

There Are More Ways than You Think to Reduce Conducted EMI



Vental Mao

Electromagnetic interference (EMI) is a troublesome issue in certain designs, especially in automotive systems, like infotainment, body electronics, ADAS and so on. When designing the schematic and drawing the layout, designers usually minimize noise at the source by reducing the high di/dt loop area and slowing down the switching slew rate.

However, sometimes no matter how carefully they design the layout and schematic, they are still unable to reduce the conducted EMI to required levels. The noise depends not only on the circuit parasitic but is also related to the current level. In addition, the action of switch turn-on and turn-off creates discontinuous current. Discontinuous current causes voltage ripple on the input capacitor, which increases EMI.

So it's a good idea to consider other ways to improve conducted EMI performance – adding an input filter to smooth the voltage perturbations or adding a shield to block the noise.

Figure 1 shows a simplified EMI filter, which includes a common-mode (CM) filter and a differential mode (DM) filter. Generally, the DM filter filters noise less than 30MHz and the CM filter filters noise from 30MHz to 100MHz. Both filters have an effect on the entire frequency band where EMI needs limiting.

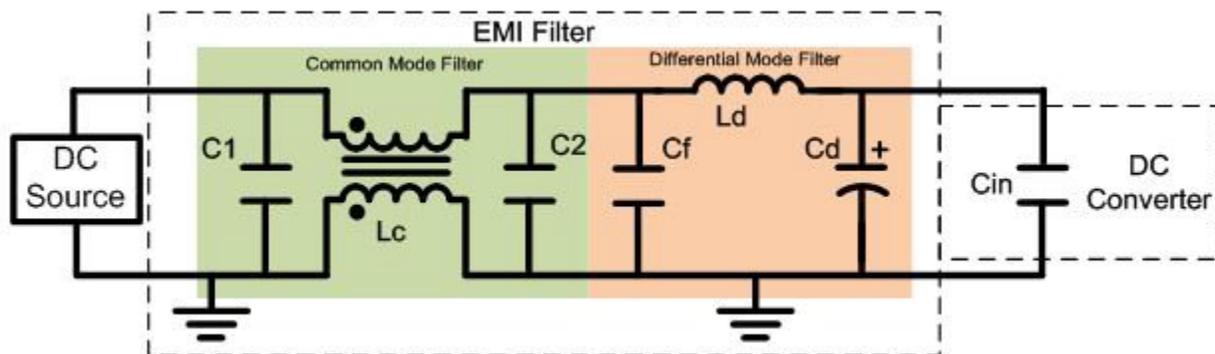


Figure 1. A Simplified EMI Filter

For example, Figure 2 shows the positive and negative noise from the input wire without any filter in the infotainment system, as well as both the peak and average noise. The system tested uses TI's SIMPLE SWITCHER® LMR14050-Q1 single channel buck converter to generate 5V at 5A and the TPS65263-Q1 triple channel buck converter to generate 1.5V at 3A, 3.3V at 2A and 1.8V at 2A. The switching frequency is 2.2MHz. The conducted EMI standard in the figure is Comité International Spécial des Perturbations Radioélectriques (CISPR) 25 Class 5.

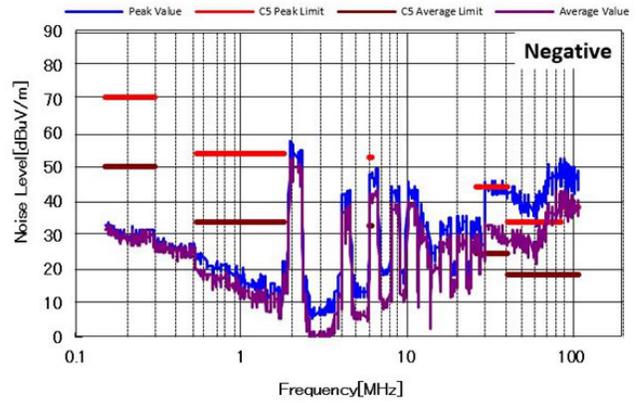
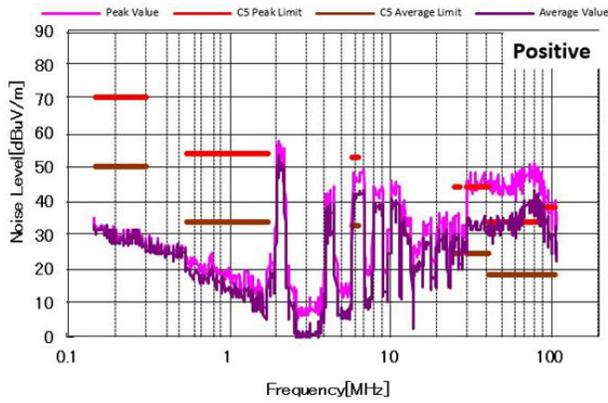


Figure 2. Noise without Any Filter against the CISPR 25 Class 5 Standard

Figure 3 shows the EMI result with a DM filter. The DM noise is attenuated nearly 35dB μ V/m by the filter in the middle frequency band (2MHz to 30MHz). The high-frequency noise (30MHz to 100MHz) is also reduced, but still exceeds the limit level. That is because a DM filter does not effectively filter CM noise.

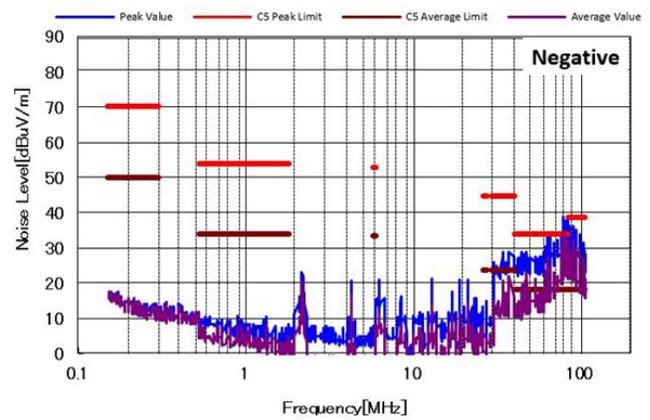
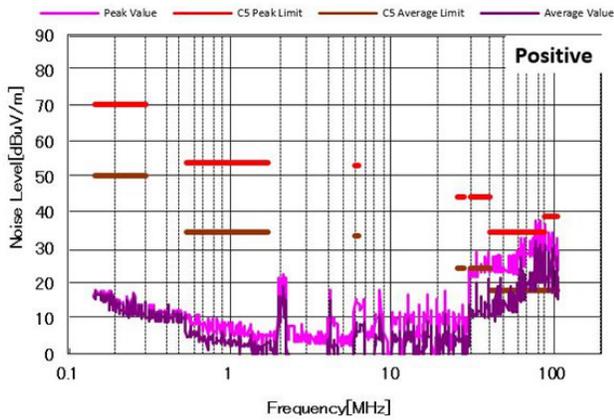


Figure 3. Noise with a DM Filter against the CISPR 25 Class 5 Standard

Figure 4 shows the noise with a DM and CM filter. Compared to Figure 3, the CM filter decreases CM noise by nearly 20dB μ V/m. The EMI performance passes CISPR 25 Class 5.

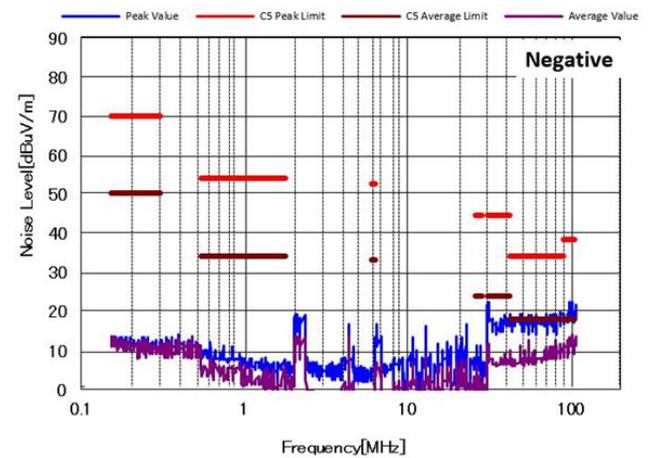
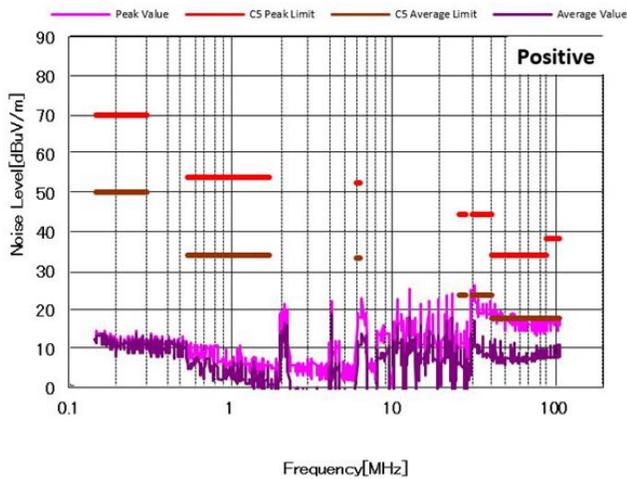


Figure 4. Noise with a DM and CM Filter against the CISPR 25 Class 5 Standard

Figure 5 also shows the noise with a DM and CM filter (the same filter with Figure 4), but with a different layout. Compared to Figure 4, the noise in the whole frequency band increases approximately 10dB μ V/m. Even worse, the high-frequency noise exceeds the standard limit.

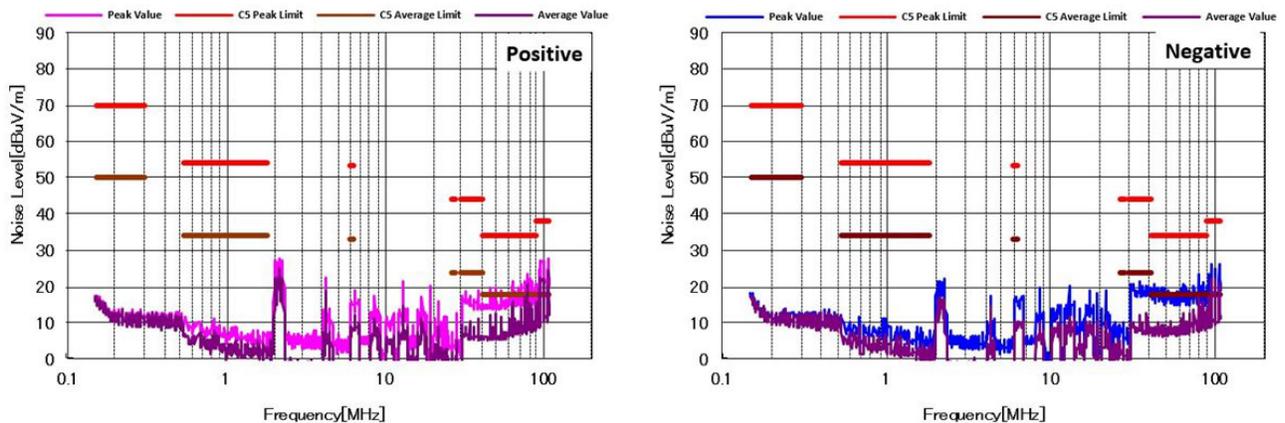


Figure 5. Noise with a DM and CM Filter against the CISPR 25 Class 5 Standard

Figure 6 shows the difference in the layout that caused the different results between Figure 4 and Figure 5. In Figure 5's layout, shown on the right side of Figure 6, the large overlying copper (GND) and V_{IN} trace form some parasitic capacitors. These parasitic capacitors provide a low impedance path for the high-frequency signal to bypass the filter. So in order to maximize the effectiveness of the filter, you must remove the overlying copper around the filter in every layer, like the layout shown on the left side of Figure 6.

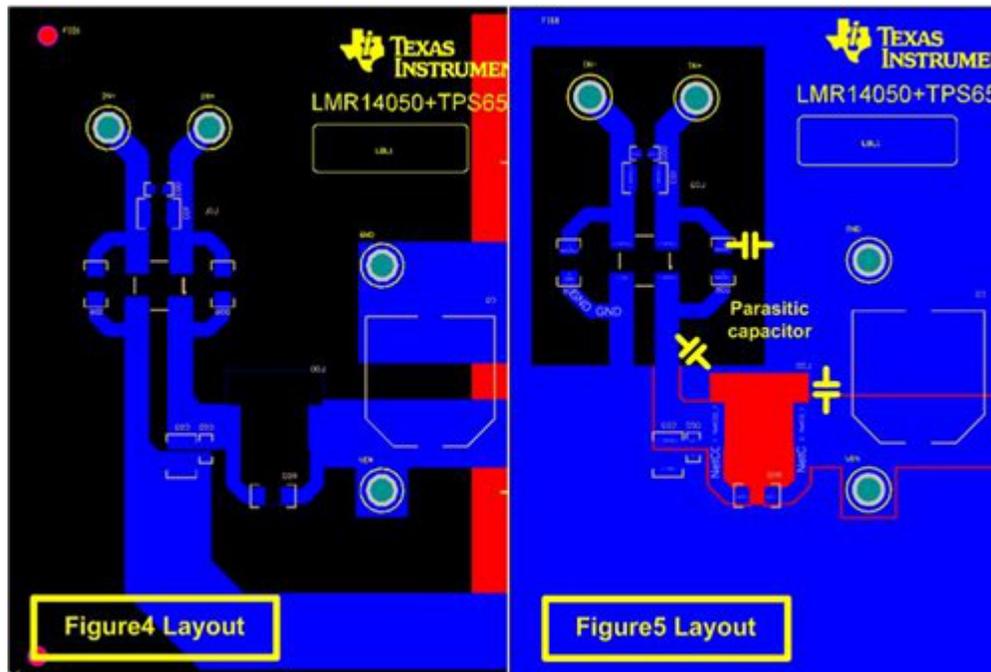


Figure 6. Different Filter Layouts

Another effective way to optimize EMI performance is to add a shield. A metal shield connected to GND can block the radiated noise. Figure 7 shows the board with the suggested placement of the shield. The shield covers all components except the filters.

Figure 8 shows the EMI result with all of the filters and the shield. In Figure 8, the shield almost eliminates noise in the whole band, so the EMI performance is excellent. The shield reduces radiated noise coupling with the long input wire, which acts as an antenna. In this design, the middle-frequency noise typically couples in this way.

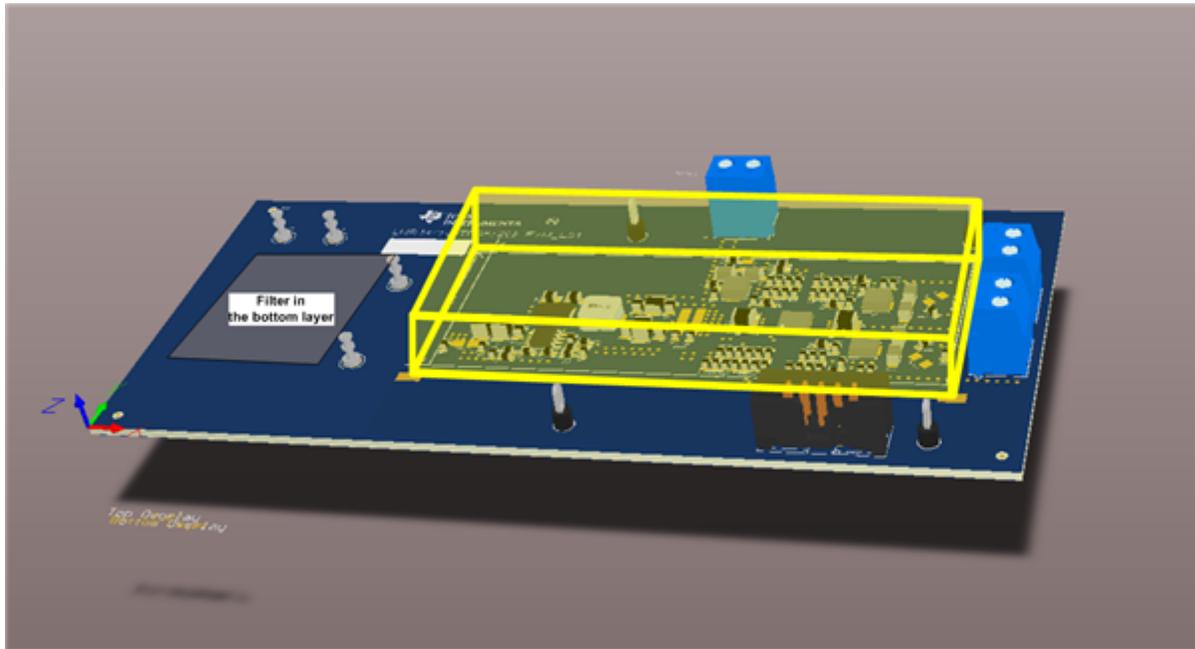


Figure 7. Board with a Shield

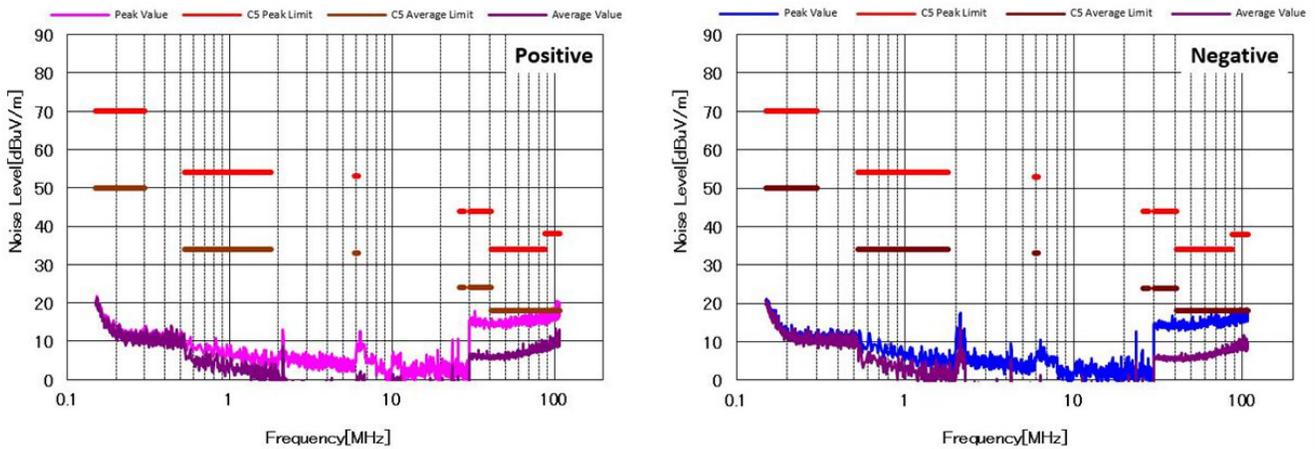


Figure 8. Noise with All Filters and a Shield against the CISPR 25 Class 5 Standard

Figure 9 also shows the noise with all filters and a modified shield. In Figure 9, the shield is a metal box enclosing the whole board; only the input wires are outside. With this shield, some radiated noise can bypass the EMI filter and couple to the power wires in the PCB, which results in worse EMI performance than the shield in Figure 8. Interestingly, the EMI result in the high-frequency band is almost the same as in Figure 4, 8 and 9 (they are all the same layout). That is because radiated noise is almost nonexistent in the high-frequency band for this design.

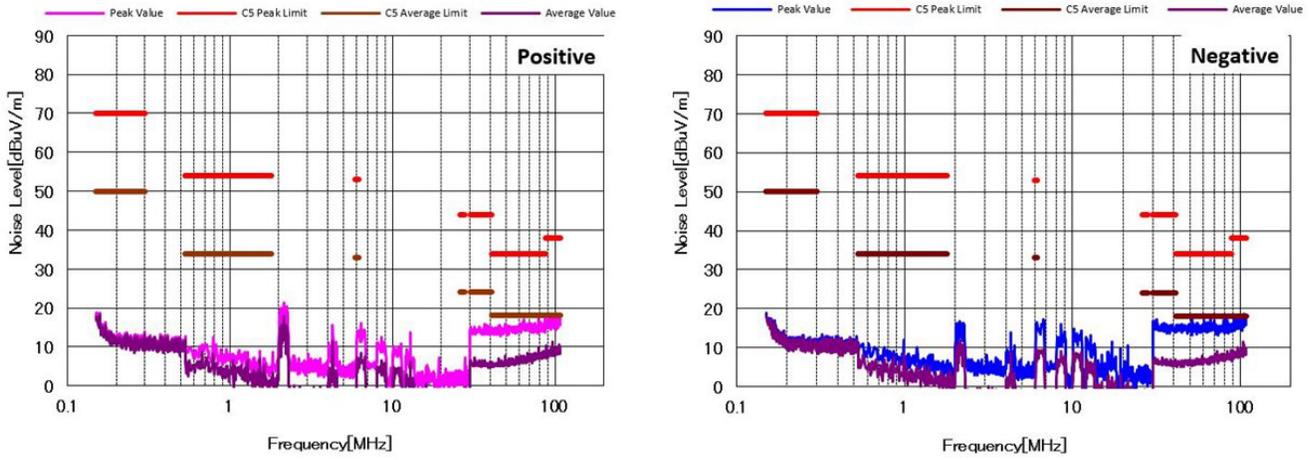


Figure 9. Noise with All Filters and a Shield against the CISPR 25 Class 5 Standard

In general, adding an EMI filter and shield are both effective ways to improve EMI performance in automotive systems. At the same time, be careful with the layout of the filter and the position of the shield. Read the application note, "[Low Conducted EMI Power Solution for Automotive Digital Cockpit with LMR14050 and TPS65263](#)" for more information.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2023, Texas Instruments Incorporated