Design Considerations for Connecting Multiple DSAs in a Cascaded-Series Configuration

Application Note 79

Summary

This application note provides the design considerations needed to connect multiple digital step attenuators (DSAs) in a cascaded-series configuration. In many applications, customers want to achieve a high attenuation value, and this higher value can be achieved by cascading multiple DSAs in series. In general, the cascaded DSAs are placed close together in a small space with shared control inputs and V_{DD} connections. A total attenuation value above 50 dB can be difficult to achieve without careful attention to the layout and design considerations. These layout and design considerations are detailed in this application note

Introduction

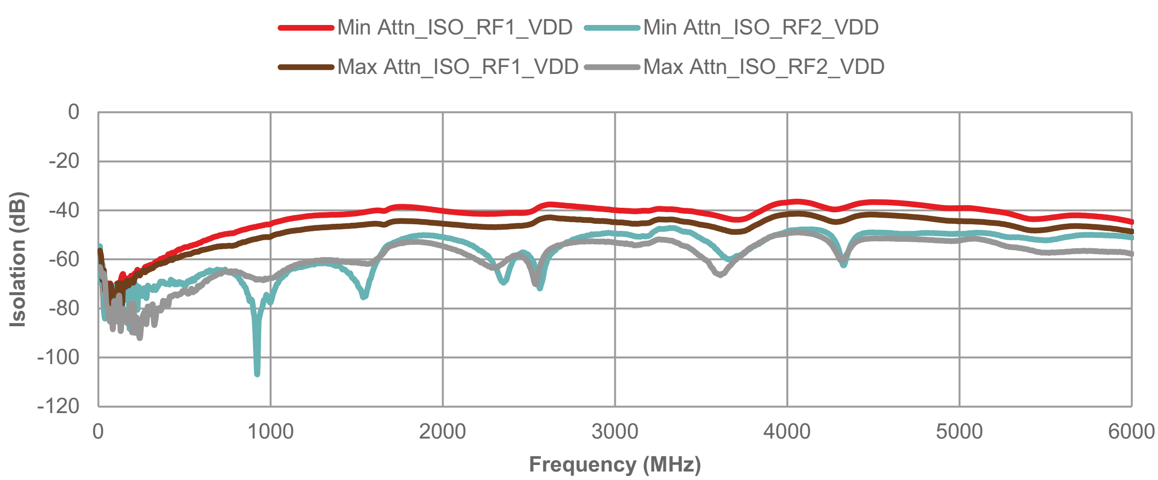
The two main considerations when cascading DSAs are the conducted leakage and radiated leakage across the circuit. Both types of leakage require that the circuit layout and the circuit interconnections be carefully defined. These leakage issues are detailed below.

Isolation Between the Digital Control or V_{DD} Connections and the DSA RF Ports

Conducted Leakage

Conducted leakage is the leakage of the RF signal across the circuit connections. In this case, we are considering the leakage from the V_{DD} or digital connections to the RF ports. These connections are often shared between cascaded DSAs and can be routes of leakage between the cascaded DSAs, which can in turn disturb each DSA's attenuation accuracy. **Figure 1** shows the isolation between digital lines and RFx ports for the pSemi PE43711 DSA. The result is almost 40 dB of isolation across the whole band of operation. This high level of isolation is typical of pSemi products. The same isolation is expected for the other digital pins such as control lines and serial interfaces as shown in **Figure 2**.

Figure 1 ▪ PE43711 V_{DD} to RF Ports Isolation

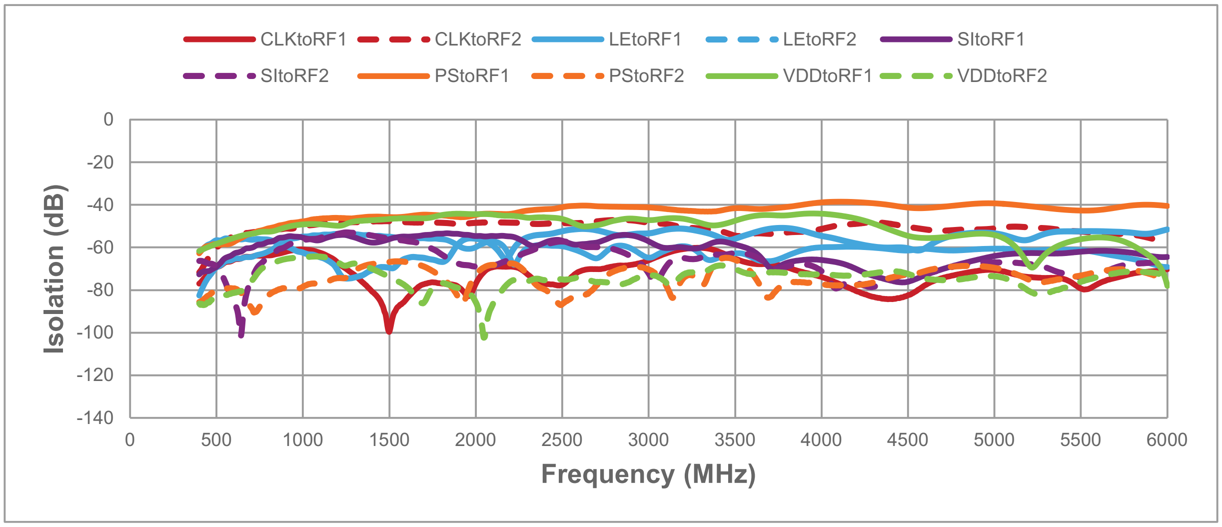


From **Figure 1**, we can assume the V_{DD} to RF isolation is approximately 40 dB in general. We cannot assume that this isolation is purely due to the conducted isolation of the part. We need to exclude any leakage caused by inadequate radiated isolation.

Radiated Leakage

Figure 2 shows the isolation from the V_{DD} to the RF port when RF shields are placed over the devices. The figure also includes isolation measurements for all of the other digital control lines (SI,CLK,P/S and LE) used in serial bus control. The parallel DSA control inputs (D1–D7) are all grounded. From this result, it is apparent that the shield has only a limited effect on the isolation. We can now conclude that the measured leakage from the control and V_{DD} lines is mostly conducted rather than radiated.

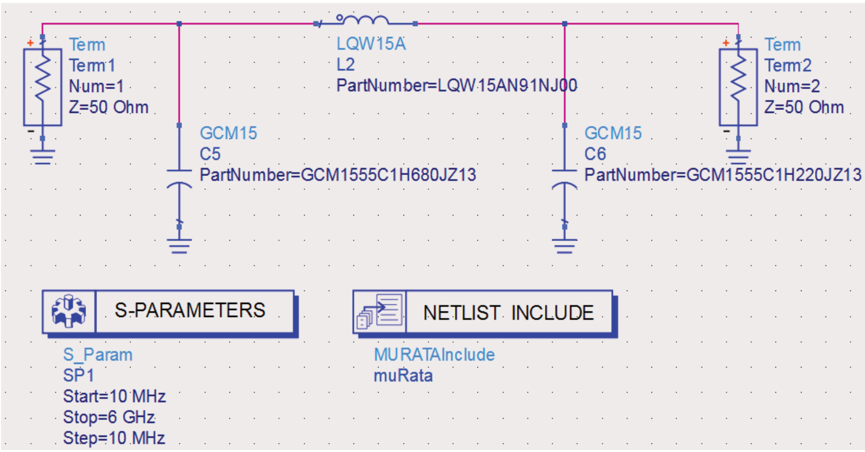
Figure 2 ▪ Isolation Between RFx and DC Lines—with Shield



In-line Filter Design

By applying a suitable filter to the V_{DD} and control lines, we can show that the leakage is dominated by the conducted leakage via the control and V_{DD} line. **Figure 3** shows the response and implementation of a suitable low-pass filter used in-line for all the control and V_{DD} connections.

Figure 3 ▪ Low Pass Filter and S-parameter



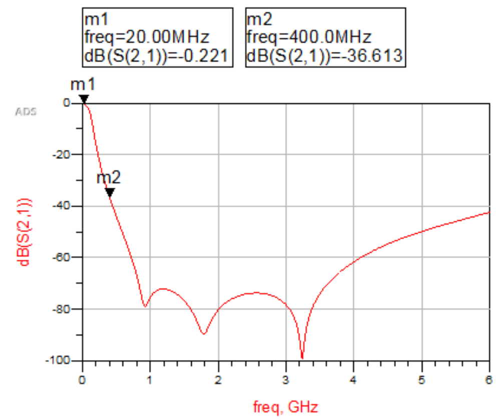
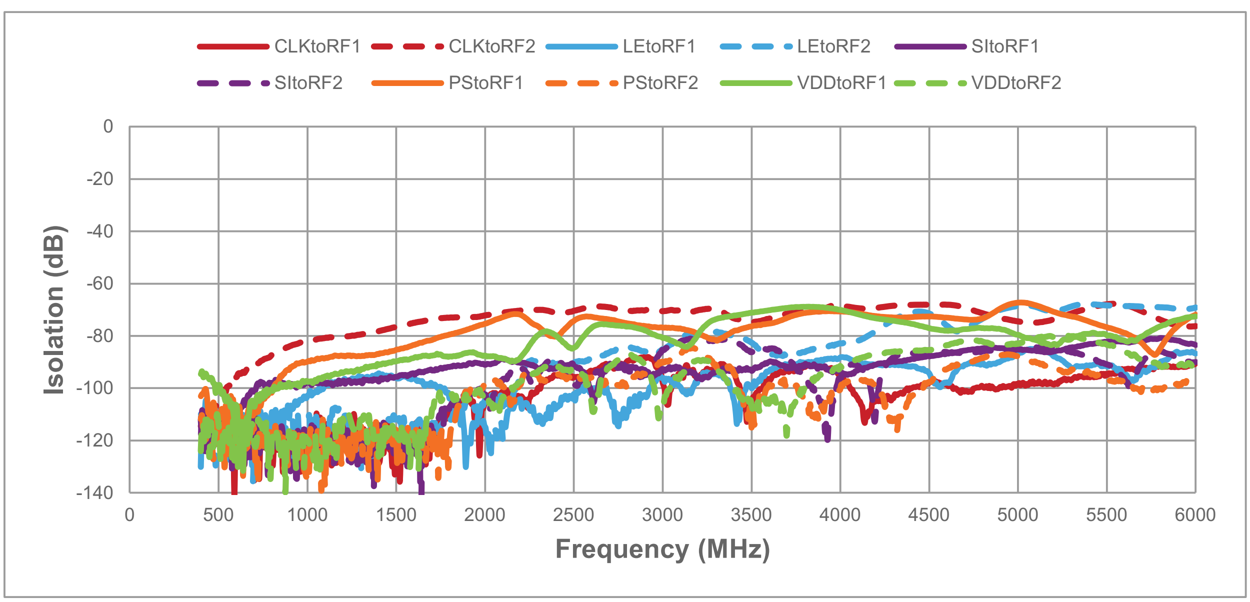


Figure 4 shows the resultant isolation from the control and V_{DD} lines to the RFx ports with the in-line filters placed in circuit and with a shield in place. It shows an isolation improvement of 20 to 30 dB with a minimum isolation of 65 dB. This result means that the minimum conducted isolation between any two RF ports via the control or V_{DD} pins should now be now >120 dB.

Figure 4 ▪ Isolation between RFx and DC Lines with In-line Filter and Shield



Final Design

With this information, we can now design a layout for the cascaded DSA board. This layout is shown in **Figure 5** with the schematic, including the in-line filters, shown in **Figure 6**.

Figure 5 ▪ Four-Cascaded PE43712 DSA Board

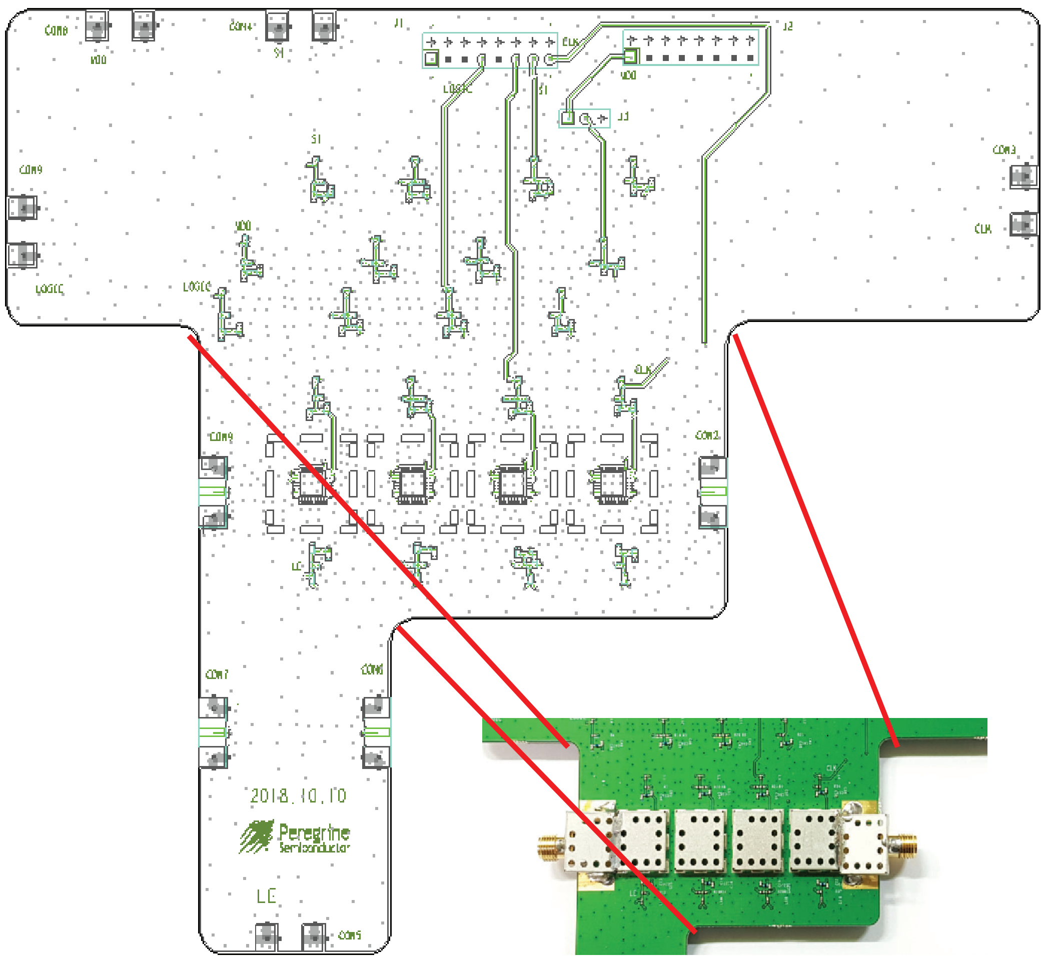
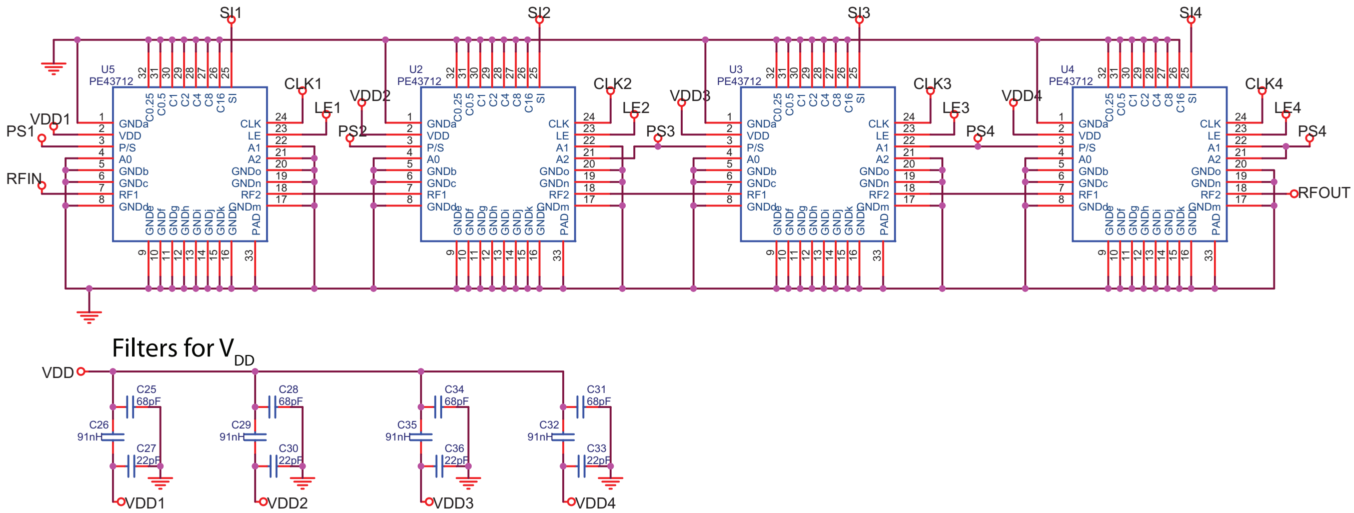


Figure 6 ▪ Four-Cascaded PE43712 DSA Schematic—Serial Addressable Control



Same filters can be applied to control lines.

Using this board, we can demonstrate the effect of the in-line filters and the RF shields on a typical cascaded DSA attenuation setting of 80 dB.

Figure 7 ▪ Attenuation vs. Frequency (@ 80 dB Attenuation) With and Without In-line Filters

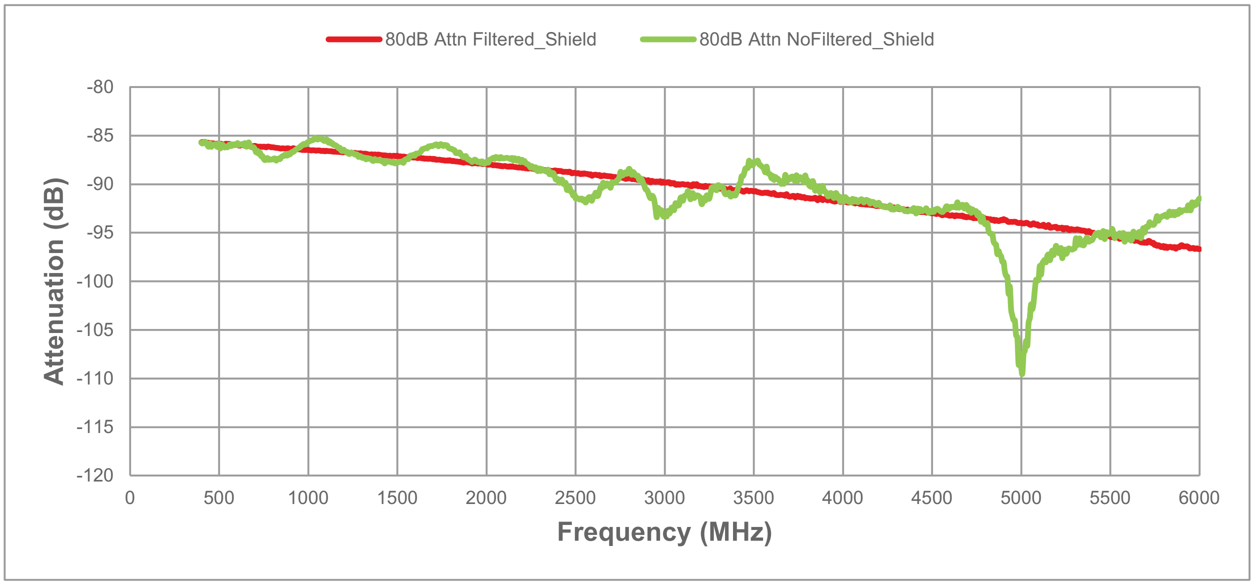
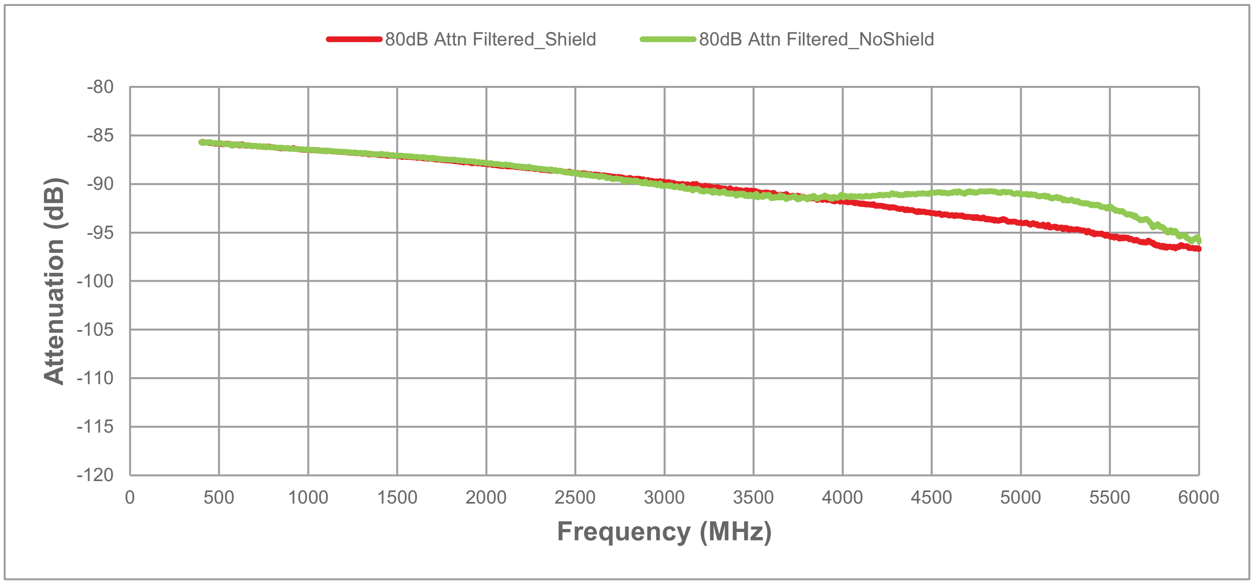


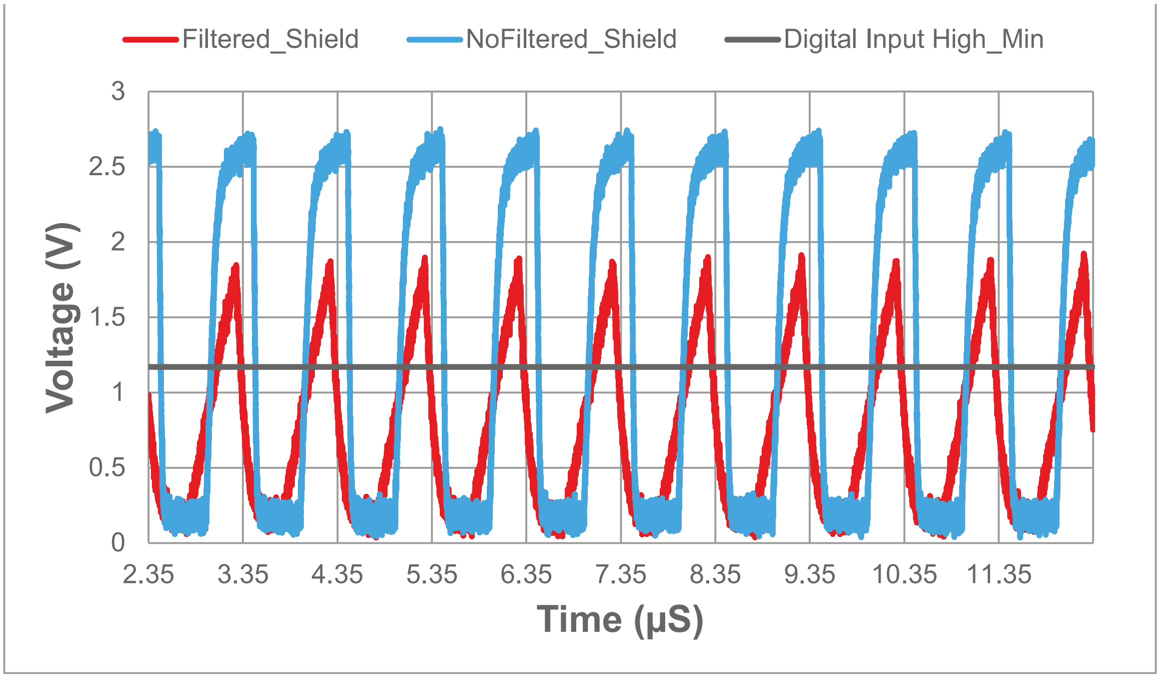
Figure 8 ▪ Attenuation vs. Frequency (@ 80 dB Attenuation) With and Without RF Shields



These results clearly show the effect of the filters on the DSA attenuation accuracy across all frequencies. **Figure 8** also shows the effect of the RF shields at the higher frequencies.

An important factor must be addressed when implementing in-line filters on the control lines.The designer must ensure that the filters do not degrade the clock and data signals. The clock and data rate must be carefully considered when implementing the filters. **Figure 9** shows the effect of the in-line filter on the 1 MHz clock signal, which shows the clock still transitions correctly.

Figure 9 ▪ Serial Interface Clock 1 MHz Waveforms With and Without In-line LPF



Results

Figure 10, **Figure 11**, and **Figure 12** show three plots of attenuation over the full attenuation ranges of all four DSAs with 5 dB steps from 0 dB to 125 dB and the maximum attenuation state of 127 dB. These figures show the effect of the RF shields and the in-line filters, and the final result with both in place. The red line is the measurement of the VNA noise floor.

Figure 10 ▪ Attenuation vs. Frequency (5 dB step); No Filter with Shield

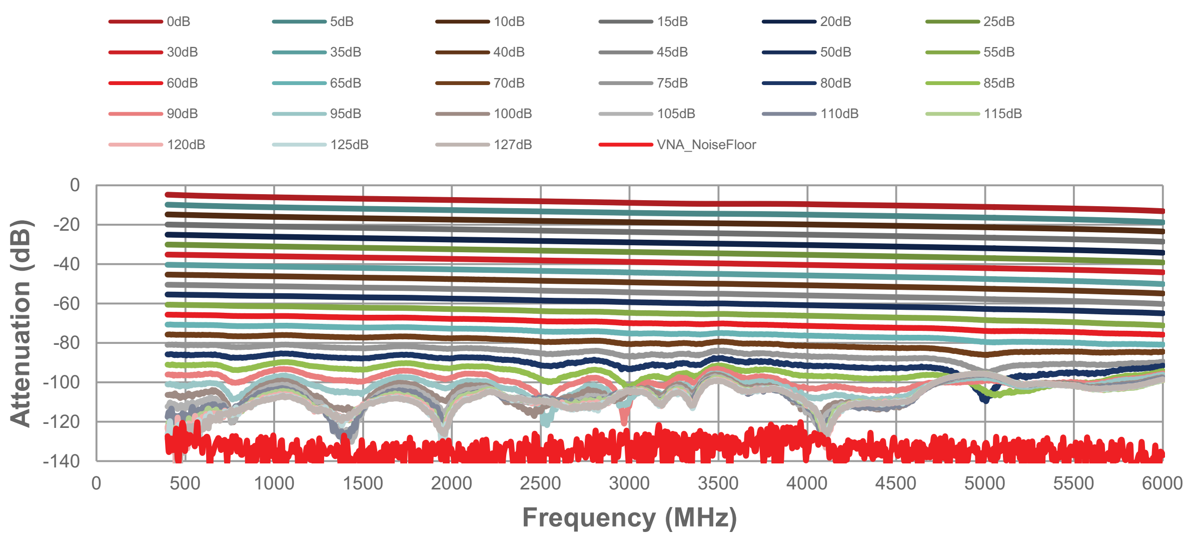


Figure 11 ▪ Attenuation vs. Frequency (5 dB step) with In-line Filter Without Shield

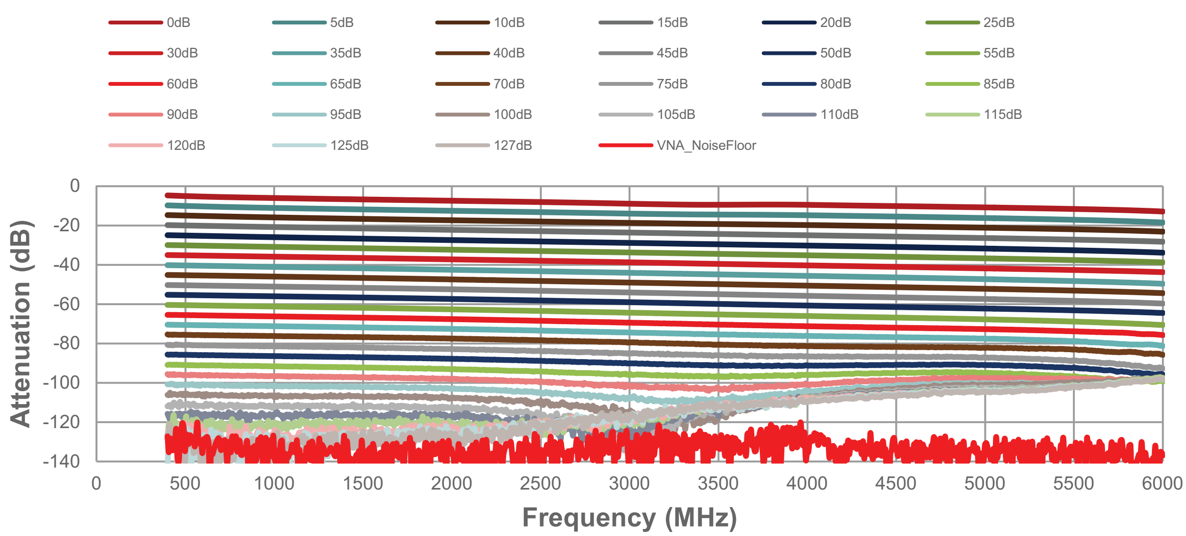
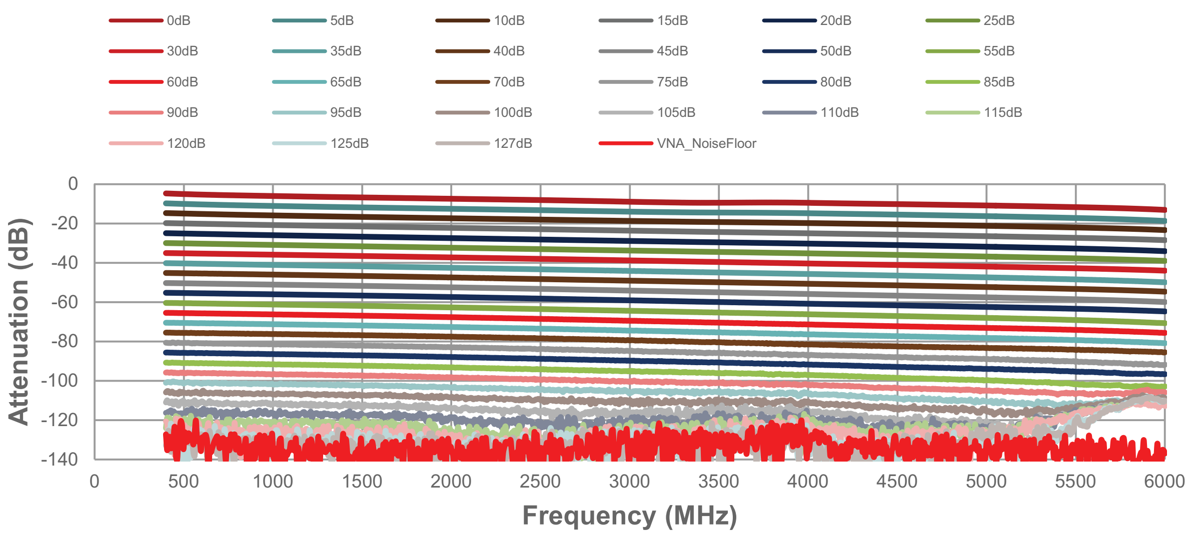


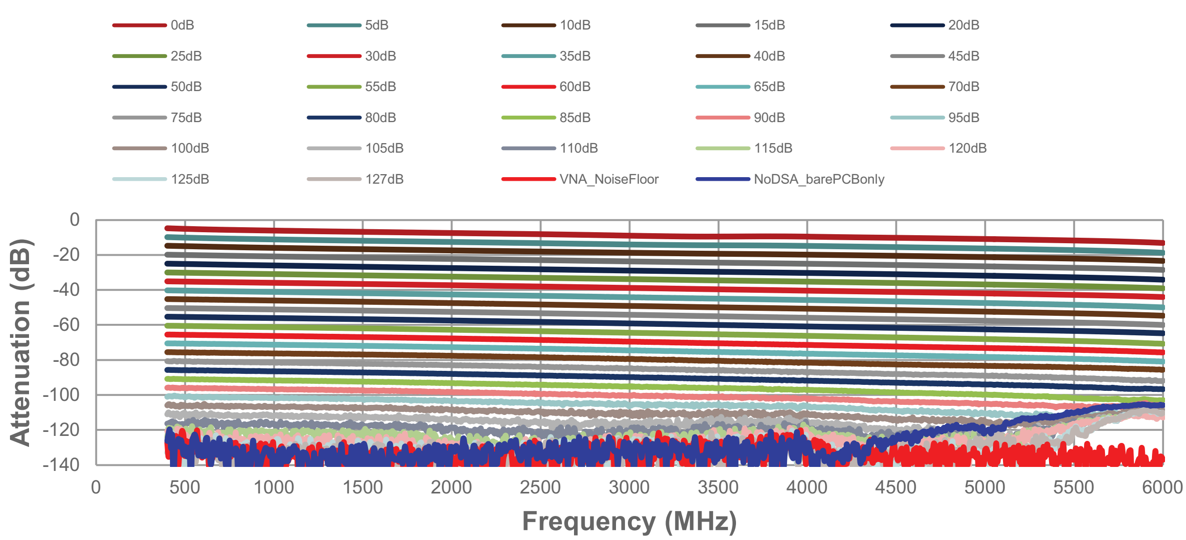
Figure 12 ▪ Attenuation vs. Frequency (5 dB Step) with Both In-line Filter and Shield



These results clearly show that both the in-line filter and RF shields are important for a successful design using cascaded DSAs when trying to achieve the highest attenuation across the whole frequency of operation. Only above 5 GHz does leakage around the DSA cause the attenuation to fall below that expected.

Figure 13 shows the board RF input to RF output isolation with the filters and RF shields in place but without the DSAs assembled to the board. This result shows that there is still some leakage across the board. To address this leakage, attention should now be focused on the adoption of vigorous EM simulations for the coplanar or stripline design, ground plane isolation, and the number and size of ground plane vias.

Figure 13 ▪ Attenuation vs. Frequency (5 dB Step)—Filtered_Shield



Conclusion

We have shown it is possible to produce a high value attenuator by cascading several DSAs in series. However DC and control line isolation and radiative isolation should be carefully considered to achieve the highest attenuation. Isolation can be improved with low pass filters on the shared the digital lines provided that the digital signal integrity is also considered. Radiative isolation can be improved with RF shields and inner layer design of the RF signals path. If customers need very high attenuation levels > 95 dB, the isolation of the board itself should be considered carefully using EM simulation to ensure better isolation of the bare board.

Sales Contact

For additional information, contact Sales at sales@psemi.com.