Whitepaper

Choosing ESD protection devices for USB4™

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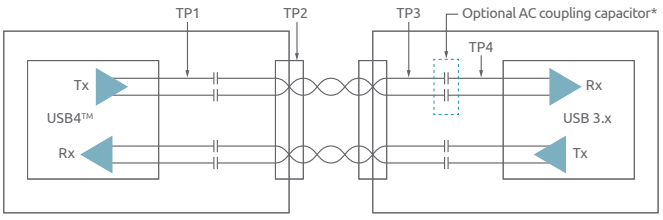
The new USB4™ specification introduced some changes, which have consequences for the selection of ESD protection components. Obviously, ESD protection needs to add low insertion loss (signal attenuation) and low return loss (signal reflection) to the system while offering low clamping to protect sensitive high-speed data lines. However, comparing the USB4™ and USB 3.2 specifications, we came across a point which might be easily overlooked – operation voltage.

The USB infrastructure is defined by these three specifications:

- The new USB4™ as well as both USB 3.2 and USB 2.0 specifications are defining the performance of an USB interface, offering up to 40 Gbps data transmission for USB4™.
- The USB Power Delivery specification is extending the possible USB power supply voltage and current levels offering up to 100 W over an USB Type-C® cable.
- Most end users will recognize the convenience of the USB Type-C® - specification however, the USB Type-C® cable and connector infrastructure is also needed to unleash the full potential offered by the USB4™ and USB Power Delivery specifications.

As a reference point, we would like to refer to Test Points TP2 and TP3 of this simplified model:



*The capacitor is optional for USB 3.2 and mandatory for USB4™, but not shown in earlier USB 3.x specifications

Figure 1: Definition of test points when an USB 3.2 system is connected to an USB4™ system

Following the signal flow, the Transmitter Tx is followed by an AC coupling capacitor, the connector (TP2), the cable and the connector of the receiver device. Between TP3 and TP4 is a second AC coupling capacitor, which was introduced as optional for USB 3.2 and is mandatory for USB4™.

Apart from being able to ignore the plug orientation, the main benefit of USB Type-C® for the end customer is the ability to connect two applications using USB Type-C® and leave it to both applications to negotiate the best way of interaction over USB Type-C®. This means, we can expect that an USB 3.2 or older 3.x enabled application (say an external HDD) will be connected to an USB4™ enabled application (say a computer).

What does this mean for the voltages to expect? Since the USB specifications are available to everyone on usb.org, this can be easily checked. Looking at Table 6.19 of the current USB 3.2 specification, there is a parameter *VTX-DC-CM (Transmitter DC common-mode voltage)*, which is explained to be *"The instantaneous allowed DC common mode voltages at the connector side of the AC coupling capacitors"*. If we ignore voltage drops due to connectors and cable, this translates to TP2 and TP3.

Still in table 6.19 of the USB 3.2 specification, the maximum of this DC voltage is defined to be +/- 2.2 V. Adding 300 mV due to voltage swing, the instantaneous AC+DC voltage at TP2 and TP3 can be up to 2.5 V. Rx detect can in principle add up to 0.6 V, which will raise this Voltage at TP2 and TP3 to 2.8 V.

Regardless, whether looking at USB4™ or USB 3.x systems, this leaves two options for the placement of ESD protection devices: They can either be placed directly at the connector (TP2 or TP3), which is the most efficient position for system-level ESD performance. In this case, they need to be able to handle the higher voltages, which can be introduced by connecting USB 3.x systems. If the ESD protection device becomes conductive at lower voltages, it must be placed at TP1 or TP4.

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Just for the record, an AC coupling capacitor of roughly 330 nF together with a single-ended line impedance of 42.5 Ohms will form a high-pass filter with a cut-off frequency of ~ 11.4 kHz and will not offer much protection by itself against fast transients such as ESD.

Placing ESD protection at TP1 or TP4 has two disadvantages, though.Firstly, this leaves the AC coupling capacitance unprotected against ESD strikes. Secondly, ESD protection is most effectivewhen placed right at the ESD entry point to the system, theconnector. To demonstrate this, we compare two H-field scans of an ESD event[1]. In this special case, the designer has placed a second ESD protection device (marked prot2) in the middle of the board on top of an ESD protection device at the connector (marked prot1). In the right picture, this second ESD protection device has been removed, while in the left picture, this ESD protection device in the middle of the board is actually increasing the amount of ESD entering the system.

As a further side note, USB Type-C® allows to transmit other data such as HDMI® in the ALT mode. It is suggested to anyone, developing HDMI over Type-C applications to check the possible voltages in this configuration. Nexperia is offering solutions for this case as well.

Comparison of EMI scans of USB 3.x transceiver board

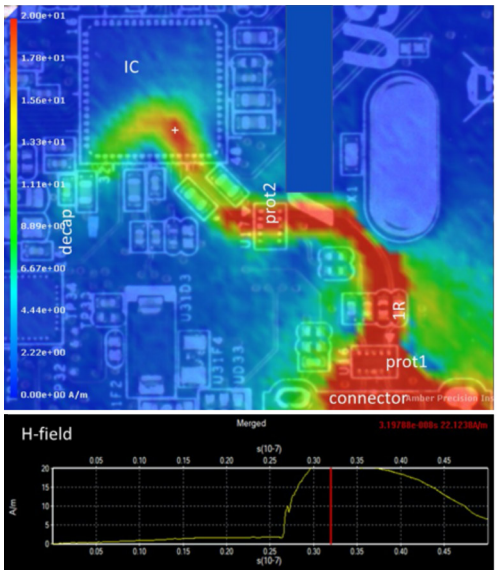

Figure 2: Original board with second ESD protection in the middle of the board (prot2) [1]

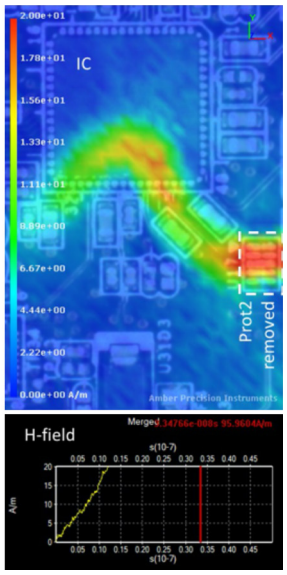

Figure 3: Same board with second ESD protection removed shows a reduction of the current flowing into the transceiver [1]

Summary

- The flexibility of the USB Type-C® connectors allows to connect devices using different data standards such as USB4 and USB 3.2 as well as older USB 3.x standards.
- The best position to place ESD protection is at the entry point, directly behind the connector.
- If ESD protection for USB4 is placed in this position, the voltage rating of this ESD protection device should be backwards compatible to all standards, which can be connected over USB Type-C®.

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[1] Notermans, G. & Bub, Sergej & Hilbrink, Ayk. (2018). Predicting System Level ESD Performance. 195-201. 10.7148/2018-0195.
http://www.scs-europe.net/dlib/2018/ecms2018acceptedpapers/0195_is_ecms2018_0882.pdf

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