SIMULATION OF HV FILTER FOR CHARGING SYSTEM

Introduction

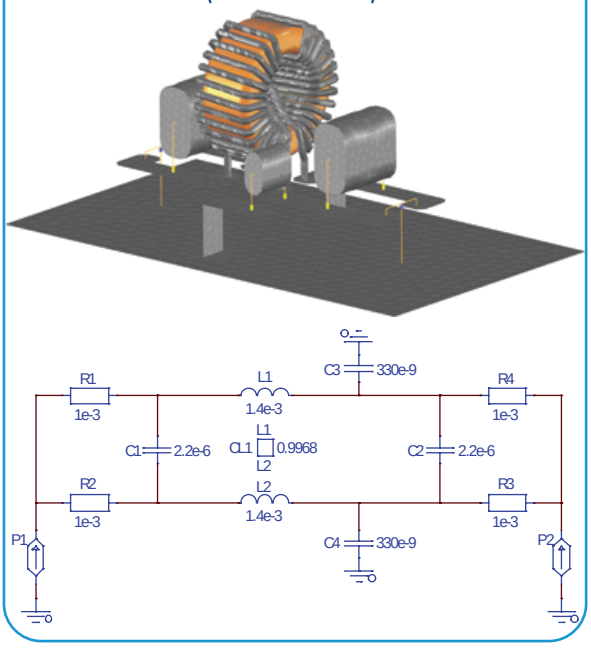
This application note presents a fast and effective method of equivalent circuit extraction for HV filter. A solution is proposed to evaluate system-level performance of low-pass filter and estimate its noise reduction effect when used as part of a charging system.

The software product EMCoS Studio is used to demonstrate the solution.

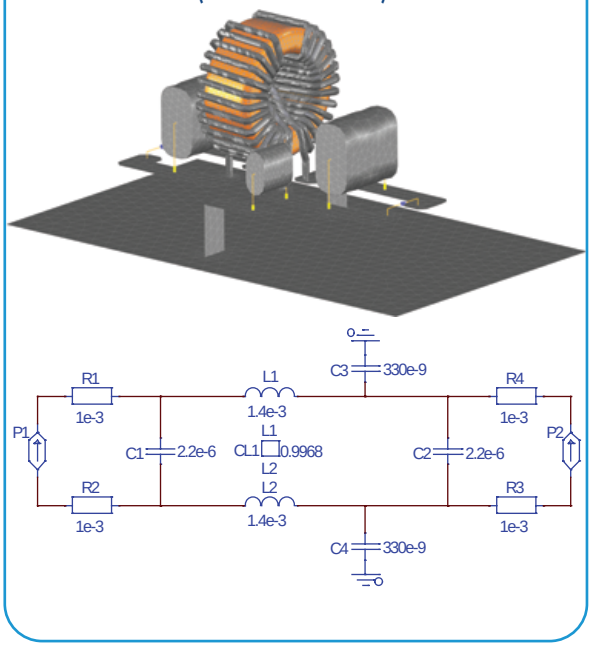
Simulation Model Description

Two 3D calculation models with corresponding equivalent circuits of low-pass HV filter connected in Common Mode (CM) and Differential Mode (DM) are considered. Capacitors are presented in 3D model as hollow metallic structures connected in series with lumped capacitance elements. Common-mode choke is made up of two conducting coils wrapped around a toroidal core with ferrite properties.

3D and Ideal Circuit Models of Filter (Common Mode)



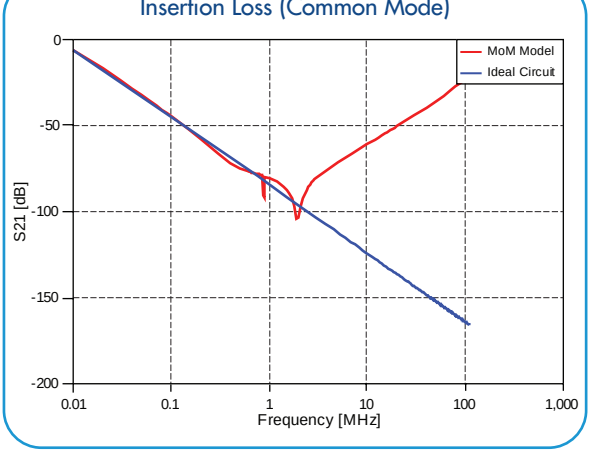
3D and Ideal Circuit Models of Filter (Differential Mode)



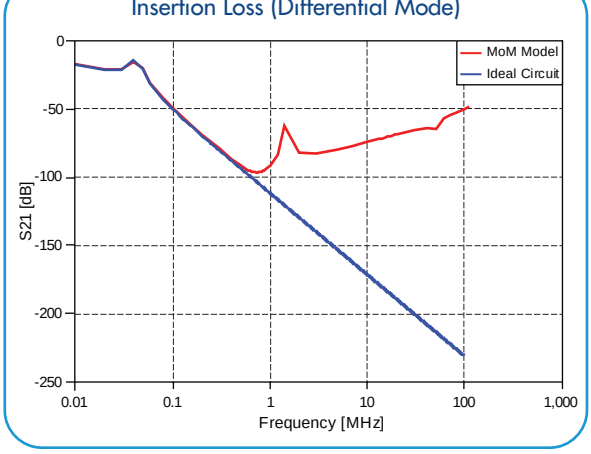
Comparison of MoM Results to Circuit Simulation

The comparison of fullwave simulation results with equivalent circuit calculation is shown in figures below. The graphs demonstrate that equivalent circuit model correctly describes filter performance only in the low frequency range, up to 1 MHz. For the upper frequency range parasitic effects originating from the mutual coupling and interconnection of filter components become considerably more important. Fullwave simulation is performed to obtain reliable results for a wide frequency range, taking into account geometrical and material properties of filter components.

Insertion Loss (Common Mode)



Insertion Loss (Differential Mode)



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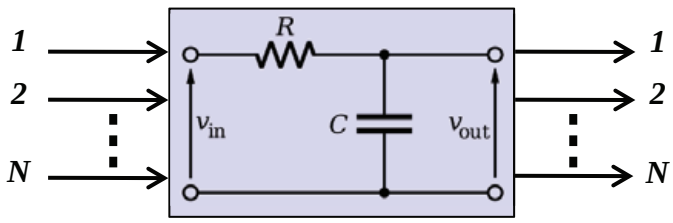
Extraction of Equivalent Circuit from Network Parameters (S2Cir)

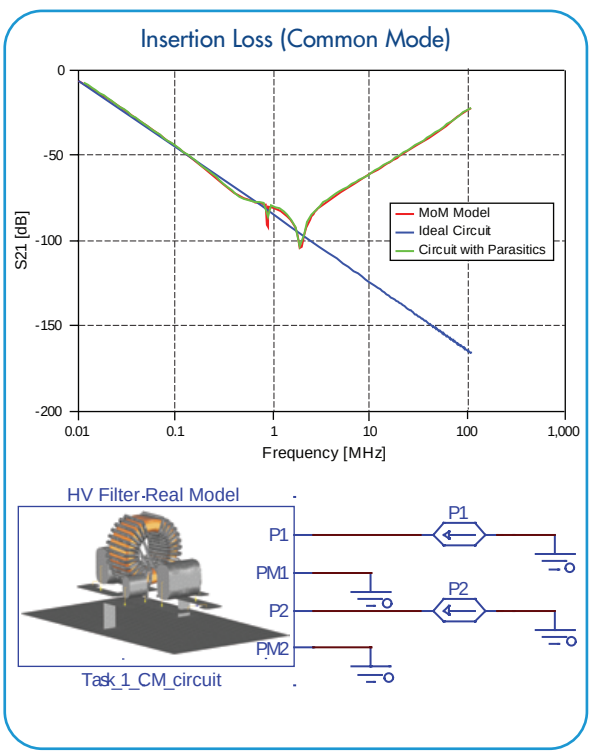
Extraction of equivalent circuit is performed by applying rational function approximation to transfer function obtained from fullwave simulation (S-parameters).

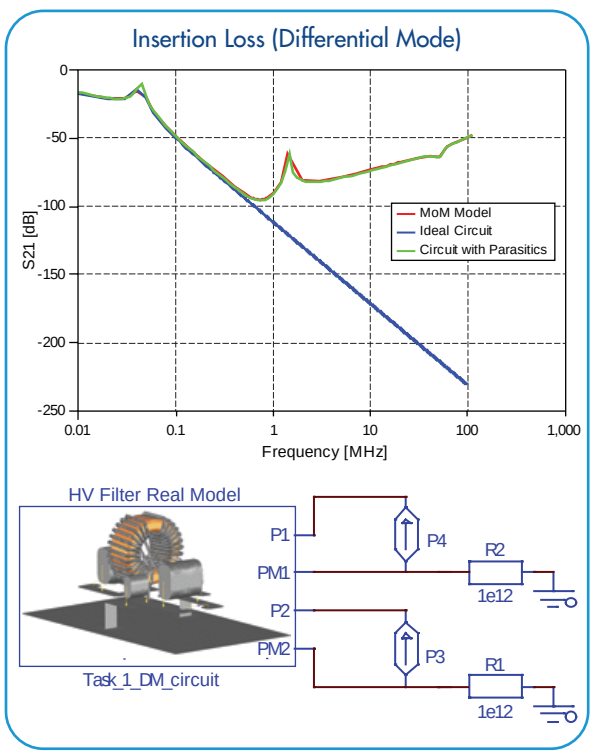
$$\begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{bmatrix}$$



Simulation of Extracted Equivalent Circuit (S2Cir)

Simulation of the extracted equivalent circuits in CM and DM shows good agreement with fullwave solution, thus confirming the validity and appropriateness of the extracted models.





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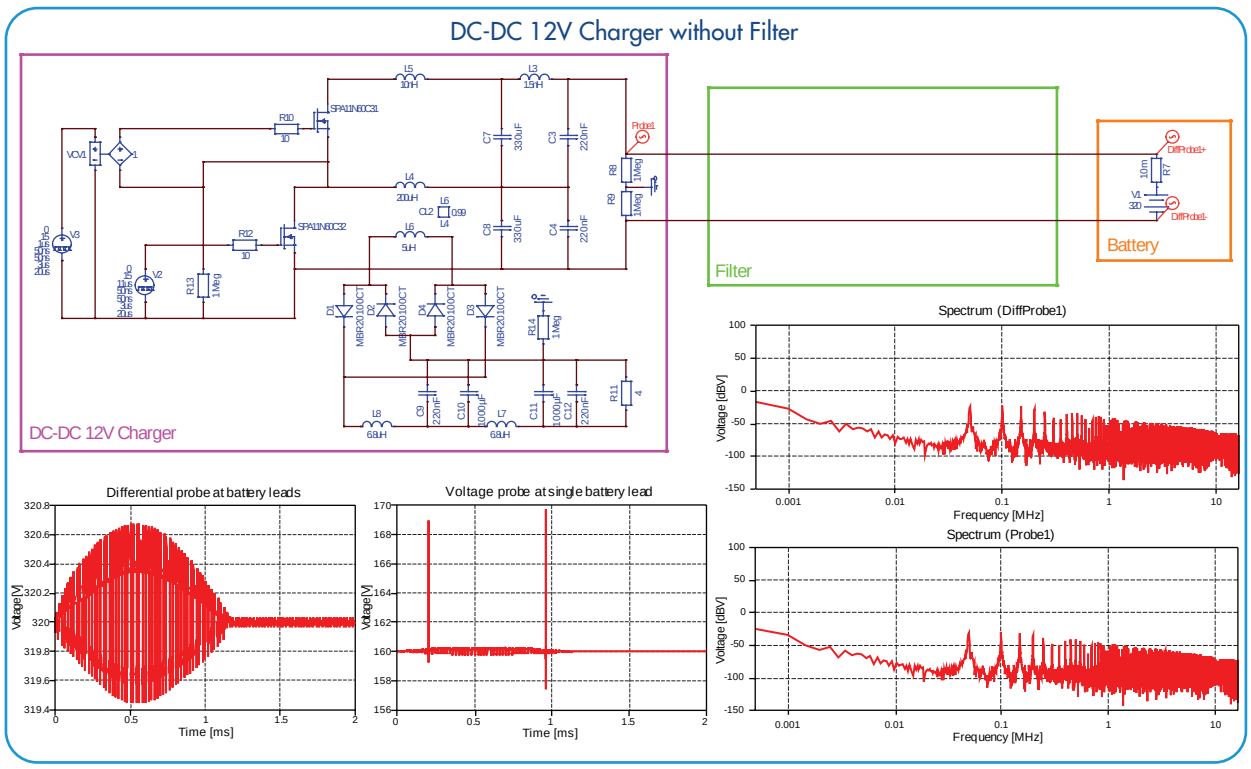
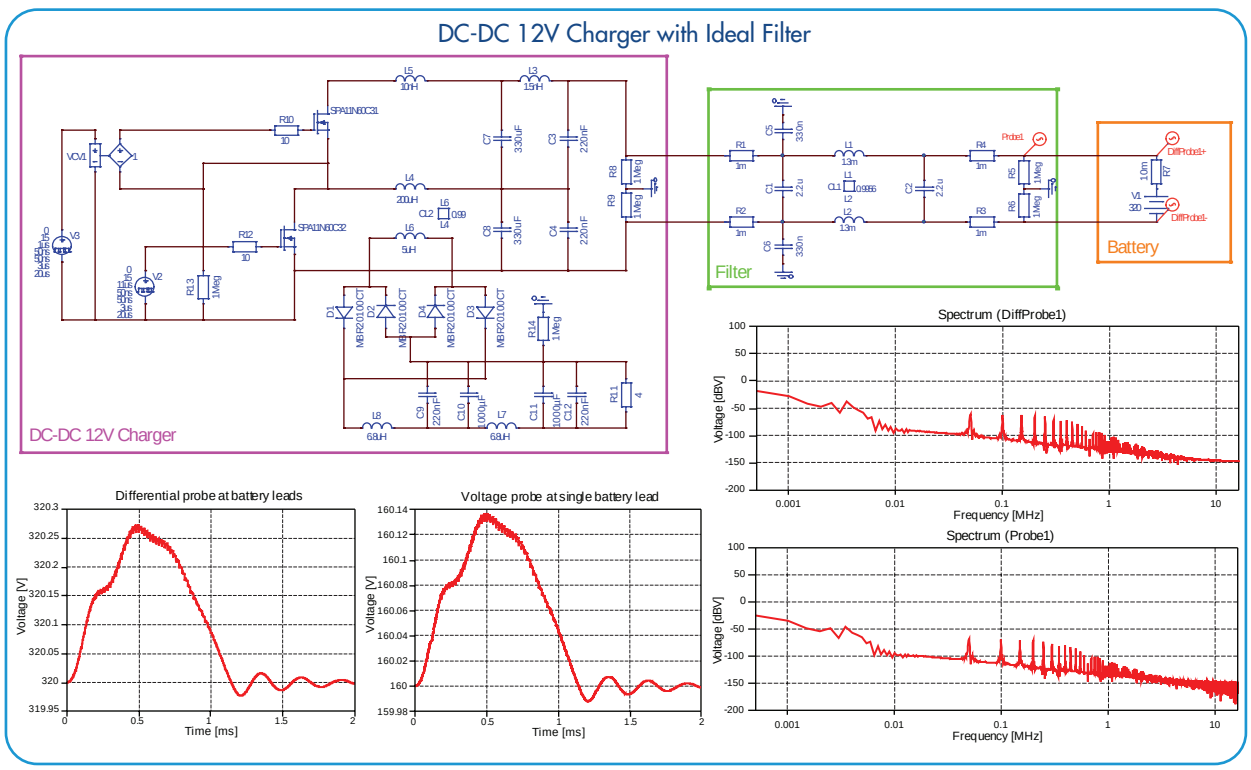
Effect of HV Filter on Charger Performance

This part of the application note demonstrates how embedding of HV filter into the charging system can reduce line noise coming in from power or control lines. Three different cases are considered: 1) no filtering; 2) ideal equivalent circuit between the power source and charger; 3) extracted circuit model in place of the ideal filter.

Figures presented below illustrate schematics, signals at voltage probe and spectra for different designs.





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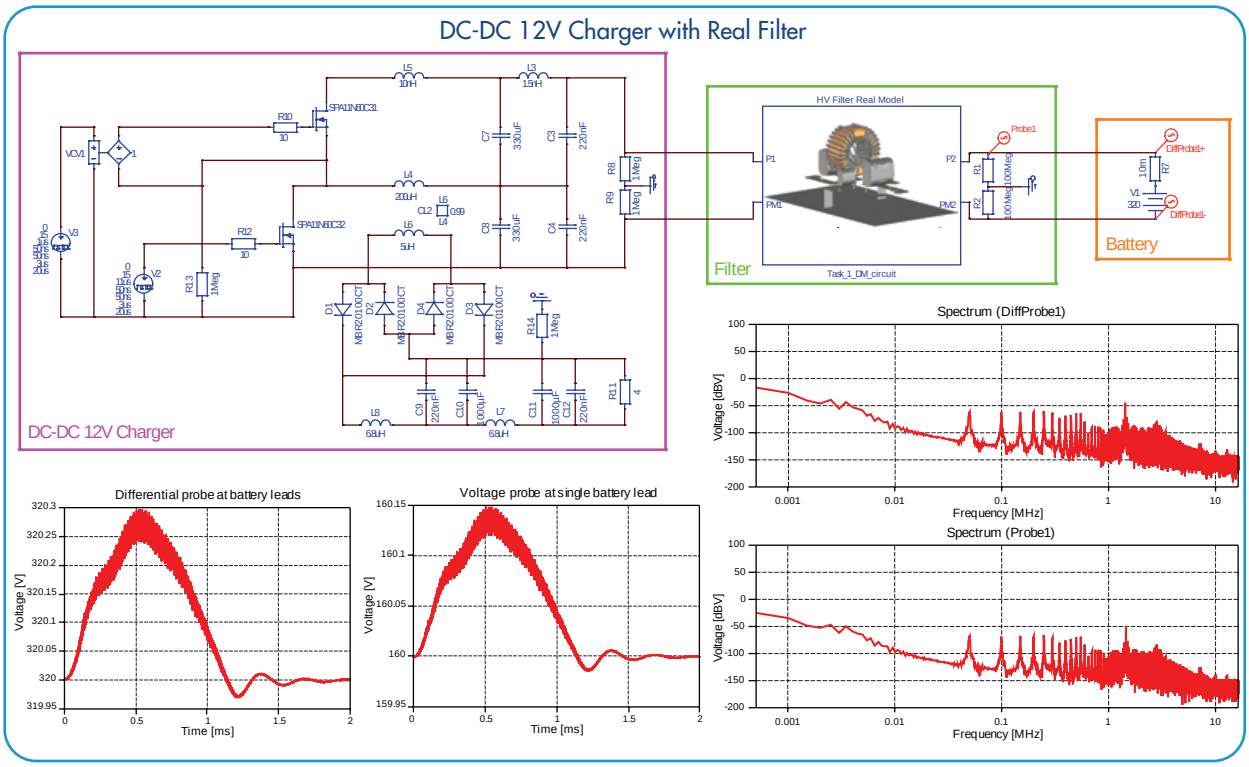
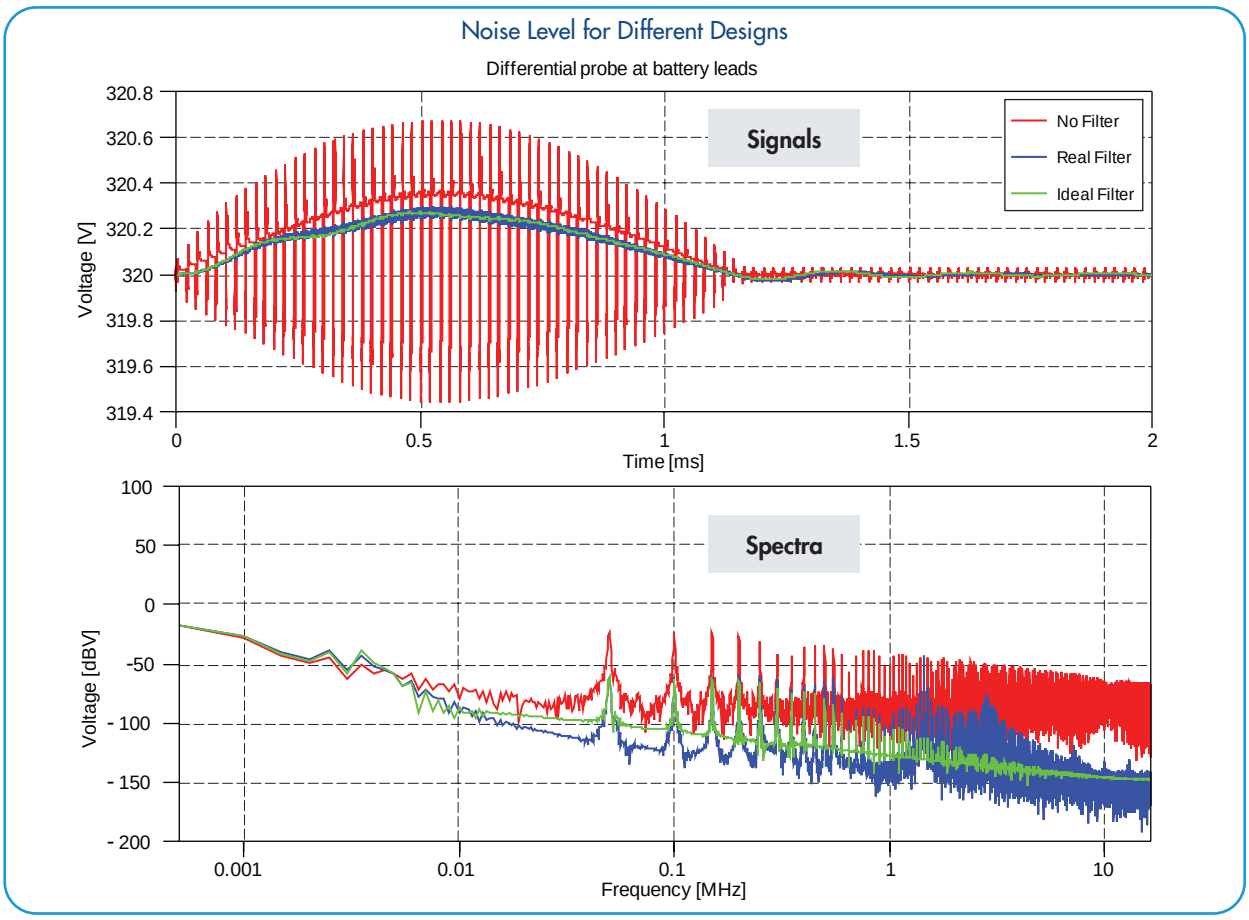


The next picture shows a comparison of signals and spectra obtained by circuit simulation of the charging system with and without filtering part. Embedding of the extracted filter model provides significant improvement in noise reduction over the design with no filtering (worst case), while taking into account all parasitic effects, which are not considered in the original circuit model (ideal case).



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