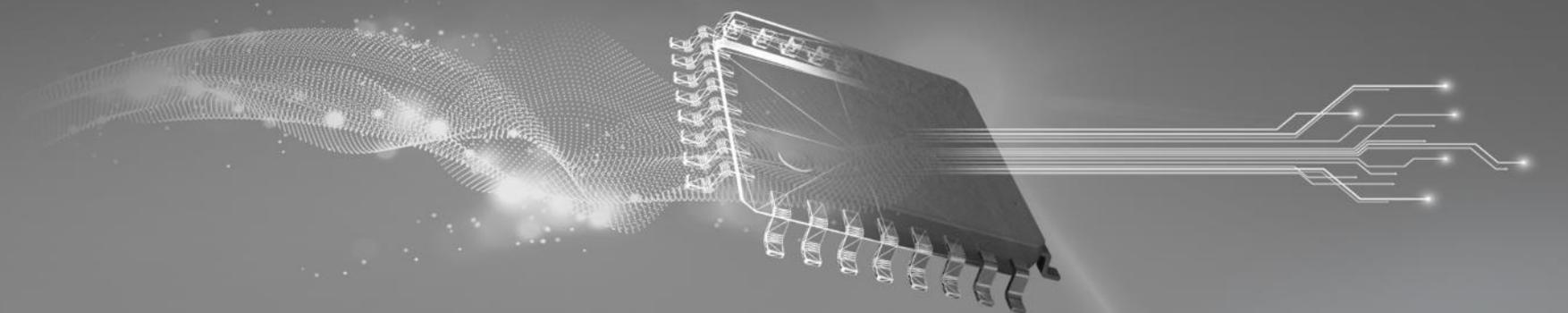


TI TECH DAYS



WEBENCH® Power Designer **Power supply design made easy**

Srikanth Pam

Sahil Gupta

Agenda

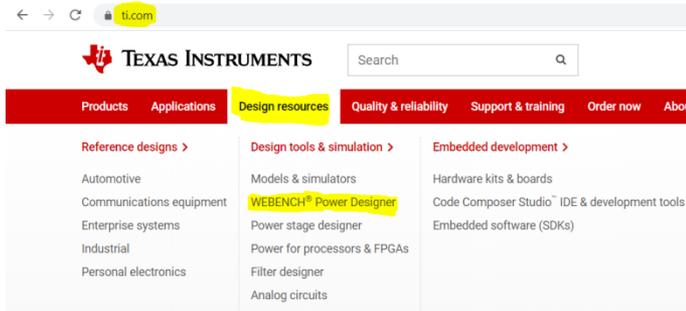
- **Introduction to WEBENCH® Power Designer**
 - What is it? How to get to the tool?
 - Design tools vs. simulation tools vs. reference designs
 - Supported TI portfolio
- **WEBENCH Power Designer tour**
- **Deep-dive of Power Supply Design using WEBENCH Power Designer**
 - DC/DC boost converter design
 - 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?

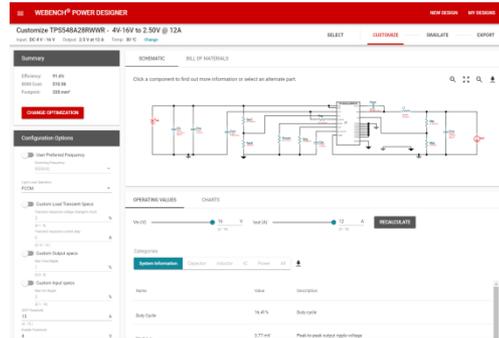
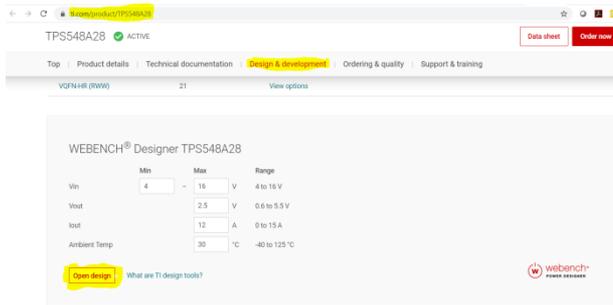
From TI.com home page -



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)
- Maxim (EE-Sim)
- Analog/Linear Tech (LTpowerCAD)
- MPS (DCDC Designer)

Simulation Tools

- TI (PSPICE for TI)
- TI (TINA-TI)
- Generic Spice models which can be used in any simulator.
- Analog/Linear Tech (LTspice)
- MPS (MPSmart)
- Any sim tool (downloaded models)

Reference Designs

- TI (TI Designs)
- ADI (Circuits from the Lab)

TI Power Management portfolio

 <h2>LDO Regulators</h2> <ul style="list-style-type: none">• Single Channel LDO• Multi Channel LDO• LDO Controllers	 <h2>DC/DC Regulators</h2> <ul style="list-style-type: none">• Step-down (Buck) • Step-Up (Boost) • Buck-boost & Invertin 	 <h2>Power Switches</h2> <ul style="list-style-type: none">• Load switches• eFuses & hot swap• Ideal Diode• Power Muxes• Smart power switches• Low side switches	 <h2>Power MOSFETs</h2> <ul style="list-style-type: none">• N-channel MOSFET • P-channel MOSFET • Power stages• Power blocks 	 <h2>IGBT, MOSFET Gate Drives</h2> <ul style="list-style-type: none">• Low-side drivers • Half-bridge drivers • Isolated gate drivers• Motor drivers
 <h2>Offline and Isolated DC/DC</h2> <ul style="list-style-type: none">• Power Factor Correction (PFC) controllers • PWM and resonant controllers • Flyback controllers • Flyback controllers 	 <h2>LED Drivers</h2> <ul style="list-style-type: none">• Automotive LED drivers• Backlight LED drivers• Flash LED drivers• General lighting LED drivers• RGB & white LED driver	 <h2>Battery Management</h2> <ul style="list-style-type: none">• Battery charger Ics• Battery fuel gauges• Battery protecotrs• Battery monitors and balancers	 <h2>Power Special Functions</h2> <ul style="list-style-type: none">• DDR memory• USB power• PoE• Supervisor & reset ICs• Sequencers	 <h2>Other</h2> <ul style="list-style-type: none">• 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

The screenshot displays the WEBENCH Power Designer web application interface. At the top, a red navigation bar contains the text "WEBENCH® POWER DESIGNER" and "MY DESIGNS" with a user profile icon. The main content area is titled "Create a new DC/DC power design" and includes a descriptive paragraph about the tool's capabilities. Below this is a search bar labeled "Part Number". The interface is divided into three main sections: "Input", "Output", and "Design Consideration".

Input Section: "Supply type is" with "DC" selected and "AC" as an alternative. "Vin Min*" is set to 14 V (range 0-1000) and "Vin Max*" is set to 22 V (range 0-1000). An "Advanced" dropdown menu is visible at the bottom.

Output Section: "Vout*" is set to 3.3 V (range -80-500) and "Iout Max*" is set to 2 A (range 0-180). An "Isolated Output" toggle switch is currently turned off. An "Advanced" dropdown menu is visible at the bottom.

Design Consideration Section: "I want my design to be" with "Balanced" selected, and "Low Cost", "High Efficiency", and "Small Footprint" as other options. A "Design Parameters" dropdown menu is visible at the bottom.

A red "VIEW DESIGNS" button is located at the bottom left of the interface.

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

The screenshot displays the WEBENCH Power Designer interface. At the top, the header reads "WEBENCH® POWER DESIGNER" with navigation options for "NEW DESIGN" and "MY DESIGNS". Below the header, the user is prompted to "Select a Design" with input parameters: "Input: DC 14 V - 22 V", "Output: 3.3 V at 2 A", and "Temp: 30 °C". The interface is divided into a left sidebar for filters and a main area for design results.

Filters Sidebar:

- Filters:** CLEAR FILTERS
- Filter by Part Number: _____
- Regulator Type:**
 - Module (Integrated Inductor)
 - Converter (Integrated Switch)
 - Controller (External Switch)
- Design Attributes:**
 - Efficiency (%):** 72 - 95
 - BOM Cost (\$):** 1 - 21
 - Footprint (mm²):** 78 - 1564
 - Switching Frequency (kHz):** 52 - 2100
 - Inductor Ripple Current (A):** 0 - 2

Main Design Results:

261 matching designs out of 262 total designs. Sort by: Default. TABLE VIEW.

Two design cards are visible, each featuring a circuit diagram and key specifications:

- TPS54239E:** 4.5V to 23V Input, 2-A Synchronous Step-Down Converter with Eco-Mode. Efficiency: 87.7%, BOM Cost: \$2.00, Footprint: 232 mm². BOM Count: 14, Topology: Buck, Frequency: 646.31 kHz. IC Cost: \$0.60 | 1ku. Actions: CUSTOMIZE, SIMULATE, EXPORT.
- TPS54339:** 4.5V to 23V Input, 3A Synchronous Step-Down Converter with D-CAP2 Mode. Efficiency: 87.8%, BOM Cost: \$2.10, Footprint: 232 mm². BOM Count: 14, Topology: Buck, Frequency: 646.31 kHz. IC Cost: \$0.70 | 1ku. Actions: CUSTOMIZE, SIMULATE, EXPORT.

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 NEW DESIGN MY DESIGNS

Customize TPS54360DDAR - 14V-22V to 3.30V @ 2A
Input: DC 14 V - 22 V Output: 3.3 V at 2 A Temp: 30 °C [Change](#)

SELECT CUSTOMIZE SIMULATE EXPORT

Summary

Efficiency: 84.7%
BOM Cost: \$3.25
Footprint: 308 mm²

[CHANGE OPTIMIZATION](#)

Configuration Options

Mode of Operation: INTERNAL_UVLO

User Preferred Frequency

Switching Frequency: 0.604 MHz
(@ 1.11111111)

Output Cap Options: AutoSelect

Max Peak to Peak Inductor Ripple: %
(0 - 200)

Max Component Height: mm
(0 - 10 k)

[REDESIGN](#)

Design Suggestions

[Add Input EMI Filter](#)

SCHEMATIC PCB LAYOUT BILL OF MATERIALS

Click a component to find out more information or select an alternate part.

OPERATING VALUES CHARTS

Vin (V) 22 V Iout (A) 2 A [RECALCULATE](#)

Categories: System Information Capacitor IC Inductor Diode Power All

Name	Value	Description
Phase Marg	66.04 *	Bode Plot Phase Margin

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

Simulate

- Electrical simulation

The screenshot displays the WEBENCH Power Designer interface. At the top, the title bar reads "WEBENCH® POWER DESIGNER" with options for "NEW DESIGN" and "MY DESIGNS". The main header shows the simulation configuration: "Simulate TPS54239EDDAR - 14.0V-22.0V to 3.30V @ 2.0A". Below this, it specifies "Input: DC 14V-22V", "Output: 3.3V at 2A", and "Temp: 30°C".

The left sidebar contains a "Simulations" section with a "Run New Simulation" button and radio buttons for "Startup", "Load Transient", "Input Transient", and "Steady State". A "START" button is also present. Below this, "Simulation Jobs" are listed, with "Load Transient - 1" selected and marked with a checkmark.

The main workspace is titled "Load Transient - 1" and is split into two panels. The left panel, "Schematic", shows a detailed circuit diagram of the TPS54239EDDAR converter, including the IC, input capacitors, output capacitors, and various resistors. The right panel, "Waveforms", displays a plot of "IOut sim: 1 (A)" versus "Time (sec)". The plot shows a transient response where the output current drops from approximately 2.0A to 0.8A, followed by a period of high-frequency oscillation, and then recovers back to 2.0A. The x-axis ranges from 0.2m to 0.7m seconds, and the y-axis ranges from 0.0 to 2.2A.

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

Simulate

- Electrical simulation

Export

- PDF report
- Export to CAD tools

The screenshot displays the WEBENCH Power Designer interface. At the top, the title bar reads "WEBENCH® POWER DESIGNER" with navigation options for "NEW DESIGN" and "MY DESIGNS". The main header shows the project name "Export TPS54360DDAR - 14V-22V to 3.30V @ 2A" and input parameters: "Input: DC 14 V - 22 V", "Output: 3.3 V at 2 A", and "Temp: 30 °C".

The interface is divided into several sections:

- Export Option:** A list of CAD tools with radio buttons: Altium Designer (selected), Cadence OrCAD, TINA-TI, CadSoft EAGLE, Mentor Graphics, and P-CAD. Below this is a note about Altium export and an "EXPORT DESIGN" button.
- Design Information:** A section titled "Schematic" showing a circuit diagram of a buck converter.
- PCB Layout:** A section showing four views of the PCB layout: Top, Mid 1, Mid 2, and Bottom.
- Summary:** A table of key metrics:

Efficiency:	84.7%
BOM Cost:	\$3.25
Footprint:	308 mm ²
BOM Count:	14
Topology:	Buck
Frequency:	604 kHz
IC Cost:	\$2.09 1ku

Below the table is a "PRINT REPORT" button.
- Bill of materials:** A section at the bottom of the interface.

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, $T_a = 30^\circ\text{C}$
- TPS40210 is a boost controller IC with adjustable switching frequency and other features

WEBENCH® POWER DESIGNER NEW DESIGN MY DESIGNS

Select a Design
Input: DC 5 V - 6 V Output: 12 V at 5 A Temp: 30 °C [Change](#)

Filters CLEAR FILTERS 25 matching designs out of 25 total designs Sort by: Default TABLE VIEW

Filter by Part Number

Regulator Type

- Module (Integrated Inductor)
- Converter (Integrated Switch)
- Controller (External Switch)

Design Attributes

Efficiency (%)
0 - 97

BOM Cost (\$)
4 - 15

Footprint (mm²)
465 - 2070

Switching Frequency (kHz)
176 - 548

Output Ripple (mV)
13 - 164

TPS40211 Compare

Wide Input Range Current Mode Boost Controller

Efficiency: 88.1% BOM Cost: \$4.10 Footprint: 764 mm² BOM Count: 23 Topology: Boost
Frequency: 512.78 kHz IC Cost: \$0.61 | 1ku

[CUSTOMIZE](#) [SIMULATE](#) [EXPORT](#)

TPS40210 Compare

4.5-52V Wide Input Range Boost/SEPIC/Flyback DC-DC Controller

Efficiency: 88.1% BOM Cost: \$4.24 Footprint: 765 mm² BOM Count: 23 Topology: Boost
Frequency: 512.78 kHz IC Cost: \$0.75 | 1ku

[CUSTOMIZE](#) [SIMULATE](#) [EXPORT](#)

DC/DC boost design using WEBENCH

- Select and compare
- Customize design

WEBENCH® POWER DESIGNER

NEW DESIGN MY DESIGNS

Customize TPS40210DGGR - 5V-6V to 12.00V @ 5A

Input: DC 5 V - 6 V Output: 12 V at 5 A Temp: 30 °C [Change](#)

SELECT CUSTOMIZE SIMULATE EXPORT

Summary

Efficiency: 88.1%

BOM Cost: \$4.24

Footprint: 765 mm²

[CHANGE OPTIMIZATION](#)

Configuration Options

User Preferred Frequency

Switching Frequency: 0.513 MHz (0.035 - 1)

User Sync Frequency

Sync Frequency: 0.513 MHz (0.035 - 1)

User Preferred Soft Start Time

Soft start Time: 1.1 ms (1 - 20)

Output Cap Options: AutoSelect

Max Peak to Peak Inductor Ripple: % (0 - 200)

Max Component Height: mm (0 - 10k)

SCHEMATIC BILL OF MATERIALS

Click a component to find out more information or select an alternate part.

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DC/DC boost design using WEBENCH

- Select and compare
- Customize design
- Simulate

WEBENCH® POWER DESIGNER NEW DESIGN MY DESIGNS

Simulate TPS40210DGQR - 5V-6V to 12.00V @ 5A
Input: DC 5 V - 6 V Output: 12 V at 5 A Temp: 30 °C [Change](#)

SELECT CUSTOMIZE **SIMULATE** EXPORT

Simulations Load Transient - 1

Run New Simulation

- Startup
- Load Transient
- Input Transient
- Steady State

START

Simulation Jobs

Load Transient - 1

Schematic

To change components, click Customize on the header

Waveforms

Show Marker

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

Performance Summary

The screenshot displays a detailed circuit schematic of a boost converter. The schematic includes an input DC source (Vin), an input capacitor (Cin), a boost inductor (L1), a MOSFET switch (M1), a diode (D1), and an output capacitor (Cout). The output is connected to a load resistor (Rload). The simulation parameters are set for a DC input of 5V-6V, an output of 12V at 5A, and a temperature of 30°C. The waveform plot shows the output current (Iout sim: 1 (A)) and output voltage (Vout sim: 1 (V)) over a 5ms period. The current starts at approximately 4.5A, drops to about 2.5A at 1ms, and then rises to 5A at 2.5ms. The voltage starts at approximately 5.5V, drops to about 11.5V at 1ms, and then rises to 12.0V at 2.5ms. The performance summary section is partially visible at the bottom.

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.
- $I_{peakcurrentlimit} \geq \left(1 + \frac{\delta}{2}\right) * \frac{I_{out} * V_{out}}{V_{inMin}}$
- So, for a 30% peak-to-peak inductor ripple current, with $V_{inMin} = 1.8V$, $V_{out}=5V$, $I_{peakcurrentlimit} = 4A$ (from datasheet)
- Maximum current that can be handled by the controller is

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

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

WEBENCH® POWER DESIGNER

NEW DESIGN MY DESIGNS

Export TPS40210DGQR - 5V-6V to 12.00V @ 5A

Input: DC 5 V - 6 V Output: 12 V at 5 A Temp: 30 °C [Change](#)

SELECT CUSTOMIZE SIMULATE EXPORT

Export Option

Altium Designer

TINA-TI

In your Altium export, you will get schematic, board, and simulation files for Altium Designer. For simulation you will need to download and install the [WEBENCH Altium Connector](#) to open the exported design in Altium Designer. For more information, check README file inside the download.

EXPORT DESIGN

Summary

Efficiency: 88.1%

BOM Cost: \$4.24

Footprint: 765 mm²

BOM Count: 23

Topology: Boost

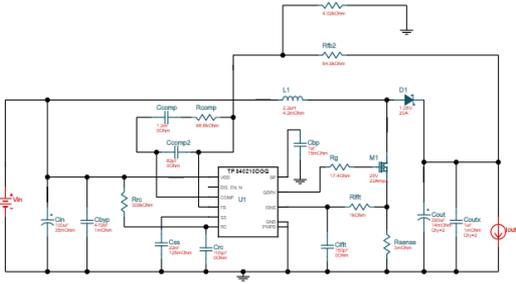
Frequency: 512.78 kHz

IC Cost: \$0.75 | 1ku

PRINT REPORT

Design Information

Schematic



Bill of materials

*Footprint is component footprint plus 1 mm per side.

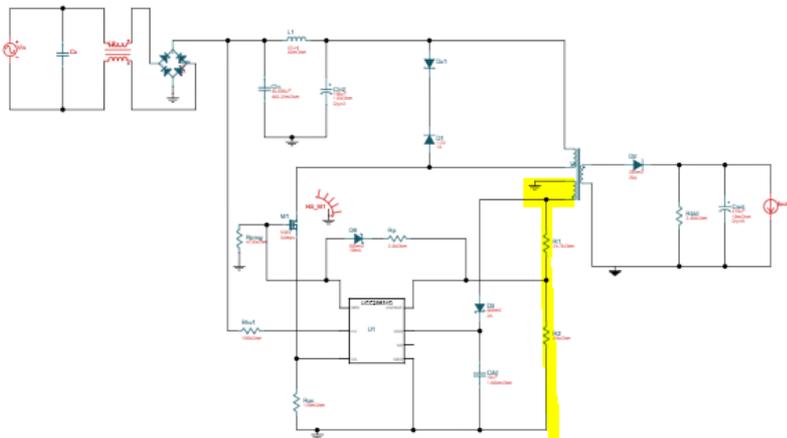
Part	Manufacturer	Part Number	Quantity	Total Price (\$)	Attribute	Total Footprint (mm²)	Top View
------	--------------	-------------	----------	------------------	-----------	-----------------------	----------

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.

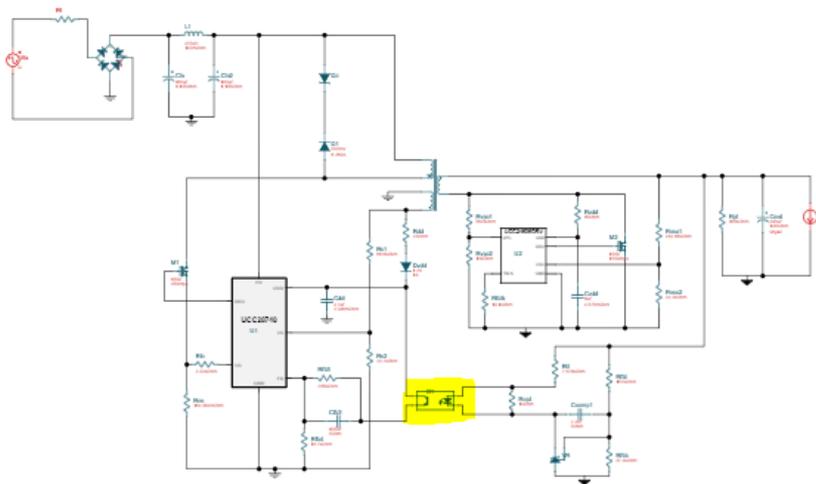
Isolated flyback design in WEBENCH

- 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 response₂₁

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

The screenshot displays the WEBENCH POWER DESIGNER interface. At the top, the header reads "WEBENCH® POWER DESIGNER" with navigation options for "NEW DESIGN" and "MY DESIGNS". Below the header, the design parameters are: "Input: AC 85 V - 265 V at 60.0 Hz", "Output: Isolated 15 V at 5 A", and "Temp: 30 °C". The interface is divided into several sections:

- Filters:** A sidebar on the left with "CLEAR FILTERS" and three sliders for "Inductor Ripple Current (A)" (range 2-4), "BOM Count" (range 24-55), and dropdown menus for "Topology", "IC Package", "IC Features", "Control Mode", and "Features".
- Search Results:** A central area showing "37 matching designs out of 37 total designs". It lists two designs with their respective circuit diagrams and specifications:

Design Name	IC	Topology	Efficiency	BOM Cost	Footprint	BOM Count	IC Cost
LM5023	LM5023	Flyback	80.4%	NA	NA	41	\$0.43 1ku
UCC28740-UCC24636	UCC28740-UCC24636	Flyback	78%	NA	NA	39	\$0.42 1ku

Each design entry includes a "Compare" checkbox and buttons for "CUSTOMIZE", "SIMULATE", and "EXPORT".

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

WEBENCH® POWER DESIGNER NEW DESIGN MY DESIGNS

Customize LM5023MM-2/NOPB - 85V-265V to 15.00V @ 5A

Input: AC 85 V - 265 V at 60.0 Hz Output: Isolated 15 V at 5 A Temp: 30 °C [Change](#) [SELECT](#) [CUSTOMIZE](#) [SIMULATE](#) [EXPORT](#)

Summary

Efficiency: 80.7%
BOM Cost: \$11.44
Footprint: 3879 mm²

[CHANGE OPTIMIZATION](#)

Design Suggestions

[Design a transformer using Core/CoilFormer?](#)

SCHEMATIC **BILL OF MATERIALS**

Click a component to find out more information or select an alternate part.

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Isolated flyback design in WEBENCH

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

The screenshot displays the WEBENCH POWER DESIGNER interface for a design titled "Export LM5023MM-2/NOPB - 85V-265V to 15.00V @ 5A". The design parameters are: Input: AC 85 V - 265 V at 60.0 Hz, Output: Isolated 15 V at 5 A, Temp: 30 °C. The interface includes a navigation bar with "NEW DESIGN" and "MY DESIGNS" buttons, and a main menu with "SELECT", "CUSTOMIZE", "SIMULATE", and "EXPORT" options. A "Summary" panel on the left lists key metrics: Efficiency: 80.7%, BOM Cost: \$11.44, Footprint: 3879 mm², BOM Count: 41, Topology: Flyback, Frequency: 54.44 kHz, and IC Cost: \$0.43 | 1ku. A "PRINT REPORT" button is located below the summary. The "Design Information" section features a "Schematic" view of the circuit. The "Bill of materials" section includes a table with columns for Part, Manufacturer, Part Number, Quantity, Total Price, Attribute, Total Footprint, and Top View, along with a download icon and a note: "*Footprint is component footprint plus 1 mm per side."

Part	Manufacturer	Part Number	Quantity	Total Price	Attribute	Total Footprint	Top View
------	--------------	-------------	----------	-------------	-----------	-----------------	----------

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.

TI Home > Semiconductors > Power management > Offline & isolated DC/DC controllers & converters > Flyback controllers >

LM5023(ACTIVE) In English Alert me

AC-DC Quasi-Resonant Current Mode PWM Controller

DATASHEET
LM5023 AC-DC Quasi-Resonant Current Mode PWM Controller datasheet (Rev. E)
View now Download

Description & parameters | Technical documents | **Design & development** | Order now | Quality & packaging

Models | Design kits & evaluation modules | Reference designs | Software | Development tools | TI design network

Models (3)

Title	Category	Type	Date
LM5023 PSpice Transient Model	PSpice Model	ZIP	31 May 2013
LM5023 TINA-TI Transient Reference Design	TINA-TI Reference Design	TSC	20 Jun 2013
LM5023 TINA-TI Transient Spice Model	TINA-TI Spice Model	ZIP	20 Jun 2013

snvm471 - Schematic Editor

File Edit Insert View Analysis T&M Tools TI Utilities Help

Basic | Switches | Meters | Sources | Semiconductors | Spice Macros

WEBENCH Design Center

LM5023 Startup Schematic

snvm471

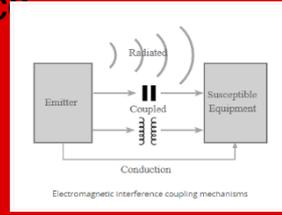
Exit

X: 832 Y: 788

Power supply design challenges

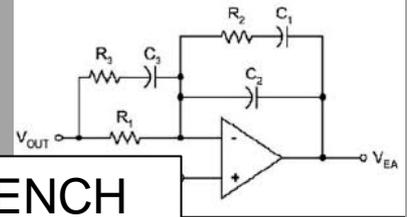
Electromagnetic interference

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

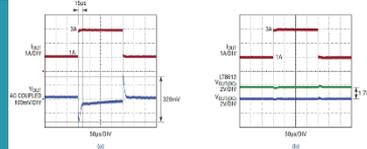
Transformer

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



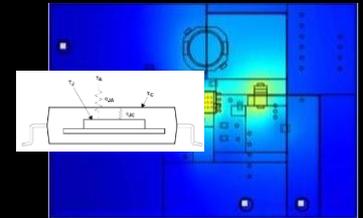
Transient specification

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:
<p>Customer wants a design using: TPS54824 V_{IN}: 8-14 V ; V_{OUT}: 1.8 V ; I_{OUT}: 8 A</p> <p>Design consideration:</p> <ul style="list-style-type: none">• Small footprint.• Low output noise.• High accuracy.• Fast load transient response. <p>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}</p>	<p>Use WEBENCH to create design for customer input conditions.</p> <p>Use optimization to trade-off for small footprint design.</p> <p>Review the design spec.</p> <p>Customize design to meet tolerance specification.</p> <p>Use advanced options in WEBENCH to meet the transient requirements</p> <p>Validate the design using simulations.</p>

Design buck POL w/ strict transient specs

Step 1:
Create design with customer specifications.

Create a new DC/DC power design

WEBENCH® Power Designer creates customized power supply circuits based on your requirements. The environment gives you end-to-end power supply design capabilities that save you time during all phases of the design process. [Learn more](#)

Q TPS54824 ×

Great! We found **TPS54824** and auto-filled the inputs for you

Input

Supply type is

DC AC

Vin Min * 8 V (4.5 - 17) Vin Max * 14 V (4.5 - 17)

Advanced ▾

Output

Vout * 1.8 V (0.6 - 12) Iout Max * 8 A (0 - 8)

Isolated Output

Advanced ▾

Design Consideration

I want my design to be

Balanced Low Cost High Efficiency **Small Footprint**

Design Parameters ▾

[VIEW DESIGN TPS54824](#)

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 mm ²	157 mm ²	180 mm ²	219 mm ²
	SELECT	SELECT	SELECT	SELECT

Design buck POL w/ strict transient specs

Step 3:

Validate design spec using OpVals and simulations.

$$V_{OUT} \text{ p-p} = 19 \text{ mV}$$

$$V_{OUT} \text{ tolerance} = 2.19\%$$

$$V_{OVERSHOOT} = 110 \text{ mV}$$

$$V_{UNDERSHOOT} = 110 \text{ mV}$$

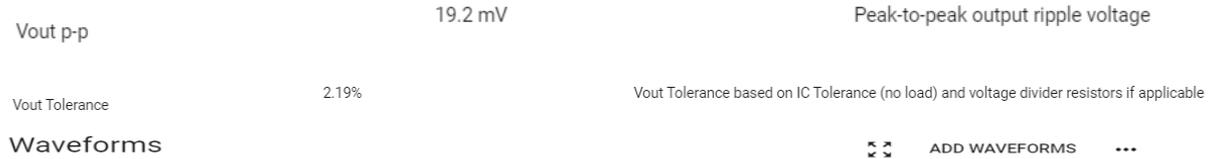
Required:

$$V_{OUT} \text{ p-p} < 18 \text{ mV}$$

$$V_{OUT} \text{ tolerance} < 1\%$$

$$V_{OVERSHOOT} < 90 \text{ mV}$$

$$V_{UNDERSHOOT} < 90 \text{ mV}$$



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



Custom Load Transient Specs

Transient response voltage change(% Vout)

3

(0.1 - 100)

Transient response current step

6

(0.08 - 7.92)

Step 4:

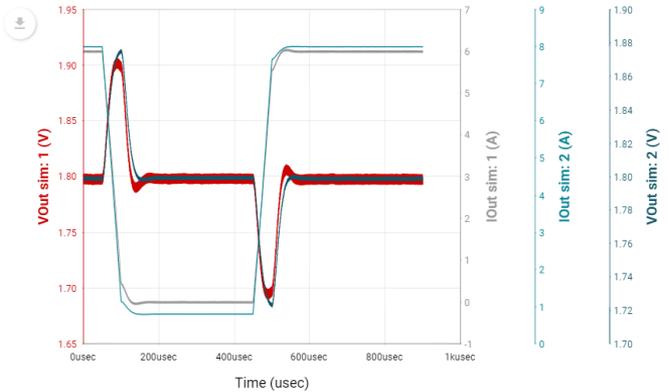
Customize design to meet the specifications. Update the design to meet transient spec using advanced options.

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

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
2	1.88 V	1.72 V	0.09 ms	0.09 ms	0.08 V	0.08 V
1	1.91 V	1.69 V	0.09 ms	0.08 ms	0.11 V	0.11 V

33

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) =

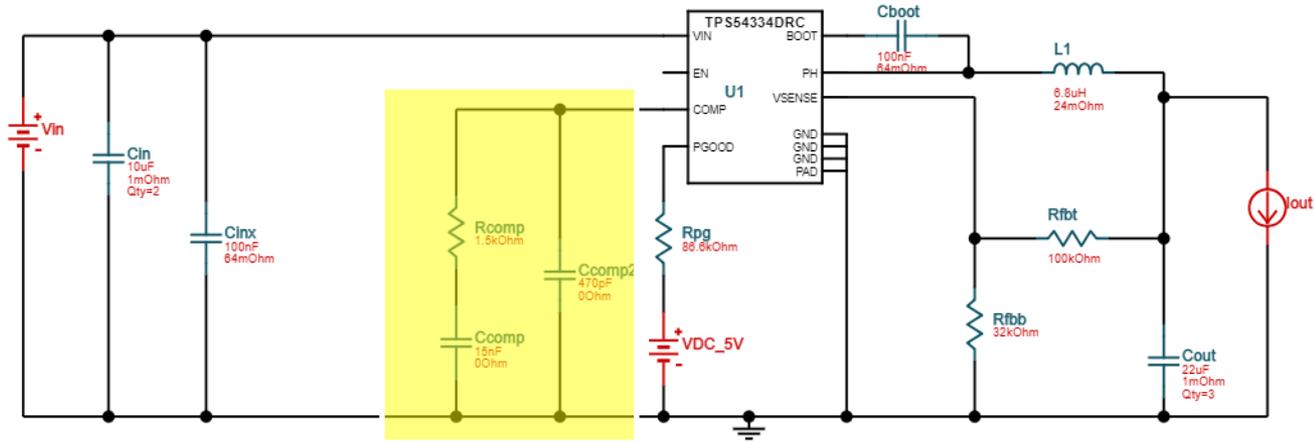
0.97%

Rf1t	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
Rf1b	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:
<p>Customer wants a design using: TPS40210</p> <p>Vin: 5-6V Vout: 12V Iout: 5A</p> <p>Customer has specified a 5.6 uH inductor that is on the customer's approved vendor list.</p>	<p>Use alternate part selection to select a 5.6 uH inductor and customize the design for this inductor.</p> <p>Check the resulting design for phase margin and crossover frequency and run a load transient simulation to confirm the behavior.</p> <p>Use the Re-Compensation feature to re-design compensation and validate the design using simulations.</p>

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

NEW DESIGN MY DESIGNS

Simulate TPS40210DGQR - 5V-6V to 12.00V @ 5A
Input: DC 5V - 6V Output: 12 V at 5 A Temp: 30 °C [Change](#)

SELECT CUSTOMIZE **SIMULATE** EXPORT

Simulations

Run New Simulation

- Startup
- Load Transient
- Input Transient
- Steady State

[START](#)

Simulation Jobs

- Load Transient - 5** ✓
- Load Transient - 4 ✓
- Load Transient - 3 ✓
- Load Transient - 2 ✓
- Steady State - 1 ✓

Load Transient - 5

Schematic

Waveforms

Show Marker

ADD WAVEFORMS

Total BOM \$8.12 Total BOM Cost

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Max Peak to Peak Inductor Ripple %
(0 - 200)

Max Component Height mm
(0 - 10 k)



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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)

$$T_j = T_a + (P_d * R_{\theta JA})$$

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

The screenshot displays the WEBENCH POWER DESIGNER interface for a power converter design. The main title is "Customize TPS62802YKAR - 4.5V-5.5V to 3.30V @ 1A". The input parameters are DC 4.5 V - 5.5 V, Output: 3.3 V at 1 A, and Temp: 100 °C. The interface is divided into several sections: Summary, Configuration Options, Design Suggestions, and a central Schematic view. The Summary section shows Efficiency: 92.1%, BOM Cost: NA, and Footprint: NA. The Configuration Options section shows Mode of Operation: Auto PSM. The Design Suggestions section has a button for "Add Input EMI Filter". The Schematic view shows a power converter circuit with a transformer (10nH, 1mOhm), a capacitor (Cout, 10uF, 1mOhm), and an output load (Iout). An "Alert Center" dialog box is open, displaying a warning: "U1 Junction temperature is too high" with a temperature of 131.92 °C and a specification of <math><130.00\text{ }^\circ\text{C}</math>. The dialog box provides suggested actions: "Suggested: <math><130.00\text{ }^\circ\text{C}</math>" and "This may lead to a device malfunction or breakdown. Some possible solutions are below:" followed by a list of solutions: "Decrease Switching Frequency to decrease MOSFET or Diode switching losses", "Decrease ambient temperature", "Decrease thermal resistance by adding a heat sink if feasible", and "Increase the copper area and thickness of the board". The dialog box also includes a "WEBENCH® Disclaimer" and a "CLOSE" button.

WEBENCH® POWER DESIGNER

NEW DESIGN MY DESIGNS

Customize TPS62802YKAR - 4.5V-5.5V to 3.30V @ 1A

Input: DC 4.5 V - 5.5 V Output: 3.3 V at 1 A Temp: 100 °C [Change](#)

SELECT CUSTOMIZE SIMULATE EXPORT

Summary

Efficiency: 92.1%
BOM Cost: NA
Footprint: NA

[CHANGE OPTIMIZATION](#)

Configuration Options

Mode of Operation
Auto PSM

[REDESIGN](#)

Design Suggestions

[Add Input EMI Filter](#)

Schematic PCB LAYOUT BILL OF MATERIALS

Click a component to find out more information or select an alternate part.

Alert Center

Vin: 5.5 V Vout: 3.3 V Iout: 1 A Temp: 100 °C

U1 Junction temperature is too high U1 Tj:131.92 °C Specification: <math><130.00\text{ }^\circ\text{C}</math>

Suggested: <math><130.00\text{ }^\circ\text{C}</math>
This may lead to a device malfunction or breakdown.
Some possible solutions are below:

- Decrease Switching Frequency to decrease MOSFET or Diode switching losses
- Decrease ambient temperature
- Decrease thermal resistance by adding a heat sink if feasible
- Increase the copper area and thickness of the board

WEBENCH® Disclaimer

[CLOSE](#)

10nH 1mOhm

Cout 10uF 1mOhm

Iout

TEXAS INSTRUMENTS

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WEBENCH® Power Designer

Solving EMI design challenges

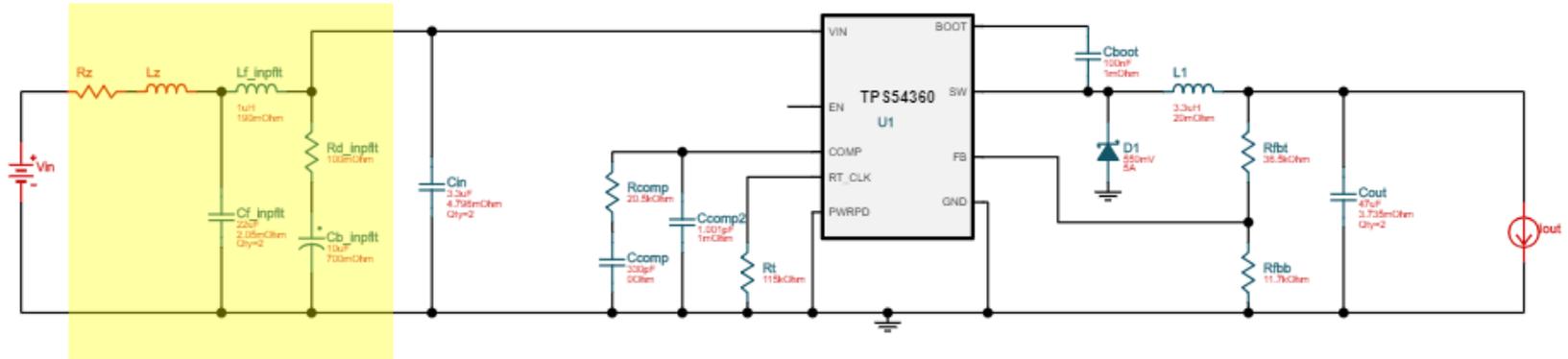
WEBENCH input EMI filter design

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:
<p>A customer wants to design a power supply for an automotive infotainment system.</p> <p>Device: LM5117-Q1</p> <p>V_{IN}: 8V-15 V</p> <p>V_{OUT}: 3.3 V</p> <p>I_{OUT}: 10 A</p> <p>Requirements:</p> <ol style="list-style-type: none">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.	<p>Design high efficiency power converter using LM5117-Q1 and customer input conditions in WEBENCH.</p> <p>Using the “Add EMI filter” option, design and customize input filter to meet the customer standard.</p> <p>Apply to design and check simulations to make sure the filter and design is stable.</p>

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.

The screenshot displays the WEBENCH POWER DESIGNER interface for a simulation of an LM5117QPMH/NOPB converter. The simulation is titled "Steady State - 2" and is configured for a DC input of 8V-15V, an output of 3.3V at 10A, and a temperature of 30°C. The simulation menu on the left shows that the "Steady State - 2" simulation is selected and completed, while the "Bode Plot - 1" simulation is also completed. The main area shows a schematic diagram of the converter circuit and a waveform plot of the input voltage (Vin sim: 2 (V)) over time (0 to 60 microseconds). The waveform shows a steady-state input voltage of approximately 11.20V with a high-frequency ripple. The bottom of the interface displays the simulation results: Efficiency is 94.4% (Steady state efficiency) and Frequency is 220.83 kHz (Switching frequency).

Parameter	Value	Description
Efficiency	94.4%	Steady state efficiency
Frequency	220.83 kHz	Switching frequency

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

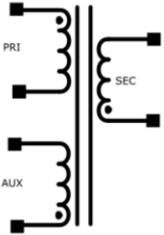
WEBENCH® Transformer Report

Design : 5030 LM5023MM-2/NOPB
LM5023MM-2/NOPB 85V-265V @ 15.00V @ 3.43A

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

Transformer Electrical Diagram

Primary		Secondary	
Turns	26.0	Turns	6.0
AWG	27.0	AWG	27.0
Layers	4.0	Layers	1.0
Strands	3.0	Strands	2.0
Insulation Type	Heavy Insulated Magnet Wire	Insulation Type	Triple Insulated



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

Transformer Losses (W)	Core Losses (W)	Copper Losses (W)	Core Geometry factor (mm²)	CBsat (T)	Number of Pins	Top View
2.69	1.34	1.34	9431	0.39	10	
2.56	1.28	1.28	8486	0.39	12	
2.72	1.36	1.36	9125	0.39	12	

[Print transformer details](#)

Transformer Construction Details

Property	Value
Primary Turns	41
Primary AWG	26
Primary Insulation	Heavy Insulated Magnet Wire
Primary Layers	4
Primary	3

CANCEL SELECT

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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

The screenshot shows the Texas Instruments website interface. At the top, there is a navigation bar with the TI logo and the text 'TEXAS INSTRUMENTS'. Below this is a search bar and a menu with tabs: 'Products', 'Applications', 'Design resources', 'Support & training', 'Order now', and 'About TI'. The 'Design resources' tab is active, and a sub-menu is displayed with categories: 'Reference designs >', 'Design tools & simulation >', and 'Embedded development >'. Under 'Design tools & simulation >', the 'WEBENCH® Power Designer' link is circled in red, and a red arrow points from this link to the text in the left-hand list. Below the navigation is a large banner for 'SimpleLink MCU' with the headline 'Say goodbye to quartz crystals'. The banner text reads: 'Introducing the world's first crystal-less wireless MCU, made possible by TI BAW resonator technology'. It lists three bullet points: 'No dependency on quartz crystals', 'Stable at +/-40ppm across full operating range', and 'An average of 12% PCB space savings'. A 'Find out more' button is located at the bottom of the banner. Below the banner, there is a section titled 'Recommendations from TI.com:' which contains three cards: 'REFERENCE DESIGN' with an image of a circuit board, another 'REFERENCE DESIGN' with an image of a PCB, and an 'APPLICATION' card with a diagram.



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