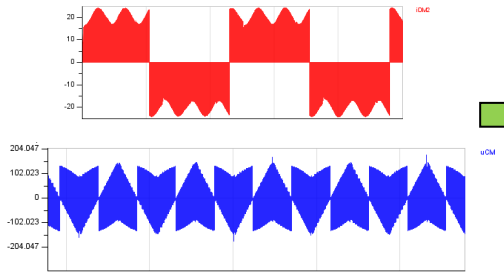
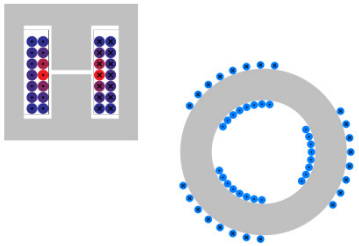
Gecko Three-Phase EMI Filter Optimizer

FREE Feature Demonstrator Application

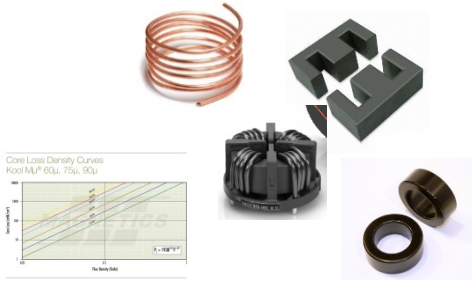
Download at http://www.gecko-simulations.com/apec2015



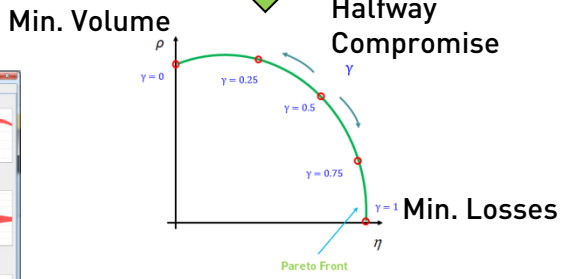
Circuit simulation
DM Current – DM Noise
CM Voltage – CM Noise



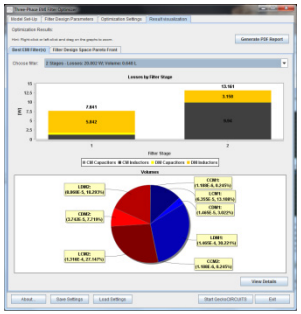
Magnetic simulation
(with thermal model)

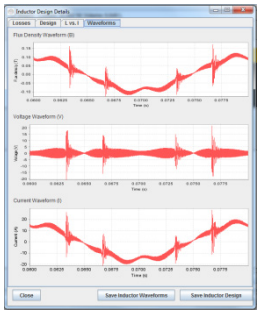


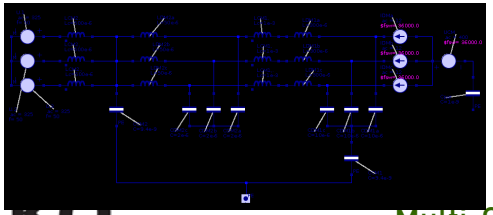
Component Design Space



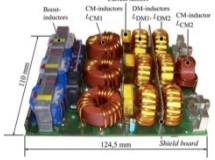
Optimization Goal

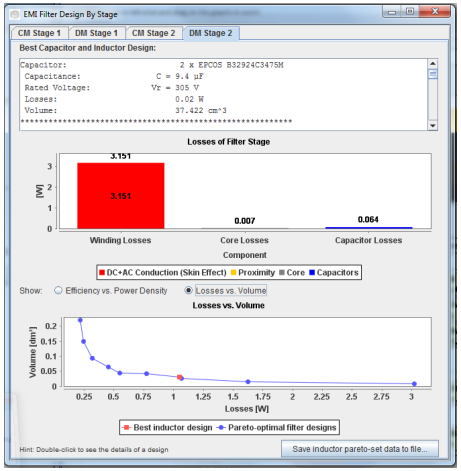






Optimization Algorithm





Multi-Objective Optimized Filter Design

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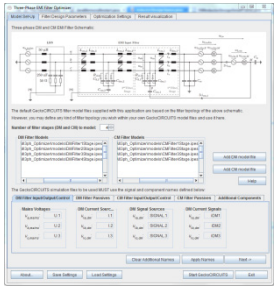
Quick Introduction

The Gecko Three-Phase EMI Filter Optimizer is a free, feature demonstrator Java application build on top of GeckoCIRCUITS and GeckoMAGNETICS for finding the optimal EMI filter design with respect to efficiency and power density within a given design space:

1) It showcases features in development (e.g. filter optimization) that will become available in upcoming Gecko-Simulations products;

2) It demonstrates how custom applications can be built on top of GeckoCIRCUITS and GeckoMAGNETICS, to solve specific real-world problems in power electronics.



The Gecko Three-Phase EMI Filter Optimizer allows you to define a design space for each filter component, and then using evaluations through simulations and an optimization algorithm, it finds the best design according to your design goal, i.e. your defined compromise between efficiency and power density.

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Optimizer Tool for Three-Phase EMI Filters

- Can be used for any three-phase converter topology (you must build appropriate noise models in GeckoCIRCUITS)
- Multiobjective optimization of an EMI filter for power density (volume) and efficiency (losses)
- Always calculates set of pareto-optimal designs, and then picks from this set based on optimization goal
- Gives LC values, attenuation distribution, and components to build inductors and capacitors from based from a list of real components in its database

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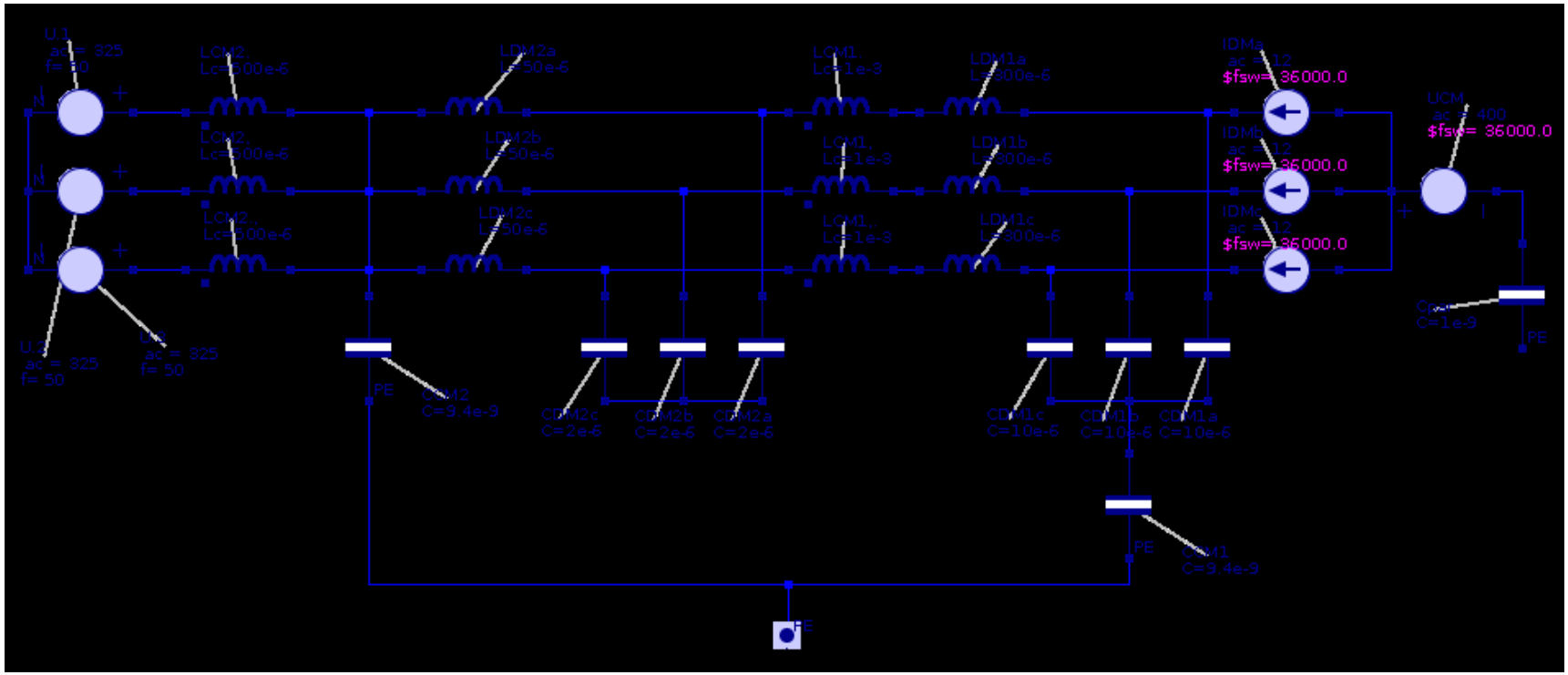
EMI Filter Modeling

- The Optimizer uses a mostly fixed *LC-LC* filter topology:



- You can select whether CM and DM capacitors are in series or not

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Starting the Optimizer

1. Unzip the downloaded Optimizer package on your computer.
2. Open the newly created directory.
3. On Windows and Linux, double-clicking StartOptimizer.jar should start the program. IF this does not work, open a terminal (console), go to the directory and type java –jar StartOptimizer.jar
4. If you still have problems, please consult the User's Manual on how to start the program manually.
5. Within a few seconds, the main optimizer window should open.

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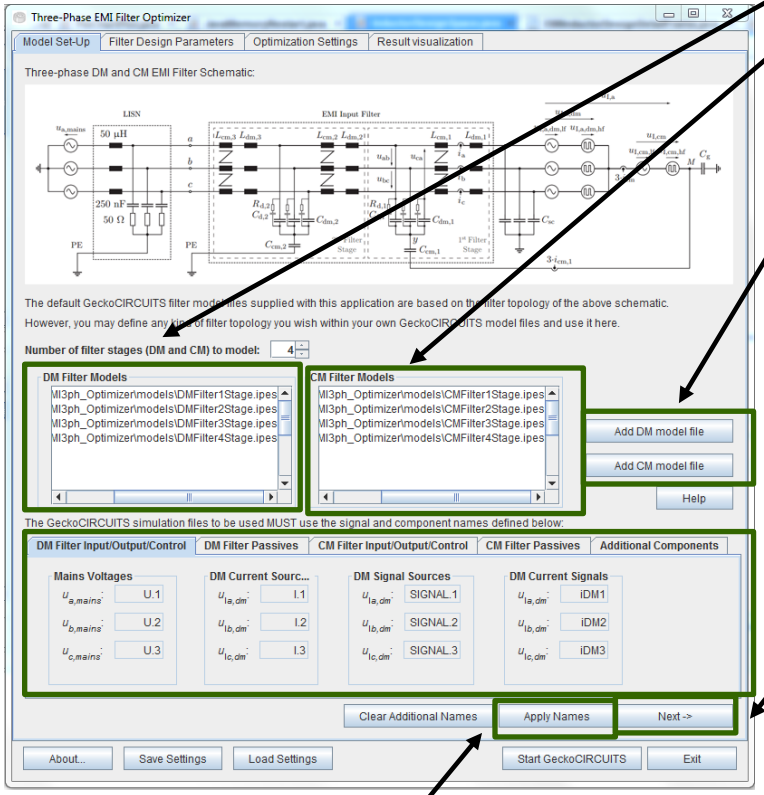
EMI Filter Circuit Simulation Models

- **First tab of window – model set up**



Sample models up to 4 filter stages are provided

You can add your own models from GeckoCIRCUITS

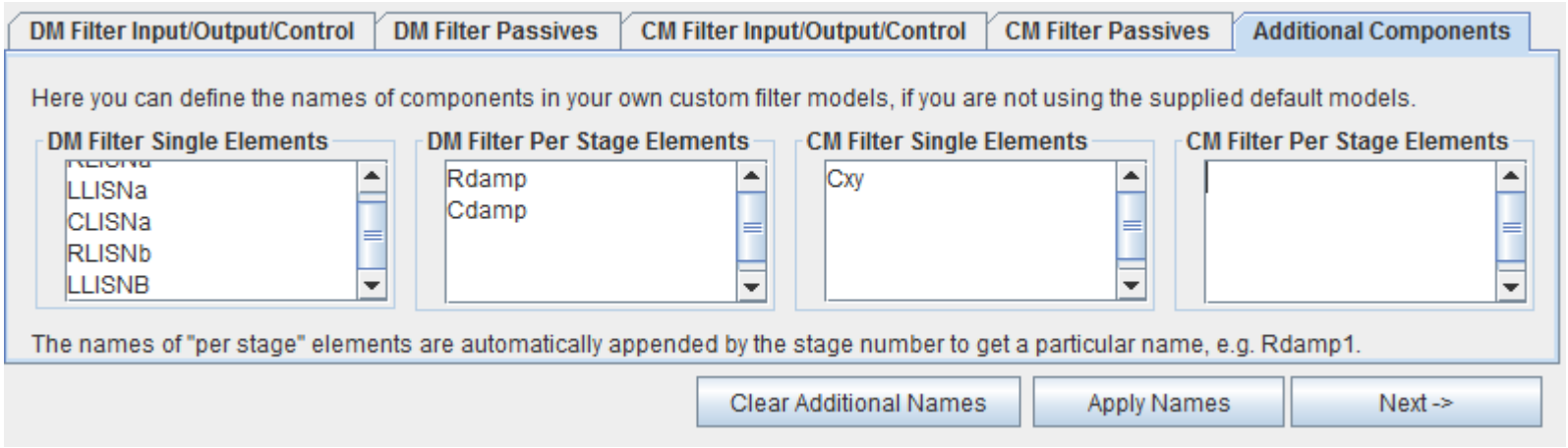
Circuit simulation models for GeckoCIRCUITS must use the element names shown here

Click "Next" to see all required elements names in simulation models, and also to define additional components (see next slide)

Click "Apply Names" when finished with this screen

EMI Filter Circuit Simulation Models

- By default, the Optimizer considers only the filtering elements (inductor and capacitors)
- However, the user can define additional components to use in the models (e.g. damping elements)



- This is done in the last sub-tab of the Model Set-Up screen
- For more details, see the User's Manual

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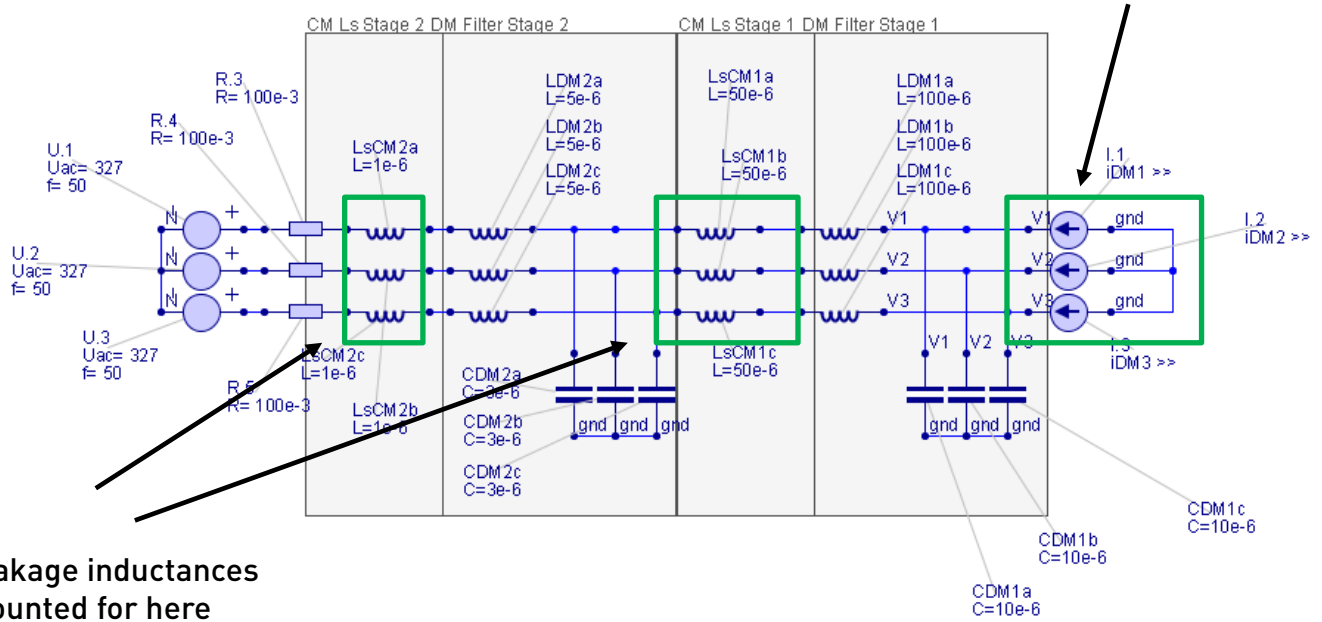
EMI Filter Circuit Simulation Models

- Click "Start GeckoCIRCUITS" and the simulation models will open
- DM noise simulation model:

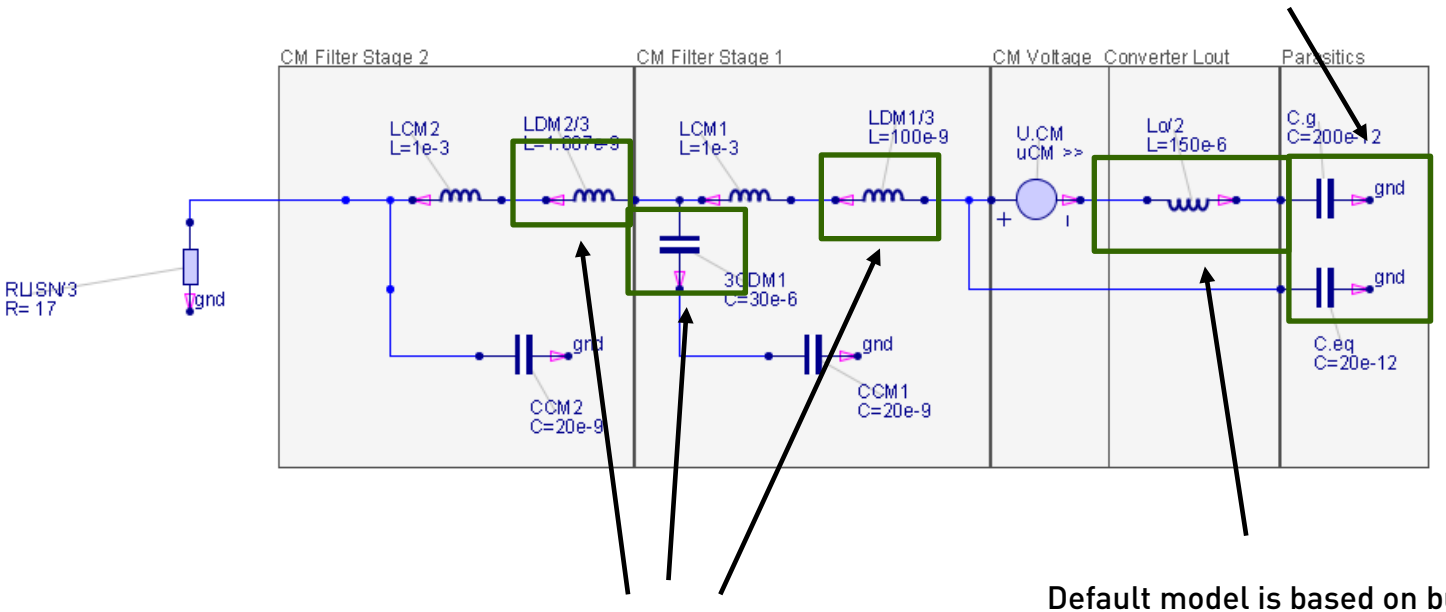
Converter modelled as current source (all three phases, properly phase shifted!)



CM choke leakage inductances are also accounted for here

EMI Filter Circuit Simulation Models

- CM noise simulation model:



For more details on the CM model, please see the User's Manual

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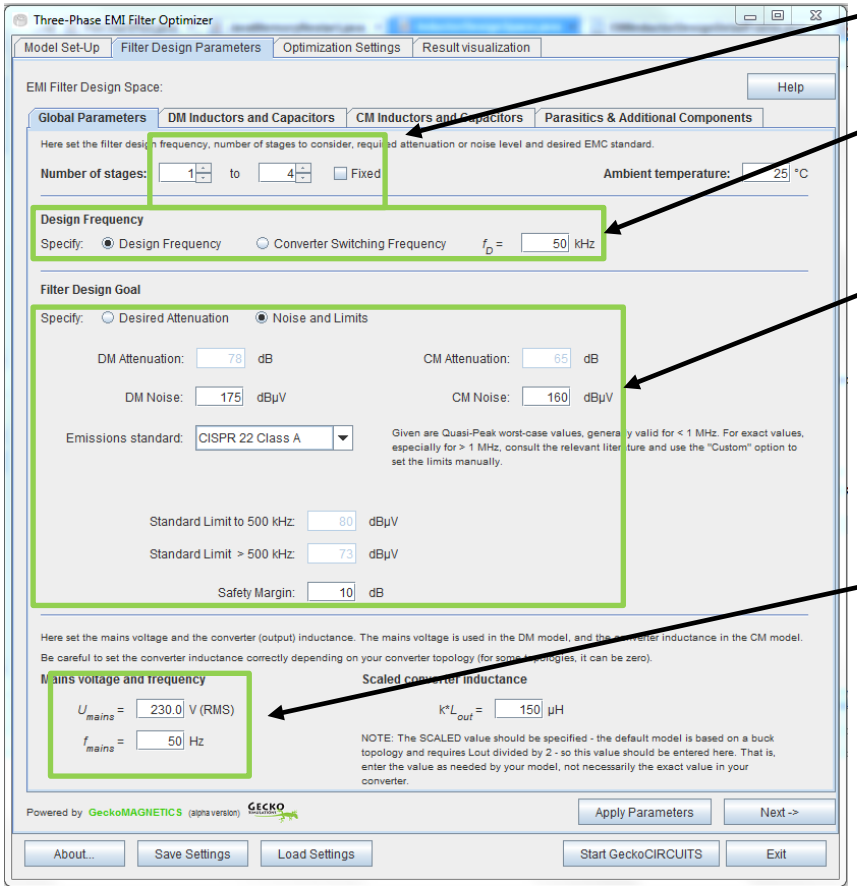
EMI Filter Global Parameters

- "Global Parameters" tab:



Set number of stages to consider

Set filter design frequency directly or specify converter switching frequency

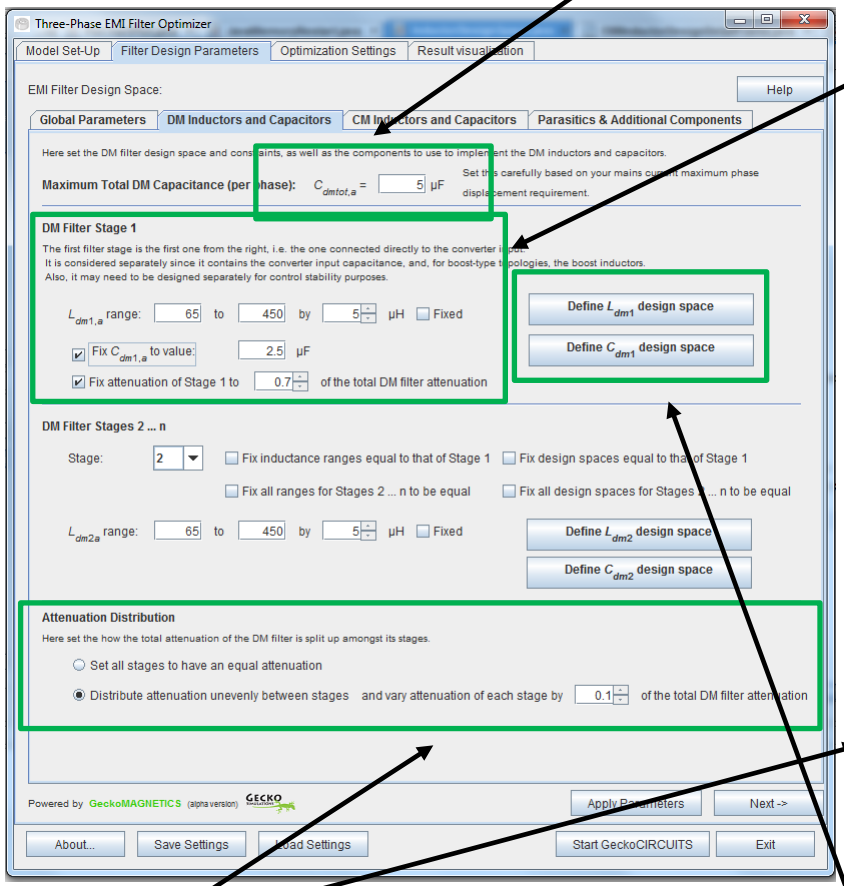
Required DM and CM attenuation can be specified directly, or instead calculated based on noise and emissions standard

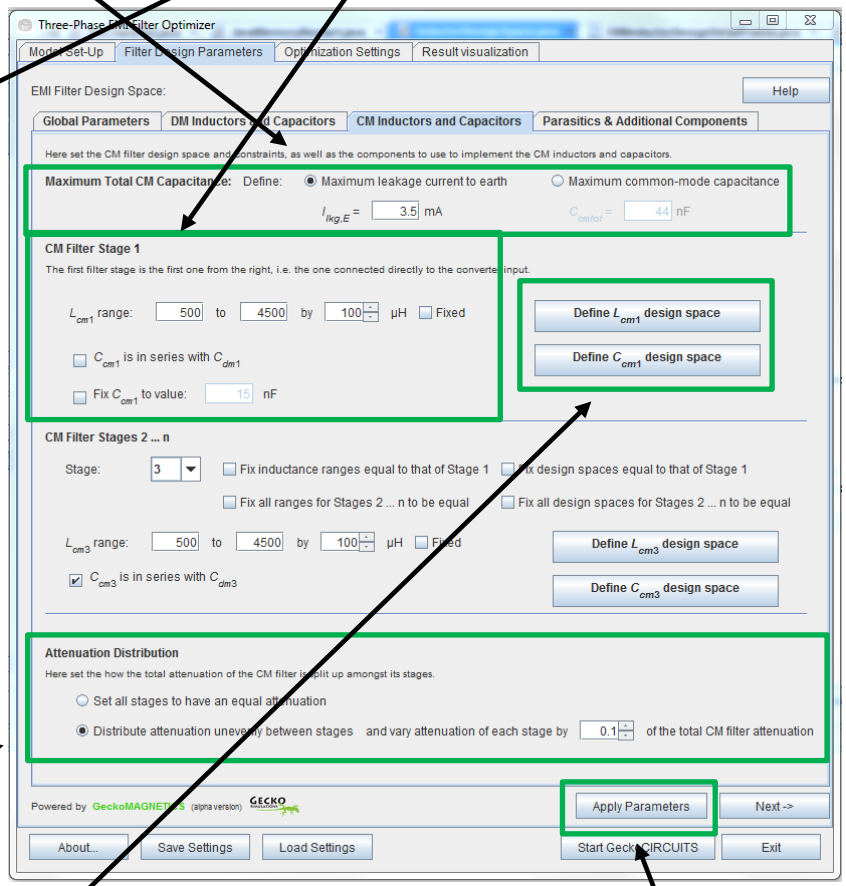
Mains voltage and frequency are also input variables

CM and DM Filters

Set maximum CM and DM capacitance

First stage can be considered separately from the rest





Set how attenuation is distributed between stages

Set Inductor and Capacitor Design Spaces

Click here when finished setting all parameters

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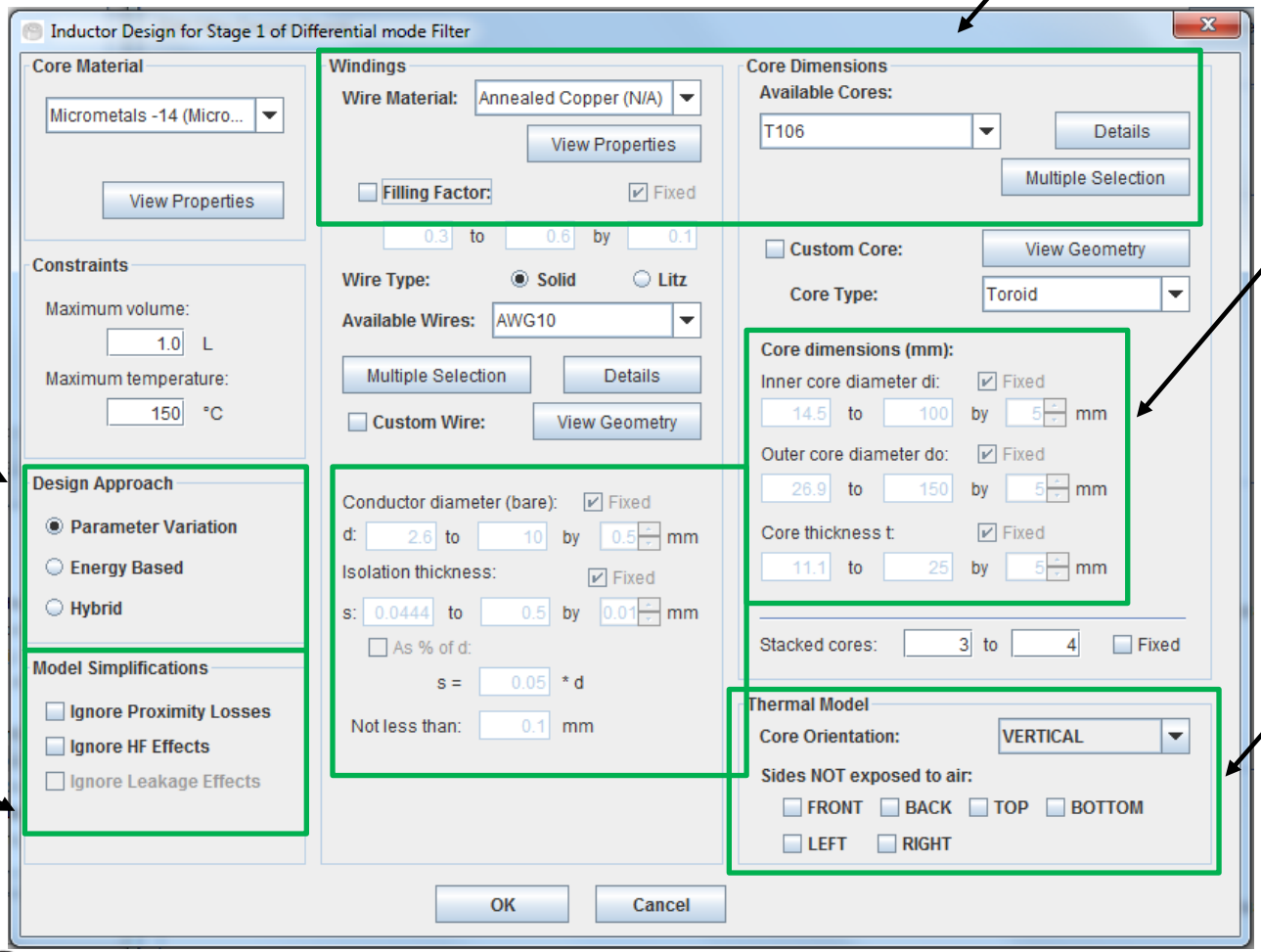
Defining an Inductor Design Space

Cores and wires from the database....



...or custom-defined by the user, with each dimension variable in a range

3 different inductor design approaches (see next slide)

Model simplifications for faster simulation

Thermal model considers natural convection only

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Defining an Inductor Design Space

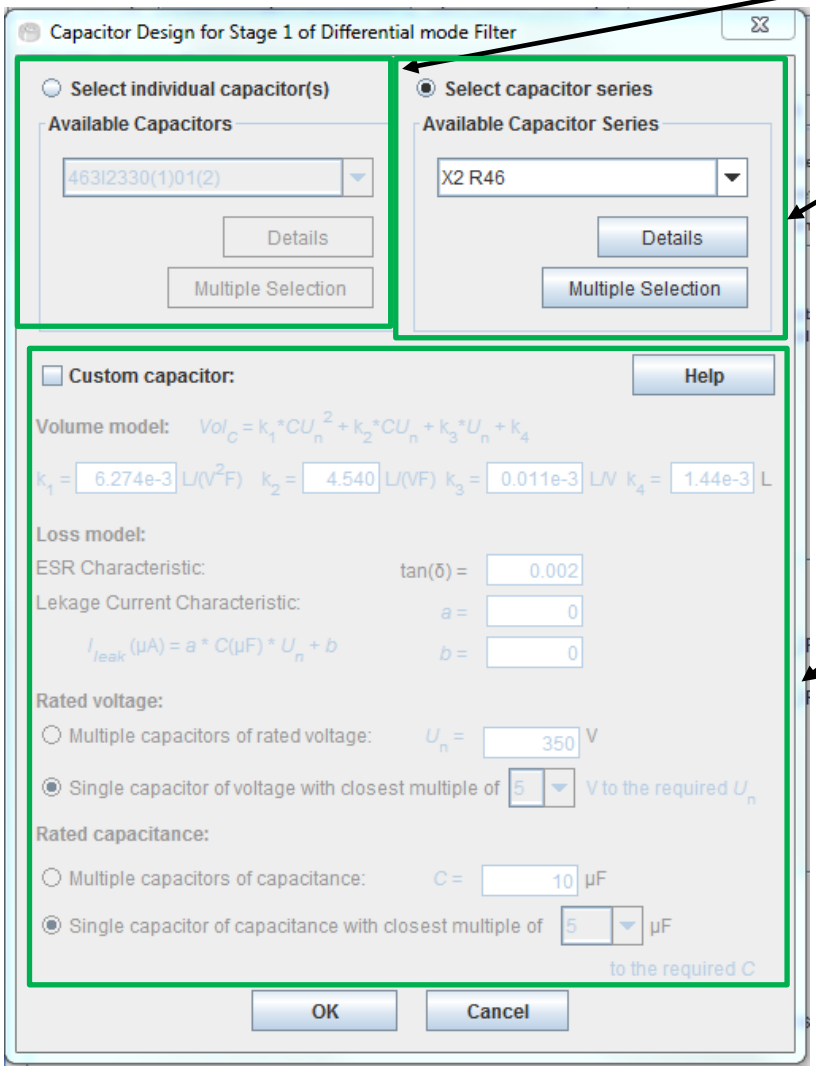
- Toroid and EE cores (latter for DM inductors only)
- Round solid and litz wires
- Three design approaches for inductors:

  - Parameter Variation: tries all values of design parameters in user defined ranges

  - Energy Based: uses the core geometry coefficient and area product when selecting which core to use for the inductor design (quickly rejects cores which are too small, but does not necessarily explore the entire design space)

  - Hybrid: combines the two approaches above (searches with a subset of the user-defined ranges arrived at through the use of the energy-based approach) – combines quick rejection of very unsuitable designs with a more detailed search of the design space

Defining a Capacitor Design Space



Can select individual capacitors from the database....

...or can select capacitor series from the database, where each series contains capacitors of various capacitance values

Alternatively, a custom capacitor model can be defined

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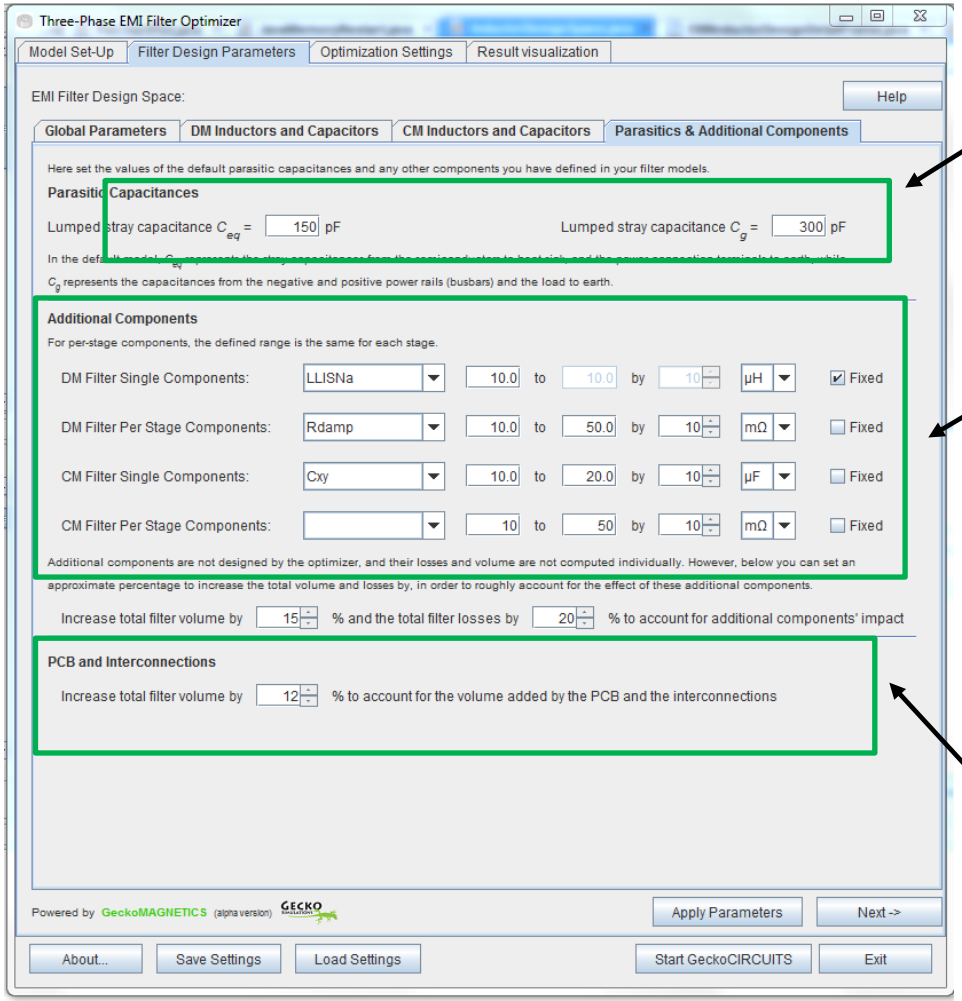
Parasitics and Additional Components

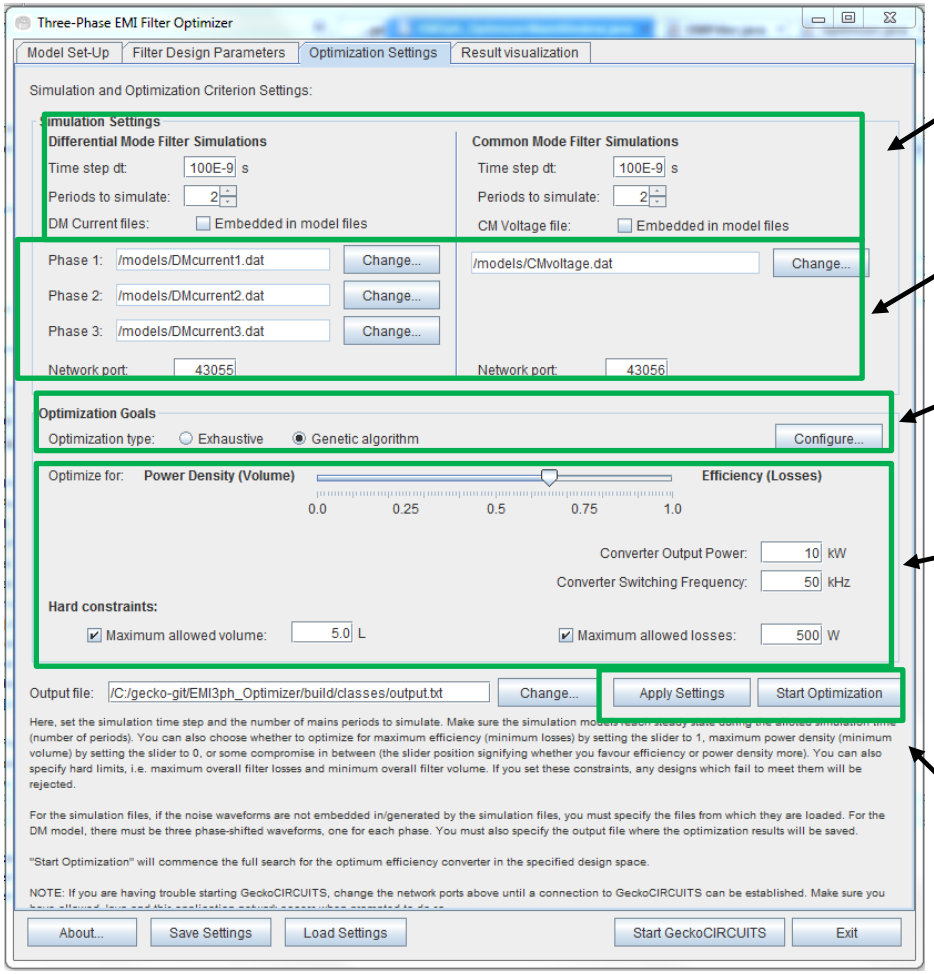


Specify value of parasitic capacitances for CM noise model

Specify value ranges of user-defined additional components, if any

Approximately account for volume of PCB and interconnections

Optimization Settings



Simulation length and time-step

Files with noise waveforms (DM current and CM voltage)

Choice between two optimization algorithms (see Manual for details)

Select optimization goal:
0 – max. power density
1 – max. efficiency
0.5 – half-way compromise
(values from 0 – 1 are possible in increments of 0.01)

This button starts the optimization process

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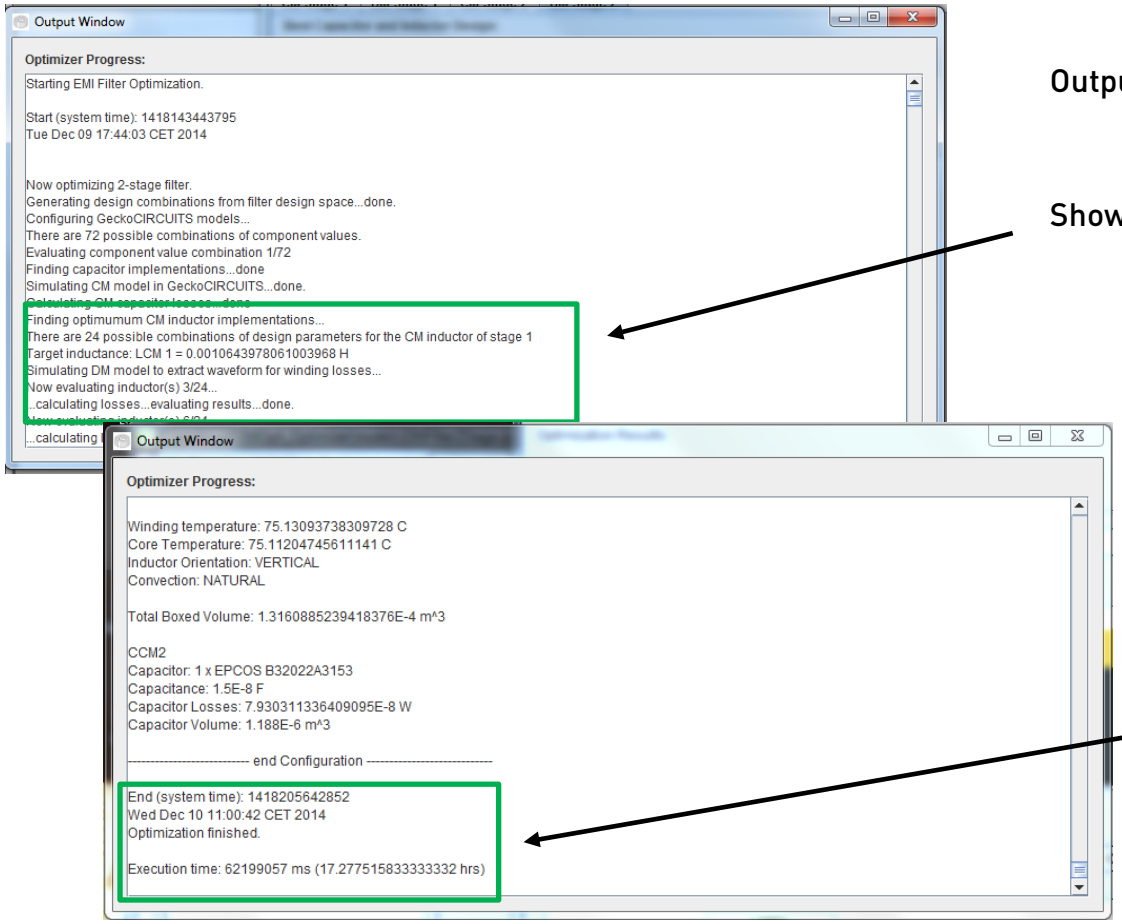
Optimization Progress



Output Window opens

Shows progress...

Shows message when finished

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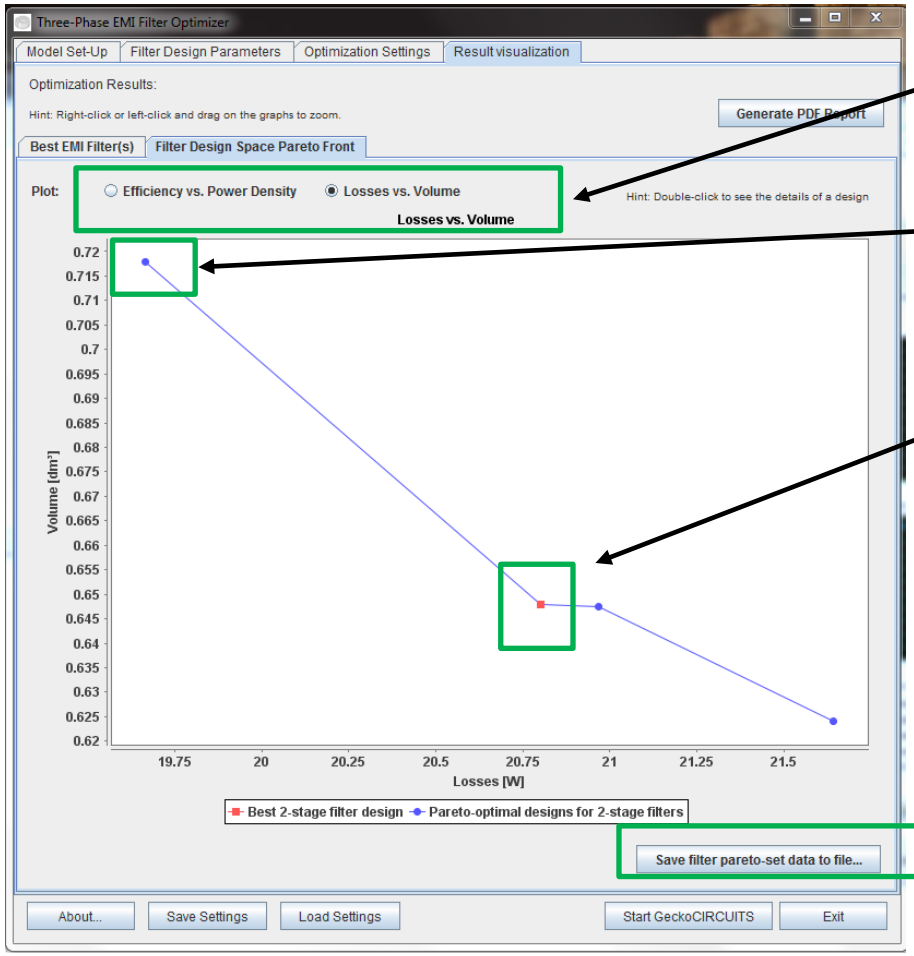
Results: EMI Filter Designs Pareto Front



Can select how to display the plot

Move mouse over any point to see summary of design, double-click to open a window showing detailed results

Best filter design with respect to the selected design goal is highlighted

The pareto front data can be saved to a file

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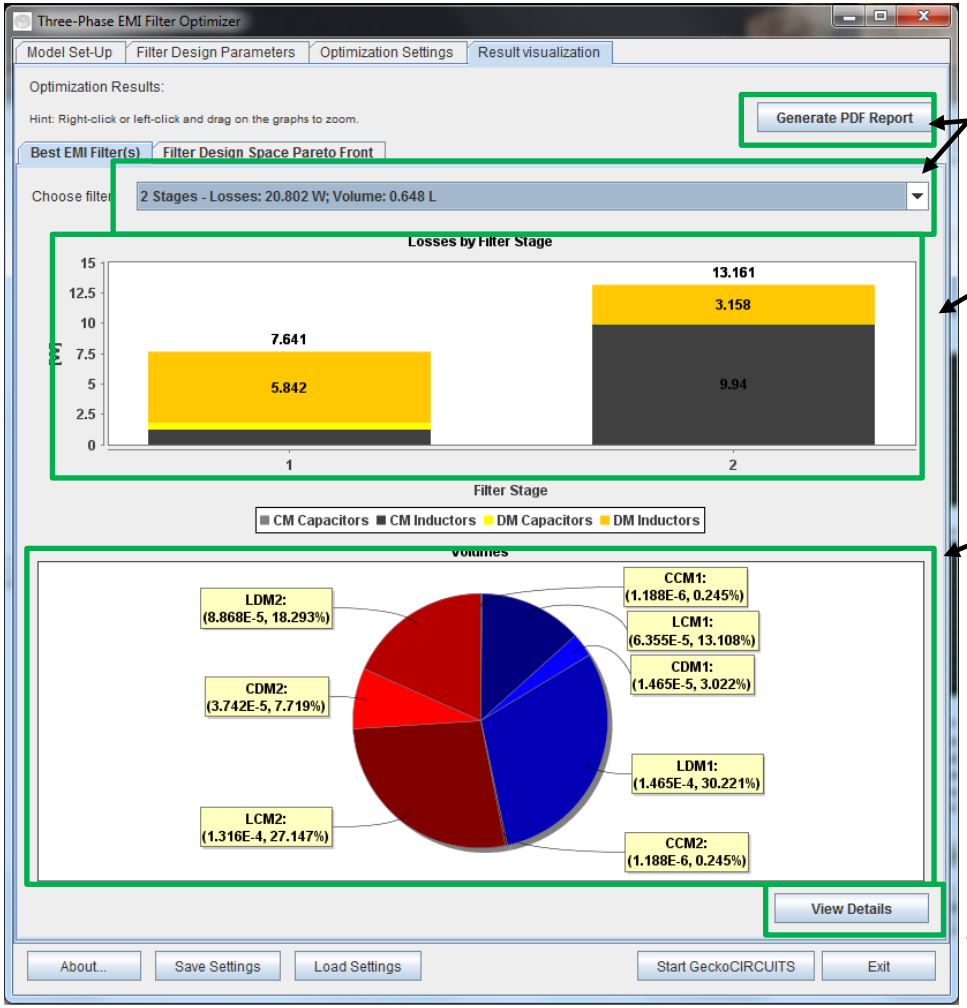
Results: Best EMI Filter Designs



Best design (based on optimization goal) for each number of stages is given here

Can save the optimization results as a PDF file

Loss breakdown by stage and component

Volume breakdown by stage and component

Click this button to view details of the filter design stage-by-stage

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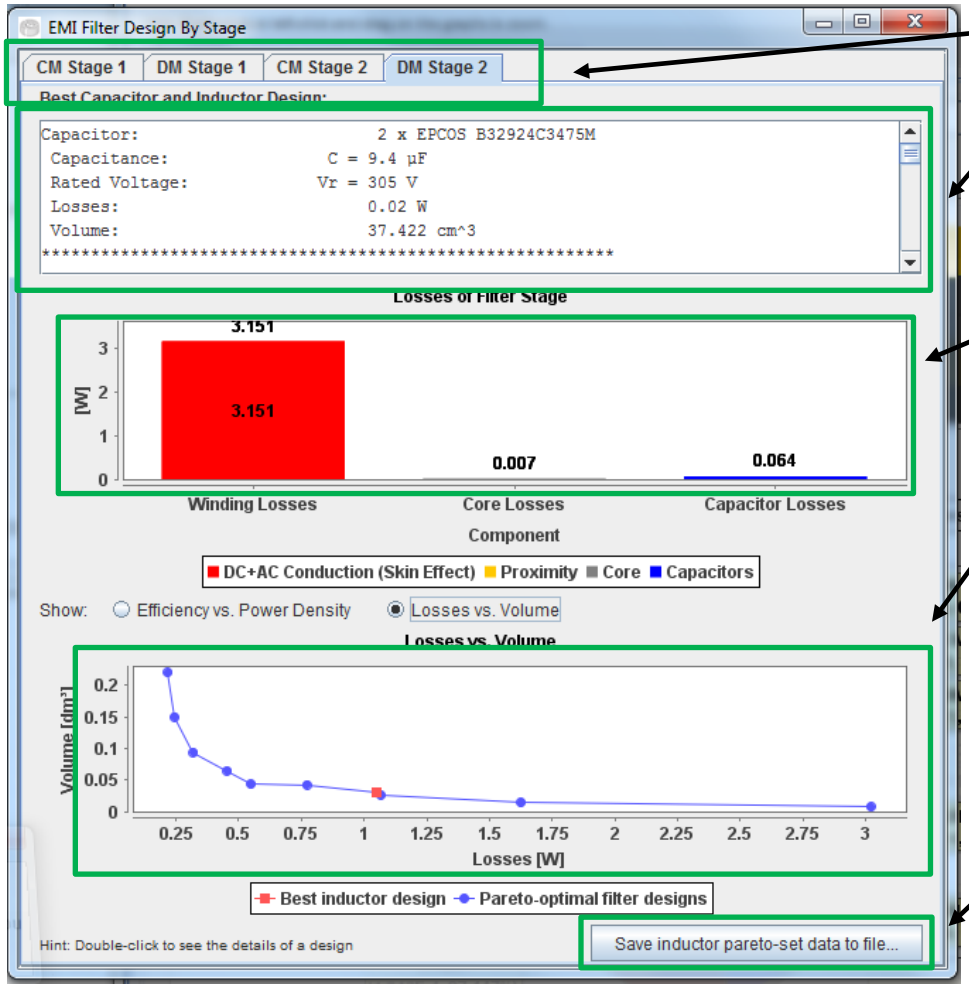
Detailed EMI Filter Results



Detailed results for each filter stage

Details for the capacitor and inductor design for this stage (components used, dimensions, exact losses and volumes)

Loss breakdown for this stage

Pareto front of the design space for this stage's inductor, showing highlighted the selected inductor design (according to the set optimization goal)

Double-click on a point to see the details of the inductor design

Inductor pareto front data can be saved to a file

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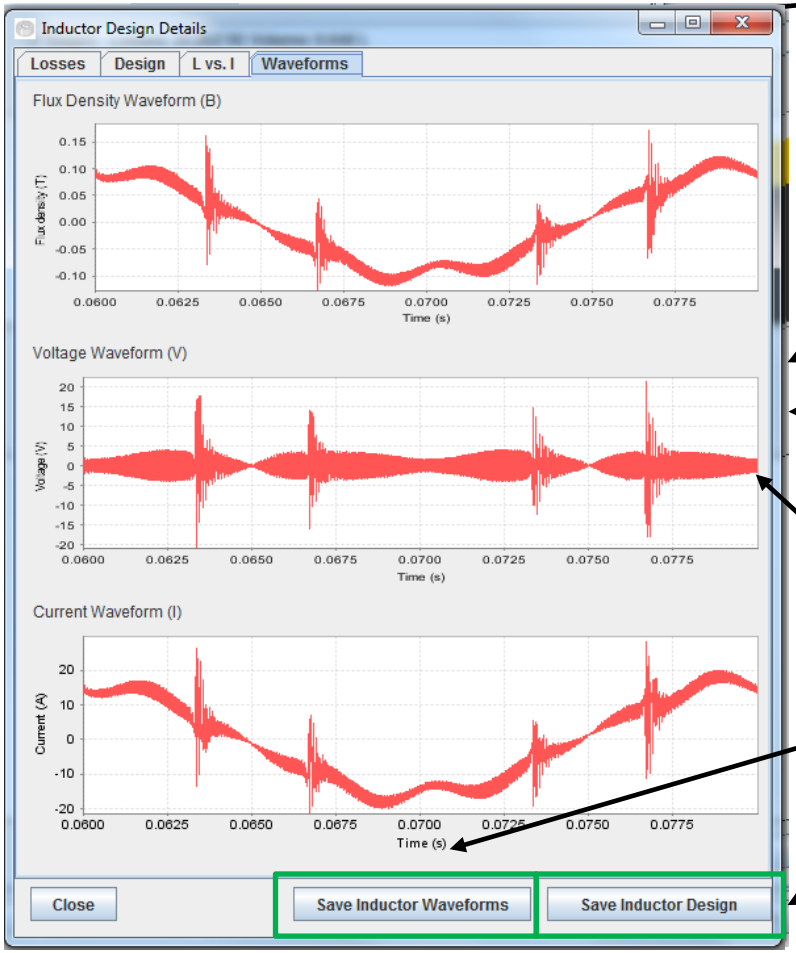
Detailed Inductor Results



Detailed results for each inductor in the pareto front

Losses for one inductor

Detailed design description

L vs. I characteristic

Inductor waveforms can be saved to file

Inductor design can be saved for loading into GeckoMAGNEITCS

User's Manual

Before using the program, and for all other details, please read the User's Manual!

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