Online Power Design Tools: Past, Present and Future

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Aiding Design Excellence

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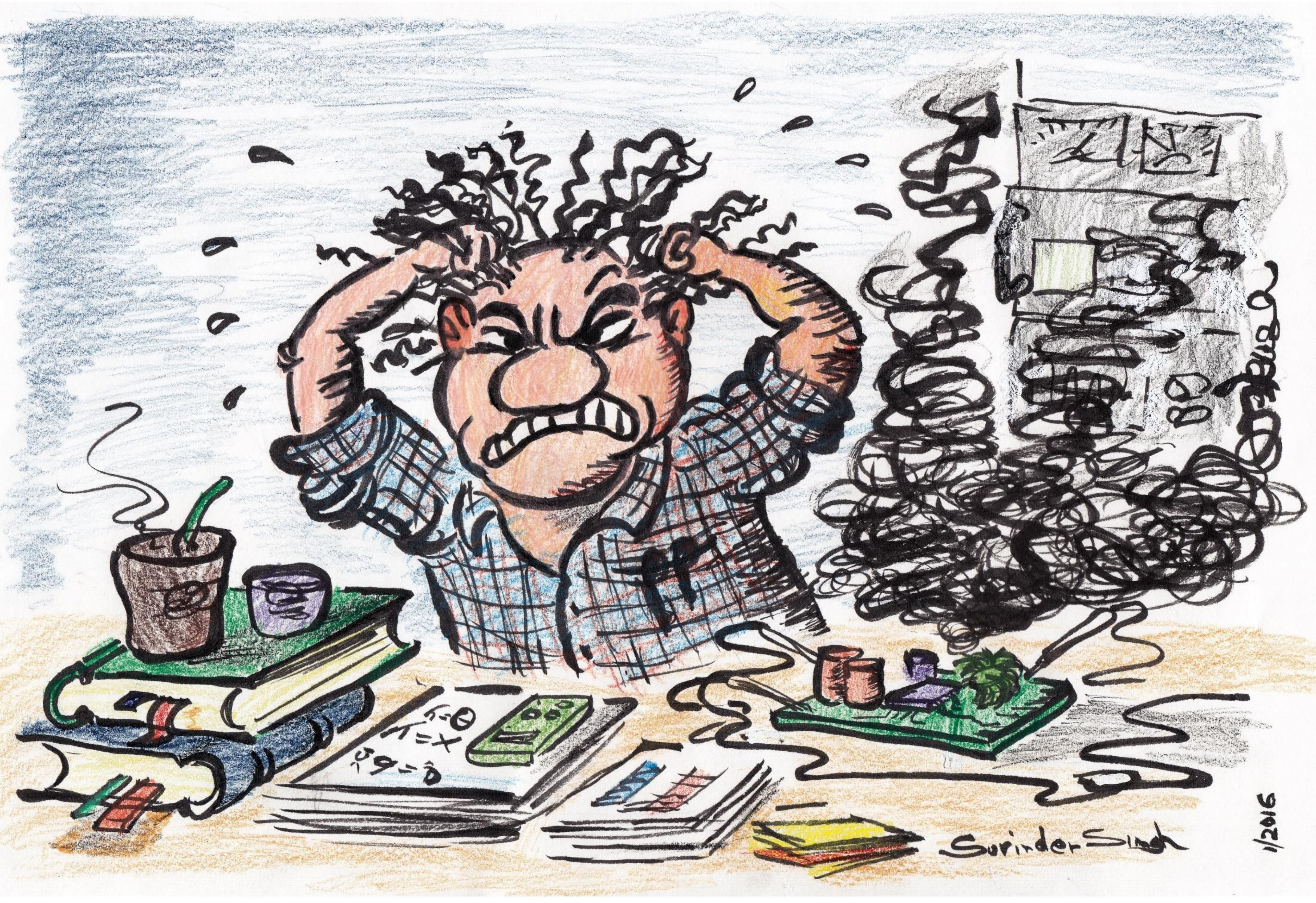
Outline

- 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!

… 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 designs 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

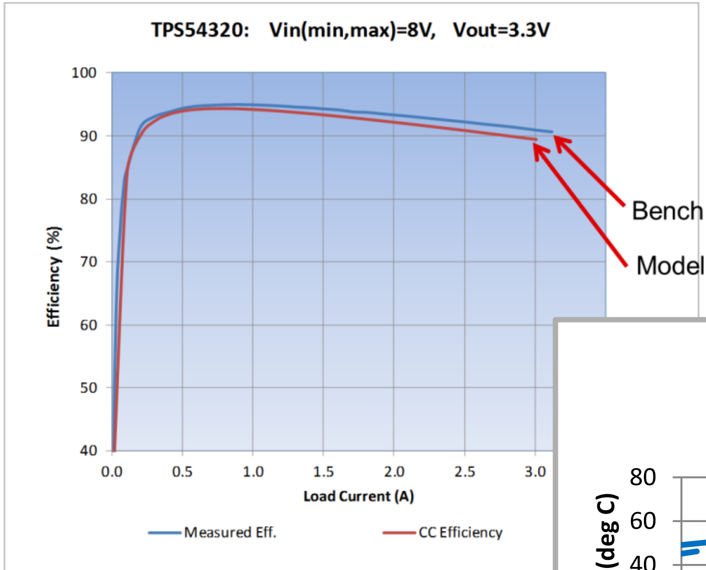
- **Con**
  - Models can only simulate effects that have been captured in the design of the model
  - Simulations are valid in the space they are created for
  - Models + numerical methods have limitations & inaccuracies
  - Some models may require prohibitively high CPU time
- **Pros**
  - Simulations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

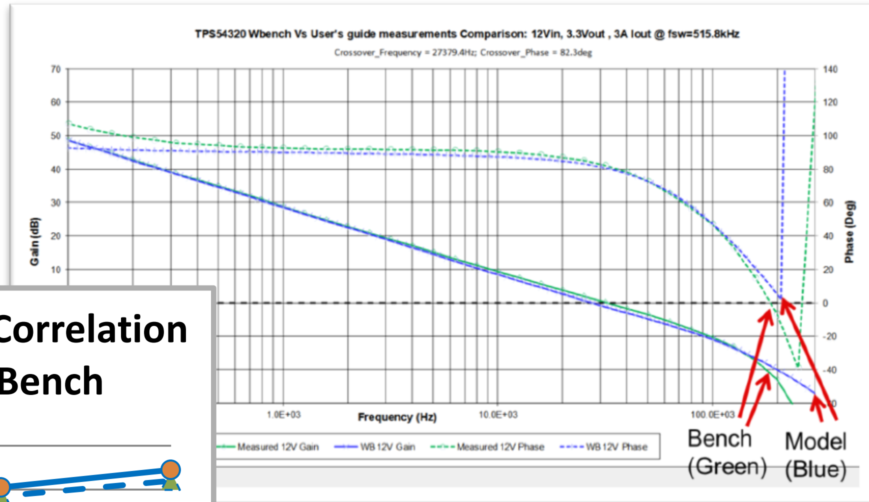
How can design tool help power designer?

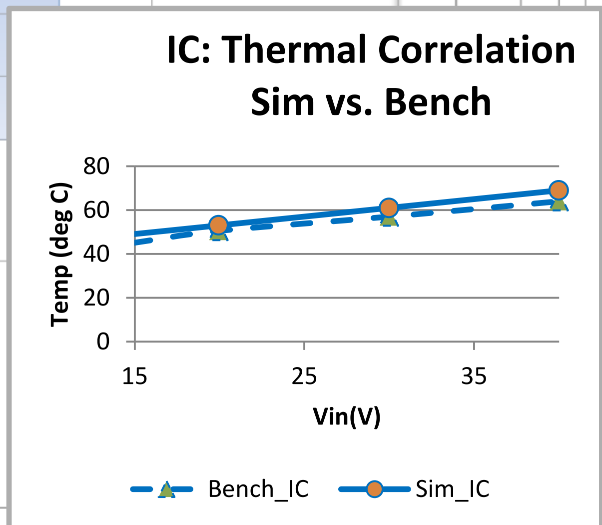
- Synthesize the custom design
  - Based on designer inputs and requirements
  - Choose the best power management IC and other BOM components
  - Allow designer to make trade offs for performance, cost, footprint
- Capability to fine tune the design and verify by simulation
  - Compensation design
  - 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 well over range of Vout, Vin, Iout, 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

Past: Offline tools & bench

Bench testing, Trial and Error, Few offline tools

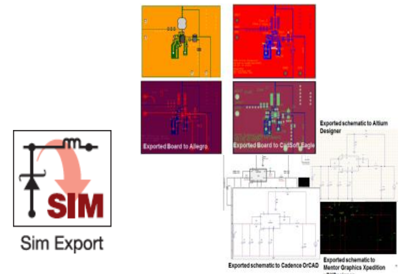
1999: Online tools

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

2010: Architect type tools

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

2016: CAD Export, Advanced tools

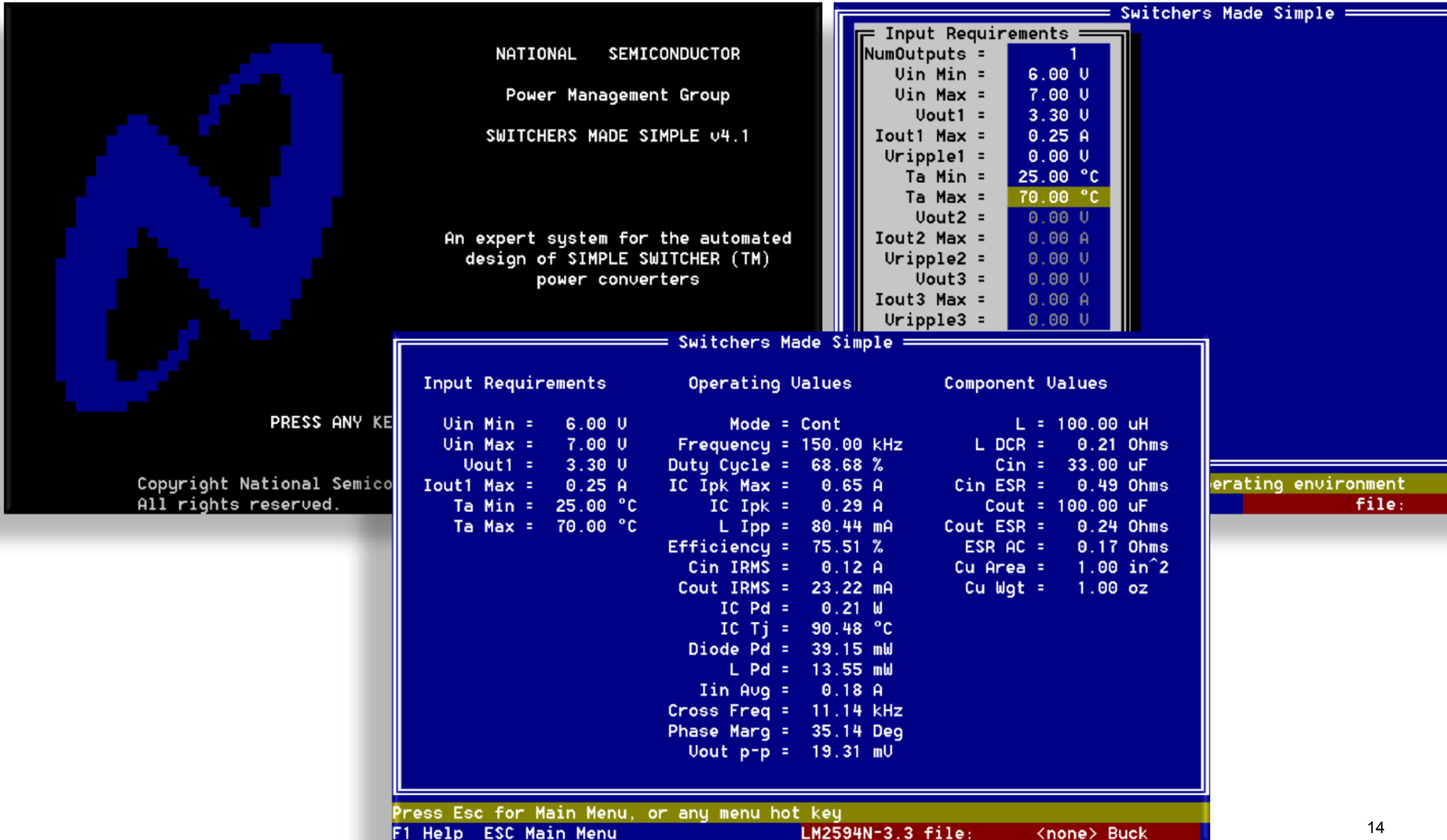


CAD export offering interoperability with other CAD tools, Online schematic editor & simulator, Advanced tools (e.g. WEBENCH re-compensation tool)

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

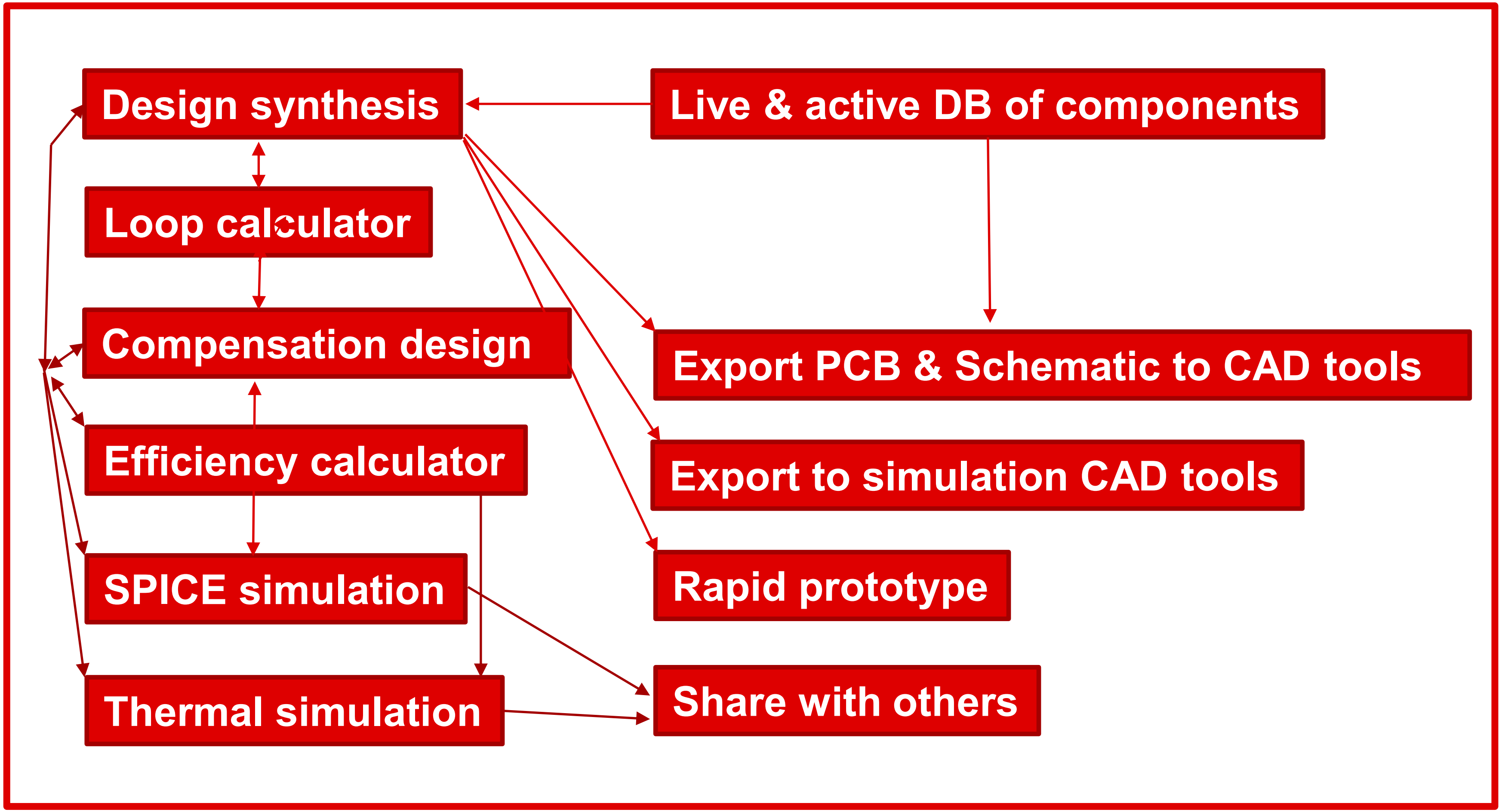
Tools in the past: off-line & text-based



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"

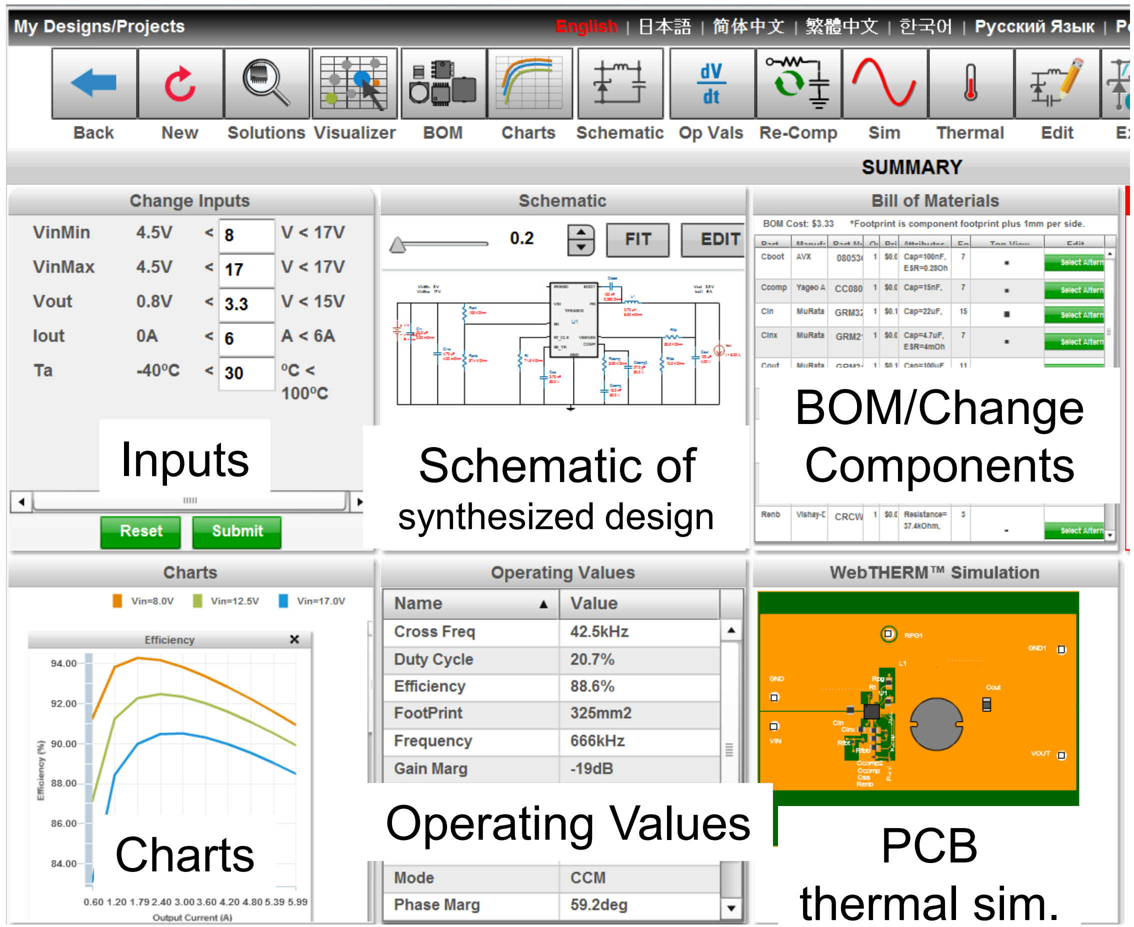


Why online?

- 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

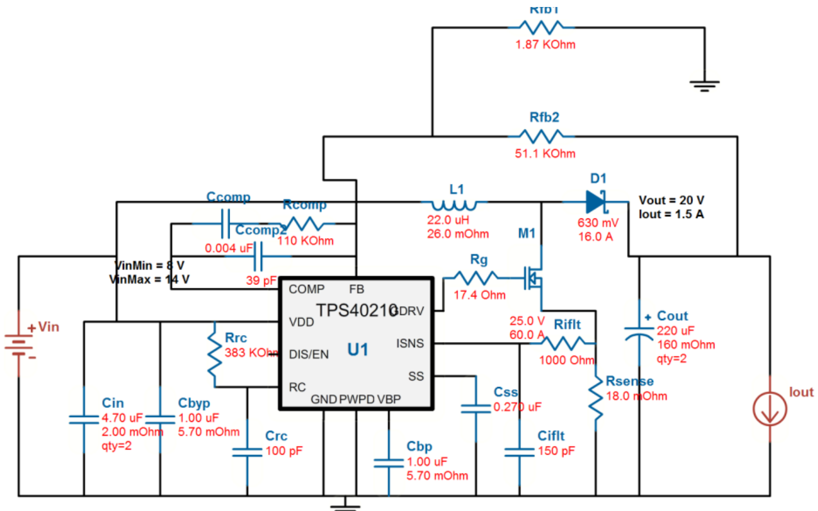
- Digital prototyping
- Start from input spec + any advanced preferences
- Use components from various manufacturers, distributors with real-time price & availability
- Ability to fine tune the design, change BOM, re-optimize stability, etc.
- Share & collaborate
- Rapid prototype capability

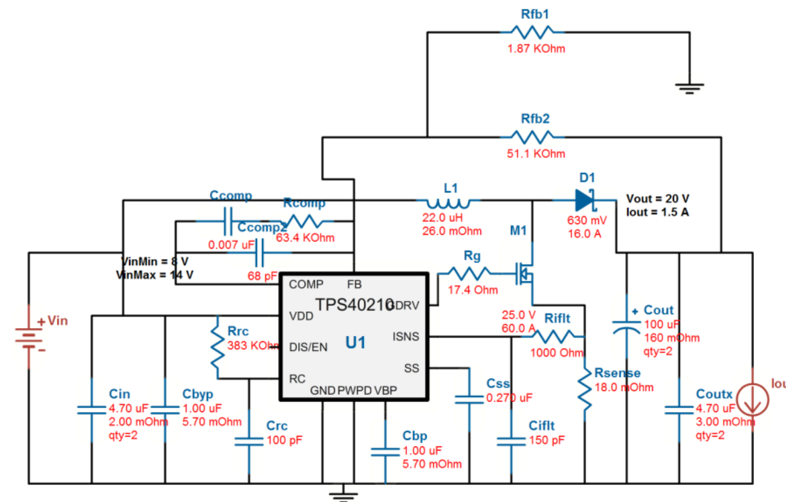


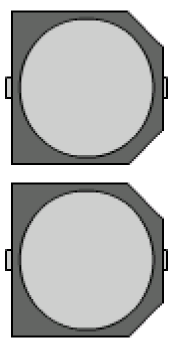
Make tradeoff between footprint, cost, and efficiency

Switching frequency modulates losses and affects the inductor size

Change output capacitor to be mix of electrolytic & ceramic type







Not Mixed

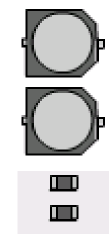
2x (220µF, 160mΩ)

Footprint	BOM Cost	Efficiency
1433	$6.99	94

$V_{OUT,Ripple}$ = 340 mVpp

Mixed

2x (100µF, 160mΩ) || 2x (4.7µF, 3mΩ)



Footprint	BOM Cost	Efficiency
820	$3.87	95

$V_{OUT,Ripple}$ = 170 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

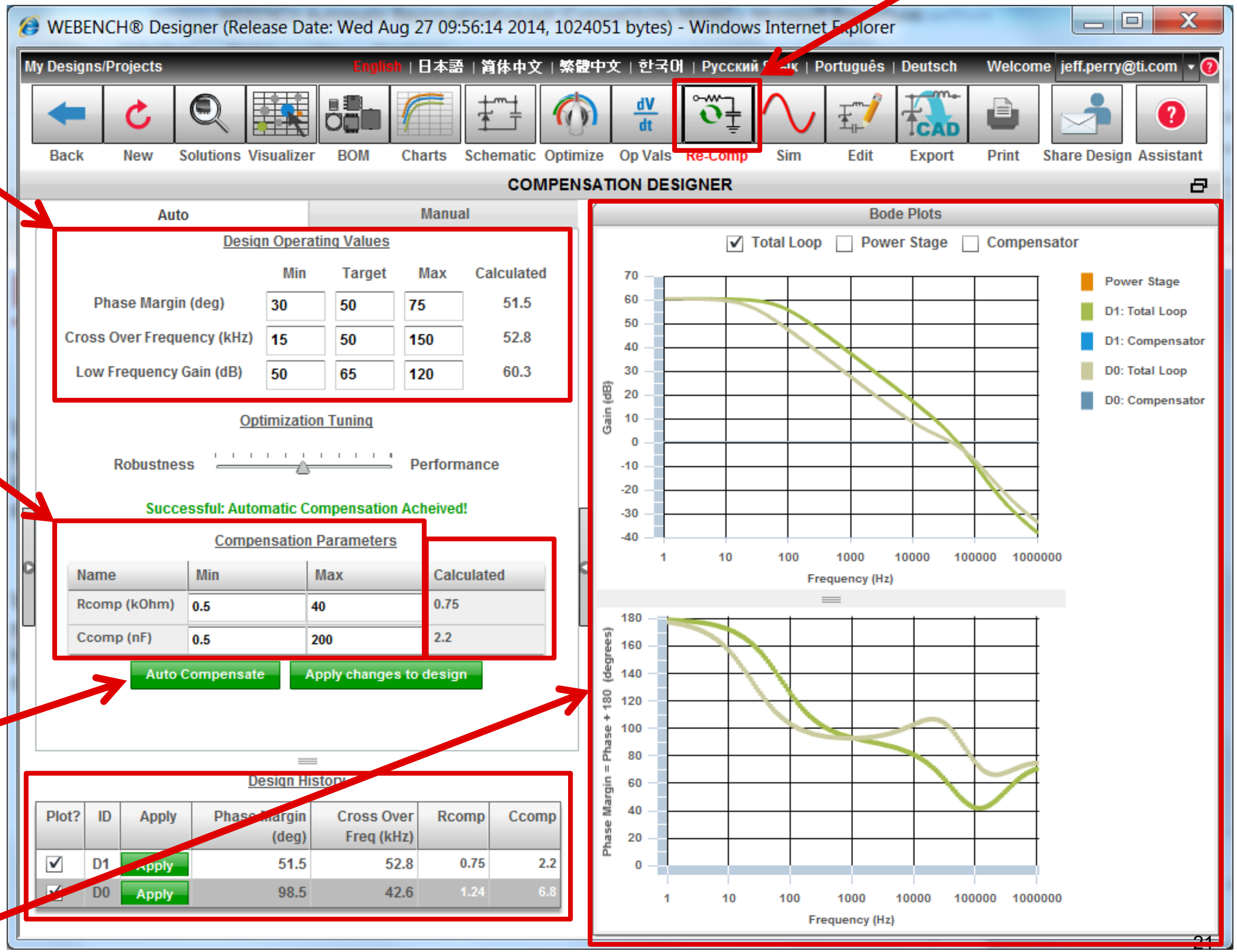
Trigger Re-Compensation

Set loop targets (Phase Margin, Crossover)

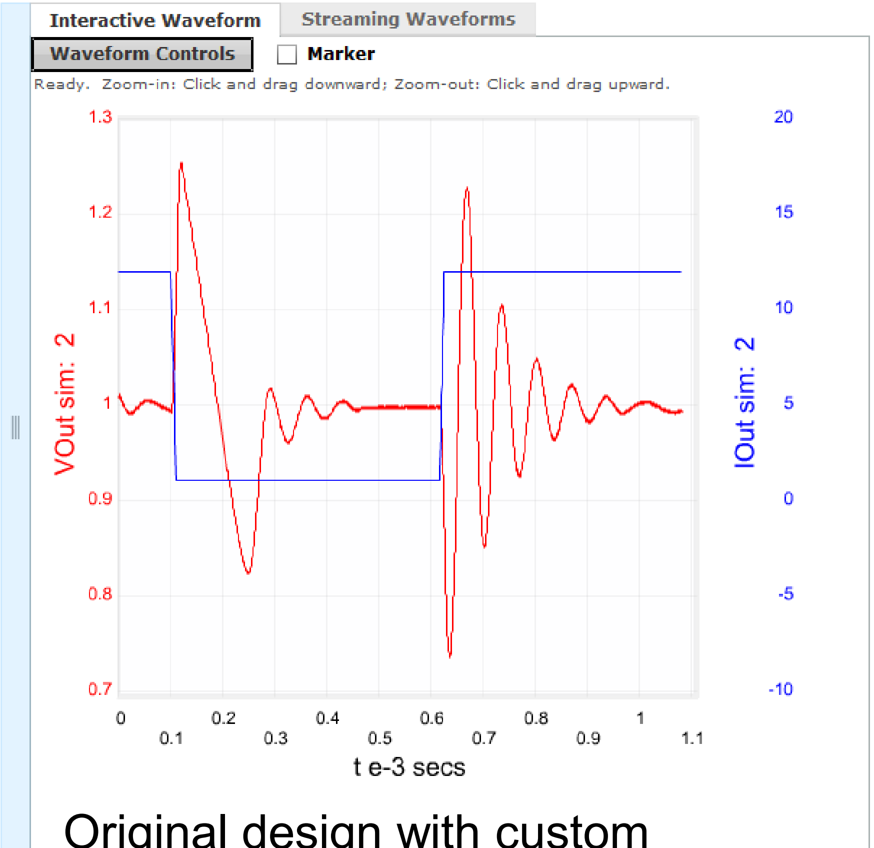
Set limits for compensation components

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

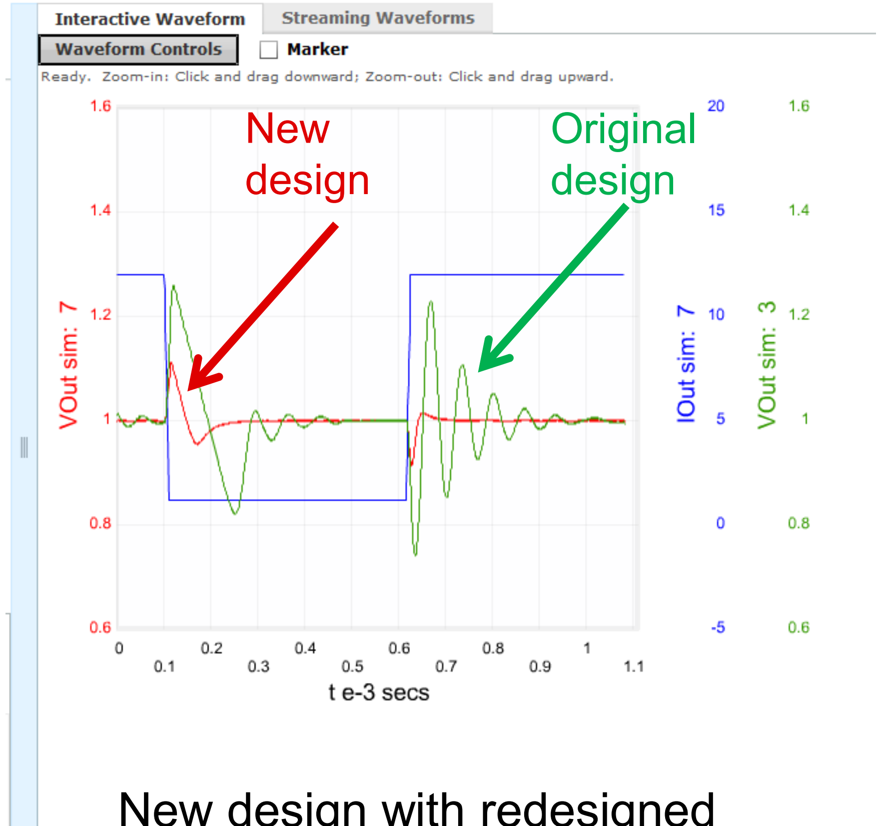
View results



Unstable design with low phase margin stabilized by Compensation Designer



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

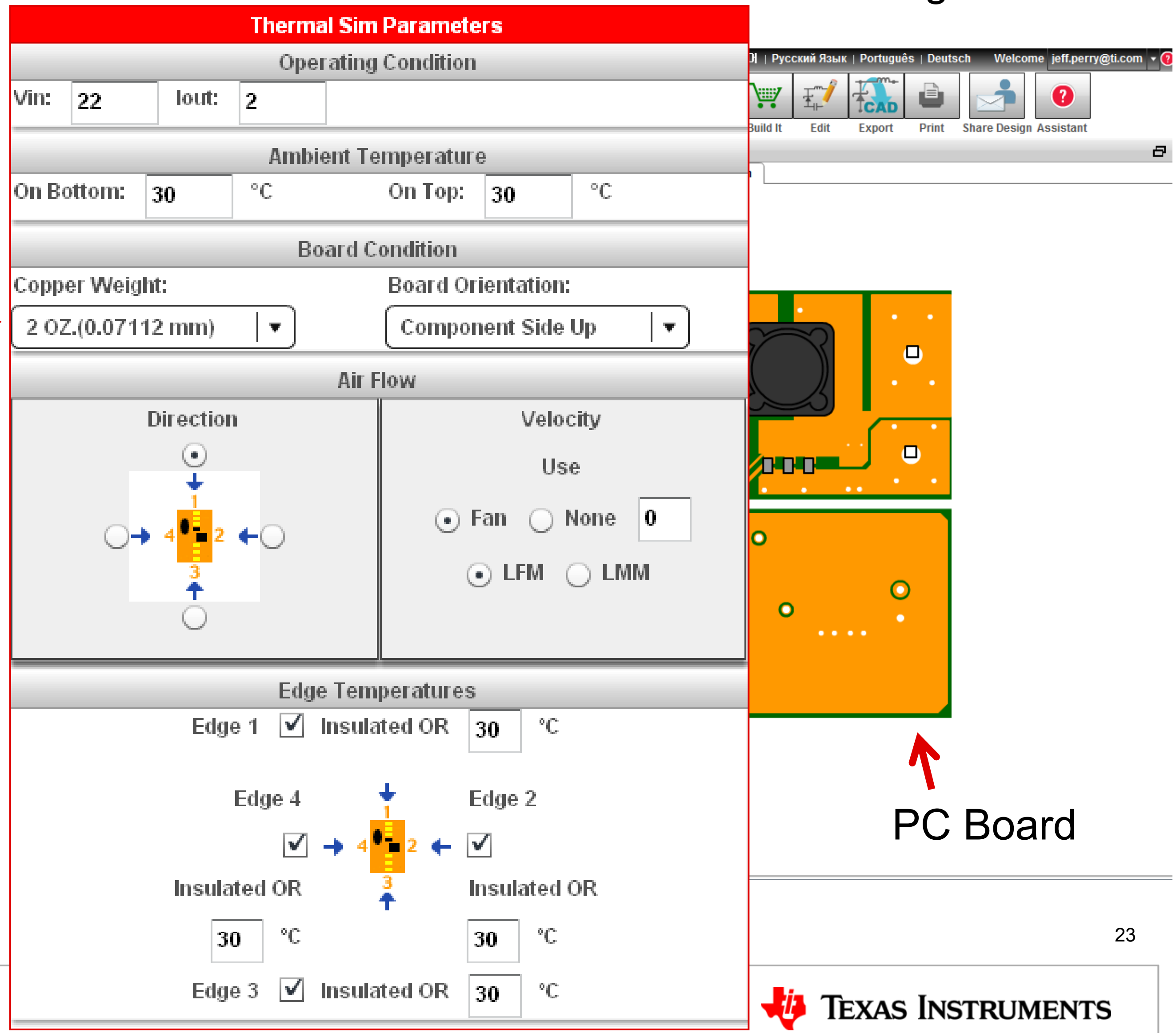


New design with redesigned compensation: Response to load step now stable

Online thermal simulation

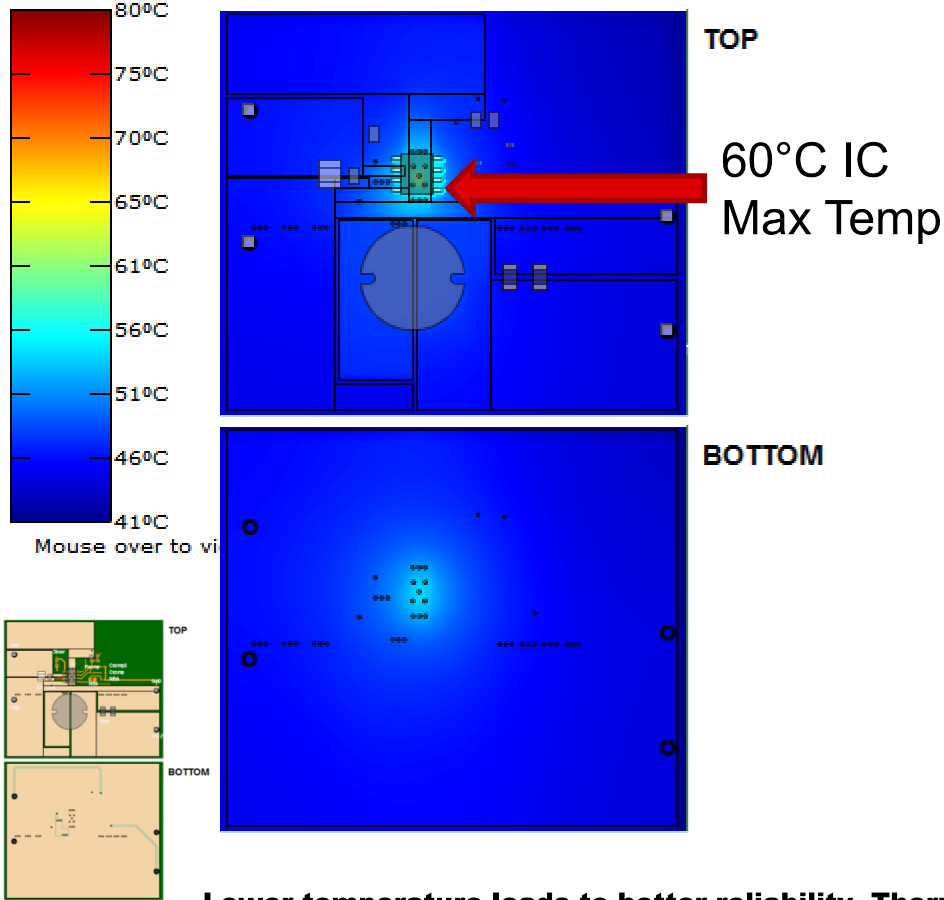
Inputs:
- Input voltage
- Current
- Top and bottom ambient temperature
- Copper thickness
- Airflow
- Board orientation

Thermal Sim Page

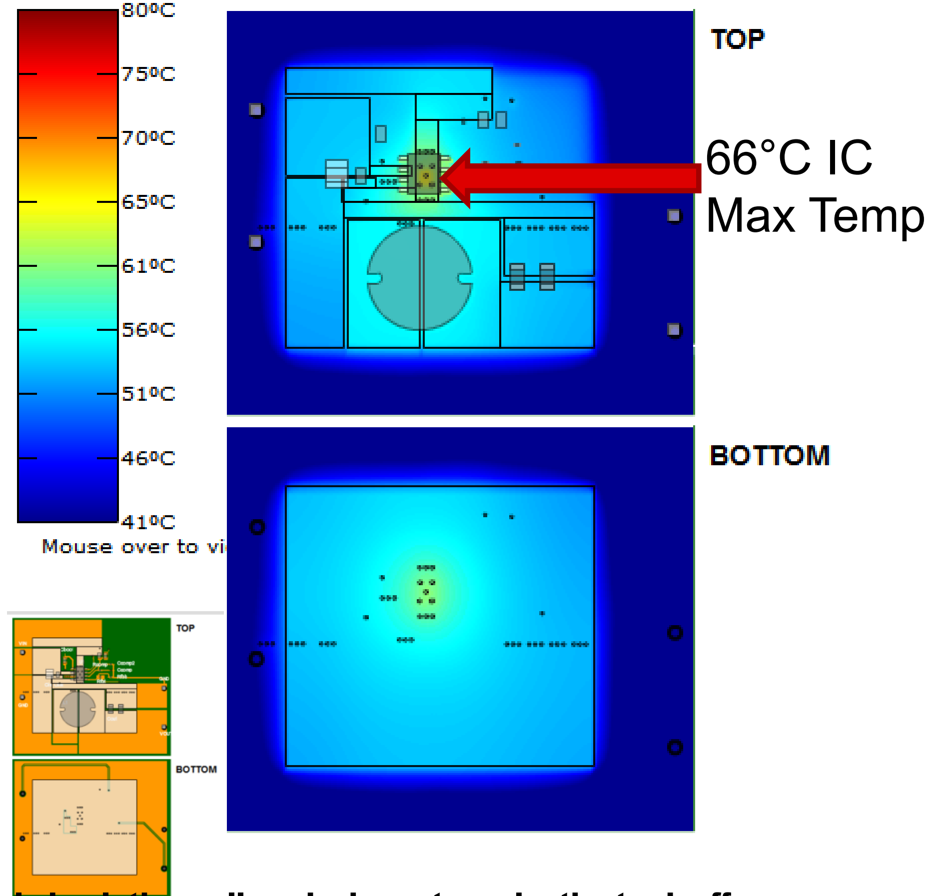


Thermal simulations insight for design: reduce Cu area impact on IC temperature

- Default Copper
  - 2.3” x 2”

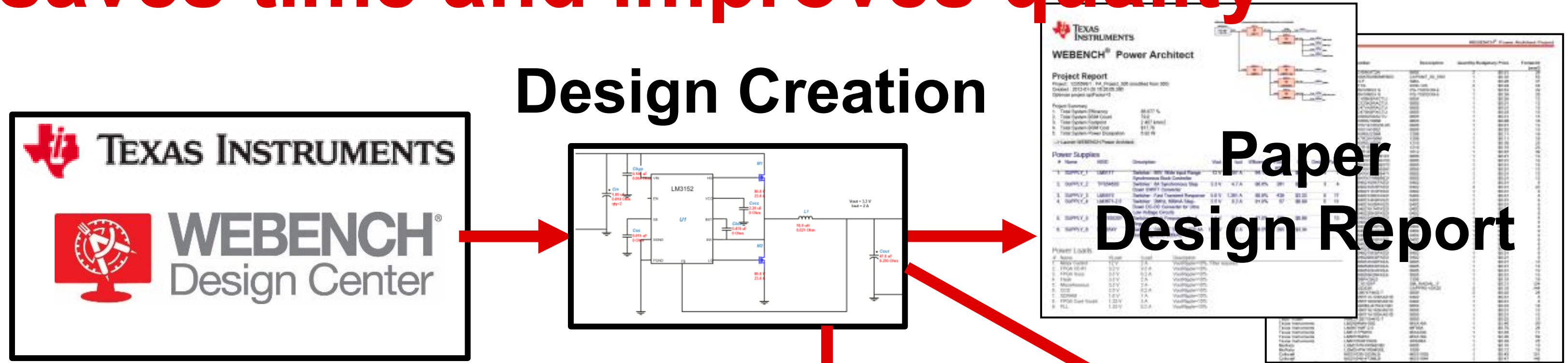


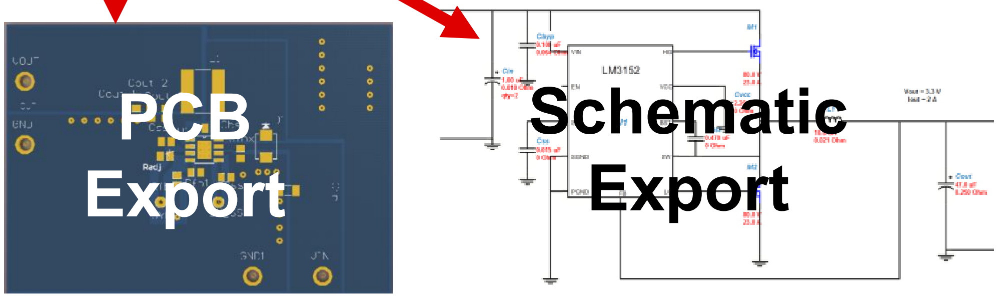
- Reduced Copper area
  - 1.5” x 1.5”



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 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

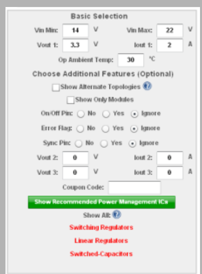
Export directly into CAD formats

- Altium Designer
- OrCAD/Allegro
- DxDesigner/PADs
- DesignSpark
- CadSoft Eagle

Design Tools:

End-to-end Selection, Design, Prototyping

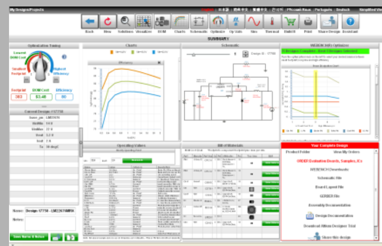
1. Select a Part



Enter Specifications

Select Part

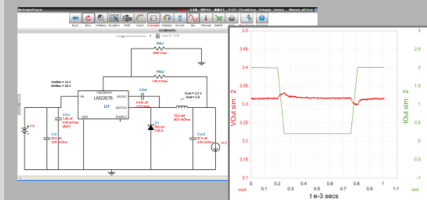
2. Create a Design



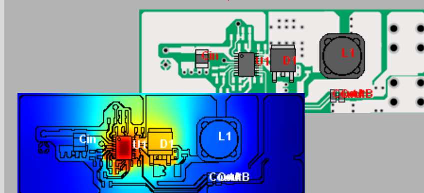
Visualize Your Design

Optimize Your Design for Efficiency, Footprint and BOM

3. Analyze a Design



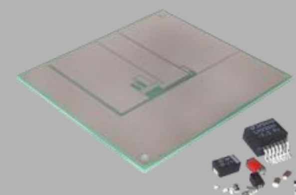
Generate Schematic
Electrical Analysis
Simulation

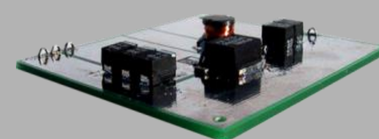


Generate Board Layout
Thermal Analysis

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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