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.

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.
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 effective when placed right at the ESD entry point to the system, the connector. To demonstrate this, we compare two H-field scans of an ESD event\(\textsuperscript{[1]}\). 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\textsuperscript{®} allows to transmit other data such as HDMI\textsuperscript{®} 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.

Summary

- The flexibility of the USB Type-C\textsuperscript{®} 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\textsuperscript{®}.