



**TI Technology Days 2010**

# **Loop Compensation with SwitcherPro**

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# SwitcherPro™

# What is SwitcherPro™?

1. SwitcherPro™ allows you to design power supplies with Texas Instruments TPS40K™ controllers, TPS60xxx low-power DC/DC converters and SWIFT™ (TPS54xxx) point-of-load step-down DC/DC products.
2. Use this tool to create, manage and share custom designs.
3. It provides EVM designs that you can use for reference or starting points for custom designs. In addition, passive components such as inductors and CICLON MOSFETs are now included in both the online and desktop applications.
4. The desktop application now allows more flexibility in creating designs since there is no need to be connected to the internet. Design and go at your own pace.

# Switcher Pro Status & Development

## Upcoming Developments

### New Parts

<b>V3.8 Release</b>	<b>Jun 11, 2010</b>	115	<a href="#">TPS54225</a>
		116	<a href="#">TPS54226</a>
		117	<a href="#">TPS54325</a>
		118	<a href="#">TPS54326</a>
		119	<a href="#">TPS54319</a>
		120	<a href="#">TPS61220</a>
		121	<a href="#">TPS61221</a>
		122	<a href="#">TPS61222</a>
		124	<a href="#">TPS62060</a>
		125	<a href="#">TPS62065</a>
		126	<a href="#">TPS62067</a>

<b>V3.9 Release</b>	<b>Jul 30, 2010</b>	127	<a href="#">TPS40197</a>
		128	<a href="#">TPS53311</a>
		129	<a href="#">TPS54060-Inverting</a>
		130	<a href="#">TPS61200</a>
		131	<a href="#">TPS61201</a>
		132	<a href="#">TPS61202</a>
		133	<a href="#">TPS54320</a>
		134	<a href="#">TPS54618</a>
		135	<a href="#">TPS62233</a>
		136	<a href="#">TPS62234</a>
		137	<a href="#">TPS62235</a>
		138	<a href="#">TPS62236</a>
		139	<a href="#">TPS62237</a>
		140	<a href="#">TPS62238</a>
		141	<a href="#">TPS62239</a>
		142	<a href="#">TPS622310</a>
		143	<a href="#">TPS622311</a>
		123	<a href="#">TPS54521</a>

**114** parts + **52** EVMs released

### Latest Developments:

- TPS63020
- TPS54260
- TPS54240

# Where to Find It

- [www.ti.com/analogelab](http://www.ti.com/analogelab) (“Design” Section)
- [www.ti.com/switcherpro](http://www.ti.com/switcherpro) (Tool Folder)
- [www.ti.com/switcherpro-dt](http://www.ti.com/switcherpro-dt) (Desktop download)

The screenshot shows the Texas Instruments Analog eLAB Design Center homepage. The navigation bar includes links for Products, Applications, Design Support, and Sample & Buy. The main content area is titled "Analog eLAB Design Center" and features a "Need Help?" section with links to contact technical support, FAQs, and distributors. Below this is a "Learn" section with various resources like online training, webcasts, and seminars. The "Design" section is highlighted with a red arrow, showing a list of design tools and resources. A red arrow points from the "Design" section to the "SwitcherPro" tool folder page.

The screenshot shows the Texas Instruments SwitcherPro(TM) Online and Desktop Design Creator and Management Software page. The page is titled "SwitcherPro(TM) Online and Desktop Design Creator and Management Software" and includes a "Status: ACTIVE" indicator. The "Description" section provides a detailed overview of the software's capabilities, including its use for designing power supplies with Texas Instruments controllers and converters. A red arrow points from the "Design" section of the Analog eLAB page to this page. Another red arrow points to the "Download & Register" button, which is highlighted in red. The page also includes a "Product Information" section with a table listing the software's name, status, and price (free).

SWITCHERPRO	
Name	SwitcherPro(TM) Online and Desktop Design Creator and Management Software
Status	ACTIVE
Price (US\$)	Free

[Use Online](#)

**Product Information**

**Description**

[View SwitcherPro Homepage Graphic](#)

**Download & Register** Download and Register for SwitcherPro™ Desktop Now.

SwitcherPro Online or Desktop Design Software allows you to design power supplies with Texas Instruments TPS40K™ controllers, TPS60xxx low-power DC/DC converters and SWIFT™ (TPSS4xxx) point-of-load step-down DC/DC products. Use this tool to create, manage and share custom designs. It provides EVM designs that you can use for reference or starting points for custom designs. In addition, passive components such as inductors and C1CLON MOSFETs are now included in both the online and desktop applications. The desktop application now allows more flexibility in creating designs since there is no need to be connected to the internet. Design and go at your own pace.

**NOTE:** New devices are being added to the tool on a regular basis. The most recent devices are listed in the "Related Products" section of this folder. Check back periodically if your device is currently not listed.

# Use Online or on Your Desktop

## Web Based Version

- Requires no installation
- Always the most recent version of the tool
- Accessible through my.TI
- Allows users to access data anywhere at anytime via a web browser
- 'Support Forum' link changed to point to TI E2E community site

## Desktop Version

- No need for internet access
- Design anytime, anywhere
- Automatically updates to current version

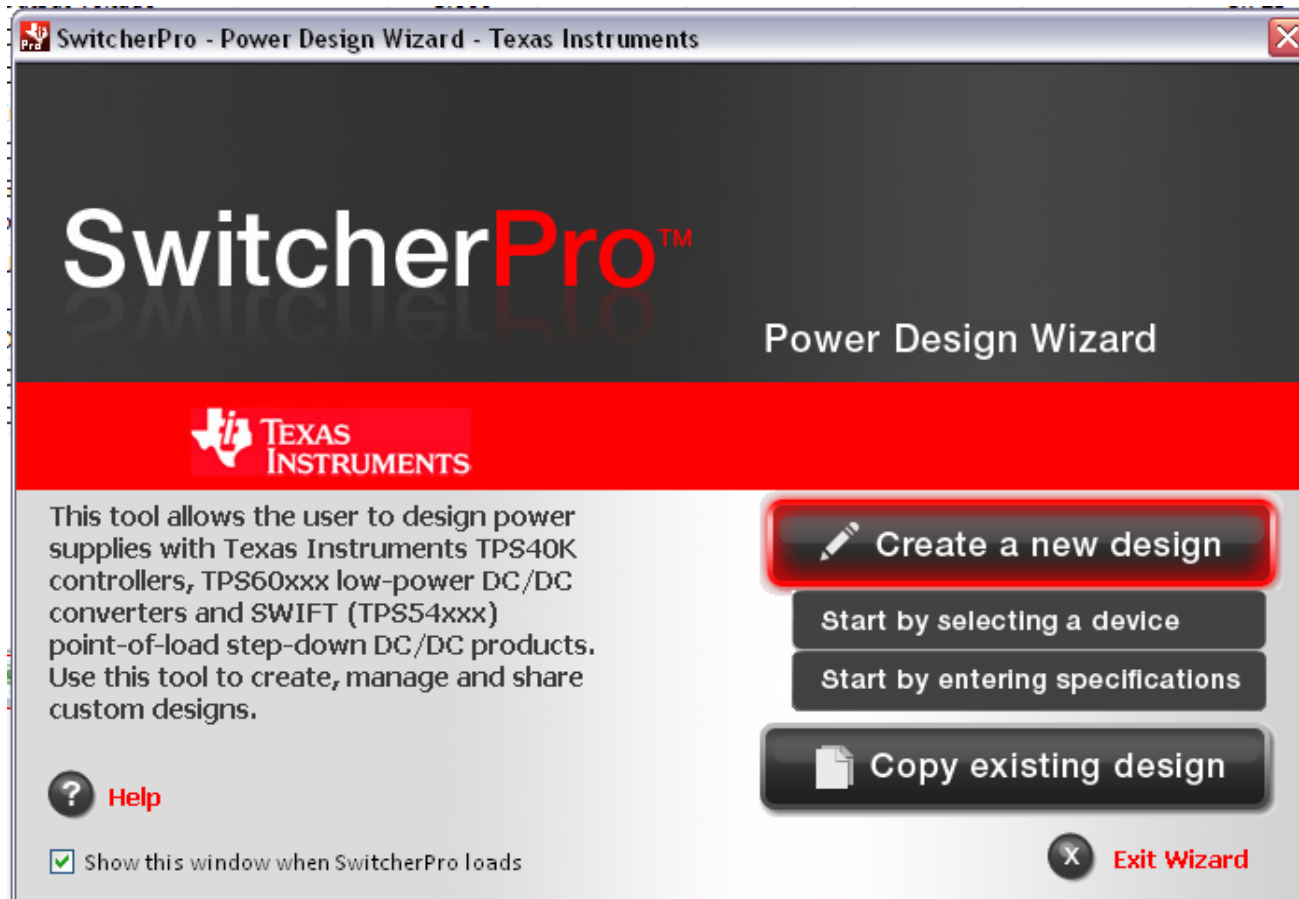
# SwitcherPro – Design Wizard

SwitcherPro has a flexible interface that allows users to develop solutions from a variety of families of DC/DC controllers and converters



# SwitcherPro – Design Wizard

Create Design either by selecting a device or by entering specifications





# SwitcherPro – Design Wizard

SwitcherPro - Create New Design - Texas Instruments

Simple Inputs | Advanced Inputs | Part Number | EVM Design

**Step 1.**  
Enter design parameters:

Design Name:  
TPS40195 12V - 1.8V @ 5A

**Input**

Vin Min (V): 10.8 \*

Vin Max (V): 13.2 \*

**Output**

Vout (V): 1.8 \*

Iout Max (A): 10 \*

\* indicates required field

**Step 2.**  
Select a device and click 'Design Now':

Part Number	Description
TPS40054	20A, 8V-40V in, 0.7V-34V out. 16 pin synchronous, step-down converter. Application: source only.
TPS40055	20A, 8V-40V in, 0.7V-34V out. 16 pin synchronous, step-down converter. Application: source/sink.
TPS40057	20A, 8V-40V in, 0.7V-34V out. 16 pin. Applications: source/sink with prebias.
TPS40140	40A, 2V-40V in, 5.8V out, Dual Or 2 Phase Buck Converter, 36-Pin PQFP
TPS40190	20A, 4.5-15V Vin, 0.591-12.75 Vout, Sync Buck Controller, 10-pin SON
TPS40192	15A, 4.5-18V Vin, 0.591-15 Vout, Sync Buck Controller, 10-pin SON
TPS40193	20A, 4.5-18V Vin, 0.591-15 Vout, Sync Buck Controller, 10-pin SON
TPS40195	17A, 4.5V-20V in, 0.59V-17V out, Synchronous Buck Controller, 16 pin PowerPAD
TPS40303	3V-20V in, 0.6V-18V out, Synchronous Buck Controller with frequency spread spectrum, 10-Pin SON
TPS40304	3V-20V in, 0.6V-18V out, Synchronous Buck Controller with frequency spread spectrum, 10-Pin SON
TPS40305	3V-20V in, 0.6V-17V out, Synchronous Buck Controller with frequency spread spectrum, 10-Pin SON
TPS51315	10A, 3V-14V in, 0.75V-5.5V out, Step Down Converter With Integrated MOSFETs, 40pin VQFN

1. Enter Parameter

2. Find Devices

3. Design Now

Find Devices

Design Now

Having trouble finding a device? More devices are available using the Power Quick Search tool on [power.ti.com](http://power.ti.com)

Exit Wizard

# Design Wizard – Advanced Inputs

**SwitcherPro - Create New Design - Texas Instruments**

Simple Inputs | **Advanced Inputs** | Part Number | EVM Design

**Step 1.**  
Enter design parameters:

Design Name:

Vin Min (V): \*

Vin Max (V): \*

Vout (V): \*

Iout Max (A): \*

Iout Min (A):

Iout Current Limit (A):

Vo Ripple (1 - 1000 mV):

Vin Ripple (1 - 1000 mV):

Output Capacitor Type:

Application Type:

Synchronous Switching Only: ☐

\* indicates required field

**Step 2.**  
Select a device and click 'Design Now':

**Clear Grid Filters**

Part Number	Description
-------------	-------------

In addition you can enter parameters like:

- Vo Ripple
- Output Capacitor Type
- Switching Frequency
- Design Priority (Efficiency, Cost, Size)
- Gain Margin
- Phase Margin

**Find Devices** **Design Now** **Exit Wizard**

Having trouble finding a device? More devices are available using the Power Quick Search tool on [power.ti.com](http://power.ti.com)

# Design List – Schematic

SwitcherPro Desktop - TPS40195 12V - 1.8V @ 5A - 1208

File Tools Order Help

Design List

- EVM Designs
  - EVMs by PartNumber
- My Designs
  - Embedded World Demo
  - TPS40195 13.2V to 1.8V @ 10A
  - TPS40195 13.2V to 1.8V @ 10A
  - TPS40195 13.2V to 1.8V @ 10A
  - TPS40195 13.2V to 1.8V @ 10A
  - TPS40195 13.2V to 5V @ 6A
  - TPS40195 13.2V to 5V @ 6A
  - TPS40195 14V to 1.5V @ 15A
  - TPS40195 14V to 5V @ 3A
  - TPS40195 TechDay
  - TPS5410 14V to 5V @ 0.5A
  - TPS54620 5.5V to 1V @ 0.1A
  - TPS54620 5.5V to 1V @ 1A
  - TPS63000 5.5V to 3.3V @ 0.8A
  - TPS40195 12V - 1.8V @ 5A**

Schematic Analysis Stress Efficiency Loop BOM Layout Notes

Edit Inputs

Name: TPS40195 12V - 1.8V @ 5A Part: TPS40195  
VinMin: 10.8 VinMax: 13.2 Vout: 1.8 Iout: 10

Note: Parts with bold red labels can be completely modified, parts with plain black labels allow only name changes.

Parts with bold red labels can be completely modified, parts with black labels allow only name changes

Design Report  
What If Analysis  
Library Manager

Texas Instruments

# Design List – Analysis Main

The screenshot shows the SwitcherPro Desktop software interface. The title bar reads "SwitcherPro Desktop - TPS40195 12V - 1.8V @ 5A - 1208". The menu bar includes File, Tools, Order, and Help. The toolbar contains icons for file operations and analysis. The left sidebar shows a "Design List" with a tree view containing "EVM Designs" and "My Designs". The "My Designs" list includes several entries for the TPS40195 converter with different input/output specifications. The main area is divided into tabs: Schematic, Analysis (selected), Stress, Efficiency, Loop, BOM, Layout, and Notes. The "Analysis" tab is active, showing a summary of the design parameters and a table of calculated values. The summary includes: Name: TPS40195 12V - 1.8V @ 5A, Part: TPS40195, VinMin: 10.8, VinMax: 13.2, Vout: 1.8, Iout: 10. The table below shows calculated values for various parameters.

Parameter	User Input Minimum	User Input Nominal	User Input Maximum	Default Input Minimum	Default Input Nominal	Default Input Maximum	Calculated Minimum	Calculated Nominal	Calculated Maximum	Units
Input Voltage	10.80	-	13.20	-	-	-	-	-	-	Volts
Input Ripple	-	-	-	-	-	264	-	-	260	mVp-p
UVLO(Start)	-	-	-	-	-	-	-	8.63	-	Volts
UVLO(Stop)	-	-	-	-	-	-	-	-	-	Volts
Switching Frequency	-	-	-	-	300	-	-	-	-	KHz
Slow Start	-	-	-	-	5	-	-	-	-	ms
Estimated PCB Area	-	-	-	-	-	-	-	654	-	mm <sup>2</sup>
Max Component Hei...	-	-	-	-	-	25	-	-	4	mm

At the bottom of the Analysis tab, there is a "Download to Excel" button.

➡ Get an overview about basic informations like, input voltage, output voltage, input ripple, switching frequency or estimated PCB area

# Design List – Analysis Output1

SwitcherPro Desktop - TPS40195 12V - 1.8V @ 5A - 1208

File Tools Order Help

Design List

- EVM Designs
  - EVMs by PartNumber
  - My Designs
    - Embedded World Demo
    - TPS40195 13.2V to 1.8V @ 10A
    - TPS40195 13.2V to 1.8V @ 10A
    - TPS40195 13.2V to 1.8V @ 10A
    - TPS40195 13.2V to 1.8V @ 10A
    - TPS40195 13.2V to 5V @ 6A
    - TPS40195 13.2V to 5V @ 6A
    - TPS40195 14V to 1.5V @ 15A
    - TPS40195 14V to 5V @ 3A
    - TPS40195 TechDay
    - TPS5410 14V to 5V @ 0.5A
    - TPS54620 5.5V to 1V @ 0.1A
    - TPS54620 5.5V to 1V @ 1A
    - TPS63000 5.5V to 3.3V @ 0.8A
    - TPS40195 12V - 1.8V @ 5A

Schematic Analysis Stress Efficiency Loop BOM Layout Notes

Edit Inputs

Name: TPS40195 12V - 1.8V @ 5A Part: TPS40195

VinMin: 10.8 VinMax: 13.2 Vout: 1.8 Iout: 10

Main Output1

Parameter	User Input Minimum	User Input Nominal	User Input Maximum	Default Input Minimum	Default Input Nominal	Default Input Maximum	Calculated Minimum	Calculated Nominal	Calculated Maximum	Units
Output Voltage	-	1.800	-	-	-	-	1.723	-	1.917	Volts
Output Ripple	-	-	-	-	-	36	-	-	15	mVp-p
Output Current	-	-	10.000	0.100	-	-	-	-	-	Amps
Inductor Peak to Pea...	-	-	-	-	-	-	3.824	-	3.970	Amps
Current Limit Thresh...	-	-	-	-	15.0	-	-	-	-	Amps
Gain Margin	-	-	-	-10	-	-	-	-20	-	dB
Phase Margin	-	-	-	45	-	-	-	45	-	Deg.
Upper FET RDSon	-	-	-	-	-	-	2	-	2	mOhms
Lower FET RDSon	-	-	-	-	-	-	2	-	2	mOhms
Duty Cycle	-	-	-	-	-	-	14.2	-	17.3	%
On Time Min(switch)	-	-	-	-	-	-	430.1	-	642.5	ns
Cross Over Frequency	-	-	-	-	-	-	-	57	-	KHz

Download to Excel

# Design List – Stress

SwitcherPro Desktop - TPS40195 12V - 1.8V @ 5A - 1208

File Tools Order Help

Design List

- EVM Designs
  - EVMS by PartNumber
- My Designs
  - Embedded World Demo
    - TPS40195 13.2V to 1.8V @ 10A
    - TPS40195 13.2V to 1.8V @ 10A
    - TPS40195 13.2V to 1.8V @ 10A
    - TPS40195 13.2V to 1.8V @ 10A
    - TPS40195 13.2V to 5V @ 6A
    - TPS40195 13.2V to 5V @ 6A
    - TPS40195 14V to 1.5V @ 15A
    - TPS40195 14V to 5V @ 3A
    - TPS40195 TechDay
    - TPS5410 14V to 5V @ 0.5A
    - TPS54620 5.5V to 1V @ 0.1A
    - TPS54620 5.5V to 1V @ 1A
    - TPS63000 5.5V to 3.3V @ 0.8A
    - TPS40195 12V - 1.8V @ 5A

Schematic Analysis Stress Efficiency Loop BOM Layout Notes

Edit Inputs Name: TPS40195 12V - 1.8V @ 5A Part: TPS40195  
VinMin: 10.8 VinMax: 13.2 Vout: 1.8 Iout: 10

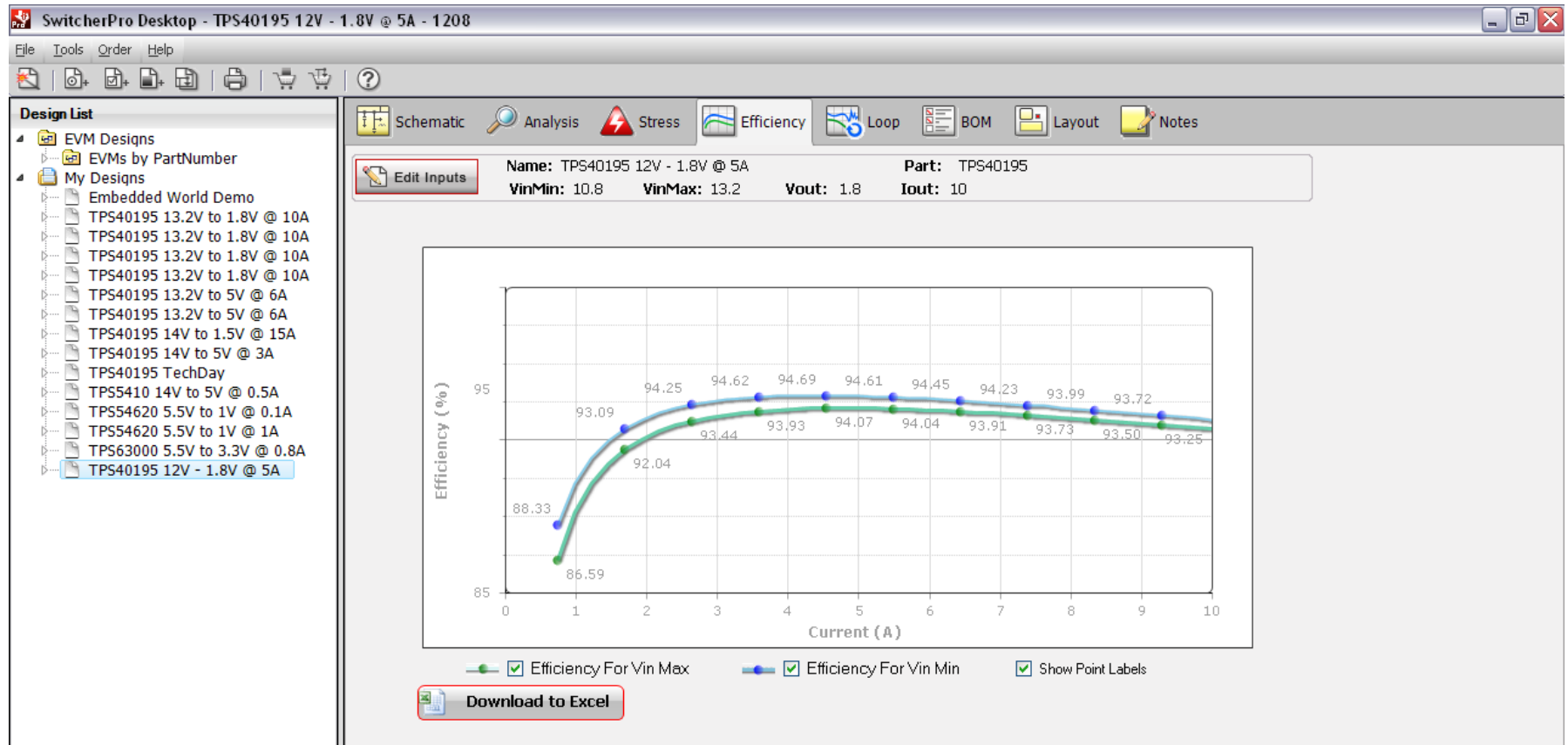
Device	Rated Voltage	Calculated Voltage	Rated Current (RMS)	Calculated Current (RMS)	Error Message	Power	Calculated Max Temp
C9 (High Freq. Inp...	25V	13.3V	3.36A	1.91A		23mW	-
C2 (Bulk Output Ca...	10V	1.81V	4.4A	0.57A		985uW	-
L1 (Output Inductor)	-	-	14A	10.1A		537mW	-
Q1 (Power Switch)	25V	13.3V	100A	4.19A		493mW	43°C
Q2 (Sync. Rectifier)	25V	13.3V	100A	9.32A		241mW	34°C

Download to Excel

Calculated RMS currents

Calculated max. Temperature

# Design List – Efficiency



# Design List – BOM

SwitcherPro Desktop - TPS40195 12V - 1.8V @ 5A - 1208

File Tools Order Help

Design List

- EVM Designs
  - EVMs by PartNumber
- My Designs
  - Embedded World Demo
  - TPS40195 13.2V to 1.8V @ 10A
  - TPS40195 13.2V to 1.8V @ 10A
  - TPS40195 13.2V to 1.8V @ 10A
  - TPS40195 13.2V to 5V @ 6A
  - TPS40195 13.2V to 5V @ 6A
  - TPS40195 14V to 1.5V @ 15A
  - TPS40195 14V to 5V @ 3A
  - TPS40195 TechDay
  - TPS5410 14V to 5V @ 0.5A
  - TPS54620 5.5V to 1V @ 0.1A
  - TPS54620 5.5V to 1V @ 1A
  - TPS63000 5.5V to 3.3V @ 0.8A
  - TPS40195 12V - 1.8V @ 5A

Schematic Analysis Stress Efficiency Loop BOM Layout Notes

Edit Inputs

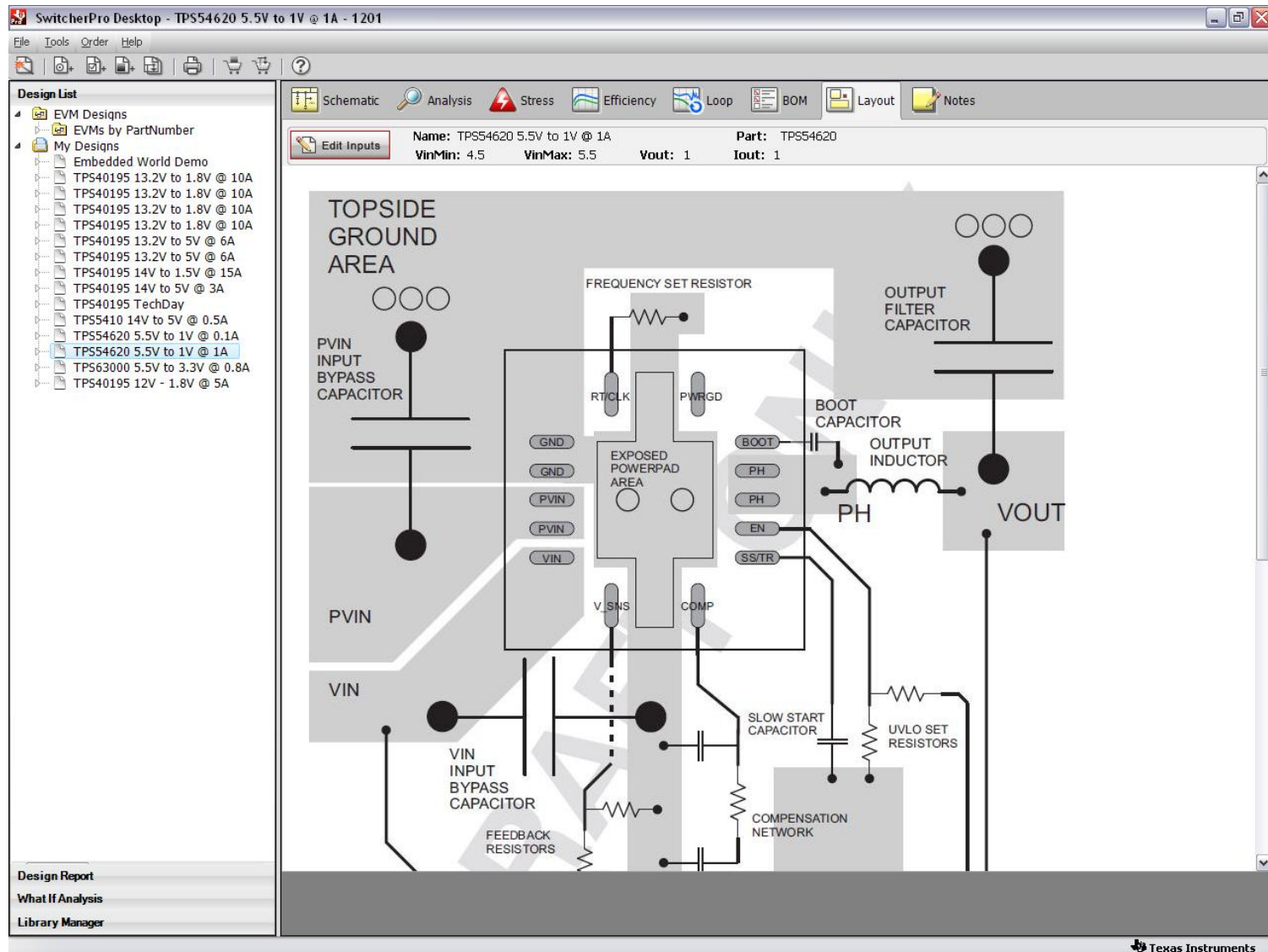
Name: TPS40195 12V - 1.8V @ 5A Part: TPS40195  
 VinMin: 10.8 VinMax: 13.2 Vout: 1.8 Iout: 10

Name	Quantity	Part Number	Description	Manufacturer	Package	Area(mm²)	Height(mm)
C12	1	Standard	Capacitor, Cera...	Standard	0805	3	1
C2	2	C5750X5R1A68...	Capacitor, Cera...	TDK	C5750 2220	31	2
C3	1	Standard	Capacitor, Cera...	Standard	0603	2	1
C5	1	Standard	Capacitor, Cera...	Standard	0805	3	1
C6	1	Standard	Capacitor, Cera...	Standard	0603	2	1
C7	1	Standard	Capacitor, Cera...	Standard	0603	2	1
C8	1	Standard	Capacitor, Cera...	Standard	0603	2	1
C9	2	C4532X5R1E15...	Capacitor, Cera...	TDK	C4532 1812	16	2
L1	1	7443552150	Inductor, 1.5u...	Würth Electron...	10x4	104	4
Q1	1	CSD16321Q5	Transistor, NFE...	Texas Instrum...	QFN 5x6	31	1
Q2	1	CSD16321Q5	Transistor, NFE...	Texas Instrum...	QFN 5x6	31	1
R1	1	Standard	Resistor, Surfa...	Standard	0805	3	1
R2	1	Standard	Resistor, Surfa...	Standard	0805	3	1
R3	1	Standard	Resistor, Surfa...	Standard	0805	3	1
R4	1	Standard	Resistor, Surfa...	Standard	2512	21	1
R5	1	Standard	Resistor, Surfa...	Standard	0805	3	1
R6	1	Standard	Resistor, Surfa...	Standard	0201	1	1
R7	1	Standard	Resistor, Surfa...	Standard	0201	1	1
R8	1	Standard	Resistor, Surfa...	Standard	0805	3	1
R9	1	Standard	Resistor, Surfa...	Standard	0805	3	1
U1	1	TPS40195	IC, Controller,...	Texas Instrum...	TSSOP	34	2

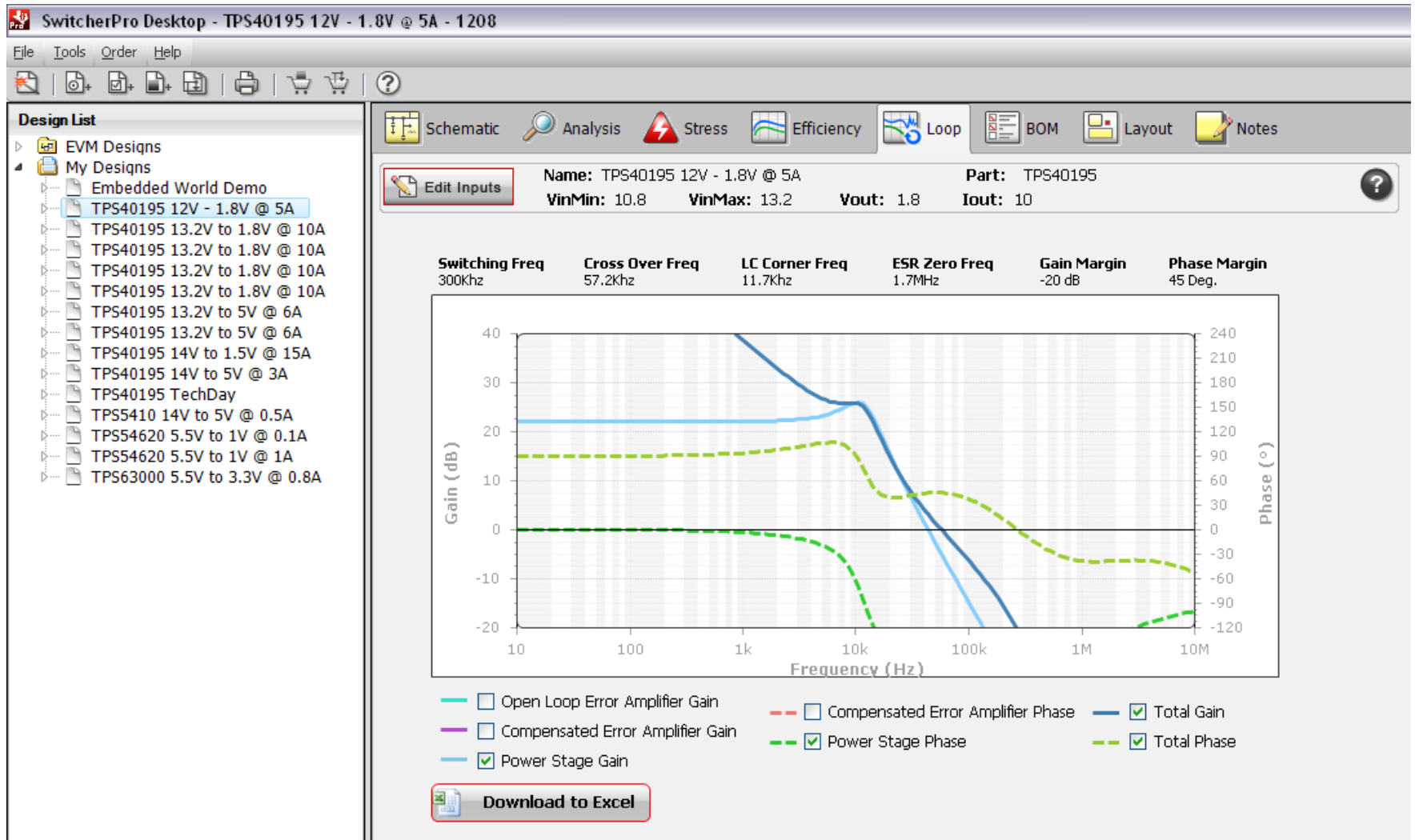
Download to Excel



# PCB Layout



# Closed Loop Analysis



# Design Report

SwitcherPro Desktop - TPS40195 12V - 1.8V @ 5A - 1208

File Tools Order Help

Design List

Design Report

Select Design Views:

- ☒ Notes
- ☒ Schematic
- ☒ Analysis
- ☒ Stress
- ☒ Efficiency
- ☒ Loop Response
- ☒ Bill Of Materials
- ☒ Layout

Notes

Name: TPS40195 12V - 1.8V @ 5A Part: TPS40195  
VinMin: 10.8 VinMax: 13.2 Vout: 1.8 Iout: 10

Design ID: 1208 Design Type: PowerSupply  
Creation Date: 27 Apr 2010  
Local Time: 11:27 AM

Schematic

Name: TPS40195 12V - 1.8V @ 5A Part: TPS40195  
VinMin: 10.8 VinMax: 13.2 Vout: 1.8 Iout: 10

Note : Parts with bold red labels can be completely modified, parts with plain black labels allow only name changes.

What If Analysis

Library Manager

Change your design view by clicking on the selected buttons and print out your report

Texas Instruments

# Library Manager

The screenshot shows the SwitcherPro Desktop application window. The title bar reads "SwitcherPro Desktop - TPS40195 12V - 1.8V @ 5A - 1208". The menu bar includes File, Tools, Order, and Help. The left sidebar contains a "Design List" with items: Design Report, What If Analysis, and Library Manager. Under Library Manager, there are two expandable sections: SystemParts and MyParts. SystemParts contains Inductors, Capacitors, MosFETs, and Diodes. MyParts also contains Inductors, Capacitors, MosFETs, and Diodes. The main area displays the "Selected Library: SystemParts" with counts: Inductors: 4716, Capacitors: 1086, MosFETs: 101, and Diodes: 106. Below this is a "Help" section with text: "The SystemParts library is managed by Texas Instruments and is read-only (cannot be edited/deleted). To add your own parts, select the 'MyParts' library." It also provides instructions on how to view, delete, and add parts. A table titled "Library Manager" shows a list of parts with columns "Part Number" and "Manufa". The first row shows "5632DCI" and "ADI". A red box highlights a delete icon next to the part number. To the right, a context menu is shown with options: "Add Inductor", "Add Capacitor", "Add MosFET", and "Add Diode".

SwitcherPro Desktop - TPS40195 12V - 1.8V @ 5A - 1208

File Tools Order Help

Design List

Design Report

What If Analysis

Library Manager

SystemParts

- Inductors
- Capacitors
- MosFETs
- Diodes

MyParts

- Inductors
- Capacitors
- MosFETs
- Diodes

Selected Library: SystemParts

Inductors: 4716 Capacitors: 1086 MosFETs: 101 Diodes: 106

Help

The SystemParts library is managed by Texas Instruments and is read-only (cannot be edited/deleted). To add your own parts, select the "MyParts" library.

To view parts, select any of the sub items within the SystemParts or MyParts tree (Ex. Inductors, Capacitors etc...).

To delete a part, click on the delete icon right next to the part number.

Add your own part by right clicking on a MyParts library tree item and choose your part type (Ex. Inductors etc...) from the context menu.

Library Manager

Part Number	Manufa
5632DCI	ADI

Library Manager

- SystemParts
- MyParts
  - Inductors
  - Capacitors
  - MosFETs
  - Diodes

- + Add Inductor
- + Add Capacitor
- + Add MosFET
- + Add Diode

Inductors: 4716

Capacitors: 1086

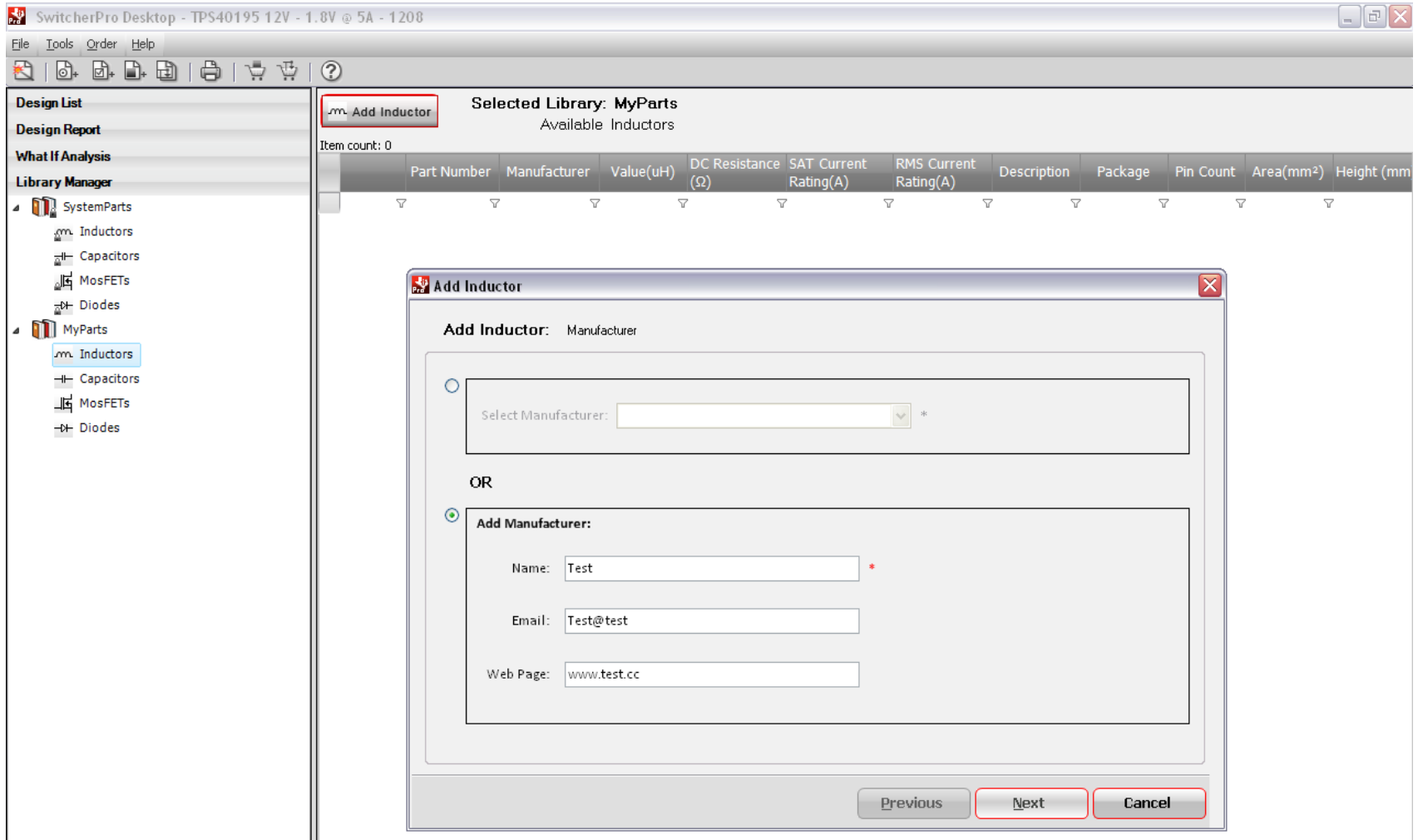
MosFETs: 101 incl. TI NexFET MosFETS

Diodes: 106



<http://www.ti.com/ww/en/analog/dualcool/index.shtml>

# Add new parts



➔ Add your own parameters for Inductors, Capacitors, MosFETs and Diodes

# Add new parts

**Add Inductor:** Manufacturer> Package

☐ Select Package:  \*

OR

☒ **Add Package:**

Name:  \*

Region:  ▼

Mount Type:  ▼

Length( mm ):

Width( mm ):

Area( mm<sup>2</sup> ):  \*

Height(mm):  \*

Max Power Loss( W ):

Pin Count:  \*

Ambient Temperature( °C ):   
Min:  Max:

➡ Enter Name, Area, Height and Pin count of your new part

# Add new parts

**Add Inductor** Manufacturer> Package> Properties

**Add Properties:**

Part Number:  \*

Description:

Value (  $\mu\text{H}$  ):  \*

DC Resistance(  $\Omega$  ):  \*

Saturation Current Rating( A ):  \*

RMS Current Rating( A ):  \*

[Previous](#) [Add Inductor](#) [Cancel](#)

➡ Enter Part Number, Value, DC resistance,  $I_{\text{SAT}}$  and  $I_{\text{RMS}}$

# What-If Analysis

SwitcherPro Desktop - TPS40195 12V - 1.8V @ 5A - 1208

File Tools Order Help

Design List  
Design Report  
What-If Analysis

- ☒ Power Stage Gain
- ☒ Power Stage Phase
- ☐ Open Loop Error Amplifier Gain
- ☐ Compensated Error Amplifier Gain
- ☐ Compensated Error Amplifier Phase
- ☒ Total Gain
- ☒ Total Phase

Name: TPS40195 12V - 1.8V @ 5A Part: TPS40195  
VinMin: 10.8 VinMax: 13.2 Vout: 1.8 Iout: 10

Compensation Power Stage Conditions

☒ Components ☐ Pole and Zero Frequencies

Edit resistor and capacitor values

Name	Value	Units
C7	150	pF
R3	4870	$\Omega$
R5	562	$\Omega$
C6	2200	pF
R1	10000	$\Omega$
C8	1000	pF

Calculate

☐ Lock Components Lock in components, so the software will not overwrite values on any design changes you make Save Changes

Edit pole and zero frequencies

Name	Value	Units
Int Pole Crossov...	7234	Hz
First Zero	15069	Hz
Second Zero	14855	Hz
First Pole	283194	Hz
Second Pole	232726	Hz

Calculate

Calculation Result

Duty Cycle	ILPP	Switching Freq	Cross Over Freq	LC Corner Freq	ESR Zero Freq	Gain Margin	Phase Margin
0.173	3.824A	300kHz	57.2Khz	11.7Khz	1.7MHz	-20 dB	45 Deg.

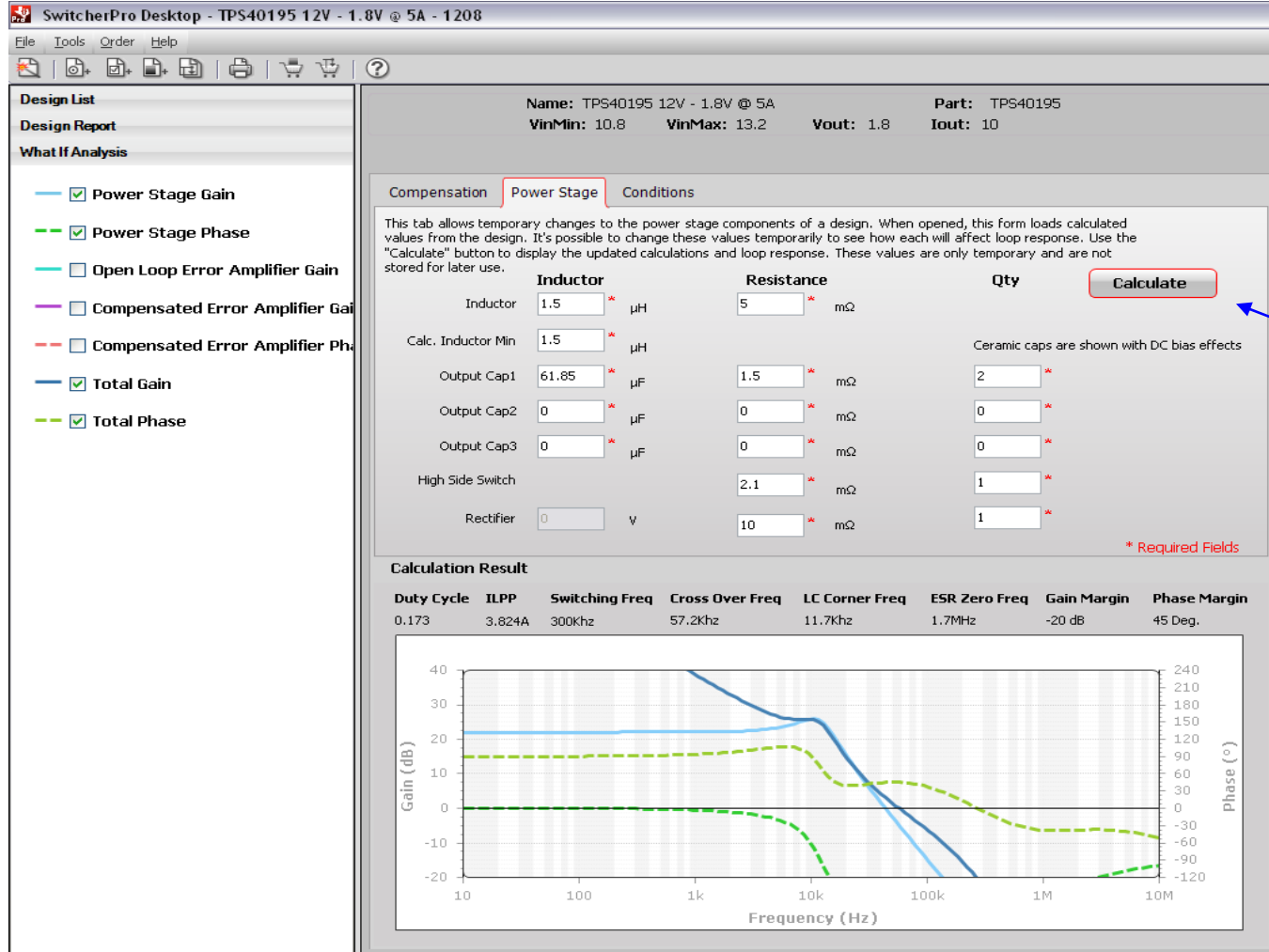
Gain (dB) vs Frequency (Hz) and Phase (°) vs Frequency (Hz) plot.

Change compensation by either editing the components or by changing the poles and zeros

Show needed curves by checking the right boxes



# What-If Analysis – Power Stage



Change Inductor, Capacitor and FET values to simulate different LC filter stages configurations

# What-If Analysis - Conditions

The screenshot shows the SwitcherPro Desktop software interface for a TPS40195 12V - 1.8V @ 5A - 1208 design. The left sidebar contains a 'Design List' with the following items:

- ☒ Power Stage Gain
- ☒ Power Stage Phase
- ☐ Open Loop Error Amplifier Gain
- ☐ Compensated Error Amplifier Gain
- ☐ Compensated Error Amplifier Phase
- ☒ Total Gain
- ☒ Total Phase

The main window displays the 'Conditions' tab, which allows for temporary changes to the conditions used when calculating loop response. The conditions are as follows:

Parameter	Value	Unit
Vin	10.8	V
Vout	1.8	V
Iout	10	A
Switching Frequency	300000	Hz

A 'Calculate' button is located at the bottom of the conditions section.

➡ Simulate different switching frequencies, different input-, output voltages and output currents

# SwitcherPro Help

- Quick start training videos allow users to get up to speed quickly with short 3-5 minute help videos from the tool folder on [www.ti.com](http://www.ti.com)
- Help files within SwitcherPro give users more details about functions and features

## Support Software

**Video for The Design Manager in SwitcherPro** (slac126.wmv, 28353 KB)

18 Jan 2007 [wmv](#)

**Video for The Design Manager in SwitcherPro** (slac126.zip, 23505 KB)

18 Jan 2007 [zip](#)

**Video for Creating Designs in SwitcherPro** (slac125.wmv, 16444 KB)

18 Jan 2007 [wmv](#)

**Video for Creating Designs in SwitcherPro** (slac125.zip, 12934 KB)

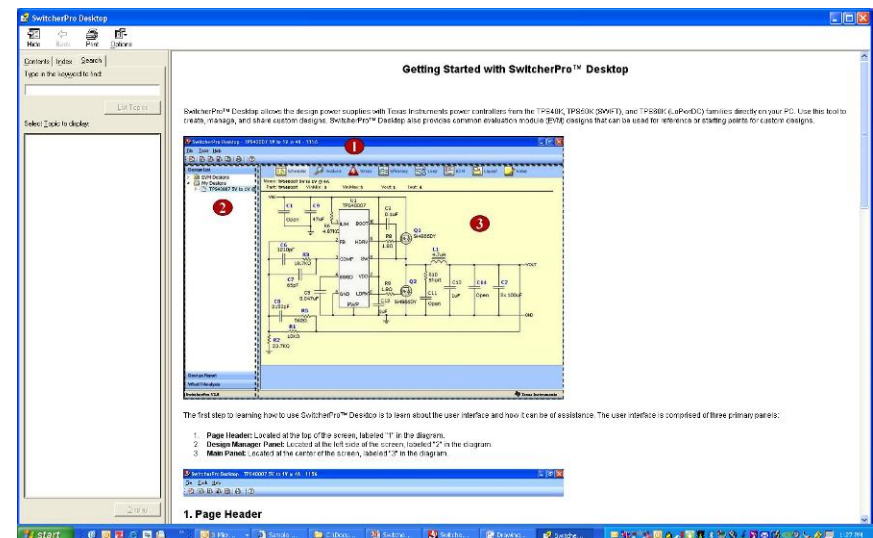
18 Jan 2007 [zip](#)

**Video for Changing/Filtering Parts in SwitcherPro** (slac124.wmv, 26584 KB)

18 Jan 2007 [wmv](#)

**Video for Changing/Filtering Parts in SwitcherPro** (slac124.zip, 21911 KB)

18 Jan 2007 [zip](#)

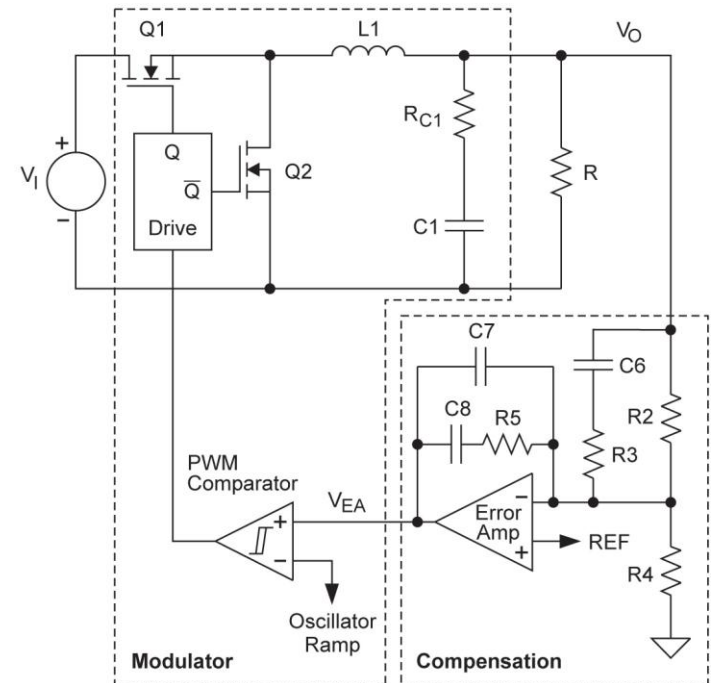
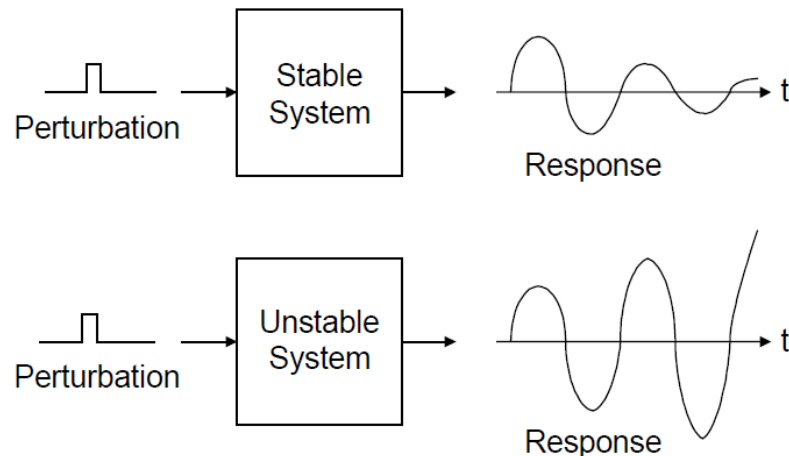


# Loop Compensation Basics

# Main task of a regulator

## Keep the voltage regulated

- Power supply is a closed loop system with negative feedback
- The feedback loop ensures that the output voltage is constant and independent of variations in
  - Input voltage
  - Load current
- The feedback loop “compensates” for changes in the input voltage or load current
- For a stable loop, negative feedback is required

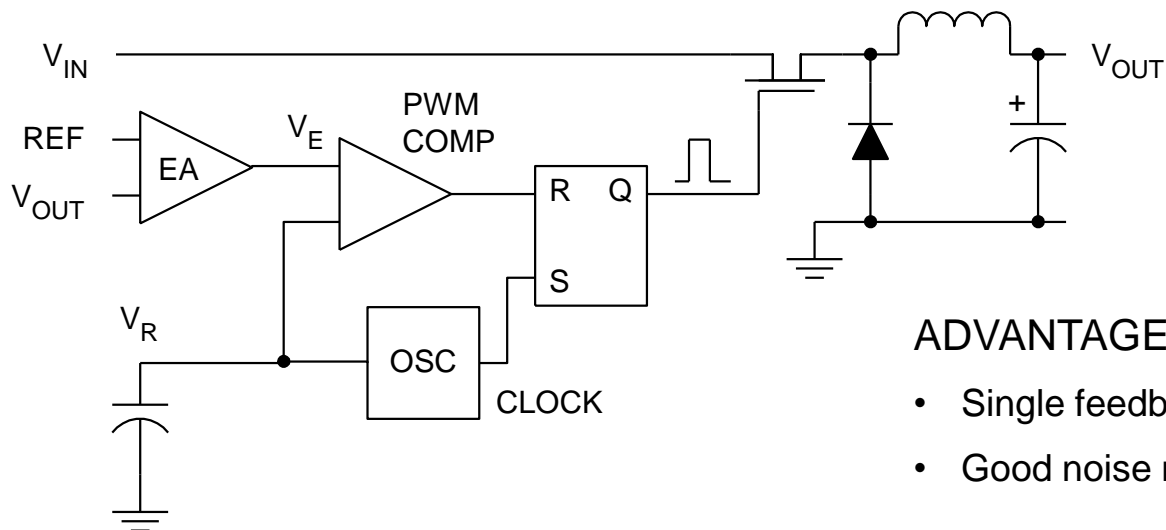


### Control Loop consisting of:

- Modulator:  
Oscillator / PWM comparator / PwrStage
- Compensator:  
E/A, Compensation network

# Control Loop Topologies

## Voltage Mode

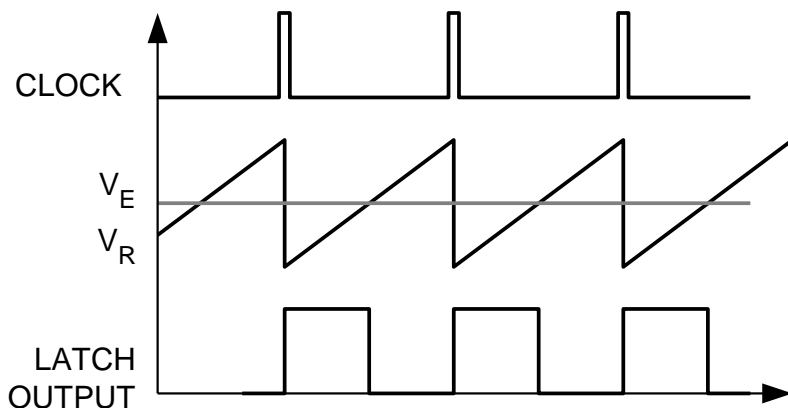


### ADVANTAGES

- Single feedback loop
- Good noise margin

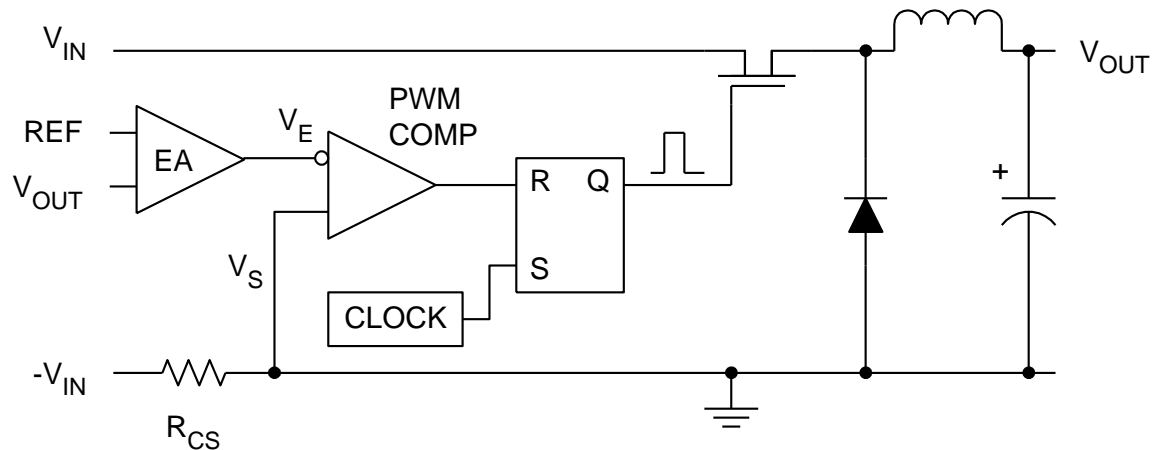
### DISADVANTAGES

- Slow dynamic response
- Double-pole compensation – Type III
- Output caps affect comp
- $V_{IN}$  affects loop gain



# Control Loop Topologies

## Current - Mode

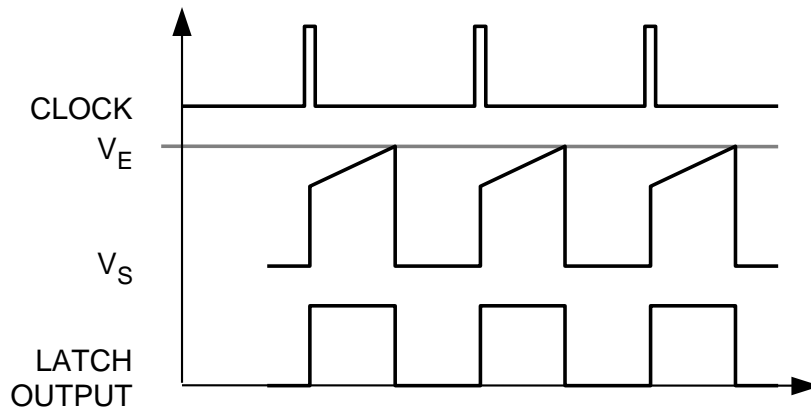


### ADVANTAGES

- Fast response to output current changes
- Single-pole compensation
- Parallelability with load sharing

### DISADVANTAGES

- Noise sensitivity to current spikes
- Two feedback loops

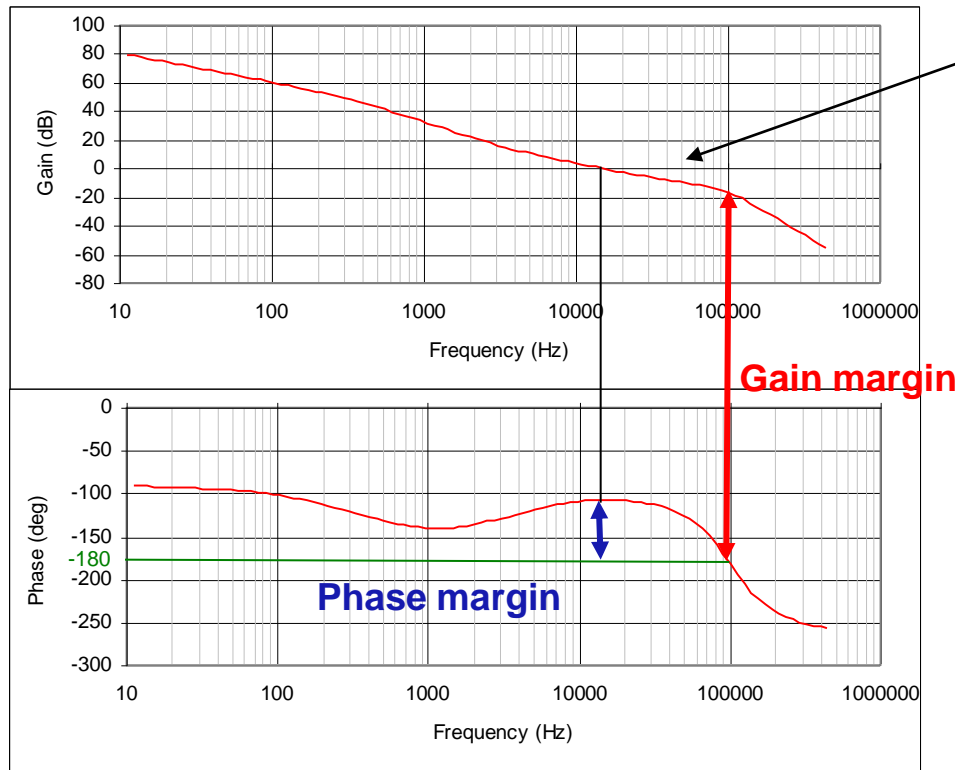


# Phase and Gain Plots

**Stability criteria:** A minimum value for both the gain and phase margin of a power supply.

In power supply design, a power supply is typically defined to be stable if the gain margin is greater than 6 dB and the phase margin is greater than 45°.

The requirement for stability is typically met if the overall gain crosses 0 dB with a slope of -20 dB/decade

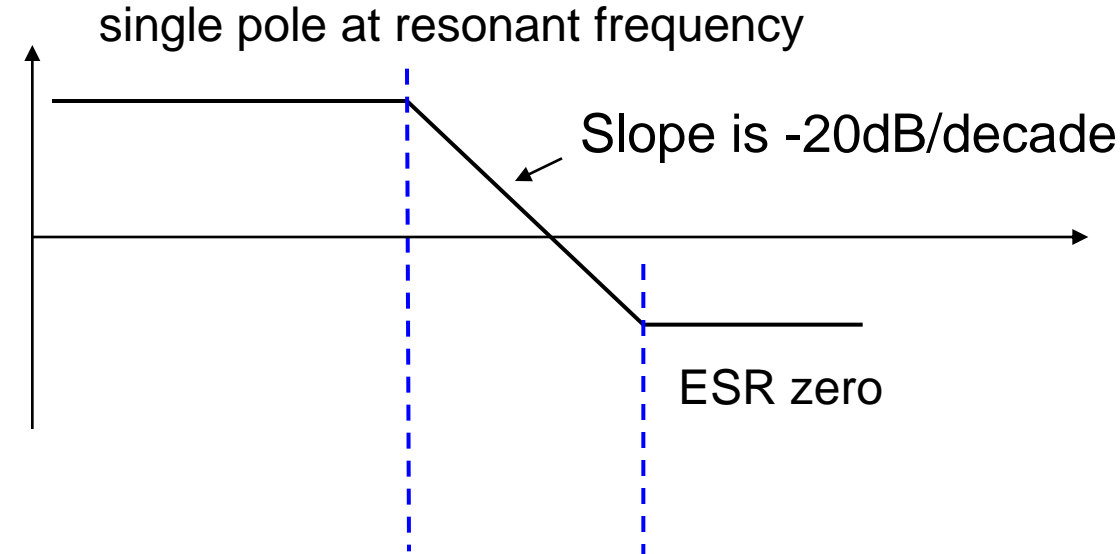


- Phase Margin @ 0dB Gain
- $180^\circ - 110^\circ = 70^\circ$  of Phase Margin
- 45° to 90° of Phase Margin is the target for a stable design



# Output Filter and Power Stage

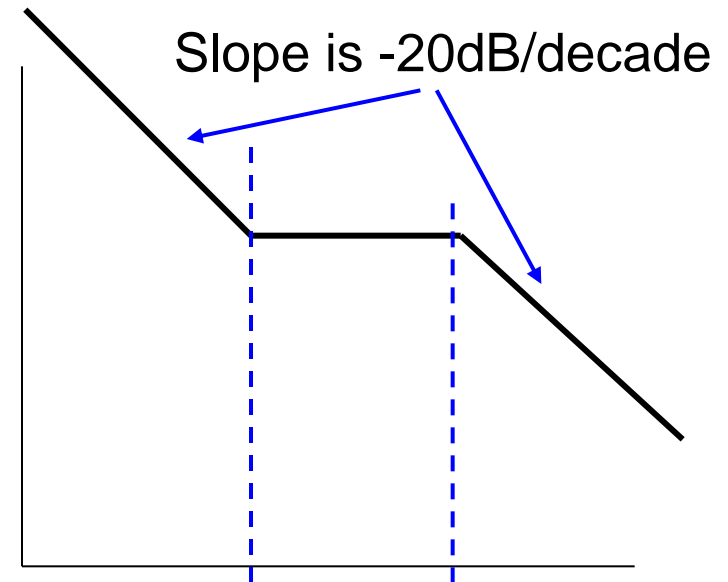
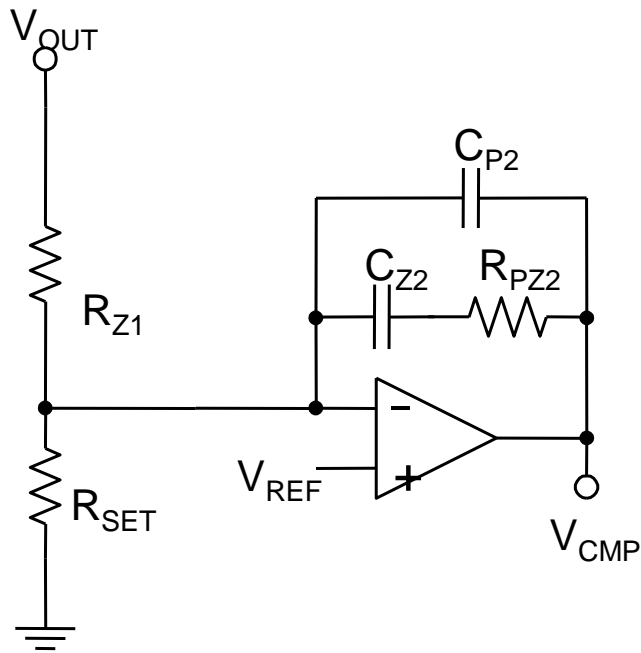
- 1st Order System adds a pole at resonant frequency
- Output capacitor ESR will add a zero



$$f_R = \frac{1}{2\pi \times C \times R_{LOAD}}$$

$$f_{ESR\_Zero} = \frac{1}{2\pi \times ESR \times C_o}$$

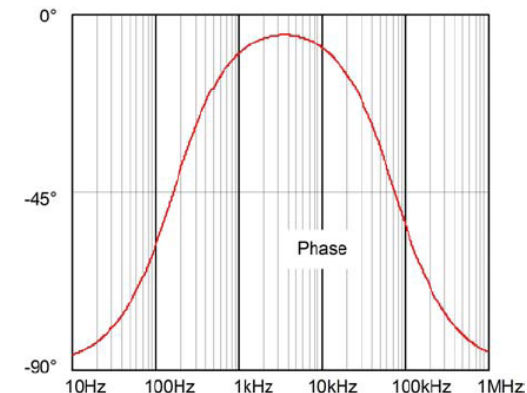
# Compensation Networks – Type II



## • Type 2.

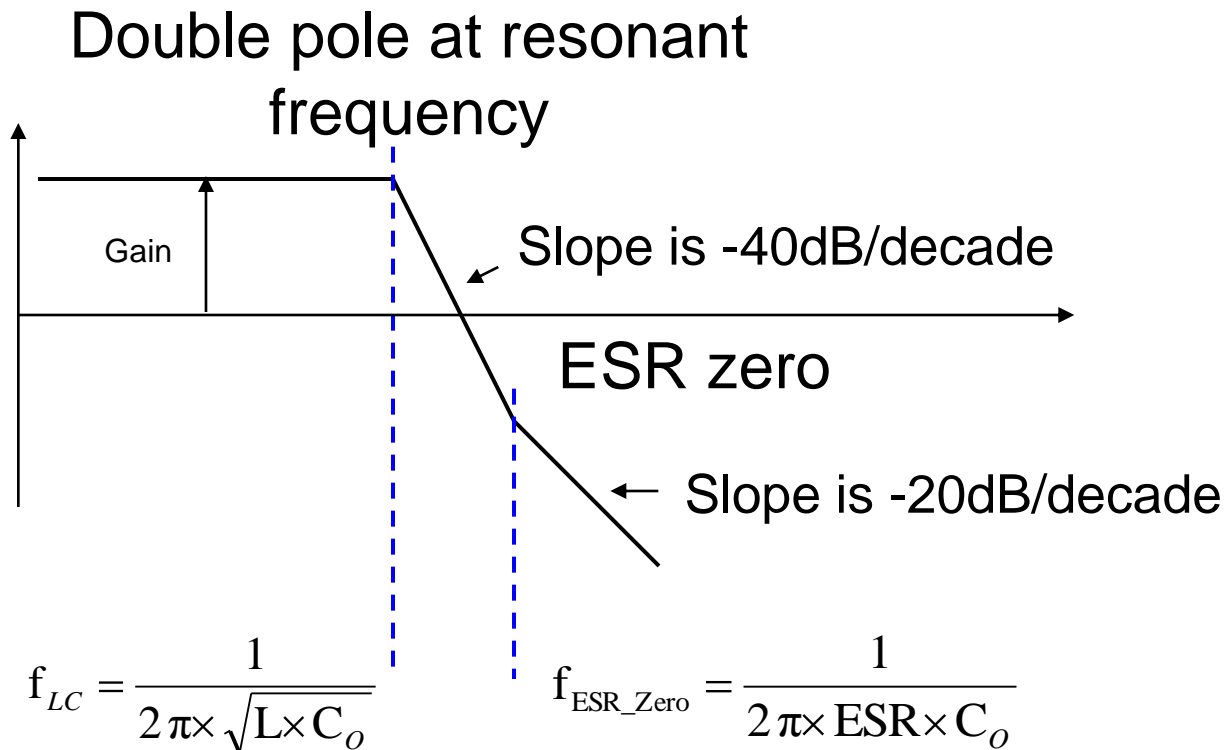
- Two poles one at origin and one set by  $R_{PZ2}$  &  $C_{P2}$
- One Zero set by  $R_{PZ2}$  &  $C_{Z2}$

$$f_{Z1} = \frac{1}{2\pi \times R_{PZ2} \times C_{Z2}} \quad f_{P1} = \frac{1}{2\pi \times R_{PZ2} \times C_{P2}}$$

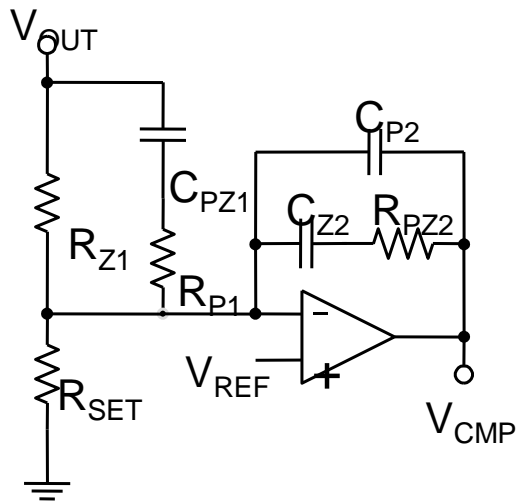


# Output Filter and Power Stage

- Output filter is an LC response
- Output capacitor ESR will add a zero



# Compensation Networks – Type III



## • Type 3.

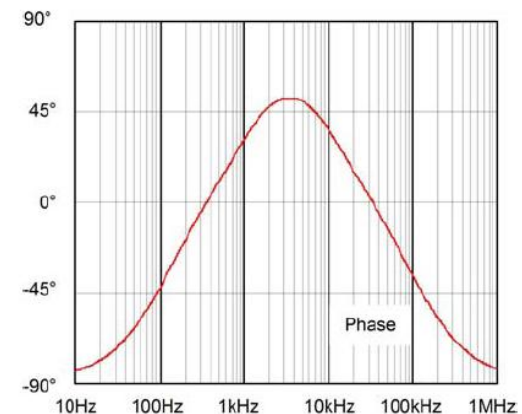
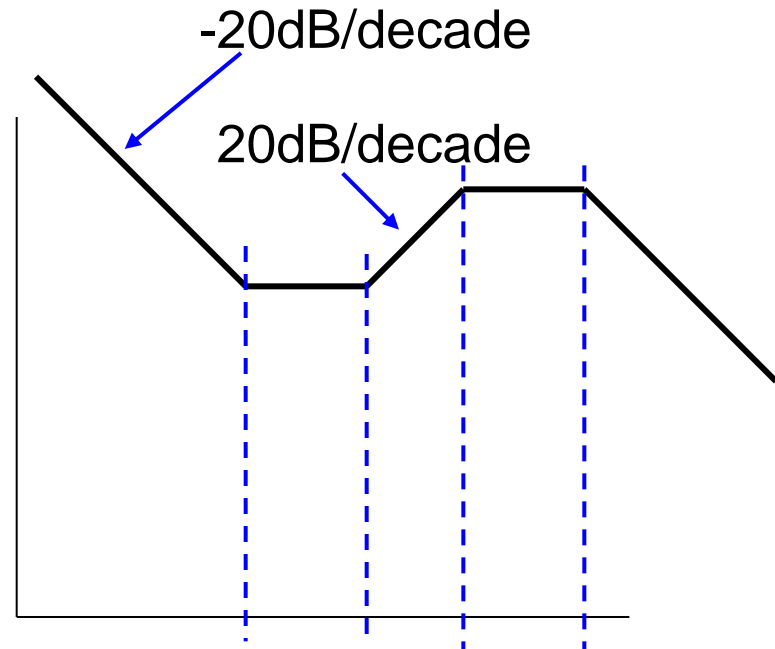
- Three poles one at origin, one set by  $R_{PZ2}$  &  $C_{P2}$  and one by  $R_{P1}$  &  $C_{PZ1}$
- Two zeros one set by  $C_{Z2}$  &  $R_{PZ2}$  and one by  $R_{Z1}$  &  $C_{PZ1}$

$$f_{Z1} = \frac{1}{2\pi \times R_{Z1} \times C_{PZ1}}$$

$$f_{P1} = \frac{1}{2\pi \times R_{P1} \times C_{PZ1}}$$

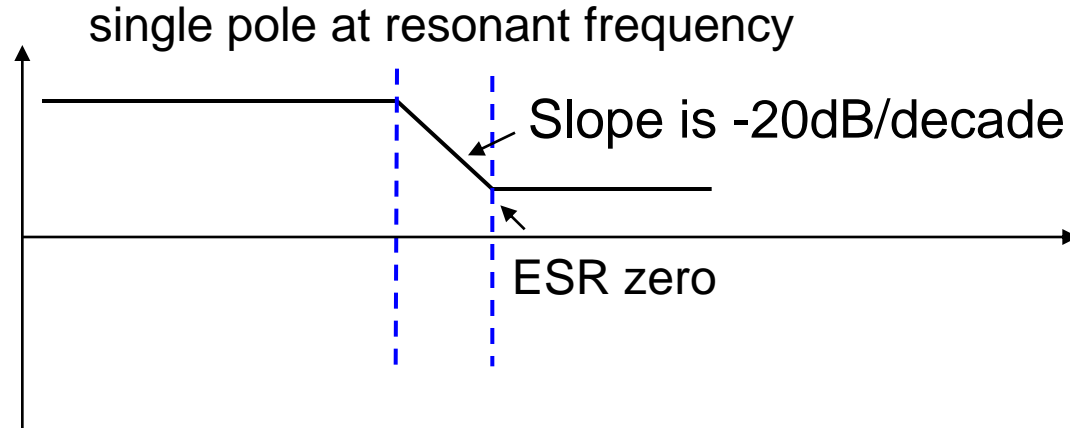
$$f_{Z2} = \frac{1}{2\pi \times R_{PZ2} \times C_{Z2}}$$

$$f_{P2} = \frac{1}{2\pi \times R_{PZ2} \times C_{P2}}$$



# Output Filter and Power Stage

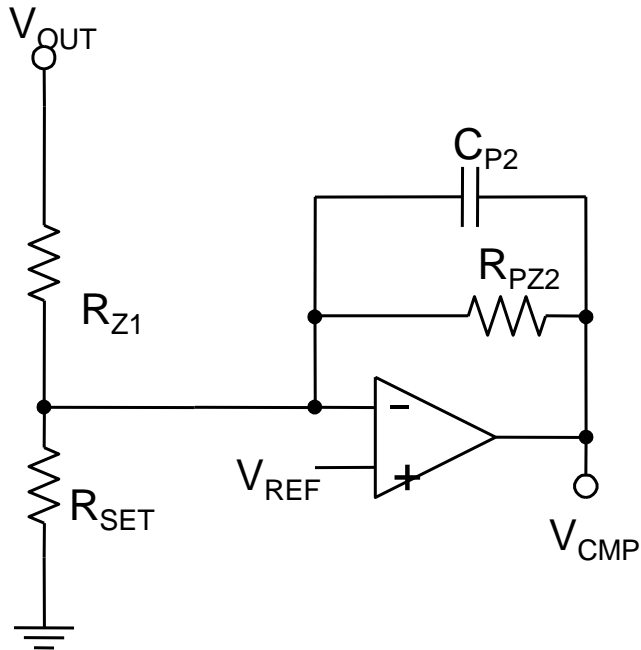
- 1st Order System adds a pole at resonant frequency
- Output capacitor ESR will add a zero



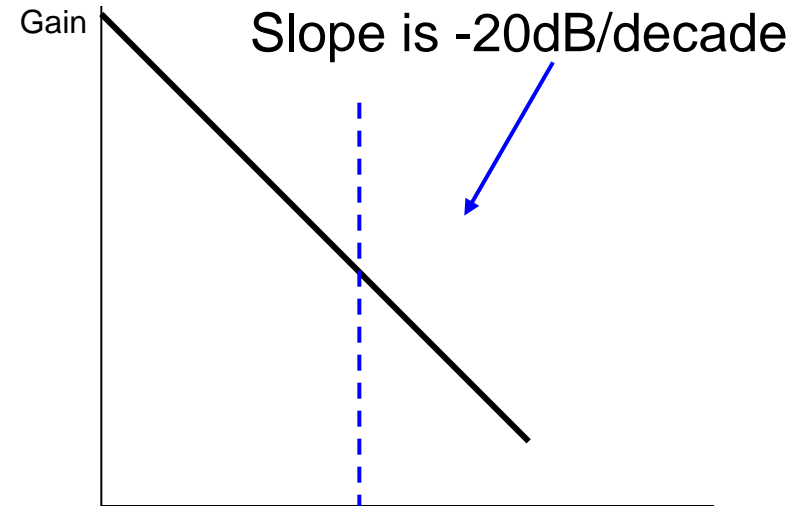
$$f_R = \frac{1}{2\pi \times C \times R_{LOAD}}$$

$$f_{ESR\_Zero} = \frac{1}{2\pi \times ESR \times C_o}$$

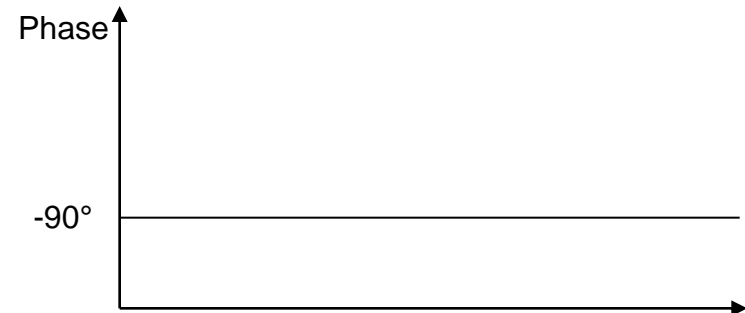
# Compensation Networks – Type I



- Type 1.
  - One pole set by  $R_{PZ2}$  &  $C_{P2}$



$$f_{DP} = \frac{1}{2\pi \times R_{PZ2} \times C_{P2}}$$



# Loop Compensation

## Step by Step Design Procedure

# DC/DC Design Example

Input Voltage: 10.8V -13.2V

Output Voltage: 1.8V

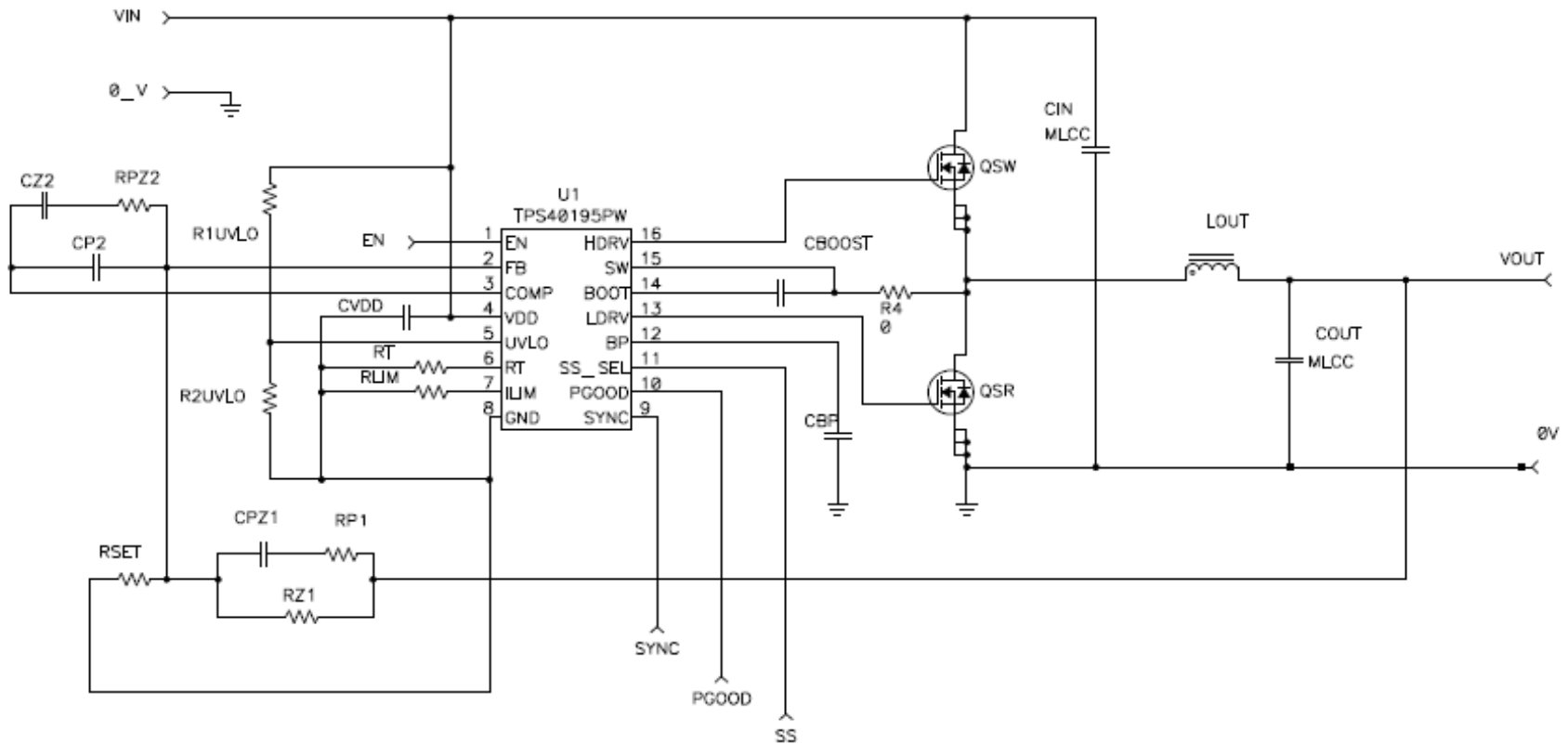
Output Current: 10A

Controller: TPS40195

Datasheet:  $V_{\text{RAMP}} = 1\text{V}$

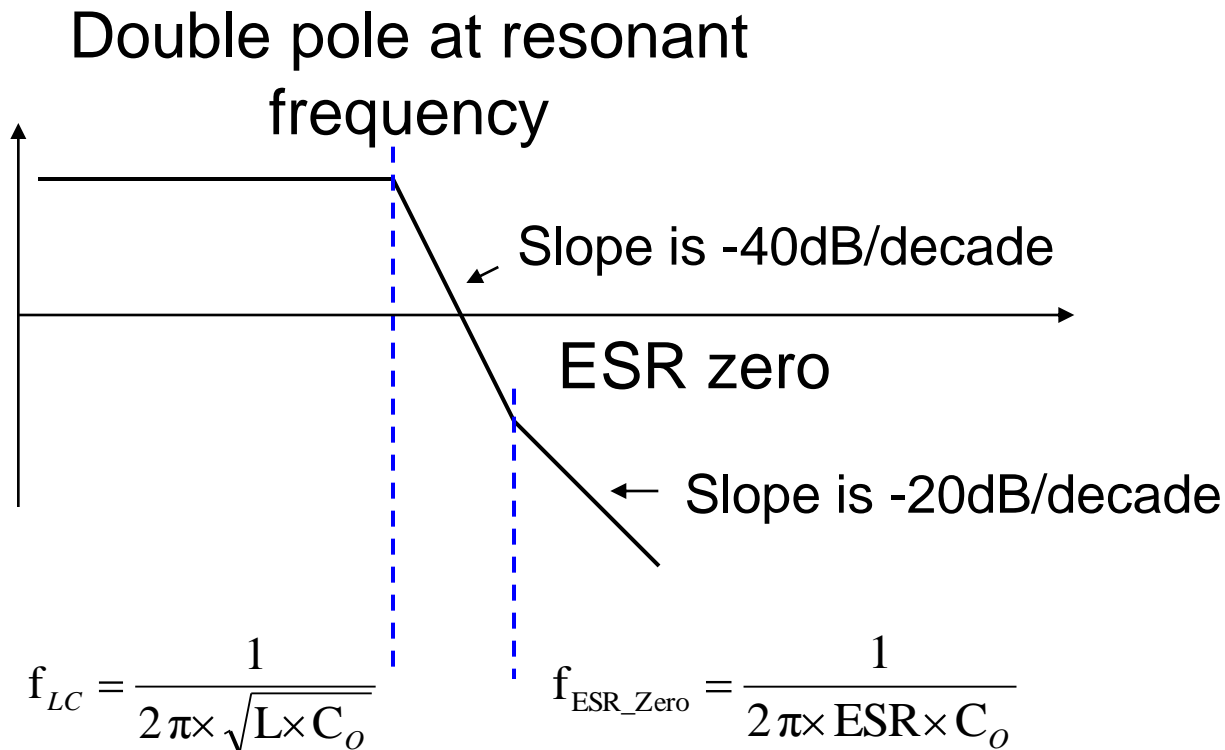


# TPS40195 Schematic



# Output Filter and Power Stage

- Output filter is an LC response
- Output capacitor ESR will add a zero



# Step-by-Step Compensation

- Draw PWM and LC filter gain.
  - PWM gain (no Voltage Feed Forward)

$$\text{DCGAIN} = 20 \times \text{LOG} \left( \frac{V_{IN}}{V_{\text{RAMP}}} \right) = 20 \times \text{LOG} \left( \frac{12}{1} \right) = 21.6 \text{ dB}$$

- LC filter resonant frequency

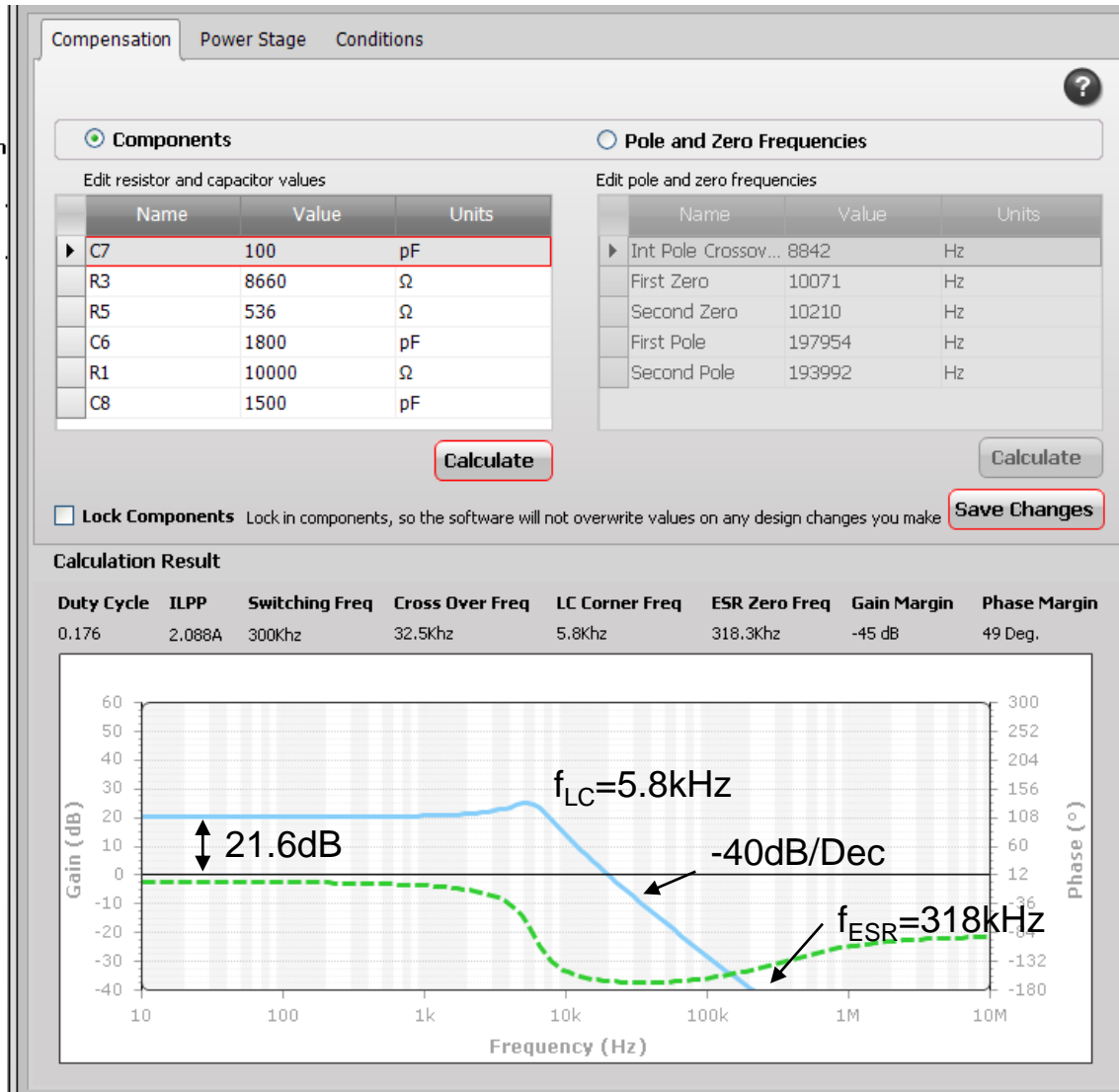
$$f_{\text{LC\_Pole}} = \frac{1}{2\pi \times \sqrt{L \times C_o}} = \frac{1}{2\pi \times \sqrt{2.5 \mu\text{H} \times 300 \mu\text{F}}} = 5.8 \text{ kHz}$$

- Maximum ESR zero

$$f_{\text{ESR\_Zero}} = \frac{1}{2\pi \times \text{ESR} \times C_o} = \frac{1}{2\pi \times 1.66 \text{ m}\Omega \times 300 \mu\text{F}} = 318 \text{ kHz}$$

# Power Stage Gain + Power Stage Phase

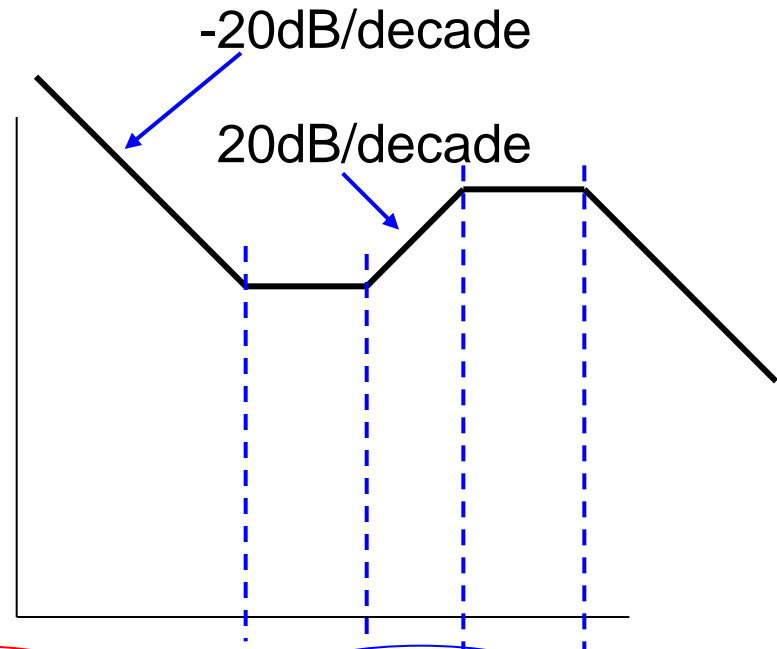
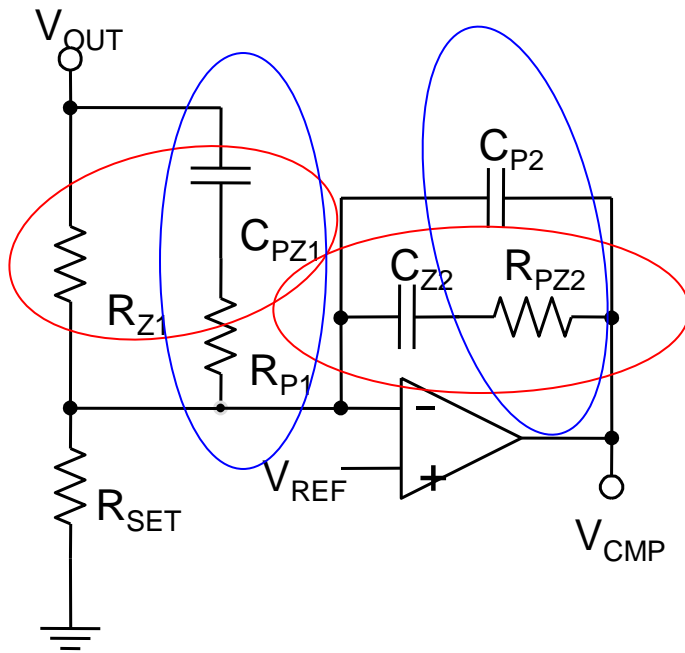
- ☒ Power Stage Gain
- ☒ Power Stage Phase
- ☐ Open Loop Error Am
- ☐ Compensated Error
- ☐ Compensated Error
- ☐ Total Gain
- ☐ Total Phase



Pole:  $-90^\circ$  phase

Zero:  $+90^\circ$  phase

# Compensation Network – Type III



$$f_{Z1} = \frac{1}{2\pi \times R_{Z1} \times C_{PZ1}}$$

$$f_{Z2} = \frac{1}{2\pi \times R_{PZ2} \times C_{Z2}}$$

$$f_{P1} = \frac{1}{2\pi \times R_{P1} \times C_{PZ1}}$$

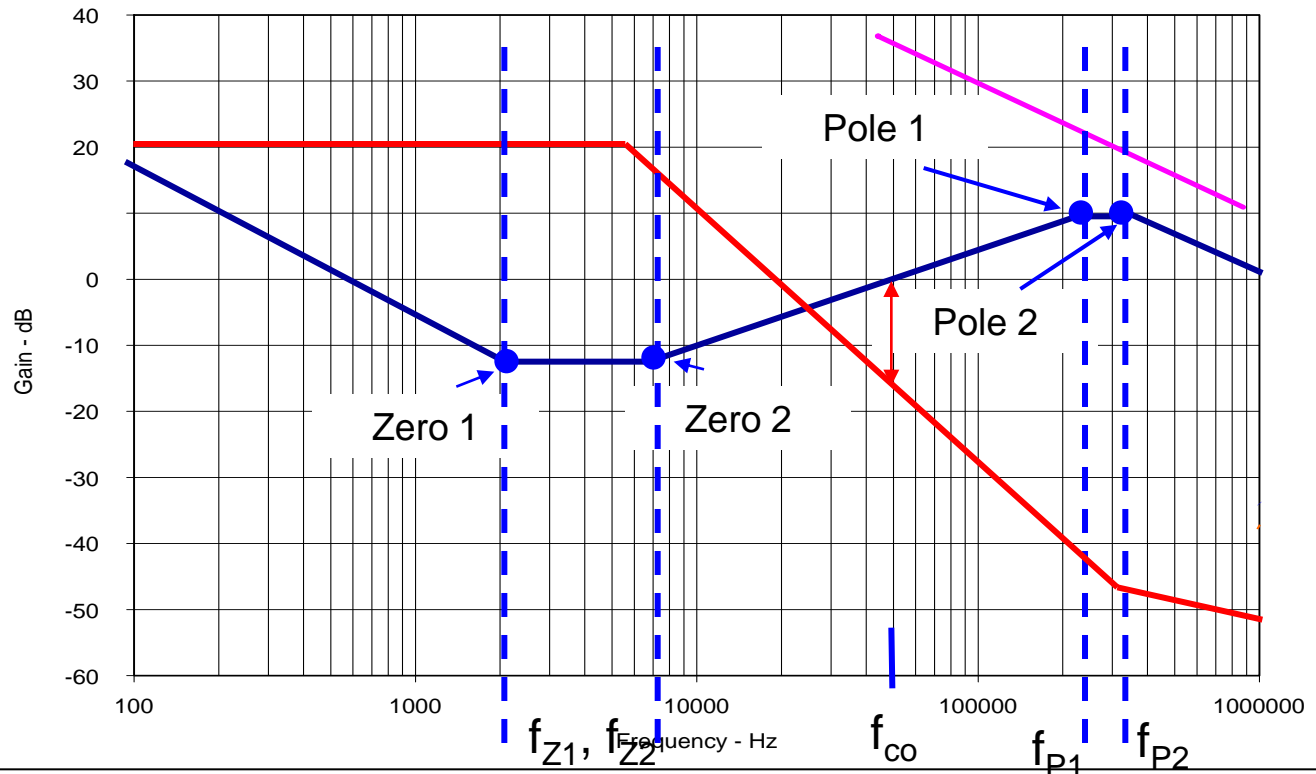
$$f_{P2} = \frac{1}{2\pi \times R_{PZ2} \times C_{P2}}$$

## • Type III

- Three poles one at origin, one set by  $R_{PZ2}$  &  $C_{P2}$  and one by  $R_{P1}$  &  $C_{PZ1}$
- Two zeros one set by  $C_{Z2}$  &  $R_{PZ2}$  and one by  $R_{Z1}$  &  $C_{PZ1}$

# Step-by-Step Compensation

- Select cross over frequency  $f_{co}$ , between  $f_s/4$  to  $f_s/10$ . Select 50kHz.
- The high frequency gain must be such that the over all system has 0 dB at the required crossover frequency → 15.8dB
- Use type III network.



# Step-by-Step Compensation

- Place one zero well below the L-C double pole at 5.8 kHz ( $f_{z1}=2.1$  kHz)
- Place the second zero near the double pole  $f_{z2}$  at 5.8 kHz ( $f_{z2} = 6.9$ kHz)
- Place one pole well above the desired cross over frequency, selected as one sixth the switching frequency,  $f_{CO} = 50$  kHz,  $f_{p1} = 300$  kHz
- Place the second pole near the ESR zero of the output capacitors of 318 kHz.  
 $f_{p2} = 318$  kHz
- Set  $R_{z1} = 51$  k $\Omega$

- Calculate  $C_{pz1}$  
$$C_{pz1} = \frac{1}{2\pi \times R_{z1} \times f_{z1}} = 1500nF$$

- Calculate  $R_{p1}$  
$$R_{p1} = \frac{1}{2\pi \times C_{pz1} \times f_{p1}} = 363\Omega \rightarrow \text{Use } 357\Omega$$

# Step-by-Step Compensation

- Calculate  $R_{PZ2}$

$$R_{PZ2} = \frac{R_{Z1} \times R_{P1}}{R_{Z1} + R_{P1}} \times GAIN = 12.7k\Omega$$

- Calculate  $C_{Z2}$

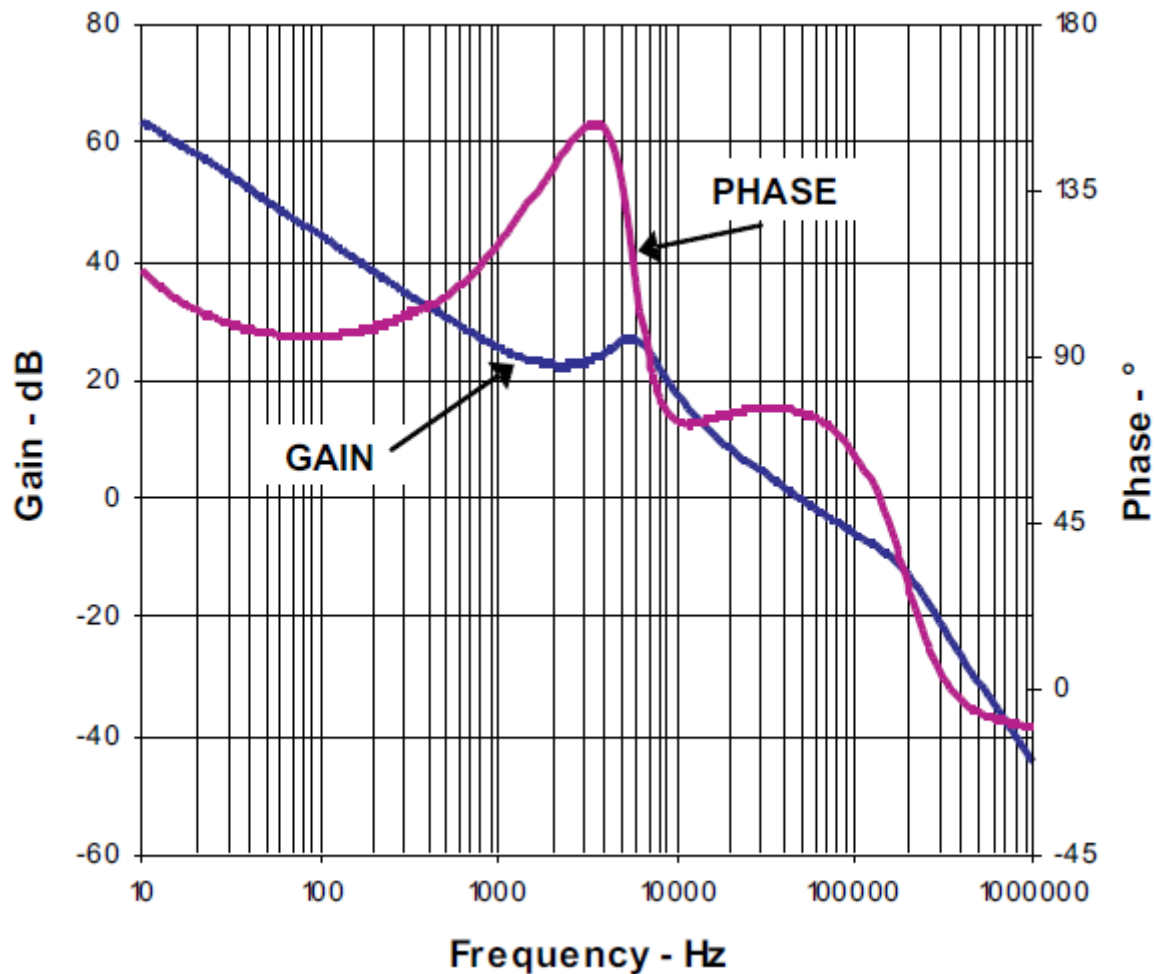
$$C_{Z2} = \frac{1}{2\pi \times R_{PZ2} \times f_{Z2}} = 1475 pF \longrightarrow \text{use } 2200pF$$

- Calculate  $C_{P2}$

$$C_{P2} = \frac{1}{2\pi \times R_{PZ2} \times f_{P2}} = 37 pF \longrightarrow \text{use } 33pF$$



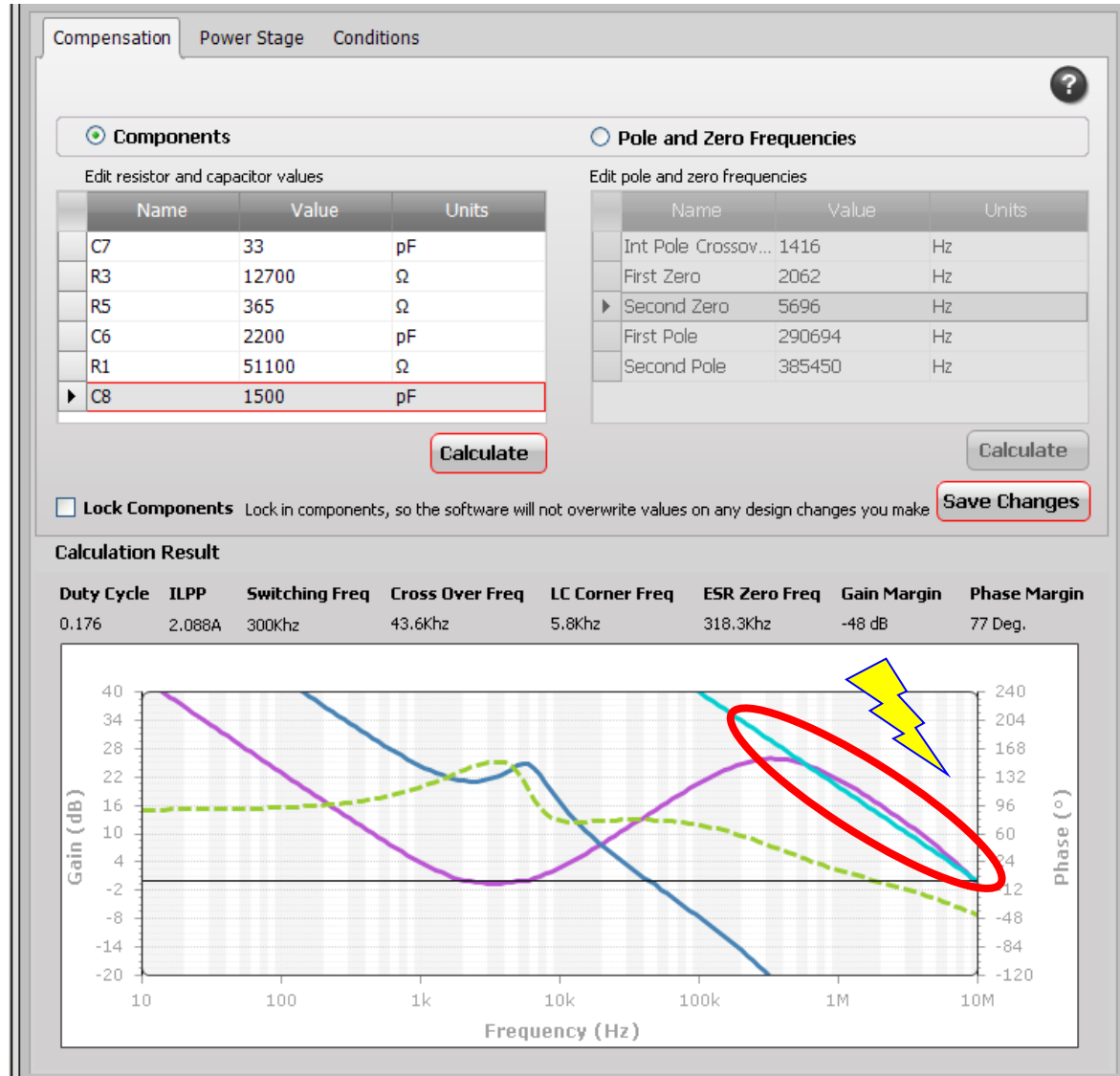
# Final Bode Plot – Real World



$f_{CO} \approx 45\text{kHz}$   
Phase Margin  $\approx 70^\circ$

# Final Bode Plot – Switcher Pro

- ☐ Power Stage Gain
- ☐ Power Stage Phase
- ☒ Open Loop Error Amplifier Gain
- ☒ Compensated Error Amplifier Gain
- ☐ Compensated Error Amplifier Phase
- ☒ Total Gain
- ☒ Total Phase



# Integrator Pole Crossover

☐ Components

Edit resistor and capacitor values

Name	Value	Units
C6	1200	pF
C7	68	pF
C8	2200	pF
R3	19600	$\Omega$

Calculate

☒ Poles And Zero Frequencies

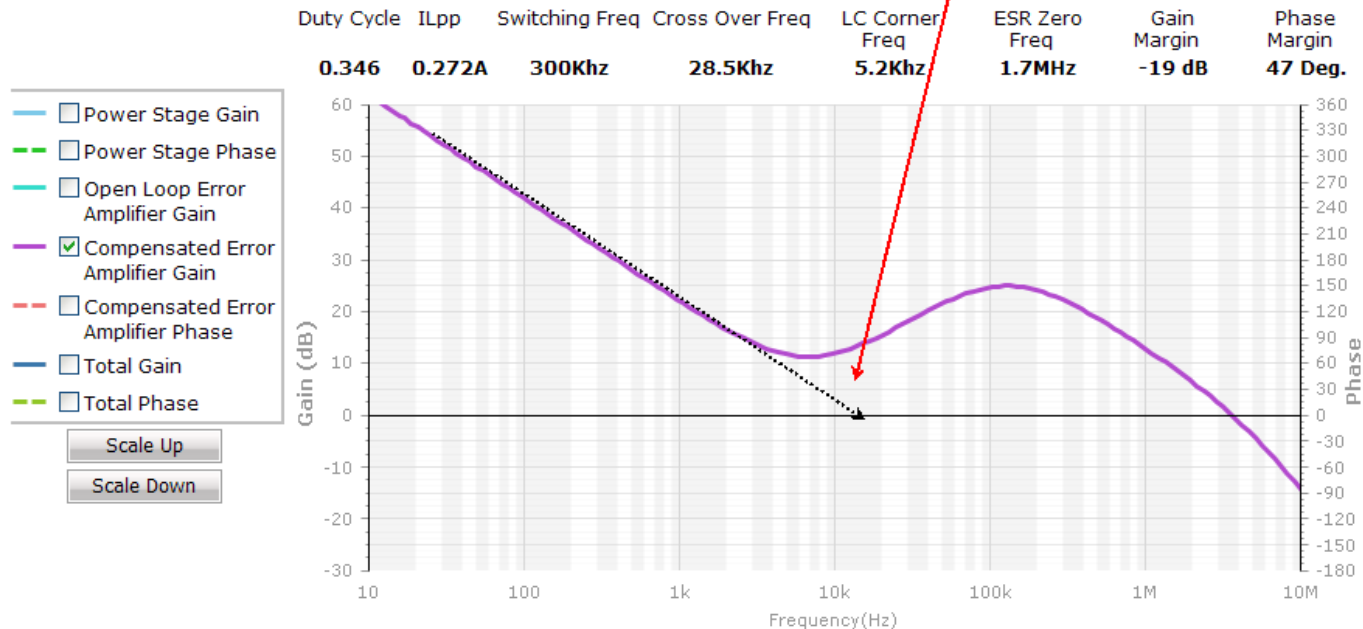
Edit pole and zero frequencies

Name	Value	Units
Int Pole Crossover	13263	Hz
First Zero	6866	Hz
Second Zero	6767	Hz
First Pole	134969	Hz

Calculate

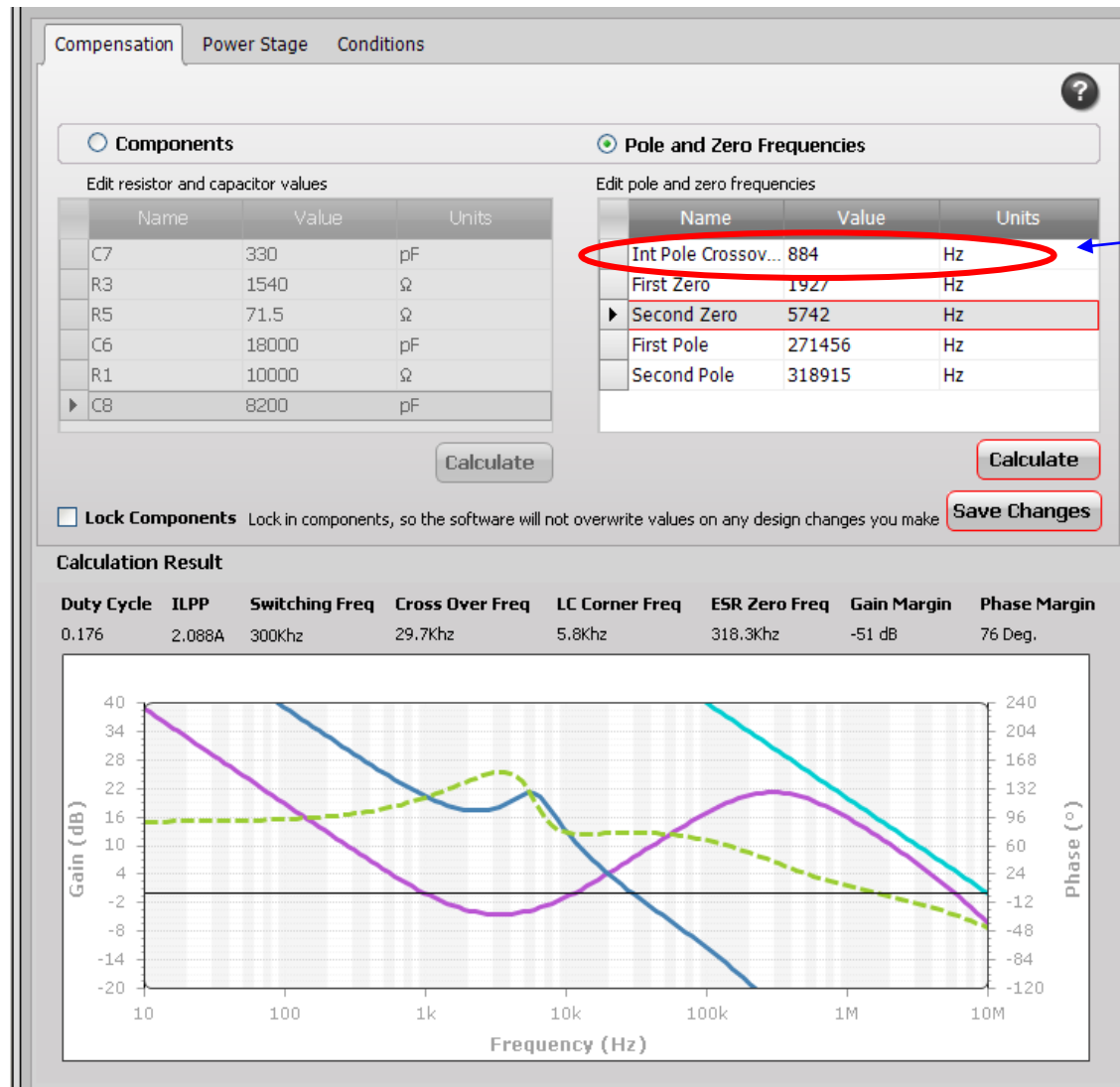
☐ Lock Components - lock in component values so the software will not overwrite values on any design changes you make.

Save Changes



# Final Bode Plot – Switcher Pro

- ☐ Power Stage Gain
- ☐ Power Stage Phase
- ☒ Open Loop Error Amplifier Gain
- ☒ Compensated Error Amplifier Gain
- ☐ Compensated Error Amplifier Phase
- ☒ Total Gain
- ☒ Total Phase

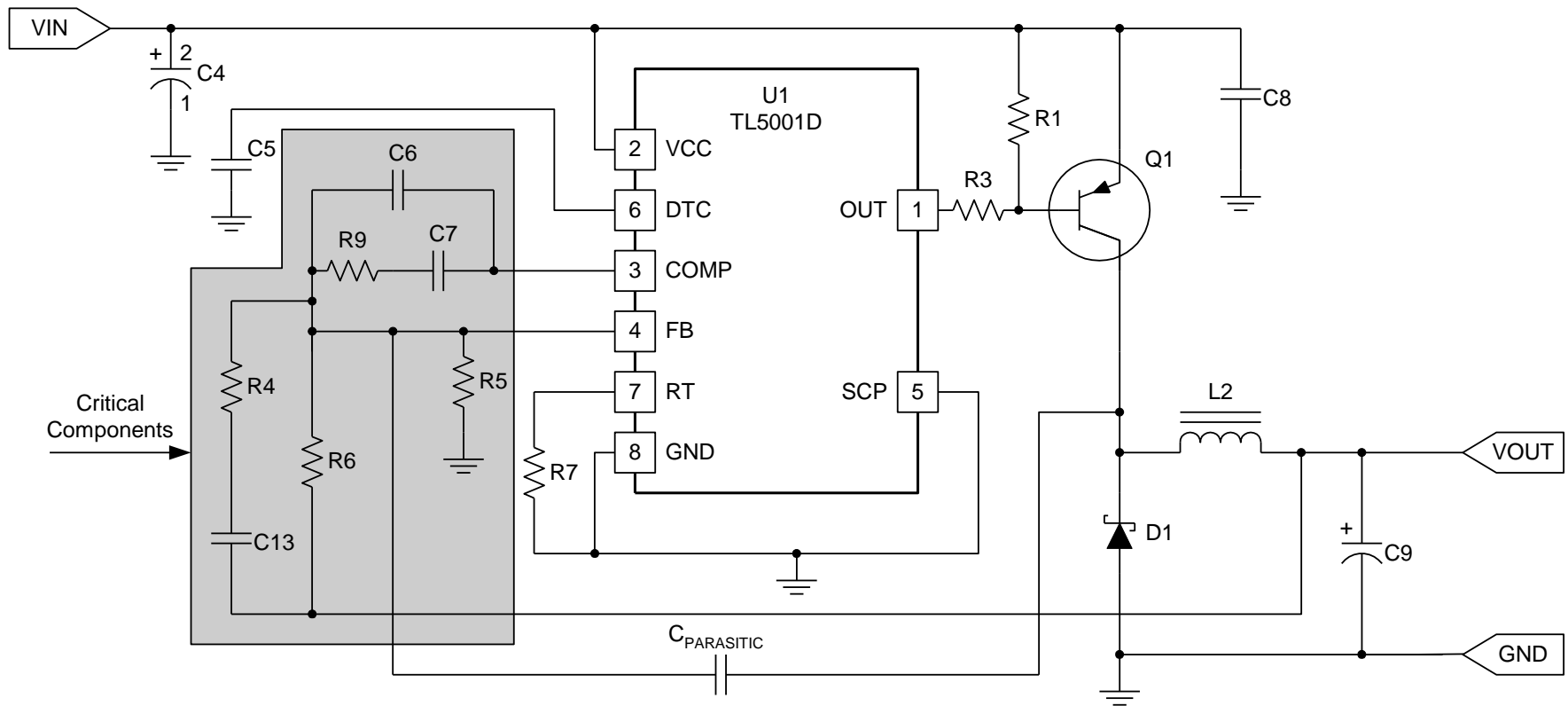


Reduce Gain

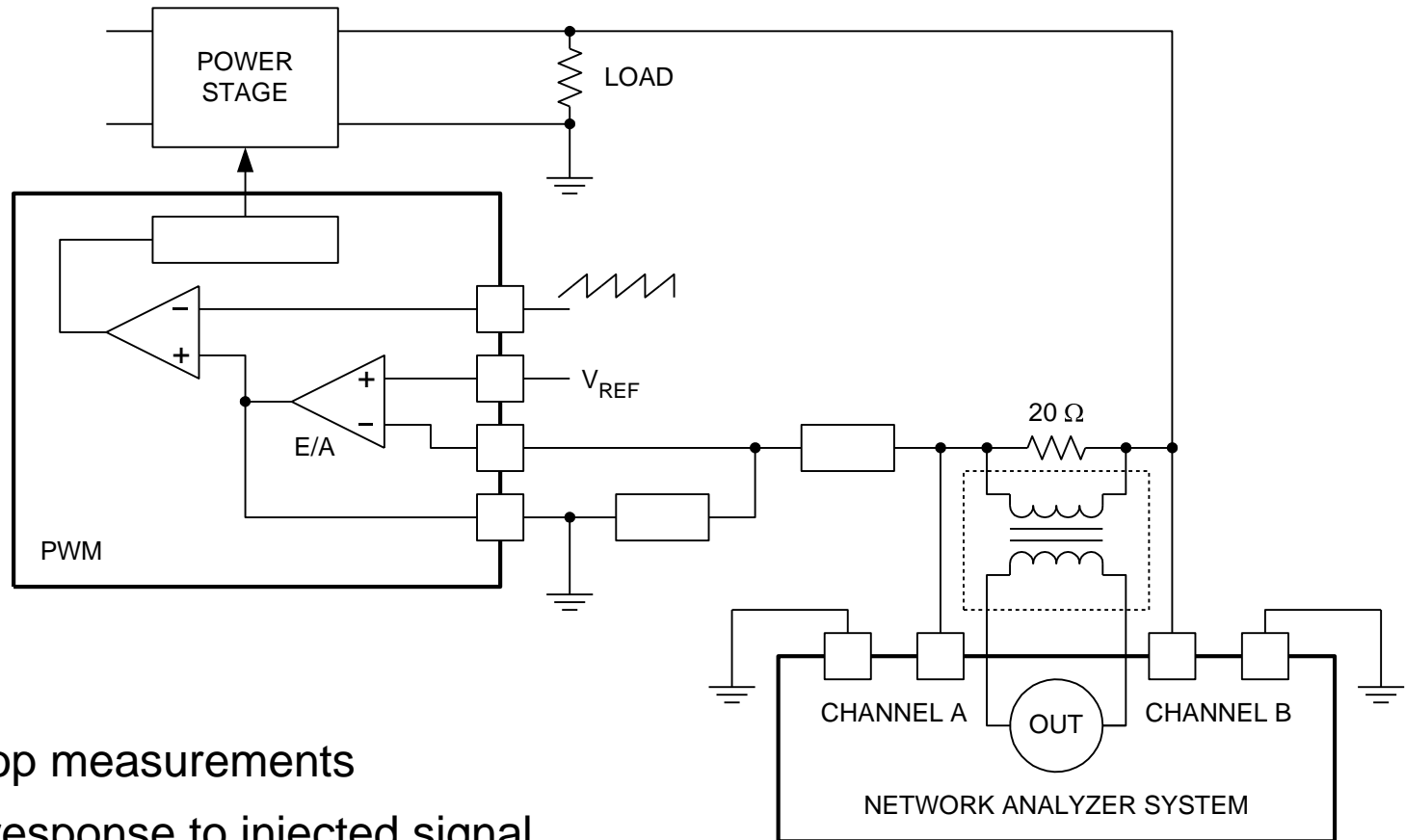
# SwitcherPro Demo

# Chaos Created by Noise Injection

- Compensation network should be placed close to error amplifier
- Place resistors so they connect to inverting input of E/A

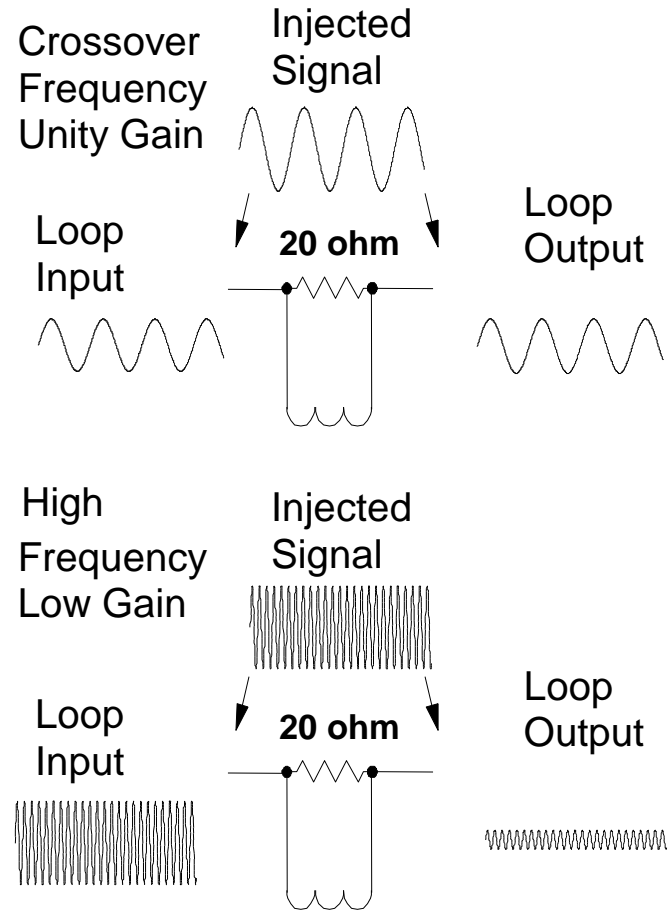
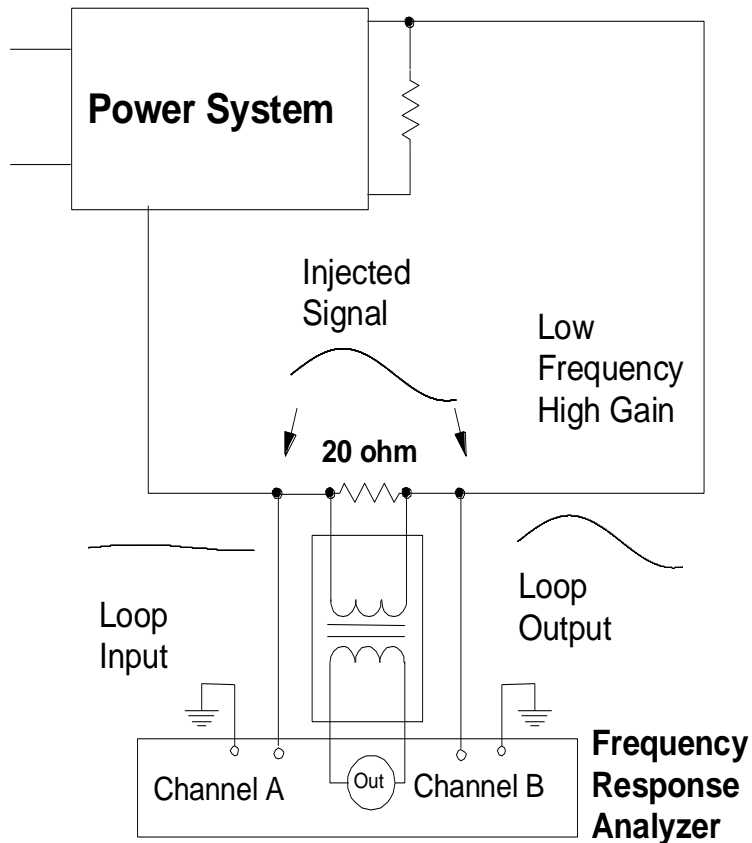


# Measuring Loop Response



- Closed loop measurements
- Measure response to injected signal
- Measurement must not affect operation
- Direct measurement of gain/phase margins

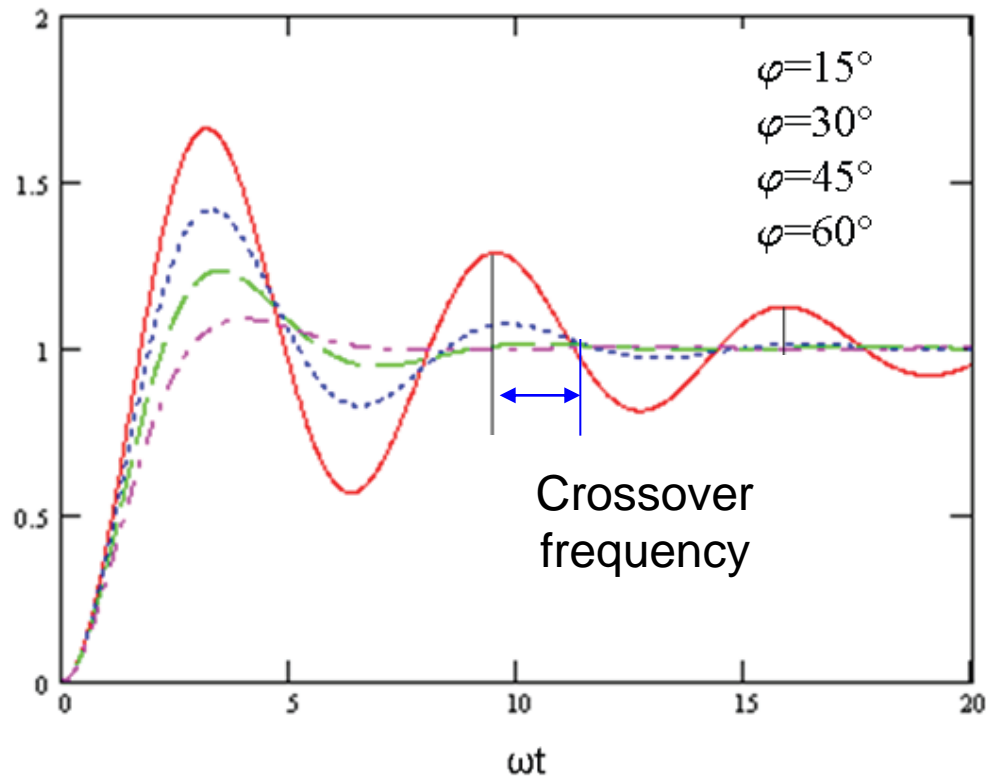
# Freq. Measurements w/Constant Injected Signal





# Loop Measurement from Transient Response

The important thing to look for is the ringing on the output immediately following the application of the load step. The frequency of the ringing indicates the control loop's crossover frequency, and the number of periods occurring before the ringing dies out indicates the phase margin.



# Thank you!