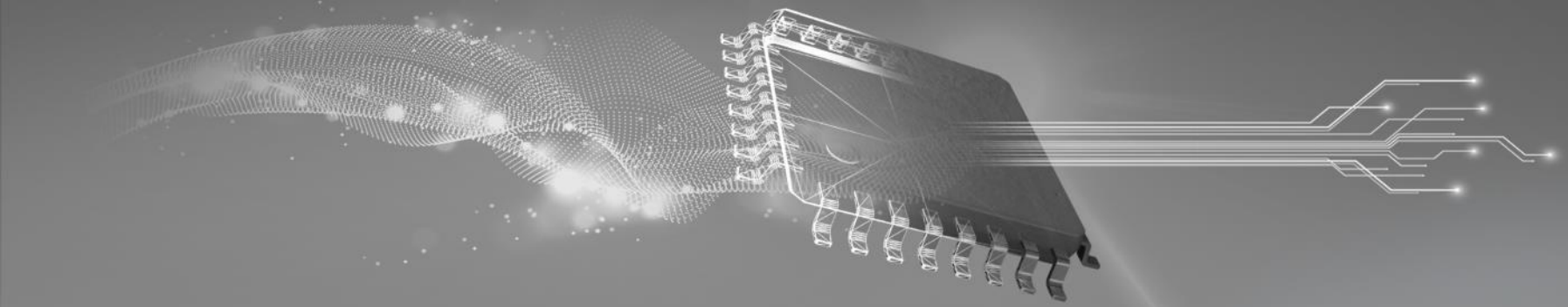
TI TECH DAYS



WEBENCH® Power Designer
Power supply design made easy

Srikanth Pam

Sahil Gupta

Texas Instruments

Agenda

- **Introduction to WEBENCH® Power Designer**
  - What is it? How to get to the tool?
  - Design tools vs. simulation tools vs. reference designs
  - Supported TI portfolio

- **WEBENCH Power Designer tour**

- **Deep-dive of Power Supply Design using WEBENCH Power Designer**
  - DC/DC boost converter design
  - Isolated flyback design
  - Solving key design challenges using WEBENCH Power Designer
    - Meet transient specifications
    - Compensation
    - Thermal issues
    - EMI filter
    - Transformer design
  - Frequently asked questions

- **Contact and Resources Links**

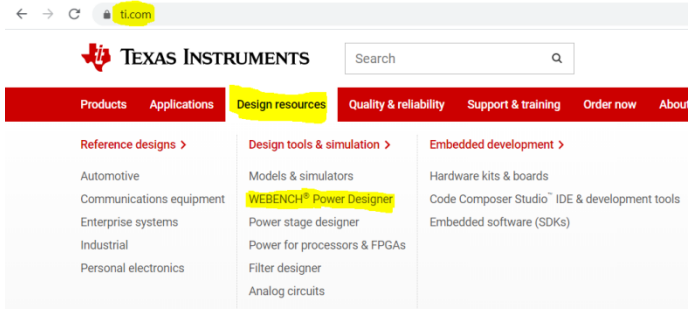
- **Q&A**

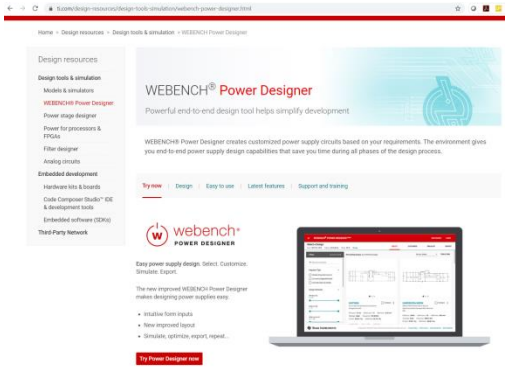
WEBENCH® Power Designer – What is it ?

- Free online power supply design tool
- Selects the right switching regulator (DC/DC or AC/DC)
- Designs the application circuit with BOM, and calculates operating values
- Allows quick electrical simulation to analyze performance
- Print PDF reports, export to CAD tools for quick prototyping
- What topologies?
  - Buck, boost, buck-boost, inverting buck-boost
  - SEPIC, flyback (PSR/SSR), half bridge LLC, active clamp forward, PFC (TM, ITM, CCM, ICCM), phase shifted full bridge
  - TI MOSFETs included in designs as applicable

How to get to the tool?

From TI.com home page -

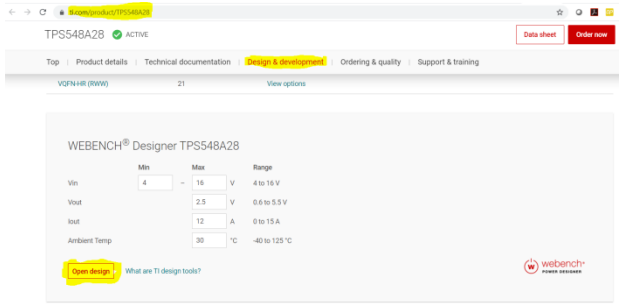


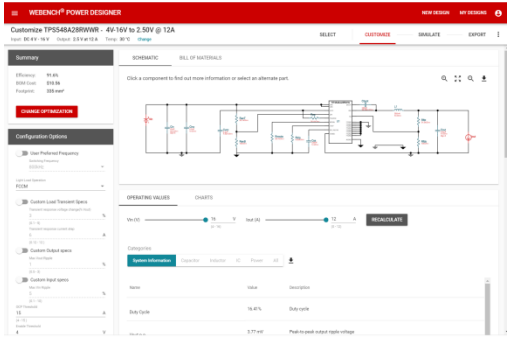


WEBENCH Power Designer home page.

Basic tool overview and link to open the tool

From Product page -





Enter required input and output conditions and create design using the product.

Directly opens the design / “Customize” page in WEBENCH (through ti.com login)

Design tools vs. sim tools vs. ref designs

Help me find a solution that works. OR Help me calculate and design BOM for my specifications.	I have the expertise to read the datasheet and calculate my own BOM. Help me analyze performance by running simulations	I have a reference design in mind. I need to build my board using this as a reference
Design Tools • TI (WEBENCH Power Designer) • TI (Excel Calculators)	**Simulation Tools** • TI (PSPICE for TI) • TI (TINA-TI) • Generic Spice models which can be used in any simulator.	**Reference Designs** • TI (TI Designs)
• Maxim (EE-Sim) • Analog/Linear Tech (LTpowerCAD) • MPS (DCDC Designer)	• Analog/Linear Tech (LTspice) • MPS (MPSmart) • Any sim tool (downloaded models)	• ADI (Circuits from the Lab)

TI Power Management portfolio

LDO Regulators

- Single Channel LDO
- Multi Channel LDO
- LDO Controllers

DC/DC Regulators

- Step-down (Buck)
- Step-Up (Boost)
- Buck-boost & Invertin

Power Switches

- Load switches
- eFuses & hot swap
- Ideal Diode
- Power Muxes
- Smart power switches
- Low side switches

Power MOSFETs

- N-channel MOSFET
- P-channel MOSFET
- Power stages
- Power blocks

IGBT, MOSFET Gate Drives

- Low-side drivers
- Half-bridge drivers
- Isolated gate drivers
- Motor drivers

Offline and Isolated DC/DC

- Power Factor Correction (PFC) controllers
- PWM and resonant controllers
- Flyback controllers
- Flybuck controllers

LED Drivers

- Automotive LED drivers
- Backlight LED drivers
- Flash LED drivers
- General lighting LED drivers
- RGB & white LED driver

Battery Management

- Battery charger Ics
- Battery fuel guages
- Battery protecotrs
- Battery monitors and balancers

Power Special Functions

- DDR memory
- USB power
- PoE
- Supervisor & reset ICs
- Sequencers

Other

- Voltage References
- Digital power
- PMIC

Supported in WEBENCH

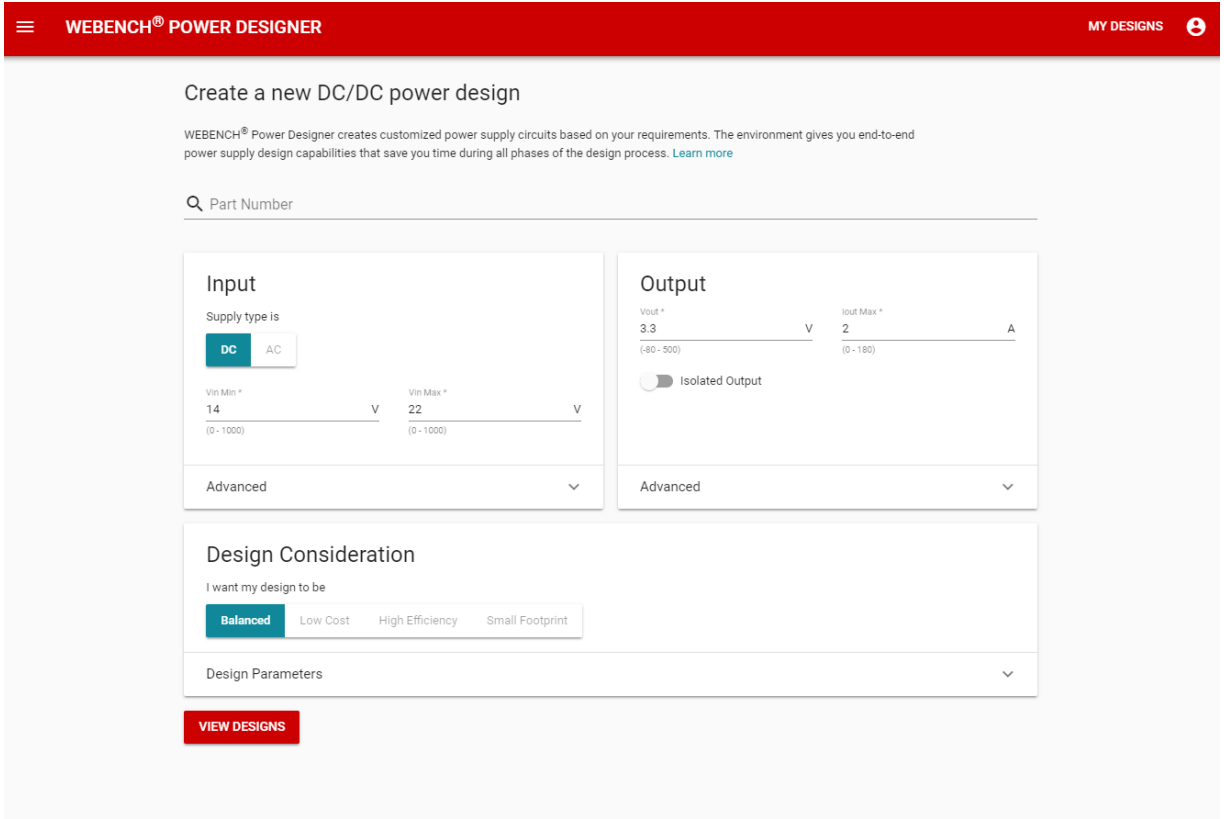
Used as companion parts in WEBENCH designs

WEBENCH® Power Designer Tour

WEBENCH Power Designer – Key features

Design Inputs

- Power supply input, output and advanced requirements
- Search for part – autofill defaults



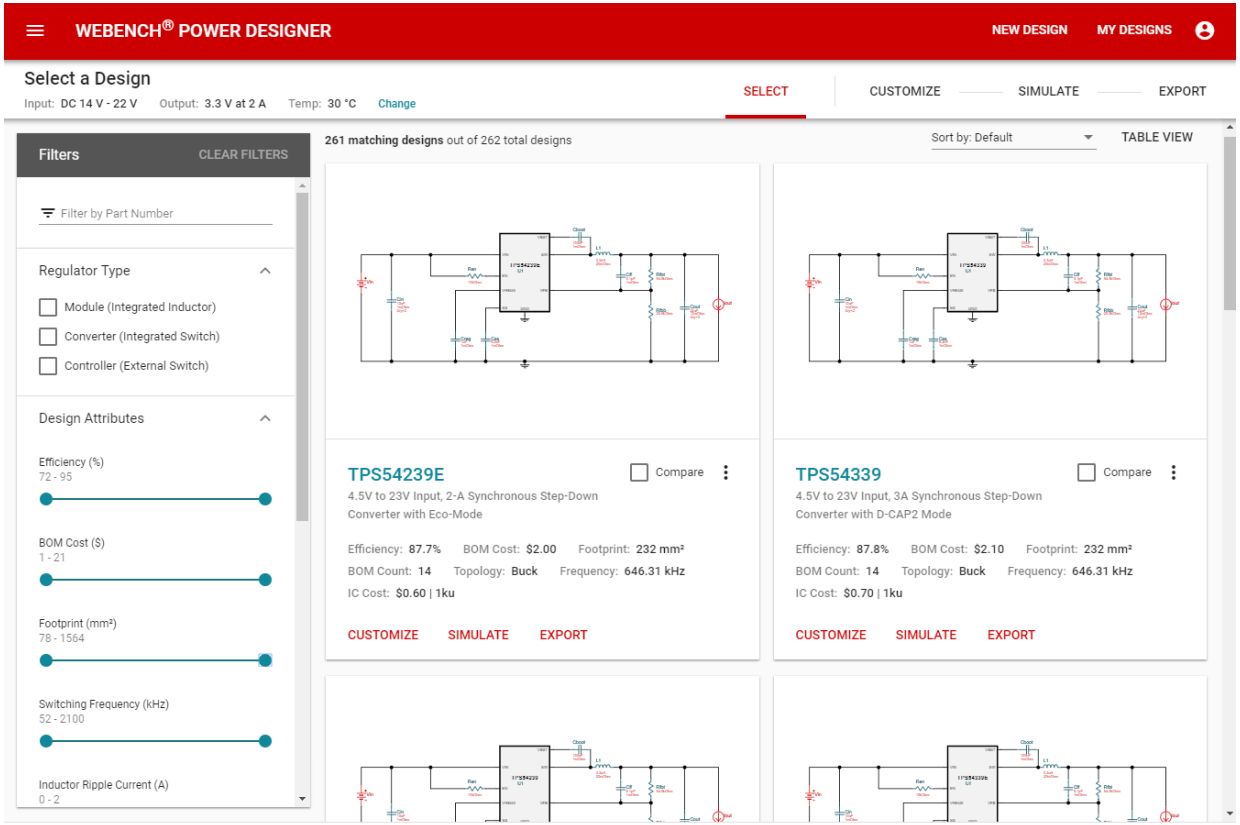
WEBENCH Power Designer – Key features

Design Inputs

- Power supply input, output and advanced requirements
- Search for part – autofill defaults

Select

- Filter by key design attributes / part features
- *Compare* designs



WEBENCH Power Designer – Key features

Design Inputs

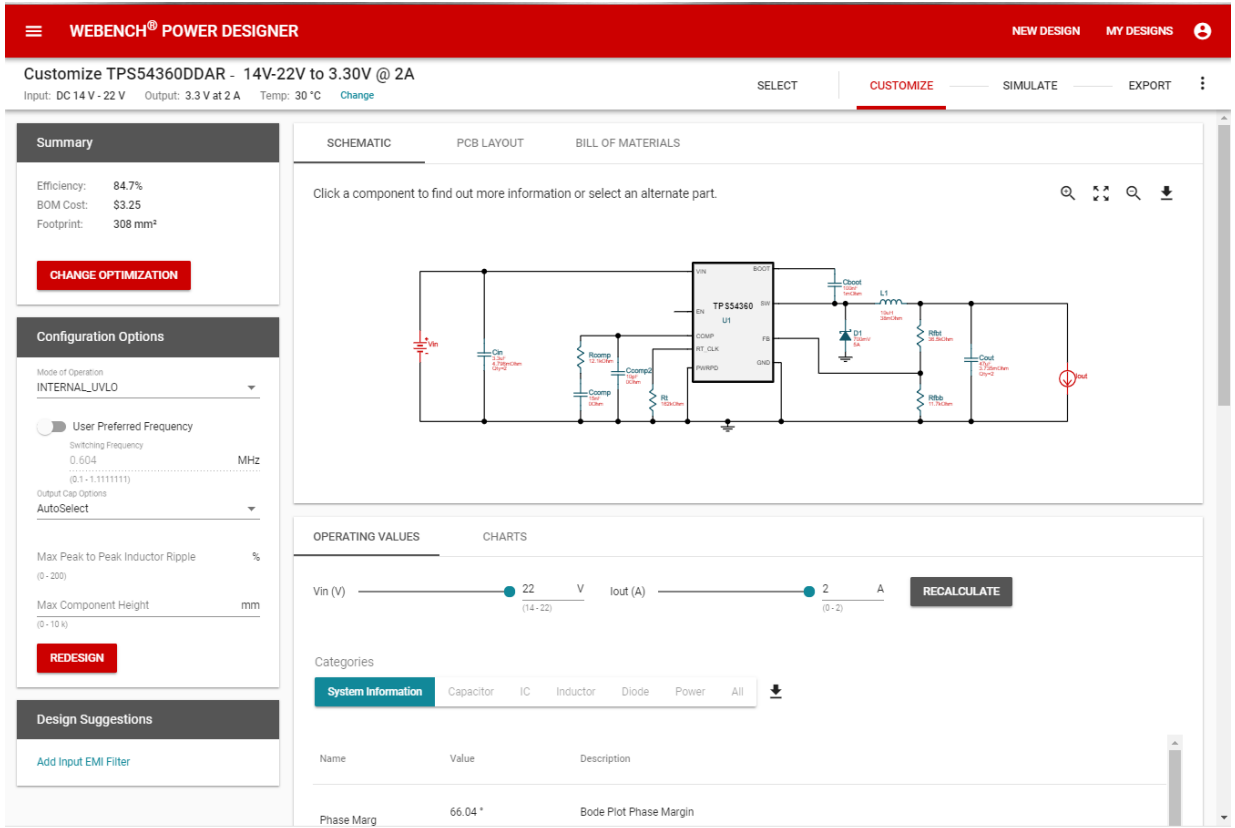
- Power supply input, output and advanced requirements
- Search for part – autofill defaults

Select

- Filter by key design attributes / part features
- Compare designs

Customize

- Optimize
- Choose alternate parts
- Advanced customization



WEBENCH Power Designer – Key features

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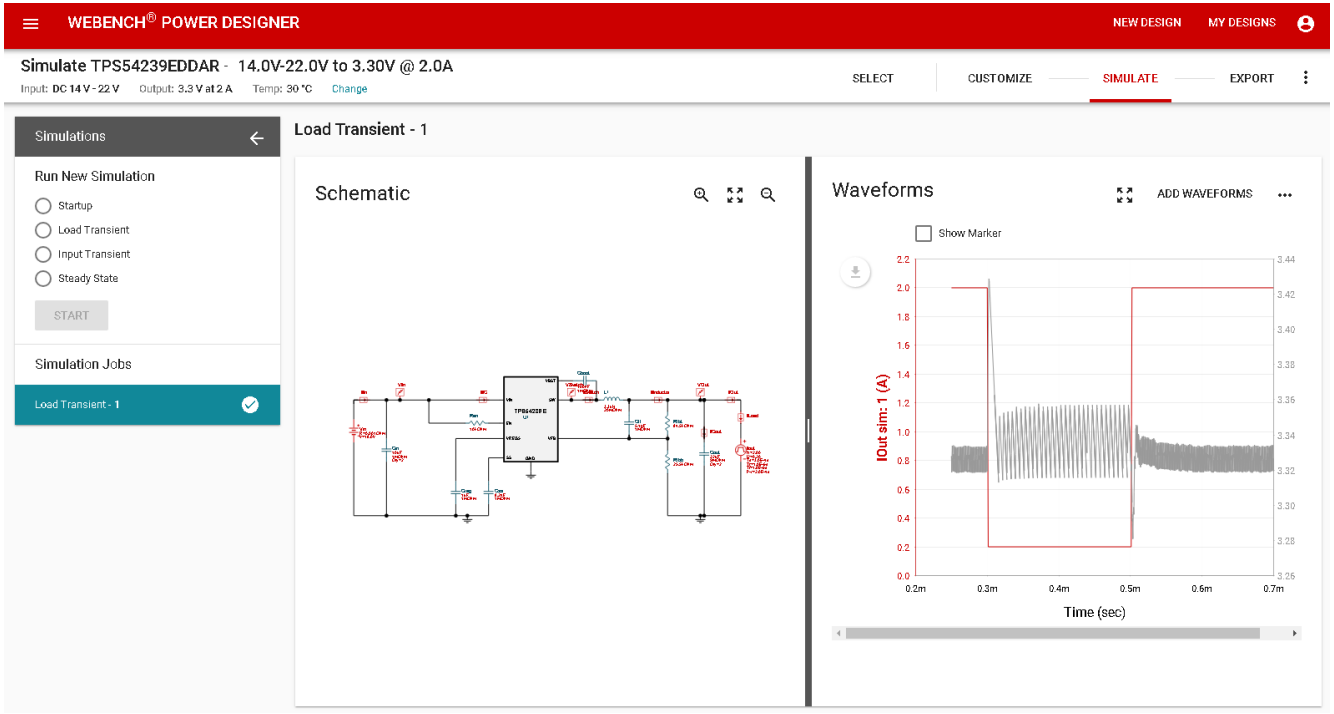
Customize

- Optimize
- Choose alternate parts
- Advanced customization

Simulate

- Electrical simulation



WEBENCH Power Designer – Key features

Design Inputs

- Power supply input, output and advanced requirements
- Search for part – autofill defaults

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- Filter by key design attributes / part features
- Compare designs

Customize

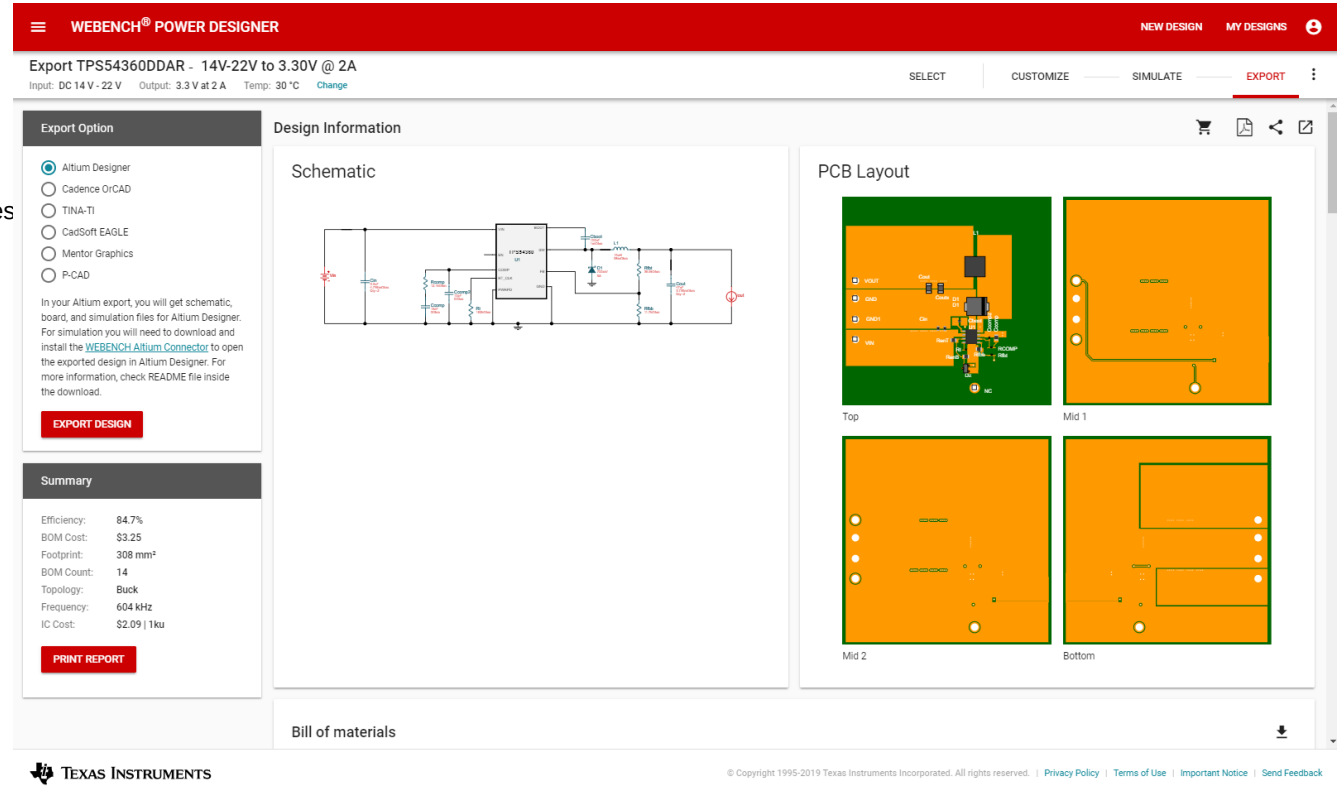
- Optimize
- Choose alternate parts
- Advanced customization

Simulate

- Electrical simulation

Export

- PDF report
- Export to CAD tools



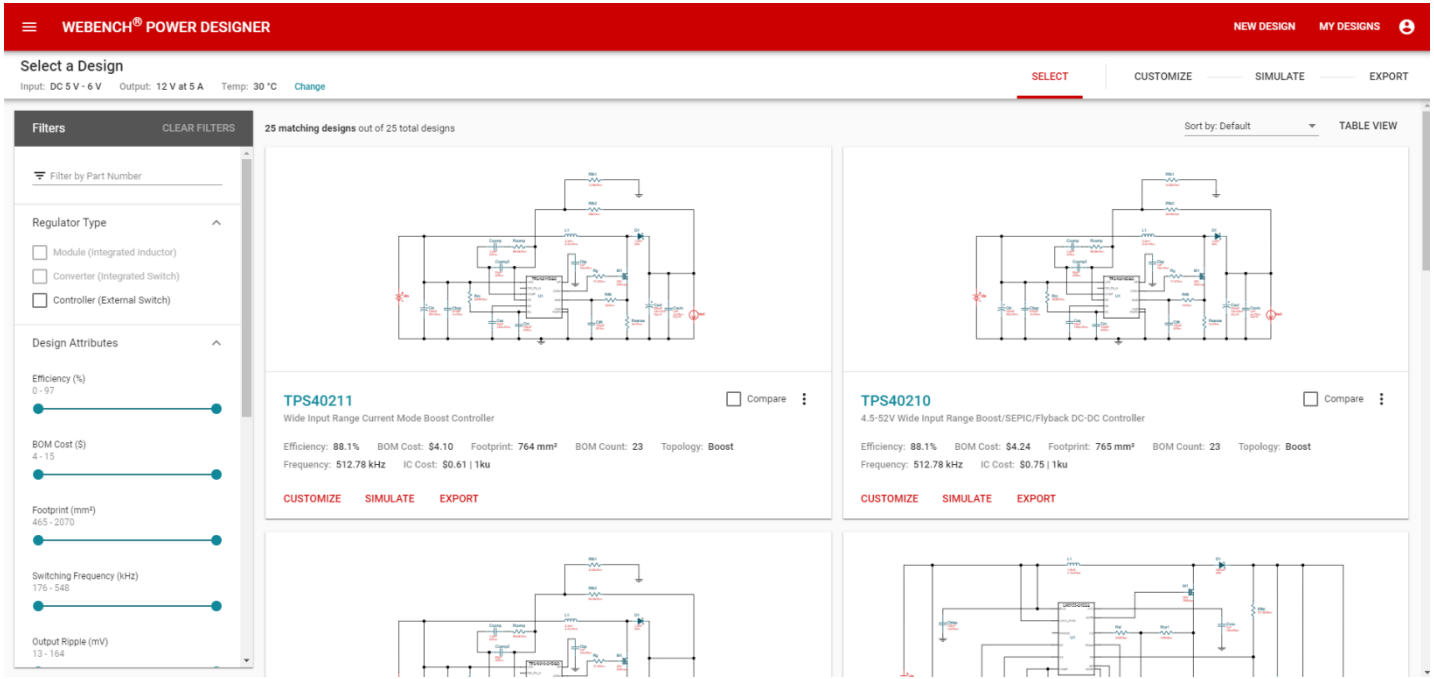
WEBENCH® Power Designer

Design of a DC/DC boost converter

DC/DC boost design using WEBENCH

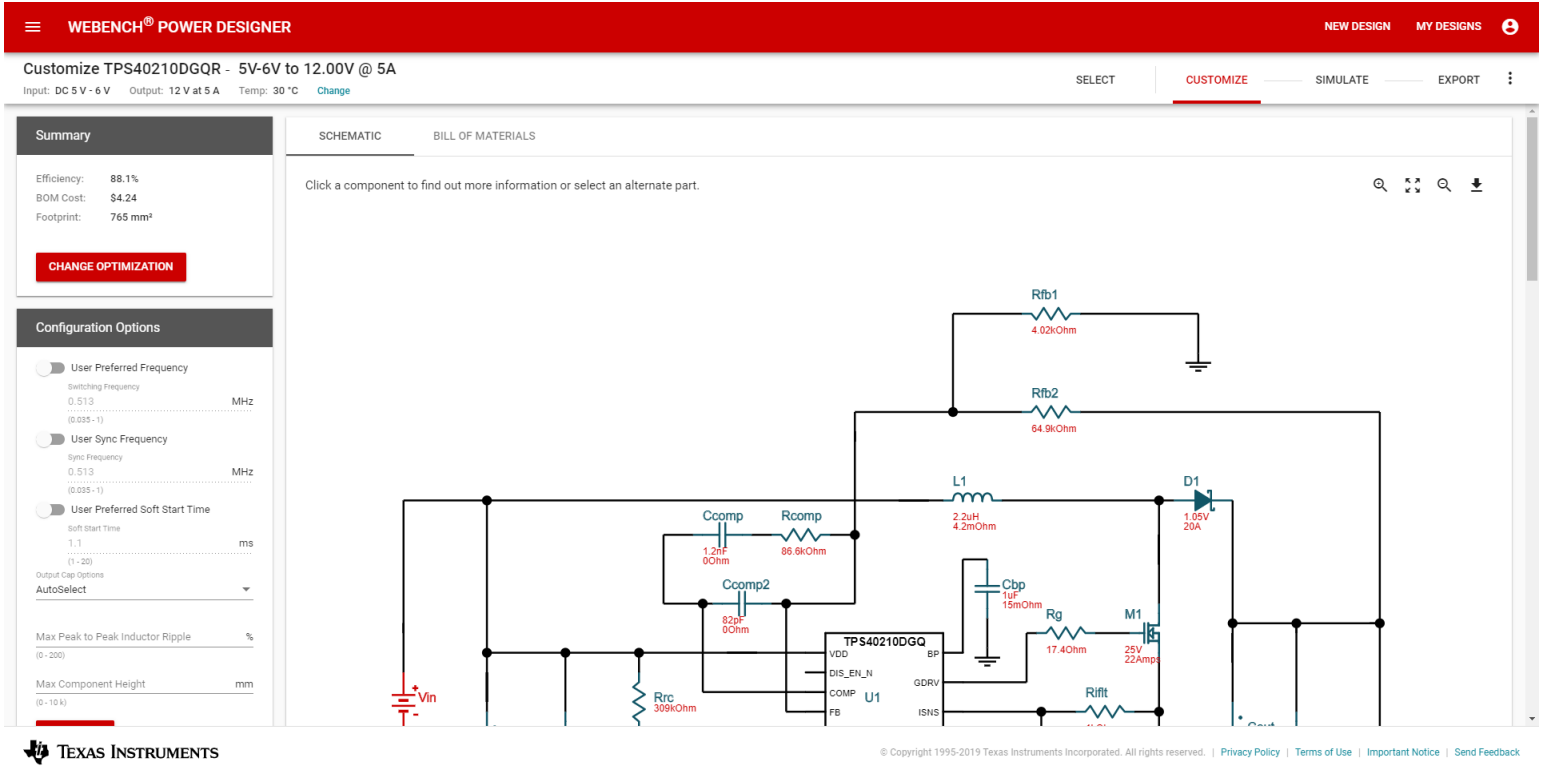
- Select and compare

- Example boost design: V_{IN}: 5 V - 6 V, V_{OUT}: 12 V, I_{OUT}: 5 A, Ta= 30ºC
- TPS40210 is a boost controller IC with adjustable switching frequency and other features



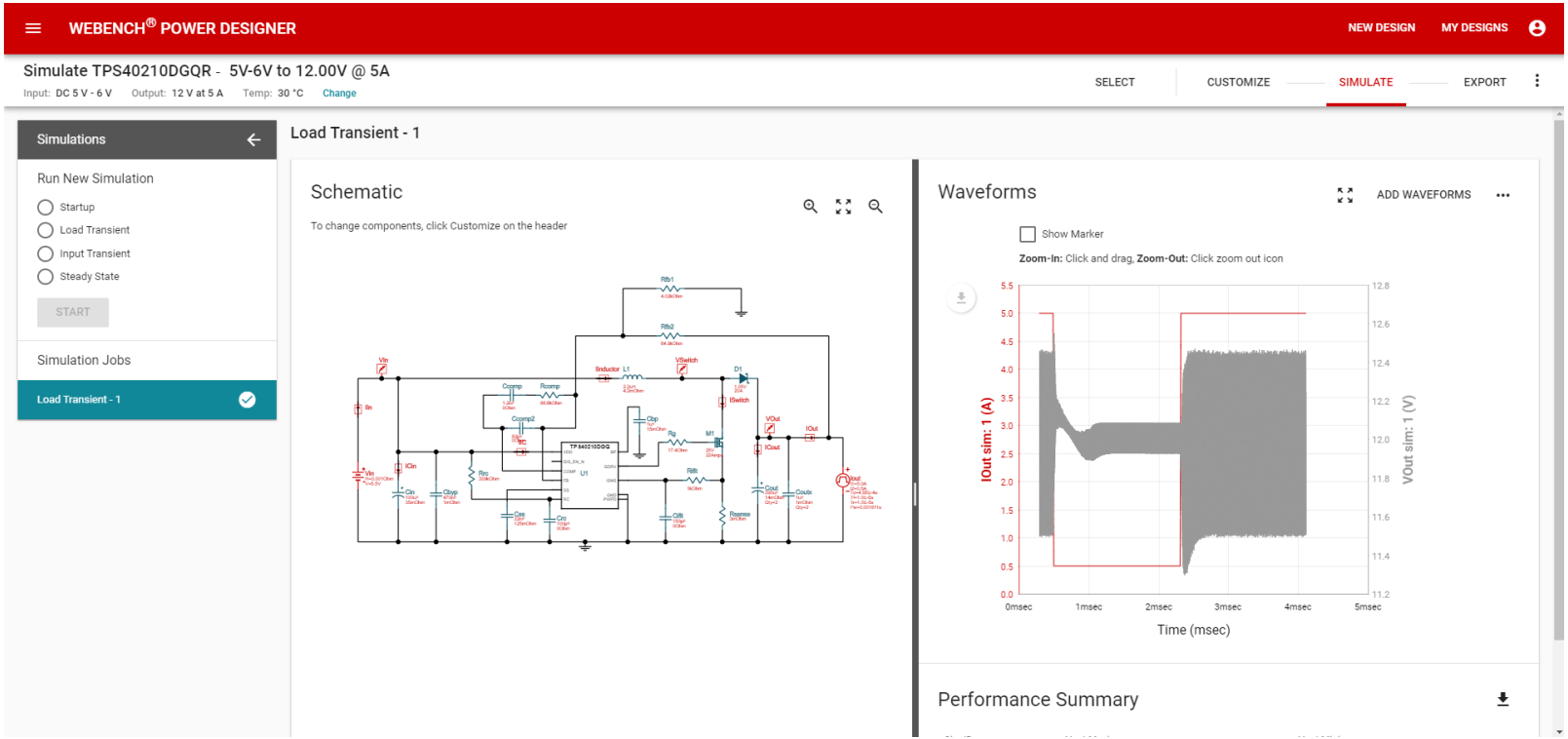
DC/DC boost design using WEBENCH

- Select and compare
- Customize design



DC/DC boost design using WEBENCH

- Select and compare
- Customize design
- Simulate



DC/DC boost current limit check

- Often, we get a question as to why the WEBENCH tool does not create a design for the entire load range for a given input and output voltage.
- This mostly is the case with integrated FET boost converter IC's where there is a peak/valley current limit that cannot be violated.
- $I_{peakcurrentlimit} \geq \left(1 + \frac{\delta}{2}\right) * \frac{Iout * Vout}{VinMin}$
- So, for a 30% peak-to-peak inductor ripple current, with VinMin = 1.8V, Vout=5V, $I_{peakcurrentlimit}$ = 4A (from datasheet)
- Maximum current that can be handled by the controller is

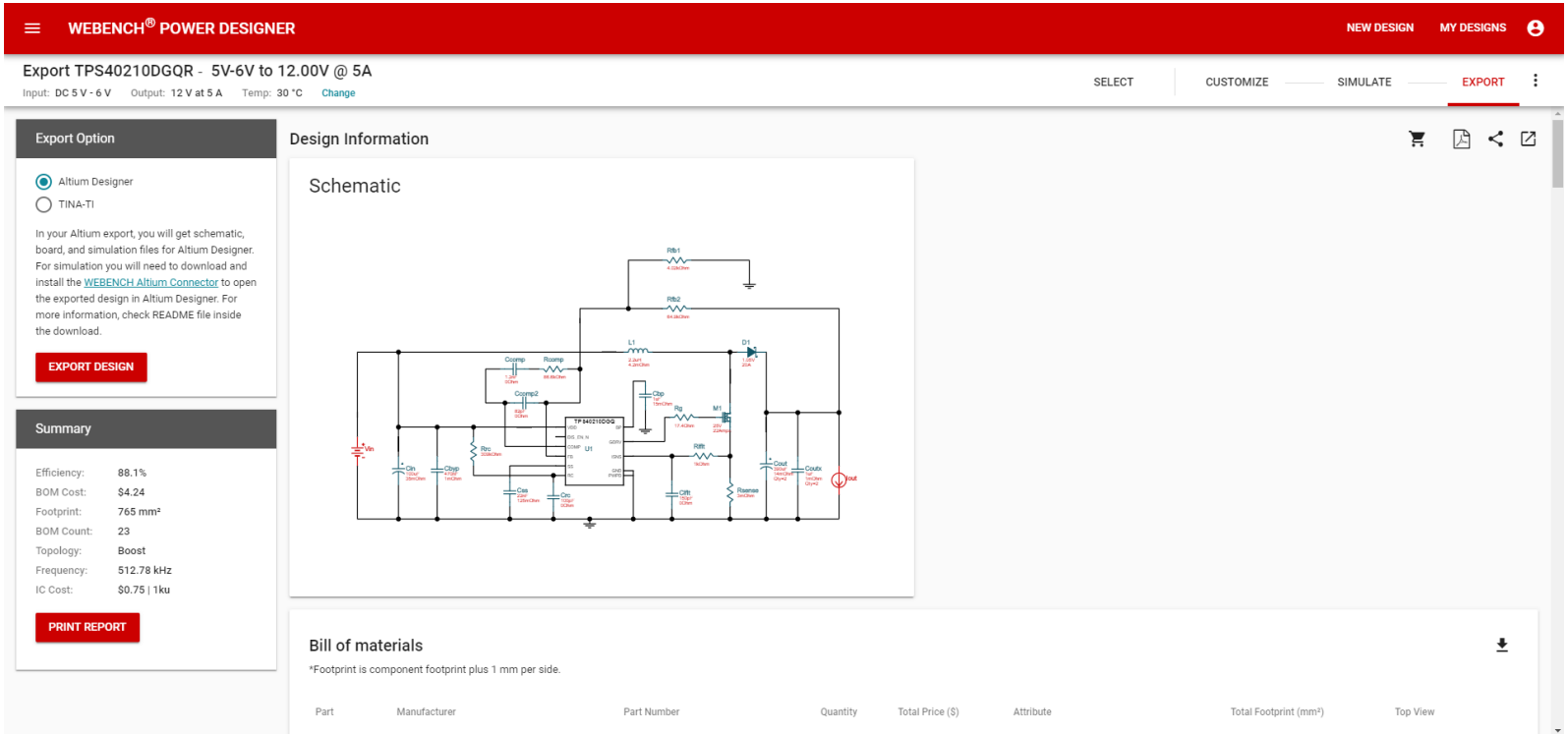
$$Iout \leq \frac{1.8V * 4A}{\left(1 + \frac{0.3}{2}\right) * 5V} \leq 1.252A$$

WEBENCH® Power Designer

Design of a AC/DC isolated flyback converter

Isolated power supply design in WEBENCH

- Select and compare
- Customize design
- Simulate
- Summary and print report

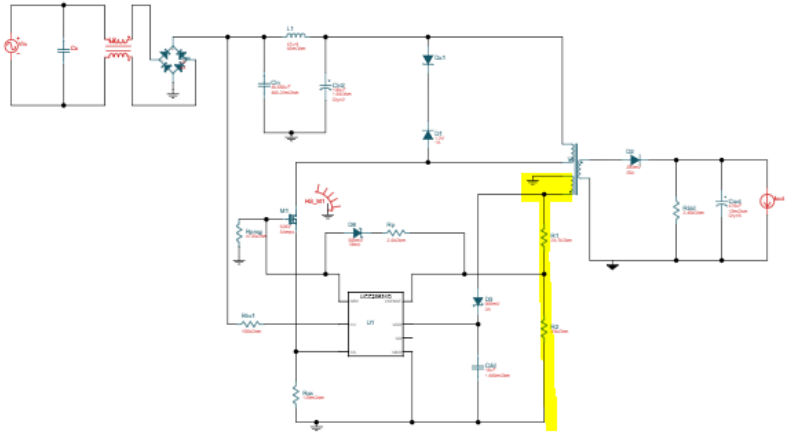


Isolated power supply design in WEBENCH

- Isolated power supplies transfer power from input to output with out a direct connection between input and output – typically using a power transformer.
- Isolation is required for safety, prevent ground loops, effective voltage level shifting and for protecting sensitive loads and improving long term reliability of the equipment.
- WEBENCH Power Designer now supports various topologies to design Isolated power supplies including – flyback, flybuck, half-bridge, active clamp forward, LLC, phase shifted full bridge and PFC.

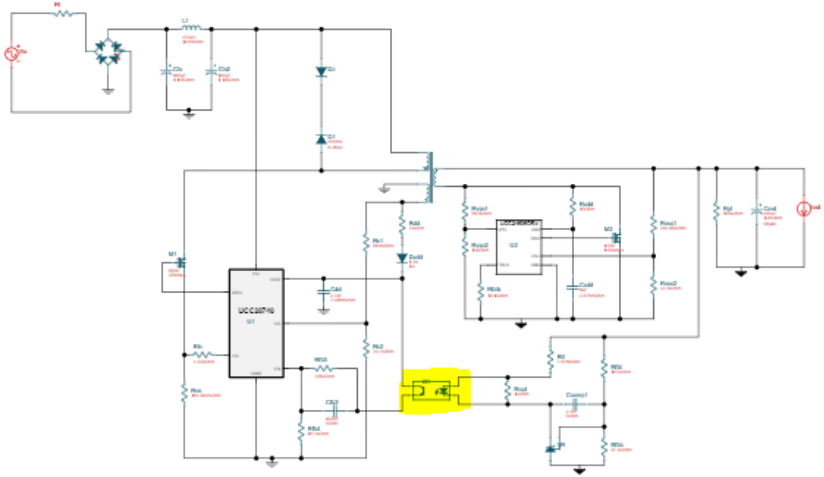
Isolated flyback design in WEBENCH

- Isolation is required in both power stage and feedback.
- WEBENCH supports Isolation in feedback using below two methods:
  - Primary side feedback using feedback from auxiliary winding on primary.
  - Secondary side feedback using optocoupler.



Primary side feedback:

- Regulation from the auxiliary winding of the transformer indirectly enables output voltage regulation.
- Simpler design with less components.
- Reduces size and enhances surge and lifetime.



Secondary side feedback:

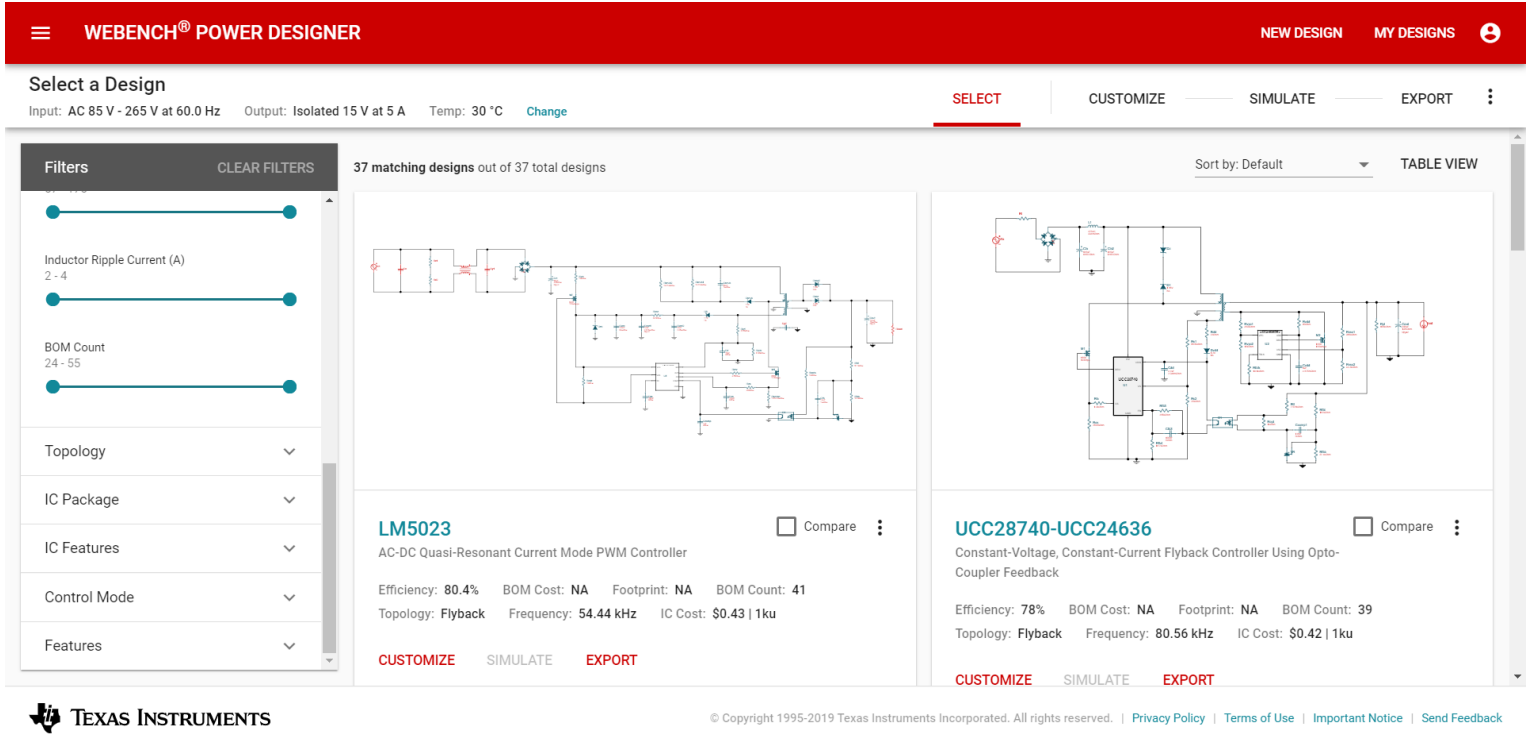
- Direct regulation of output voltage with optocoupler feedback to maintain galvanic isolation.
- Provides best regulation accuracy and transient response.

Isolated flyback design in WEBENCH

- Let us take the below design example to explore Isolated design –
  - Universal AC input : 85 to 265 V, 60 Hz
  - 15 V output
  - 75 W output max power.
  - High regulation accuracy and fast transient response.
  - High efficiency > 80%.
- From the above specs we can make below observations –
  - Flyback is a good topology choice. (How do I choose which topology is right ?).
  - High regulation accuracy and fast transient response requires a secondary side feedback with optocoupler.
  - Flyback typically offers moderate efficiency with a simple design – but improvements in control mode using “quasi-resonant” switching or using an active-clamp instead of a dissipative clamp provides significantly improved efficiency.

Isolated flyback design in WEBENCH

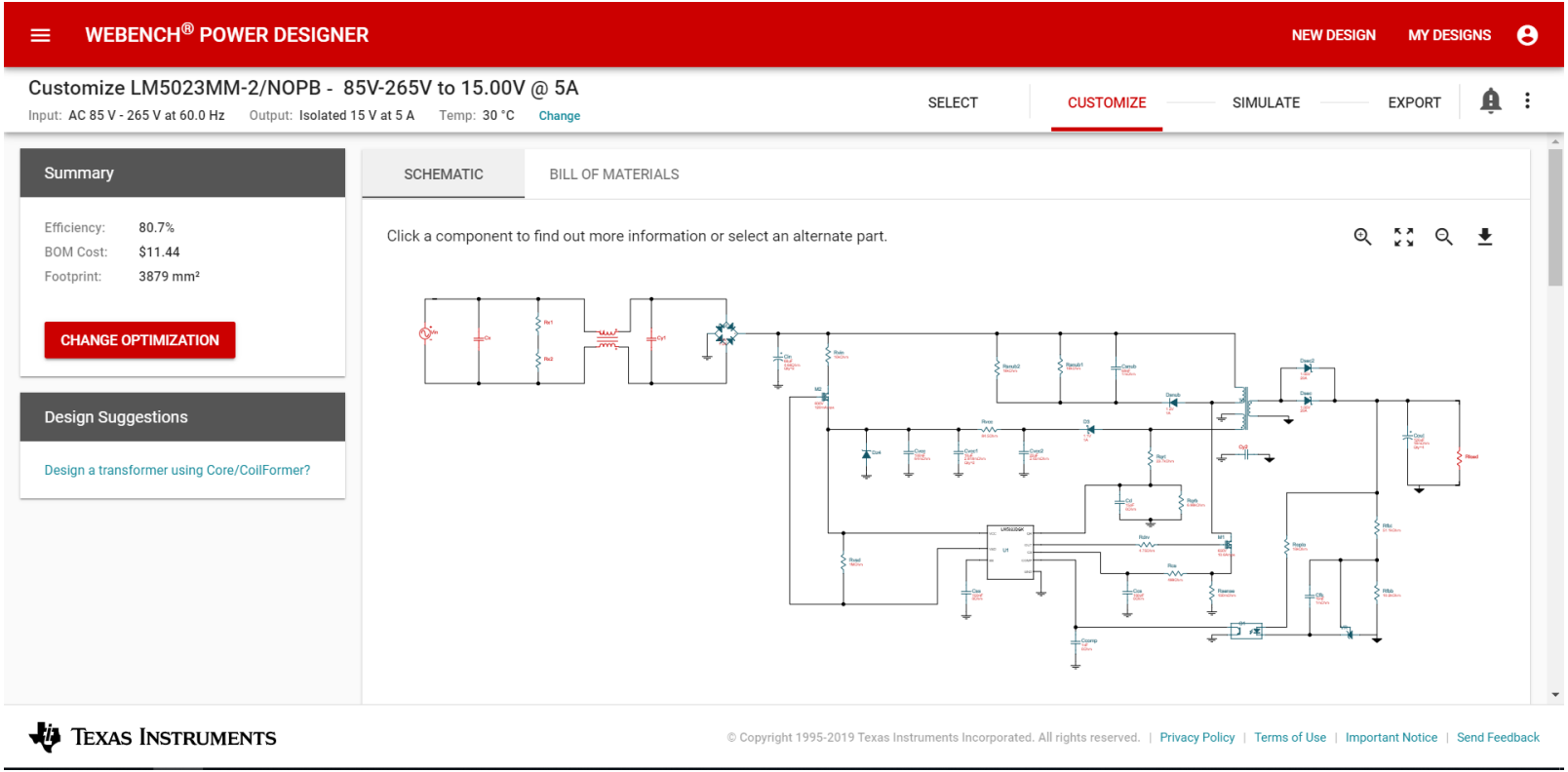
- Select and compare



Note that the first choice from WEBENCH suggestions is secondary side feedback, quasi-resonant topology.

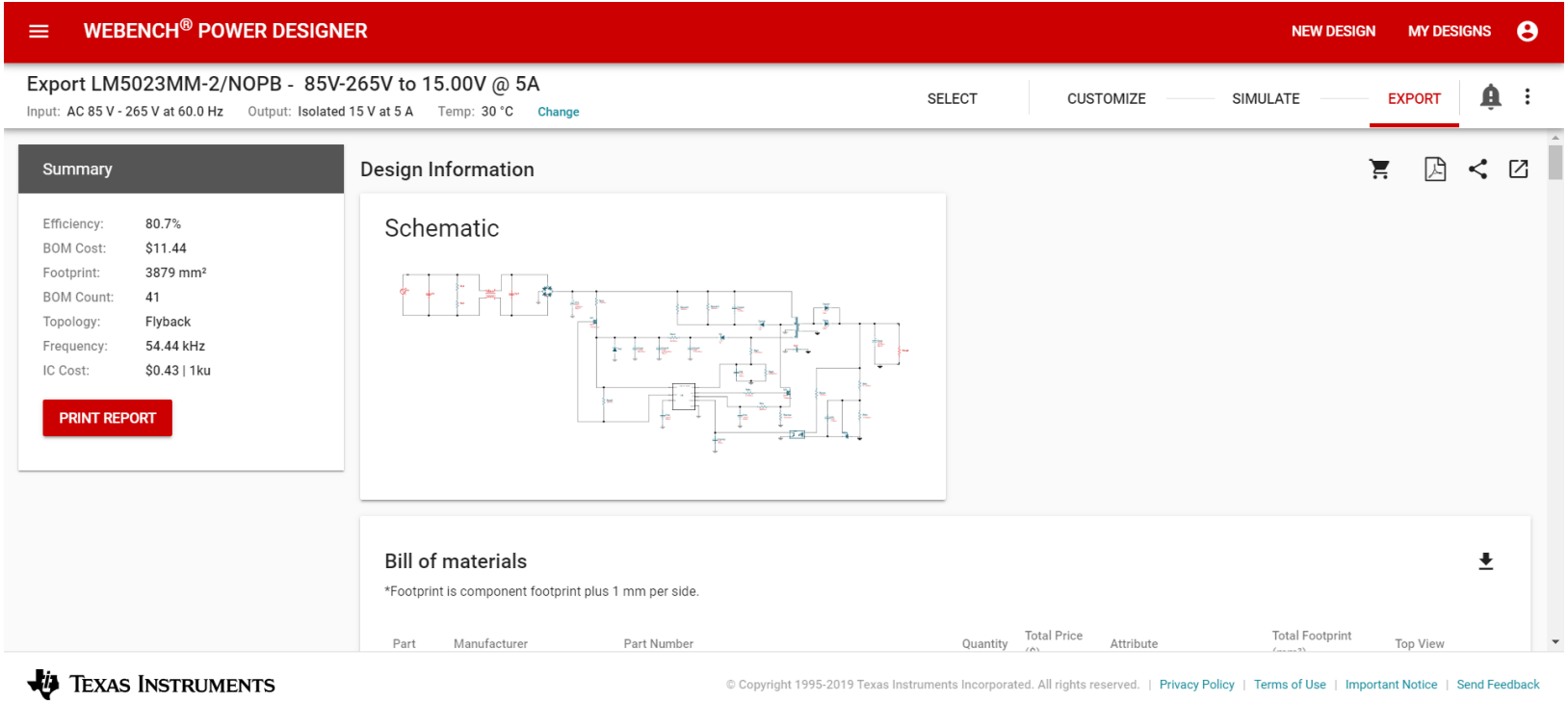
Isolated flyback design in WEBENCH

- Select and compare
- Customize design



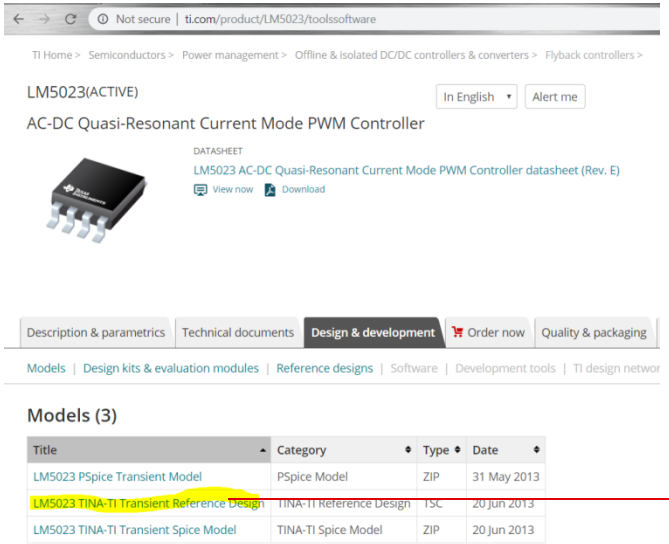
Isolated flyback design in WEBENCH

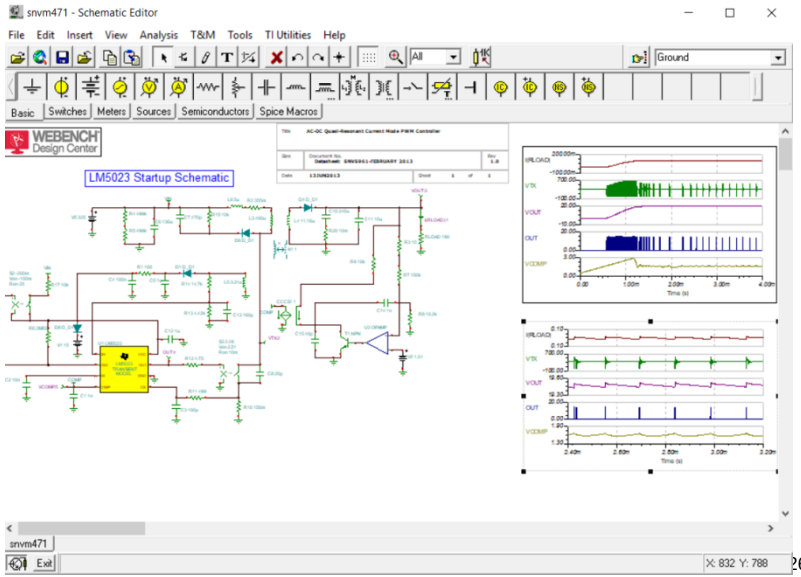
- Select and compare
- Customize design
- Summary and print report



Isolated flyback design in WEBENCH

- Can I use WEBENCH to simulate/export my isolated designs ?
  - Most non-isolated topologies can be simulated or exported to standard CAD tools.
  - WEBENCH does not support simulation / export for isolated designs due to the complexity of designs and availability of simulation models for key components like Transformer, Optocoupler used in isolated designs.
  - Customers are encouraged to use SPICE models and example schematics available in product folders to create the WEBENCH design in their favorite CAD tool, simulate and verify before moving to actual manufacturing of the board.

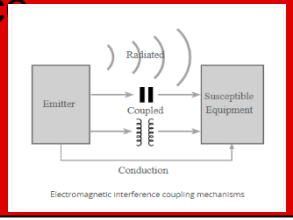




Power supply design challenges

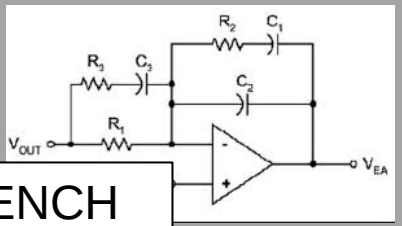
Electromagnetic interference

Design power supply to meet EMI specifications



Compensation design

Design compensation to make power supply feedback loop stable.



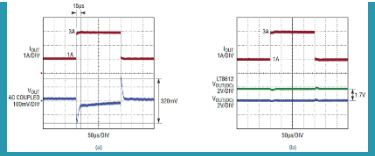
In this presentation we will learn how to use WEBENCH Power Designer to solve these design challenges

Transformer

Select the right core, coil former, winding geometry and number of turns to meet power supply specifications

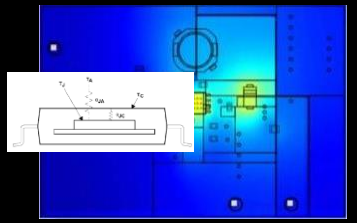
Transient specification

Design power supply to meet ripple, transient overshoot specifications



Thermal issues

Detect and fix potential thermal hot-spots early in design cycle



WEBENCH® Power Designer

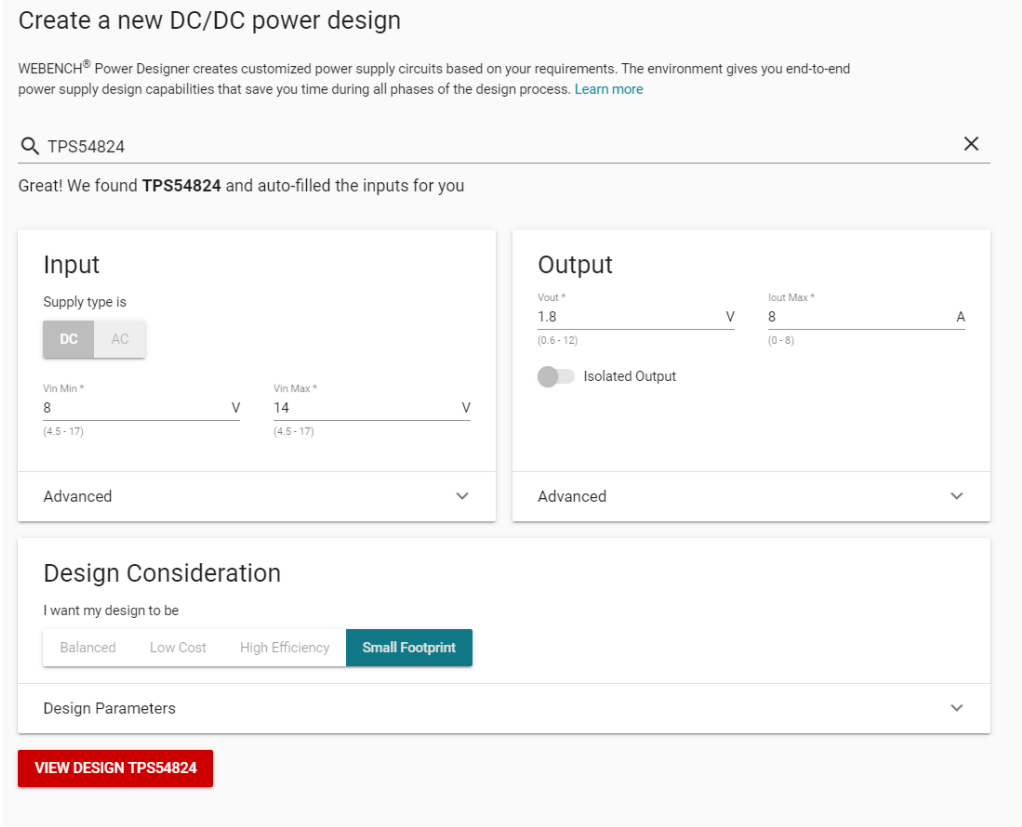
Design POL buck with stringent transient specifications

Design buck POL w/ strict transient specs

Design problem:	Goals:
Customer wants a design using: **TPS54824** V_{IN}: **8-14 V ;** V_{OUT}: **1.8 V ;** I_{OUT}: **8 A** **Design consideration:** • Small footprint. • Low output noise. • High accuracy. • Fast load transient response. V_{OUT} tolerance < 1% V_{OUT} ripple spec : 1% of V_{OUT} V_{OUT} transient spec : 2-8-A load step 5% of V_{OUT}	Use WEBENCH to create design for customer input conditions. Use optimization to trade-off for small footprint design. Review the design spec. Customize design to meet tolerance specification. Use advanced options in WEBENCH to meet the transient requirements Validate the design using simulations.

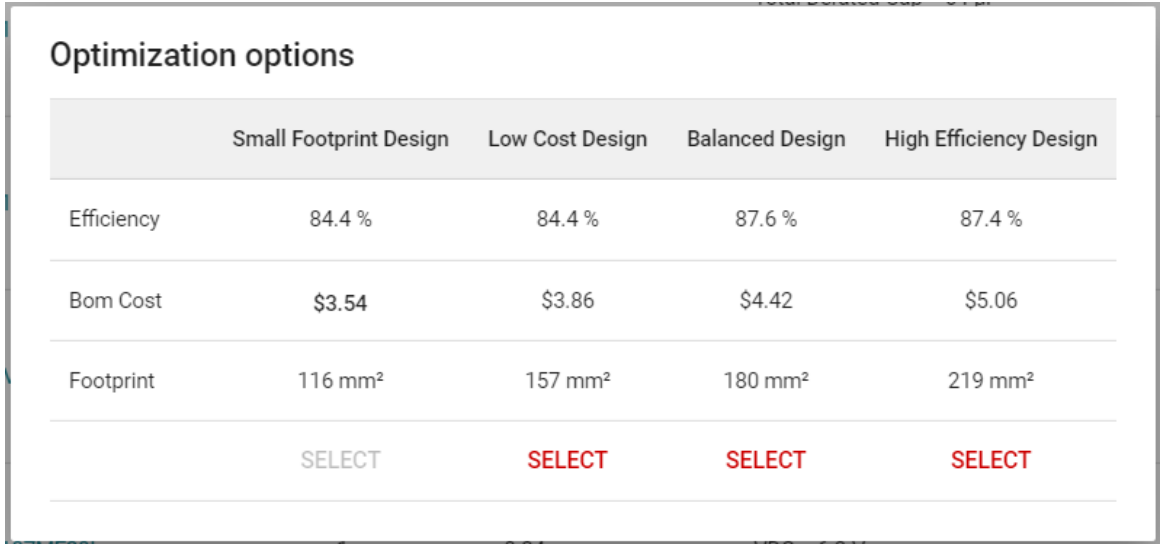
Design buck POL w/ strict transient specs

Step 1:
Create design with customer specifications.



Design buck POL w/ strict transient specs

Step 2:
Review tradeoffs using optimization buttons.



Optimization options

	Small Footprint Design	Low Cost Design	Balanced Design	High Efficiency Design
Efficiency	84.4 %	84.4 %	87.6 %	87.4 %
Bom Cost	$3.54	$3.86	$4.42	$5.06
Footprint	116 mm²	157 mm²	180 mm²	219 mm²
	SELECT	SELECT	SELECT	SELECT

Design buck POL w/ strict transient specs

Step 3:
Validate design spec using OpVals and simulations.

V_{OUT} p-p = 19 mV
V_{OUT} tolerance = 2.19%
$V_{OVERSHOOT}$ = 110 mV
$V_{UNDERSHOOT}$ = 110 mV

Required:

V_{OUT} p-p < 18 mV
V_{OUT} tolerance < 1%
$V_{OVERSHOOT}$ < 90 mV
$V_{UNDERSHOOT}$ < 90 mV

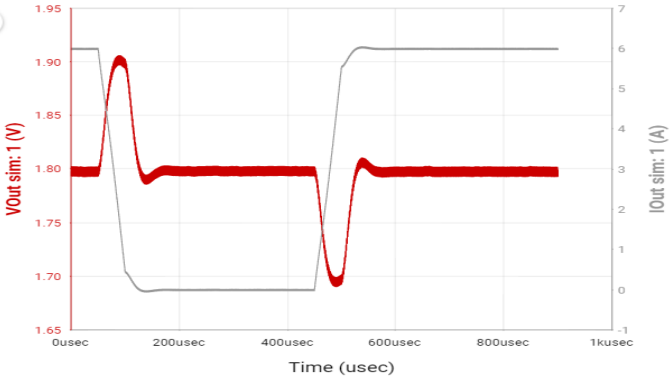
Vout p-p	19.2 mV	Peak-to-peak output ripple voltage
Vout Tolerance	2.19%	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable

Waveforms

ADD WAVEFORMS

Show Marker

Zoom-In: Click and drag, **Zoom-Out:** Click zoom out icon



Performance Summary

Sim ID	Vout Maximum	Vout Minimum	Overshoot Settle Time	Undershoot Settle Time	Overshoot	Undershoot
1	1.91 V	1.69 V	0.09 ms	0.08 ms	0.11 V	0.11 V

Design buck POL w/ strict transient specs

Step 4:
Customize design to meet the specifications.
Update the design to meet transient spec using advanced options.

$V_{OVERSHOOT}$: 0.8 V
$V_{UNDERSHOOT}$: 0.8 V

Design buck POL w/ strict transient specs

Step 5:
Customize design to meet the specifications.

Update feedback resistors to 0.1% tolerance using alternate component selection to meet tolerance specification.

V_{OUT} tolerance (before) = 2.19%

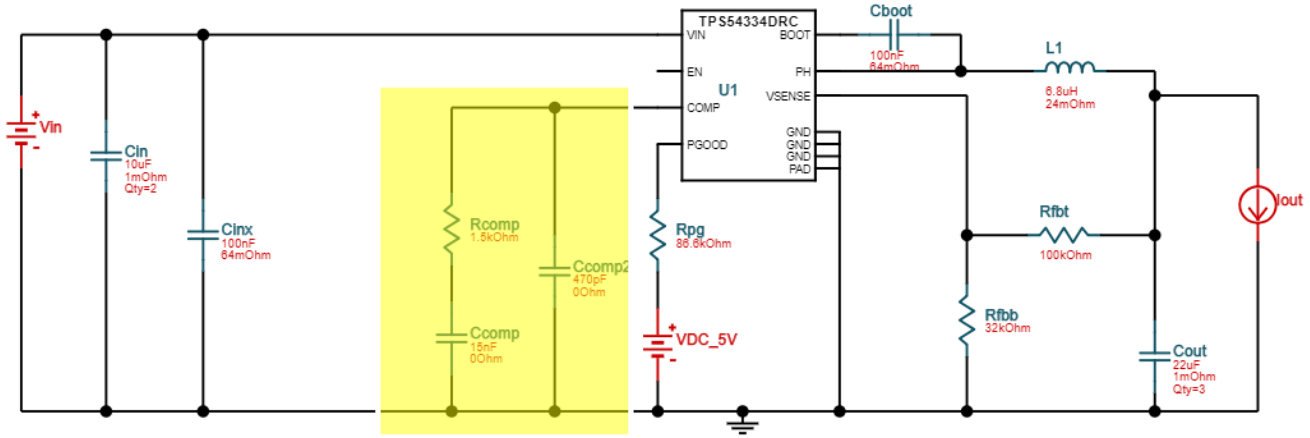
V_{OUT} tolerance (after) = 0.97%

Rfbt	Yageo	RT0603BRD0720KL	1	0.04	Resistance = 20 kΩ Tolerance = 0.1% Power = 100 mW
Rcomp	Vishay-Dale	CRCW04022K32FKED	1	0.01	Resistance = 2.32 kΩ Tolerance = 1.0% Power = 63 mW
Rfbb	Susumu Co Ltd	RG1608P-103-B-T5	1	0.04	Resistance = 10 kΩ Tolerance = 0.1% Power = 100 mW

WEBENCH® Power Designer

Solving power supply compensation design challenges

Compensation design challenges



- Often, customers need to change power supply design components and customize to their specific needs (e.g. customer wants to use specific inductor/capacitor as they have it in their approved vendor list, customer wants to optimize load transient response, etc.)
- Making such a change can cause the power supply to go unstable. This may require a re-design of their compensation network – which can be an iterative and time consuming process.

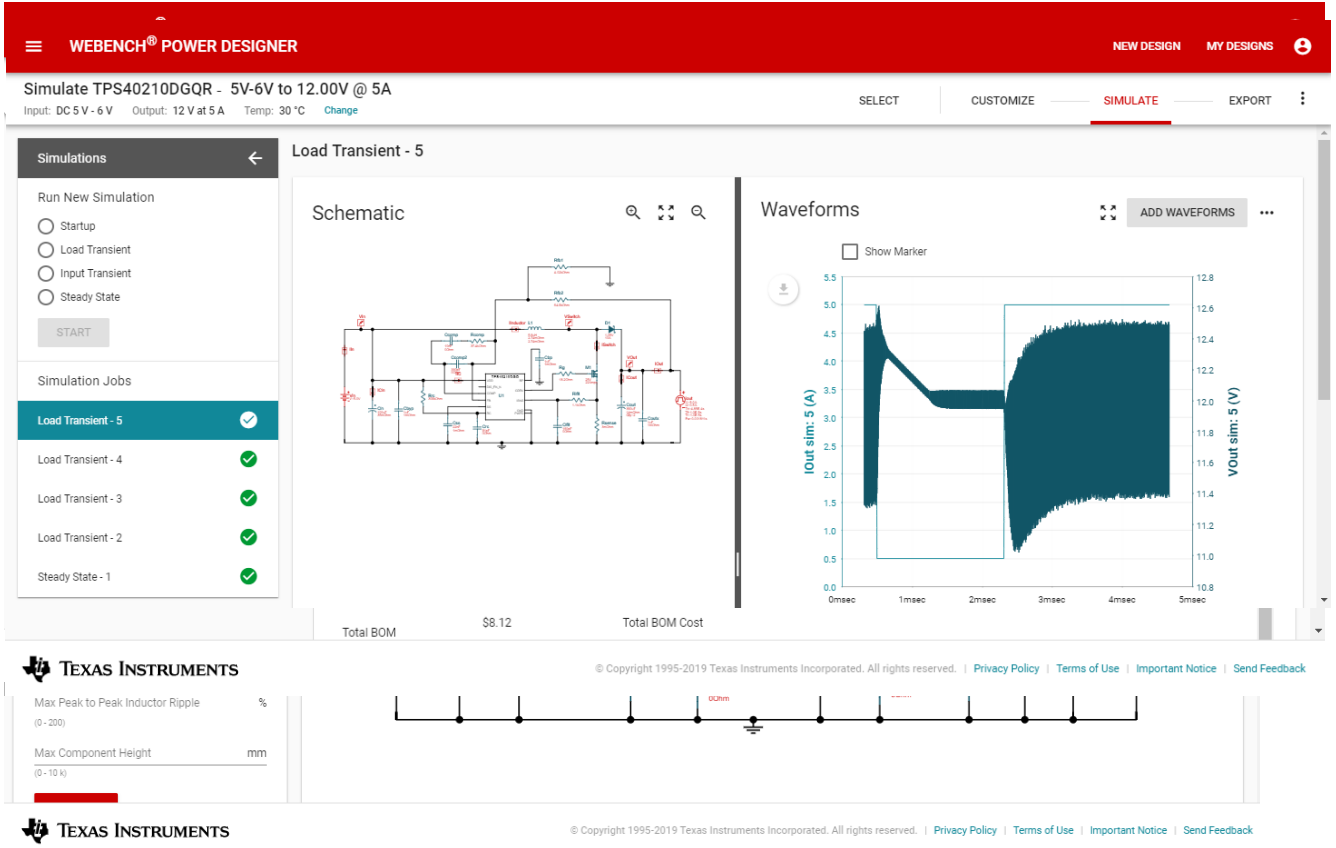
Exercise: Change in L1 causes instability

Use stability alerts to fix compensation

Design Problem:	Goals:
Customer wants a design using: **TPS40210** Vin: **5-6V** Vout: **12V** Iout: **5A** Customer has specified a **5.6 uH** inductor that is on the customer's approved vendor list.	Use alternate part selection to select a 5.6 uH inductor and customize the design for this inductor. Check the resulting design for phase margin and crossover frequency and run a load transient simulation to confirm the behavior. Use the Re-Compensation feature to re-design compensation and validate the design using simulations.

Re-compensation

- Create a boost design with TPS40210 with customer given inputs.
- Use alternate part selection to select 5.6 uH inductor.
- Verify design stability from phase margin OpVals and by simulation.
- Use alerts / Re-comp feature to re-design the compensation and verify phase margin in OpVal table.
- Validate the design stability by simulations.



WEBENCH® Power Designer

Solving power supply thermal design challenges

Thermal design challenges

- Accurately calculating power dissipation and estimating the die temperature for different components across all operating values of the power supply is complex.
- Identifying potential thermal issues early in the design cycle is critical to avoid time consuming and expensive re-design of the power supply.

Thermal calculations (Buck converter IC Tj example)

$$Tj = Ta + (Pd * RthetaJA)$$

Tj = Junction temperature of the IC (degC)

Ta = Ambient temperature of the IC (degC)

Pd = Power dissipation of the IC (W)

RthetaJA = Junction to ambient thermal resistance (degC/W) {Use effective RthetaJA to match with EVM PCB layout)

Power dissipation calculations
IC : Quiescent current losses, internal LDO (for gate driver) losses

IC High side and low side MOSFET: Conduction losses, Switching losses, Gate Driver losses, Coss losses, Reverse Recovery losses

Cin **:** ESR losses

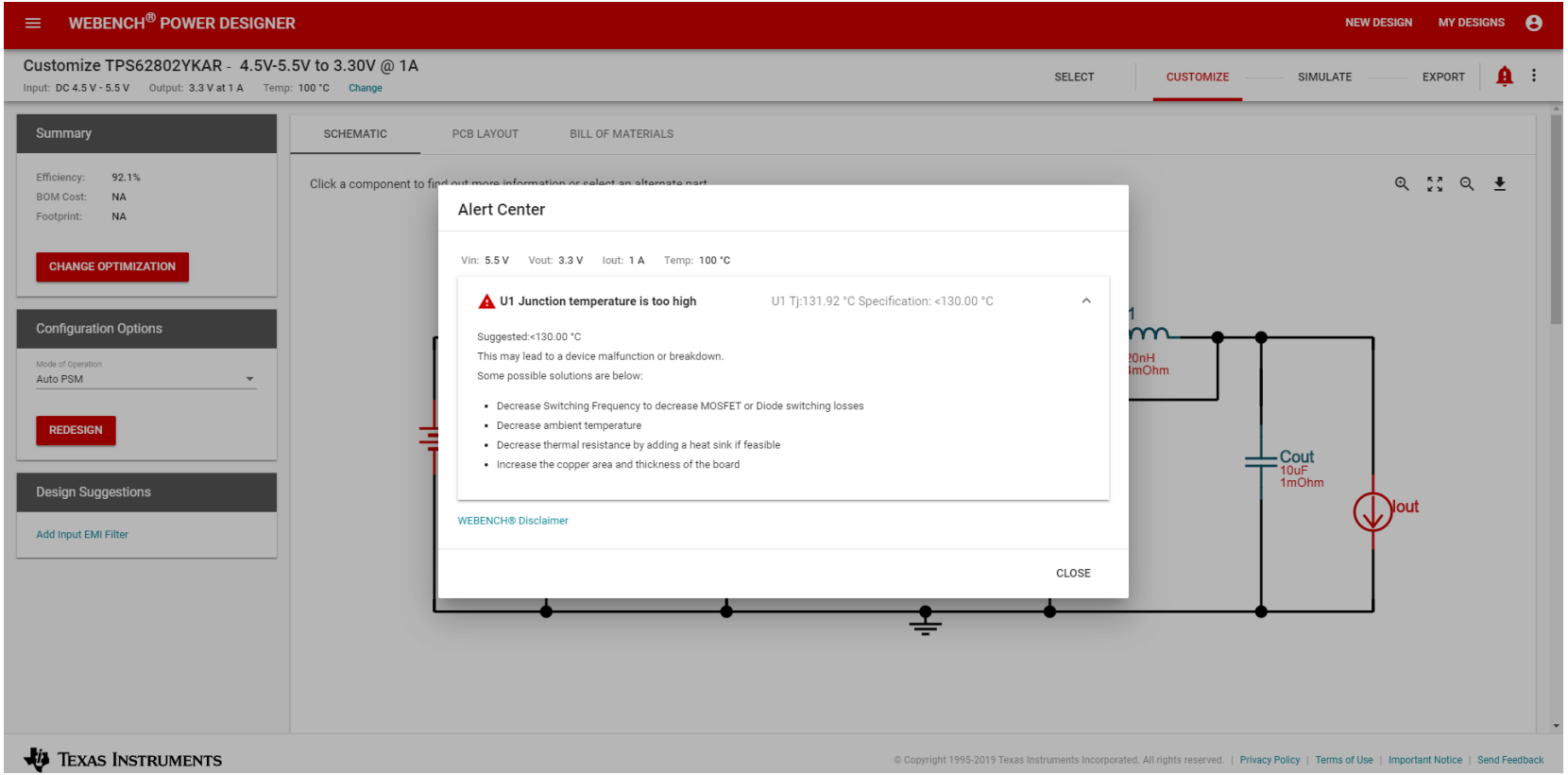
Cout**:** ESR losses

Inductor**:** DCR losses

Body-diode: Body diode losses

Feedback divider: Feedback divider losses

Thermal alerts



WEBENCH® Power Designer

Solving EMI design challenges

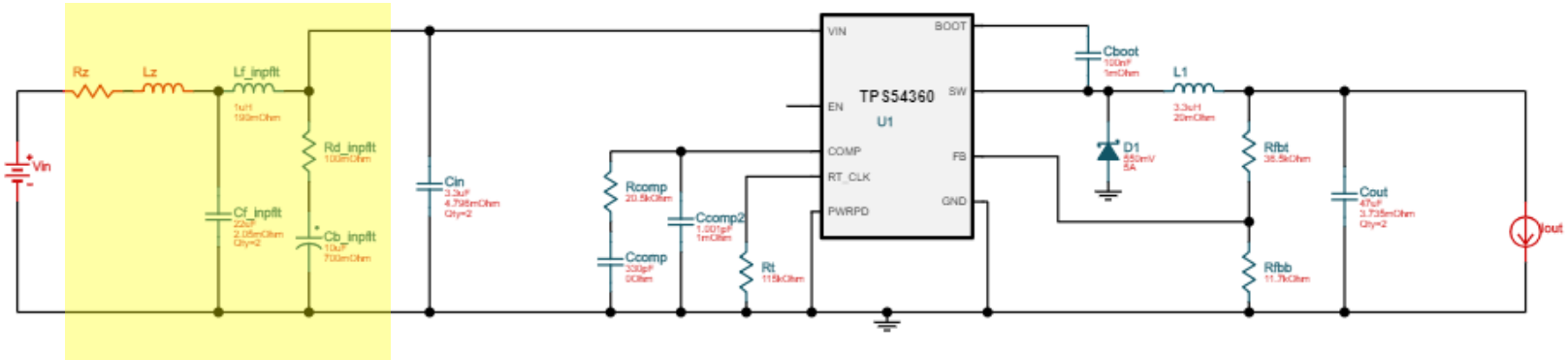
WEBENCH input EMI filter design

Input filter design for switching regulators to satisfy CISPR “conducted” EMI noise specs

CISPR 25: Class 5,4,3,2,1

CISPR 22: Class A, B

Waveform shows fundamental + 14 harmonics

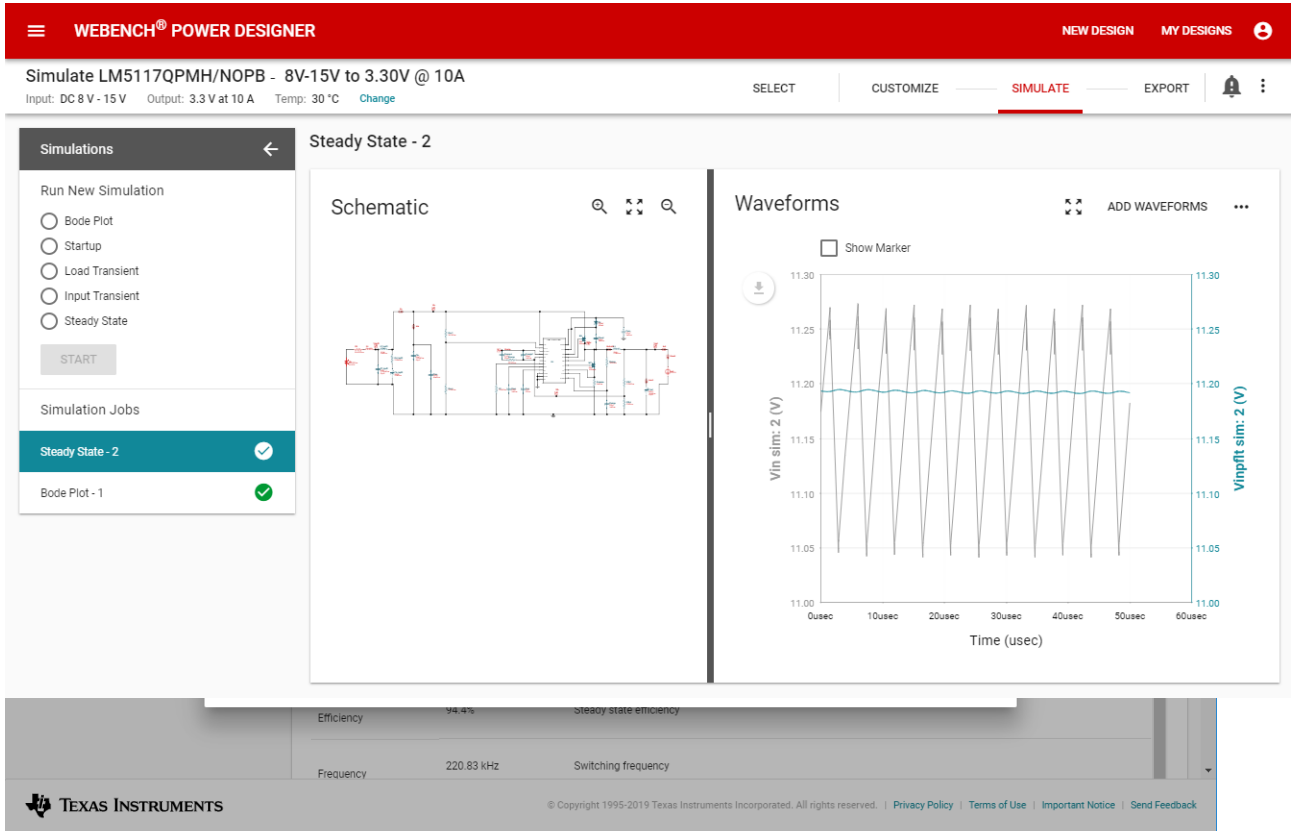


Exercise: Design low noise supply

Design Problem:	Goals:
A customer wants to design a power supply for an automotive infotainment system. Device: LM5117-Q1 V_{IN}: 8V-15 V V_{OUT}: 3.3 V I_{OUT}: 10 A Requirements: 1. High efficiency (>90%). 2. Customer needs a very low noise supply meeting CISPR 25, Class 5 noise standard. 3. Customer specified the line impedance characterized as 50mOhm Resistor in series with 0.5uH Inductance.	Design high efficiency power converter using LM5117-Q1 and customer input conditions in WEBENCH. Using the “Add EMI filter” option, design and customize input filter to meet the customer standard. Apply to design and check simulations to make sure the filter and design is stable.

Exercise: Input EMI filter

- Create design with customer given inputs.
- Click on “Add Input EMI Filter” from design suggestions and select CISPR noise standard and class.
- Enter specified line impedance.
- Verify the design meets the requirements.
- Add EMI filter to design and validate using simulations.

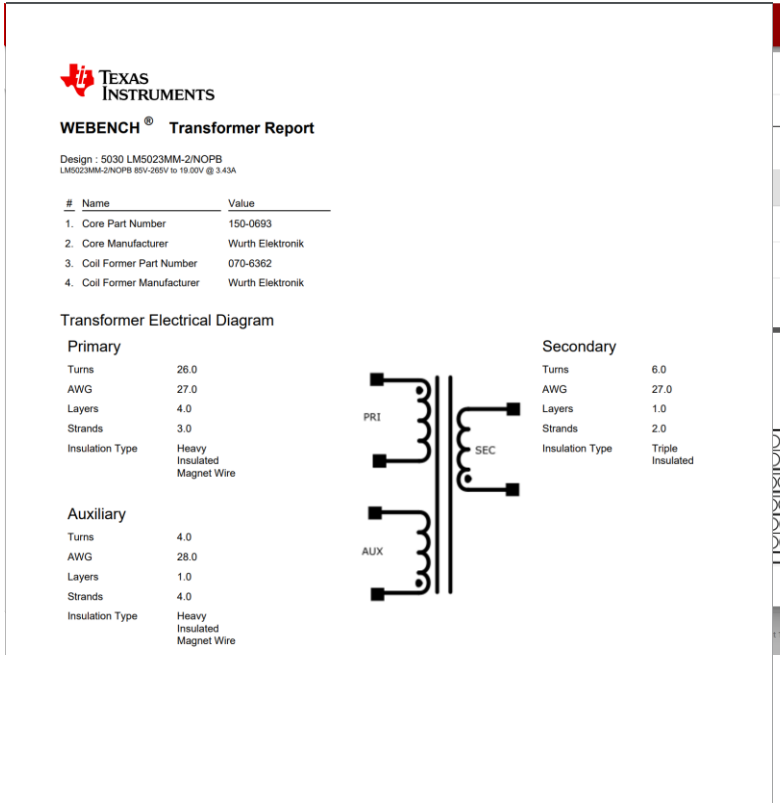


WEBENCH® Power Designer

Solving transformer design challenges

Exercise: Transformer design

- Click on “Design transformer using Core / Coil Former” from design suggestions.
- Trade off cost, power dissipation to select an appropriate custom transformer.
- Print transformer details report to share the requirements with transformer vendor to build the transformer.



TEXAS INSTRUMENTS

WEBENCH® Transformer Report

Design : 5030 LM5023MM-2/NOPB
LM5023MM-2/NOPB 85V-265V to 19.00V @ 3.43A

#	Name	Value
1.	Core Part Number	150-0693
2.	Core Manufacturer	Wurth Elektronik
3.	Coil Former Part Number	070-6362
4.	Coil Former Manufacturer	Wurth Elektronik

Transformer Electrical Diagram

Primary

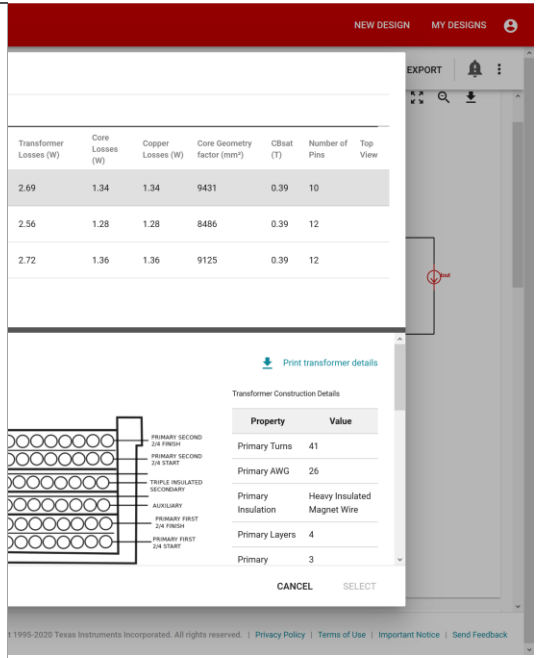
Turns	26.0
AWG	27.0
Layers	4.0
Strands	3.0
Insulation Type	Heavy Insulated Magnet Wire

Auxiliary

Turns	4.0
AWG	28.0
Layers	1.0
Strands	4.0
Insulation Type	Heavy Insulated Magnet Wire

Secondary

Turns	6.0
AWG	27.0
Layers	1.0
Strands	2.0
Insulation Type	Triple Insulated



Summary

- WEBENCH® supports DC/DC and AC/DC switch mode power supply

- WEBENCH® can help you with:
  - Device selection.
  - Application design.
  - Electrical simulation.
  - CAD export.

- **Try the new WEBENCH® power designer** at http://webench.ti.com/power-designer

Frequently asked questions

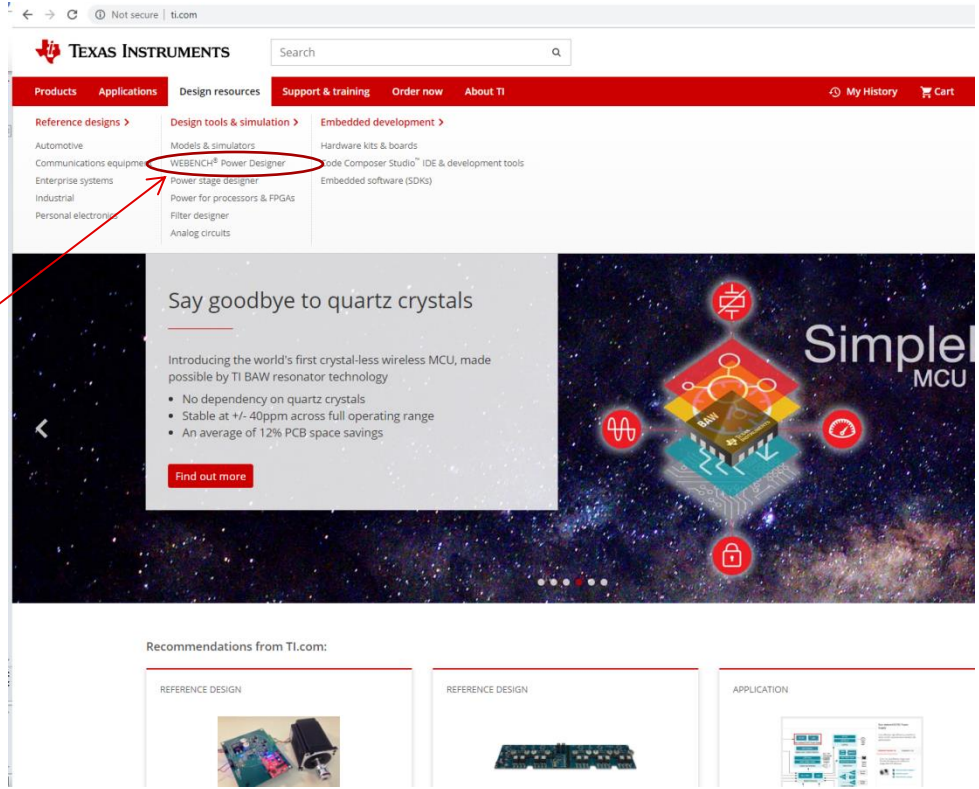
- Datasheet specification shows the boost maximum current as 8 A - why does WEBENCH fail design at 5 A.
  - Answer: Typically two types of current limits specified in datasheet: Peak switch current limit, Valley switch current limit. Actual output current limit value will depend on other factors like Vin, Vout, Duty, Inductor value etc.
- Datasheet specification shows the Buck converter frequency range as 500 kHz to 2.2 MHz - but WEBENCH advanced options shows the range as 500 kHz to 1.6 MHz.
  - Answer: Factors which affect the switching frequency:
    - min Toff limit at high duty cycles leading to frequency foldback
    - min Ton limit at low duty cycle leading to frequency foldback
    - high losses leading to high temperatures and WEBENCH intelligently lowers the frequency to be within the thermal limit of the part.
  - Note: While maximum operating frequency may be 2.2 MHz – data sheet does not guarantee such operation across all operating points / inputs and outputs.

Frequently asked questions - continued

- Why my hands-on calculation of capacitance value (or other parameters) from datasheet equations shows much smaller capacitor (or different values) than recommended by WEBENCH design?
  - Answer: Multiple factors may be responsible for difference in values :
    - WEBENCH uses de-rating for capacitor values and thus the nominal capacitance could be higher than the actual capacitance value – displayed in capacitor properties.
    - WEBENCH uses 1% ripple / 5-10% overshoot based calculations and uses larger of the two capacitances to meet the requirements – data sheet may not always provide equations for overshoot based calculation which may be the deciding factor.
    - More accurate modeling in WEBENCH may lead to some difference with ideal datasheet calculations.
- How can I get lower cost design – lower than low cost solution in WEBENCH?
  - Answer: WEBENCH provides optimization options as a good starting point based on customer requirements. While this is a good starting point for design – customer can freely further optimize the design by changing components / looking for lower cost components within their AVL / online distributor websites to get better pricing. Note that WEBENCH provides 1k pricing based on ti.com, mouser, digikey feeds – but high volume pricing could be significantly lower.

Resources

- Launch the new tool:
  - https://webench.ti.com/power-designer
- Contact us on E2E with questions:
  - https://e2e.ti.com/support/tools/sim-hw-system-design/
- You can also access the tool through the “Design resources” tab on ti.com



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