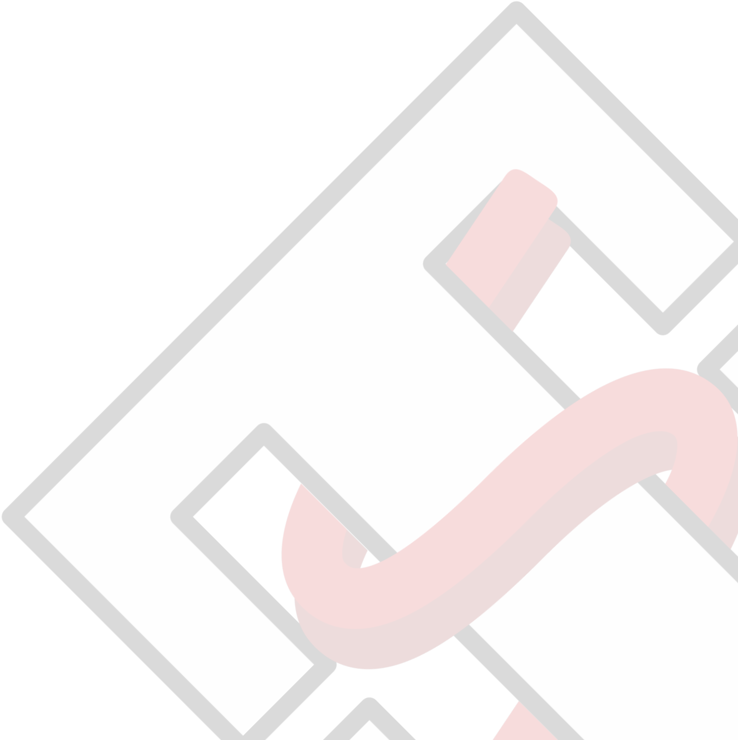
SmartNetics

Inductor analysis and optimization

Tutorial - February 2026



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Contents

Introduction

SmartNetics is a software for the design and analysis of magnetic devices: inductors and transformers.

In previous tutorials (available at www.powersmartcontrol.com), we have shown how to design a dedicated magnetic component. In this case, we will showcase another capability that the tool provides: the **analysis and optimization of a component**.

This tutorial aims to illustrate how to tackle the analysis of a magnetic component that was already manufactured, and how to redesign it to adapt to a new power stage specification. In addition to getting the main parameters, SmartNetics gives the user the opportunity to know if a device will be able to operate in different conditions, to check how far it will be from saturating or burning, and even to simulate it in third-party software.

This time, we are going to analyze an inductor that was already manufactured for an old project. Once the current design is characterized, we will see how to improve it to adapt it to a new power stage specification. The inductor currently in use is shown in Figure 1.

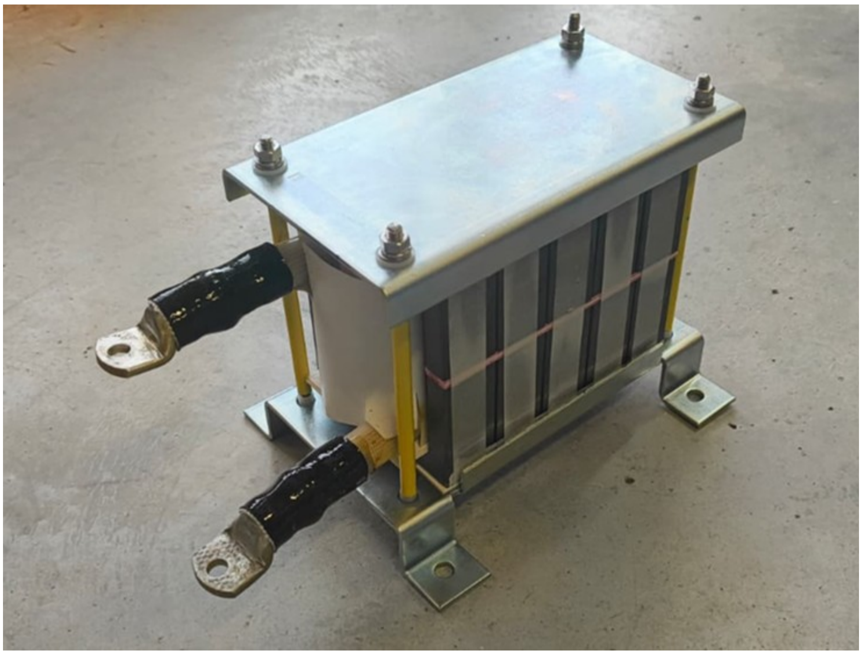


Figure 1: Inductor under analysis

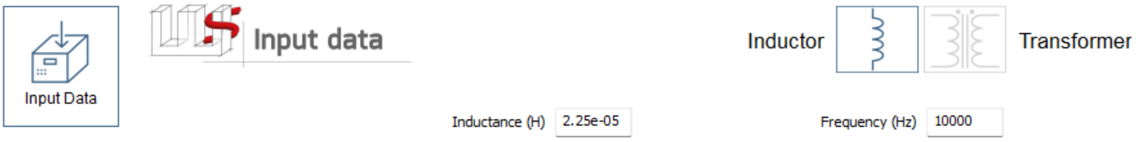
Analysis of the current device

The device was made for an old project, so we have its data. The main parameters are illustrated here:

- Inductance: $22.5\,\mu H$.
- Operation frequency: $10\,kHz$
- Current: triangular $200\,A$ (peak-to-peak).
- Core geometry: $E100/60/28$.
- Number of stacked cores: 5.
- Core material: $N87$ (by TDK).
- Conductor: $Enameled\,copper\,awg7$.
- Number of turns: 3.
- Wires in parallel: 20.
- Total gap length: $2.17\,mm$.

We can reproduce the same design in SmartNetics following the steps described in this section.

First, Inductance and operating Frequency can be set on the top bar of the first dialog (“Input data”), once “Inductor” has been selected in the top switch, as shown in Figure 2.

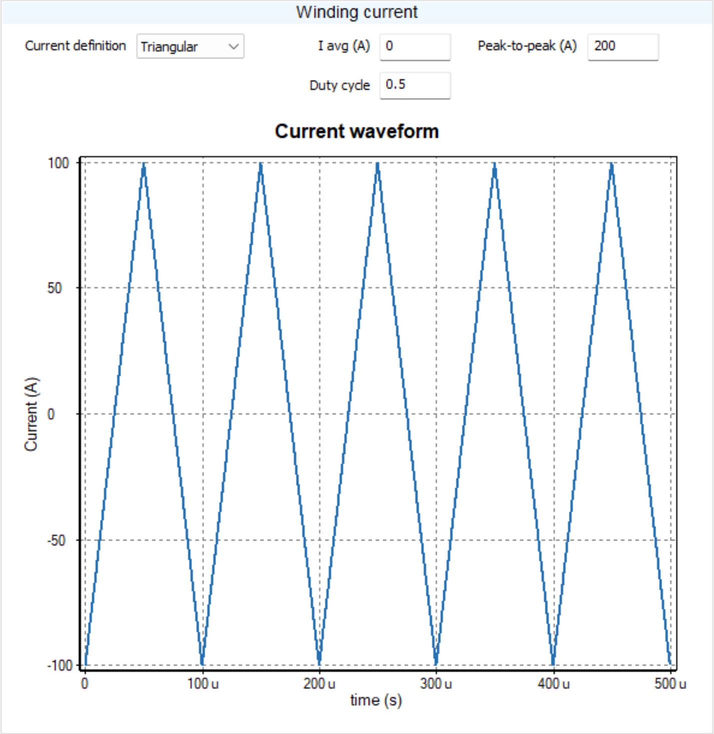


Inductance (H) 2.25e-05

Frequency (Hz) 10000

Figure 2: Inductance and frequency

For an inductor, only the current waveform is needed. It can be described right below the inductance and frequency parameters:



Winding current

Current definition: Triangular

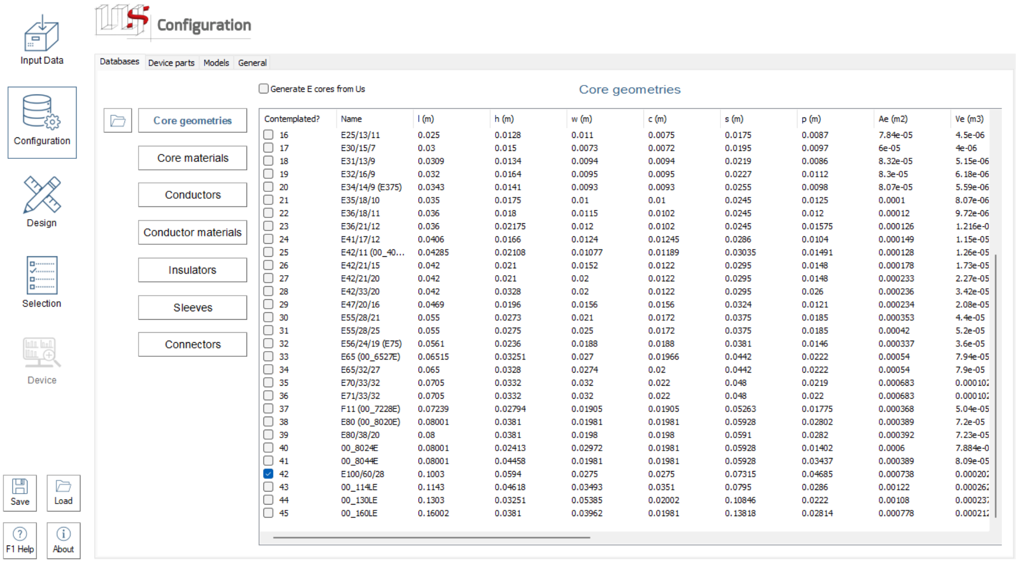
I avg (A): 0

Peak-to-peak (A): 200

Duty cycle: 0.5

Figure 3: Current

Since we know the core and winding materials and geometries, we can activate only those particular entries in the database. This can be done in the second dialog ("Configuration") in the "Databases" tab, as shown in the next figures:

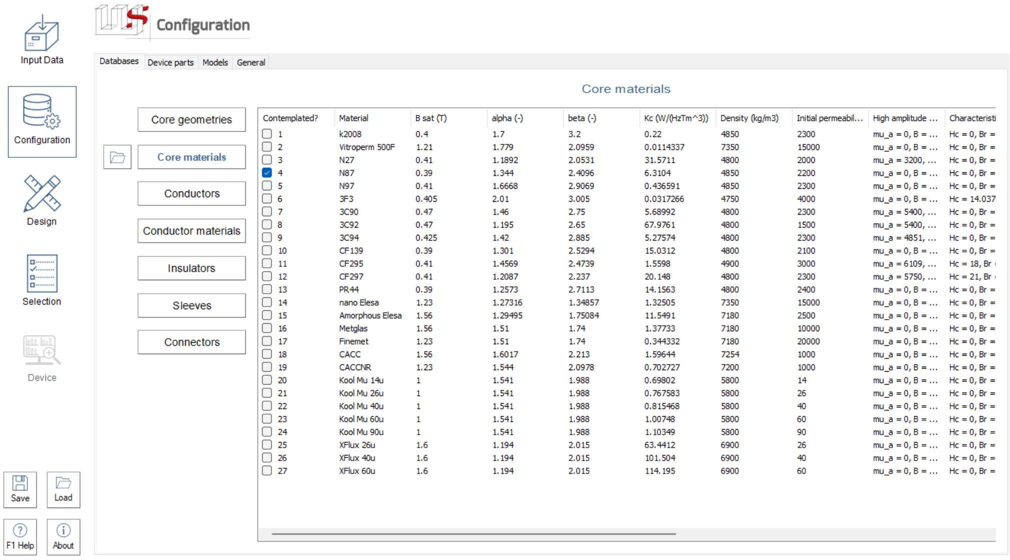


☐ Generate E cores from Us

Core geometries

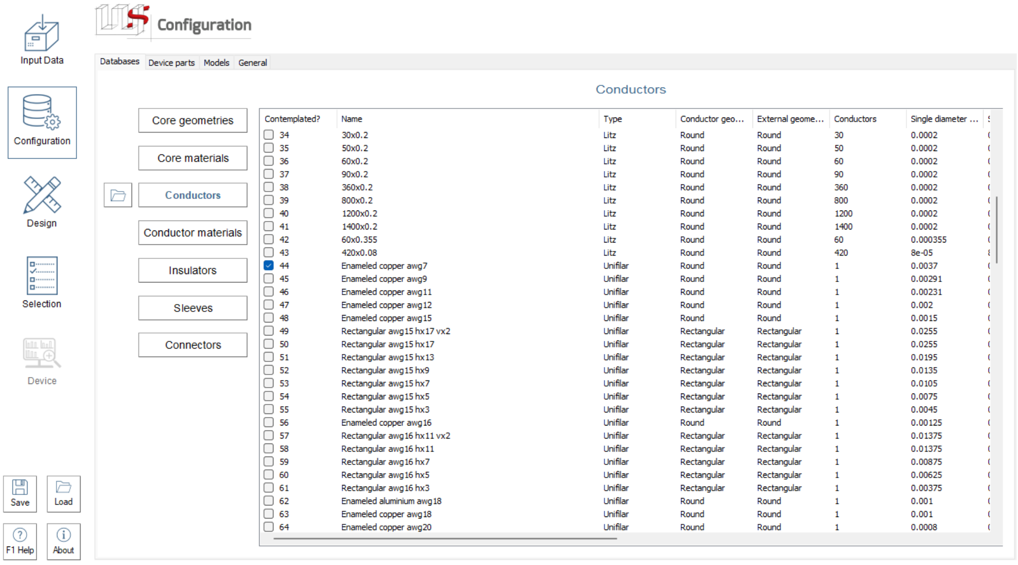
Contemplated?	Name	l (m)	h (m)	w (m)	c (m)	s (m)	p (m)	Ae (m2)	Ve (m3)
☐ 16	E25/13/11	0.025	0.0128	0.011	0.0075	0.0175	0.0087	7.84e-05	4.5e-06
☐ 17	E30/15/7	0.03	0.015	0.0073	0.0072	0.0195	0.0097	6e-05	4e-06
☐ 18	E31/13/9	0.0309	0.0134	0.0094	0.0094	0.0219	0.0086	8.32e-05	5.15e-06
☐ 19	E32/16/9	0.032	0.0164	0.0095	0.0095	0.0227	0.0112	8.3e-05	6.18e-06
☐ 20	E34/14/9 (E375)	0.0343	0.0141	0.0093	0.0093	0.0255	0.0098	8.07e-05	5.59e-06
☐ 21	E35/18/10	0.035	0.0175	0.01	0.01	0.0245	0.0125	0.0001	8.07e-06
☐ 22	E36/18/11	0.036	0.018	0.0115	0.0102	0.0245	0.012	0.00012	9.72e-06
☐ 23	E36/21/12	0.036	0.02175	0.012	0.0102	0.0245	0.01575	0.000126	1.216e-0
☐ 24	E41/17/12	0.0406	0.0166	0.0124	0.01245	0.0286	0.0104	0.000149	1.15e-05
☐ 25	E42/11 (00_40…	0.04285	0.02108	0.01077	0.01189	0.03035	0.01491	0.000128	1.26e-05
☐ 26	E42/21/15	0.042	0.021	0.0152	0.0122	0.0295	0.0148	0.000178	1.73e-05
☐ 27	E42/21/20	0.042	0.021	0.02	0.0122	0.0295	0.0148	0.000233	2.27e-05
☐ 28	E42/33/20	0.042	0.0328	0.02	0.0122	0.0295	0.026	0.000236	3.42e-05
☐ 29	E47/20/16	0.0469	0.0196	0.0156	0.0156	0.0324	0.0121	0.000234	2.08e-05
☐ 30	E55/28/21	0.055	0.0273	0.021	0.0172	0.0375	0.0185	0.000353	4.4e-05
☐ 31	E55/28/25	0.055	0.0275	0.025	0.0172	0.0375	0.0185	0.00042	5.2e-05
☐ 32	E56/24/19 (E75)	0.0561	0.0236	0.0188	0.0188	0.0381	0.0146	0.000337	3.6e-05
☐ 33	E65 (00_6527E)	0.06515	0.03251	0.027	0.01966	0.0442	0.0222	0.00054	7.94e-05
☐ 34	E65/32/27	0.065	0.0328	0.0274	0.02	0.0442	0.0222	0.00054	7.9e-05
☐ 35	E70/33/32	0.0705	0.0332	0.032	0.022	0.048	0.0219	0.000683	0.00010
☐ 36	E71/33/32	0.0705	0.0332	0.032	0.022	0.048	0.022	0.000683	0.00010
☐ 37	F11 (00_7228E)	0.07239	0.02794	0.01905	0.01905	0.05263	0.01775	0.000368	5.04e-05
☐ 38	E80 (00_8020E)	0.08001	0.0381	0.01981	0.01981	0.05928	0.02802	0.000389	7.2e-05
☐ 39	E80/38/20	0.08	0.0381	0.0198	0.0198	0.0591	0.0282	0.000392	7.23e-05
☐ 40	00_8024E	0.08001	0.02413	0.02972	0.01981	0.05928	0.01402	0.0006	7.884e-0
☐ 41	00_8044E	0.08001	0.04458	0.01981	0.01981	0.05928	0.03437	0.000389	8.09e-05
☑ 42	E100/60/28	0.1003	0.0594	0.0275	0.0275	0.07315	0.04685	0.000738	0.00020
☐ 43	00_114LE	0.1143	0.04618	0.03493	0.0351	0.0795	0.0286	0.00122	0.00026
☐ 44	00_130LE	0.1303	0.03251	0.05385	0.02002	0.10846	0.0222	0.00108	0.00023
☐ 45	00_160LE	0.16002	0.0381	0.03962	0.01981	0.13818	0.02814	0.000778	0.00021

Figure 4: Core geometries database



Contemplated?	Material	B sat (T)	alpha (-)	beta (-)	Kc (W/(HzTm^3))	Density (kg/m3)	Initial permeabil…	High amplitude …	Characteristi
☐ 1	k2008	0.4	1.7	3.2	0.22	4850	2300	mu_a = 0, B = …	Hc = 0, Br =
☐ 2	Vitroperm 500F	1.21	1.779	2.0959	0.0114337	7350	15000	mu_a = 0, B = …	Hc = 0, Br =
☐ 3	N27	0.41	1.1892	2.0531	31.5711	4800	2000	mu_a = 3200, …	Hc = 0, Br =
☑ 4	N87	0.39	1.344	2.4096	6.3104	4850	2200	mu_a = 0, B = …	Hc = 0, Br =
☐ 5	N97	0.41	1.6668	2.9069	0.436591	4850	2300	mu_a = 0, B = …	Hc = 0, Br =
☐ 6	3F3	0.405	2.01	3.005	0.0317266	4750	4000	mu_a = 0, B = …	Hc = 14.037
☐ 7	3C90	0.47	1.46	2.75	5.68992	4800	2300	mu_a = 5400, …	Hc = 0, Br =
☐ 8	3C92	0.47	1.195	2.65	67.9761	4800	1500	mu_a = 5400, …	Hc = 0, Br =
☐ 9	3C94	0.425	1.42	2.885	5.27574	4800	2300	mu_a = 4851, …	Hc = 0, Br =
☐ 10	CF139	0.39	1.301	2.5294	15.0312	4800	2100	mu_a = 0, B = …	Hc = 0, Br =
☐ 11	CF295	0.41	1.4569	2.4739	1.5598	4900	3000	mu_a = 6109, …	Hc = 18, Br
☐ 12	CF297	0.41	1.2087	2.237	20.148	4800	2300	mu_a = 5750, …	Hc = 21, Br
☐ 13	PR44	0.39	1.2573	2.7113	14.1563	4800	2400	mu_a = 0, B = …	Hc = 0, Br =
☐ 14	nano Elesa	1.23	1.27316	1.34857	1.32505	7350	15000	mu_a = 0, B = …	Hc = 0, Br =
☐ 15	Amorphous Elesa	1.56	1.29495	1.75084	11.5491	7180	2500	mu_a = 0, B = …	Hc = 0, Br =
☐ 16	Metglas	1.56	1.51	1.74	1.37733	7180	10000	mu_a = 0, B = …	Hc = 0, Br =
☐ 17	Finemet	1.23	1.51	1.74	0.344332	7180	20000	mu_a = 0, B = …	Hc = 0, Br =
☐ 18	CACC	1.56	1.6017	2.213	1.59644	7254	1000	mu_a = 0, B = …	Hc = 0, Br =
☐ 19	CACCNR	1.23	1.544	2.0978	0.702727	7200	1000	mu_a = 0, B = …	Hc = 0, Br =
☐ 20	Kool Mu 14u	1	1.541	1.988	0.69802	5800	14	mu_a = 0, B = …	Hc = 0, Br =
☐ 21	Kool Mu 26u	1	1.541	1.988	0.767583	5800	26	mu_a = 0, B = …	Hc = 0, Br =
☐ 22	Kool Mu 40u	1	1.541	1.988	0.815468	5800	40	mu_a = 0, B = …	Hc = 0, Br =
☐ 23	Kool Mu 60u	1	1.541	1.988	1.00748	5800	60	mu_a = 0, B = …	Hc = 0, Br =
☐ 24	Kool Mu 90u	1	1.541	1.988	1.10349	5800	90	mu_a = 0, B = …	Hc = 0, Br =
☐ 25	XFlux 26u	1.6	1.194	2.015	63.4412	6900	26	mu_a = 0, B = …	Hc = 0, Br =
☐ 26	XFlux 40u	1.6	1.194	2.015	101.504	6900	40	mu_a = 0, B = …	Hc = 0, Br =
☐ 27	XFlux 60u	1.6	1.194	2.015	114.195	6900	60	mu_a = 0, B = …	Hc = 0, Br =

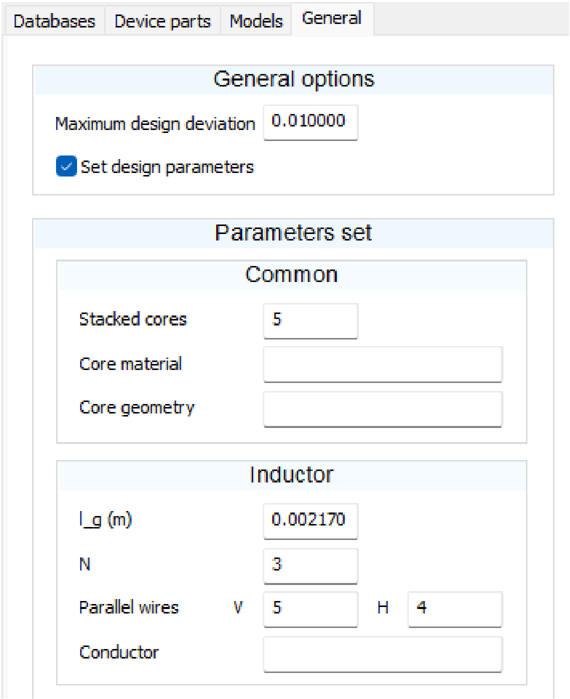
Figure 5: Core materials database



Contemplated?	Name	Type	Conductor geo…	External geome…	Conductors	Single diameter …
☐ 34	30x0.2	Litz	Round	Round	30	0.0002
☐ 35	50x0.2	Litz	Round	Round	50	0.0002
☐ 36	60x0.2	Litz	Round	Round	60	0.0002
☐ 37	90x0.2	Litz	Round	Round	90	0.0002
☐ 38	360x0.2	Litz	Round	Round	360	0.0002
☐ 39	800x0.2	Litz	Round	Round	800	0.0002
☐ 40	1200x0.2	Litz	Round	Round	1200	0.0002
☐ 41	1400x0.2	Litz	Round	Round	1400	0.0002
☐ 42	60x0.355	Litz	Round	Round	60	0.000355
☐ 43	420x0.08	Litz	Round	Round	420	8e-05
☑ 44	Enameled copper awg7	Unifilar	Round	Round	1	0.0037
☐ 45	Enameled copper awg9	Unifilar	Round	Round	1	0.00291
☐ 46	Enameled copper awg11	Unifilar	Round	Round	1	0.00231
☐ 47	Enameled copper awg12	Unifilar	Round	Round	1	0.002
☐ 48	Enameled copper awg15	Unifilar	Round	Round	1	0.0015
☐ 49	Rectangular awg15 hx17 vx2	Unifilar	Rectangular	Rectangular	1	0.0255
☐ 50	Rectangular awg15 hx17	Unifilar	Rectangular	Rectangular	1	0.0255
☐ 51	Rectangular awg15 hx13	Unifilar	Rectangular	Rectangular	1	0.0195
☐ 52	Rectangular awg15 hx9	Unifilar	Rectangular	Rectangular	1	0.0135
☐ 53	Rectangular awg15 hx7	Unifilar	Rectangular	Rectangular	1	0.0105
☐ 54	Rectangular awg15 hx5	Unifilar	Rectangular	Rectangular	1	0.0075
☐ 55	Rectangular awg15 hx3	Unifilar	Rectangular	Rectangular	1	0.0045
☐ 56	Enameled copper awg16	Unifilar	Round	Round	1	0.00125
☐ 57	Rectangular awg16 hx11 vx2	Unifilar	Rectangular	Rectangular	1	0.01375
☐ 58	Rectangular awg16 hx11	Unifilar	Rectangular	Rectangular	1	0.01375
☐ 59	Rectangular awg16 hx7	Unifilar	Rectangular	Rectangular	1	0.00875
☐ 60	Rectangular awg16 hx5	Unifilar	Rectangular	Rectangular	1	0.00625
☐ 61	Rectangular awg16 hx3	Unifilar	Rectangular	Rectangular	1	0.00375
☐ 62	Enameled aluminium awg18	Unifilar	Round	Round	1	0.001
☐ 63	Enameled copper awg18	Unifilar	Round	Round	1	0.001
☐ 64	Enameled copper awg20	Unifilar	Round	Round	1	0.0008

Figure 6: Wire geometries database

The remaining known parameters can be set to the right values in the last tab of this same dialog, “General”, after checking the “Set design parameters” box. The full configuration to reproduce the parameters described at the beginning of this section is shown in Figure 7. Notice how not every parameter needs to be set, since they are left empty (or set to 0). The remaining parameters will be calculated by the tool.



General options

Maximum design deviation 0.010000

☑ Set design parameters

Parameters set

Common

Stacked cores 5

Core material

Core geometry

Inductor

l_g (m) 0.002170

N 3

Parallel wires V 5 H 4

Conductor

Figure 7: Set parameters

There are many ways to wind a given number of wires in parallel. In the previous figure, we have set it to $V = 5$ and $H = 4$, which means there will be 20 wires in parallel in every turn, arranged in rectangles of 5 wires vertically and 4 wires horizontally. The wire stacking strategy in SmartNetics is always rectangular, as described in the help files and summarized for an example in Figure 8.

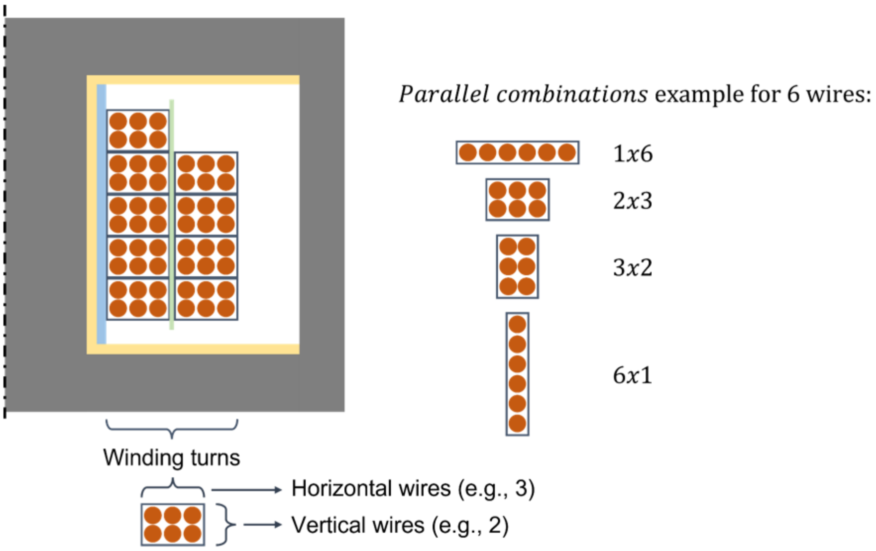
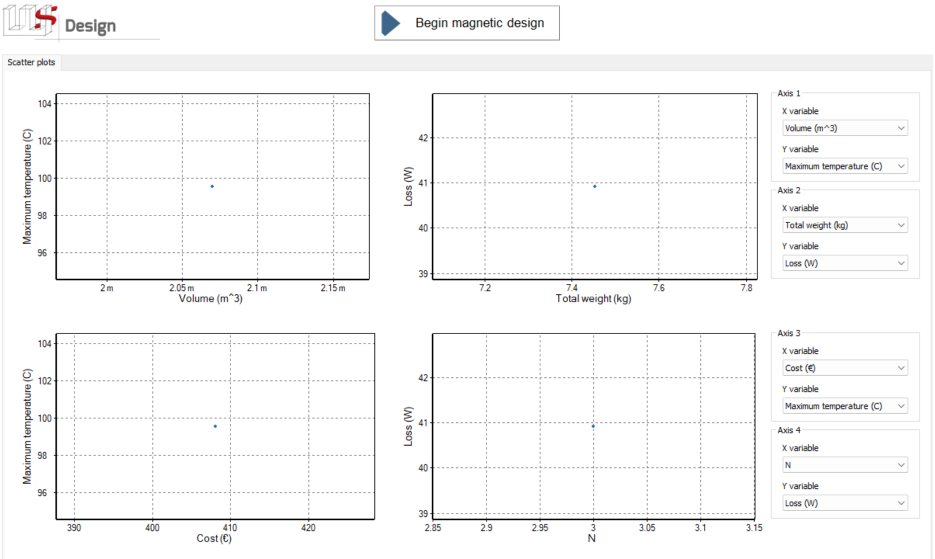


Figure 8: Rectangular wire stacking

Once everything is set, we can analyze the device. The first step is to ask the tool to design every inductor that, using every free parameter and the entries available in the database, matches the specifications.

Since we have set everything to a given value, there is a single solution. That solution is displayed in Figure 9 and corresponds to the device we are currently analyzing.



Axis 1
X variable: Volume (m^3)
Y variable: Maximum temperature (C)

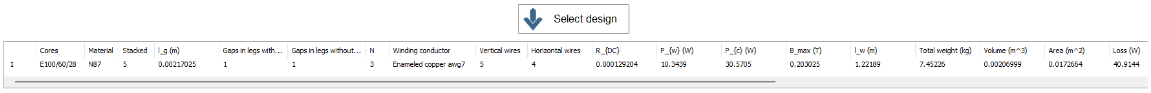
Axis 2
X variable: Total weight (kg)
Y variable: Loss (W)

Axis 3
X variable: Cost (€)
Y variable: Maximum temperature (C)

Axis 4
X variable: N
Y variable: Loss (W)

Figure 9: Original design

In the dialog shown in the previous figure, only 8 variables can be displayed at the same time. For a deeper analysis, we can access the next dialog, "Selection", and select the only available design. Once selected, every detail of the design is shown in the bottom bar:



	Cores	Material	Stacked	l_g (m)	Gaps in legs with...	Gaps in legs without...	N	Winding conductor	Vertical wires	Horizontal wires	R_{DC}	P_{w} (W)	P_{c} (W)	B_max (T)	l_w (m)	Total weight (kg)	Volume (m^3)	Area (m^2)	Loss (W)
1	E100/60/28	N87	5	0.00217025	1	1	3	Enameled copper awg7	5	4	0.000129204	10.3439	30.5705	0.203025	1.22189	7.45226	0.00206999	0.0172664	40.9144

Figure 10: Original design main parameters

In this dialog, the user has access to the main parameters expected for the device, like inductance, losses (divided in core and winding), maximum temperature, maximum magnetic field, etc.

Now that a single device is selected, the user can access the last dialog, "Device", for a graphical view of the most important parameters, like the temperature distribution (in the "Performance" tab) shown in Figure 11.

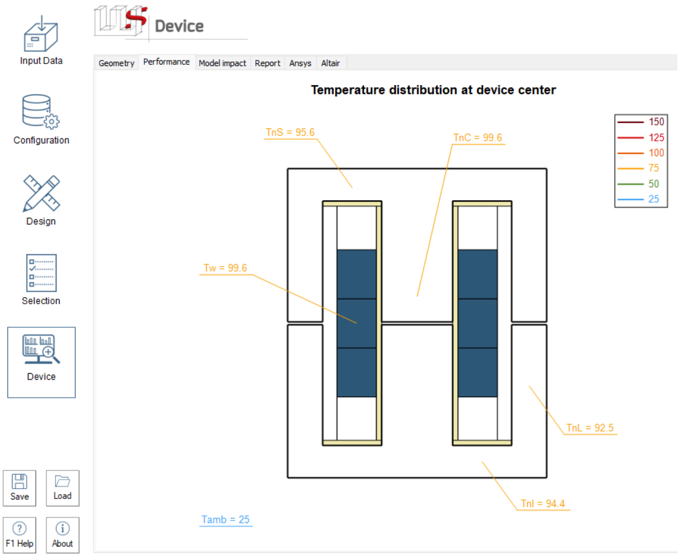


Figure 11: Original design temperature distribution

A 3D representation of the device and its parts can be seen in the "Geometry" tab:

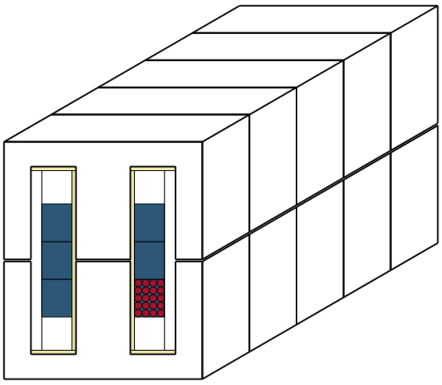


Figure 12: Original design geometry

On top of the analysis performed by SmartNetics, the user can also export their design to third-party tools, like Ansys (Maxwell and Icepak) or Altair-Flux, for a 3D or 2D Finite Element Analysis of the electromagnetic and thermal response.

Thanks to the procedure shown in this chapter, SmartNetics can be used not only as a design tool, but as an analysis one. The user can get the expected losses, thermal behavior, saturation limits, etc. of a device that was already manufactured, and they can assess its validity for a new application or under different conditions. On top of that, that same design can be exported to third-party Finite Element Analysis tools, without the need to learn how to use those tools or to take the time to recreate the design in them.

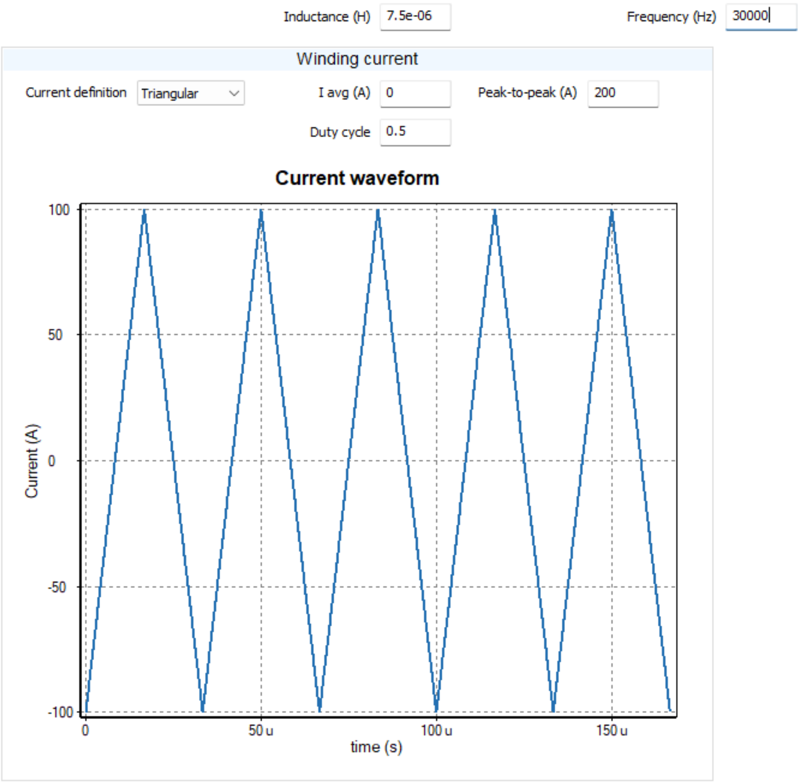
In the next sections of this tutorial, we will show how to use SmartNetics not to analyze a design, but to optimize it for any application different from that originally intended.

New specification

There was a limitation with the previous design that needed to be tackled. By switching at 10 kHz, we were able to keep switching losses low, but the converter was generating audible sound that needed to be reduced.

To solve this issue, the decision was to allow higher losses in the semiconductors in exchange for that noise reduction. That was done by increasing the frequency by 3 times, up to 30 kHz, to move it beyond the audible range, while reducing the inductance by the same factor, to keep the current ripple as it was before.

The new specification for the inductor changes the inductance and frequency from $22.5\,\mu H$ and $10\,kHz$ to $7.5\,\mu H$ and $30\,kHz$. The new current and target inductance are shown in Figure 13.



Inductance (H) 7.5e-06

Frequency (Hz) 30000

Winding current

Current definition Triangular

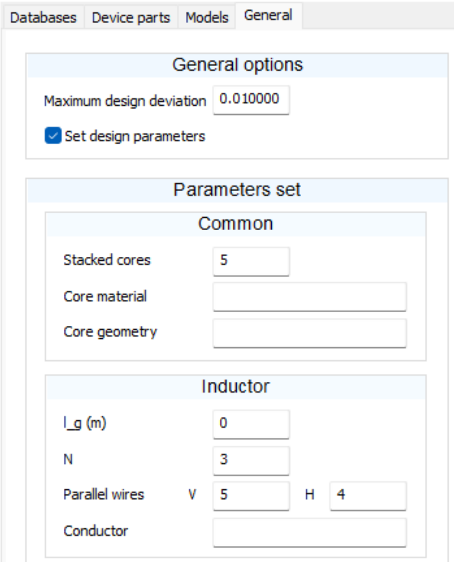
I avg (A) 0

Peak-to-peak (A) 200

Duty cycle 0.5

Figure 13: New input parameters

Keeping the same original design, but for the new specifications, we can run the design again. To see if the previous inductor will be able to operate in these new conditions with minimal modifications, we can keep everything set to its current value, with the exception of the gap length, which will have to be recalculated to adapt it to the new inductance value. We can set that value ($l_g\,(m)$) to 0 to make the tool run the calculation, while leaving everything else set, in the "Configuration" dialog, in the "General" tab:



General options

Maximum design deviation: 0.010000

☑ Set design parameters

Parameters set

Common

Stacked cores: 5

Core material:

Core geometry:

Inductor

l_g (m): 0

N: 3

Parallel wires V: 5 H: 4

Conductor:

Figure 14: Design set with unrestricted gap

If we run the design process once more, we obtain a single solution, since everything was set to a given value, with the only distinction of the gap length, which has been recalculated to get the desired inductance. This new design can be seen as the single point displayed in Figure 15.

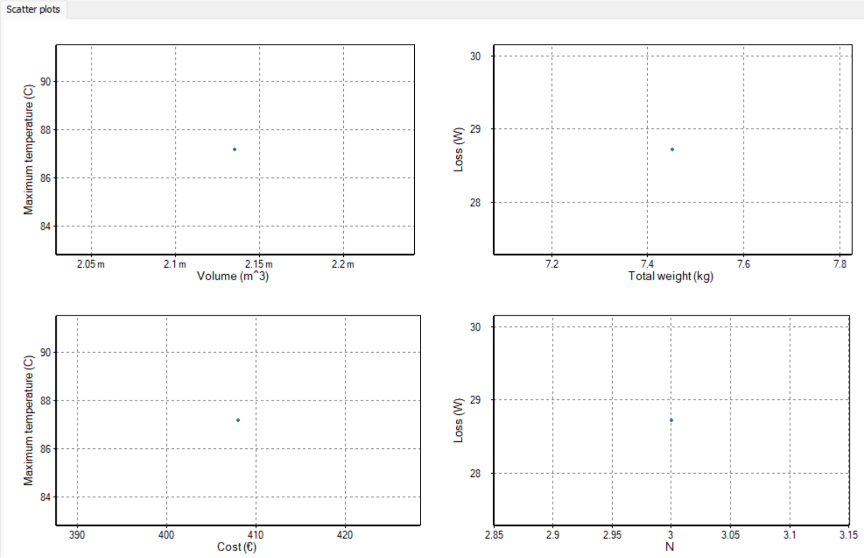
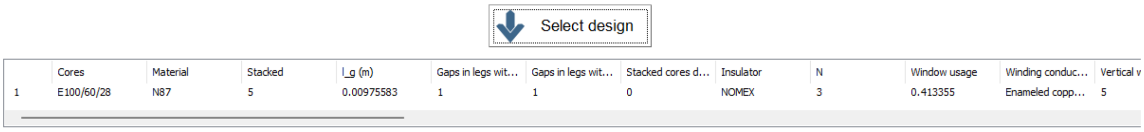


Figure 15: Original design under new specifications

As we can see, just by changing the gap, we can already have a device that can work under the new specifications. The new expected losses (core and winding), inductance, maximum temperature, maximum magnetic field, etc., can be seen in the “Selection” dialog, as shown in Figure 16.



	Cores	Material	Stacked	l_g (m)	Gaps in legs wit...	Gaps in legs wit...	Stacked cores d...	Insulator	N	Window usage	Winding conduc...	Vertical v
1	E100/60/28	N87	5	0.00975583	1	1	0	NOMEX	3	0.413355	Enameled copp...	5

Figure 16: Original design under new specifications. Main parameters

Of course, apart from inductance, losses have also changed, so we will get a different temperature distribution, which is displayed in the “Device” dialog:

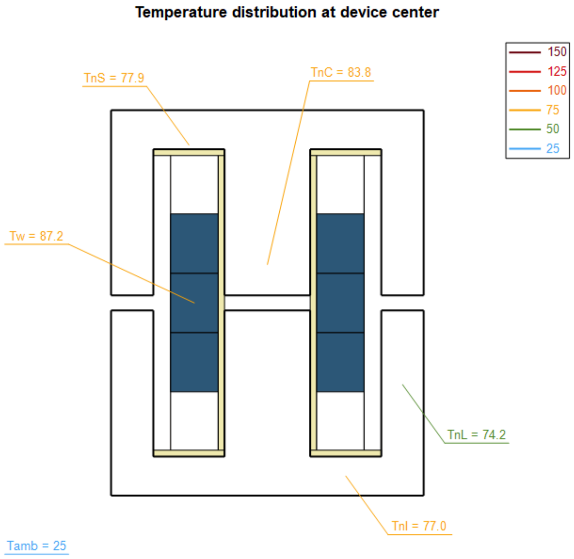


Figure 17: Original design under new specifications. Temperature distribution

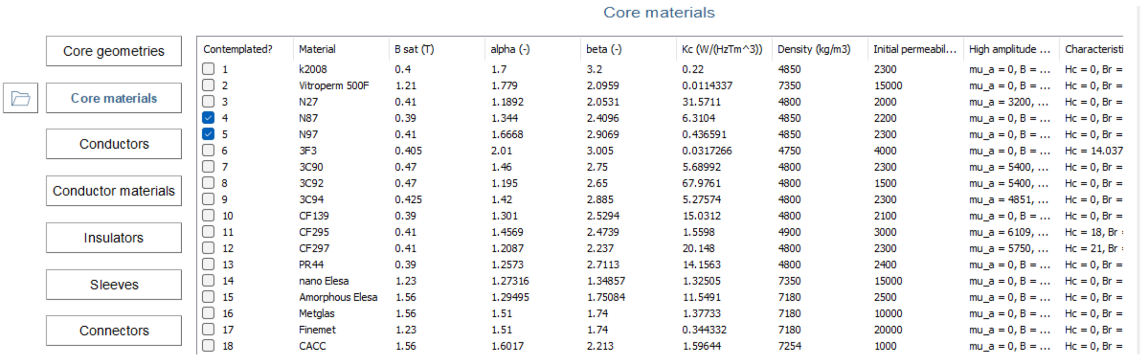
Even though we have already seen that the device can operate under this new specification, we can take advantage of the fact that we need to manufacture new devices, to change some of its parameters and optimize it for the new application.

Optimization

In this case, since the increase in frequency is expected to increase the losses in the semiconductors, the aim of the redesign of the inductor is to reduce its losses as much as possible. By doing this, we can avoid the audible sound problem, while keeping the efficiency and heat dissipation needs as good as they were before.

1 New core material

The first step is to select a material better suited for this higher frequency. To see how big an improvement the one suggested by the manufacturer would be, we will select a new entry in the core materials database, the N97, also by TDK. The new core materials database is the one shown in Figure 18.



Contemplated?	Material	B sat (T)	alpha (-)	beta (-)	Kc (W/(HzTm^3))	Density (kg/m3)	Initial permeabil...	High amplitude ...	Characteristi
☐ 1	k2008	0.4	1.7	3.2	0.22	4850	2300	mu_a = 0, B = ...	Hc = 0, Br =
☐ 2	Vitroperm 500F	1.21	1.779	2.0959	0.0114337	7350	15000	mu_a = 0, B = ...	Hc = 0, Br =
☐ 3	N27	0.41	1.1892	2.0531	31.5711	4800	2000	mu_a = 3200, ...	Hc = 0, Br =
☑ 4	N87	0.39	1.344	2.4096	6.3104	4850	2200	mu_a = 0, B = ...	Hc = 0, Br =
☑ 5	N97	0.41	1.6668	2.9069	0.436591	4850	2300	mu_a = 0, B = ...	Hc = 0, Br =
☐ 6	3F3	0.405	2.01	3.005	0.0317266	4750	4000	mu_a = 0, B = ...	Hc = 14.037
☐ 7	3C90	0.47	1.46	2.75	5.68992	4800	2300	mu_a = 5400, ...	Hc = 0, Br =
☐ 8	3C92	0.47	1.195	2.65	67.9761	4800	1500	mu_a = 5400, ...	Hc = 0, Br =
☐ 9	3C94	0.425	1.42	2.885	5.27574	4800	2300	mu_a = 4851, ...	Hc = 0, Br =
☐ 10	CF139	0.39	1.301	2.5294	15.0312	4800	2100	mu_a = 0, B = ...	Hc = 0, Br =
☐ 11	CF295	0.41	1.4569	2.4739	1.5598	4900	3000	mu_a = 6109, ...	Hc = 18, Br
☐ 12	CF297	0.41	1.2087	2.237	20.148	4800	2300	mu_a = 5750, ...	Hc = 21, Br
☐ 13	PR44	0.39	1.2573	2.7113	14.1563	4800	2400	mu_a = 0, B = ...	Hc = 0, Br =
☐ 14	nano Elesa	1.23	1.27316	1.34857	1.32505	7350	15000	mu_a = 0, B = ...	Hc = 0, Br =
☐ 15	Amorphous Elesa	1.56	1.29495	1.75084	11.5491	7180	2500	mu_a = 0, B = ...	Hc = 0, Br =
☐ 16	Metglas	1.56	1.51	1.74	1.37733	7180	10000	mu_a = 0, B = ...	Hc = 0, Br =
☐ 17	Finemet	1.23	1.51	1.74	0.344332	7180	20000	mu_a = 0, B = ...	Hc = 0, Br =
☐ 18	CACC	1.56	1.6017	2.213	1.59644	7254	1000	mu_a = 0, B = ...	Hc = 0, Br =

Figure 18: New core material added to the database

Once the new material is included, we can run the design again to see if it is going to improve our design in any aspect, going back to the "Design" dialog and clicking on "Begin magnetic design" again. After the design procedure finishes, two results are obtained: the original one, using an N87 core, and the new one, which uses the N97 material. The core loss and maximum temperature of both devices can be displayed in any of the axis, as shown in Figure 19.

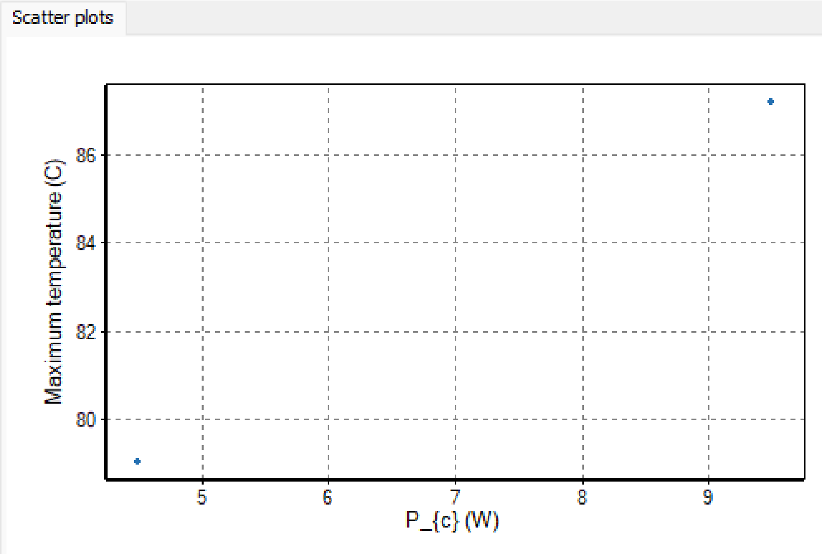
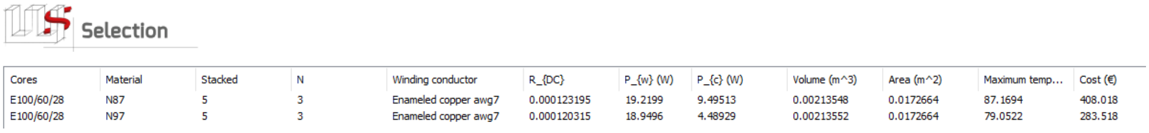


Figure 19: Temperature vs core loss for both materials

As we can see, one of the devices allows halving the total core loss (from 9.5 W to 4.5 W) and a reduction of 8 degrees for the maximum temperature (from 87 °C to 79 °C). We can see every detail and the whole impact of the improvement in the next dialog, "Selection".



Cores	Material	Stacked	N	Winding conductor	R_{DC}	P_{w} (W)	P_{c} (W)	Volume (m^3)	Area (m^2)	Maximum temp...	Cost (€)
E100/60/28	N87	5	3	Enameled copper awg7	0.000123195	19.2199	9.49513	0.00213548	0.0172664	87.1694	408.018
E100/60/28	N97	5	3	Enameled copper awg7	0.000120315	18.9496	4.48929	0.00213552	0.0172664	79.0522	283.518

Figure 20: Main parameters for both materials

Since we can achieve an improvement thanks to this core material, we will select it as a single option in the database, so we can go back to a single result. This can be done by unchecking the other materials available in the database, that were shown in Figure 18. The single available design, with the N97 material:

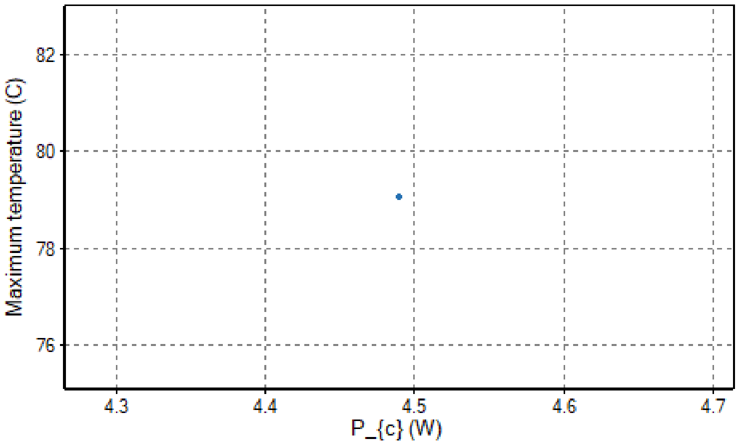


Figure 21: Single result for N97

Now, we can select it and analyze the results provided in the last dialog, “Device”. In the first tab, “Geometry”, a 3D simplified version of the device is shown:

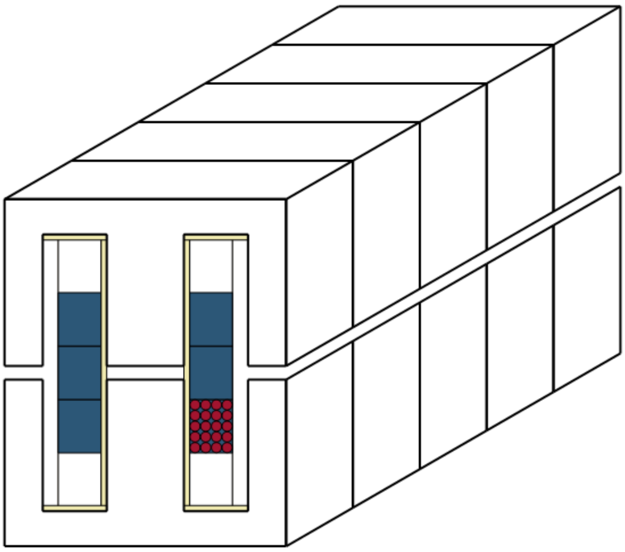
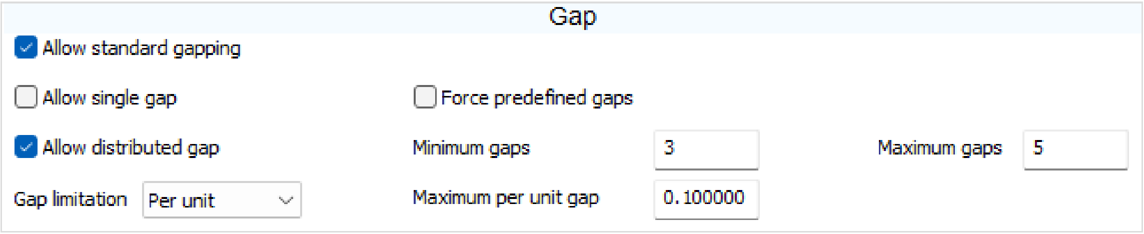


Figure 22: Geometry detail for N97 design

As we can see, there may be an issue with Electromagnetic Interference (EMI) if this device is used. Since the gap is large for this geometry, the fringing flux is going to leak way beyond the inductor limits and cause several problems. We cannot change the core geometry because it is imposed by the space and connections of a previous project, so we need to change how we create the required gap.

2 New gap distribution

The biggest change regarding EMI can come from a different gap distribution. Up to this point we have only allowed a *regular* gap distribution, where the gap is the same in every column. One alternative to improve that, when the gap is so big, is to divide that single gap into several smaller ones. That option can be activated in the second dialog, “Configuration”, in the “Device parts” tab, under “Core” - “Gap”, as shown in the next figure:



Gap

☑ Allow standard gapping

☐ Allow single gap

☐ Force predefined gaps

☑ Allow distributed gap

Minimum gaps: 3

Maximum gaps: 5

Gap limitation: Per unit

Maximum per unit gap: 0.100000

Figure 23: New gap distribution setting

If we now run the design again, new options appear:

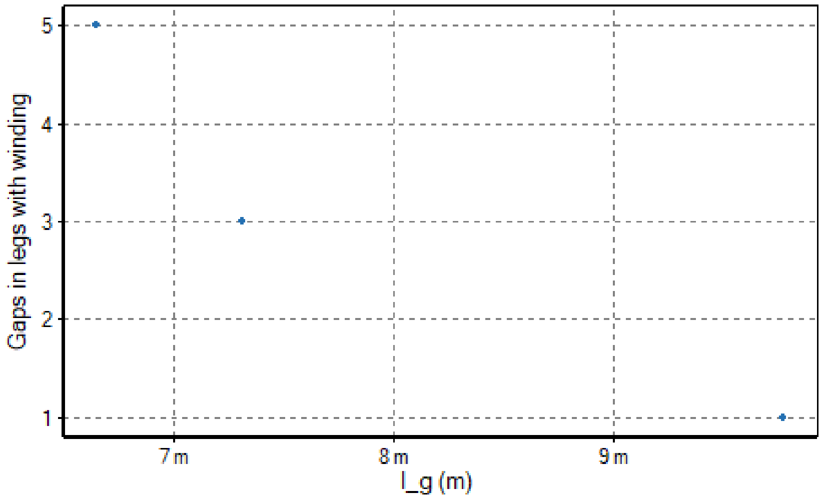
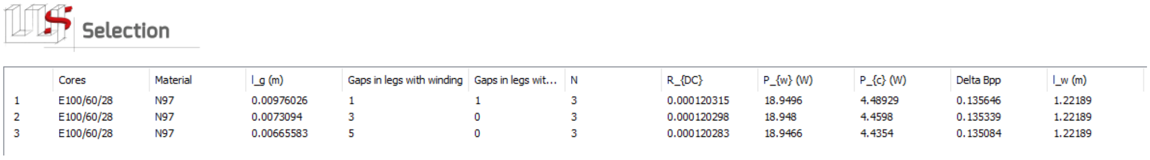


Figure 24: Results with new gap options

We can select every option and see the detailed results, displayed in Figure 25.



	Cores	Material	l_g (m)	Gaps in legs with winding	Gaps in legs wit...	N	R_{DC}	P_{w} (W)	P_{c} (W)	Delta Bpp	l_w (m)
1	E100/60/28	N97	0.00976026	1	1	3	0.000120315	18.9496	4.48929	0.135646	1.22189
2	E100/60/28	N97	0.0073094	3	0	3	0.000120298	18.948	4.4598	0.135339	1.22189
3	E100/60/28	N97	0.00665583	5	0	3	0.000120283	18.9466	4.4354	0.135084	1.22189

Figure 25: Results with new gap options. Detail

As can be seen, the main difference is the number of gaps and the total length of those gaps. To reduce the length of every single gap as much as possible, we can select the device with the highest gap count, 5 in this case, displayed in the *Gaps in legs with winding* column. After selecting it, we can analyze the new device, starting by its geometry, shown in Figure 26.

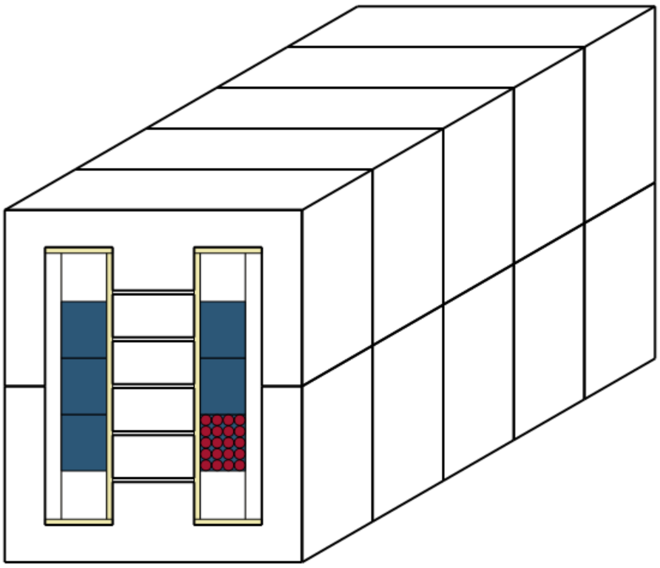
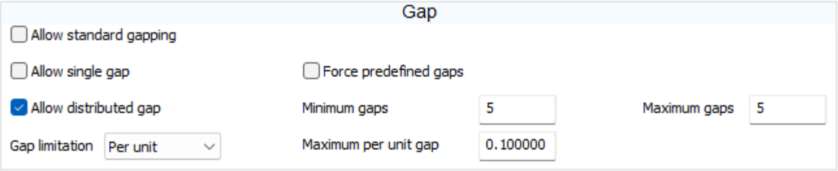


Figure 26: Geometry with 5 distributed gaps

This gaping strategy seems like a much better solution, so we will set it as the only option to get a single result again, before further modifying the design. This can be done by reducing the possibilities in the "Configuration" dialog. The new configuration is shown in Figure 27.



Gap

☐ Allow standard gapping

☐ Allow single gap

☐ Force predefined gaps

☑ Allow distributed gap

Minimum gaps: 5

Maximum gaps: 5

Gap limitation: Per unit

Maximum per unit gap: 0.100000

Figure 27: Distributed gap setting

Now that a better core material has been selected and the gaps are small enough, we can proceed to the next tab "Model impact" to check if we can also improve the winding strategy.

3 New winding strategy

In this tab, we can see the differences that some models produce in several calculations.

In this case, we will focus on the second axis: "Conductor loss". There are three models present here:

- **DC**: Only considers losses due to the DC resistance.
- **Skin**: Adds the skin effect to the calculation.
- **Dowell**: Takes skin and proximity effect into account.

The losses that the three models provide for this particular design are shown in Figure 28. The model actually used for the calculations that were shown up to this tab (used to estimate total loss, temperature, etc.) is shown in a light blue color, while the other possibilities use a dark blue.

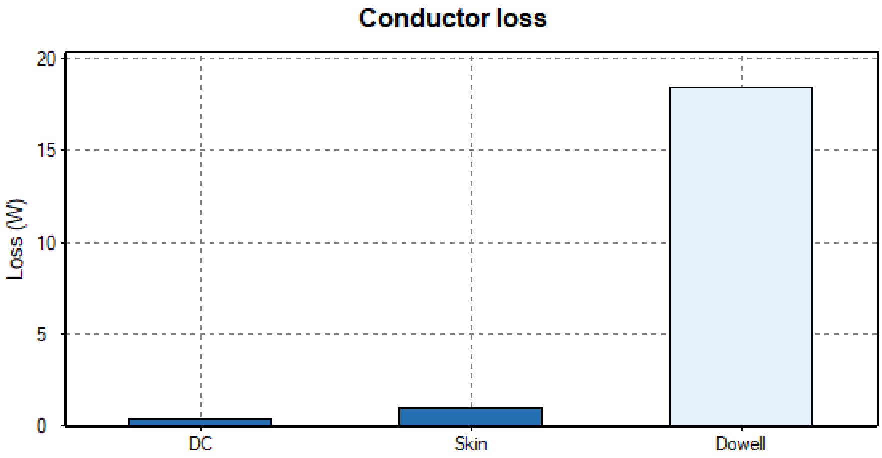
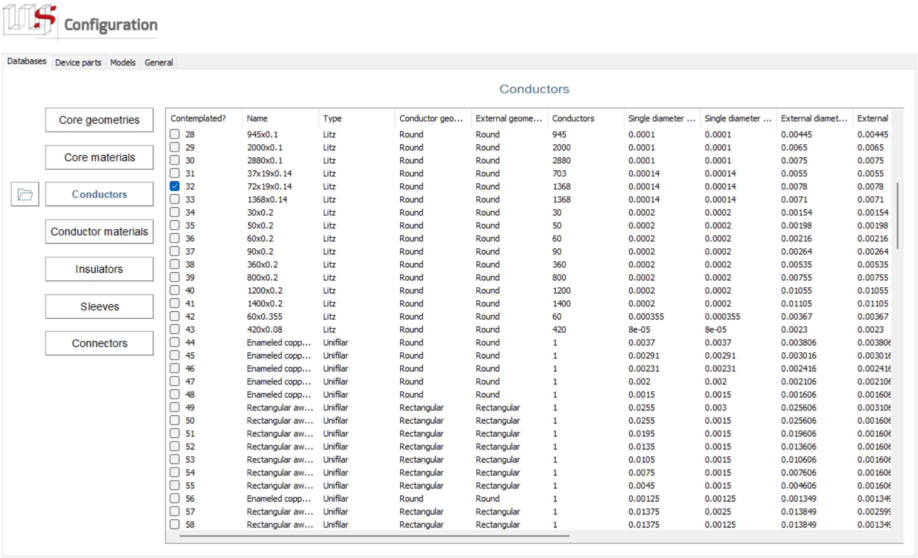


Figure 28: Solid conductor loss models

This indicates that the selected wire has skin and proximity losses much higher than its DC loss, which indicates that the selected wire may not be well suited for the frequency of the new design.

This behavior is in part due to the use of a rigid copper wire. To improve on this, we can select a different wire type, in this case a Litz wire, to reduce those high-frequency AC losses.

For this example, we are allowing a single Litz wire for the design, the 72x19x0.14 Litz, in “Configuration” - “Databases” - “Conductors”, as shown in the next figure:

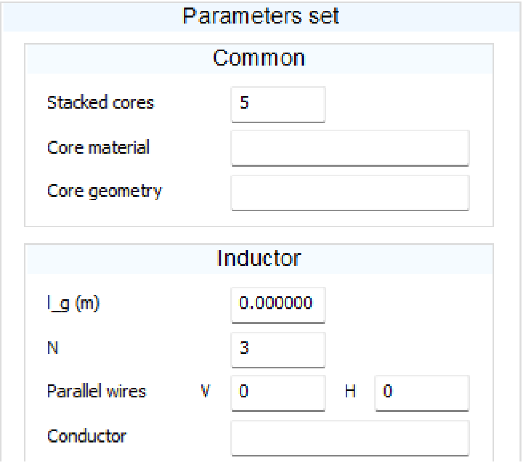


Conductors

Contemplated?	Name	Type	Conductor geo...	External geome...	Conductors	Single diameter ...	Single diameter ...	External diamet...	External
☐ 28	945x0.1	Litz	Round	Round	945	0.0001	0.0001	0.00445	0.00445
☐ 29	2000x0.1	Litz	Round	Round	2000	0.0001	0.0001	0.0065	0.0065
☐ 30	2880x0.1	Litz	Round	Round	2880	0.0001	0.0001	0.0075	0.0075
☐ 31	37x19x0.14	Litz	Round	Round	703	0.00014	0.00014	0.0055	0.0055
☑ 32	72x19x0.14	Litz	Round	Round	1368	0.00014	0.00014	0.0078	0.0078
☐ 33	1368x0.14	Litz	Round	Round	1368	0.00014	0.00014	0.0071	0.0071
☐ 34	30x0.2	Litz	Round	Round	30	0.0002	0.0002	0.00154	0.00154
☐ 35	50x0.2	Litz	Round	Round	50	0.0002	0.0002	0.00198	0.00198
☐ 36	60x0.2	Litz	Round	Round	60	0.0002	0.0002	0.00216	0.00216
☐ 37	90x0.2	Litz	Round	Round	90	0.0002	0.0002	0.00264	0.00264
☐ 38	360x0.2	Litz	Round	Round	360	0.0002	0.0002	0.00535	0.00535
☐ 39	800x0.2	Litz	Round	Round	800	0.0002	0.0002	0.00755	0.00755
☐ 40	1200x0.2	Litz	Round	Round	1200	0.0002	0.0002	0.01055	0.01055
☐ 41	1400x0.2	Litz	Round	Round	1400	0.0002	0.0002	0.01105	0.01105
☐ 42	60x0.355	Litz	Round	Round	60	0.000355	0.000355	0.00367	0.00367
☐ 43	420x0.08	Litz	Round	Round	420	8e-05	8e-05	0.0023	0.0023
☐ 44	Enameled copp...	Unifilar	Round	Round	1	0.0037	0.0037	0.003806	0.00380
☐ 45	Enameled copp...	Unifilar	Round	Round	1	0.00291	0.00291	0.003016	0.00301
☐ 46	Enameled copp...	Unifilar	Round	Round	1	0.00231	0.00231	0.002416	0.00241
☐ 47	Enameled copp...	Unifilar	Round	Round	1	0.002	0.002	0.002106	0.00210
☐ 48	Enameled copp...	Unifilar	Round	Round	1	0.0015	0.0015	0.001606	0.00160
☐ 49	Rectangular aw...	Unifilar	Rectangular	Rectangular	1	0.0255	0.003	0.025606	0.00310
☐ 50	Rectangular aw...	Unifilar	Rectangular	Rectangular	1	0.0255	0.0015	0.025606	0.00160
☐ 51	Rectangular aw...	Unifilar	Rectangular	Rectangular	1	0.0195	0.0015	0.019606	0.00160
☐ 52	Rectangular aw...	Unifilar	Rectangular	Rectangular	1	0.0135	0.0015	0.013606	0.00160
☐ 53	Rectangular aw...	Unifilar	Rectangular	Rectangular	1	0.0105	0.0015	0.010606	0.00160
☐ 54	Rectangular aw...	Unifilar	Rectangular	Rectangular	1	0.0075	0.0015	0.007606	0.00160
☐ 55	Rectangular aw...	Unifilar	Rectangular	Rectangular	1	0.0045	0.0015	0.004606	0.00160
☐ 56	Enameled copp...	Unifilar	Round	Round	1	0.00125	0.00125	0.001349	0.00134
☐ 57	Rectangular aw...	Unifilar	Rectangular	Rectangular	1	0.01375	0.0025	0.013849	0.00259
☐ 58	Rectangular aw...	Unifilar	Rectangular	Rectangular	1	0.01375	0.00125	0.013849	0.00134

Figure 29: Litz wire selected in the database

Since we have selected a different wire, there is no need to restrict the design to the same number of wires in parallel, so we will remove that restriction in “Configuration” - “General” - “Inductor”. Remember that if we leave the values for V and H as 0, the tool will calculate the possible combinations that provide a valid solution. The new configuration is shown in Figure 30.



Parameters set

Common

Stacked cores: 5

Core material:

Core geometry:

Inductor

l_g (m): 0.000000

N: 3

Parallel wires: V 0 H 0

Conductor:

Figure 30: Unrestricted vertical and horizontal wires

Now, if we run the design again, we can see that there are multiple solutions, with different numbers and arrangements of wires in parallel:

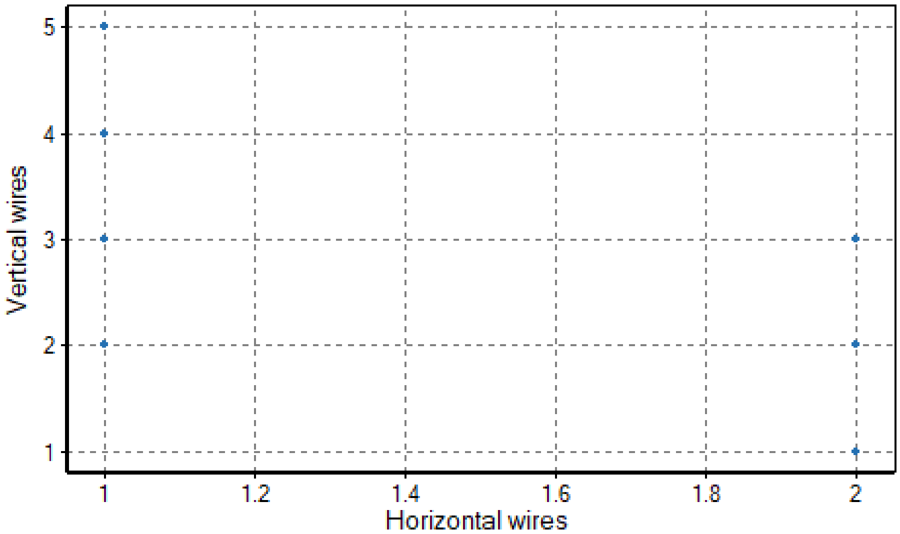
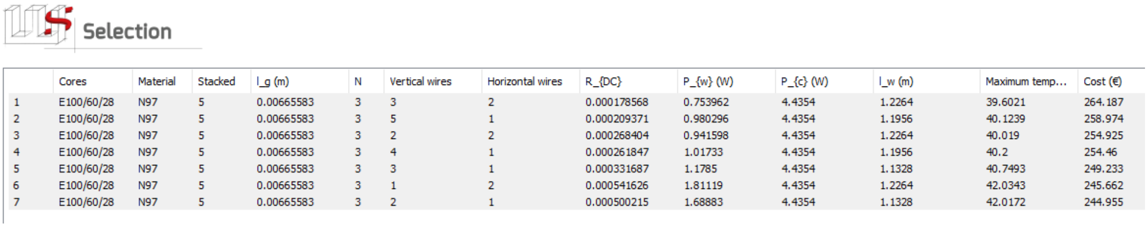


Figure 31: Parallel wire options

We can select all of them to get the next table in the "Selection" dialog:

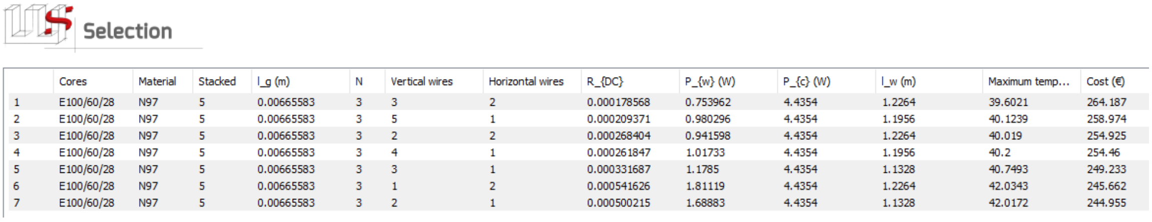


	Cores	Material	Stacked	l_g (m)	N	Vertical wires	Horizontal wires	R_{DC}	P_{w} (W)	P_{c} (W)	l_w (m)	Maximum temp...	Cost (€)
1	E100/60/28	N97	5	0.00665583	3	3	2	0.000178568	0.753962	4.4354	1.2264	39.6021	264.187
2	E100/60/28	N97	5	0.00665583	3	5	1	0.000209371	0.980296	4.4354	1.1956	40.1239	258.974
3	E100/60/28	N97	5	0.00665583	3	2	2	0.000268404	0.941598	4.4354	1.2264	40.019	254.925
4	E100/60/28	N97	5	0.00665583	3	4	1	0.000261847	1.01733	4.4354	1.1956	40.2	254.46
5	E100/60/28	N97	5	0.00665583	3	3	1	0.000331687	1.1785	4.4354	1.1328	40.7493	249.233
6	E100/60/28	N97	5	0.00665583	3	1	2	0.000541626	1.81119	4.4354	1.2264	42.0343	245.662
7	E100/60/28	N97	5	0.00665583	3	2	1	0.000500215	1.68883	4.4354	1.1328	42.0172	244.955

Figure 32: Parallel wire options. Details

Every design is a valid solution within the restrictions imposed for the design. From them, the user can select the one they prefer, like the one with the lowest loss or the cheapest. One of the advantages of SmartNetics is that it provides access to the full data; thanks to this, the user can select devices that may not be the best in some numerical parameters, but that are more convenient in metrics hard to describe with a figure of merit, like manufacturability.

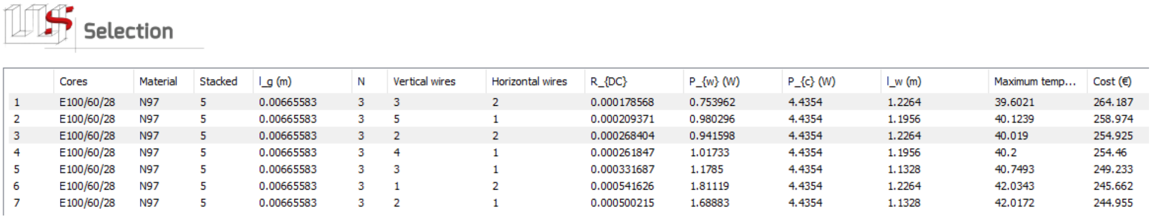
From the valid designs, the ones with a very different number of wires in vertical and horizontal are usually difficult to manufacture, so we will discard them:



	Cores	Material	Stacked	l_g (m)	N	Vertical wires	Horizontal wires	R_{DC}	P_{w} (W)	P_{c} (W)	l_w (m)	Maximum temp...	Cost (€)
1	E100/60/28	N97	5	0.00665583	3	3	2	0.000178568	0.753962	4.4354	1.2264	39.6021	264.187
2	E100/60/28	N97	5	0.00665583	3	5	1	0.000209371	0.980296	4.4354	1.1956	40.1239	258.974
3	E100/60/28	N97	5	0.00665583	3	2	2	0.000268404	0.941598	4.4354	1.2264	40.019	254.925
4	E100/60/28	N97	5	0.00665583	3	4	1	0.000261847	1.01733	4.4354	1.1956	40.2	254.46
5	E100/60/28	N97	5	0.00665583	3	3	1	0.000331687	1.1785	4.4354	1.1328	40.7493	249.233
6	E100/60/28	N97	5	0.00665583	3	1	2	0.000541626	1.81119	4.4354	1.2264	42.0343	245.662
7	E100/60/28	N97	5	0.00665583	3	2	1	0.000500215	1.68883	4.4354	1.1328	42.0172	244.955

Figure 33: Parallel wire options. Details (reduced)

For the remaining ones, we can take a look at the P_w column to see the impact that different configurations would have. We will select the two designs with the lowest wire loss:



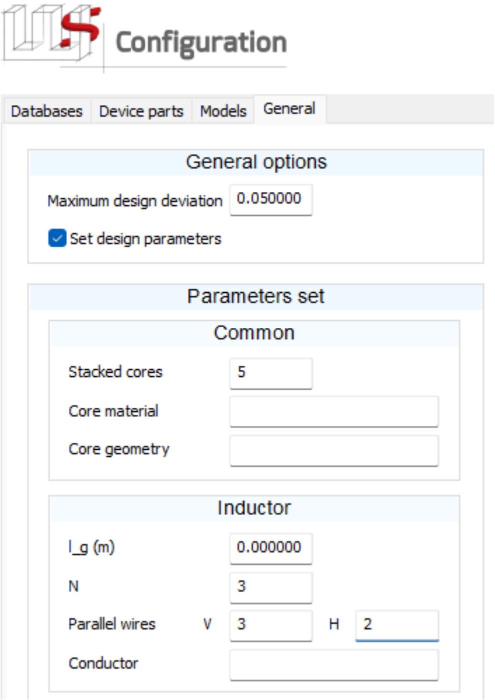
Selection

	Cores	Material	Stacked	l_g (m)	N	Vertical wires	Horizontal wires	R_{DC}	P_{w} (W)	P_{c} (W)	l_w (m)	Maximum temp...	Cost (€)
1	E100/60/28	N97	5	0.00665583	3	3	2	0.000178568	0.753962	4.4354	1.2264	39.6021	264.187
2	E100/60/28	N97	5	0.00665583	3	5	1	0.000209371	0.980296	4.4354	1.1956	40.1239	258.974
3	E100/60/28	N97	5	0.00665583	3	2	2	0.000268404	0.941598	4.4354	1.2264	40.019	254.925
4	E100/60/28	N97	5	0.00665583	3	4	1	0.000261847	1.01733	4.4354	1.1956	40.2	254.46
5	E100/60/28	N97	5	0.00665583	3	3	1	0.000331687	1.1785	4.4354	1.1328	40.7493	249.233
6	E100/60/28	N97	5	0.00665583	3	1	2	0.000541626	1.81119	4.4354	1.2264	42.0343	245.662
7	E100/60/28	N97	5	0.00665583	3	2	1	0.000500215	1.68883	4.4354	1.1328	42.0172	244.955

Figure 34: Parallel wire options. Details (last)

Both options provide valid solutions. The first one describes a component with lower winding loss, but that uses more wire and is more expensive; the second one reduces copper usage in exchange for an increase in loss and temperature. For this particular example, the design with the lowest losses is selected, with the aim of pushing the efficiency of the converter:

If we want to have a single result, we can go back again to "Configuration" - "General" - "Inductor" and set the desired number of wires in parallel:



General options

Maximum design deviation 0.050000

☑ Set design parameters

Parameters set

Common

Stacked cores 5

Core material

Core geometry

Inductor

l_g (m) 0.000000

N 3

Parallel wires V 3 H 2

Conductor

Figure 35: Parallel wire set options

Now we have a single design with a good window utilization and gap distribution, displayed in Figure 36.

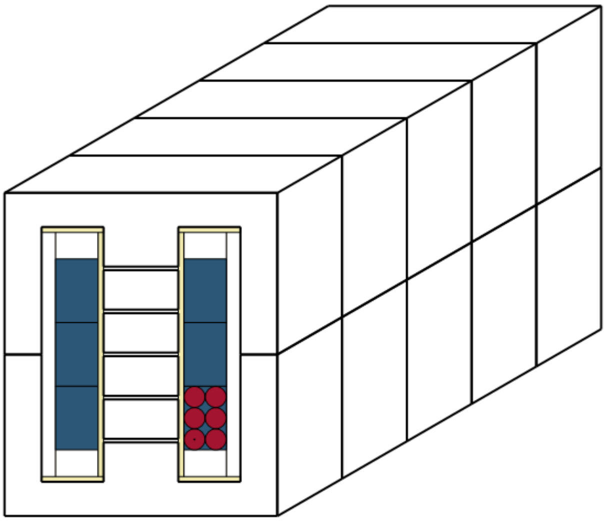


Figure 36: Final design 3D

Thanks to the change in wire geometry and distribution, we have achieved wire losses that are an order of magnitude lower (compared to the solid wire loss, shown in Figure 28). This is due to the reduced high-frequency impact when using this Litz wire, demonstrated by the fact that DC, Skin, and Dowell loss estimations are now very close, as displayed in Figure 37.

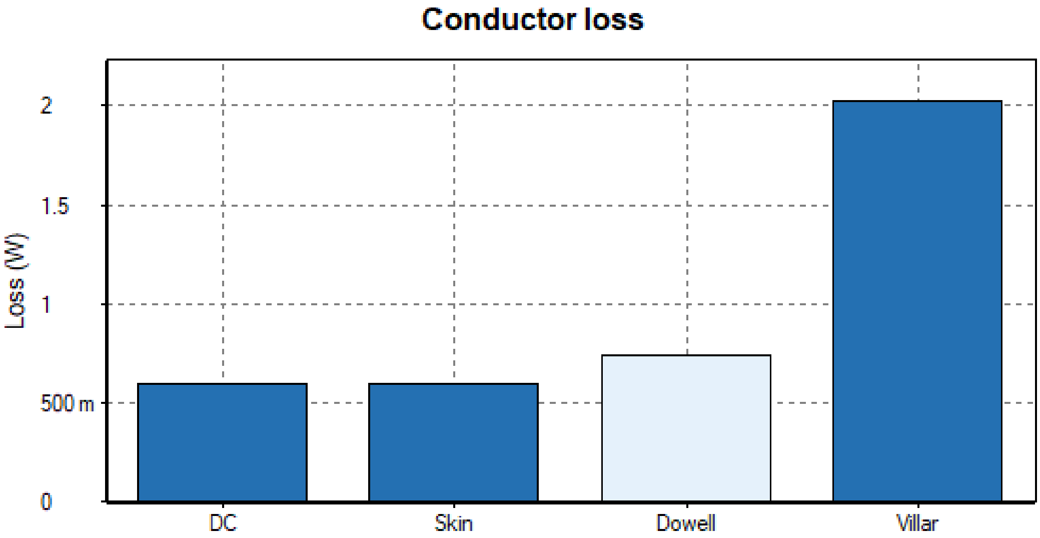


Figure 37: Final design wire loss models

The additional loss model shown in the figure (*Villar*) is not considered for this design, since it can improve the results for some particular configurations but reduce it for others.

Once we have a design that achieves the desired performance, in the next dialog we can see the expected temperature distribution. Thanks to the high reduction in losses, both in core and winding, we now have a device that with a significantly lower temperature and that can easily operate without forced convection or any other cooling strategy. The new temperatures are shown in the next figure:

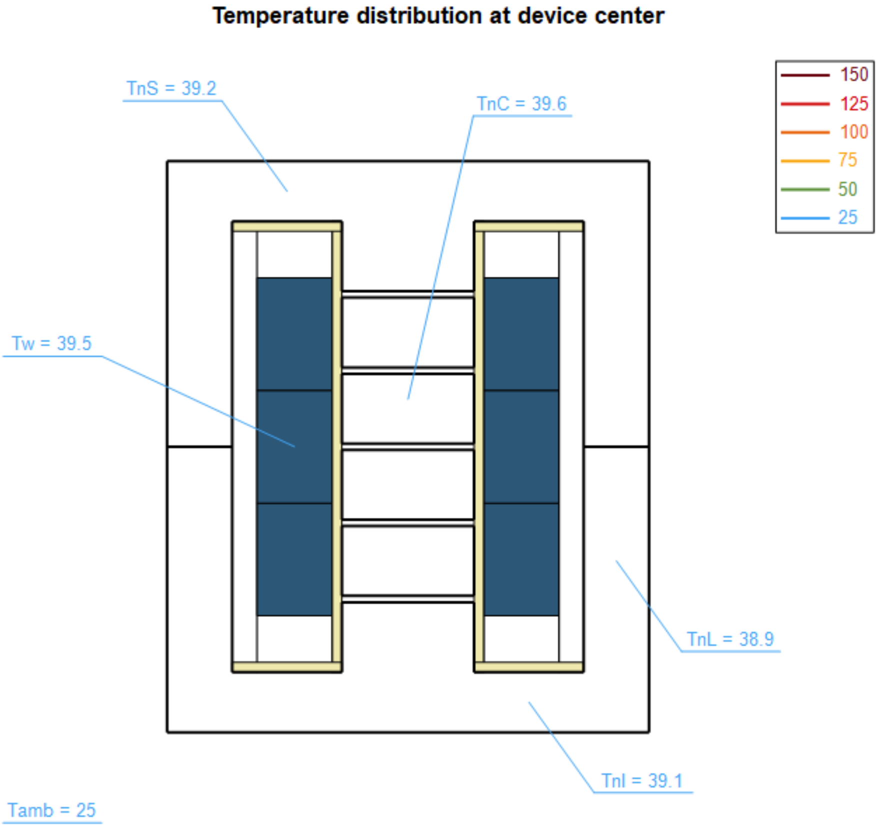


Figure 38: New design temperature distribution

Validation

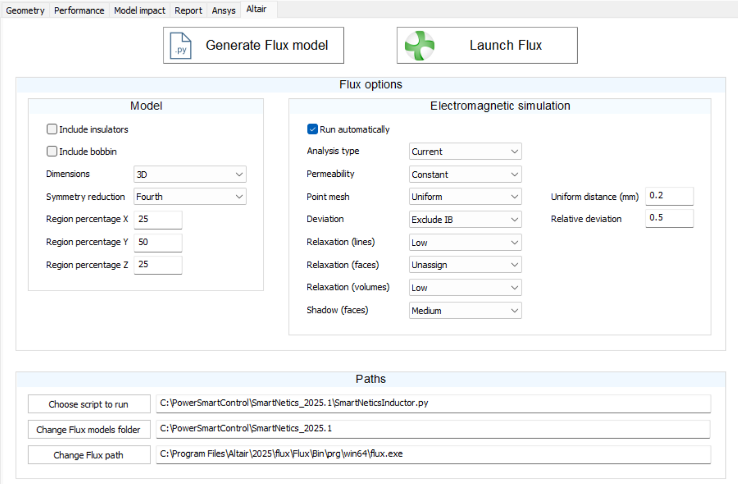
Up to this point, every result displayed has been obtained by means of analytical equations, which allows the very fast calculations of any number of possible combinations. Once the component has been redesigned and a single device has been selected, we can double-check its main parameters by exporting it to third-party tools.

In this regard, SmartNetics provides two exporting options to Finite Element Analysis software: Ansys (Maxwell for electromagnetic and Icepak for thermal) and Altair-Flux (only for electromagnetic).

1 Altair Flux

The first step is to check if the inductance value matches the specifications. We can check that value in Altair-Flux. To increase the precision, we will run a 3D simulation and, to reduce simulation time, we will only simulate one fourth of the device, thanks to its symmetry.

The configuration used can be seen in the next figure:



☐ Include insulators
☐ Include bobbin
Dimensions: 3D
Symmetry reduction: Fourth
Region percentage X: 25
Region percentage Y: 50
Region percentage Z: 25

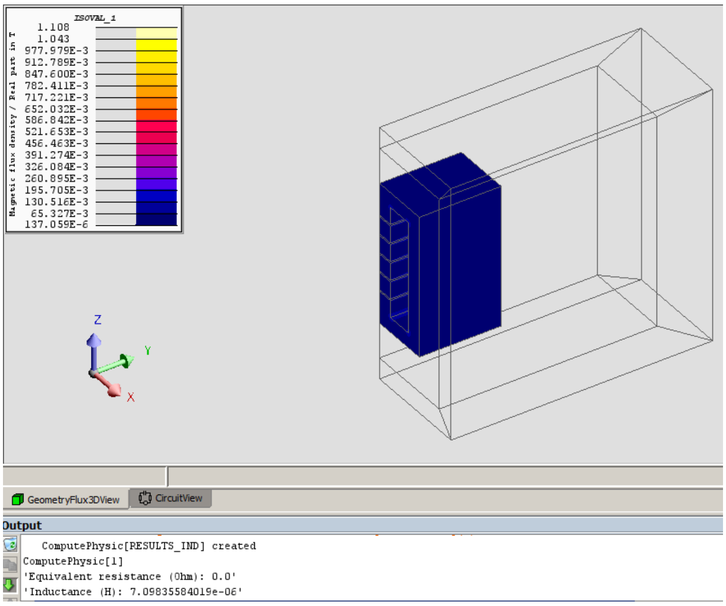
☑ Run automatically
Analysis type: Current
Permeability: Constant
Point mesh: Uniform
Uniform distance (mm): 0.2
Deviation: Exclude IB
Relative deviation: 0.5
Relaxation (lines): Low
Relaxation (faces): Unassign
Relaxation (volumes): Low
Shadow (faces): Medium

Choose script to run: C:\PowerSmartControl\SmartNetics_2025.1\SmartNeticsInductor.py
Change Flux models folder: C:\PowerSmartControl\SmartNetics_2025.1
Change Flux path: C:\Program Files\Altair\2025\flux\Flux\Bin\prg\win64\flux.exe

Figure 39: Flux export configuration

After the simulation finishes we can check the results and see if the inductance matches the expected values. The results after the simulation finishes are shown in

Figure 40.



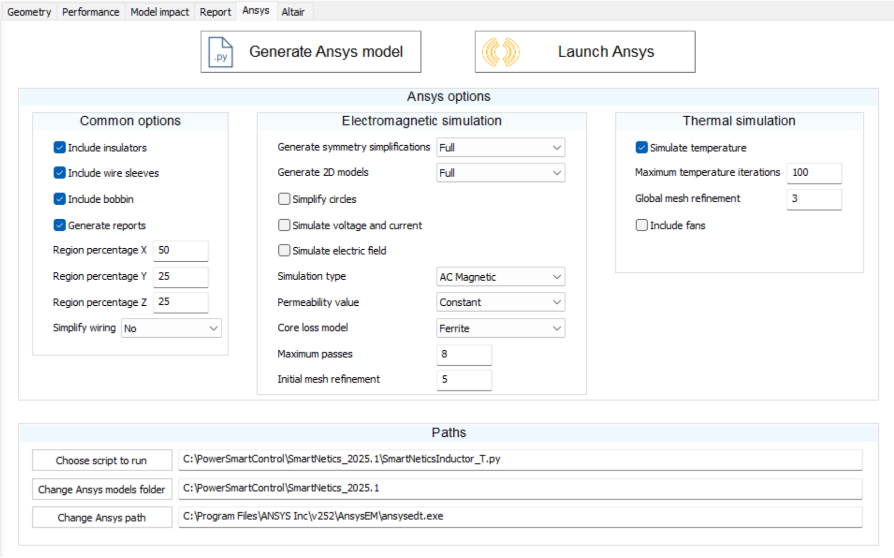
```
   ComputePhysic[RESULTS_IND] created
ComputePhysic[1]
'Equivalent resistance (Ohm): 0.0'
'Inductance (H): 7.09835584019e-06'
```

Figure 40: Flux simulation results

As can be seen, SmartNetics was able to predict the inductance of the device with high accuracy, allowing us to assess the impact of every modification in an instant, without the need of a long Finite Element simulation, which is used only for validation.

2 Ansys Icepak

Using Ansys Icepak we can check the temperature distribution for the full volume of the device. To provide a good depiction of the real problem, we will include every component in the simulation. Apart from the core and winding, we will use the check-boxes to include insulators, wire sleeves and bobbin, as shown in the next figure:



Ansys options

Common options

☑ Include insulators
☑ Include wire sleeves
☑ Include bobbin
☑ Generate reports
Region percentage X: 50
Region percentage Y: 25
Region percentage Z: 25
Simplify wiring: No

Electromagnetic simulation

Generate symmetry simplifications: Full
Generate 2D models: Full
☐ Simplify circles
☐ Simulate voltage and current
☐ Simulate electric field
Simulation type: AC Magnetic
Permeability value: Constant
Core loss model: Ferrite
Maximum passes: 8
Initial mesh refinement: 5

Thermal simulation

☑ Simulate temperature
Maximum temperature iterations: 100
Global mesh refinement: 3
☐ Include fans

Paths

Choose script to run: C:\PowerSmartControl\SmartNetics_2025.1\SmartNeticsInductor_T.py
Change Ansys models folder: C:\PowerSmartControl\SmartNetics_2025.1
Change Ansys path: C:\Program Files\ANSYS Inc\v252\AnsysEM\ansysedt.exe

Figure 41: Ansys export configuration

After the simulation runs, we can check the temperature distribution:

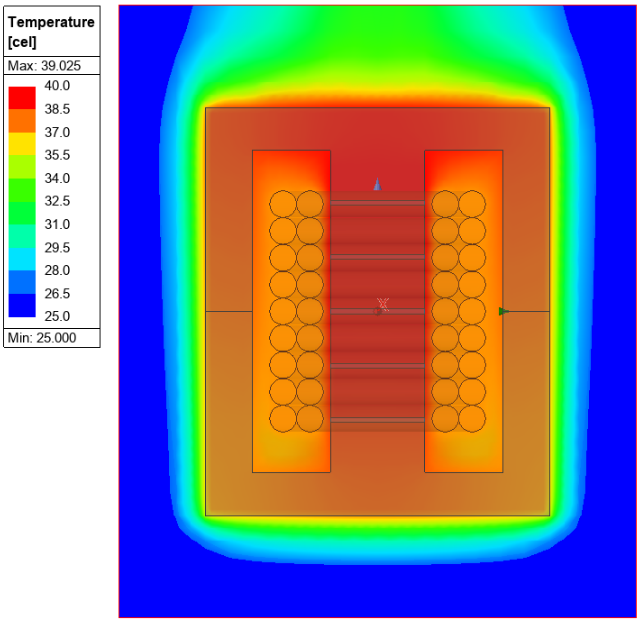


Figure 42: Icepak temperature results

As can be seen, there is a great match between both results, with an expected maximum temperature of 39.6 °C (as shown in Figure 38) versus the one provided by the Icepak 3D simulation of 41.09 °C.

Conclusions

In this tutorial, we have shown how to analyze and optimize an inductor that was already built for a different project.

Thanks to SmartNetics capabilities, we have been able to keep the original footprint, size, and connections of a device that was intended for $22.5\,\mu H$ and $10\,kHz$ and adapt it to a new specification of $7.5\,\mu H$ and $30\,kHz$. All that, while optimizing the materials and component selection to comply with the aim of this particular project, which was to reduce losses as much as possible.

Last but not least, the user can automatically export the full model to third-party tools for its simulation, including Ansys (Maxwell or Icepak) and Altair-Flux.

This tutorial is intended as an example, so the user is encouraged to try different configurations to find the one that is best suited for their particular project. Please, keep in mind that the images shown in this document may not exactly match with the options and distribution shown in the application, since different updates may result in slight changes.