LaurTec

EMC filter
Low voltage PCB

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Abstract

No matter how good your PCB layout would be, you are going to have stray capacitance and inductance. Because of that, the energy associated with voltage and current transients will couple with other traces. This will reflect in having unwanted noise on other traces.

Good PCB design, to guaranty that the end product, will comply with the EMC (ElectroMagnetic Interference) standards such as the CISPR 14, CISPR 32, must limit the energy associated to the noise that goes out from the system. This energy, while described by the Maxwell's equations, are divided in two types, conducted and radiated noise. In this article, it will be presented a filter you can add before your system to limit the conducted noise energy that goes out from the system or try to enter into it. The project is a general purpose PCB that can be used to design an ad-hoc filter.

Specifications

The filter is designed to be used for low voltage applications. The definition of "Low Voltage" may differ from what specified below, depending on the applied standards or specific enforced regulations. In that case, those standards or regulations, supersede the PCB specifications

Operating voltage: max. 60Vdc or 42Vac

Operating current: max. 3A continuous

The PCB is conforming the directive: **2011/65/UE**

The PCB and electronic systems, must not be thrown in the domestic garbage. They must be disposed in the specific containers with electronic equipment. Specific local laws and dispositions must be followed.

EMI filter for conducted noise

Limiting conducted noise, helps indirectly also radiated noise. Often it ends up to be a must to have some sort of EMI filter on the input. During the design phase, it should be already clear, at high level, where the majority of the noise could be. For instance by considering the DC-DC converter switching frequencies or used crystals. Nevertheless, a good EMI filter design can be done only by measuring the conducted noise and understand how much attenuation would be needed. To really optimize the filter size, an impedance analysis could be done at system level as well. Indeed, the input impedance of the system changes versus frequency. Nevertheless, a perfect match between the EMC filter and the system, that includes the impedance, may non be worthy, considering the components tolerances and the fact that beside reducing the energy that goes out, you may need also to attenuate energy getting in to the system. This may be unknown, while there are tests for it that try to emulate some scenarios. Since the incoming noise is unknown, often the trade-off on the EMI system immunity, may actually be cost and size. The advantage of knowing the system impedance is related to the fact that the filter cutoff frequency will be influenced by that, since it represents the filter load. Thus, taking into account the system impedance can help. On the same, way beside the system impedance, it helps to know the source impedance.

Last, but not least, systems that have DC-DC converter on the input, exhibit a negative impedance, thus special care must be taken to avoid that the filter impedance, at the resonance frequency (if made of LC components), intersect the negative input impedance of the DC-DC converter.

Not everything can be considered during the design phase, thus, typically, the conducted noise filtering ends up with some last minutes changes.

Sometime those changes are done on the board, if there was already a plan for the filter, or by adding external filtering, by purchasing a ready to use filter. Last minute changes, are the one that are typically more expensive, and the worst you can do from the optimization perspective. Impedance measure of the source and load, it could be often too much, but last minute changes is really too less.

EMI filter PCB

The PCB presented here, is a general purpose PCB that can be used for low voltage applications up to 60V DC 3A. The schematic, shown in Figure 1, has several components, but not all must be assembled. The complexity for the filter, is justified for having enough place on the PCB to assemble different filter types and make tests and measurements for different system cost and scenarios.

The PCB enables Pi filter, LC filter, assemble ferrite bead instead of L1 and L2. Add a bulk capacitor as snubber or add a dedicated snubber via C9 and R1.

To attenuate the common mode noise, there is the option for the common mode filter FL1 CY (C2, C3) capacitors, thus beside the differential conducted noise you can filter out the common mode part of it. Additional space is dedicated to the CX (C1).

The PCB offers the option to assemble a symmetric and not symmetric filter, indeed the + and – lines do offer the same passive components. Inductors that are not used should be shorted with a wire or a solder point. All L1, L2, L3, and L4 offer a jumper pad with close pads distance that can be easily soldered out to short the component.

Not symmetric filters are typically suitable for the majority of power line systems that are not exposed to a high common mode conducted noise.

If this assumption would not be valid, the – line should have a mirrored path as the + line. This would limit the common mode noise to be converted in differential noise. This conversion is particularly harmful to data lines, where the data filter symmetry is typically a must.

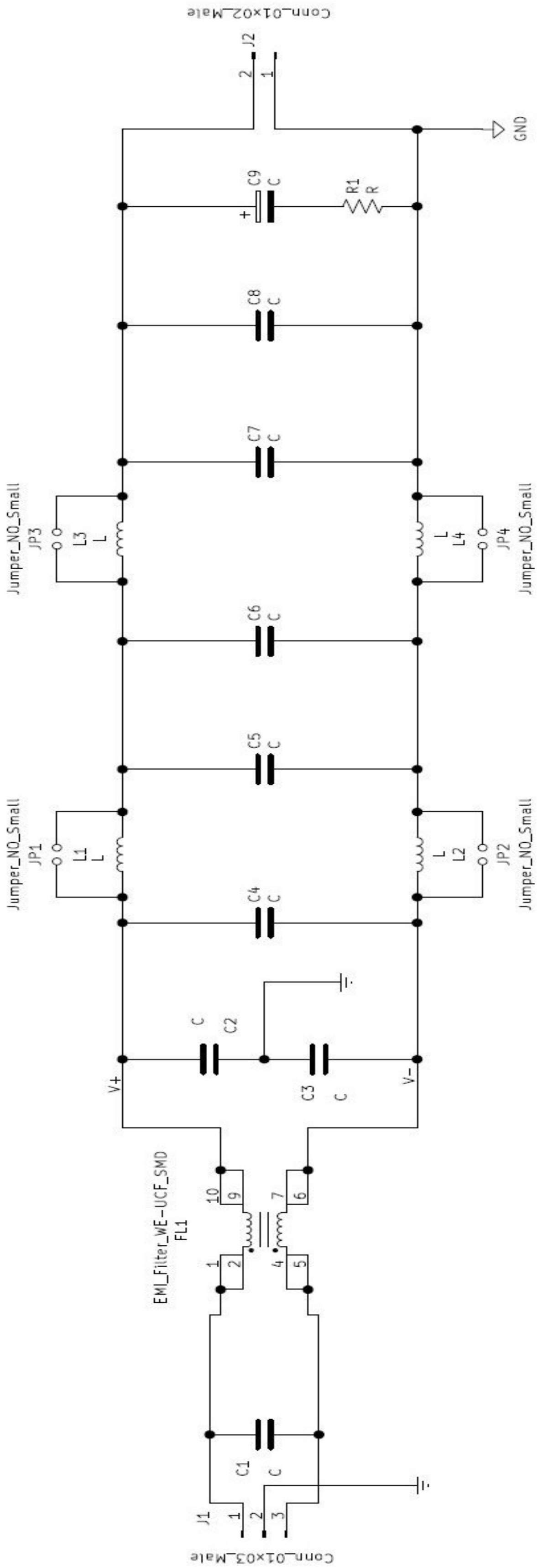

Figure 1: *EMC filter schematic* .

EMI filter BOM

The part list below is a short summary of the supported components. In particular, the list shows the component family and pad size, so that you can easily change between other models as well. The pad size may allow soldering additional components that are similar in size. The specific values will be application specific.

Supported Component list

C1: Through hall 7.5mm, 10mm and 1812 SMD (Class X)
C2: Through hall 7.5mm, 10mm and 1812 SMD (Class Y)
C3: Through hall 7.5mm, 10mm and 1812 SMD (Class Y)
C4-C8: SMD 1812 and 1210 (Ceramic)
C9: SMD 4x5.8, 6.3x5.8 or 8x6.2 (higher is possible)
R1: SMD 1812 and 1206
L1: Wuerth 7850 and 5848 size (WE-PD2 SMT family). Ferrite bead 1812.
L2: Wuerth 7850 and 5848 size (WE-PD2 SMT family). Ferrite bead 1812.
L3: Wuerth 7850 and 5848 size (WE-PD2 SMT family). Ferrite bead 1812.
L4: Wuerth 7850 and 5848 size(WE-PD2 SMT family). Ferrite bead 1812.
FL1: common mode choke - Wuerth WE-UCF family and Coilcraft (multiple families)
J1: Phoenix MSTBA 5.08 and Wago 5.08 1x3
J2: Phoenix MSTBA 5.08 and Wago 5.08 1x2

Figure 2 shows the filter PCB (size 39x90mm).

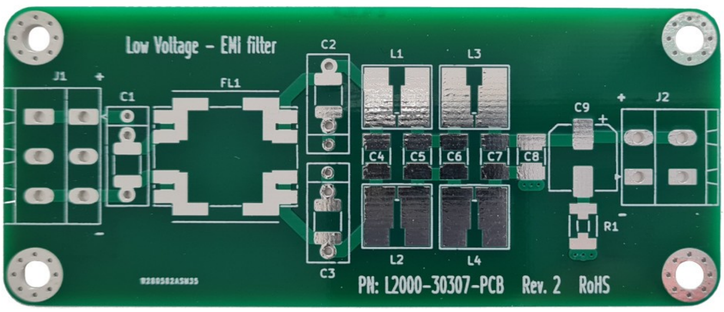

Figure 2: *EMC filter PCB.*

Figure 3 shows a full 3D filter assembly example, using a Wuerth common mode choke.

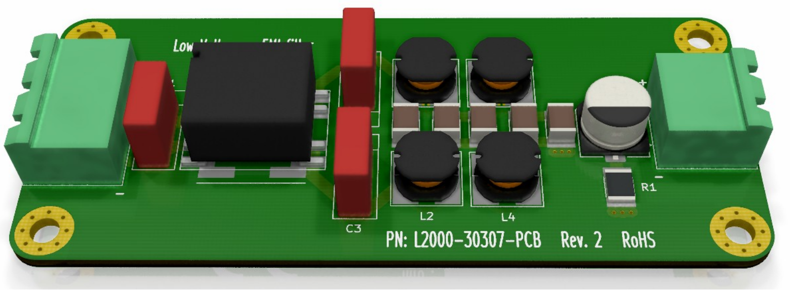

Figure 3: *EMC filter assembled – using Wuerth common mode choke .*

Figure 4 show an example of a lab prototype.

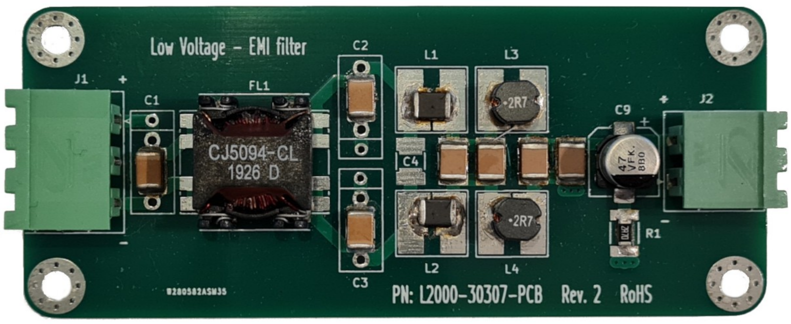

Figure 4: *EMC filter PCB assembled with Coilcraft common mode choke.*

Use case

Using the EMI filter, enables debugging and design the right solution that fits the system requirements. Figures 5 and 6 shows the conducted noise measured on the input of a DC-DC converter against the CISPR 25 standard.

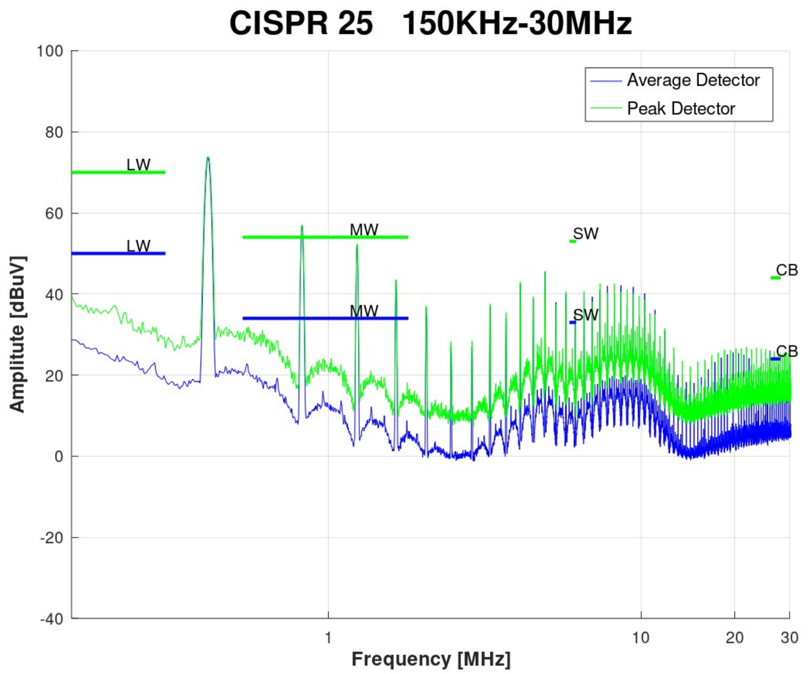

Figure 5: *EMC conducted tests – DC-DC converter 150KHz-30MHz (without filter) .*

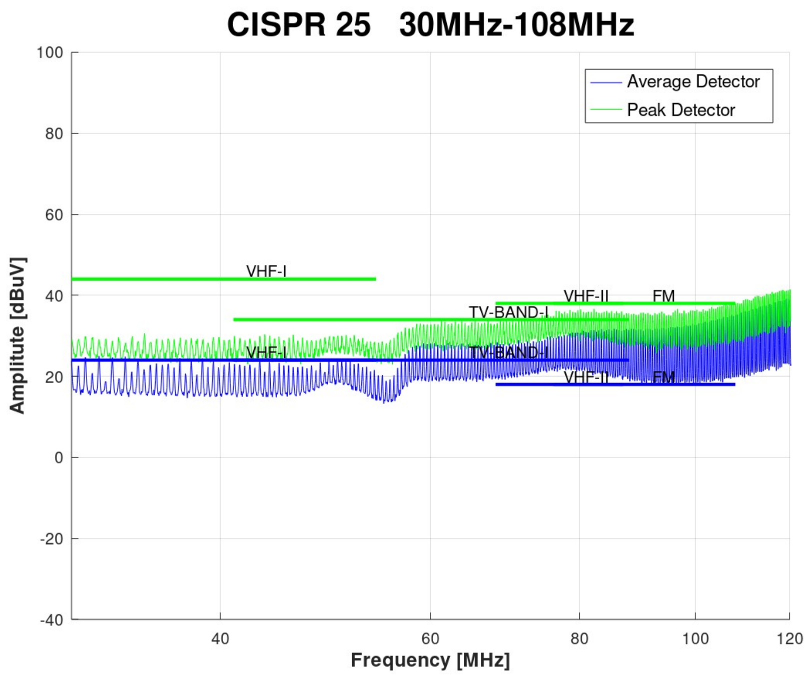

Figure 6: *EMC conducted tests – DC-DC converter 30MHz-108MHz (without filter) .*

It is possible to see that in both bandwidth of interest, the noise goes beyond the limits. By designing the right filter and adding it into the input of the power line, it is possible to reduce the noise and make the system comply with the CISPR 25 standard (Figure 7 and Figure 8).

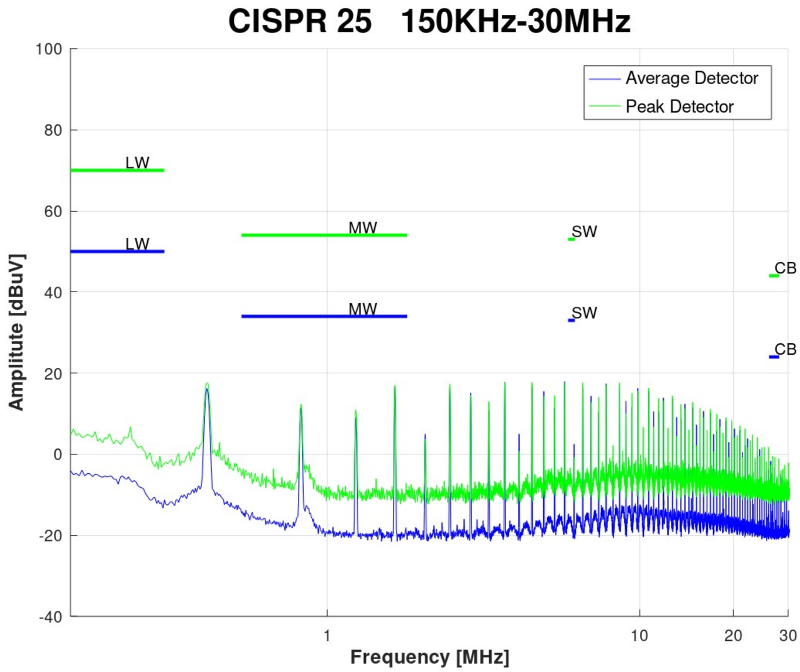

Figure 7: *EMC conducted tests – DC-DC converter 150KHz-30MHz (with filter)* .

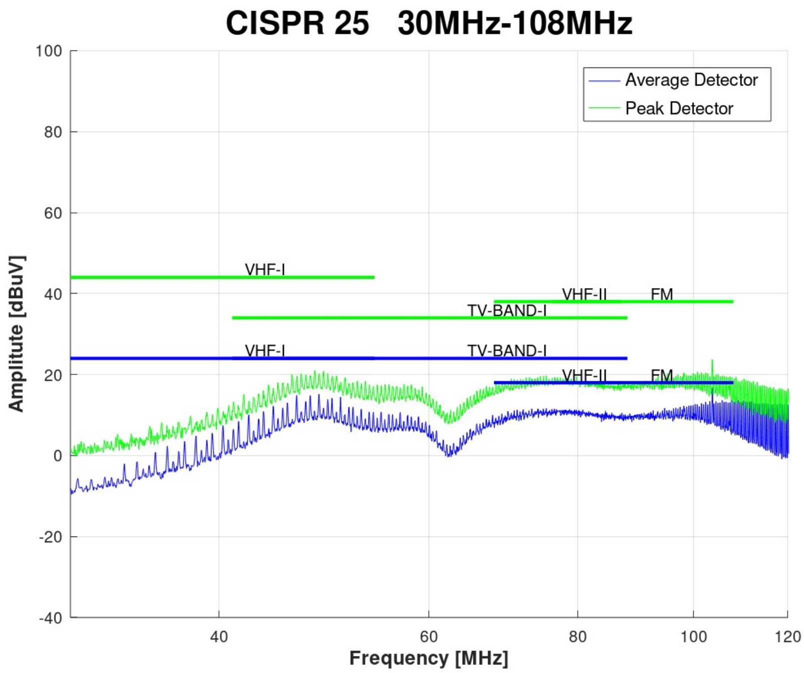

Figure 8: *EMC conducted tests – DC-DC converter 30MHz-108MHz (with filter)* .

Conclusions

The filter presented in the article, is suitable to attenuate the common mode noise getting in and out from the system. In particular, it offers the option to filter both the differential part of the noise and the common mode part of it. The filter can be used as standalone solution or to be added on system with problems, during the debugging phase. The flexibility allows optimizing the filter components without blue wiring. An optimal size solution, may be added at the end, directly on the final product.

Bibliography

[1] www.LaurTec.it: official site where you can download the "EMC Testing" series.

History

Date	Version	Author	Revision	Description
16. Jan. 2022	1.0	Mauro Laurenti	Mauro Laurenti	Original version.