khs instruments

EMI Filter Development and Evaluation with analog::blocks

From LISN Measurements to TEM Cell Evaluation

Application Note

Rev. 1.0

© Dr. Schmidt Messtechnik • Annette-Kolb-Weg 9 • D-85635 Höhenkirchen • Tel: +49 (0)8102 / 779172 • www.khs-instruments.com

A Modular Approach to Conducted and Radiated Interference Measurements

1. Introduction

Switching DC/DC converters generate high-frequency interference that can propagate along their supply lines and contribute to radiated emissions.

Developing an effective EMI filter requires measurements of both conducted and radiated interference. In addition to the filter components themselves, PCB layout, grounding and parasitic impedances have a significant influence on the results.

The analog::blocks platform provides an RF-optimized modular environment for investigating these effects.

This application note demonstrates a three-stage approach to EMI filter development:

1. Measure the conducted interference generated by a DC/DC converter using a plug-in LISN module.
2. Insert and optimize a filter module between the LISN and the converter.
3. Evaluate the resulting reduction of radiated interference using a TEM cell.

The same modular hardware concept is used throughout the development process.

2. Measuring Conducted Interference with the LISN Module

The first step is to characterize the interference generated by the DC/DC converter without an additional filter.

An analog::blocks LISN (Line Impedance Stabilization Network) module is inserted between the power supply and the DC/DC converter.

The LISN provides a measurement port for observing high-frequency disturbances on the supply line with a spectrum analyzer.

The measured spectrum identifies the frequencies at which the converter produces significant interference and establishes a reference for subsequent filter measurements.

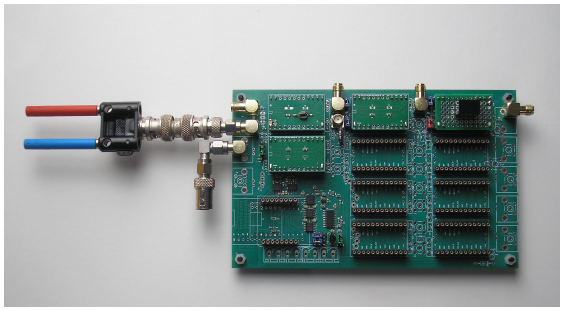


Figure 1: analog::blocks LISN module and unfiltered DC/DC converter.

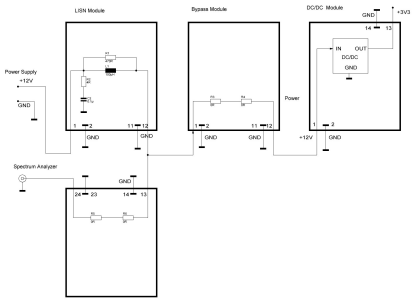


Figure 2: analog::blocks LISN module and unfiltered DC/DC converter schematic.

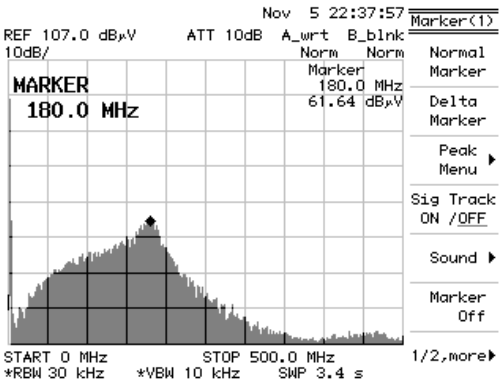


Figure 3: Spectrum of the DC/DC with filter bypass module.

3. Developing the EMI Filter

A filter module is inserted between the LISN and the DC/DC converter.

The measurement is repeated under comparable operating conditions. The filtered and unfiltered spectra can now be compared directly.

The modular construction allows inductors, capacitors and filter configurations to be exchanged without redesigning the complete test setup.

For the experiments described here, a π-filter was assembled on an analog::blocks Transmission Board.

The filter consists of two 10 µF ceramic capacitors connected to the ground plane and a 6.8 µH series inductor. The capacitors are separated by approximately 30 mm of 50 Ω transmission line.

The RF-optimized PCB structure provides short ground connections and defined signal paths, making it possible to investigate filter behavior well into the VHF range.

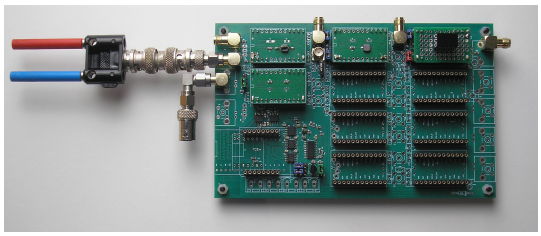


Figure 4: LISN, filter and DC/DC converter installed on the Base Board.

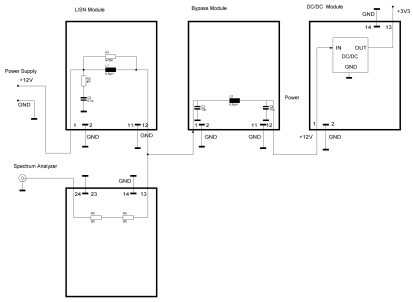


Figure 5: Schematic of the LISN, EMI filter and DC/DC converter test setup.

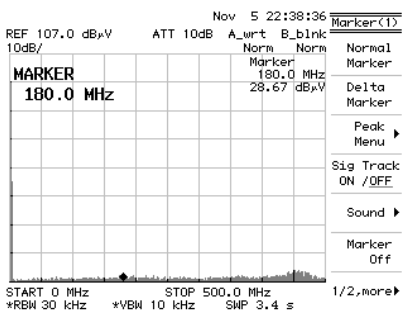


Figure 6: Spectrum of the DC/DC with filter module inserted.

4. Measuring the Filter Transmission Characteristics

In addition to measuring conducted interference with the LISN, the filter can be characterized independently using a tracking generator and spectrum analyzer.

Representative transmission measurements of the investigated filter yielded:

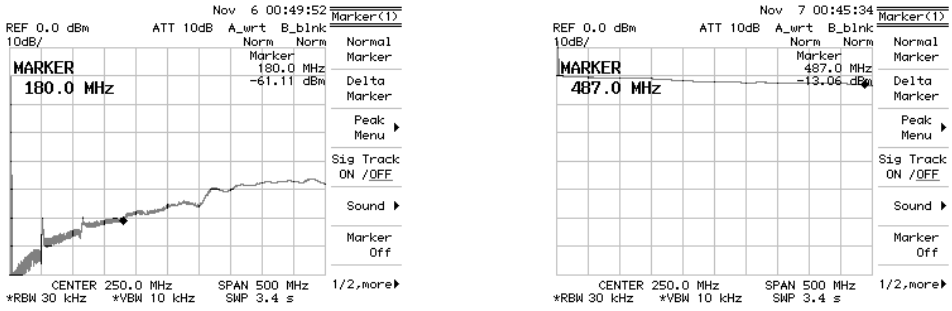


Figure 7: Filter transmission measured in a 50 Ω system.

Note: The bandwidth of the module slot used for the measurement in Figure 7 is reduced by the additional jumper connections.

At approximately 180 MHz, the measured filter transmission is about −50 dB. This is consistent with the substantial reduction of conducted interference observed in Figure 6, where the measured spectrum approaches the background level.

Further experiments showed that even a single 10 µF shunt capacitor produced significant high-frequency attenuation. Adding the second capacitor increased the attenuation further.

These measurements illustrate the influence of component parasitics, transmission line geometry and grounding on filter performance.

5. Evaluating Radiated Interference in a TEM Cell

Once the conducted interference measurements indicate satisfactory filter performance, the converter and filter are investigated in a TEM cell.

For this purpose, a Y2 100 mil analog::blocks prototype board is modified as a miniature Base Board.

The compact assembly accommodates the DC/DC converter and the interchangeable filter module and shows the flexibility of the analog::blocks design.



Figure 8: Mini Base Board with Power Adapter.

To obtain reproducible results, the assembly was mounted on a wooden support. Its position was marked inside the TEM cell, allowing it to be returned to the same location after each filter modification. This minimizes changes in cable routing and mechanical geometry between measurements.

The power supply wiring was connected through an external LISN to isolate the measurement setup from high-frequency interference originating from the power supply.

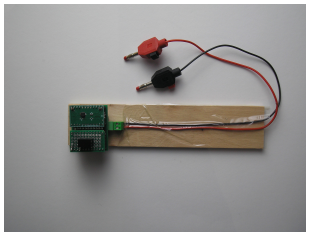


Figure 9: Mini Base Board with mounted modules.

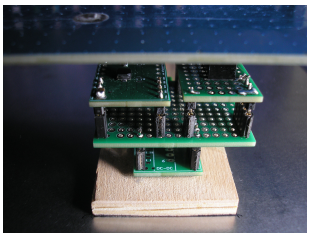


Figure 10: Miniature Base Board with DC/DC converter and filter inside the TEM cell.

With the π-filter installed, the interference measured in the TEM cell decreased by approximately **20 dB over a broad frequency range between 80 MHz and 220 MHz**.

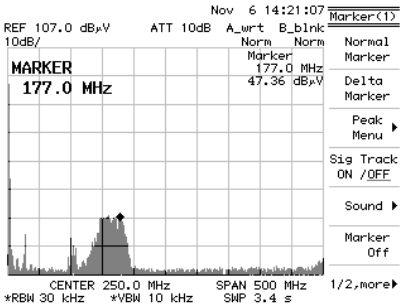


Figure 11: Interference with bypass module.

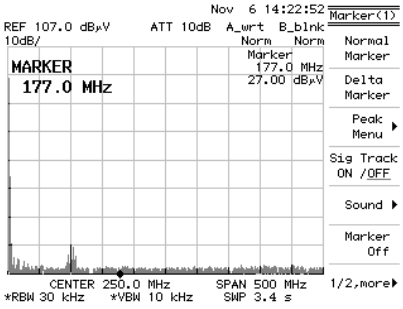


Figure 12: Interference with filter module.

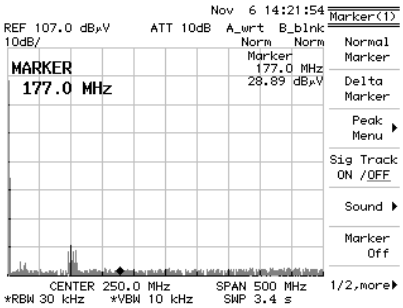


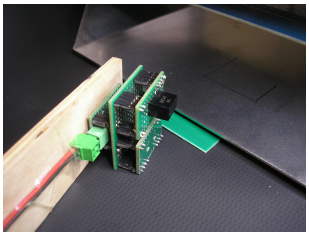
Figure 13: Interference with power off.

As shown in Figure 10, the DC/DC converter is positioned very close to the TEM cell septum. Nevertheless, with the EMI filter installed, the measured interference approaches the background level. This suggests that the supply wiring, rather than the converter itself, is the dominant radiation path in this setup.

6. Evaluating Radiated Interference via the Wiring

To investigate radiation from the supply wiring, the DC/DC converter and its supply cable were first positioned outside the TEM cell. A small PCB spacer was used to maintain a reproducible position of the converter relative to the TEM cell opening.

The converter was then kept outside the TEM cell while its supply cable was placed inside. Finally, the EMI filter was inserted to evaluate its effect on the measured interference.



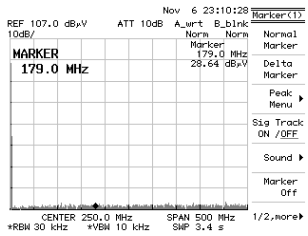
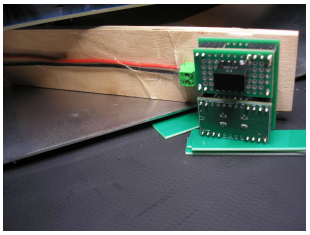


Figure 14: Interference with DC/DC outside the TEM cell.



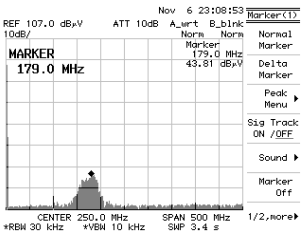
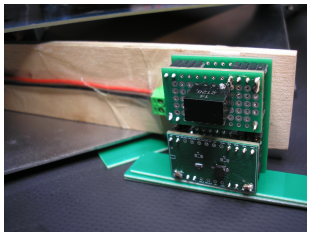


Figure 15: Interference with DC/DC cable inside the TEM cell.



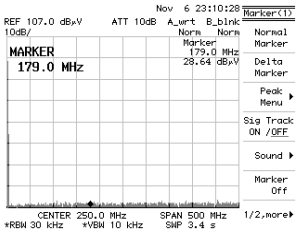


Figure 16: Interference with DC/DC filter installed.

Significant interference remained detectable when the converter without filter was placed outside the TEM cell while its supply wiring remained inside.

The measurements indicate that the supply wiring is the dominant source of radiated interference in the investigated setup.

As shown in Figure 10, the DC/DC converter is positioned very close to the TEM cell septum. Nevertheless, with the EMI filter installed, the measured interference approaches the background level.

Additional experiments were performed with the DC/DC converter positioned completely outside the TEM cell. Its position relative to the cell was kept reproducible using a small PCB spacer.

When the supply cable was placed inside the TEM cell, significant interference was detected even though the converter itself remained outside. Inserting the EMI filter substantially reduced this interference.

These observations indicate that the electromagnetic interference is predominantly radiated by the supply wiring rather than directly by the DC/DC converter.

This result demonstrates that effective filtering of the supply lines can substantially reduce radiated interference without requiring extensive shielding of the converter itself.

7. Discussion

The experiments demonstrate that the analog::blocks platform provides a practical environment for investigating conducted and radiated interference from DC/DC converters.

The LISN module allows interference on the supply lines to be measured directly. By inserting a filter module between the LISN and the converter, different filter configurations can be evaluated without redesigning the test setup.

The RF-optimized Base Board and Transmission Boards provide controlled signal paths and short ground connections, allowing filter characteristics to be investigated up to several hundred megahertz.

The TEM cell measurements provide an additional and particularly important result: In the investigated buck converter setup, radiated interference is predominantly associated with the supply wiring rather than direct radiation from the converter.

Even with the converter positioned close to the TEM cell septum, the measured interference approaches the background level when the filter is installed. Additional measurements with the converter outside the TEM cell confirm that significant interference is coupled into the cell through the supply cable.

This demonstrates that suppressing high-frequency interference on the supply lines can substantially reduce radiated emissions.

The modular construction also allows filter components to be modified while maintaining a reproducible measurement arrangement. This is particularly useful when evaluating small changes in filter performance at high frequencies.

Although TEM cell measurements do not replace standardized radiated-emission compliance testing, they provide an effective method for evaluating EMI filter designs during development.

8. Conclusion

The analog::blocks platform enables a systematic approach to EMI filter development, from conducted interference measurements using a LISN to the evaluation of the interference coupled into the TEM cell.

The RF-optimized modular design allows filter configurations to be developed, modified and characterized without repeatedly designing new PCBs.

In the investigated buck converter application, a simple π-filter reduced the interference measured in the TEM cell by approximately 20 dB over a broad frequency range.

The experiments also demonstrate that the supply wiring is the dominant radiation path in this setup. Effective filtering of the supply lines reduced the measured interference to approximately the background level, even with the DC/DC converter positioned close to the TEM cell septum.

These results show that analog::blocks can be used not only for developing EMI filters, but also for identifying interference mechanisms and evaluating practical solutions before transferring the circuit to a final product PCB.

History:

Revision	date yy/mm/dd	Changes
1.0	26/11/06	Initial.