# AN-5086/D

# USB Type-C, CC Pin Design Considerations

## High voltage design considerations for Type−C connector pins in systems supporting non-USB standard charging protocol and/or fault cases

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APPLICATION NOTE


### SUMMARY

When designing hardware systems with Type−C connectors, a designer also has to consider all legacy, standard, and non-standard specifications that exist in the USB connector eco system. With the introduction of the Type−C connector and the Configuration channel (CC Pin) new challenges occur trying to ensure overall system robustness. This note addresses some of the concerns with the CC pin in a robust system environment.


### DESIGN CONSIDERATIONS – SYSTEM ESD AND SURGE

IEC61000−4−2 (henceforth called just “IEC”) is the industry’s standard for system level ESD testing. IEC testing is a system level test, while other ESD specifications like Charged Device Model (CDM) and Human Body Model (HBM) target the manufacturing process and human handling. Most IC’s have integrated Electro-Static Discharge (ESD) protection intended to protect the device during manufacturing while external protection in the form of a TVS is added for the IEC system level testing. It is very important to understand that, implementing TVS protection at the system level and having it work together with the individual IC, is the best way to achieve overall system robustness.

Below are few important specifications to ensure the right TVS is selected based on the Type−C specification, and the Type−C controller ESD protection.

#### Reverse Standoff Voltage

This specification is important spec to look at when selecting a TVS, due to the types of signals that will utilize the CC pin during normal operation, as well as absolute maximum spec. of the CC controller IC. Selecting the right value ensures the TVS is actually effective in protecting the system. Reverse Standoff Voltage, $V_{RWM,}$ is a common specification in a TVS product data sheet. For the CC pin, we should pick a 5 V maximum for the $V_{RWM}$, due to normal operation of the CC pin, there should never be a case where the CC pin should exceed 5 V, and also the reverse standoff voltage should be lower than the absolute maximum voltage on the CC controller IC.

#### Diode Capacitance

In Power Delivery specification, section 5.8.6, BMC receiver capacitance requirements are shown below in Table 1.

**Table 1. BCM RECEIVER NORMATIVE REQUIREMENTS**

| Name | Description | Min | Nom | Max | Unit | Comment |
|---|---|---|---|---|---|---|
| cReceiver | CC Receiver Capacitance | 200 | − | 600 | pF | The DFP or UFP system shall have capacitance within this range when not transmitting on the line |

The cReceiver requirement of the CC receiver capacitance is 200 pF to 600 pF, this has a direct impact on PD communication. Any device in the CC path, such as a TVS diode, needs to ensure that capacitance of the device does not exceed this specification but can also be used to meet the minimum capacitance requirements. By choosing the appropriate TVS that works well in the system, you can avoid placing additional capacitance on the CC line by utilizing just the diode capacitance.

#### Breakdown Voltage

Breakdown voltage is the voltage threshold where the TVS diode becomes more conductive to ground and allows higher amount of current flow from cathode to anode. Figure 1 shows a typical TVS I−V cure, and as we can see after the $V_{BR,}$ the current shot up very quickly as the TVS became very conductive. The voltage increases until it hits the clamping voltage where the TVS effectively becomes a resistor that shorts to ground. With a large amount of current passing though the TVS, it will eventually burn up and destroy the diode in this clamped state.

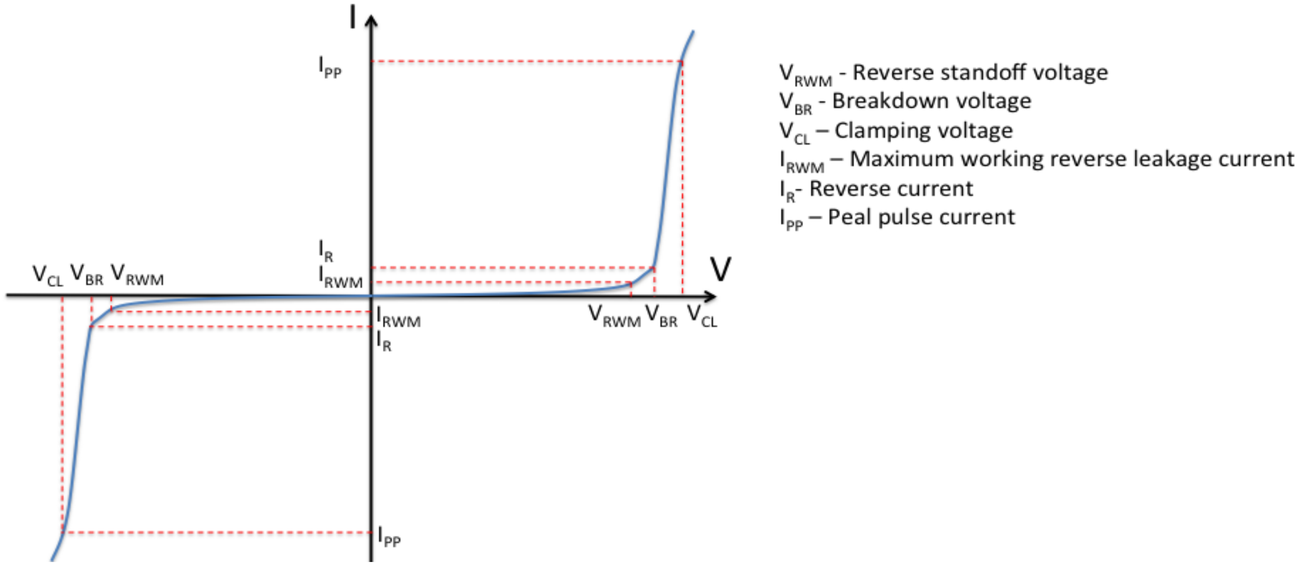


**Figure 1. TVS I−V Curve**

In order to make sure proper function of the Type−C CC line communication, and overall system are protected in ESD/Surge event, the correct breakdown voltage must be considered. In Type−C design, the CC pin break down voltage should be above 5 V to ensure normal operation, and below 7 V to ensure that the TVS can help direct extra charge to ground when fault occurs.

## DESIGN CONSIDERATION – NONE USB STANDARD CHARGING PROTOCOL

Standard USB2.0 spec. of 500 mA charging current is clearly not enough for the majority of the devices in the market today, power/process intensive devices such as mobile phones have implemented higher than standard USB2.0 charging protocol to allow for shorter and faster charging. Due to the limitation of the USB cable it is not ideal to push more than 2.4 A of current. In order to be able to charge at higher wattage, non-Type−C connector based designs have gone above 5 V on $V_{BUS}$ to reduce charging time of the device. Due to backward compatibility support of Type−C, the Type−C specification allows legacy adapters like a Type−A to Type−C Cable. The Type−A to Type−C and Type−C to USB−μB cable integrate an internal pull up resistor ($R_p$) in the cable. Below is a functional model in the specification 4.5.3.2.4.

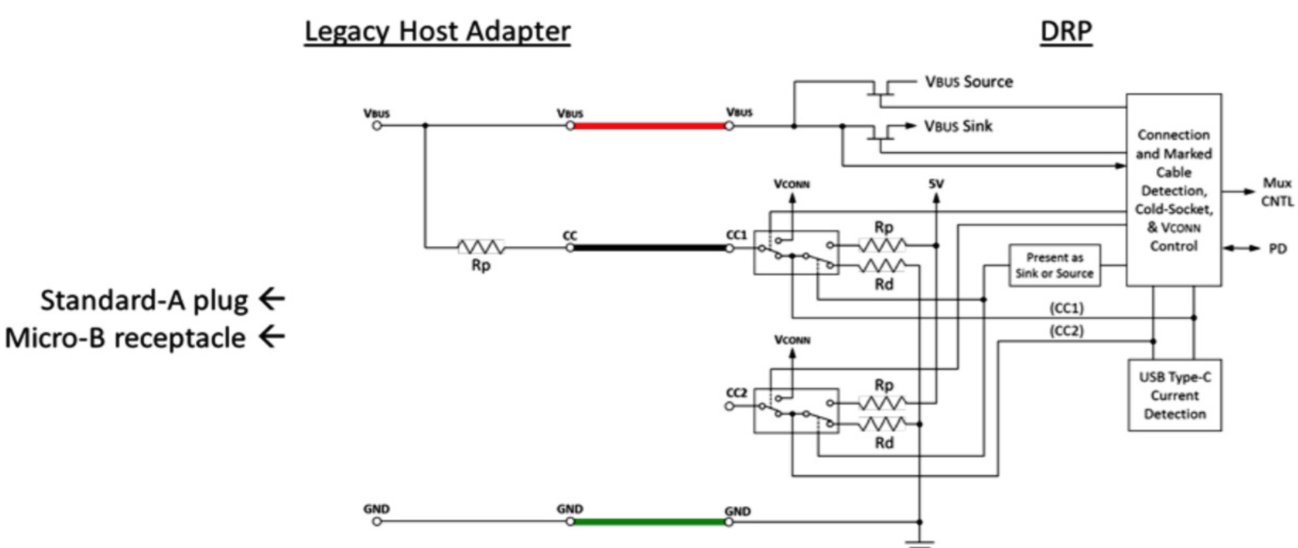


**Figure 2. Legacy Host Port to DRP Functional Model**

In this case when the non-standard USB charging protocol increases the $V_{BUS}$ voltage level, the CC pin will also be pulled up due to $R_p$. When following the Type−C specification, the $R_p$ value should be 56 kΩ, which means there will be two cases of higher than normal voltage present on the CC line.

### Case 1 – $R_d$ is Enabled

We can simply calculate the voltage that will show up on the CC line with Equation 1.

$$V_{CC} = V_{BUS} \times 0.0835 \qquad \text{(eq. 1)}$$

Assume $R_d$ = 5.1 kΩ, $R_p$ = 56 kΩ

In Table 2 we can find the typical $V_{BUS}$ voltage of non-standard charging protocol and its corresponding CC voltage.

**Table 2. $V_{BUS}$ TO CC VOLTAGE WHEN $R_d$ ENABLED**

| $V_{BUS}$ | $V_{CC}$ |
|---|---|
| 9 V | 0.75 V |
| 12 V | 1.00 V |
| 15 V | 1.25 V |
| 20 V | 1.67 V |

Table 2 shows that voltage on CC line is still relatively low, so there is no high voltage concern for this case.

### Case 2 – $R_d$ is Disabled

With $R_d$ disabled, the CC line will be pulled high to $V_{BUS}$ voltage, so in this case high voltage will show up on the CC line, thus protection is needed. However, since the current is limited by the 56 kΩ we can uses the Zener diode to clamp the voltage down. We will discuss how to select the correct Zener in the next section. If the proper Zener diode is selected, it can also protect against Illegal Type−A to Type−C cables with incorrect $R_p$.

### Case 3 – Rapid Insert and Removal of Cable

Some non-standard USB legacy chargers achieve faster charging time by increasing the $V_{BUS}$ voltage. In certain cases, when a user unplugs the device from the charger/host adapter and cable, while the system is charging at higher than 5 V, there will be a short time period for the charger to recognize disconnect event and disable the $V_{BUS}$ supply. During this time, if the $R_p$ is still connected to $V_{BUS,}$ and since it is no longer connected to the device, the residual charge will bring the CC pin to the same voltage as $V_{BUS}$ and slowly discharge over time. If the user decides to quickly plug the charger back in, there will be a higher than normal voltage on the CC pin that we would need to consider. However, in this case the time duration is very short, and the charge remaining on the CC pin is not very large. Incorporating a protection device like a Zener diode or TVS diode in the system can prevent damages to the system.

## DESIGN CONSIDERATION – ILLEGAL TYPE−A TO TYPE−C CABLE

The support of existing standard A connectors/host adapters was achieved with a Type−A to Type−C cable shown in Figure 3. Although, the Type−C Specification is public, there are still a lot of bad cables with illegal $R_p$ resistors made and being sold on the market today. Application note AN−6012 explains in detail the bad/illegal cable and how to utilize the Zener diode to protect against it, as well as how to pick the right Zener diode to use.

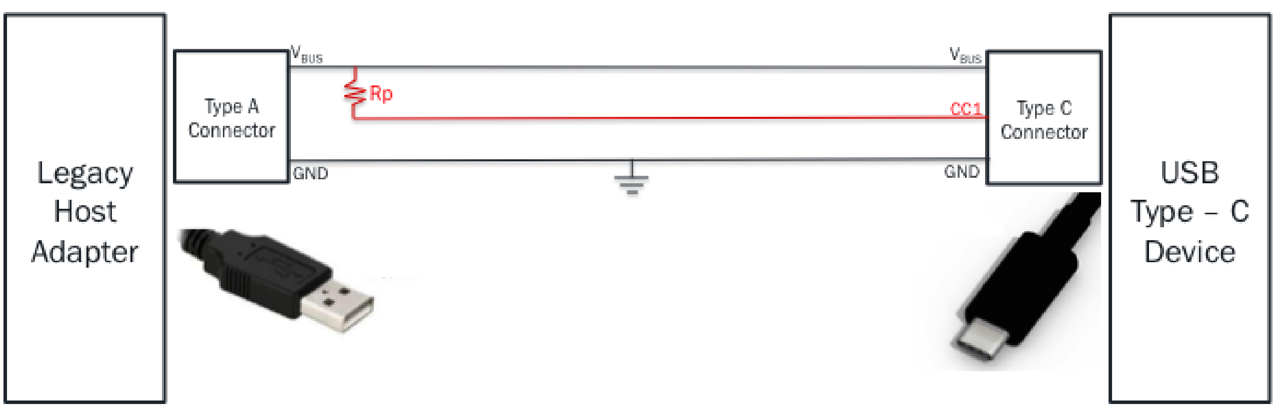


**Figure 3. Example of Type−A to Type−C Cable**

## RELATED RESOURCES

- FUSB301 − Autonomous USB Type−C Controller with Super Speed Switch Control
- FUSB301A − Autonomous USB Type−C Control with Configurable I$^2$C Address
- FUSB302 − Programmable USB Type−C Controller w/PD
- AN−6102 – USB Type−C, CC Pin Protection Application Note
- AN−6105 – USB Type–C Design Considerations



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