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Web-Based Toolset Accelerates Power Supply Design For Both Power Electronics Experts And Non-Experts

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In developing power supplies or power converters, it is common for engineers to spend a large portion of their time in the design phase optimizing the power train design on the lab bench. Mostly, this activity involves testing various combinations of magnetic components, MOSFETs and switching frequencies. This process is important, yet very time consuming. Power supply design and simulation tools can speed up this process by permitting virtual prototyping of designs. However, the ability of these tools to reduce the need for physical prototyping and thereby save time, depends heavily on their functionality, ease of use, and simulation speed.

These qualities have been optimized in a free online, power supply design and simulation toolset called PowerEsim, which is available from PowerELab at www.powerEsim.com. Within PowerEsim, there are several tools including a circuit simulation tool, a loss analysis tool, a thermal simulation tool, an input harmonic analysis tool, a Monte Carlo analysis tool, Magnetic Builder, and others. What's more, these individual tools are seamlessly integrated with one another so that the users feel as if they are using a single tool. Instead of passing data and models from one tool to another manually, the tool automates these transfers. Once a condition or component is changed, all tools are updated automatically.

Furthermore, PowerESim has been optimized to perform very fast simulations. With some topologies, it can run hundreds of simulations per second, so that an engineer can optimize thousands of combinations within hours instead of months. These simulations include accurate models of magnetic components that have been designed using the Magnetic Builder tool. Therefore the magnetic devices being designed and simulated in PowerESim closely match the magnetic components you would physically build in the real world.

By offering three different options for starting a power converter design, PowerESim accommodates the varying skill levels and requirements of both power supply and non-power supply designers. After briefly describing these options, this article demonstrates how a power supply designer could use this tool to design a power factor correction (PFC) stage.

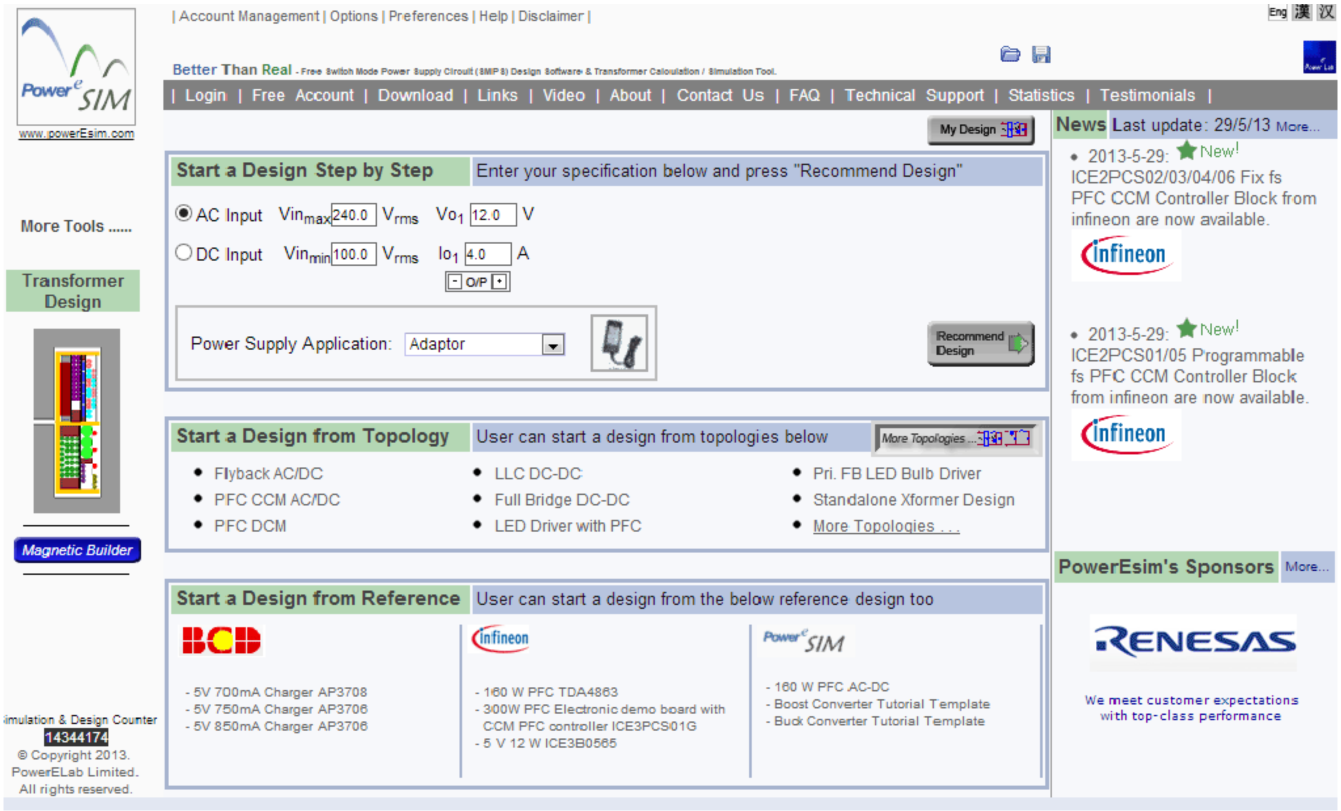
Different Ways To Start A Power Supply Design

A look at the PowerESim home page pictured in Fig. 1 reveals some unique aspects of the software. First, it is sponsored by component manufacturers. Mainly, this means that the components offered by sponsoring companies are favored in the design and selection process, though the software also features many components from non-sponsor companies. However, to access the components from the non-sponsoring companies, the user can select a sponsor account or register for a seven-day private account. A sponsor account allows the user to select all of the 140,000 components modeled in PowerESim except for those parts belonging to the sponsor's competitors. Both the sponsor account and the private account are free and allow users to access the advanced features of all the tools.

On the front page, you will also see four important features of Power ESim, which include the three options for creating a power supply design and the magnetics design tool. The "Start a design step by step" feature is for the non-power supply engineer who needs to create a working power supply design.

The "Start a design from topology" feature is for the power supply engineer as it allows the power electronics specialist to choose one of the more than 30 topologies that are modeled in Power ESim. The user simply clicks the button "Other Topologies" to see all the topologies, which include the most common flyback, buck, boost, active clamp, LLC half-bridge, phase bridge, forward, LED driver, etc.

The "Start a design from reference" feature can be ideal for the non-power supply engineer if they find a suitable application in that section. It is always easier to slightly modify an existing design than to create everything from scratch.



Start a Design Step by Step Enter your specification below and press "Recommend Design"

● AC Input Vin_{max} 240.0 V_{rms} Vo_1 12.0 V

○ DC Input Vin_{min} 100.0 V_{rms} Io_1 4.0 A

Power Supply Application: Adaptor

Start a Design from Topology User can start a design from topologies below

- Flyback AC/DC
- PFC CCM AC/DC
- PFC DCM
- LLC DC-DC
- Full Bridge DC-DC
- LED Driver with PFC
- Pri. FB LED Bulb Driver
- Standalone Xformer Design
- More Topologies . . .

Start a Design from Reference User can start a design from the below reference design too

- 5V 700mA Charger AP3708
- 5V 750mA Charger AP3706
- 5V 850mA Charger AP3706

- 160 W PFC TDA4863
- 300W PFC Electronic demo board with CCM PFC controller ICE3PCS01G
- 5 V 12 W ICE3B0565

- 160 W PFC AC-DC
- Boost Converter Tutorial Template
- Buck Converter Tutorial Template

News Last update: 29/5/13 More...

- 2013-5-29: New! ICE2PCS02/03/04/06 Fix fs PFC CCM Controller Block from infineon are now available.
- 2013-5-29: New! ICE2PCS01/05 Programmable fs PFC CCM Controller Block from infineon are now available.

PowerEsim's Sponsors More...

We meet customer expectations with top-class performance

Simulation & Design Counter 14344174

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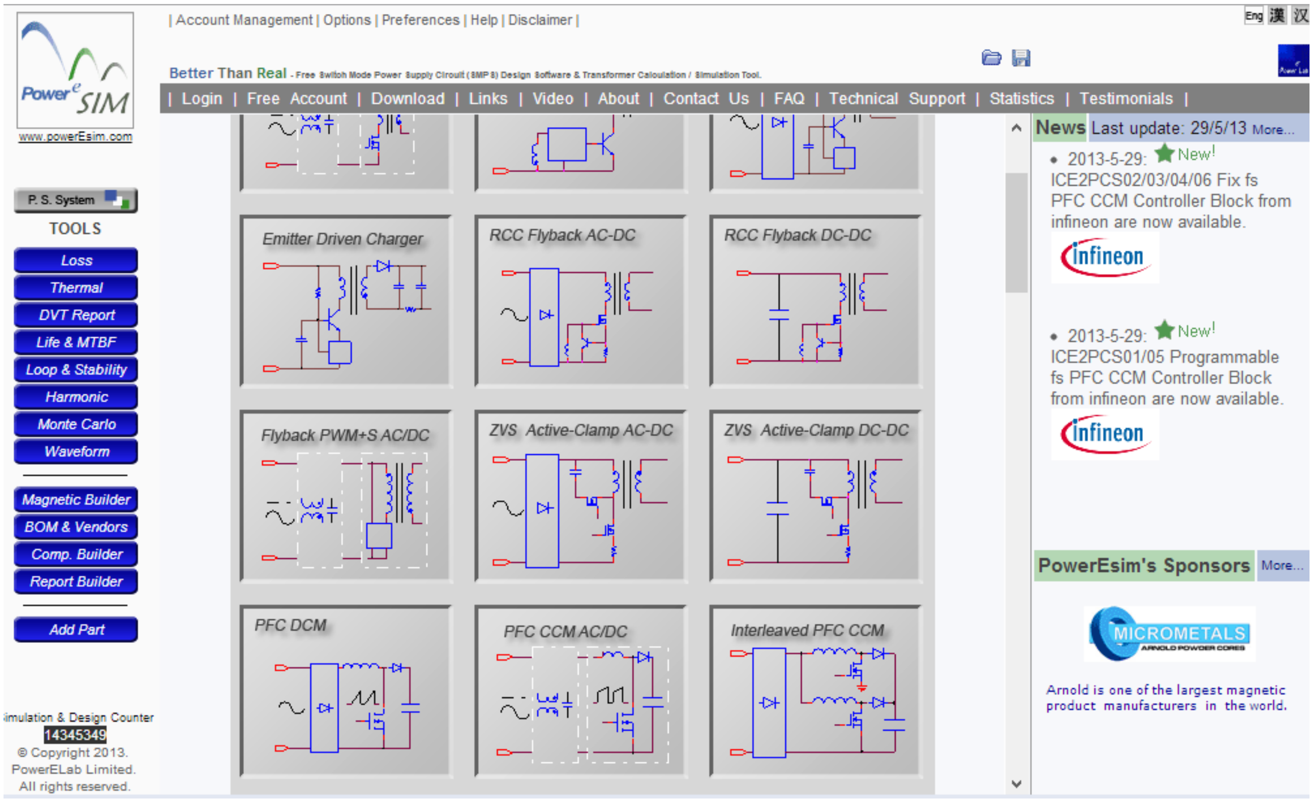
Fig.1. PowerEsim front page.

Finally, there is Magnetic Builder, which is the most popular tool in PowerEsim. Almost 50% of the simulations performed in PowerESim involve this tool. Magnetic Builder provides a virtual environment for the engineer to easily "wind" or construct a transformer using commercially available wires and cores, and then immediately simulate the design. Within a spit second, the tool simply shows the engineer the loss of that magnetic component under circuit operation.

The engineer does not need to go back and forth to handle the modeling issues that might arise between the circuit simulator and Magnetic Builder as these two tools are seamlessly integrated. With every change of the wire's location or size, the engineer can immediately see the resulting change in loss. Even better, the engineer can generate a transformer drawing with a click of the mouse. This drawing can be saved or sent to a transformer manufacturer for samples and quotation.

Starting A PFC Design

Perhaps the easiest way to explain the capabilities of PowerESim is to demonstrate the use of the software with a design example. In this case, it is assumed that the user is a power supply engineer, so we'll begin by clicking the "More Topologies" button. Doing this calls up a topologies page as shown in Fig. 2.



- 2013-5-29: New! ICE2PCS02/03/04/06 Fix fs PFC CCM Controller Block from infineon are now available.
- 2013-5-29: New! ICE2PCS01/05 Programmable fs PFC CCM Controller Block from infineon are now available.

Arnold is one of the largest magnetic product manufacturers in the world.

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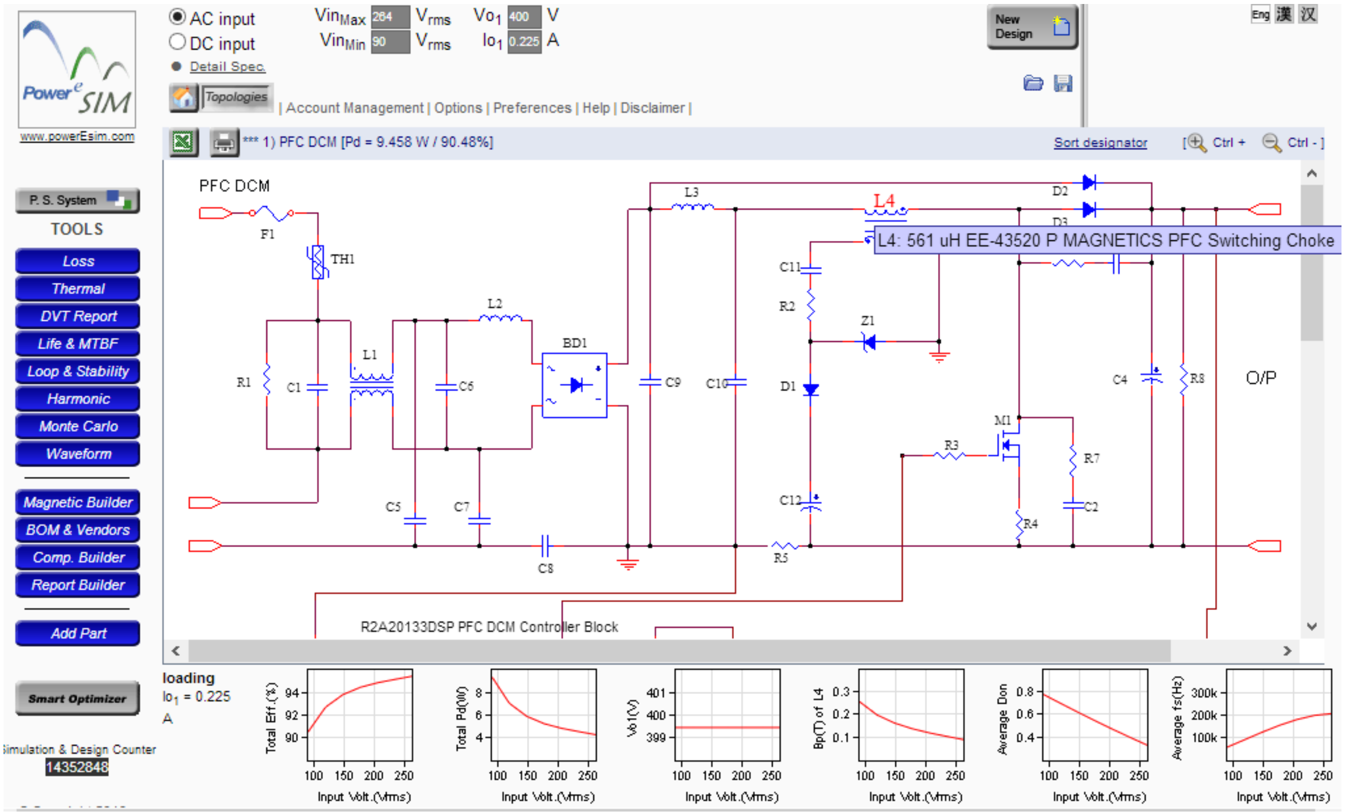
Fig. 2. The More Topologies page.

With this option, more than 20 topology blocks are built and ready for simulation. By clicking on the PFC DCM block, the user will enter into the converter circuit page, and a PFC converter design with default input and output conditions is recommended. Now, the user can click the "New Design" button and enter the new input and output specifications. For example, in this case we'll specify a 90-V ac to 264-V ac input range with 400-V dc 0.225-A 90-W output PFC. Next, we will click the "Initialize Design" button, so that the user will then see the recommended design as shown in Fig. 3.


● AC input
○ DC input
VinMax 264 Vrms
VinMin 90 Vrms
Vo1 400 V
Io1 0.225 A

*** 1) PFC DCM [Pd = 9.458 W / 90.48%]

L4: 561 uH EE-43520 P MAGNETICS PFC Switching Choke

loading
Io1 = 0.225 A

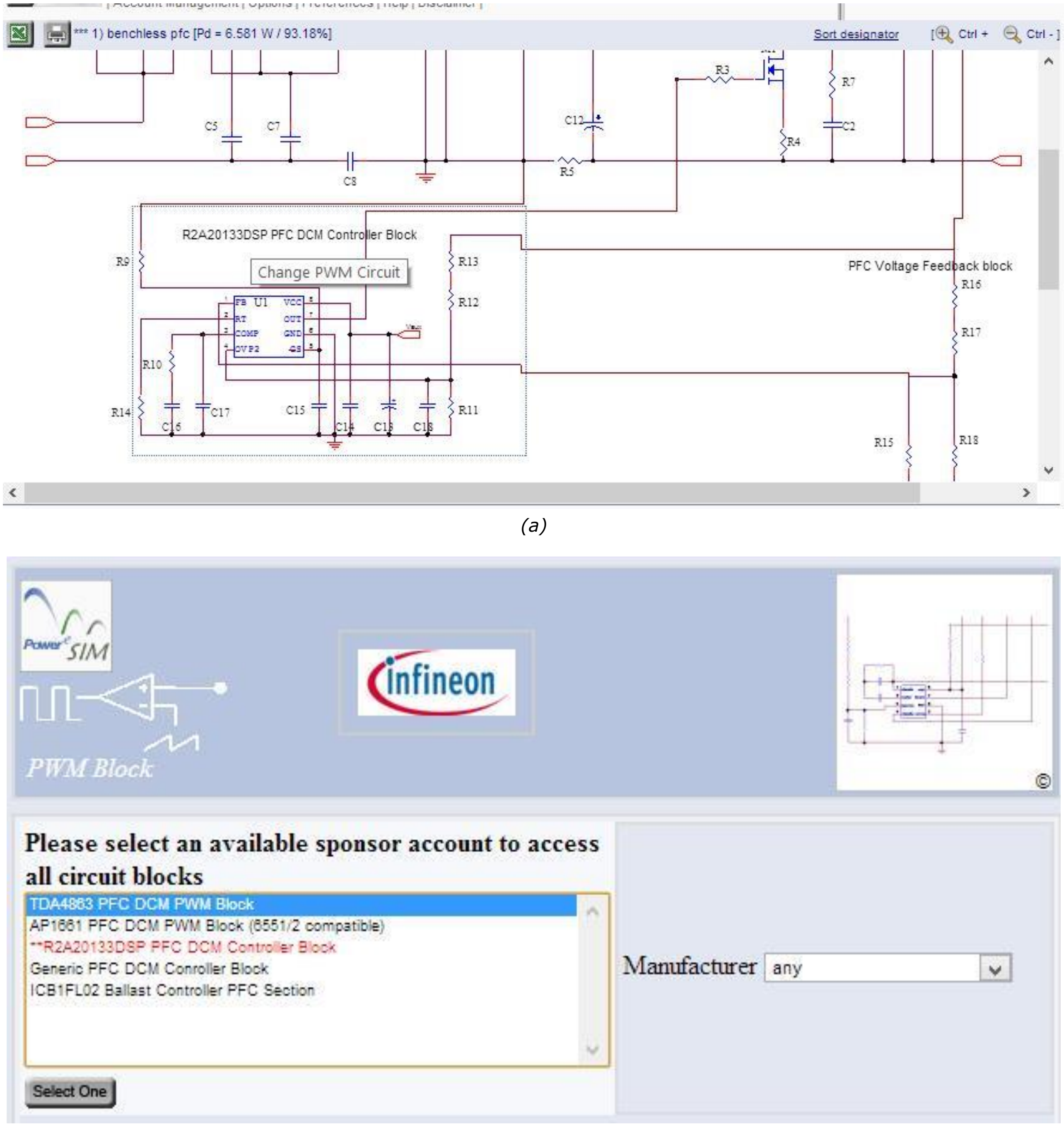
Simulation & Design Counter 14352848

Fig. 3. Initialized PFC design.

A summary of the converter's performance can be found at the bottom of the page with charts depicting efficiency, total loss, output voltage, peak flux level of PFC choke, averaged duty cycle, and averaged switching frequency versus input voltage range. Any update that the user makes to the circuit's operating conditions or components will produce a corresponding update in these charts, which is helpful for circuit optimization.

Users will find that if they click the "Initialize Design" button again, different components appear in the BOM even if the input and output conditions have not been changed. That is because our system tries to give each of our component sponsors an equal chance of having its components selected for a given design.

The user can change any component in the schematic or even the whole PWM control block as shown in Fig. 4. But this capability extends much further than that because the basic design building concept behind PowerEsim is a component-based approach. So, every aspect of a design is treated as a component that can be selected and changed. Naturally, this means a user can select and change a real component such as a transformer, but it also means a user can select and change parameters within that component, like number of turns or primary inductance. At a higher level, the user can select and change a circuit block or topology or even the whole power supply design.


*** 1) benchless pfc [Pd = 6.581 W / 93.18%]

Please select an available sponsor account to access all circuit blocks

TDA4863 PFC DCM PWM Block
AP1661 PFC DCM PWM Block (6561/2 compatible)
**R2A20133DSP PFC DCM Controller Block
Generic PFC DCM Conroller Block
ICB1FL02 Ballast Controller PFC Section

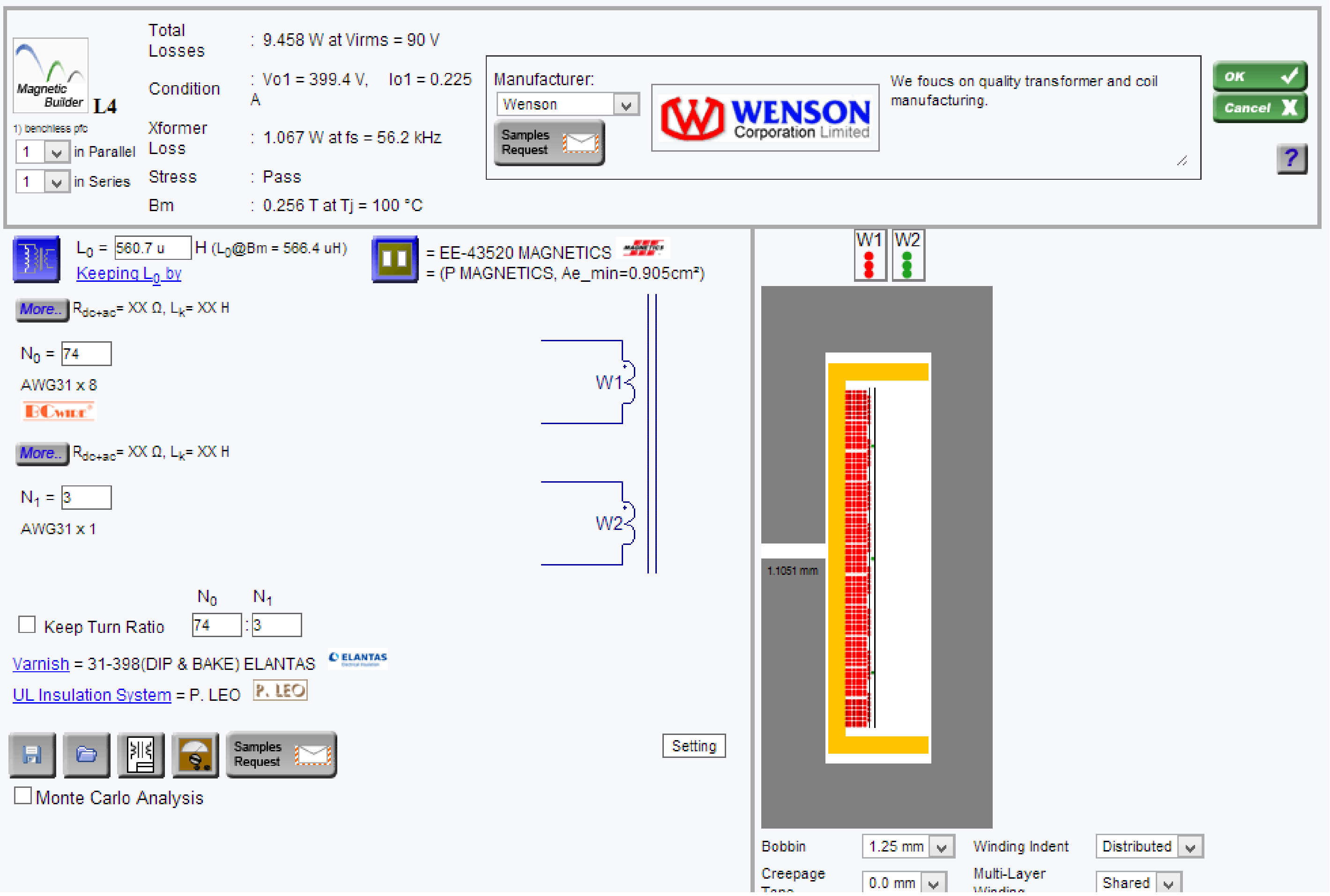
Manufacturer any

(a)

(b)

Fig. 4. Changing the PWM circuit block is accomplished by clicking a PWM circuit block (a) and then choosing a PWM circuit block (b).

At this point in the example design, an experienced engineer could start to optimize the design. For critical-conduction mode PFC, the most essential part is the PFC choke design. So here the user would click PFC choke L4 calling up the detailed construction of the PFC choke shown in Fig. 5.



L4
1) benchless pfc
1 in Parallel
1 in Series

Total Losses : 9.458 W at Virms = 90 V
Condition : Vo1 = 399.4 V, Io1 = 0.225 A
Xformer Loss : 1.067 W at fs = 56.2 kHz
Stress : Pass
Bm : 0.256 T at Tj = 100 °C

Manufacturer: Wenson

We foucs on quality transformer and coil manufacturing.

L_0 = 560.7 u H (L_0@Bm = 566.4 uH)
Keeping L_0 by

= EE-43520 MAGNETICS
= (P MAGNETICS, Ae_min=0.905cm²)

More.. R_{dc+ac}= XX Ω, L_k= XX H
N_0 = 74
AWG31 x 8

More.. R_{dc+ac}= XX Ω, L_k= XX H
N_1 = 3
AWG31 x 1

☐ Keep Turn Ratio N_0 74 : N_1 3

Varnish = 31-398(DIP & BAKE) ELANTAS
UL Insulation System = P. LEO

☐ Monte Carlo Analysis

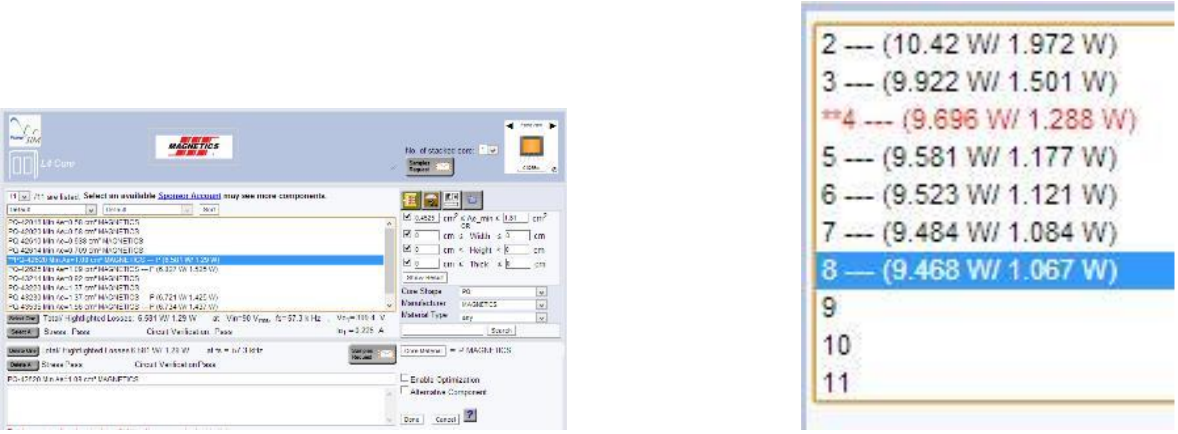
Bobbin 1.25 mm
Winding Indent Distributed
Creepage 0.0 mm
Multi-Layer Shared

Fig. 5. PFC choke construction.

Clicking on any magnetic part in the schematic activates the Magnetic Builder tool, which enables the user to define the construction of a magnetic component. The tool will not ask for abstract knowledge of the component—the user only needs to define how the wires are located inside a core. All the necessary magnetics theory has been embedded within the tool, so that the Magnetic Builder just shows the user results after any change in a component's physical construction. The theories of transformer operation may be complex and difficult but the definition of a transformer is simple and easy. After all, a physical design is just wires and turns.

In this example, the recommend transformer uses a Magnetics EE-43520 core with a min Ae of 0.905 cm^2. Assuming the user needs a small core—as it is expected the PFC will be used in a small notebook adaptor—a smaller size core is needed. So in this case, a PQ42620 is a good choice.

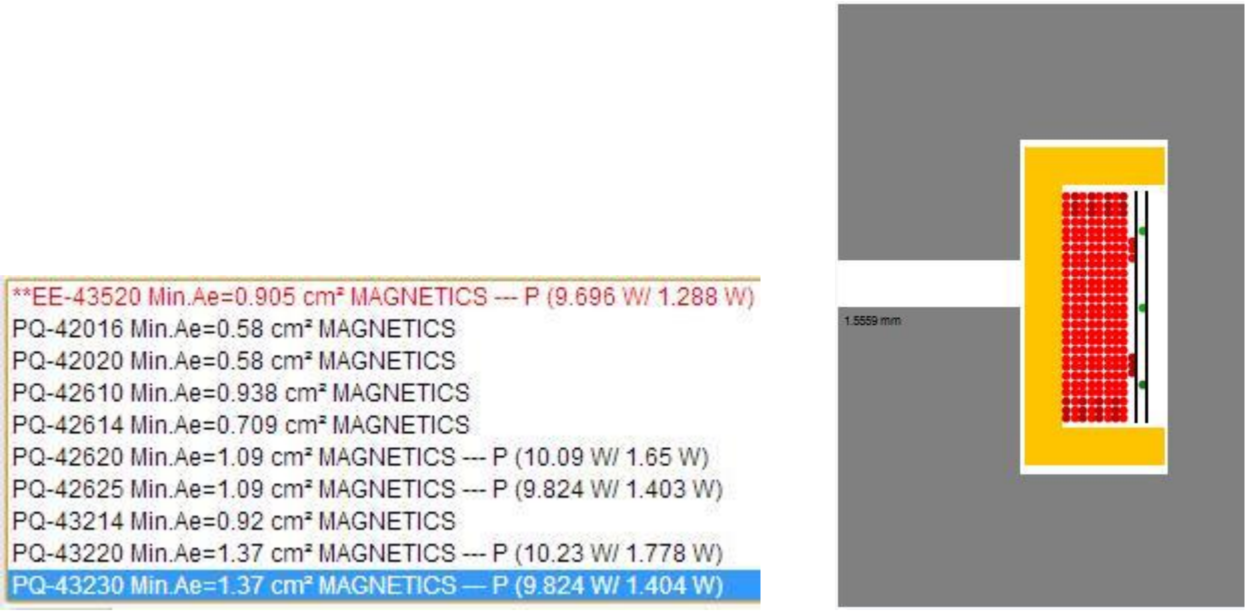
To change the core shape, simply click the core shape button, and a Component Finder page pops up as in Fig. 6a. A list of components is shown according to the search parameters defined on the right side of the Component Finder. Changing the range of the parameter will produce a different set of listed components.



2 --- (10.42 W/ 1.972 W)
3 --- (9.922 W/ 1.501 W)
**4 --- (9.696 W/ 1.288 W)
5 --- (9.581 W/ 1.177 W)
6 --- (9.523 W/ 1.121 W)
7 --- (9.484 W/ 1.084 W)
8 — (9.468 W/ 1.067 W)
9
10
11

(a) Component finder

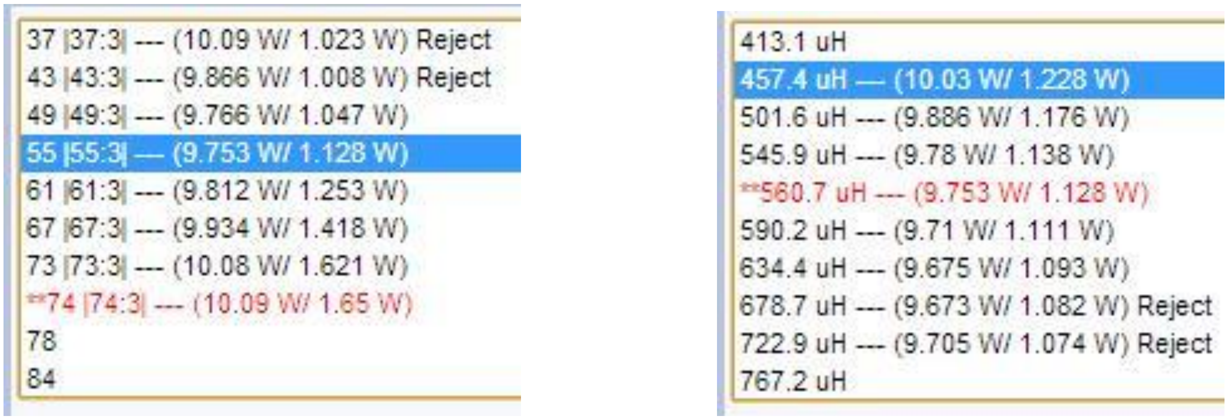
(b) Npp = 8 to Npp = 4, 1.07 W to 1.29 W



**EE-43520 Min.Ae=0.905 cm² MAGNETICS --- P (9.696 W/ 1.288 W)
PQ-42016 Min.Ae=0.58 cm² MAGNETICS
PQ-42020 Min.Ae=0.58 cm² MAGNETICS
PQ-42610 Min.Ae=0.938 cm² MAGNETICS
PQ-42614 Min.Ae=0.709 cm² MAGNETICS
PQ-42620 Min.Ae=1.09 cm² MAGNETICS --- P (10.09 W/ 1.65 W)
PQ-42625 Min.Ae=1.09 cm² MAGNETICS --- P (9.824 W/ 1.403 W)
PQ-43214 Min.Ae=0.92 cm² MAGNETICS
PQ-43220 Min.Ae=1.37 cm² MAGNETICS --- P (10.23 W/ 1.778 W)
PQ-43230 Min.Ae=1.37 cm² MAGNETICS — P (9.824 W/ 1.404 W)

(c) EE to PQ42620, 1.29 W to 1.65 W

(d) PQ2620 cross-section construction



37 |37:3| --- (10.09 W/ 1.023 W) Reject
43 |43:3| --- (9.866 W/ 1.008 W) Reject
49 |49:3| --- (9.766 W/ 1.047 W)
55 |55:3| — (9.753 W/ 1.128 W)
61 |61:3| --- (9.812 W/ 1.253 W)
67 |67:3| --- (9.934 W/ 1.418 W)
73 |73:3| --- (10.08 W/ 1.621 W)
**74 |74:3| --- (10.09 W/ 1.65 W)
78
84

413.1 uH
457.4 uH — (10.03 W/ 1.228 W)
501.6 uH --- (9.886 W/ 1.176 W)
545.9 uH --- (9.78 W/ 1.138 W)
**560.7 uH --- (9.753 W/ 1.128 W)
590.2 uH --- (9.71 W/ 1.111 W)
634.4 uH --- (9.675 W/ 1.093 W)
678.7 uH --- (9.673 W/ 1.082 W) Reject
722.9 uH --- (9.705 W/ 1.074 W) Reject
767.2 uH

(e) N_0 = 74 to N_0 = 55, 1.65 W to 1.128 W

(f) L_0=560 μH, 1.128 W to 1.128 W

Fig. 6. Optimizing the PFC choke.

Before replacing the core shape, it makes sense to ensure that all the wires will be able to fit into the smaller core. Now the choke is using an AWG31 x 8 as the default design for the relatively large EE core, so optimizing the number of parallel wires may be the first step in component optimization. To do this, the user clicks the "x 8" wording at N_0 so that a Component Finder page showing a list for the number of parallel wires appears. Highlight the number of parallel wires one by one to see the associated losses. In this case, we choose 4 as the number of parallel wires to ensure a smaller PQ core can accommodate the required amount of copper. As a result of this selection, the transformer loss increases from 1.07 W to 1.29 W as shown in Fig. 6b.

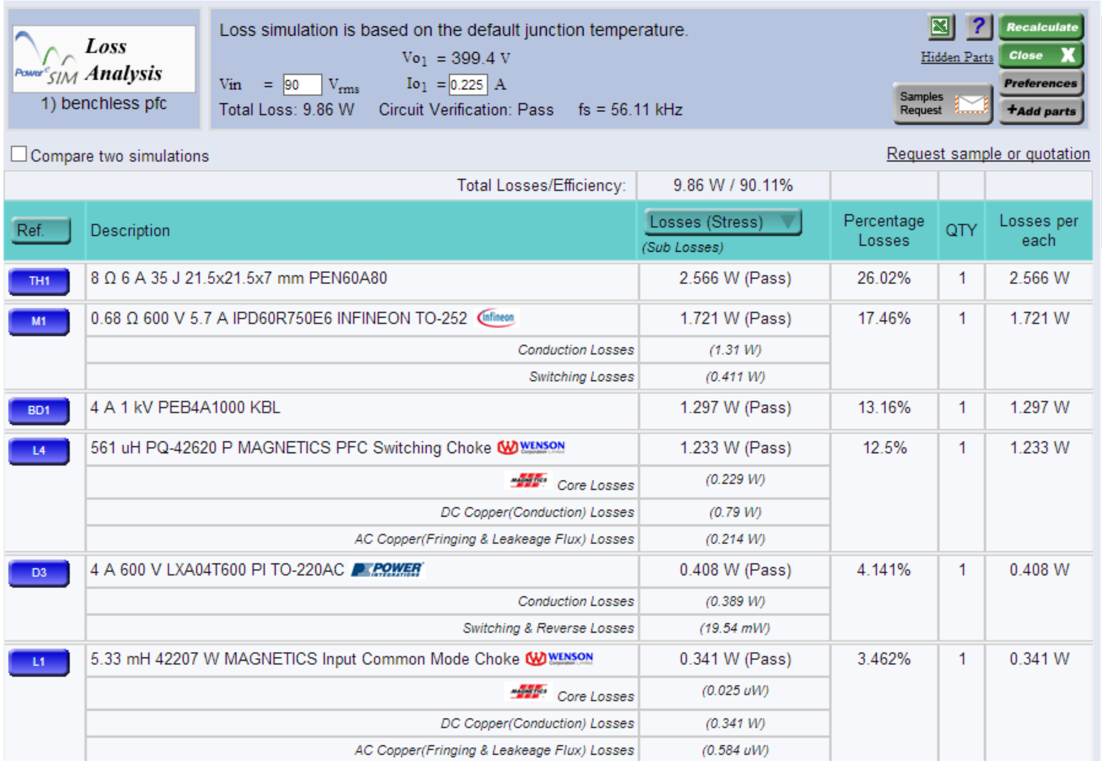
If we click the core shape button and change the core to PQ42620 as shown in Fig. 6c the loss will further increase from 1.29 W to 1.65 W. The user can see the cross section of the winding window in Magnetic Builder as shown in Fig. 6d.

When we repeat this procedure for the number of turns, clicking N_0 and highlighting the list of turns as shown in Fig. 6e, it shows that when N_0 is smaller than 43 turns, a reject message appears as the flux density has obviously exceeded the maximum limit. So to play it safe, N_0 = 55 turns is chosen, and the loss is reduced from 1.65 W to 1.13 W.

Now, when we do a similar highlighting for primary inductance L_0 as shown in Fig. 6f, it seems that the original inductance value is a good choice as too high an inductance will cause saturation and too low a value will increase losses. As this example illustrates, within just a few minutes, a user can in effect wind dozens of transformers in a virtual environment and thereby optimize the transformer design to obtain a pretty good solution.

If a user would like to further optimize the magnetic component design down to the last digit of losses, the above steps can be repeated. Users do not need to follow these steps one-by-one in order. Even reversing the order of the steps does not really harm the process.

Now that the most critical part of a PFC choke has been optimized, the designer needs to know the distribution of losses among the other components. To obtain this information, we click on the Loss button on the left side of the schematic page so that a list of losses is displayed as shown in Fig. 7.



1) benchless pfc

Loss simulation is based on the default junction temperature.

Vo_1 = 399.4 V

Vin = 90 V_{rms} Io_1 = 0.225 A

Total Loss: 9.86 W Circuit Verification: Pass fs = 56.11 kHz

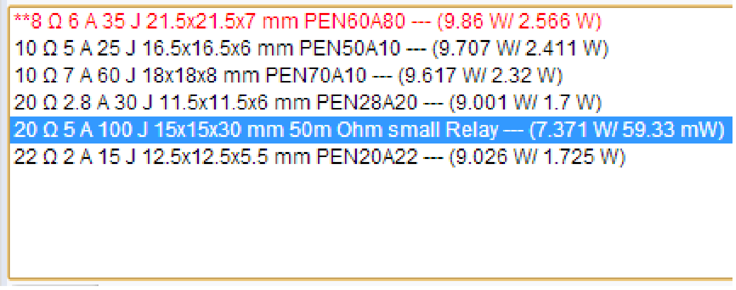
☐ Compare two simulations

Ref.	Description	Losses (Stress) (Sub Losses)	Percentage Losses	QTY	Losses per each
	Total Losses/Efficiency:	9.86 W / 90.11%			
TH1	8 Ω 6 A 35 J 21.5x21.5x7 mm PEN60A80	2.566 W (Pass)	26.02%	1	2.566 W
M1	0.68 Ω 600 V 5.7 A IPD60R750E6 INFINEON TO-252	1.721 W (Pass)	17.46%	1	1.721 W
	Conduction Losses	(1.31 W)			
	Switching Losses	(0.411 W)			
BD1	4 A 1 kV PEB4A1000 KBL	1.297 W (Pass)	13.16%	1	1.297 W
L4	561 uH PQ-42620 P MAGNETICS PFC Switching Choke	1.233 W (Pass)	12.5%	1	1.233 W
	Core Losses	(0.229 W)			
	DC Copper(Conduction) Losses	(0.79 W)			
	AC Copper(Fringing & Leakeage Flux) Losses	(0.214 W)			
D3	4 A 600 V LXA04T600 PI TO-220AC	0.408 W (Pass)	4.141%	1	0.408 W
	Conduction Losses	(0.389 W)			
	Switching & Reverse Losses	(19.54 mW)			
L1	5.33 mH 42207 W MAGNETICS Input Common Mode Choke	0.341 W (Pass)	3.462%	1	0.341 W
	Core Losses	(0.025 uW)			
	DC Copper(Conduction) Losses	(0.341 W)			
	AC Copper(Fringing & Leakeage Flux) Losses	(0.584 uW)			

Fig. 7. Loss analysis table.

In this example, it makes sense that the part with the greatest loss is the NTC input current limiter. To reduce this component's loss contribution, we can consider other options for the current limiter. Clicking the blue button "TH1" will direct the user to the Component Finder of TH1. Then, by highlighting the parts in the list, the user will see the general trend that the smaller-size NTCs will exhibit lower losses as the smaller NTCs will get hotter resulting in lower resistance during circuit operation, even though their nominal resistance is higher at 25°C.

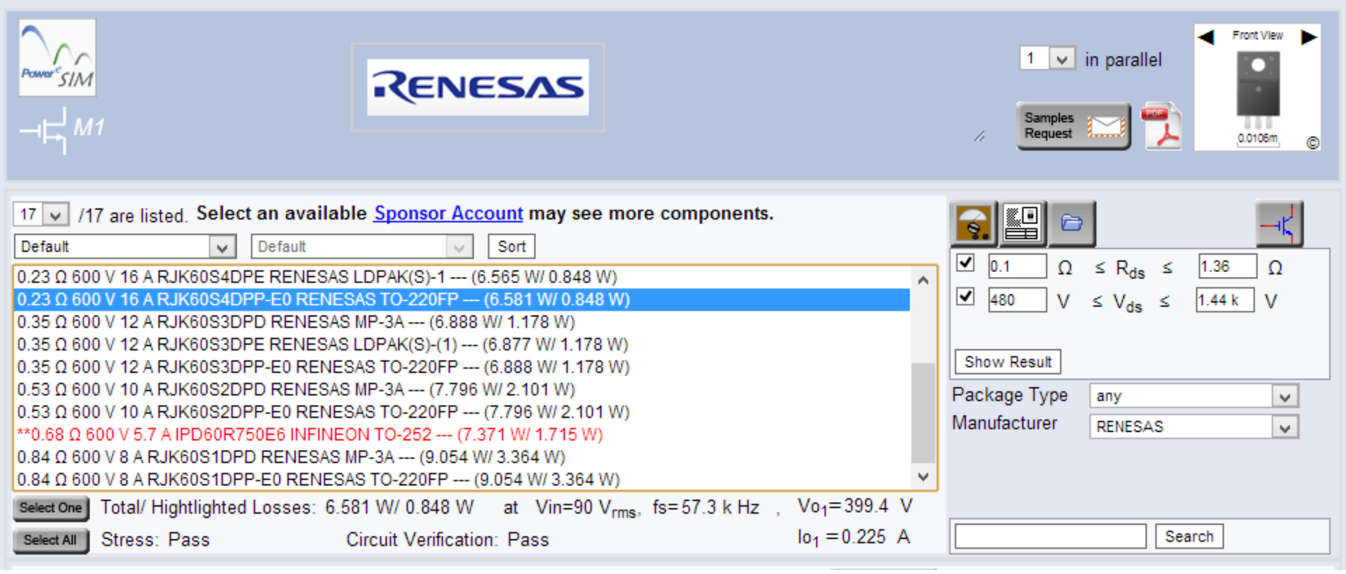
The user may also see a part called "20 Ohm 5A 100J 15x15x30 mm 50m Ohm small relay" that is an equivalent circuit of a 20-Ω resistor in parallel with a relay with 50-mΩ contact resistance. Once it is chosen, the total loss reduces from 9.86 W to 7.37 W as shown in Fig. 8.



**8 Ω 6 A 35 J 21.5x21.5x7 mm PEN60A80 --- (9.86 W/ 2.566 W)
10 Ω 5 A 25 J 16.5x16.5x6 mm PEN50A10 --- (9.707 W/ 2.411 W)
10 Ω 7 A 60 J 18x18x8 mm PEN70A10 --- (9.617 W/ 2.32 W)
20 Ω 2.8 A 30 J 11.5x11.5x6 mm PEN28A20 --- (9.001 W/ 1.7 W)
20 Ω 5 A 100 J 15x15x30 mm 50m Ohm small Relay — (7.371 W/ 59.33 mW)
22 Ω 2 A 15 J 12.5x12.5x5.5 mm PEN20A22 --- (9.026 W/ 1.725 W)

Fig. 8. TH1 NTC Component Finder list. Replacing the original NTC current limiter with a 50-mΩ small relay reduces the overall losses of the PFC stage from 9.86 W to 7.37 W.

At this point, checking the Loss tool again, the user will find that the highest loss is now coming from the main MOSFET M1. Clicking on this part, the user will see a list of potential replacements for M1 as shown in Fig. 9. In this case, we will select a 0.23-Ω MOSFFET for its tradeoff of cost and performance. This change results in a reduction in total losses from 7.37 W to 6.58 W. The user can see a more detailed breakdown of the losses into conduction loss and switching loss on the loss page (as was shown previously in Fig. 7 for the original parts list.)



1 in parallel

17 /17 are listed. **Select an available Sponsor Account may see more components.**

Default | Default

0.23 Ω 600 V 16 A RJK60S4DPE RENESAS LDPAK(S)-1 --- (6.565 W/ 0.848 W)
0.23 Ω 600 V 16 A RJK60S4DPP-E0 RENESAS TO-220FP — (6.581 W/ 0.848 W)
0.35 Ω 600 V 12 A RJK60S3DPD RENESAS MP-3A --- (6.888 W/ 1.178 W)
0.35 Ω 600 V 12 A RJK60S3DPE RENESAS LDPAK(S)-(1) --- (6.877 W/ 1.178 W)
0.35 Ω 600 V 12 A RJK60S3DPP-E0 RENESAS TO-220FP --- (6.888 W/ 1.178 W)
0.53 Ω 600 V 10 A RJK60S2DPD RENESAS MP-3A --- (7.796 W/ 2.101 W)
0.53 Ω 600 V 10 A RJK60S2DPP-E0 RENESAS TO-220FP --- (7.796 W/ 2.101 W)
**0.68 Ω 600 V 5.7 A IPD60R750E6 INFINEON TO-252 --- (7.371 W/ 1.715 W)
0.84 Ω 600 V 8 A RJK60S1DPD RENESAS MP-3A --- (9.054 W/ 3.364 W)
0.84 Ω 600 V 8 A RJK60S1DPP-E0 RENESAS TO-220FP --- (9.054 W/ 3.364 W)

Total/ Hightlighted Losses: 6.581 W/ 0.848 W at Vin=90 V_{rms}, fs=57.3 k Hz , Vo_1=399.4 V

Stress: Pass Circuit Verification: Pass Io_1 =0.225 A

☑ 0.1 Ω ≤ R_{ds} ≤ 1.36 Ω
☑ 480 V ≤ V_{ds} ≤ 1.44 k V

Package Type: any
Manufacturer: RENESAS

Fig. 9. M1 MOSFET Component Finder list shows how replacement of the original MOSFET with one having lower on-resistance reduces overall losses of the PFC design from 7.37 W to 6.58 W.

In this design example, within just a few minutes, we have effectively built more than 30 transformers and performed the equivalent of 50 procedures of soldering and test work—all done in a virtual environment. In the process, efficiency has been optimized to almost 94% at low line as shown in Fig. 10. In real life, doing all this work on the bench might take several weeks to complete.

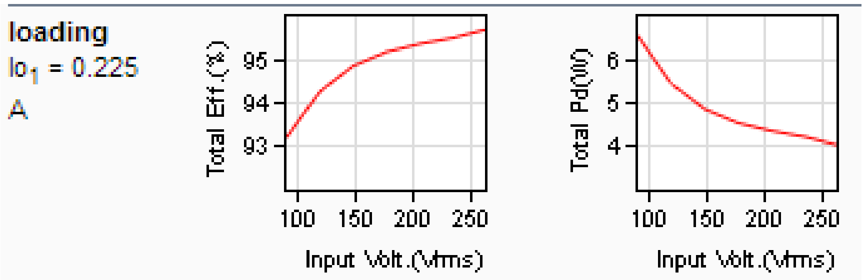
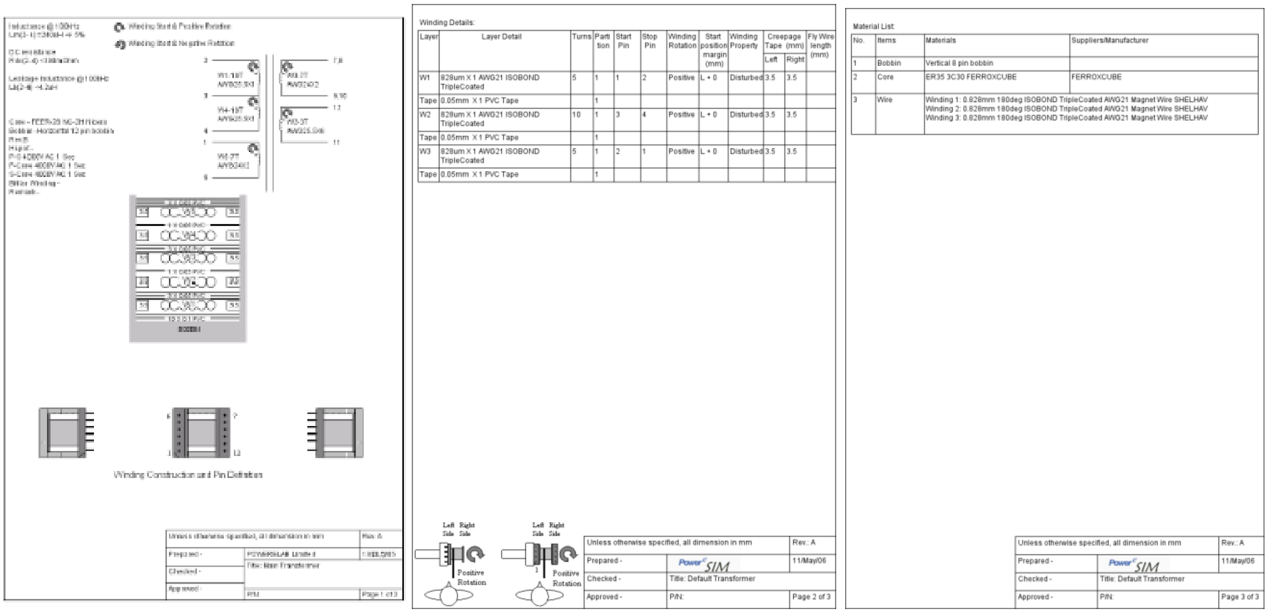


Fig. 10. Efficiency and loss against Vi.

This level of productivity really turns the design work into fun. And more than that, the user can store and print out all the magnetic drawings and send them to the transformer manufacturer for samples as shown in Fig. 11.



Winding Details:

Layer	Layer Detail	Turns	Partition	Start Pin	Stop Pin	Winding Rotation	Start position margin (mm)	Winding Property	Creepage Tape (mm)		Fly Wire length (mm)
									Left	Right	
W1	828um X 1 AWG21 ISOBOND TripleCoated	5	1	1	2	Positive	L + 0	Disturbed	3.5	3.5	
Tape	0.05mm X 1 PVC Tape		1								
W2	828um X 1 AWG21 ISOBOND TripleCoated	10	1	3	4	Positive	L + 0	Disturbed	3.5	3.5	
Tape	0.05mm X 1 PVC Tape		1								
W3	828um X 1 AWG21 ISOBOND TripleCoated	5	1	2	1	Positive	L + 0	Disturbed	3.5	3.5	
Tape	0.05mm X 1 PVC Tape		1								

Unless otherwise specified, all dimension in mm		Rev.: A
Prepared -	Power e SIM	11/May/06
Checked -	Title: Default Transformer	
Approved -	P/N:	Page 2 of 3

Material List:

No.	Items	Materials	Suppliers/Manufacturer
1	Bobbin	Vertical 8 pin bobbin	
2	Core	ER35 3C30 FERROXCUBE	FERROXCUBE
3	Wire	Winding 1: 0.828mm 180deg ISOBOND TripleCoated AWG21 Magnet Wire SHELHAV Winding 2: 0.828mm 180deg ISOBOND TripleCoated AWG21 Magnet Wire SHELHAV Winding 3: 0.828mm 180deg ISOBOND TripleCoated AWG21 Magnet Wire SHELHAV	

Unless otherwise specified, all dimension in mm		Rev.: A
Prepared -	Power e SIM	11/May/06
Checked -	Title: Default Transformer	
Approved -	P/N:	Page 3 of 3

Fig. 11. Magnetic drawing.

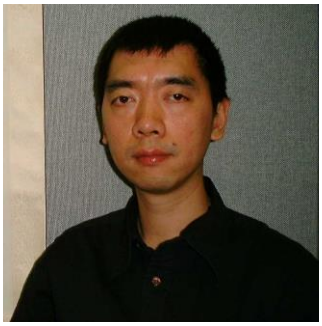
The last thing for the engineer to do may be to create the PCB layout and build an actual prototype. Unfortunately, PowerEsim is not integrated with a PCB layout tool, so the user will need to find another tool for schematic capture and PCB layout.

Nevertheless, most simulations performed in PowerESim do consider PCB trace inductance at the power path using reasonably practical values. The user should follow good PCB design practices in setting the lengths of the high-frequency and power traces and in establishing a good grounding arrangement. In short, after a fine tuning of PCB layout or wiring of a prototype, engineers should find that the measured losses are in close agreement with PowerEsim's simulated results.

Conclusion

A free online power supply design and simulation toolset has been presented. And as the PFC design example illustrates, the software's features exceed the standard for circuit simulation, transforming circuit simulation into a virtual design experience while accelerating the trial-and-error processes beyond what was previously possible. Keep in mind that this article has introduced only a fraction of the features in PowerESim. There are many more features within the software that are ready for the user to explore.

About The Author



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For further reading on power supply design tools, see the How2Power Design Guide, select the Advanced Search option, go to Search by Design Guide Category and select "Design Tools" in the Component category.