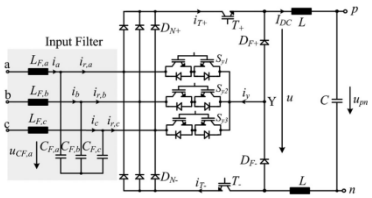
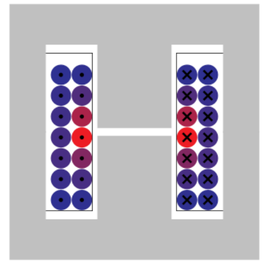
Gecko Swiss Rectifier Optimizer

FREE Feature Demonstrator Application

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



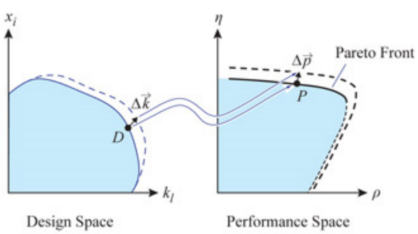
Circuit simulation
(electrical & thermal)



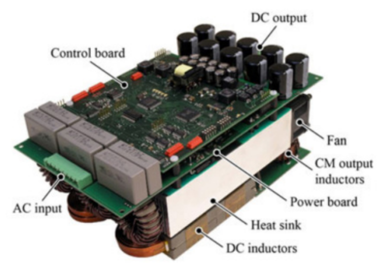
Magnetic simulation
(with thermal model)

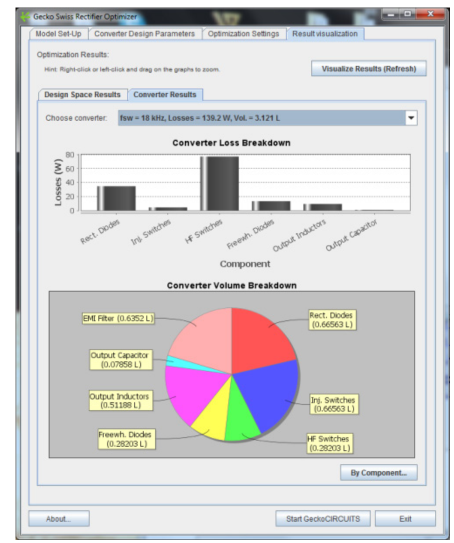
Component Design Space

Optimization Algorithm



Optimized Maximum-Efficiency Converter





GECKO SIMULATIONS

Power Electronic Systems Laboratory

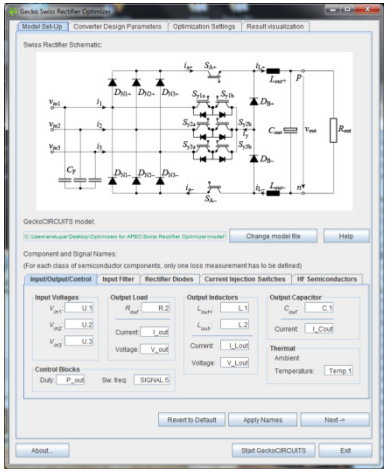
ETH Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Quick Introduction

The Gecko PES Swiss Rectifer Optimizer is a free, feature demonstrator Java application build on top of GeckoCIRCUITS and GeckoMAGNETICS for finding the highest efficiency Swiss Rectifier Design within a given design space:

1) It showcases features in development (e.g. converter 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.



This is shown on the example of the Swiss Rectifier, a three-phase PFC rectifier topology developed at the Power Electronics Systems Laboratory at ETH Zurich:

The Gecko PES Swiss Rectifier Optimizer allows you to define a design space for each converter component, and then using evaluations through simulations and an optimization algorithm, it finds the maximum efficiency converter design.

IMPORTANT!

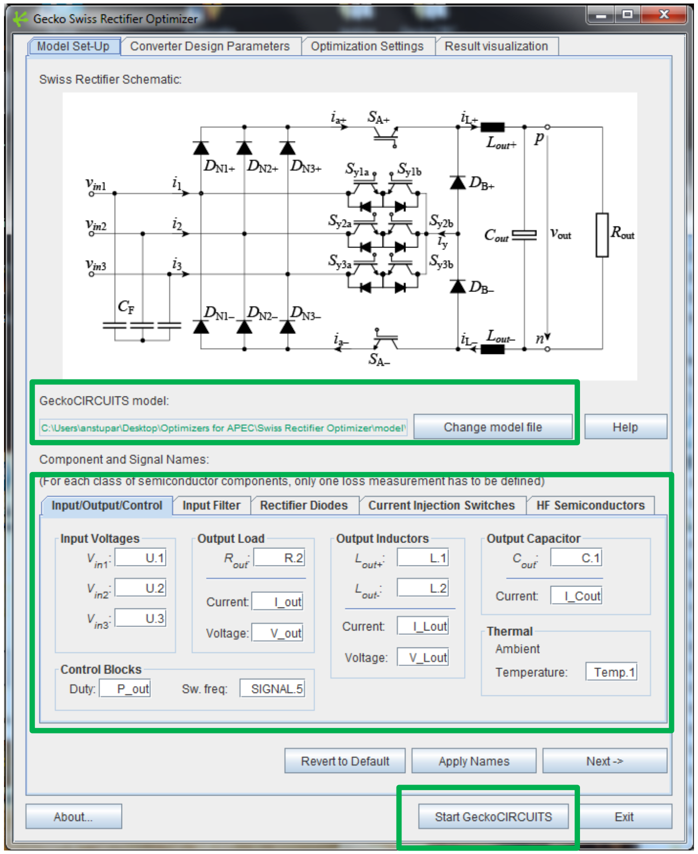
This presentation gives a Quick Introduction to using the Swiss Rectifier Optimizer. No detailed manual is supplied, since after this introduction using the program should be relative straight-forward and self-explanatory.

Also, "Help" buttons are available at almost every stage of the program's interface, which give a more detailed explanation of the available options.

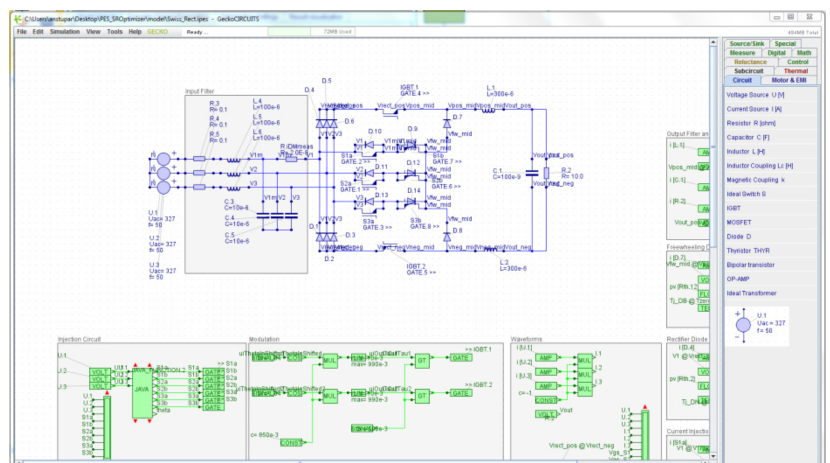
BEFORE STARTING THE PROGRAM, please read the file README_FIRST.txt, supplied with the application and in the same directory as this presentation.

Feel free to send questions and comments to andrija.stupar@gecko-simulations.com

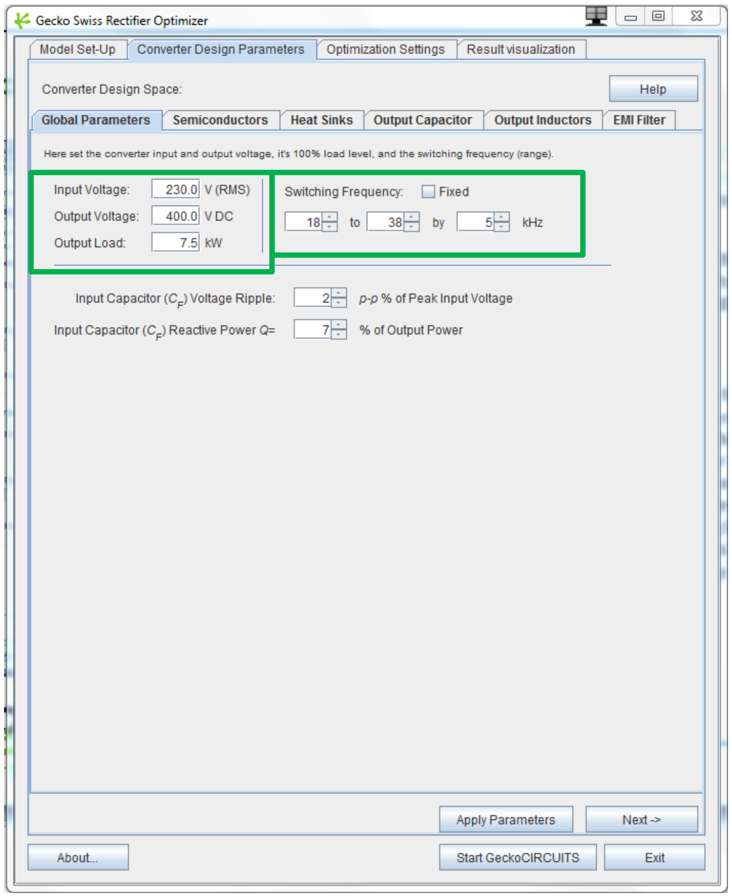
Specifying the GeckoCIRCUITS Simulation Model



- The Optimizer uses a model of the Swiss Rectifer in GeckoCIRCUITS to extract electrical and thermal waveforms
- In the first tab (Model Set-Up), the names of the various converter components and measurement signals must be defined
- The default names work with the default supplied model – if using it, no change to the input field in this tab are necessary
- Click "Start GeckoCIRCUITS" to open the model



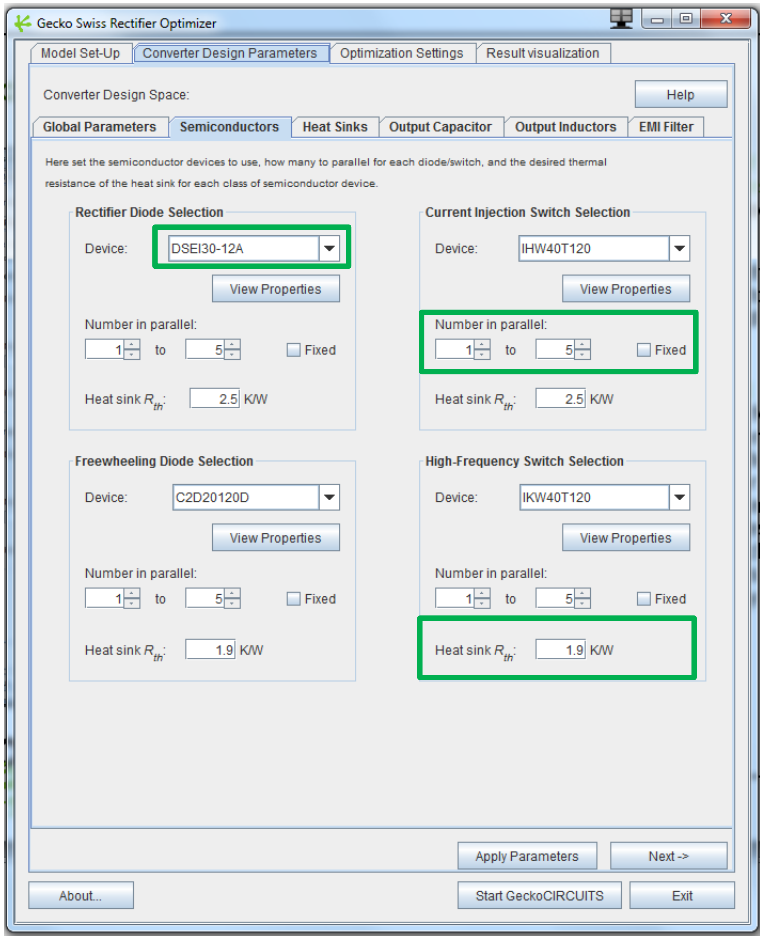
Specifying the Design Space



- In the next tab (Converter Design Parameters), you are then guided, step-by-step, to define the design space of the converter
- Some parameters are fixed for each optimization (e.g. input voltage, output load, etc.)
- Most parameters (e.g. switching frequency) are variable, and you can specify a range, the increment for that range (e.g. frequencies from 18 to 50 kHz in increments of 2 kHz), or fix those parameters to one value

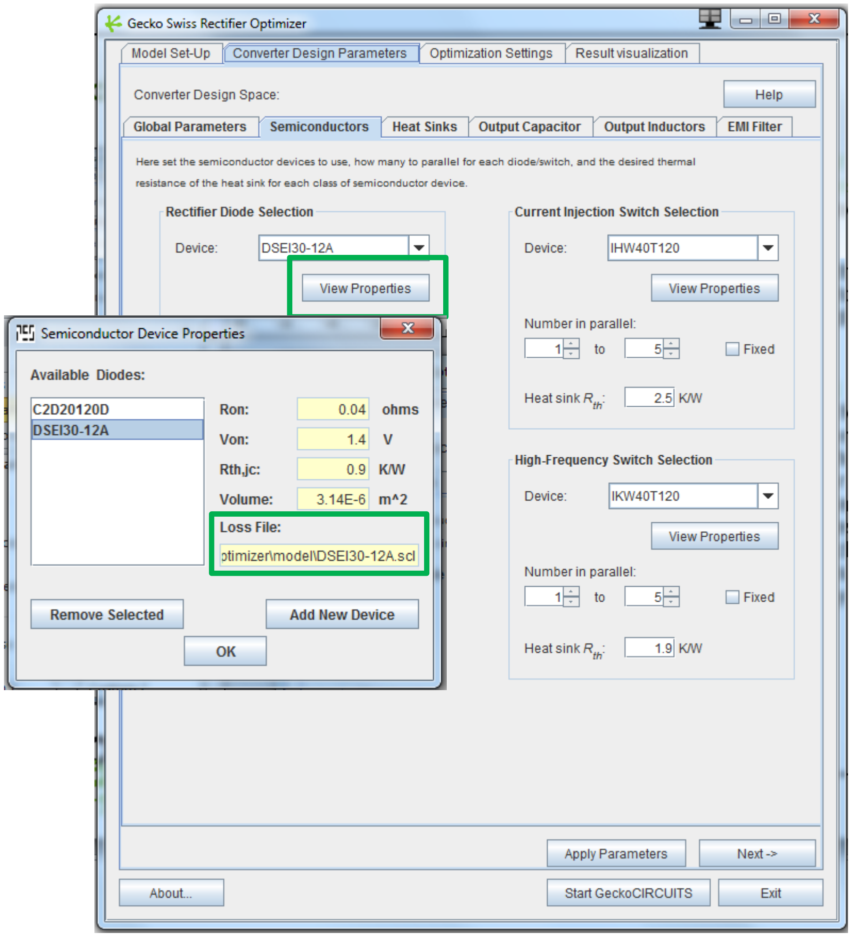
GECKO SIMULATIONS

Specifying the Design Space – Semiconductors



- You can select from a list of available diodes or switches, for each class of semiconductor device in the rectifier
- The variable parameter is the number of devices used in parallel to implement each switch or diode (increment is by 1)
- You must specify a thermal resistance of the heat sink for each device. Note: this is the thermal resistance of the "piece of heat sink" under each particular device, i.e. if there are 5 switches in parallel, it is the thermal resistance under each of the five switches (so the total underneath all 5 is the single resistance divided by 5)

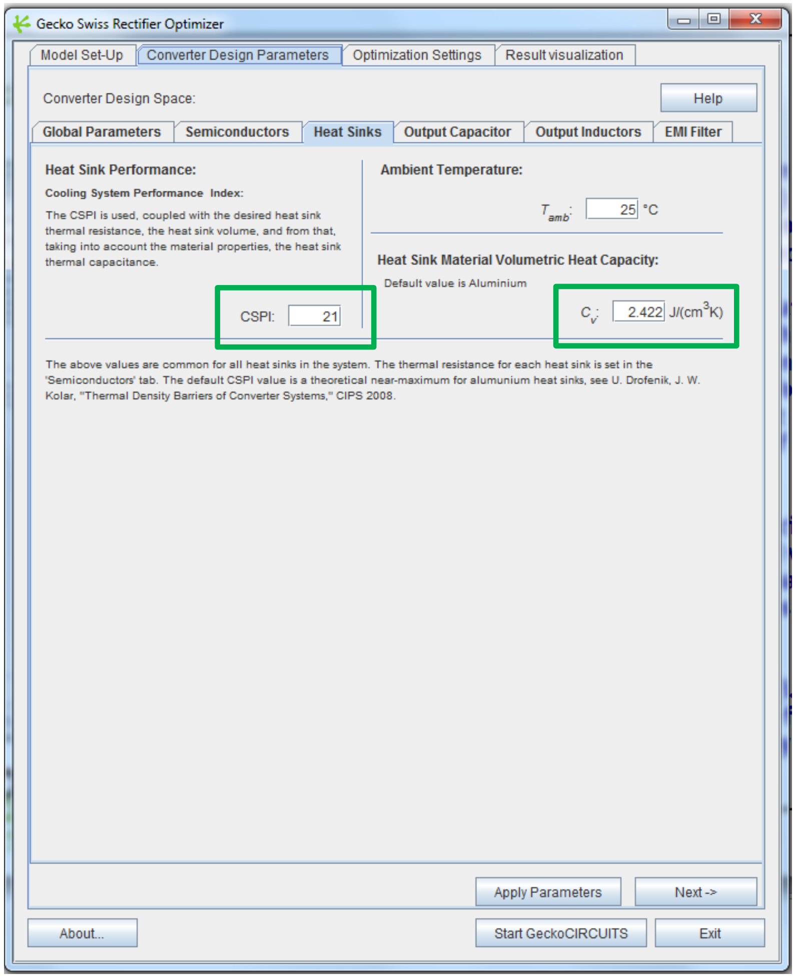
Specifying the Design Space – Semiconductors



- ▶ You must give a reasonable thermal resistance value, otherwise temperatures (and losses) will be unrealistically high or unrealistically low
- ▶ By clicking on "View Properties", the detailed properties of the selected semiconductor are shown – here you can examine all the devices available by default and compare their basic properties, and add new devices of your own
- ▶ NOTE: newly added devices are not saved to disk (when you close the program, they disappear)
- ▶ Each device MUST have a GeckoCIRCUITS loss file (.scl)

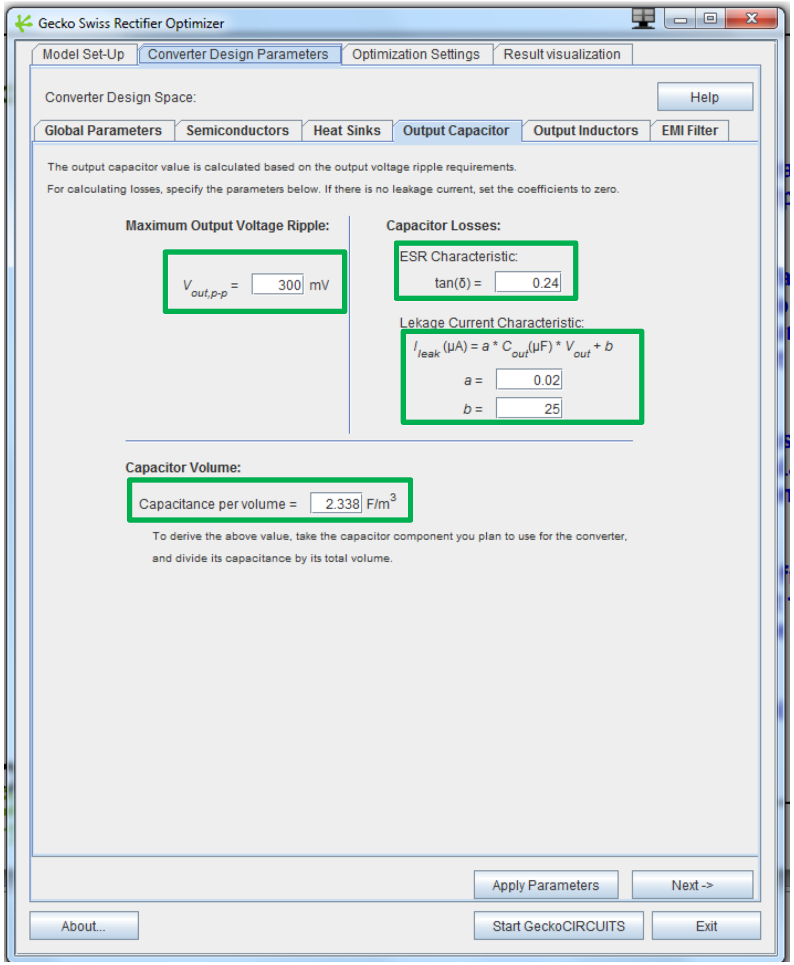
GECKO SIMULATIONS

Specifying the Design Space – Heat Sinks



- For the heat sink, a cooling system performance index (CSPI) and a volumetric heat capacity of the material must be specified
- The CSPI is used to calculate the heat sink volume using the specified thermal resistances from the previous tab – therefore, a different (separate) heat sink is assumed for each class of semiconductors
- The volumetric heat capacity is then used with this calculated volume to calculate the thermal capacitance of the heat sink (which goes into the simulation model)
- Fans are not considered (i.e. their losses), the effect of the fan is assumed accounted for by the CSPI

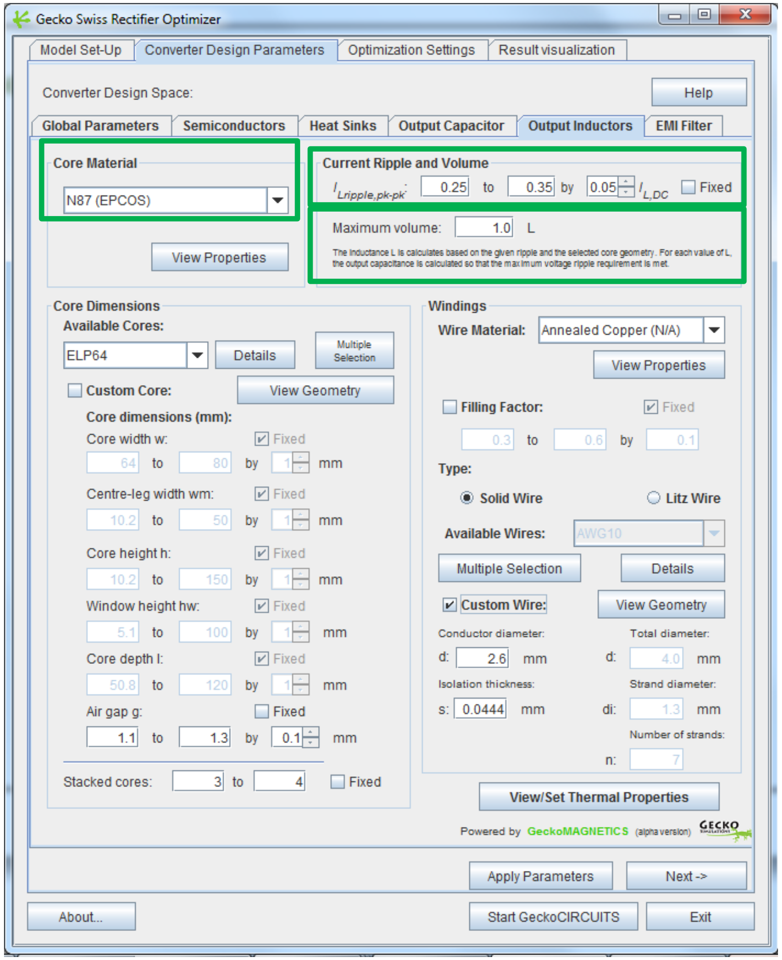
Specifying the Design Space – Output Capacitor



- Here a very important parameter is specified – maximum output voltage ripple
- Furthermore a tan-delta factor can be specified for conduction losses, and a simple (not really universal) model for leakage current losses is also specifiable
- A volumetric constant must be supplied in order to calculate the volume once the capacitance is calculated
- Capacitance is calculated from the voltage and current ripple specification

GECKO SIMULATIONS

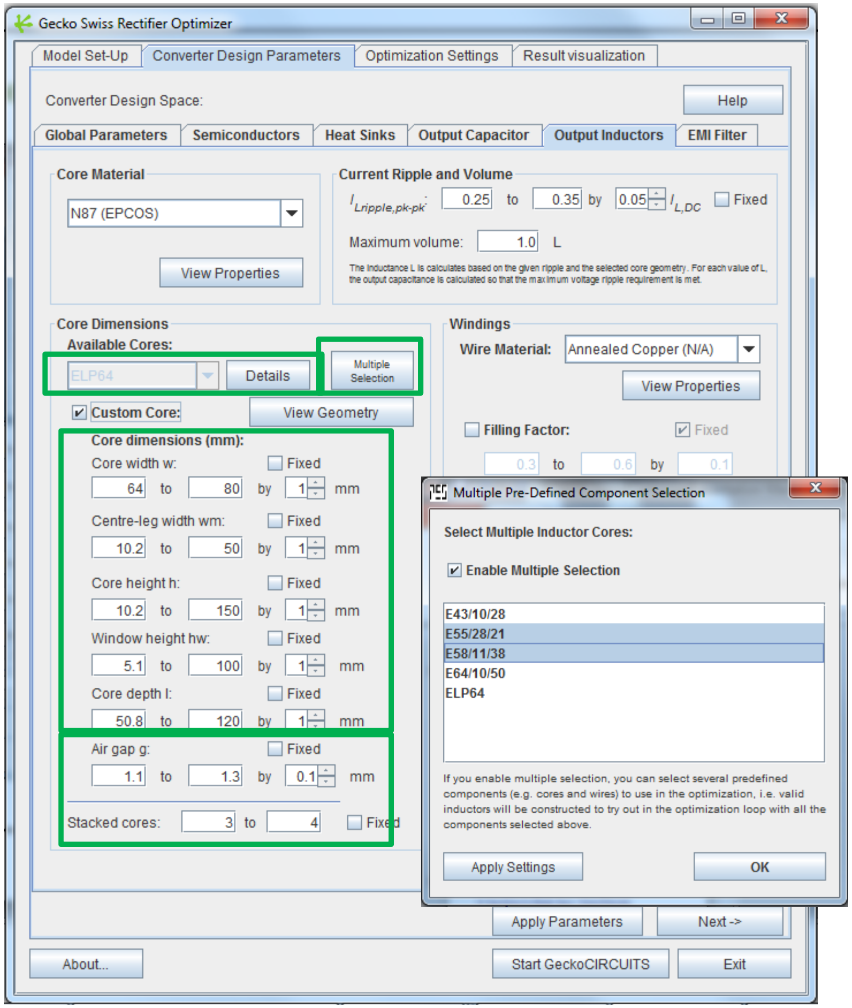
Specifying the Design Space – Output Inductors



- The most different parameters to set are for the output inductor design
- Here you can select a core material – several are offered – this choice is a fixed parameter
- The main parameter for inductor design is the current ripple – this can be specified as a range, and in turn determines the required inductance L
- A maximum allowed volume must also be specified

GECKO SIMULATIONS

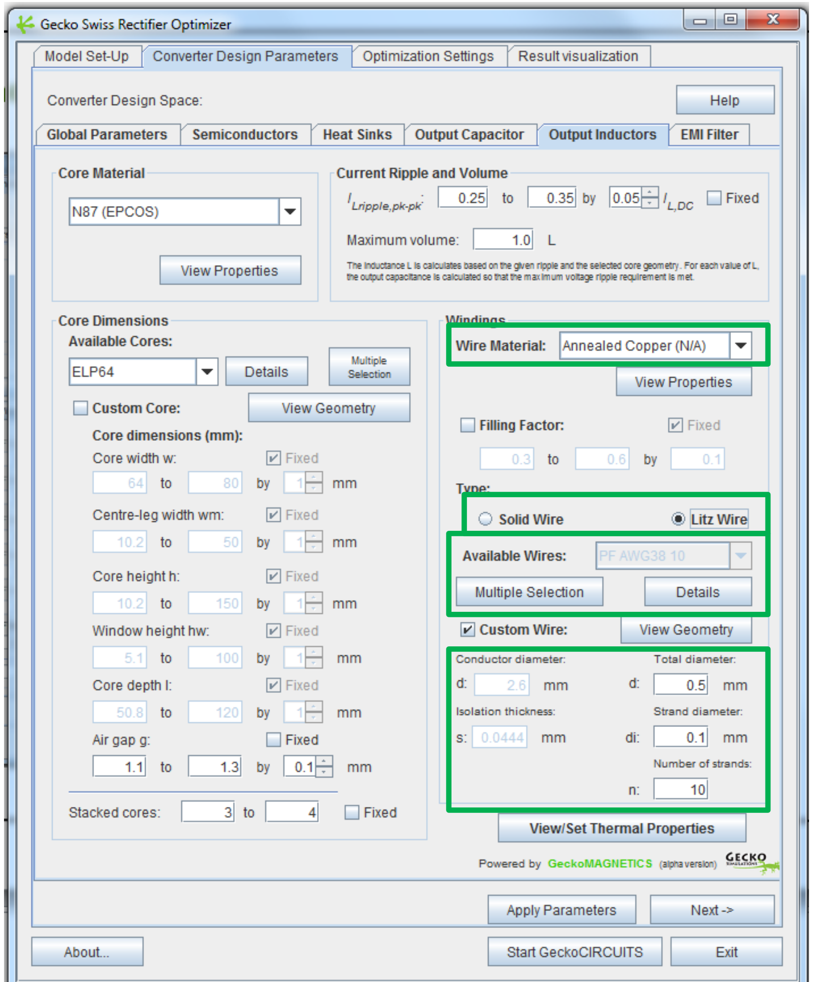
Specifying the Design Space – Output Inductors



- **Cores:** Only EE-Cores with three air gaps are available
- You can select a predefined core from the drop-down list, or define a custom core by defining a value range for each core dimension parameter
- Besides setting ranges for a custom EE-Core geometry, you can also do a multiple selection of predefined cores, so that the program tries out all of them
- Whether using predefined cores or a custom core, you must define the air gap range and the number of stacked cores (also variable)

GECKO SIMULATIONS

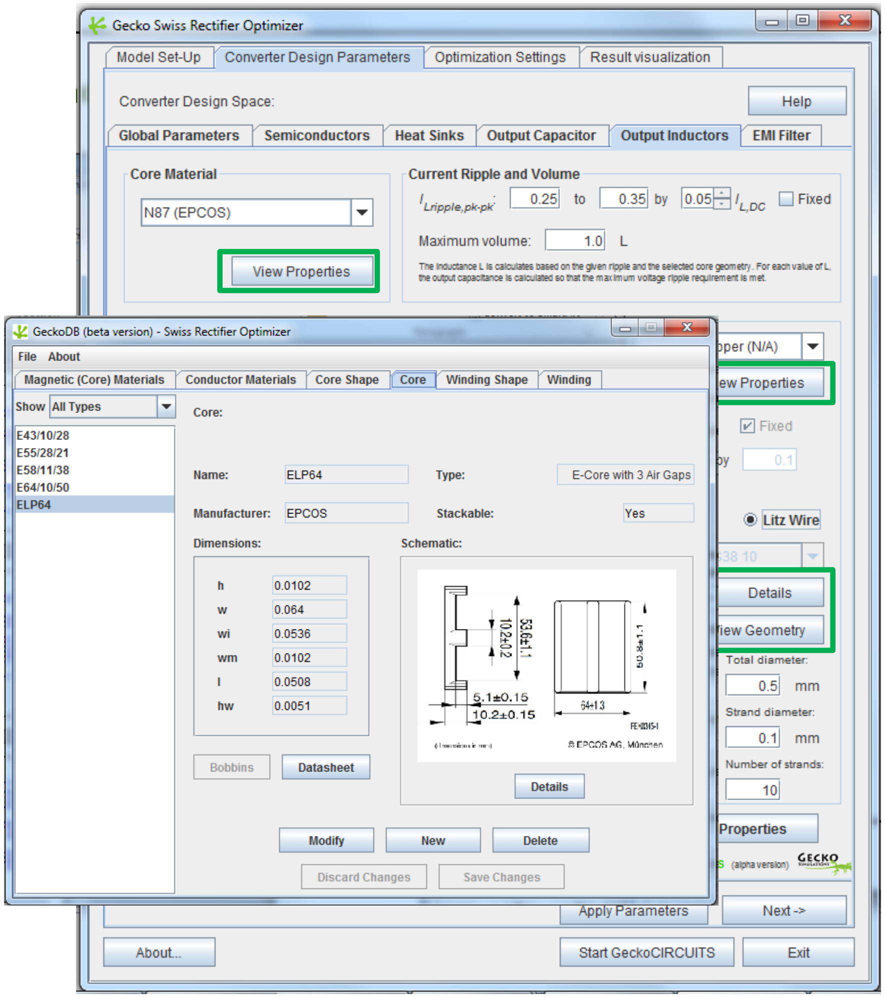
Specifying the Design Space – Output Inductors



- **Windings:** you can select solid round or litz wire (but not both at the same time)
- One fixed winding material (several predefined available)
- Like with cores, you can select one or multiple pre-defined windings
- However, if you choose a custom wire, the parameters are fixed – no range can be defined, and only that single wire is used during the entire optimization process

GECKO SIMULATIONS

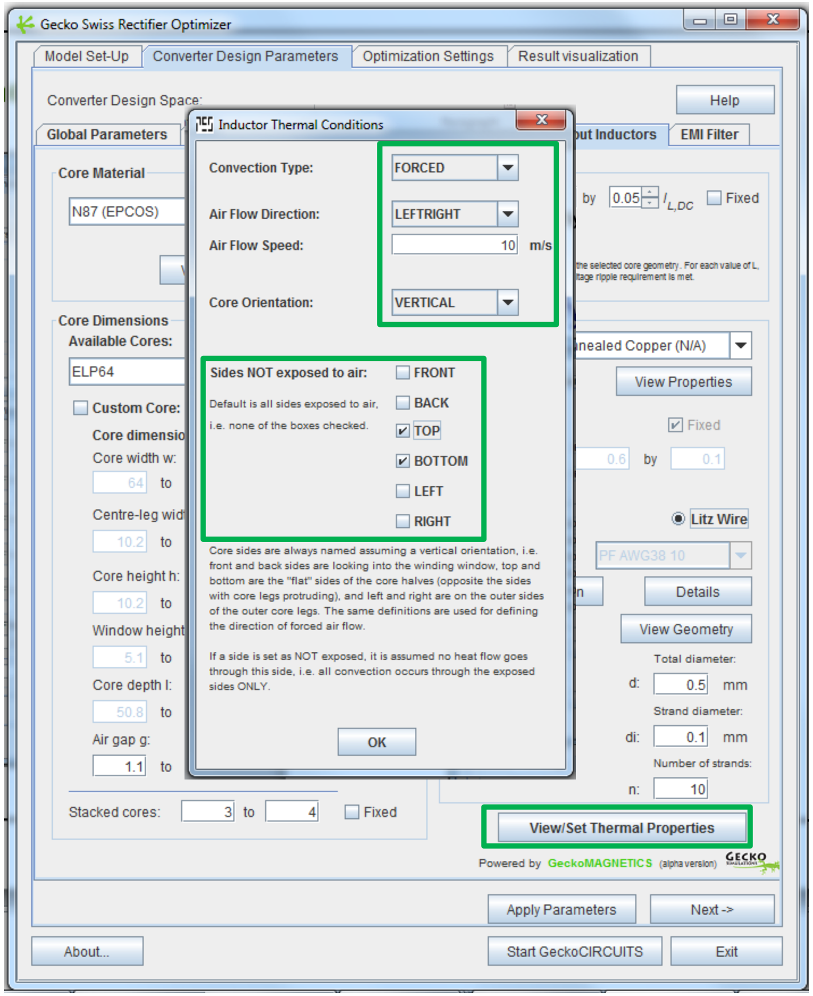
Specifying the Design Space – Output Inductors



- Whenever you click on a "View Geometry" or "View Properties" button, the magnetic component database - GeckoDB - opens up

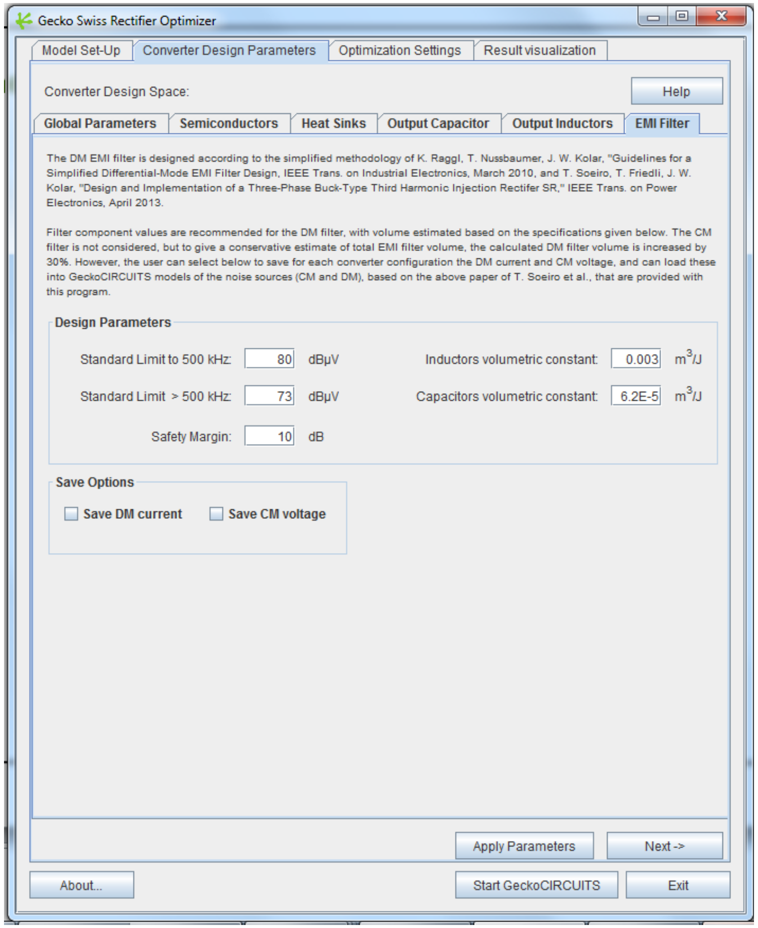
- Here you can define your own core and wire sizes and core materials – any changes or additions to make are saved to disk and are available next time you start the program

Specifying the Design Space – Output Inductors



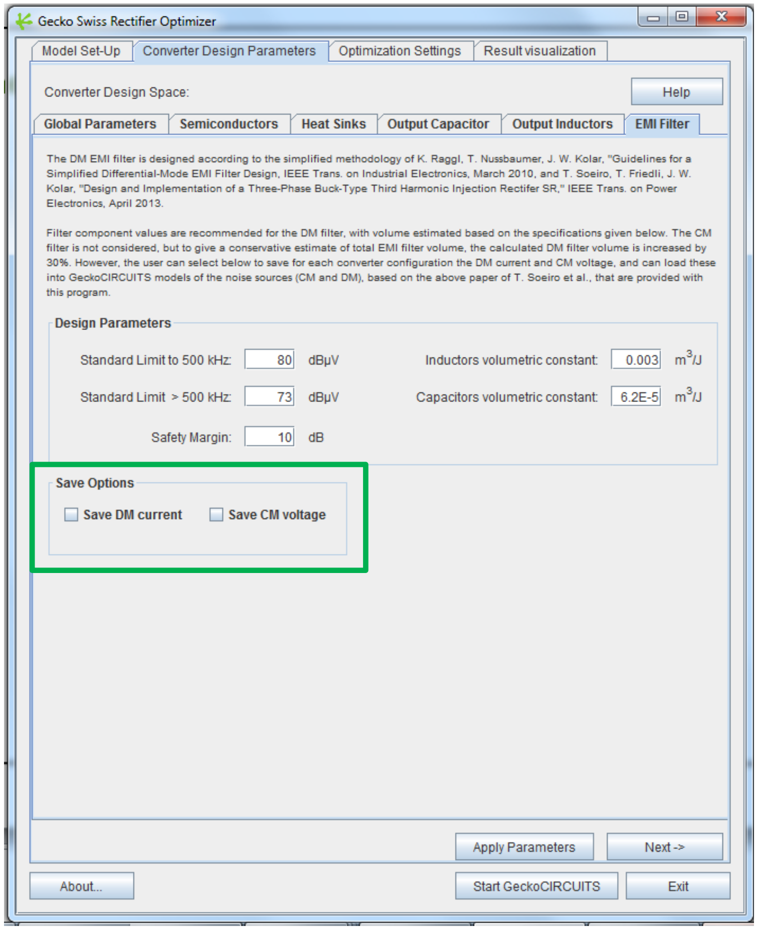
- The thermal properties are set in a separate window by clicking on the lower-right button
- You can select the type of convection (natural or forced – and if forced, at which air speed and in which direction of airflow), the orientation of the core with respect to gravity, and which of the sides are exposed to air flow
- Thermal model is only stationary (resistances, no capacitances)
- Sides not exposed to air are assumed to transfer no heat
- Volume or losses of the fan blowing if forced convection is selected are not taken into account at this point

Specifying the Design Space – EMI Filter



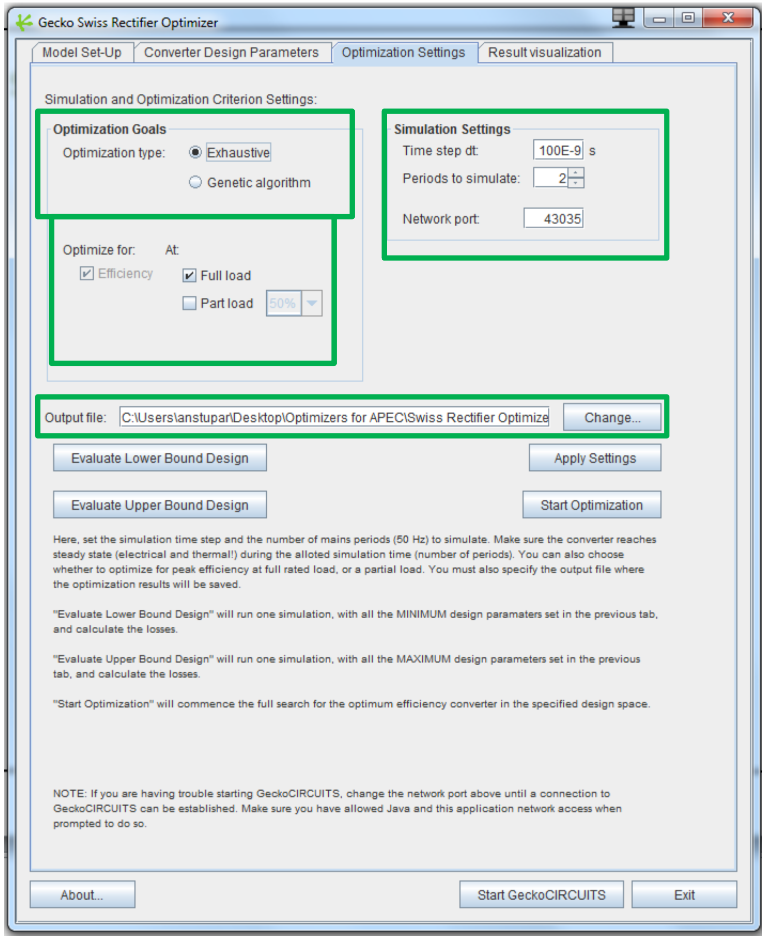
- For the EMI filter, you can specify the limits of the standard being used, the safety margin for the attenuation, and the volumetric constants of the inductors and capacitors that are to be used for the filter
- After a converter is optimized at a certain switching frequency, from simulation data of the differential mode current the required attenuation is calculated
- From this attenuation, a two-stage *LC* input DM EMI filter is calculated, with the volume calculated based on the volumetric constants
- CM filter is not calculated; volume of DM filter is increased by 30% to approximate the effect of the CM filter on total volume
- DM filter LC values (1st and 2nd stage) are given in the Output Window and in the output file at the end of the optimization

Specifying the Design Space – EMI Filter



- ▶ To perform a detailed optimization of the EMI filter for a particular efficiency optimized converter design, including all losses and the CM filter design, select the options to save the DM current and CM voltage
- ▶ Then load these saved waveforms into the Swiss Rectifier CM and DM noise models supplied with this program and load them into the Gecko Three-Phase EMI Filter Optimizer

Optimization Settings



- Here you must specify:

  The output file to which the optimization results will be written

  Simulation settings: the time-step and the number of periods to simulate (make sure the circuit is in steady-state in the last simulated period)

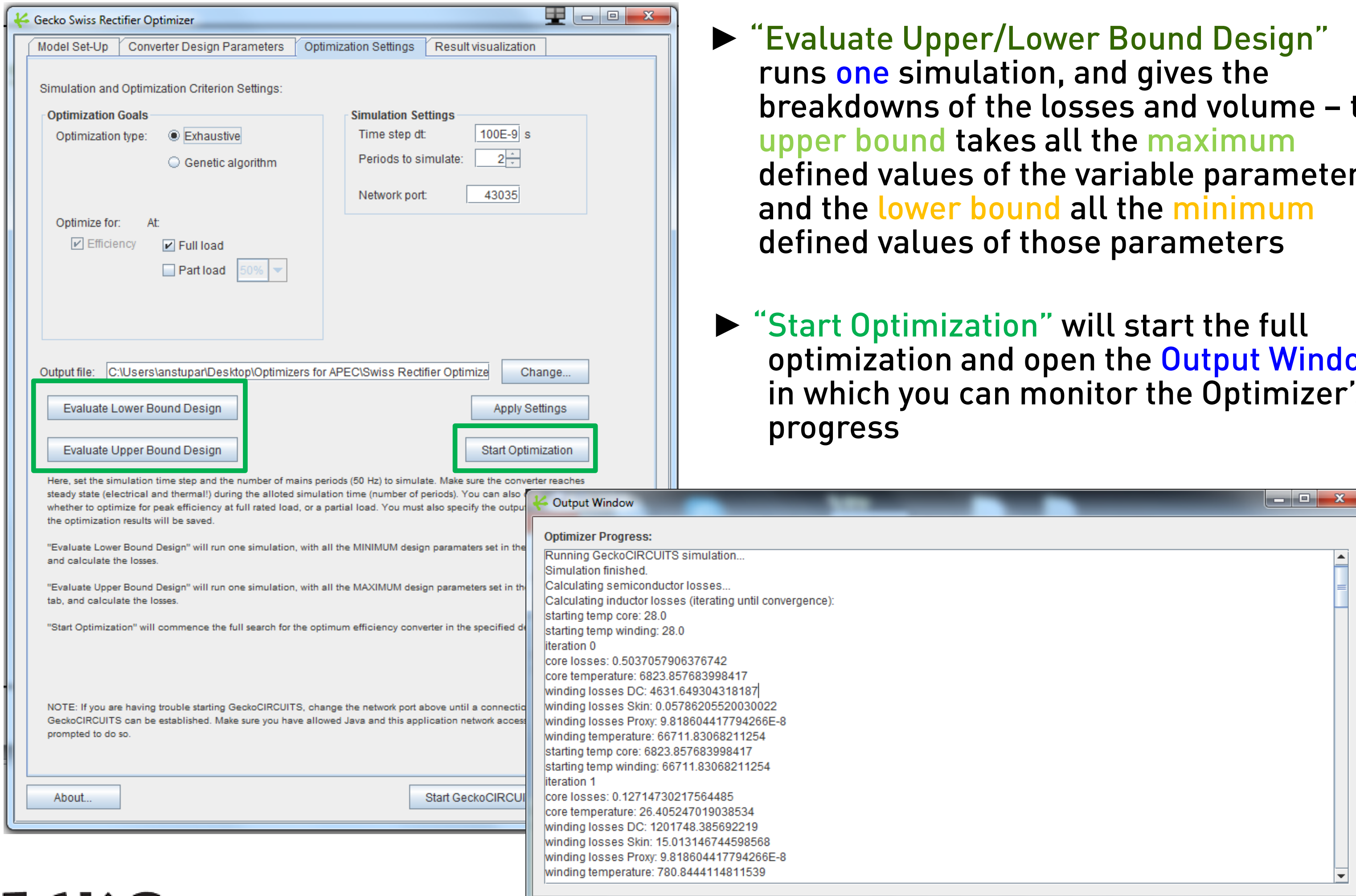
  Whether to optimize for full or partial output load

  Optimization algorithm: exhaustive (brute-force) or genetic

    The usage of the genetic algorithm is recommended for large design spaces

GECKO SIMULATIONS

Optimization Settings

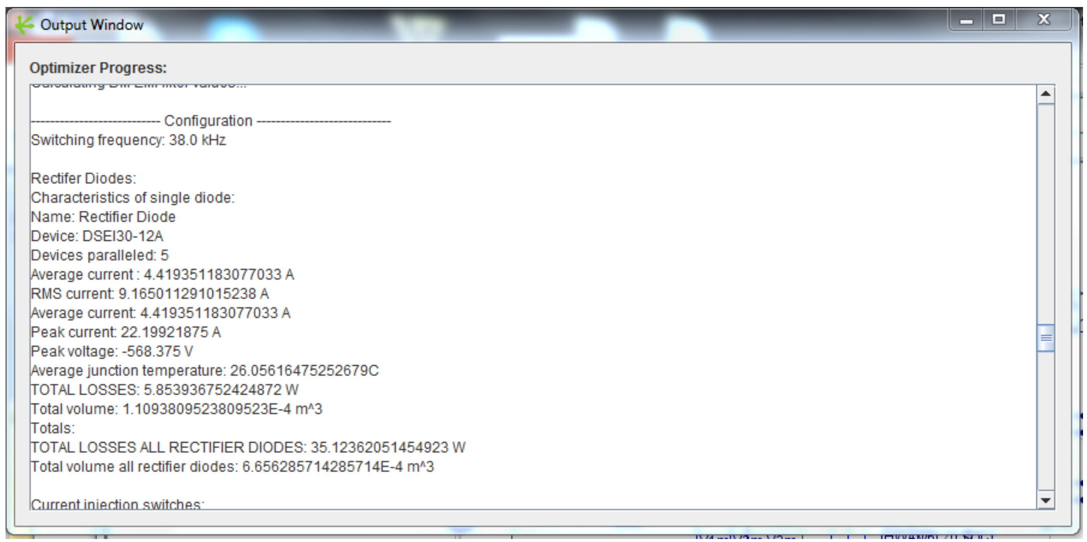


- "Evaluate Upper/Lower Bound Design" runs one simulation, and gives the breakdowns of the losses and volume – the upper bound takes all the maximum defined values of the variable parameters, and the lower bound all the minimum defined values of those parameters

- "Start Optimization" will start the full optimization and open the Output Window in which you can monitor the Optimizer's progress

Optimization Results

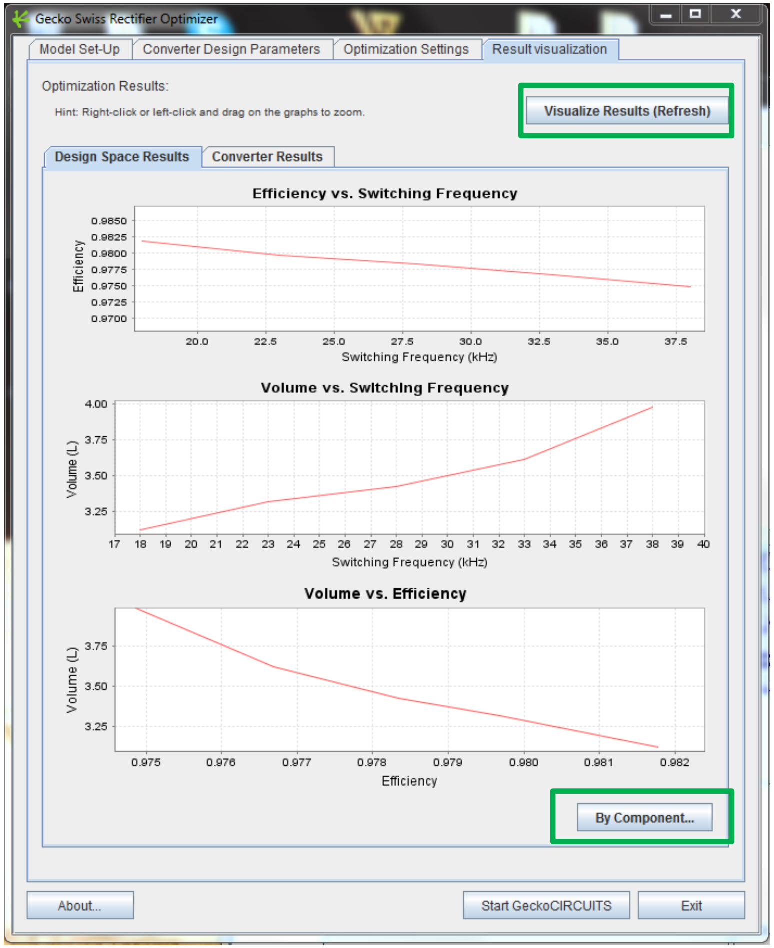
- At the end, for each switching frequency, the maximum efficiency design is specified in the Output Window
- Given are all the component values, which components to use and how many (how many diodes and switches to place in parallel, how many cores of which size, turns of which wire, etc).



- The same information is written to the output file you have previously specified

GECKO SIMULATIONS

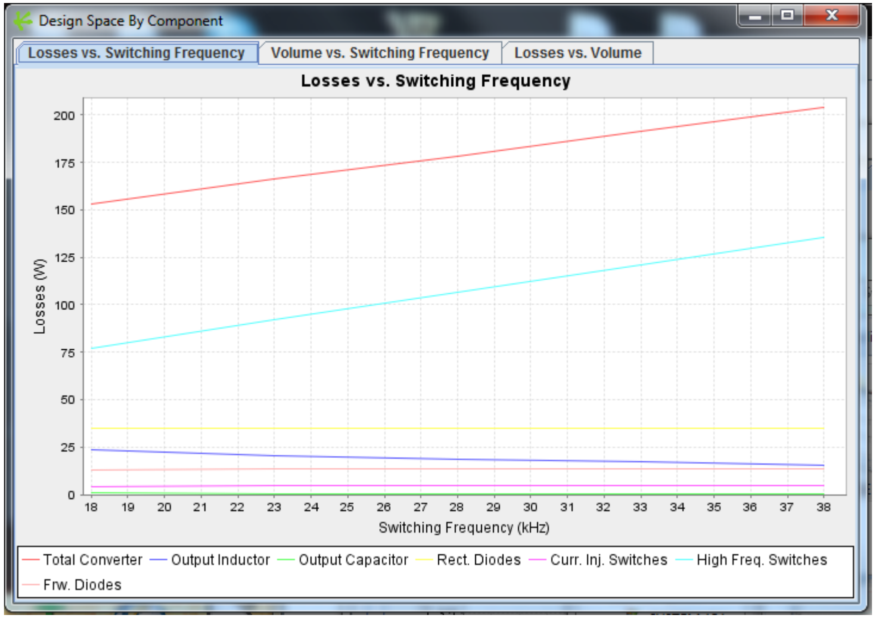
Visualization of Results – Design Space

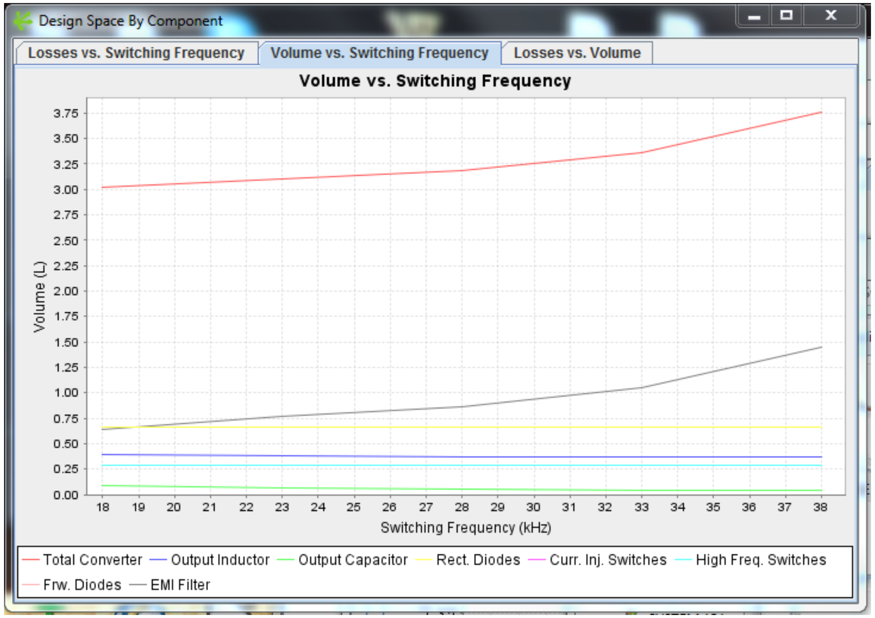


- When the optimization finishes, click "Visualize Results (Refresh)" in the Result visualization tab to see plots and graphs of the resulting designs
- The "Design Space" visualization gives the key characteristics of the efficiency-optimized converters over the switching frequency range
- Clicking "By Component" ...

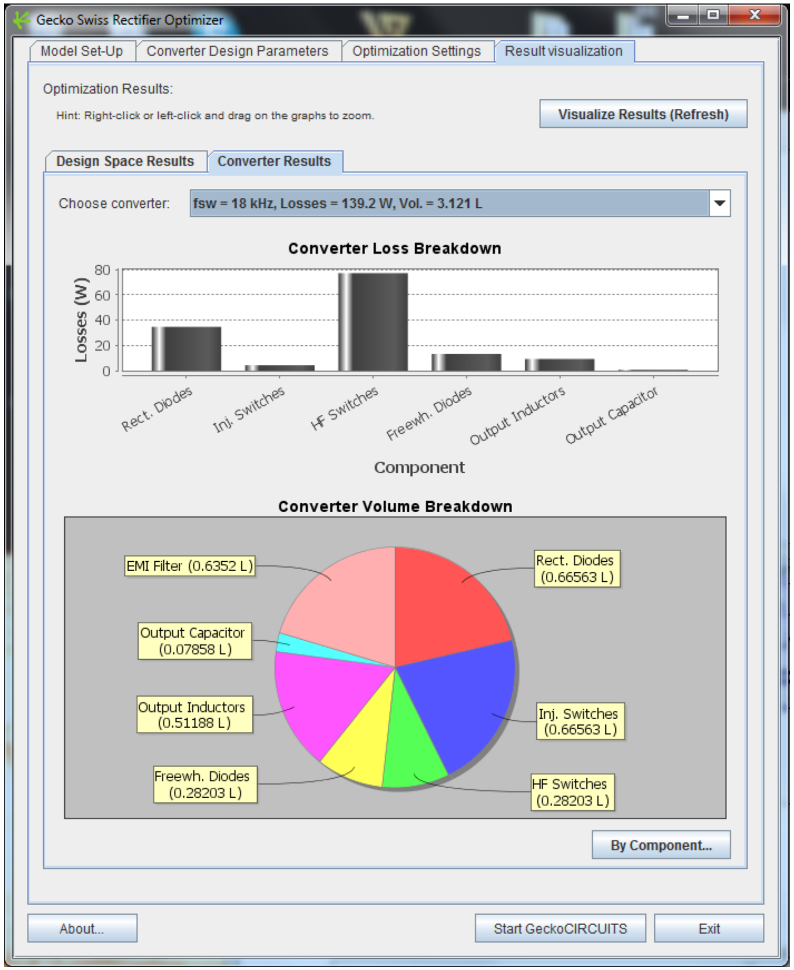
Visualization of Results – Design Space

... will show the same plots, but broken down by component type, so you can see how the design of e.g. the inductor moves over frequency

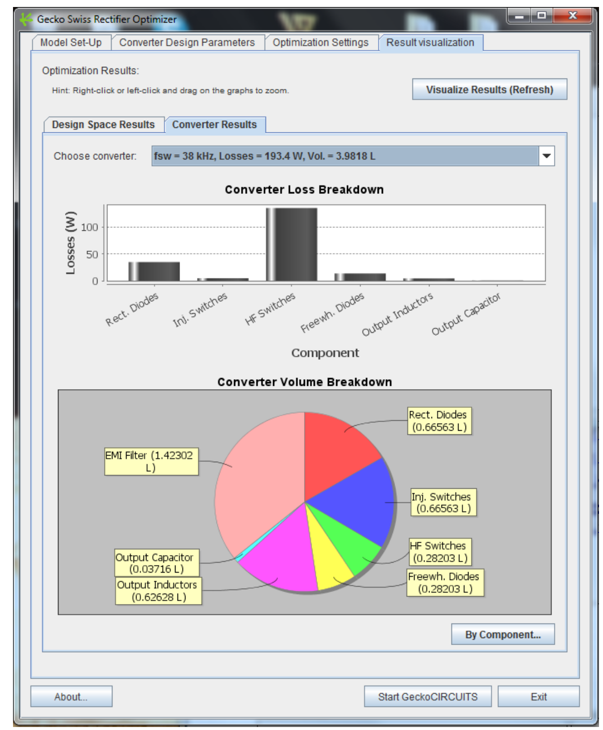




Visualization of Results – Converter Results

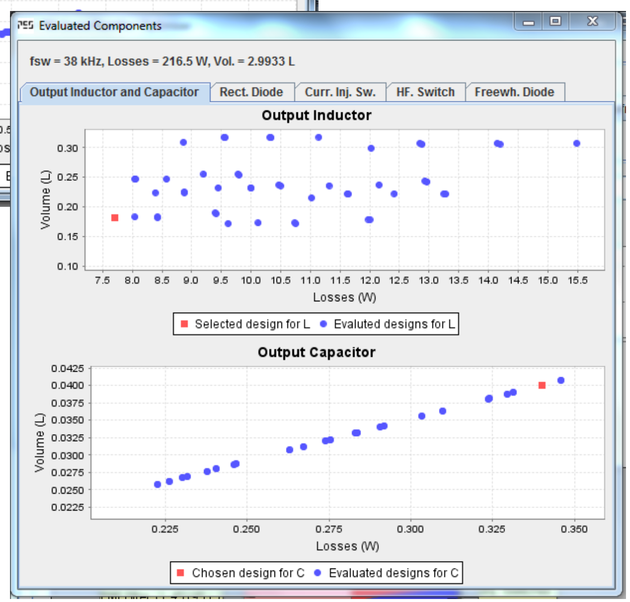


- ▶ The "Converter Results" visualization gives loss and volume breakdown by component for the optimum-efficiency converter at each frequency

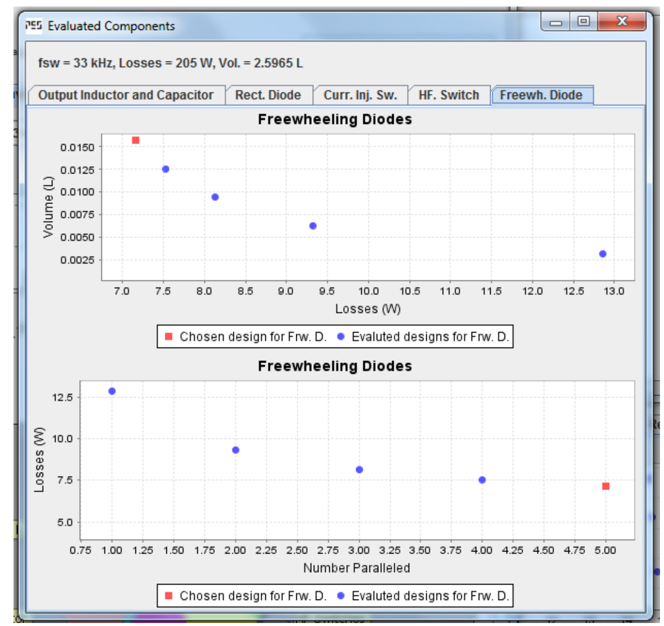


GECKO SIMULATIONS

Visualization of Results – Converter Results



- ▶ Clicking "By Component" gives, for that switching frequency, all the designs evaluated for a particular component (e.g. all inductors simulated) in a loss vs. volume plot, and shows also the selected (optimum) design



GECKO SIMULATIONS

Gecko-Simulations AG

Physikstrasse 3, 8092 Zurich,
Switzerland

contact@gecko-simulations.com