩ ± 5%	4.7 kΩ ± 5%

Note 1: For Rp when implemented in the USB Type-C plug on a USB Type-C to ***USB 3.1*** Standard-A Cable Assembly, a USB Type-C to USB 2.0 Standard-A Cable Assembly, a USB Type-C to ***USB 2.0*** Micro-B Receptacle Adapter Assembly or a USB Type-C captive cable connected to a USB host, a value of 56 kΩ ± 5% ***shall*** be used, in order to provide tolerance to IR drop on VBUS and GND in the cable assembly.

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Note 1: For Rp when implemented in the USB Type-C plug on a USB Type-C to ***USB 3.1*** Standard-A Cable Assembly, a USB Type-C to USB 2.0 Standard-A Cable Assembly, a USB Type-C to ***USB 2.0*** Micro-B Receptacle Adapter Assembly or a USB Type-C captive cable connected to a USB host, a value of 56 kΩ ± 5% ***shall*** be used, in order to provide tolerance to IR drop on VBUS and GND in the cable assembly.

Note 2: Each value above is the total current or resistance into the Source CC pin including all leakage and parallel resistance.

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Table 4-28 Sink CC Termination (Rd) Requirements

Rp Implementation	Nominal Value	Can detect power capability?	Max voltage on pin
± 20% voltage clamp[1]	1.1 V	No	1.32 V
± 20% resistor to GND	5.1 kΩ	No	2.18 V
± 10% resistor to GND	5.1 kΩ	Yes	2.04V

Note 1: The clamp implementation inhibits ***USB PD*** communication although the system can start with the clamp and transition to the resistor once it is able to do ***USB PD***.

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Table 4-28 Sink CC Termination (Rd) Requirements

Rd Implementation	Nominal Value	Can detect power capability?	Max voltage on pin
± 20% voltage clamp[1]	1.1 V	No	1.32 V
± 20% resistor to GND[2]	5.1 kΩ[2]	No	2.18 V
± 10% resistor to GND[2]	5.1 kΩ[2]	Yes	2.04V

Note 1: The clamp implementation inhibits ***USB PD*** communication although the system can start with the clamp and transition to the resistor once it is able to do ***USB PD***.

Note 2: This is the total equivalent resistance into the Sink CC pin including all internal resistances.