

Online Power Design Tools: Past, Present and Future

**APEC 2016 Industry Session
Aiding Design Excellence**

March, 2016

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Acknowledgment

- Howard Chen
- Mike Meyers
- Rich Levine
- Laura Herriott
- Gayle Bullock
- Cindy Plante

Outline

- Challenges facing a Power Designer
- Design, as it has been practiced
 - Reference designs, datasheets, simulations, models, tools
- Evolution of design tools
 - Past, present, future
- Examples of how design tools can help
 - Design synthesis
 - Tradeoff of cost, footprint, and efficiency
 - Mixed-cap
 - Compensation design
 - Thermal simulation and copper area
 - CAD export
- Thoughts on future trends in design tools

Power management applications are everywhere!

Industrial Control

Motor Control
& Automation



Test & Instrumentation



Digital Radio & Audio



Automotive
Infotainment, ANC,
Vision Control, Central
Body Controller



Consumer
Electronics



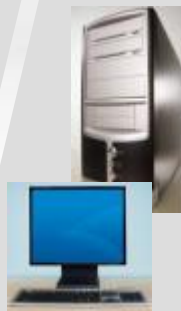
LED & LCD
Displays



Video
Conferencing &
Surveillance



Computing



Communication
Infrastructure

Gateway, Router & Switch



Ultrabooks,
Smartphones,
& Tablets



Communication
Peripherals

IP Phones, PoE &
WAPs



... and so are the challenges of power design



Challenges facing a Power Designer

- Power management solutions are needed everywhere by the expanding electronic, information, and mobile revolution
- Requirements by modern systems from power designers have become more demanding and more complex
 - Traditional concerns still there: like performance, efficiency, form factor, cost
 - Newer concerns have emerged: light-load efficiency, digital control, mobile battery-operated systems, energy harvesting, sequencing, protection
 - New regulatory standards
- Challenges for a designer
 - Huge choice of power management options
 - Large # of devices & manufacturers of ICs, FETs, diodes, magnetics, C, R
 - Competing choice of topology, control, PMBus, I2C
 - PCB layout and its interplay with performance is critical
 - Thermal concerns

Design as it has been practiced

- Designers have traditionally used an iterative trial-and-error approach to power design
 - Paper design
 - Prototype
 - Bench testing
- Deficiencies of this approach
 - Inefficient process
 - Non-optimal design
 - Little maintainability or scalability
- Design aids:
 - Datasheet
 - Evaluation modules (EVM)
 - reference designs
- As CAD & design tools started becoming available, they were used as “point tools”, like circuit simulations, PCB layout, thermal analysis

Design tools versus design aids of reference designs, datasheet

- Datasheet versus design tools and models
 - Datasheets accurately show performance over some representative conditions
 - Models cover a larger design space
 - Design flow in datasheet is geared towards hand design, but model-based design can be more complex and gives more optimized solutions
- Reference designs versus design tools
 - Reference designs are tailored into a certain set of requirements only
 - Design tools customize the design to user's requirements
 - Design tools are dynamic and refreshed; reference designs are static, unless redesigned again

Simulation versus board

- **Con**

- Models can only simulate effects that have been captured in the design of the model
- Simulations are valid in the space they are created for
- Models + numerical methods have limitations & inaccuracies
- Some models may require prohibitively high CPU time

- **Pros**

- Simulations help fine-tune and optimize the design
- Make the tradeoffs in conceptualization phase, much ahead of prototyping
- Zero in to the type of solution, topology etc.
- Accelerate time to market
- What-if experiments can be done more rapidly than on bench (no need to procure parts, make a prototype, and test it)

- Simulations and models are not guaranteed to be perfect, so designers should

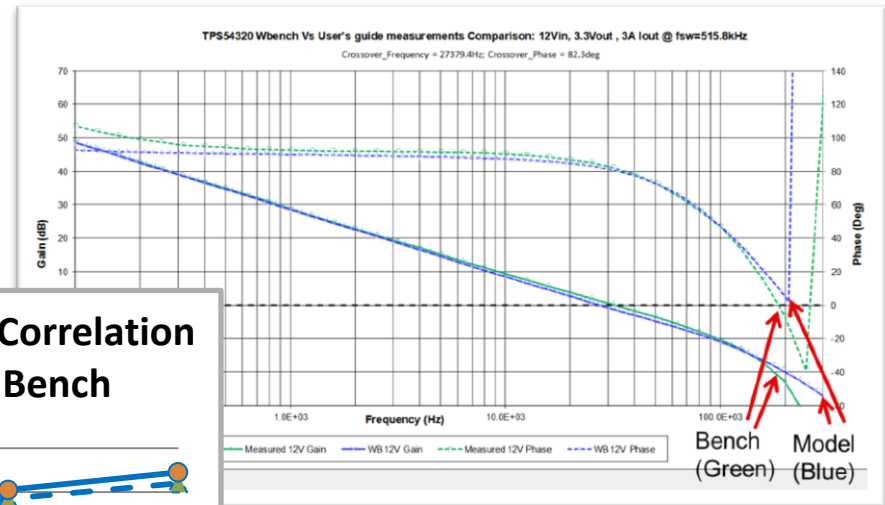
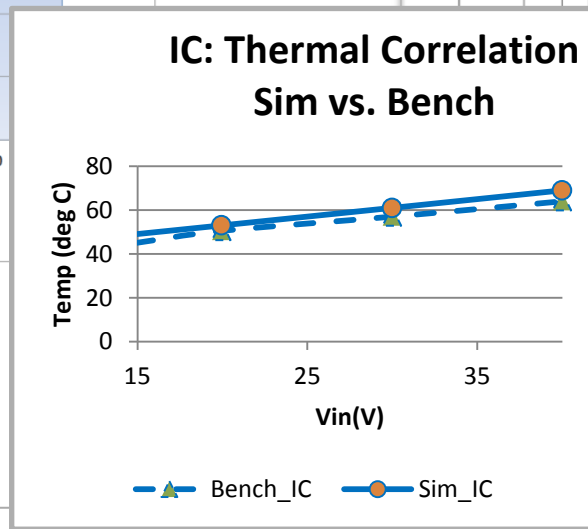
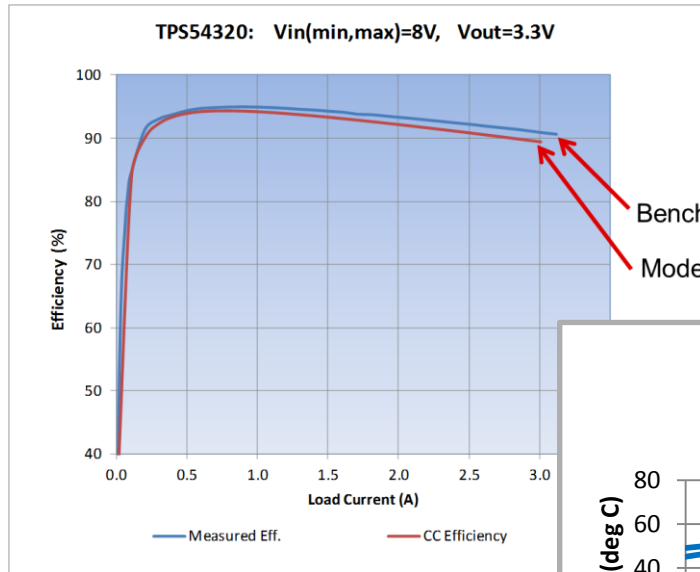
- Prototype on real board
- Know the limitations of the model and range of accuracy well
- Tight integration of model developer with silicon process development, applications, system and IC designers ensures high quality models

How can design tool help power designer?

- Synthesize the custom design
 - Based on designer inputs and requirements
 - Choose the best power management IC and other BOM components
 - Allow designer to make trade offs for performance, cost, footprint
- Capability to fine tune the design and verify by simulation
 - Compensation design
 - Circuit electrical simulation
 - Thermal simulation
- Export the generated PCB to CAD formats
- Well calibrated models will good model fidelity to bench data

Models have to be calibrated to bench data for reliable design generation

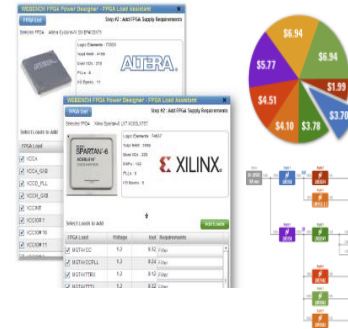
- Efficiency, loop, IC temperature calibrate to bench data to model over range of V_{out} , V_{in} , I_{out} , temperature, F_{SW}
- Inaccuracies can lead to poor designs and design failures. Well calibrated models are essential



Evolving design tools can help the designer with new and advanced capabilities

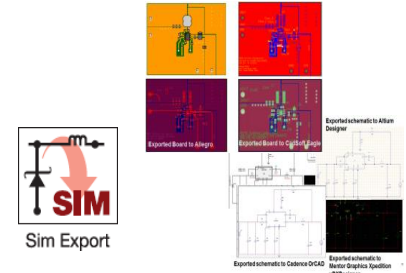
New Capabilities

2010: Architect type tools



Complex system-level power design (e.g. WEBENCH Power Architect)

2016: CAD Export, Advanced tools



CAD export offering interoperability with other CAD tools, Online schematic editor & simulator, Advanced tools (e.g. WEBENCH re-compensation tool)

1999: Online tools



Comprehensive online design tools, online electrical and thermal simulation (e.g. WEBENCH® Design Tools)

Past: Offline tools & bench



Bench testing, Trial and Error, Few offline tools

Design tools: past, present and future

- **Past**

- Offline tools; distributed via floppy disks
- DOS programs, text-mode, little graphics, or spreadsheet-based
- E.g. Switchers Made Simple tool

- **Present**

- Online tools
- Use advanced web technologies & GUI
- Feature rich, e.g. SPICE, thermal simulation
- Database of components with real-time availability & pricing
- Ecosystem of features and tools working seamlessly together
- E.g. WEBENCH® Power Designer & Architect tools

- **Future**

- Online tools and expansion to mobile, touch-based platforms
- Co-design power at system-level
- Advanced simulations and interoperable tool support
- Embrace the advanced software, GUI and web technologies

Tools in the past: off-line & text-based

NATIONAL SEMICONDUCTOR

Power Management Group

SWITCHERS MADE SIMPLE v4.1

An expert system for the automated
design of SIMPLE SWITCHER (TM)
power converters

PRESS ANY KE

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Input Requirements

```

NumOutputs = 1
Vin Min = 6.00 U
Vin Max = 7.00 U
Uout1 = 3.30 U
Iout1 Max = 0.25 A
Uripple1 = 0.00 U
Ta Min = 25.00 °C
Ta Max = 70.00 °C
Uout2 = 0.00 U
Iout2 Max = 0.00 A
Uripple2 = 0.00 U
Uout3 = 0.00 U
Iout3 Max = 0.00 A
Uripple3 = 0.00 U
    
```

Switchers Made Simple

Switchers Made Simple

Input Requirements

```

Vin Min = 6.00 U
Vin Max = 7.00 U
Uout1 = 3.30 U
Iout1 Max = 0.25 A
Ta Min = 25.00 °C
Ta Max = 70.00 °C
    
```

Operating Values

```

Mode = Cont
Frequency = 150.00 kHz
Duty Cycle = 68.68 %
IC Ipk Max = 0.65 A
IC Ipk = 0.29 A
L Ipp = 80.44 mA
Efficiency = 75.51 %
Cin IRMS = 0.12 A
Cout IRMS = 23.22 mA
IC Pd = 0.21 W
IC Tj = 90.48 °C
Diode Pd = 39.15 mW
L Pd = 13.55 mW
Iin Avg = 0.18 A
Cross Freq = 11.14 kHz
Phase Marg = 35.14 Deg
Uout p-p = 19.31 mU
    
```

Component Values

```

L = 100.00 uH
L DCR = 0.21 Ohms
Cin = 33.00 uF
Cin ESR = 0.49 Ohms
Cout = 100.00 uF
Cout ESR = 0.24 Ohms
ESR AC = 0.17 Ohms
Cu Area = 1.00 in^2
Cu Wgt = 1.00 oz
    
```

operating environment

file:

Press Esc for Main Menu, or any menu hot key

F1 Help ESC Main Menu

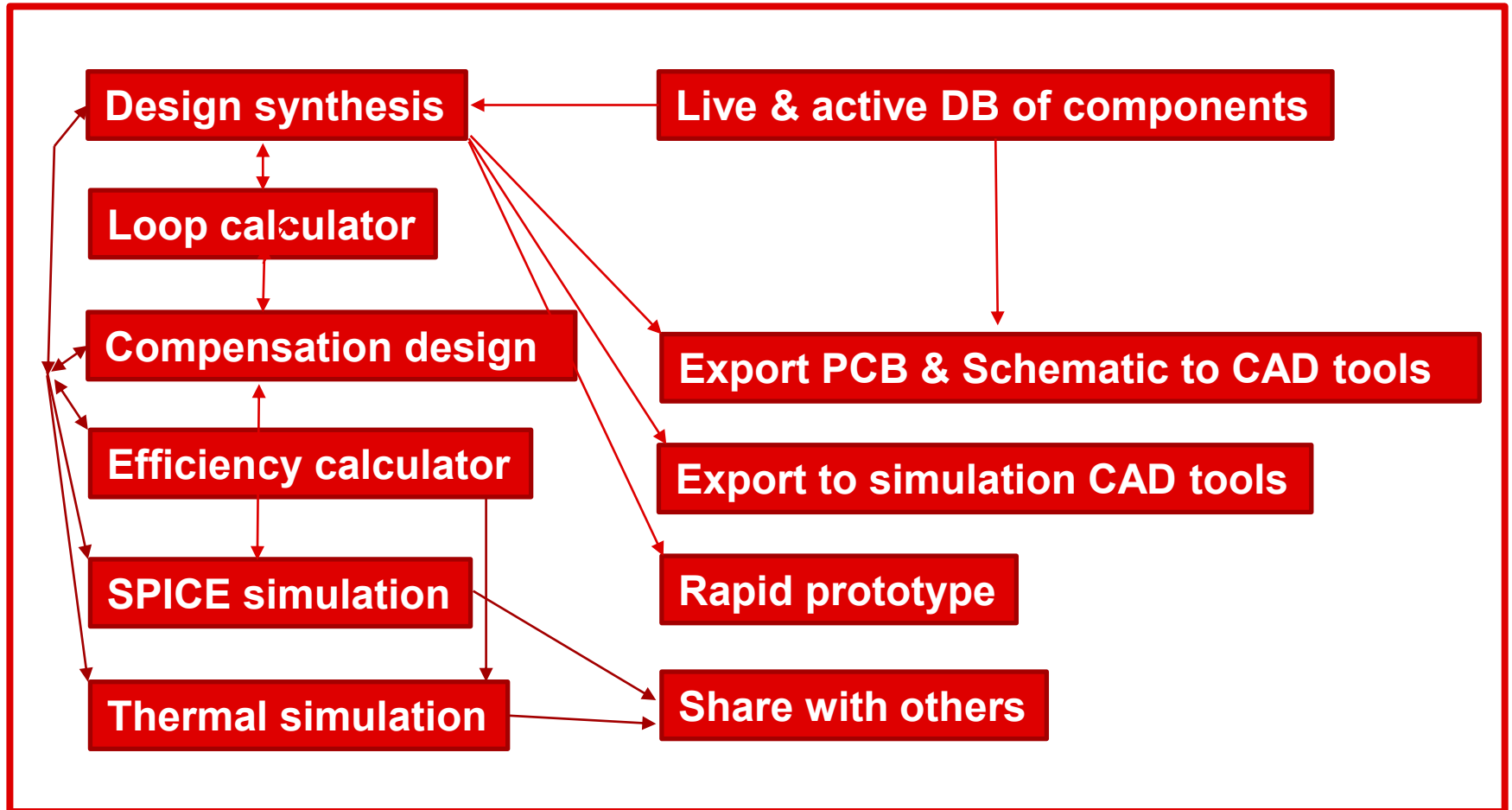
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Tools of today

- Good tools have excellent UX/GUI combined with modern numerical techniques, programmed with latest web technologies, and support the diversity of computing platforms
- Power tools have whole design ecosystem within the tool, working seamlessly with each other
 - Design synthesis using live database of parts
 - Calculation, simulation and design-aid features working together
 - Encompass the system-level view
 - Point tools, even if they are powerful, are less effective
- Tools support rapid prototyping
 - Design synthesis + circuit calculations (Efficiency + Loop) + compensation design + PCB layout + electrical & thermal simulation + Export = **Rapid Prototyping**
- Tools have to be predictive & accurate, which is possible only when models are well calibrated against bench data
- **The whole is greater than the sum of its parts**

Ecosystem in the tool is critical: “The whole is greater than the sum of its parts”



Why online?

- All computational burden is on the online servers, not local host machine; puts powerful capabilities in the hands of all devices, even mobile devices
- Automatic software updates
- Cloud storage of designs
- Tools and designs accessible from all devices and locations
- No burden on designer for software downloads, updates, OS compatibility, and no cost to purchase tools and simulators
- Share designs with others and collaborate

Design Synthesis

- Digital prototyping
- Start from input spec + any advanced preferences
- Use components from various manufacturers, distributors with real-time price & availability
- Ability to fine tune the design, change BOM, re-optimize stability, etc.
- Share & collaborate
- Rapid prototype capability

The screenshot displays a comprehensive design synthesis software interface. At the top, there's a navigation bar with icons for Back, New, Solutions, Visualizer, BOM, Charts, Schematic, Op Vals, Re-Comp, Sim, Thermal, and Edit. Below this is a 'SUMMARY' section with three main panels:

- Inputs:** A table for changing input parameters.

Parameter	Value	Constraint	Limit
VinMin	4.5V	< 8	V < 17V
VinMax	4.5V	< 17	V < 17V
Vout	0.8V	< 3.3	V < 15V
Iout	0A	< 6	A < 6A
Ta	-40°C	< 30	°C < 100°C
- Schematic:** A visual representation of the synthesized design, showing a power converter circuit with components like capacitors, inductors, and a controller IC. It includes zoom and fit controls.
- Bill of Materials:** A table listing components with their footprints and selection options.

Part	Manufacturer	Part No.	Qty	Footprint	Value	Unit	Footprint	Value	Unit	Footprint	Value	Unit	Footprint	Value	Unit	Footprint	Value	Unit	
Boot	AVX	880531	1	80.0	Cap=150nF, ESR=0.330H	7													
Comp	Yageo A	CC080	1	80.0	Cap=15nF	7													
Ch	MuRata	GRM32	1	80.1	Cap=22uF	15													
Ch2	MuRata	GRM2	1	80.0	Cap=4.7uF, ESR=4m0H	7													
Foot	MuRata	RM080	1	80.1	Cap=100uF	11													
ResB	Vishay C	CR0W	1	80.0	Resistance= 27.0K0H	3													

Below the summary panels are three more sections:

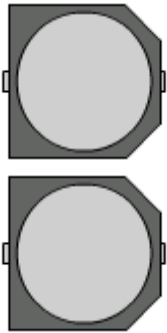
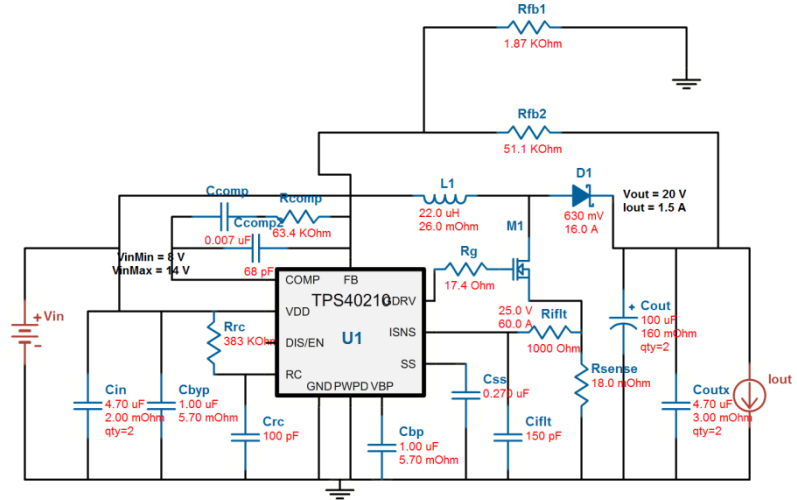
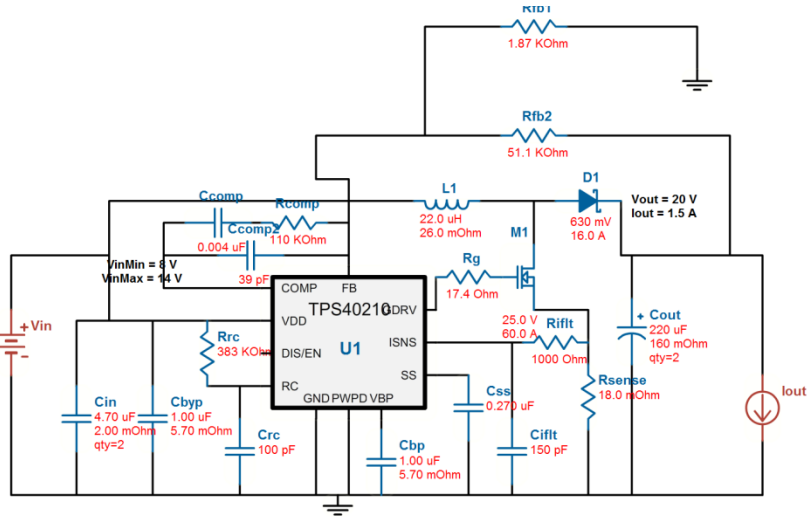
- Charts:** A graph showing Efficiency (%) vs Output Current (A) for three different input voltages: Vin=8.0V (orange), Vin=12.5V (green), and Vin=17.0V (blue). The efficiency peaks around 3.00A and then declines.
- Operating Values:** A table of key performance indicators.

Name	Value
Cross Freq	42.5kHz
Duty Cycle	20.7%
Efficiency	88.6%
FootPrint	325mm ²
Frequency	666kHz
Gain Marg	-19dB
Mode	CCM
Phase Marg	59.2deg
- WebTHERM™ Simulation:** A 3D thermal simulation of the PCB, showing temperature distribution across the board and components.

Make tradeoff between footprint, cost, and efficiency

Switching frequency modulates losses and affects the inductor size

Change output capacitor to be mix of electrolytic & ceramic type



Not Mixed

2x (220 μ F, 160m Ω)

Footprint	BOM Cost	Efficiency
1433	\$6.99	94

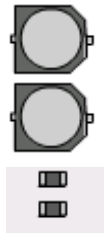
$$V_{OUT,Ripple} = 340 \text{ mVpp}$$

Mixed

2x (100 μ F, 160m Ω) || 2x (4.7 μ F, 3m Ω)

Footprint	BOM Cost	Efficiency
820	\$3.87	95

$$V_{OUT,Ripple} = 170 \text{ mVpp}$$



Mixed-cap design (24 components, 21 unique) results in **42% smaller footprint**, **44% lower cost**, and **50% smaller output ripple** than **non-mixed design** (22 components, 20 unique)

Compensation design: aid to the designer to stabilize & fine-tune the design

Trigger Re-Compensation

Set loop targets (Phase Margin, Crossover)

Set limits for compensation components

Create a new compensation network (using the advanced numerical algorithms)

View results

The screenshot shows the WEBENCH Designer interface. The top toolbar includes buttons for Back, New, Solutions, Visualizer, BOM, Charts, Schematic, Optimize, Op Vals, **Re-Comp** (highlighted with a red box and arrow), Sim, Edit, Export, Print, and Share Design Assistant. The main window is titled "COMPENSATION DESIGNER" and has tabs for Auto and Manual. The "Auto" tab is active, showing "Design Operating Values" and "Compensation Parameters".

	Min	Target	Max	Calculated
Phase Margin (deg)	30	50	75	51.5
Cross Over Frequency (kHz)	15	50	150	52.8
Low Frequency Gain (dB)	50	65	120	60.3

Optimization Tuning: Robustness (slider) Performance (slider)

Successful: Automatic Compensation Achieved!

Name	Min	Max	Calculated
Rcomp (kOhm)	0.5	40	0.75
Ccomp (nF)	0.5	200	2.2

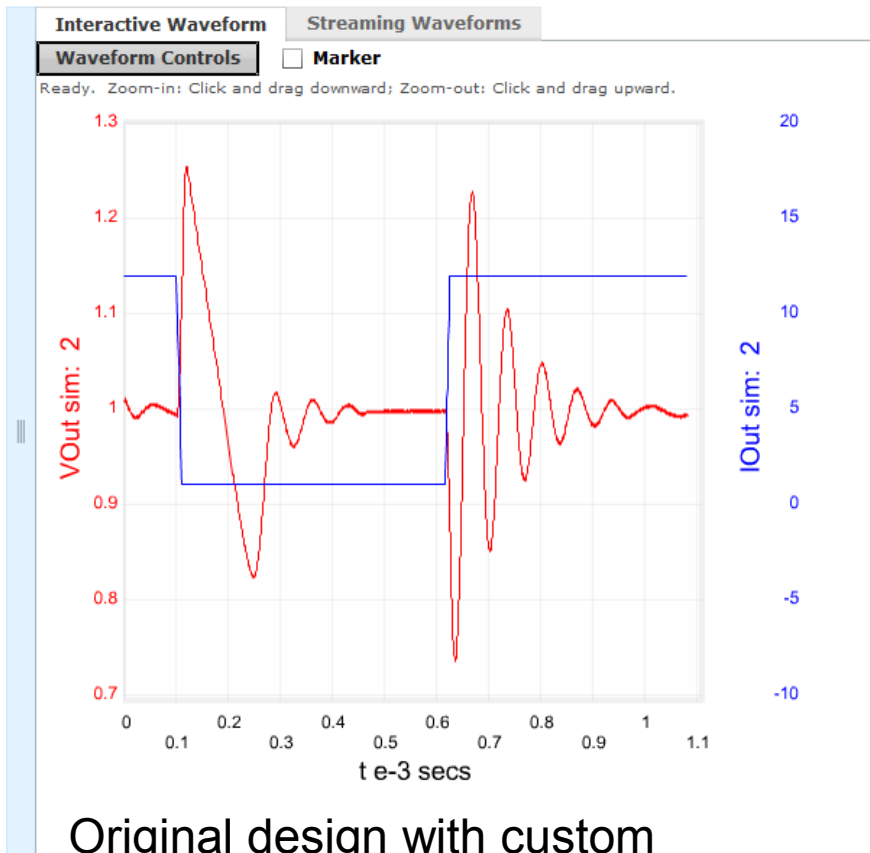
Buttons: Auto Compensate, Apply changes to design

Plot?	ID	Apply	Phase Margin (deg)	Cross Over Freq (kHz)	Rcomp	Ccomp
<input checked="" type="checkbox"/>	D1	Apply	51.5	52.8	0.75	2.2
<input checked="" type="checkbox"/>	D0	Apply	98.5	42.6	1.24	6.8

Design History

Bode Plots: Total Loop, Power Stage, Compensator. Gain (dB) vs Frequency (Hz) and Phase Margin = Phase + 180 (degrees) vs Frequency (Hz).

Unstable design with low phase margin stabilized by Compensation Designer



Original design with custom inductor: Oscillations in output voltage due to low PM



New design with redesigned compensation: Response to load step now stable

Online thermal simulation

Thermal Sim Page

- Inputs:
- Input voltage
 - Current
 - Top and bottom ambient temperature
 - Copper thickness
 - Airflow
 - Board orientation

Thermal Sim Parameters

Operating Condition

Vin: 22 Iout: 2

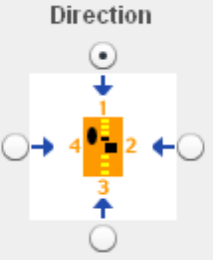
Ambient Temperature

On Bottom: 30 °C On Top: 30 °C

Board Condition

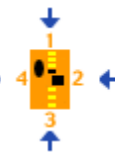
Copper Weight: 2 OZ.(0.07112 mm) Board Orientation: Component Side Up

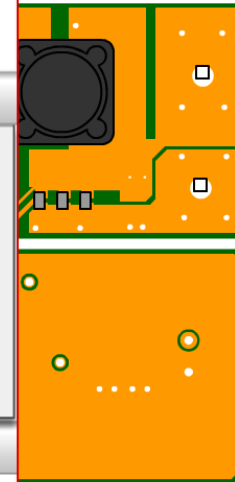
Air Flow

Direction: 

Velocity: Use Fan None 0 LFM LMM

Edge Temperatures

Edge 1	<input checked="" type="checkbox"/> Insulated OR	30 °C
Edge 4	<input checked="" type="checkbox"/> 	Edge 2
Insulated OR	<input checked="" type="checkbox"/> Insulated OR	Insulated OR
30 °C		30 °C
Edge 3	<input checked="" type="checkbox"/> Insulated OR	30 °C

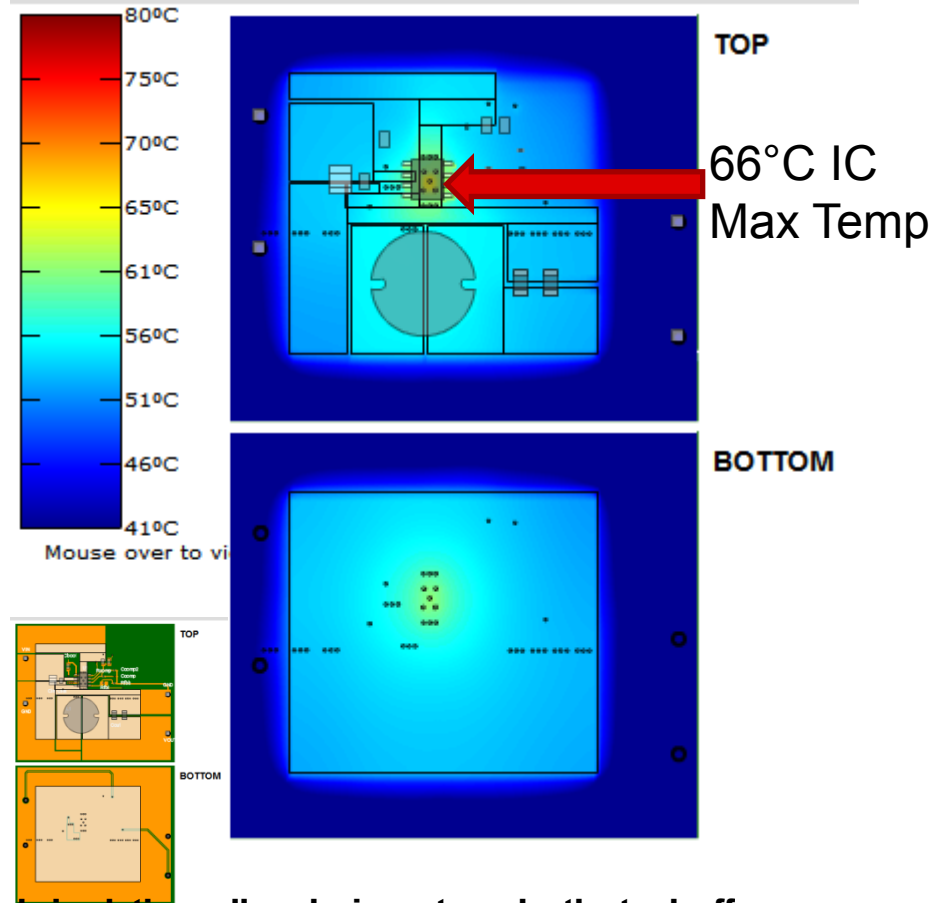
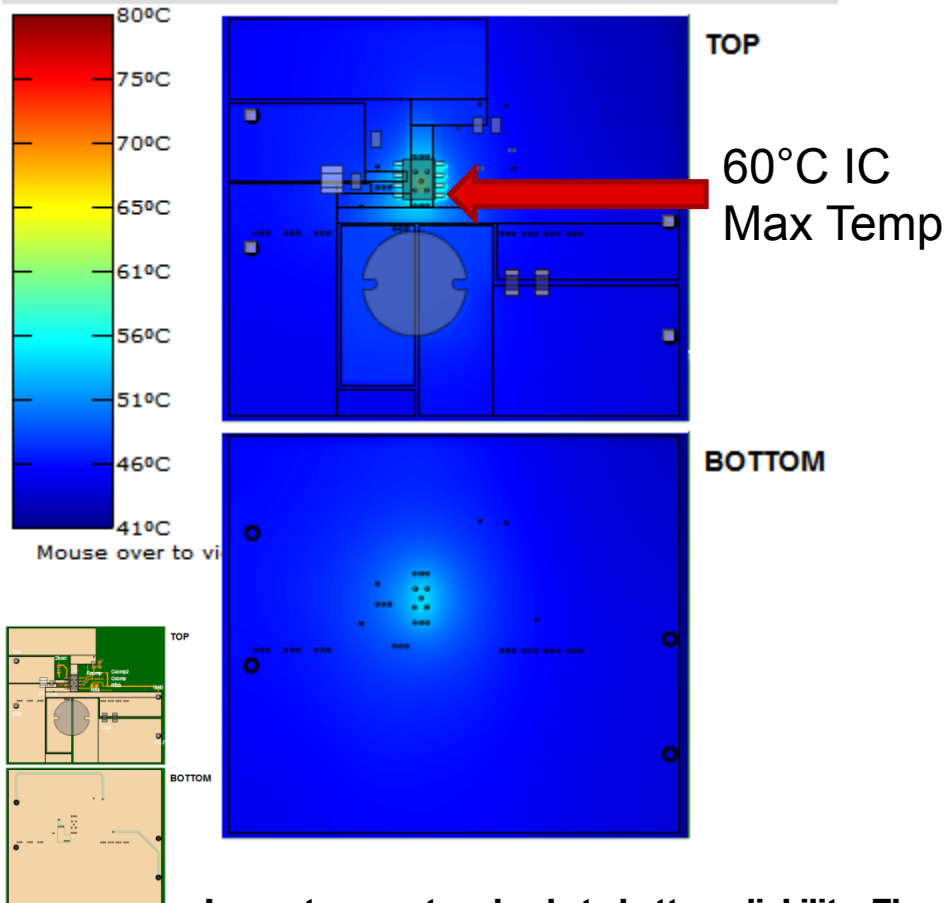


PC Board

Thermal simulations insight for design: reduce Cu area impact on IC temperature

- Default Copper
 - 2.3" x 2"

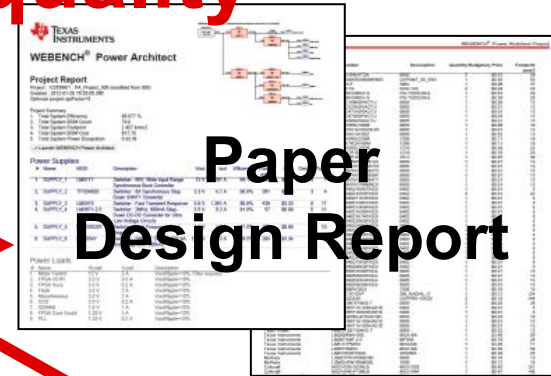
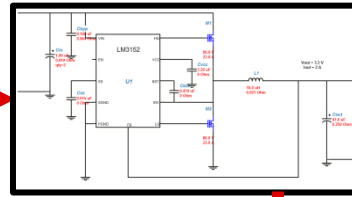
- Reduced Copper area
 - 1.5" x 1.5"



Lower temperature leads to better reliability. Thermal simulations allow designer to make the tradeoff of reliability with footprint.

Export designs to different CAD tools saves time and improves quality

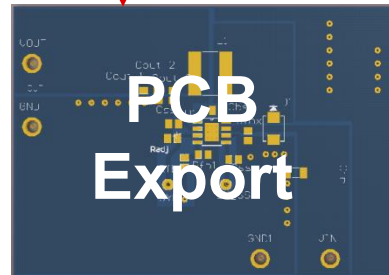
Design Creation



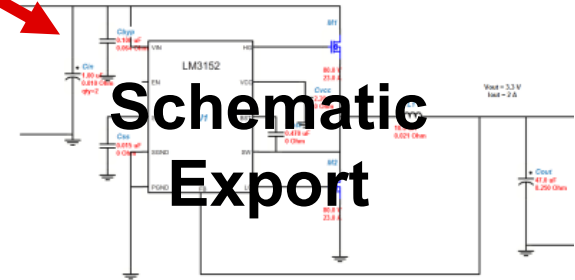
Paper Design Report

Design Synthesis:

- PCB layout is critical, should be based on proven boards & be of good quality
- Component footprints, schematic, PCB export needed
- Time savings:
 - 1 hr. for library, FP
 - 2 hr. for schematic
 - 2-4 hr. for PCB



PCB Export



Schematic Export

Export directly into CAD formats



Altium Designer
OrCAD/Allegro
DxDesigner/PADs
DesignSpark
CadSoft Eagle

Design Tools:

End-to-end Selection, Design, Prototyping

1. Select a Part

Basic Selection

Vin Min: 14 V Vin Max: 22 V
Vout 1: 3.3 V Iout 1: 2 A
Op Ambient Temp: 30 °C

Choose Additional Features (Optional)

Show Alternate Topologies

On/Off Flag: No Yes Ignore
Error Flag: No Yes Ignore
Sync Flag: No Yes Ignore

Vout 2: 0 V Iout 2: 0 A
Vout 3: 0 V Iout 3: 0 A

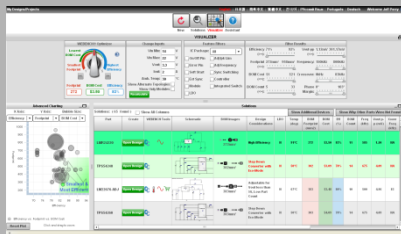
Complex Code:

Show Recommended Power Management ICs

Show All

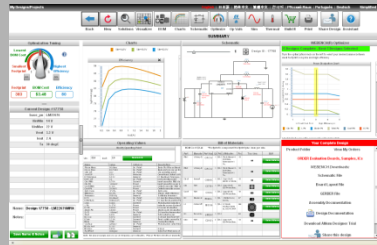
Subclass Regulators
Linear Regulators
Switched Capacitors

Enter Specifications



Select Part

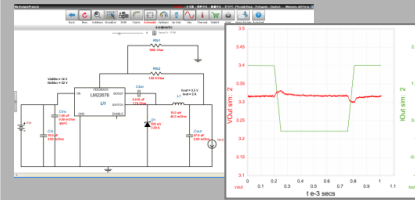
2. Create a Design



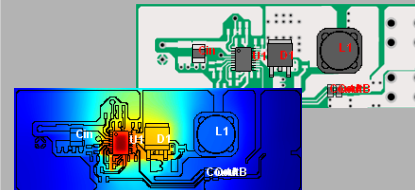
Visualize Your Design

Optimize Your Design for Efficiency, Footprint and BOM

3. Analyze a Design



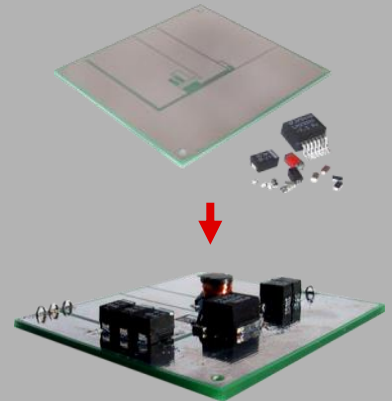
Generate Schematic
Electrical Analysis
Simulation



Generate Board Layout
Thermal Analysis

4. Build It!

Schematic Export to CAD tools
Request Prototype Kit



Prototype

Future trends: some thoughts

- **Software & Platform**

- Online will be the predominant platform of choice
- Tools will embrace the emerging computing paradigms of mobile touch-based devices and the diversity of devices & platforms

- **Tool Characteristics**

- Interoperability of CAD tools will continue to be critical; designs done in one tool will need to work in another tool
- Power will be co-designed at system-level with other tool from other domains
- Online tools will communicate & configure the board (PMBus, digital control)
- End-to-end rapid prototyping will continue to be essential

- **Models and Simulations**

- Simulations will become more complex & computationally-expensive, but will be done mainly online
- Models & tools will be expected to be highly accurate and predictive (models will have to be well calibrated to bench data)
- Increased design support for high bandgap devices like GaN, SiC

- Ecosystem of tools will have to make the “whole” more powerful than the parts:

The whole is greater than the sum of its parts

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