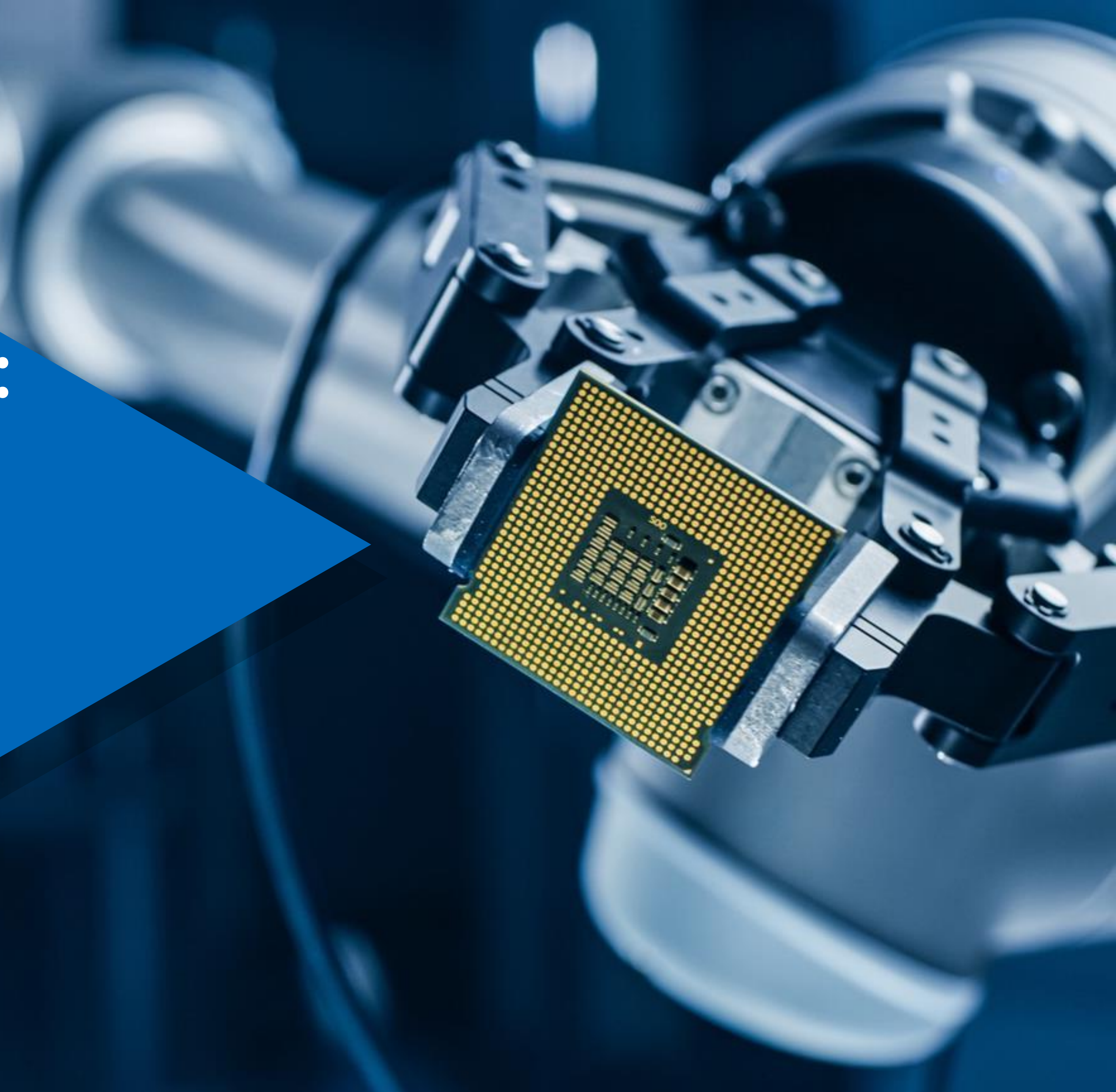
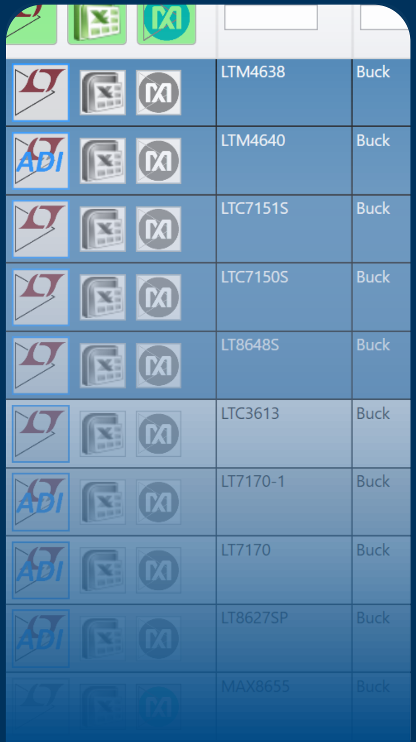
ADI Power Seminar: Power Supply Design using LTpowerCAD

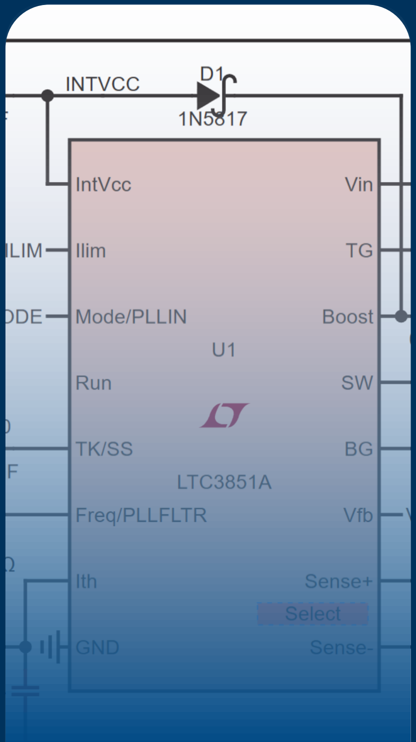
Jake Ciolfi



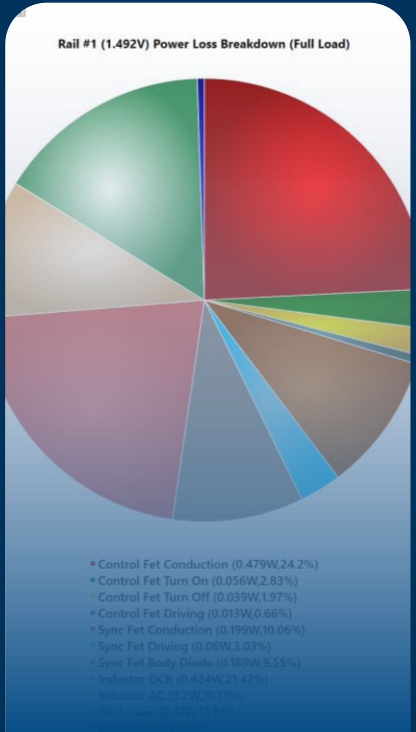
LTpowerCAD: Power Supply Design in 5 Easy Steps



Product Selection



Schematic
(warnings, suggest)



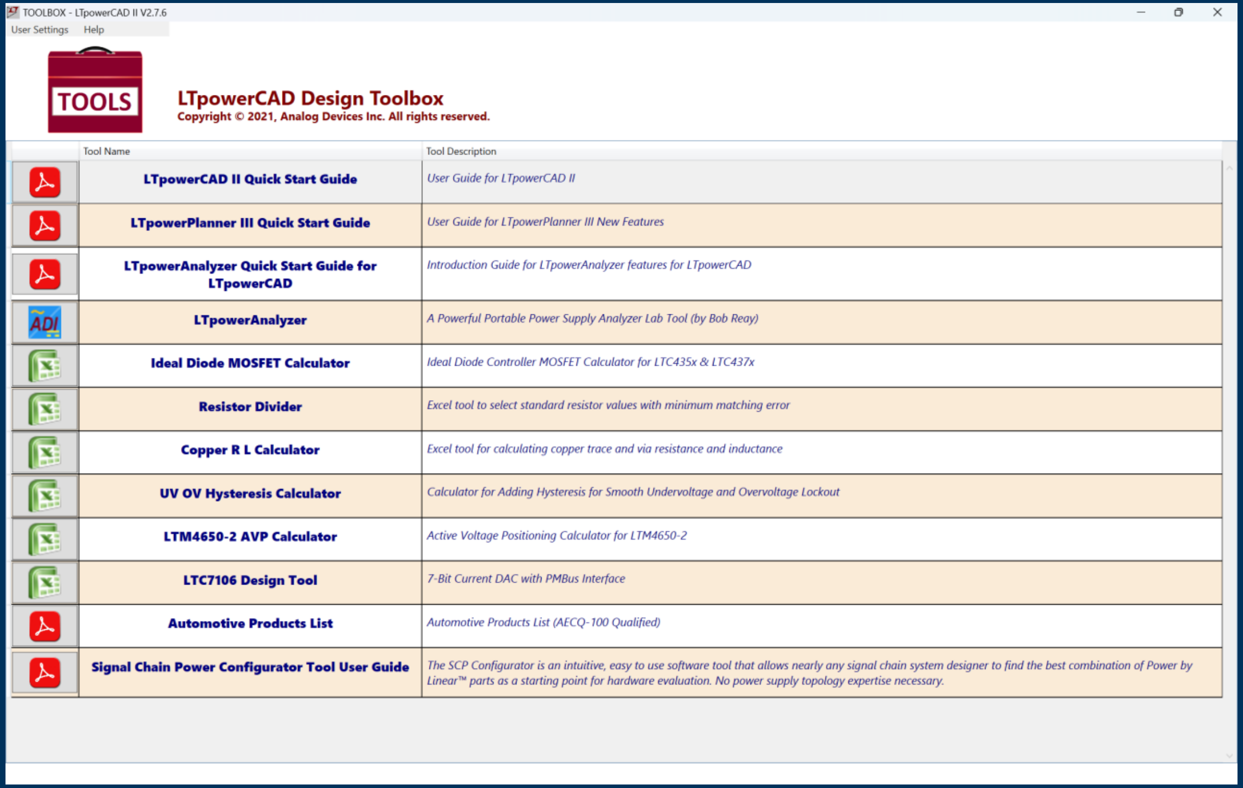
Optimize Efficiency

Optimize Transient, Loop

Design Summary, Cost

Free download @ www.analog.com/LTpowerCAD

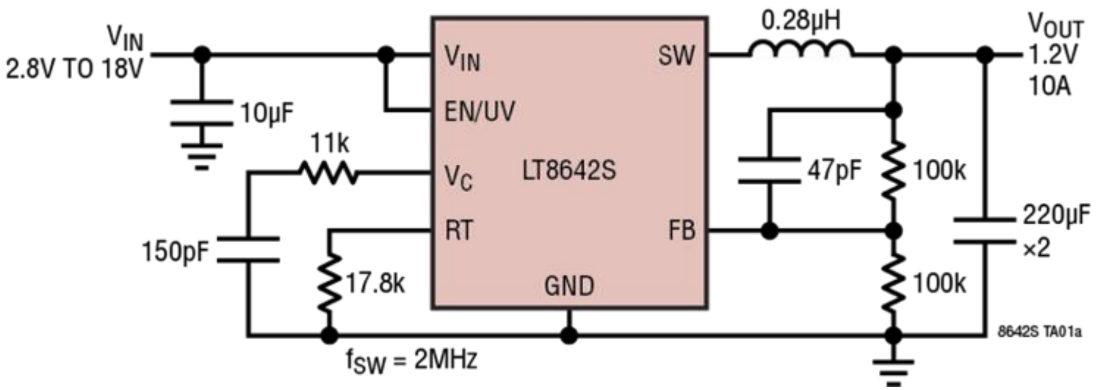
LTpowerCAD: Tools & Advanced Features



Tool Name	Tool Description
LTpowerCAD II Quick Start Guide	User Guide for LTpowerCAD II
LTpowerPlanner III Quick Start Guide	User Guide for LTpowerPlanner III New Features
LTpowerAnalyzer Quick Start Guide for LTpowerCAD	Introduction Guide for LTpowerAnalyzer features for LTpowerCAD
LTpowerAnalyzer	A Powerful Portable Power Supply Analyzer Lab Tool (by Bob Reay)
Ideal Diode MOSFET Calculator	Ideal Diode Controller MOSFET Calculator for LTC435x & LTC437x
Resistor Divider	Excel tool to select standard resistor values with minimum matching error
Copper R L Calculator	Excel tool for calculating copper trace and via resistance and inductance
UV OV Hysteresis Calculator	Calculator for Adding Hysteresis for Smooth Undervoltage and Overvoltage Lockout
LTM4650-2 AVP Calculator	Active Voltage Positioning Calculator for LTM4650-2
LTC7106 Design Tool	7-Bit Current DAC with PMBus Interface
Automotive Products List	Automotive Products List (AECQ-100 Qualified)
Signal Chain Power Configurator Tool User Guide	The SCP Configurator is an intuitive, easy to use software tool that allows nearly any signal chain system designer to find the best combination of Power by Linear™ parts as a starting point for hardware evaluation. No power supply topology expertise necessary.

- Design Curves: how does the input voltage affect the operating point?
- EMI Filter Design: will your design pass common EMI certifications?
- Component Selection:
  - Browse from component library or add a new component
  - DC Bias derating
  - Effect of T_J in RDSON and DCR
- Auto-compensation
- Export/Print Plots

Example: Step-Down Design using LTpowerCAD



DC2560A: 18V, 10A Evaluation Kit featuring the LT8642S Silent Switcher 2 step down regulator

Evaluation Kits

DC2560A

18V, 10A Synchronous Step-Down Silent Switcher 2

LTpowerAnalyzer

EVAL-LTPA-KIT | Low-cost, High Performance, Compact Laboratory Tool for Evaluating and Characterizing Power Supply Designs

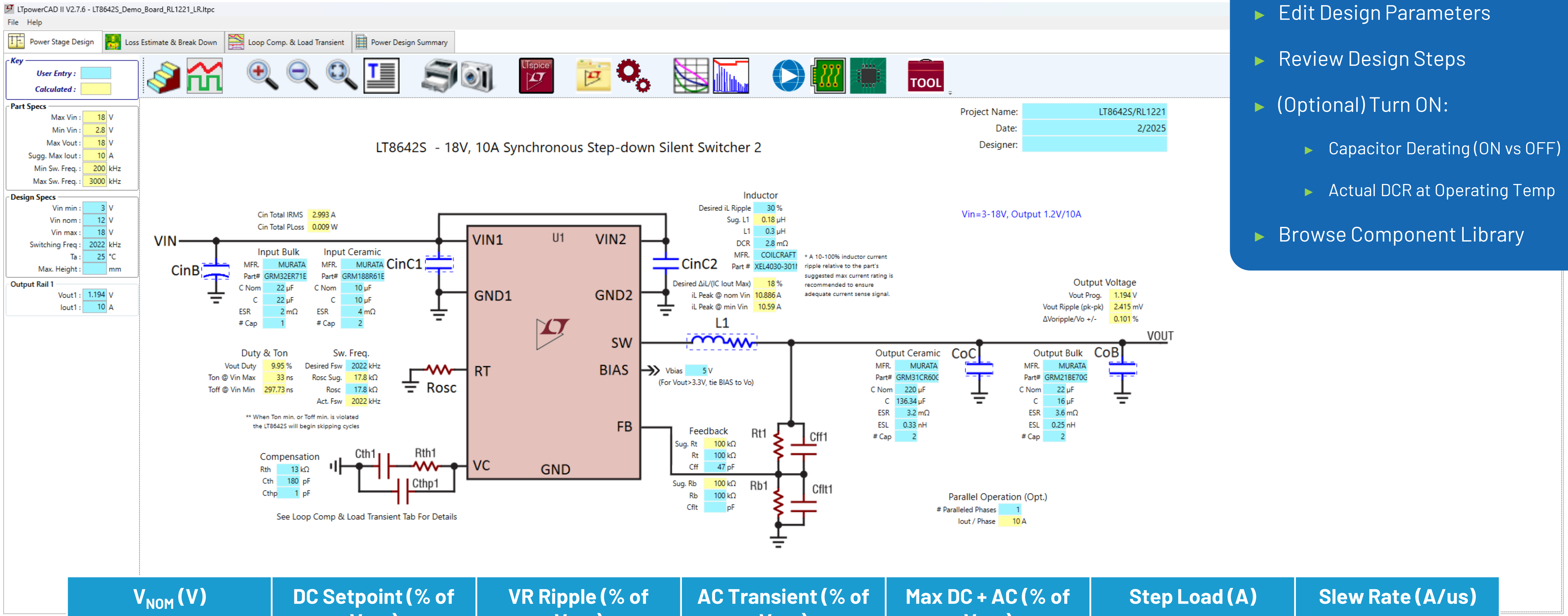
Specification	Value	Units
$V_{NOMINAL}$	1.2	V
DC Setpoint (% of V_{NOM})	0.5	%
VR Ripple (% of V_{NOM})	1	%
AC Transient (% of V_{NOM})	2.5	%
MAX DC + AC (% of V_{NOM})	3.0	%
Step Load	5	A
Slew Rate	10	A/us

+New AI/ML Processor Vendors

Automotive Datacenter Communication Industrial

FPGA and Processors Compatible Reference Designs | Analog Devices

Schematics and Power Stage Design



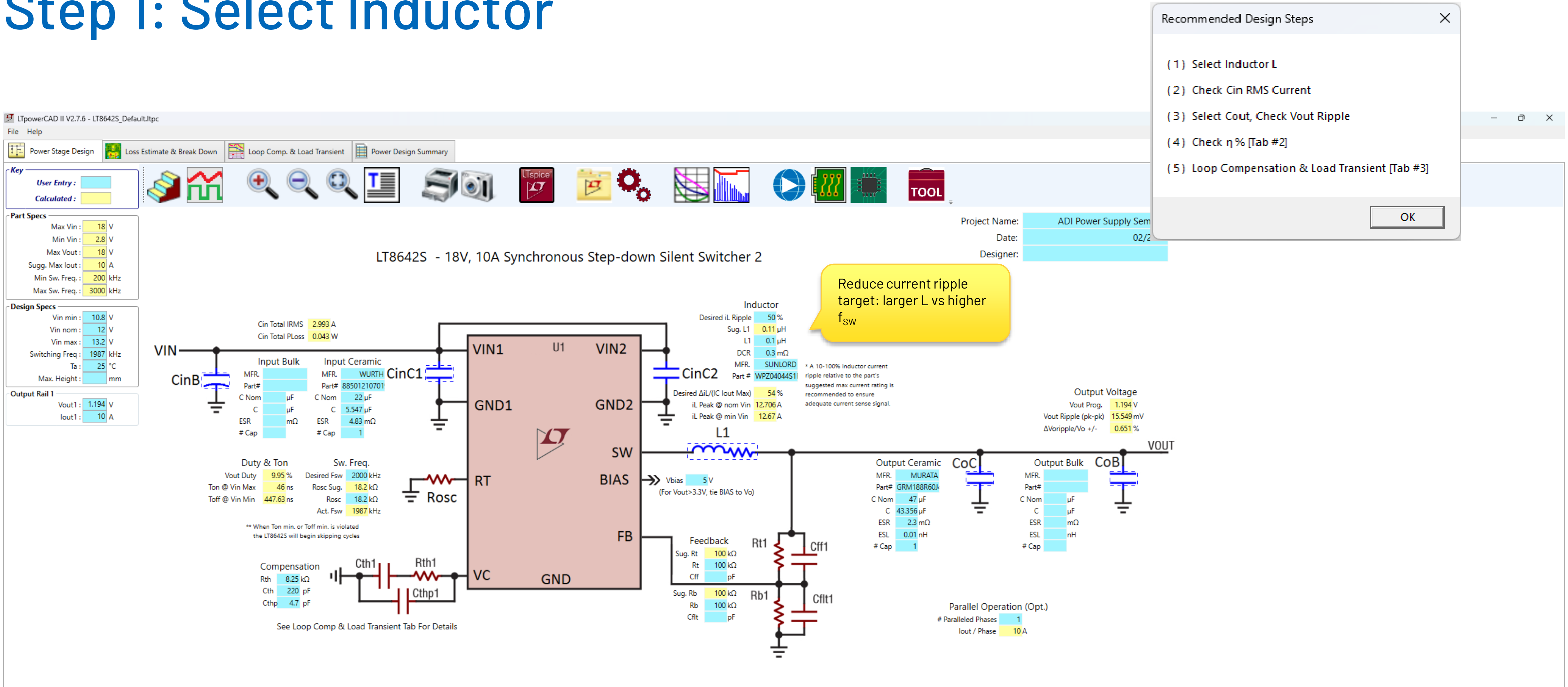
Power Stage Design Tab

- Edit Design Parameters
- Review Design Steps
- (Optional) Turn ON:
  - Capacitor Derating (ON vs OFF)
  - Actual DCR at Operating Temp
- Browse Component Library

V_{NOM} (V)	DC Setpoint (% of V_{NOM})	VR Ripple (% of V_{NOM})	AC Transient (% of V_{NOM})	Max DC + AC (% of V_{NOM})	Step Load (A)	Slew Rate (A/us)
1.2	0.5	1	2.5	3.0	5	10

LTpowerCAD File: ADIPowerSeminar_LT8642S_Default_Feb2025

Step 1: Select Inductor



V_{NOM} (V)	DC Setpoint (% of V_{NOM})	VR Ripple (% of V_{NOM})	AC Transient (% of V_{NOM})	Max DC + AC (% of V_{NOM})	Step Load (A)	Slew Rate (A/us)
1.0	0.5	1	2.5	3.0	5	10

LTpowerCAD File: ADIPowerSeminar_LT8642S_Inductor_Feb2025

Step 1: Select Inductor (Component Library)

Recommended Design Steps

(1) ~~Select Inductor L~~

(2) Check Cin RMS Current

(3) Select Cout, Check Vout Ripple

(4) Check η % [Tab #2]

(5) Loop Compensation & Load Transient [Tab #3]

OK

INDUCTOR Library

Search Settings | User Table Options

○ Show All ◉ Show Suggested ○ Show Suggested w/ AC Loss Info

Key : *Built-in Parts :* *User Parts :*

* Loss values calculated at Vin nom. and Iout max.

All Parts | User Parts

Vendor	Name	Area(mm2)	DC Loss(W)	AC Loss(W)	Total Loss(W)	L(µH)	L Tol(%)	DCR(mΩ)	DCR Tol(%)	I Sat(A)	L Dec.(%)	I Heat(A)	T Rise(C)	Core	L(mm)	W(mm)				
SUNLORD	WTX0430TR33MTR01	16	0.147			0.33	20	2	10	18.8	30	19.4	40	Metal	4	4				
SUNLORD	WTX0420TR33MTR01	16	0.22			0.33	20	3	20	15.7	30	19.9	40	Metal	4	4				
BOURNS	SRP4020TA-R33M	18.1	0.573			0.33	20	7.8	10	18	20	10	40	Carbonyl powder	4.45	4.06	1.8		150	True
COILCRAFT	**XGL4040-301MEC**	**18.5**	**0.162**	**0.097**	**0.259**	**0.3**	**20**	**2.2**	**10**	**15.3**	**30**	**24.6**	**40**	**Composite**	**4.3**	**4.3**	**4.1**	**80**	**165**	**True**
COILCRAFT	**XGL4030-301MEC**	**18.5**	**0.184**	**0.07**	**0.254**	**0.3**	**20**	**2.5**	**10**	**17**	**30**	**24**	**40**	**Ferrite**	**4.3**	**4.3**	**3.1**	**80**	**165**	**True**
COILCRAFT	**XEL4030-301MEB**	**18.5**	**0.206**	**0.073**	**0.279**	**0.3**	**20**	**2.8**	**10**	**19**	**30**	**18.9**	**40**	**Powdered Iron**	**4.3**	**4.3**	**3.2**	**80**	**165**	**True**
COILCRAFT	**XEL4030V-301MEC**	**18.5**	**0.206**	**0.073**	**0.279**	**0.3**	**20**	**2.8**	**10**	**19**	**30**	**18.9**	**40**	**Composite**	**4.3**	**4.3**	**3.2**	**120**	**165**	**True**
COILCRAFT	**XGL4025-331MEC**	**18.5**	**0.198**	**0.093**	**0.291**	**0.33**	**20**	**2.7**	**10**	**16.2**	**30**	**21.6**	**40**	**Composite**	**4.3**	**4.3**	**2.5**	**80**	**165**	**True**
COILCRAFT	**XGL4020-331MEC**	**18.5**	**0.22**	**0.123**	**0.343**	**0.33**	**20**	**3**	**10**	**15.2**	**30**	**23**	**40**	**Ferrite**	**4.3**	**4.3**	**2.1**	**80**	**165**	**True**
COILCRAFT	**XEL4020-331MEB**	**18.5**	**0.381**	**0.129**	**0.51**	**0.33**	**20**	**5.18**	**10**	**15.7**	**30**	**15.4**	**40**	**Powdered Iron**	**4.3**	**4.3**	**2.1**	**80**	**165**	**True**
COILCRAFT	**XEL4020V-331MEC**	**18.5**	**0.381**	**0.129**	**0.51**	**0.33**	**20**	**5.18**	**10**	**15.7**	**30**	**15.4**	**40**	**Composite**	**4.3**	**4.3**	**2.1**	**120**	**165**	**True**
COILCRAFT	**XGL4030-401MEC**	**18.5**	**0.205**	**0.089**	**0.294**	**0.4**	**20**	**2.8**	**10**	**15.5**	**30**	**22.5**	**40**	**Ferrite**	**4.3**	**4.3**	**3.1**	**80**	**165**	**True**
EPCOS / TDK	SPM5030T-R35M	26	0.286			0.35	20	3.9	10	14.9	20	16.6	40	Metal	5.2	5	3	40	125	False
EPCOS / TDK	SPM5030VT-R33M-D	27	0.309			0.33	20	4.2	10	24.9	30	14.2	40	Metal	5.3	5.1	3	40	155	True
PANASONIC	ETQP3MR33KVP	27.5	0.356			0.33	20	4.85	10	21.8	30	10.6	40	Metal Composite	5.5	5	3	55	155	True
BOURNS	SRP5030TA-R33M	27.6	0.316			0.33	20	4.3	20	18	20	14	40	Carbonyl powder	5.3	5.2	2.8		150	True
VISHAY	IHLP2020CZERR33M01	28.4	0.389			0.33	20	5.3	10	19	20	13.7	40	Powdered Iron	5.49	5.18	3		125	False
VISHAY	IHLP2020CZERR33MA1	28.4	0.389			0.33	20	5.3	10	19	20	13.7	40	Powdered Iron	5.49	5.18	3		125	True
VISHAY	IHLP2020BZERR33M01	28.4	0.558			0.33	20	7.6	10	25	20	12	40	Powdered Iron	5.49	5.18	2		125	False
SUNLORD	WTXE0530TR33MTR01	28.9	0.132			0.33	20	1.8	20	20.8	30	24.3	40	Metal	5.28	5.48	2.8	40	150	False
WURTH	784774003	30.2	0.441			0.33	20	6	33	15.3	10	10.8	40	NiZn	5.2	5.8	4.5		125	True
COILCRAFT	**XGL5050-331MEC**	**31.1**	**0.118**	**0.072**	**0.19**	**0.33**	**20**	**1.6**	**10**	**23.5**	**30**	**24.6**	**40**	**Composite**	**5.68**	**5.48**	**5.1**	**80**	**165**	**True**
COILCRAFT	**XGL5020-331MEC**	**31.1**	**0.198**	**0.095**	**0.293**	**0.33**	**20**	**2.7**	**10**	**18.8**	**30**	**24.4**	**40**	**Composite**	**5.68**	**5.48**	**2.1**	**80**	**165**	**True**
COILCRAFT	**XAL5030-331MEB**	**31.1**	**0.235**	**0.127**	**0.362**	**0.33**	**20**	**3.2**	**10**	**26**	**30**	**19.2**	**40**	**Powdered Iron**	**5.68**	**5.48**	**3.1**	**60**	**165**	**True**
COILCRAFT	**XAL5020-331MEB**	**31.1**	**0.47**	**0.108**	**0.578**	**0.33**	**20**	**6.4**	**10**	**17.1**	**30**	**14.4**	**40**	**Powdered Iron**	**5.68**	**5.48**	**2**	**60**	**130**	**True**
COILCRAFT	**XGL5030-351MEC**	**31.1**	**0.132**	**0.075**	**0.207**	**0.35**	**20**	**1.8**	**10**	**24.5**	**30**	**30.6**	**40**	**Composite**	**5.68**	**5.48**	**3.2**	**80**	**165**	**True**
COILCRAFT	**XGL5030-401MEC**	**31.1**	**0.161**	**0.085**	**0.246**	**0.4**	**20**	**2.2**	**10**	**23**	**30**	**25.1**	**40**	**Composite**	**5.68**	**5.48**	**3.2**	**80**	**165**	**True**
XFMRS	XFHCL22-R33M	31.3	0.512			0.33	20	6.97	15	25	20	12	40	Composite	5.75	5.45	2	80	125	True
WURTH	**744316033**	**32.5**	**0.129**	**0.201**	**0.33**	**0.33**	**20**	**1.75**	**10**	**20**	**30**	**18.5**	**50**	**Superflux**	**5.8**	**5.6**	**4.3**	**80**	**150**	**True**

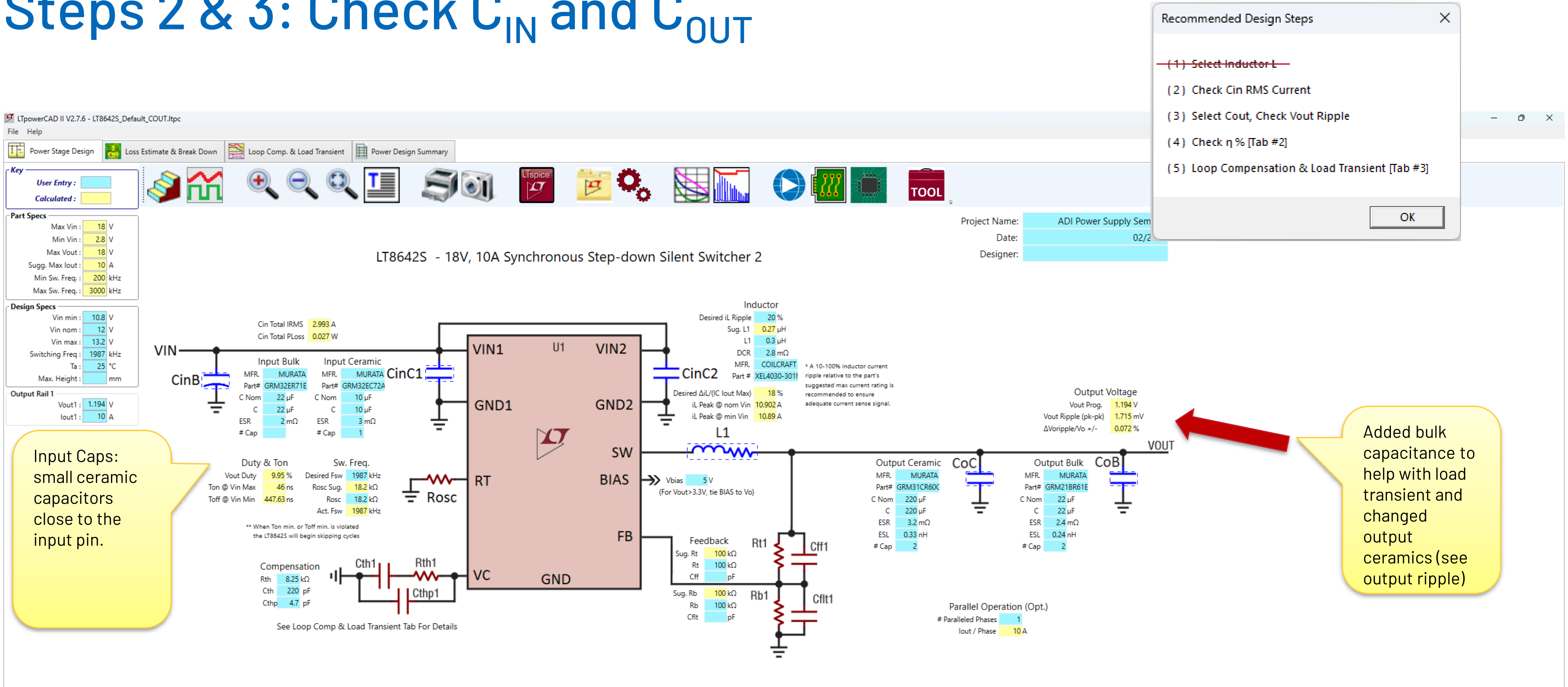
\# Suggested Parts : 186 # Parts in Library : 188

* So far only Wurth and Coilcraft provide AC loss estimations. Comparing AC loss between vendors may not be accurate due to different estimation methods.

Vendor Search Tools

LTpowerCAD File: ADIPowerSeminar_LT8642S_Inductor_Feb2025

Steps 2 & 3: Check C_{IN} and C_{OUT}



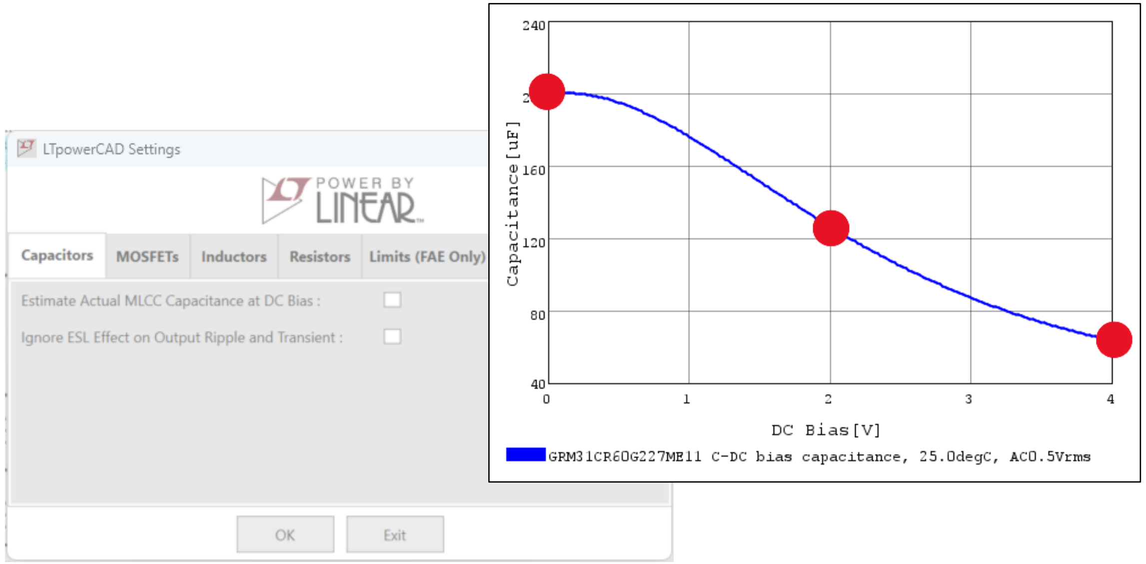
Input Caps: small ceramic capacitors close to the input pin.

Added bulk capacitance to help with load transient and changed output ceramics (see output ripple)

V_{NOM} (V)	DC Setpoint (% of V_{NOM})	VR Ripple (% of V_{NOM})	AC Transient (% of V_{NOM})	Max DC + AC (% of V_{NOM})	Step Load (A)	Slew Rate (A/us)
1.0	0.5	1	2.5	3.0	5	10

LTpowerCAD File: ADIPowerSeminar_LT8642S_CIN_COUT_Feb2025

Capacitor Derating: Tips & Tricks

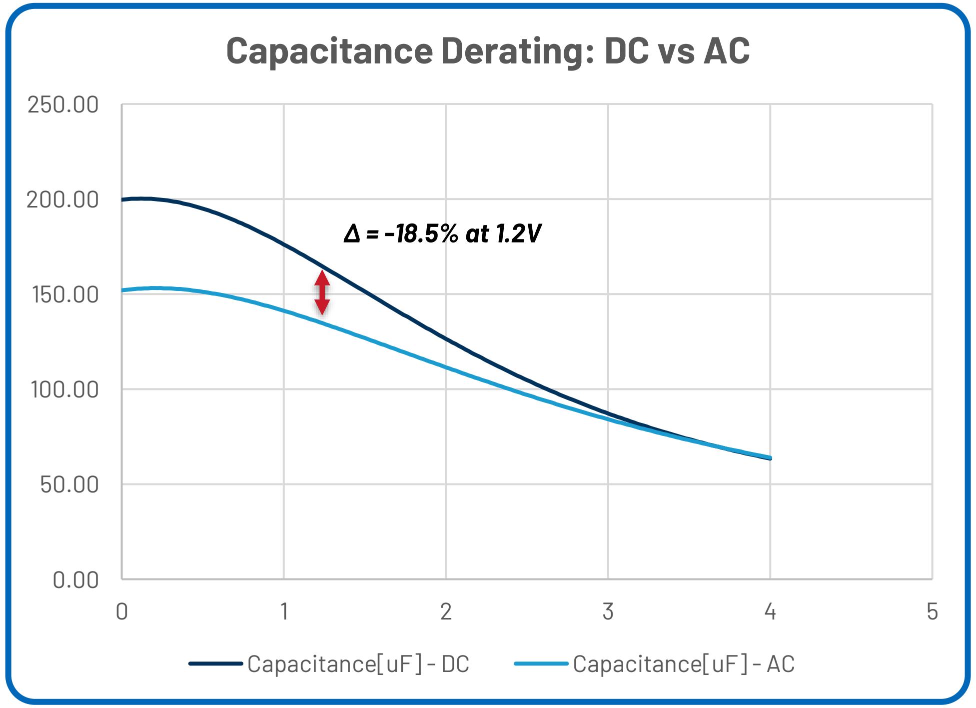


Part Number	C_{NOM} (uF)	LTpowerCAD Derating (uF)	$C_{DC\text{-}BIAS}$ (uF)	$C_{AC\text{-}BIAS}$ (uF)
GRM31CR60G227ME11	220	177.35	168.51	136.34
GRM21BD70J226ME44	22	21.125	20.65	16.58

*LTpowerCAD uses a 3-point interpolation and does not derate capacitance based on AC voltage or temperature

Additional Information:

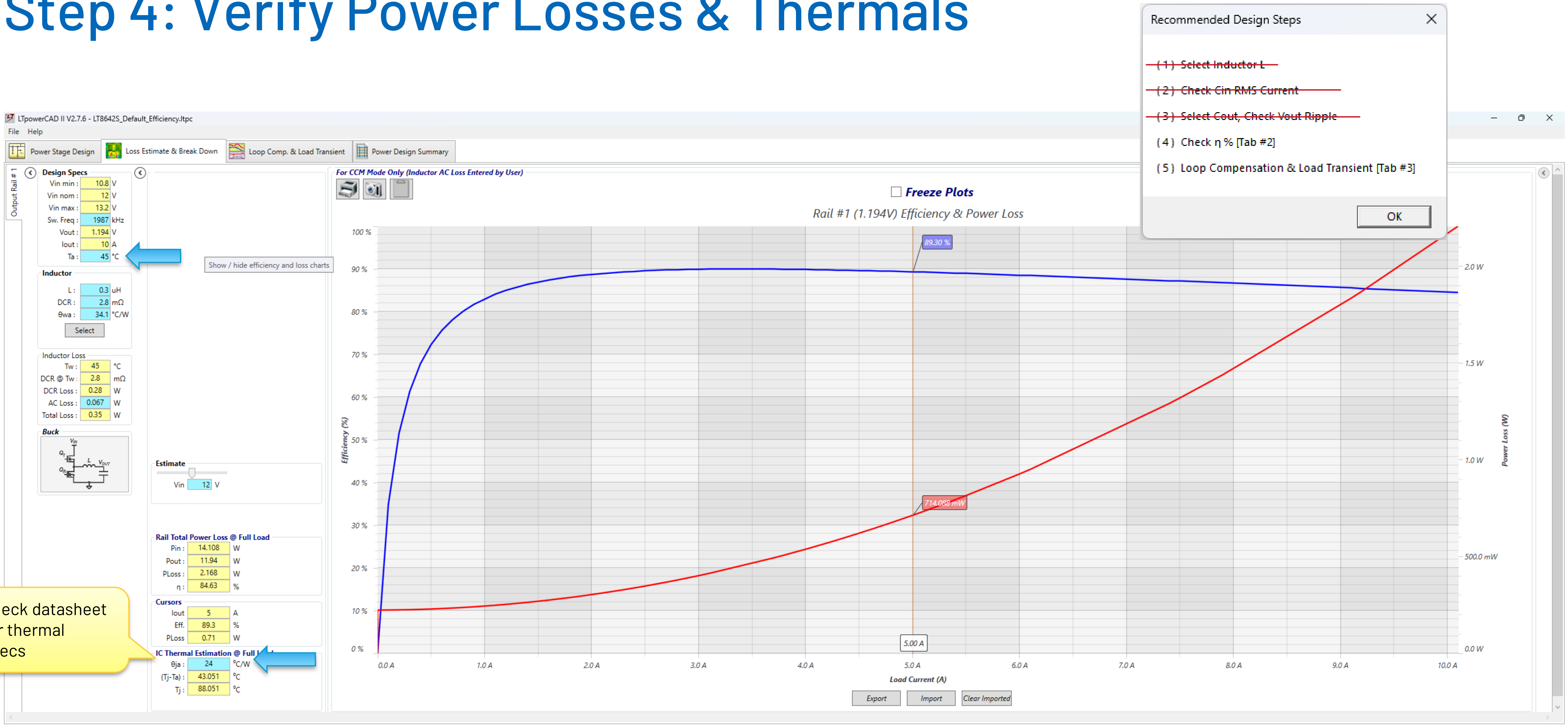
- Murata: The voltage characteristics of electrostatic capacitance | Murata Manufacturing Articles
- Kemet: Here's What Makes MLCC Dielectrics Different



Performance characteristic curves obtained from Murata's Simsurfing Tool.

Homework: compare LTpowerAnalyzer frequency response (or any frequency analyzer) of the LT8642S demo board with different LTpowerCAD derating models.

Step 4: Verify Power Losses & Thermals



Check datasheet for thermal specs

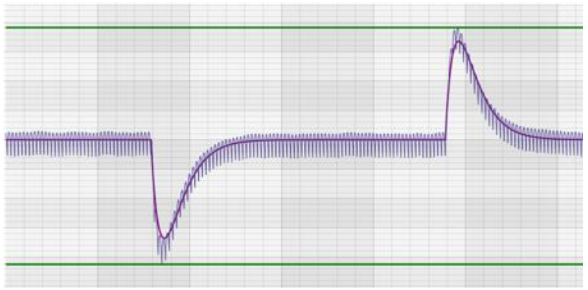
LTpowerCAD File: ADIPowerSeminar_LT8642S_Efficiency_Feb2025

LT8642S: Design of Compensation Network

▶ **High loop DC Gain (by default).**

Target #1) Fast Transient Response. (High BW)

→ **Loop BW <= 1/5~ 1/10 f_{SW}**



Target #2) Stability. (across operating range)

→ **PM ≥45 degree. (≥60 degree preferred.)**

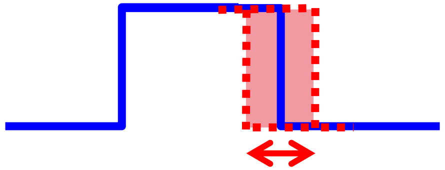
→ **GM ≥ 10dB**

Component	Value	Units
R_{TH}	OPEN	kΩ
C_{TH}		pF
C_{THP}		pF
C_{FF}		pF

Proposed initial values for LT8642S example

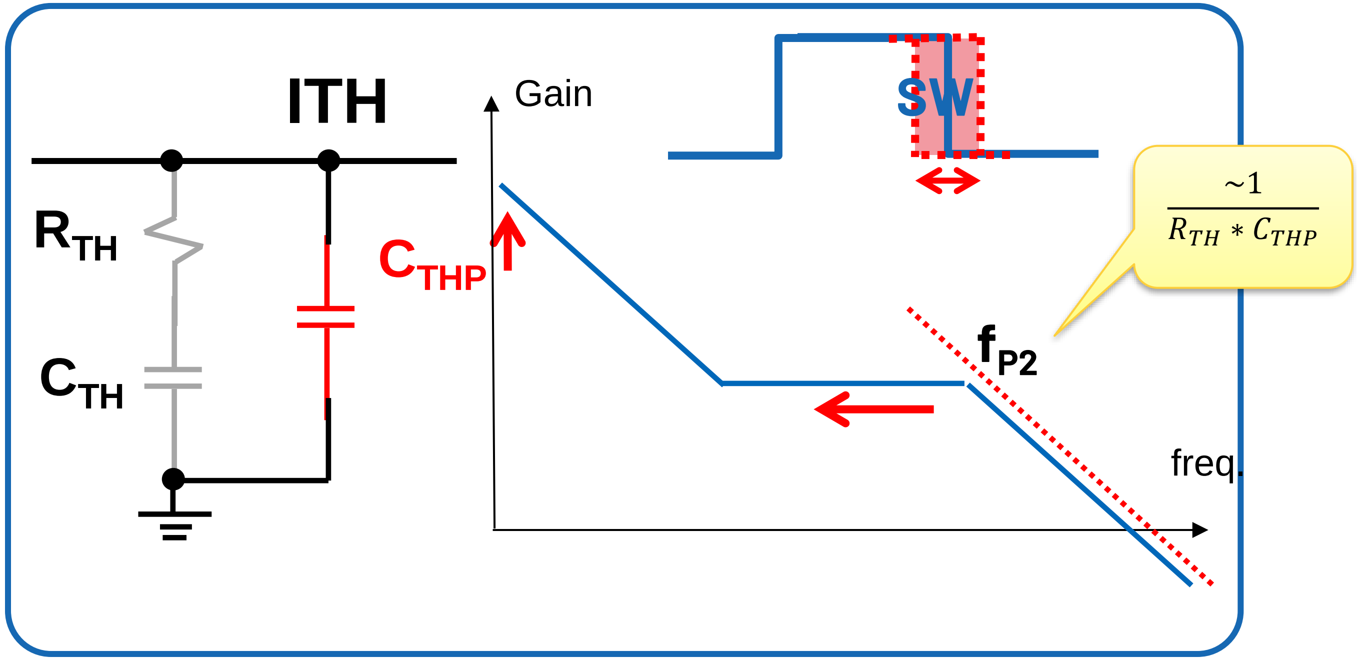
Target #3) Attenuate switching noises.

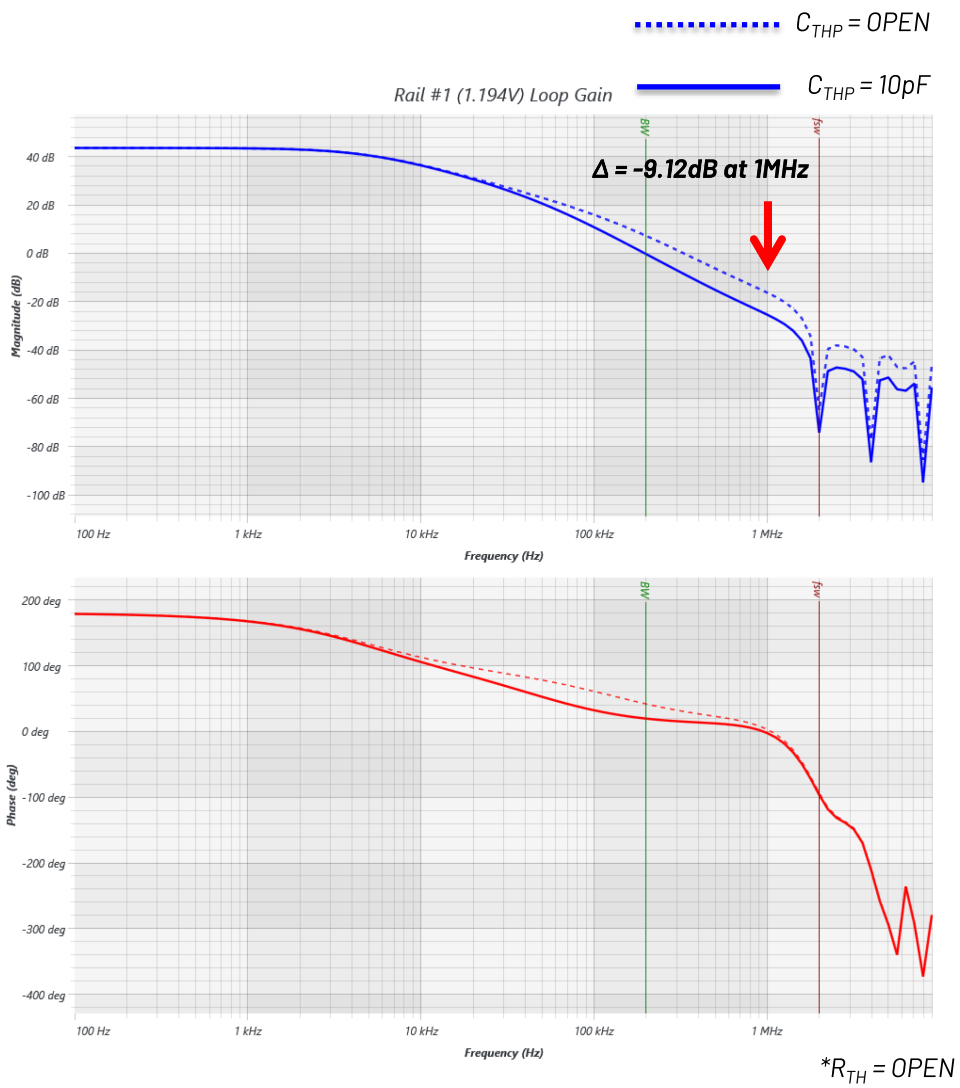
→ **Gain @ $f_{SW}/2$ ≤ -8dB.**



LTpowerCAD File:ADIPowerSeminar_LT8642S_BlankCompensation_Feb2025

Step 1: HF Gain Attenuation (C_{THP})





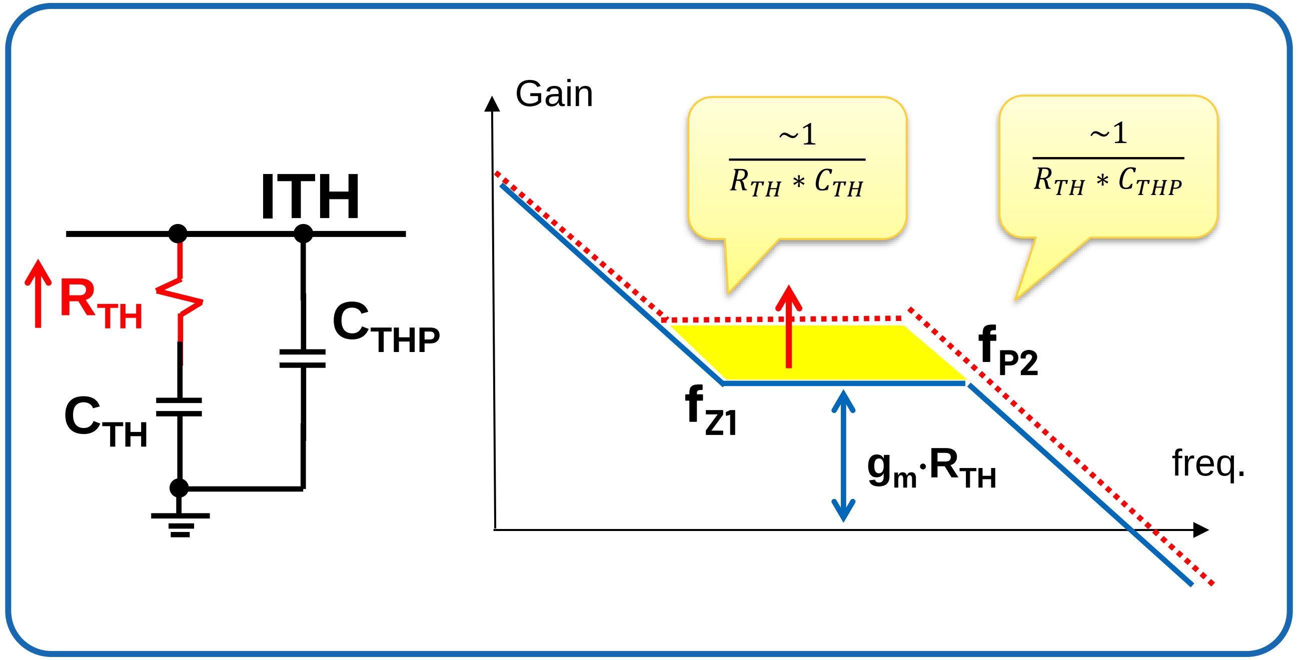
- Higher C_{THP} reduces HF gain, improve noise immunity
- f_{P2} moves to a lower frequency and will affect PM
- Slightly increase transient ΔV_{OUT}

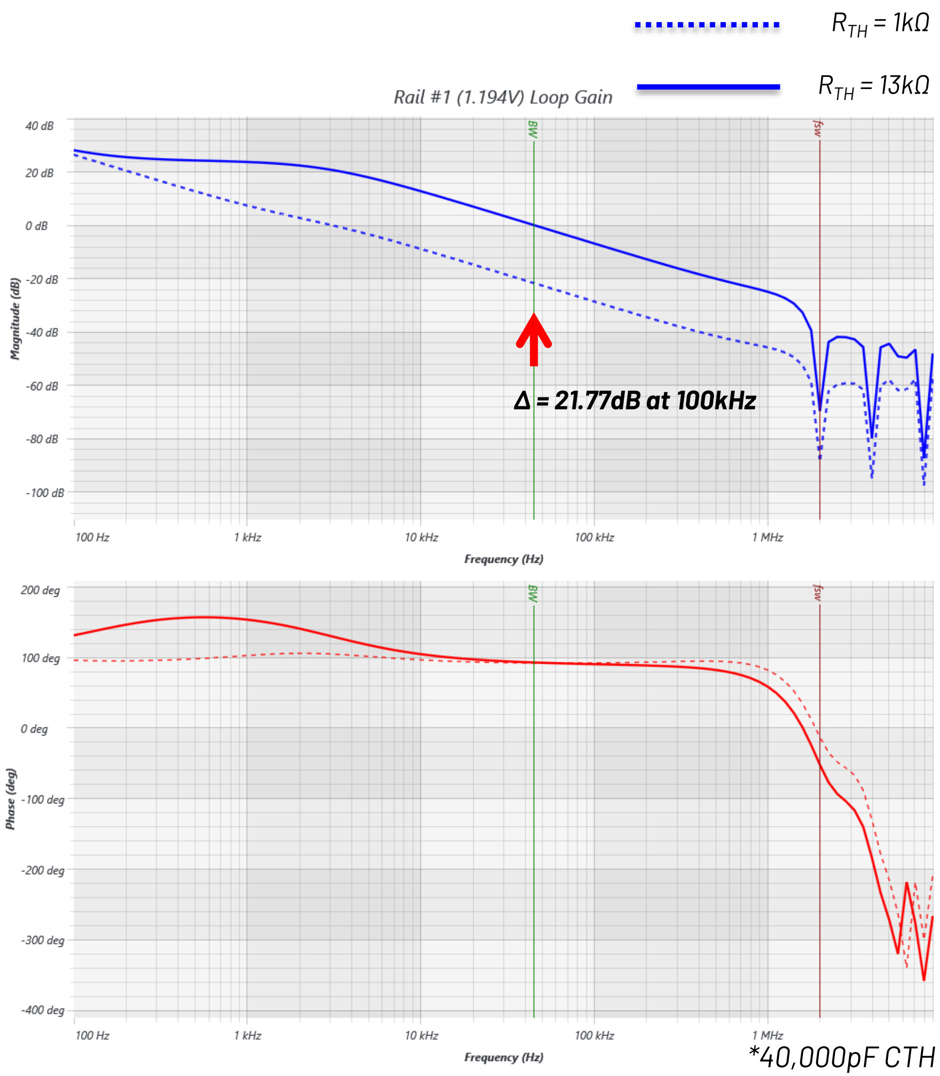
Stability Metric	CTHP = OPEN	CTHP = 10pF
Bandwidth (kHz)	316.23	199.53
Phase Margin (Deg)	30.88	18.93
Gain @ fSW/2 (dB)	**-16.21**	**-25.33**
Gain Margin (dB)	-18.08	-25.33

- ❑ **Gain @ $f_{SW}/2 < -8dB$**
- ❑ PM > 45°
- ❑ GM > 10dB
- ❑ Loop BW: 1/10 to 1/5 f_{SW}

LTpowerCAD File: ADIPowerSeminar_LT8642S_Efficiency_Feb2025

Step 2: Set Loop Gain & Load Transient





- Higher R_{TH} increases gain at BW frequency target
  - Reduces ΔV_{OUT} during load transients
  - Reduces phase margin

Stability Metric	R_{TH} = 1kΩ	R_{TH} = 13kΩ
Bandwidth (kHz)	**3.16**	**44.67**
Phase Margin (Deg)	104.84	93.03
Gain @ fSW/2 (dB)	-45.71	-24.84
Gain Margin (dB)	-88.56	-39.31

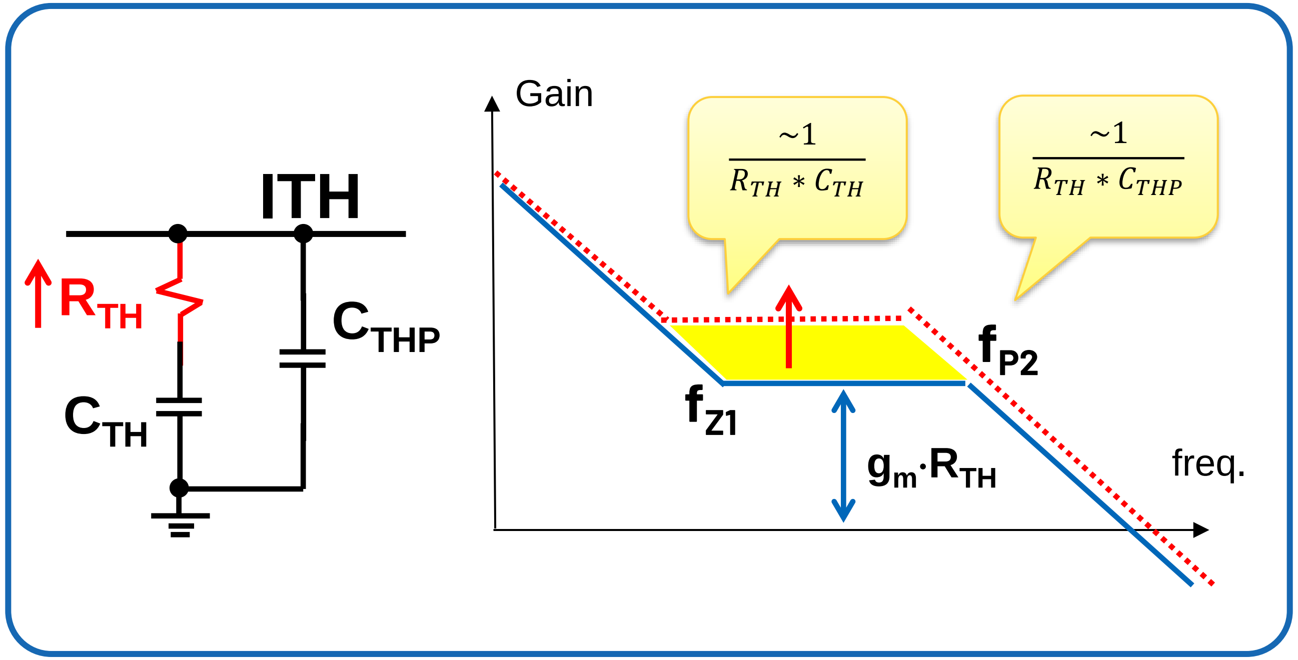
❑ Gain @ $f_{SW}/2$ < -8dB

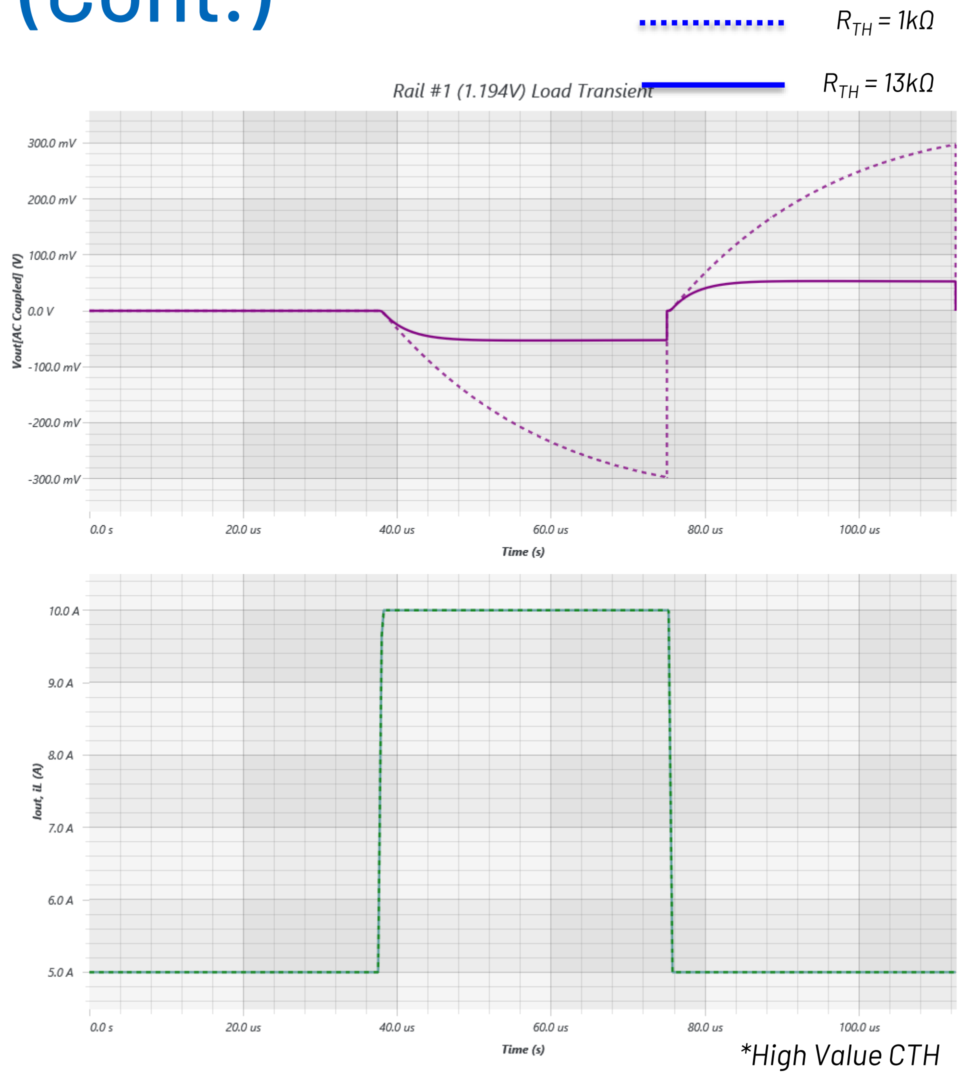
❑ **PM > 45°**

❑ GM > 10dB

❑ **Loop BW: 1/10 to 1/5 f_{SW}**

Step 2: Set Loop Gain & Load Transient (Cont.)





*High Value CTH

- Higher R_{TH} increases gain at BW frequency target
  - Reduces ΔV_{OUT} during load transients
  - Reduces phase margin

Stability Metric	R_{TH} = 1kΩ	R_{TH} = 13kΩ
Bandwidth (kHz)	**3.16**	**44.67**
Phase Margin (Deg)	104.84	93.03
Gain @ fSW/2 (dB)	-45.71	-24.84
Gain Margin (dB)	-88.56	-39.31

❑ Gain @ $f_{SW}/2 < -8$dB

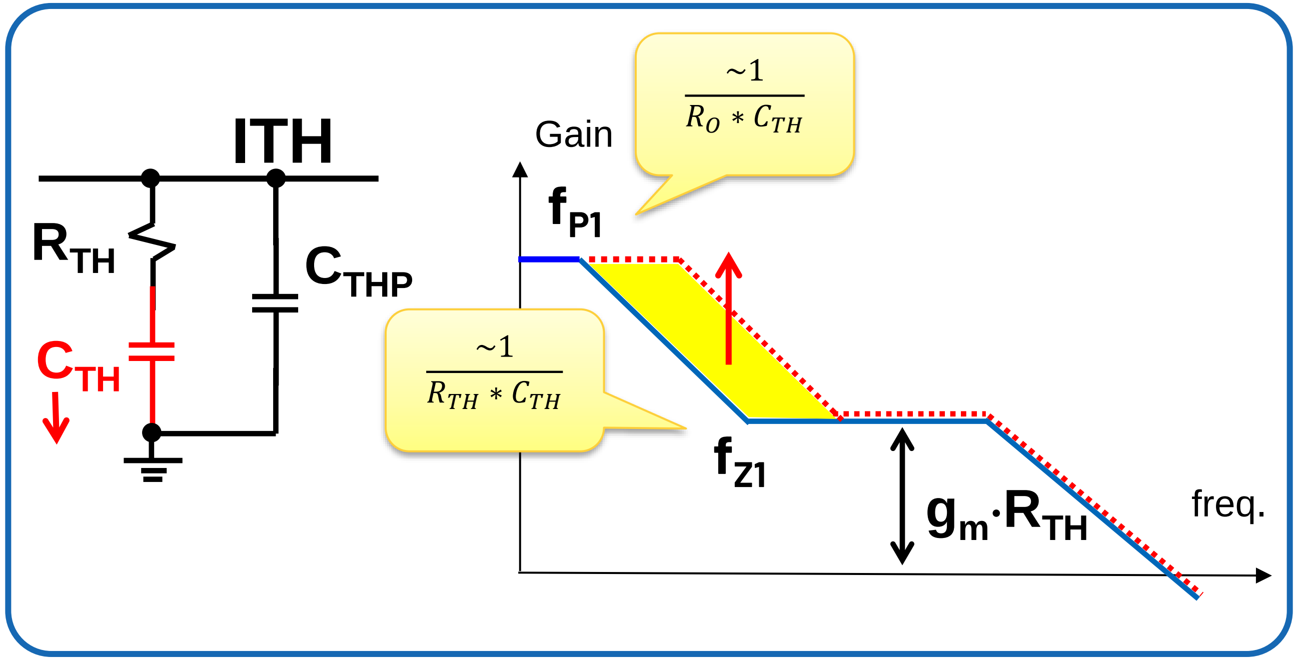
❑ PM > 45°

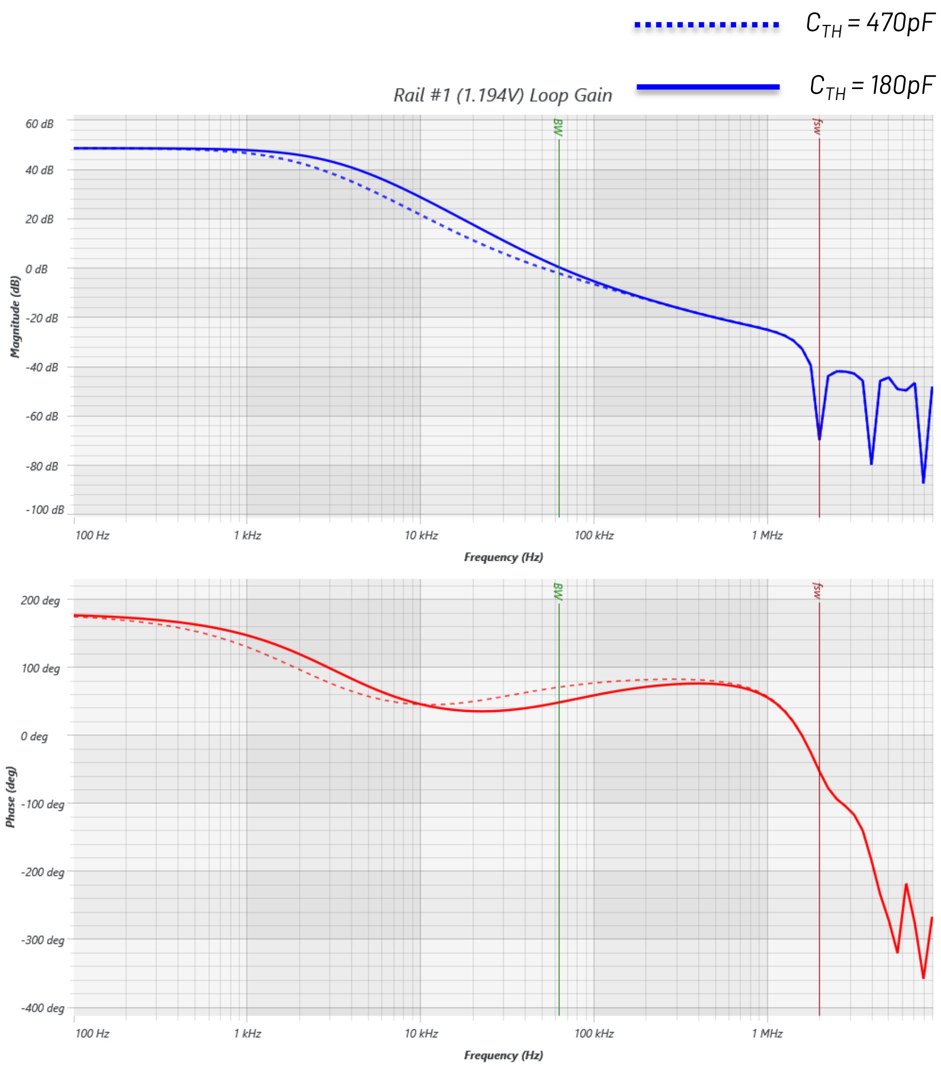
❑ GM > 10dB

❑ Loop BW: 1/10 to 1/5 f_{SW}

Analog Devices

Step 3: Adjust Settling Time



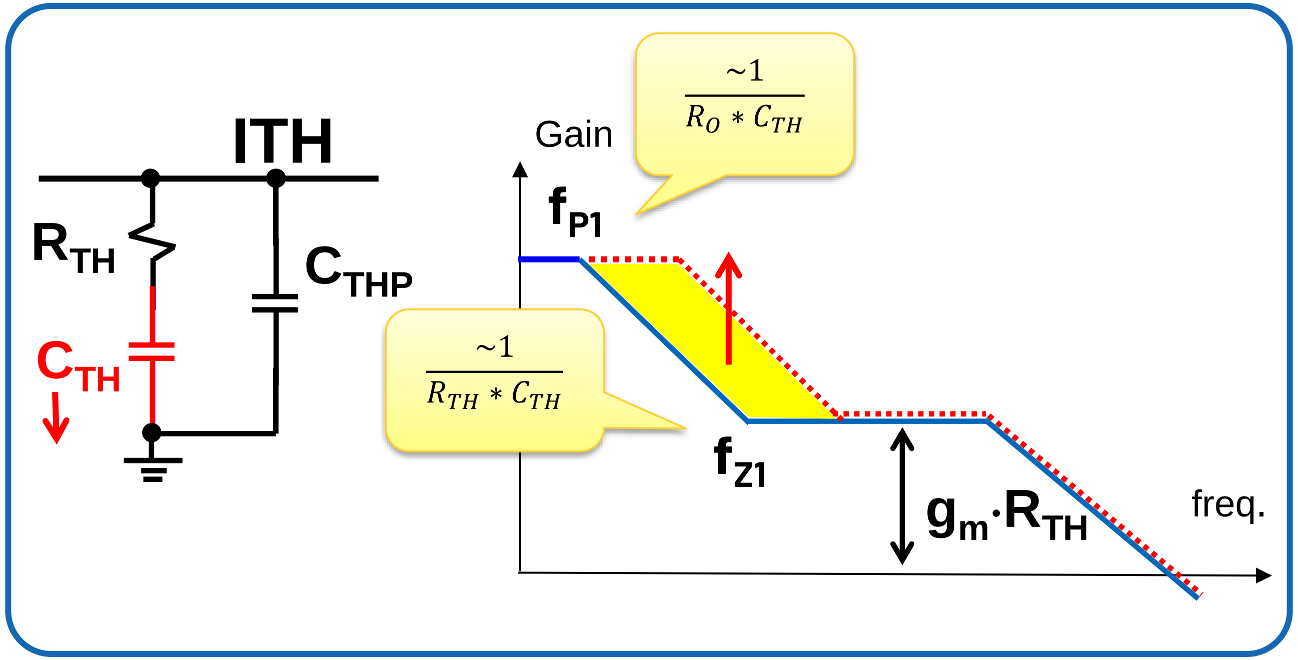


- Lower C_{TH} reduces settling time.
  - Make sure PM > 45°
  - Keep f_{Z1} < BW

Stability Metric	C_{TH} = 470pF	C_{TH} = 180pF
Bandwidth (kHz)	**50.12**	**63.1**
Phase Margin (Deg)	67.09	48.52
Gain @ fSW/2 (dB)	-24.92	-25.03
Gain Margin (dB)	-39.37	-32.78

❑ Gain @ $f_{SW}/2$ < -8dB ❑ PM > 45° ❑ GM > 10dB ❑ Loop BW: 1/10 to 1/5 f_{SW}

Step 3: Adjust Settling Time (Cont.)



- Lower C_{TH} reduces settling time.
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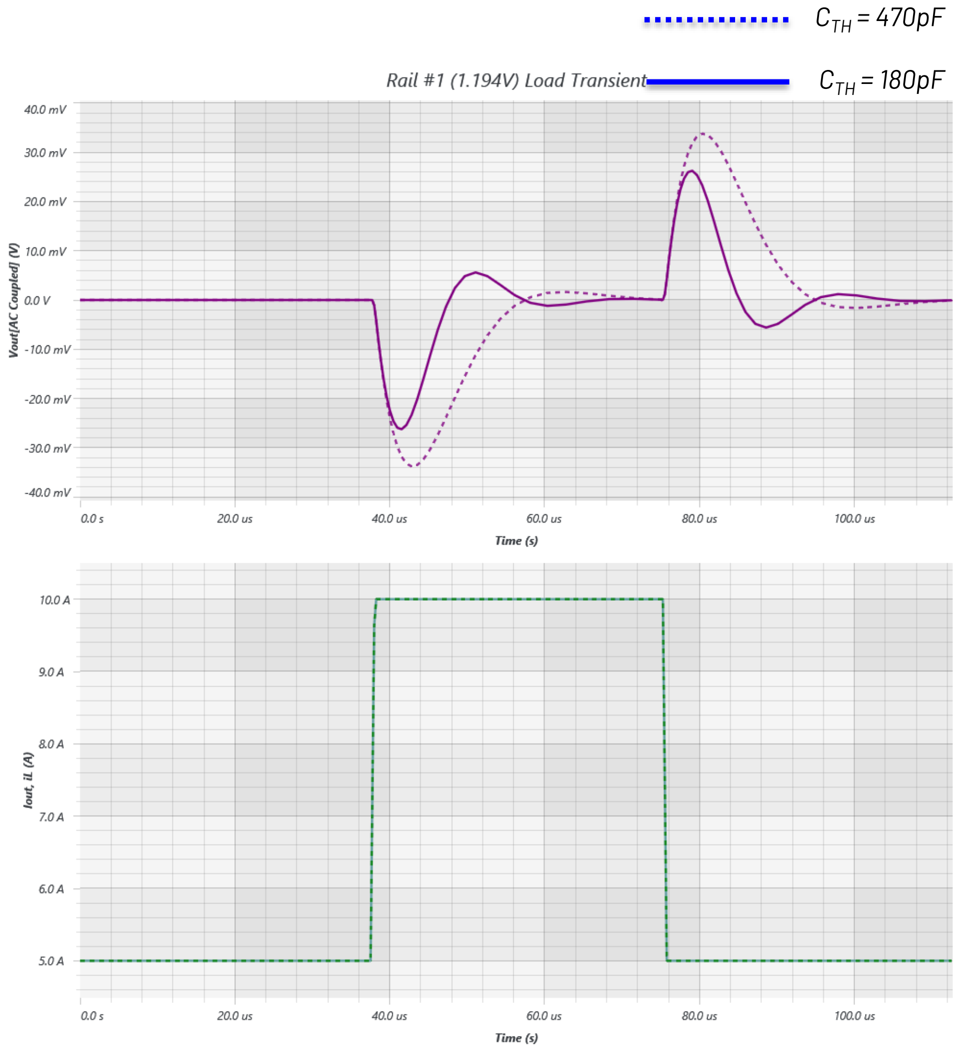
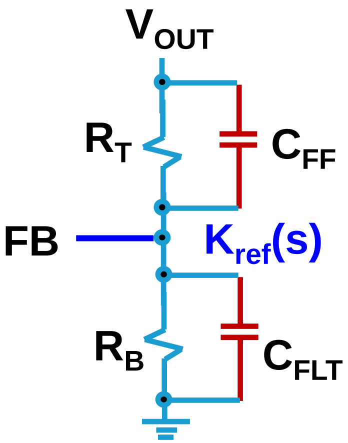
Gain @ fSW/2 (dB)	-24.92	-25.03
Gain Margin (dB)	-39.37	-32.78



❑ Gain @ $f_{SW}/2$ < -8dB ❑ PM > 45° ❑ GM > 10dB ✓ Loop BW: 1/10 to 1/5 f_{SW}

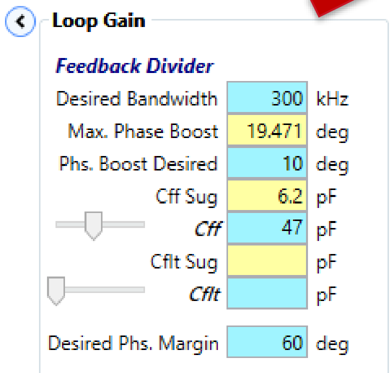
Step 4 (Opt.): FB Capacitors

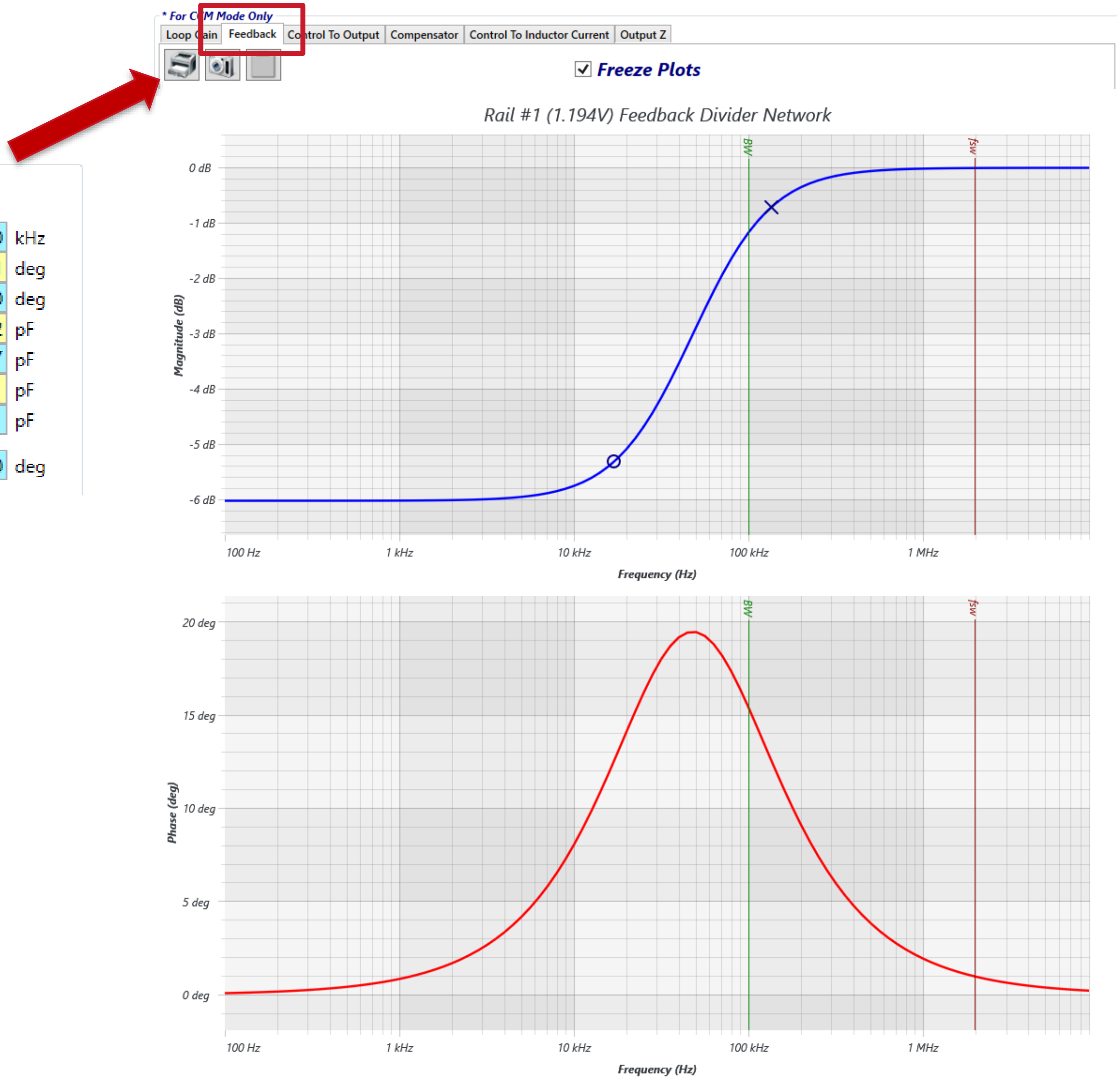


$$f_{z-CFF} = \frac{1}{2*\pi*R_{TOP}*C_{FF}}$$

$$f_{P-CFF} = \frac{1}{2*\pi*(R_{TOP}||R_{BOT})*C_{FF}}$$

$$f_{P-CFILT} = \frac{1}{2\pi(R_{TOP}||R_{BOT})*C_{FILT}}$$





- Only add if necessary to provide additional BW and PM
  - Set phase boost peak f_{BST} around f_{BW}
  - Recommended: leave C_{ff} footprints on PCB

Stability Metric	C_{FF} = OPEN	C_{FF} = 47pF
Bandwidth (kHz)	**63.1**	**100**
Phase Margin (Deg)	48.52	74.26
Gain @ fSW/2 (dB)	-25.03	-19.03
Gain Margin (dB)	-32.78	-33.45

❑ Gain @ $f_{SW}/2$ < -8dB ✓ PM > 45° ✓ GM > 10dB ❑ Loop BW: 1/10 to 1/5 f_{SW}

Final Step: Confirm Design Targets

Bode Plot

Vin	12	V
Io	5	A
Bandwidth	100	kHz
Phase Margin	74.26	deg
Gain @ fsw/2	-19.03	dB
Gain @ -180°	-33.45	dB

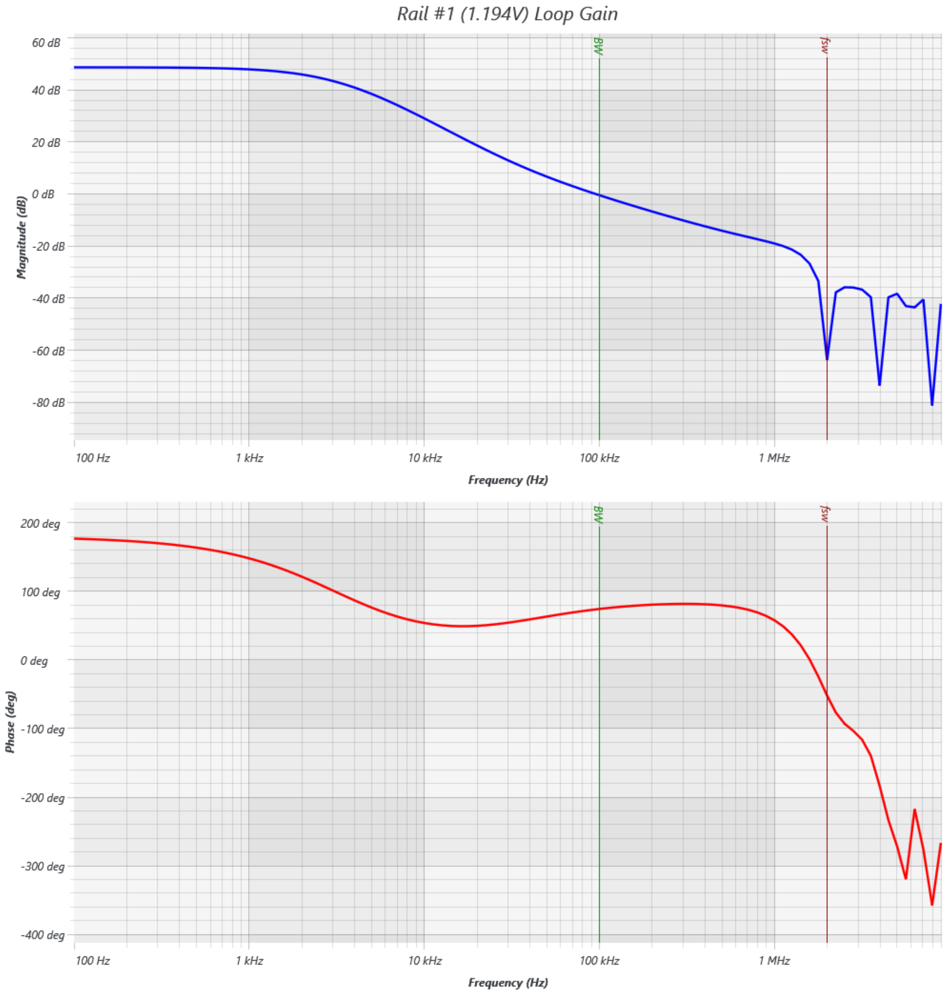
Load Step

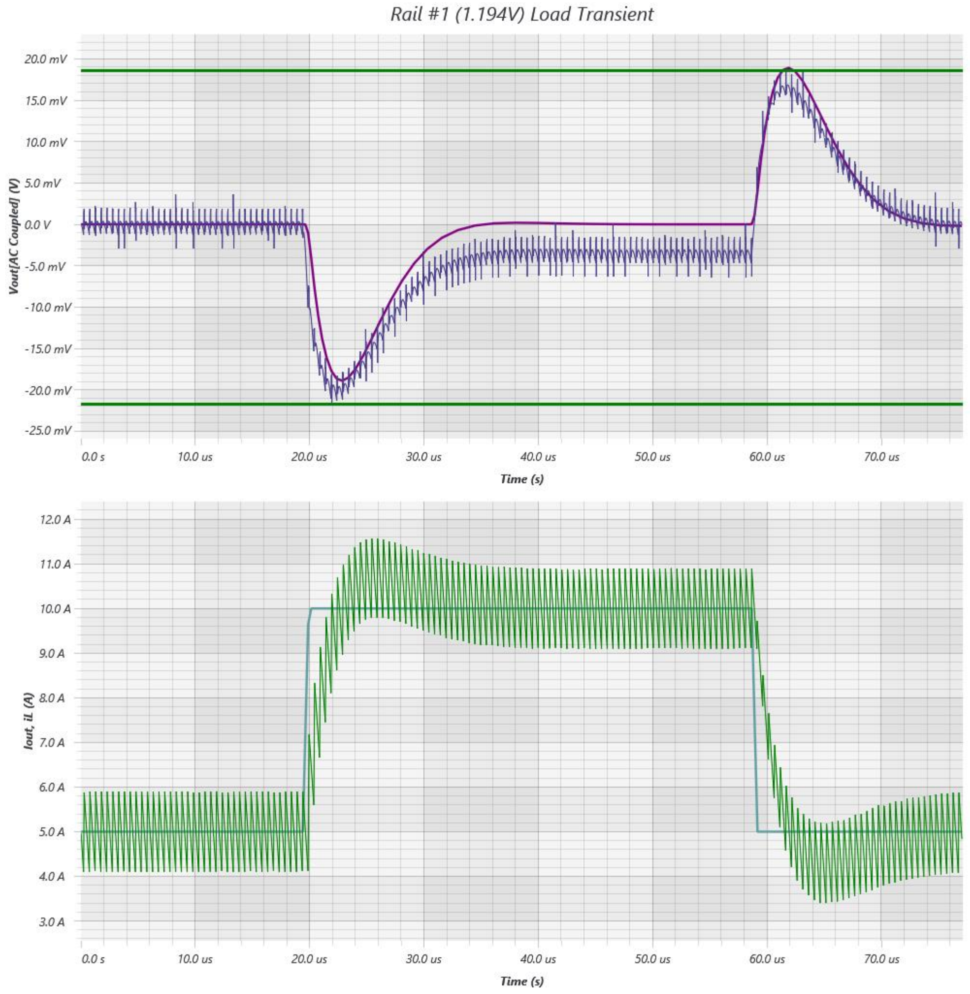
High	10	A
Low	5	A
ΔI/Δt	10	A/µs

ΔVo Target & Response

Target Total ΔVo ±	3	%
Target ΔVoRipple ±	1	%
ΔVoRipple ±	0.28	%
Allowed ΔVoStep ±	2.72	%
ΔVoStep ±	1.82	%
Total ΔVo ±	2.1	%

Component	Value	Units
R_{TH}	13	kΩ
C_{TH}	180	pF
C_{THP}	1	pF
C_{FF}	47	pF



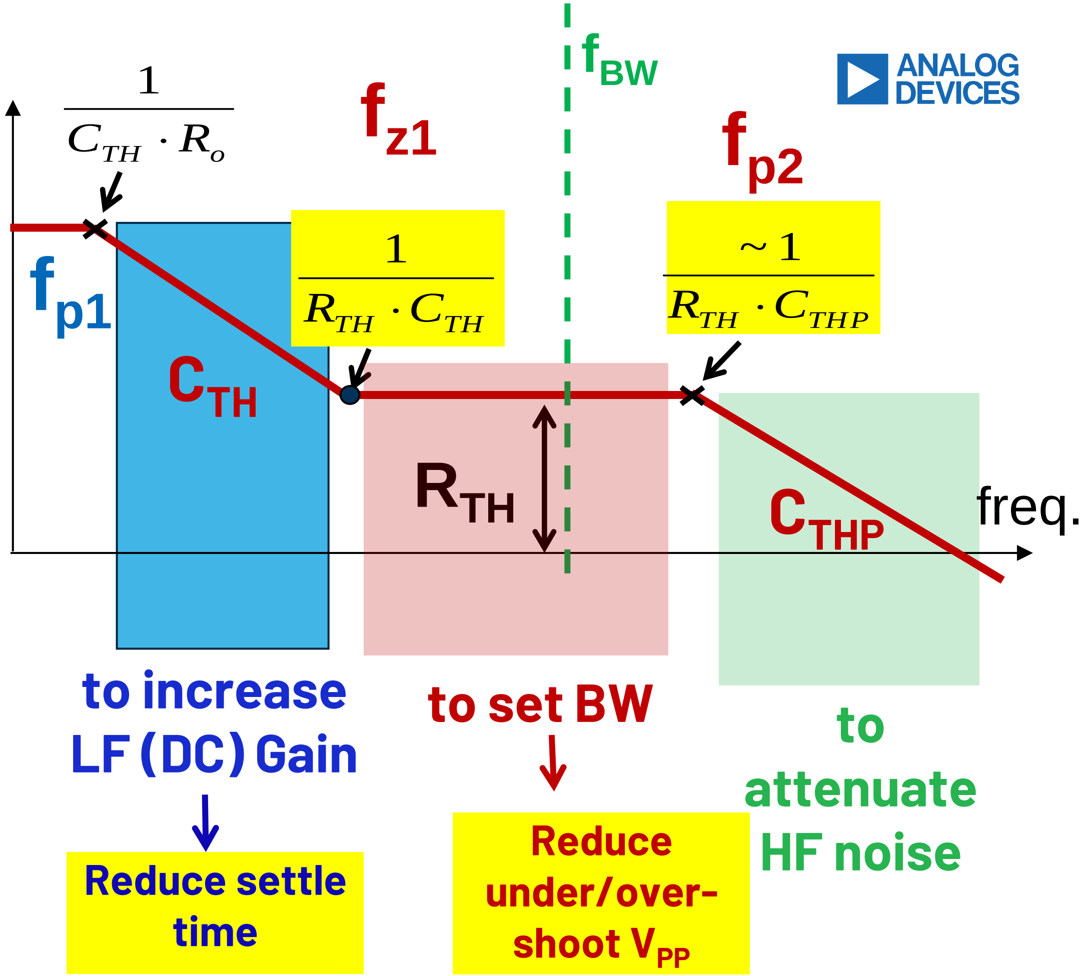


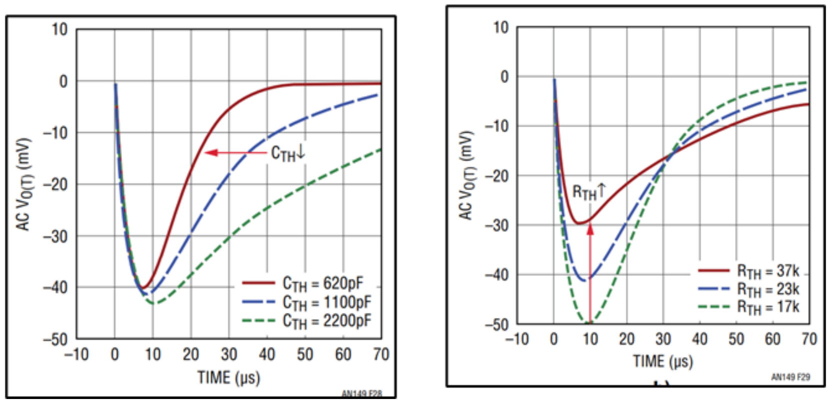
- ✓ Gain @ $f_{SW}/2 < -8dB$
- ✓ PM > 45°
- ✓ GM > 10dB
- ❑ Loop BW: 1/10 to 1/5 f_{SW}

LTpowerCAD File:ADIPowerSeminar_LT8642S_RL1221_Feb2025

Summary of Compensation Design

1. Set Bandwidth and Transient Response
   1. Adjust RTH (higher RTH increases BW, decreases PM)
   2. Check for transient response target
2. Set Settling Time
   1. Adjust CTH (lower CTH reduces settling time at the expense of PM)
3. Check for HF Attenuation
   a) Adjust CTHP (higher CTHP improves noise immunity at the expense of BW)
4. Optional: Feedforward Capacitor
   1. Check if phase boost is needed by looking at the PM and transient response
5. Close the loop (pun intended)
   1. Confirm design targets

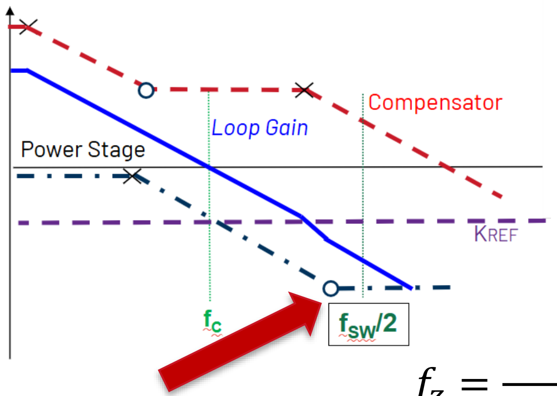




Final Thoughts & Questions

Component / Spec	Tolerance	Min	Normal	Max	Units
Inductor	**20%**	**240**	**300**	**360**	**nH**
VOUT Ripple		3.018	2.415	2.012	mV
Bandwidth			12.20%		%
Phase Margin			4.77%		%
COUT	**20%**	**240**	**304.68**	**366**	**uF**
Bandwidth			36.77		%
COUT ESR			**±2**		**mΩ**
Phase Margin			23.52		%
LTPowerCAD vs LTspice					
Bandwidth			2.02		%
Phase Margin			7.82		%
LTPowerCAD vs LTPowerAnalyzer					
Bandwidth			6.25		%
Phase Margin			24.71		%

LTPowerCAD vs LTspice vs LTPowerAnalyzer results comparison



$$f_z = \frac{1}{2 * \pi * R_{ESR} * C_{OUT}}$$

Final Thoughts

- Ideal BW range is lower on high FSW designs
- Simulation model accuracy depends on "precise" passive models
  - Board parasitics play a role on BW & PM
- LTspice and additional simulation capabilities:
  - Second stage filter & split rails
  - Up/downstream converters