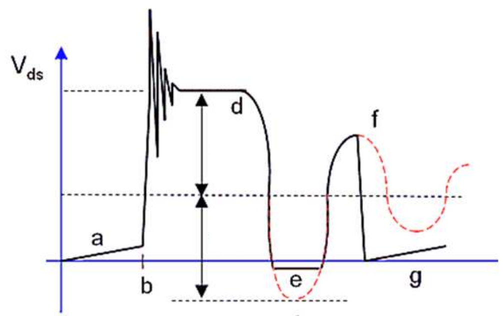
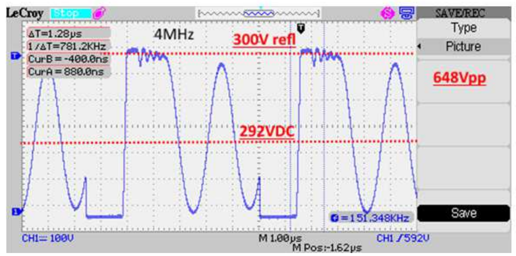
Computer-based Modelling and Experimental Optimization of Power Supplies

Agenda

TOPICS:

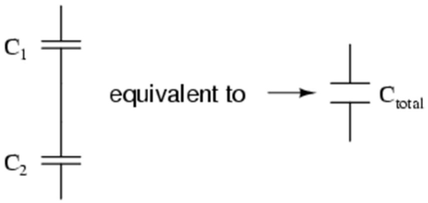


ref. 1



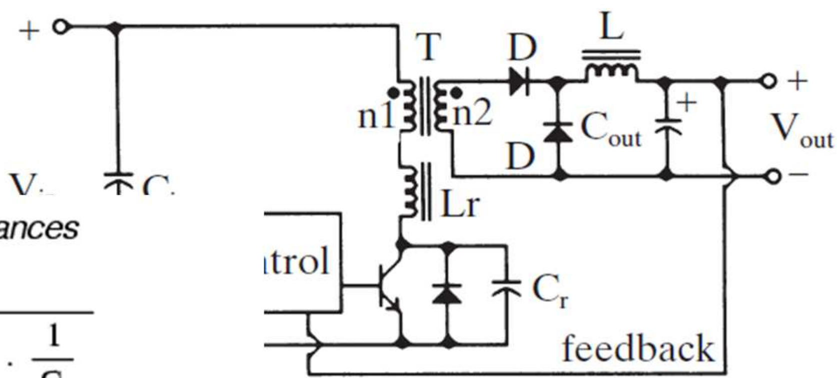
Everything Looks Better But

- 30 kV OEM cap. charger
- Prototype evaluation
- Safe background
- Auxiliary PSU
- 1T Forward Converter
- Reflected impedance by N^2



Series Capacitances

$$C_{total} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \ldots \frac{1}{C_n}}$$



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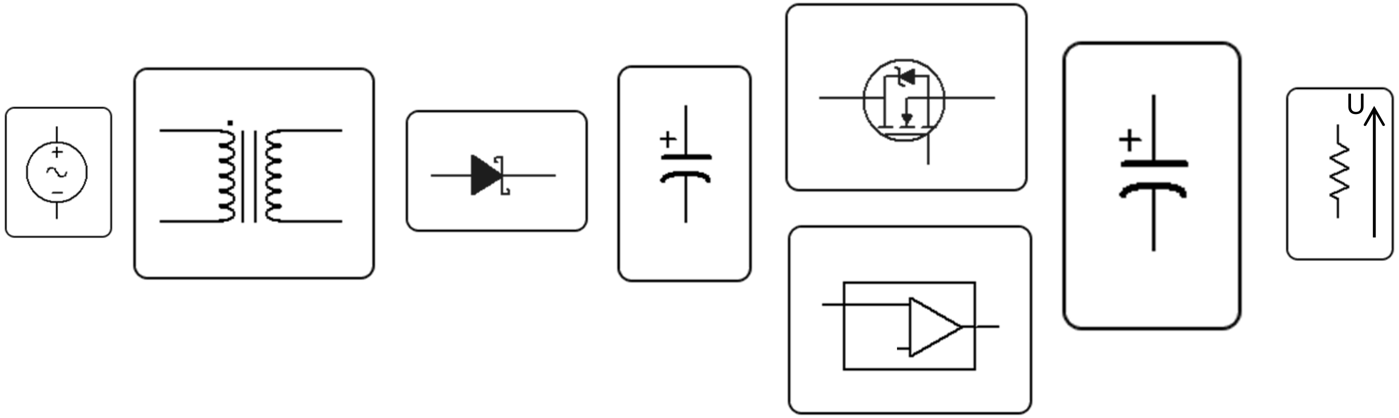
Linear Power Supply Design



size

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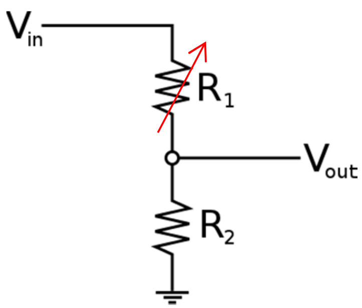
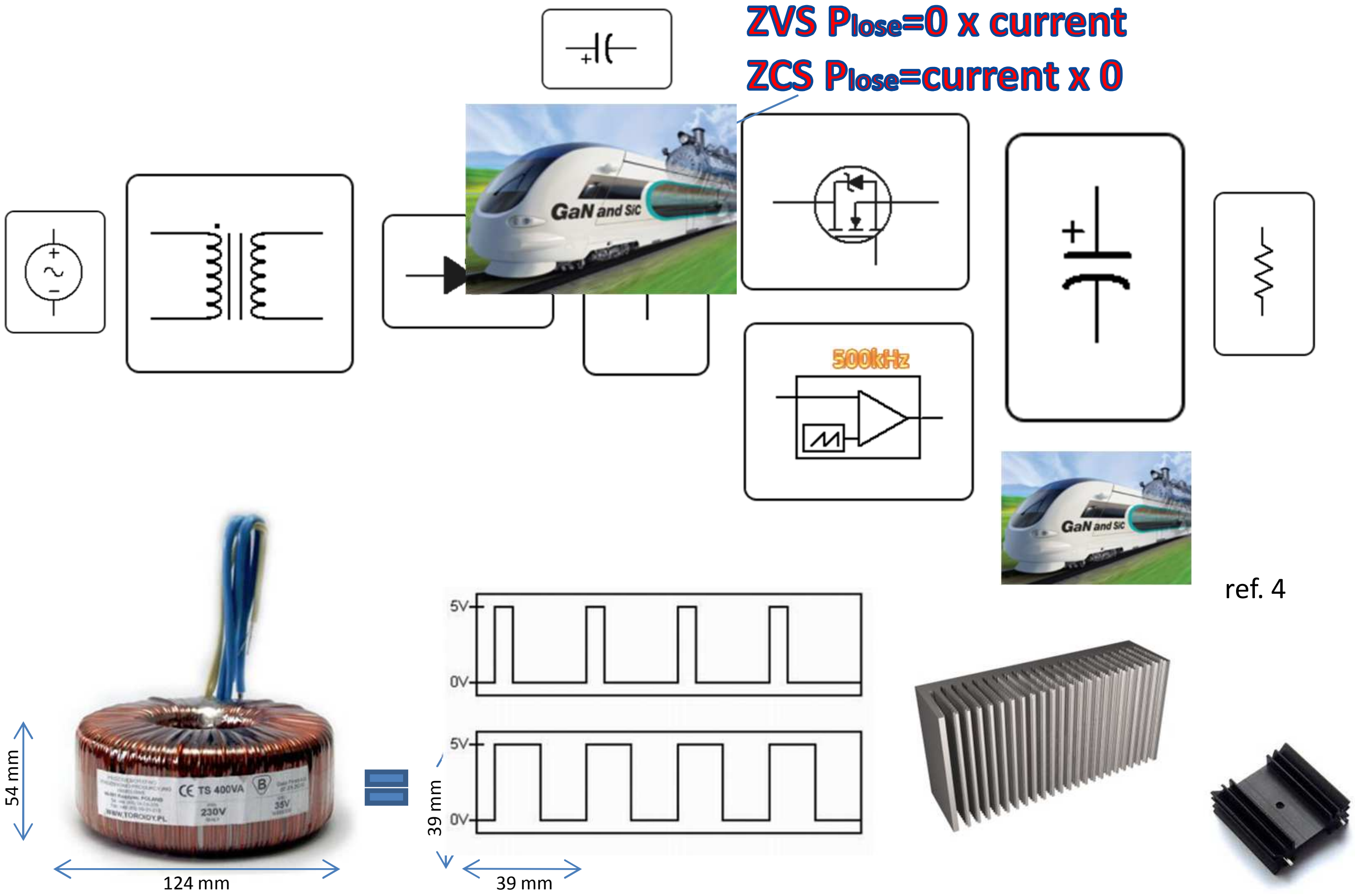


heat

WHY DO WE WANT TO BUILD A SWITCHING POWE SUPPLY

Switching Power Supply Design



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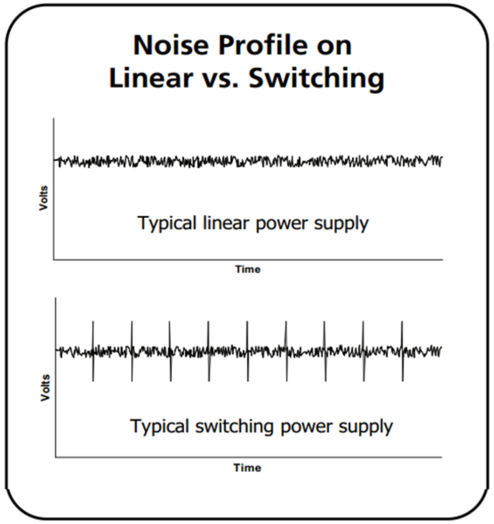
Everything Looks Better But

- Reliability
- Safety
- Development Time
- Custom Magnetic
- EMI
- Testing and Qualification
- Required Design Expertise.

ref. 5

Linear or Switching Supply?

- ❑ **Linear**: Low ripple and noise specification
- ❑ **Linear**: fast transient response
- ❑ **Linear**: inefficient and generates heat
- ❑ **SMPS**: Efficient, can generate noise
  - ❑ SMPS: noise Vpp from 20Hz to 20MHz
- ❑ **QR SMPS**: ZVS improves ripple and noise
- ❑ **QR SMPS**: Higher power density and flexible.



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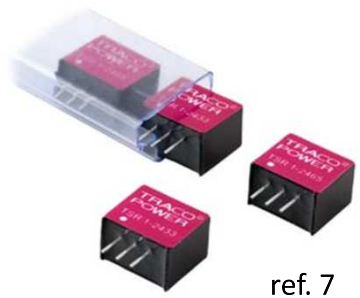

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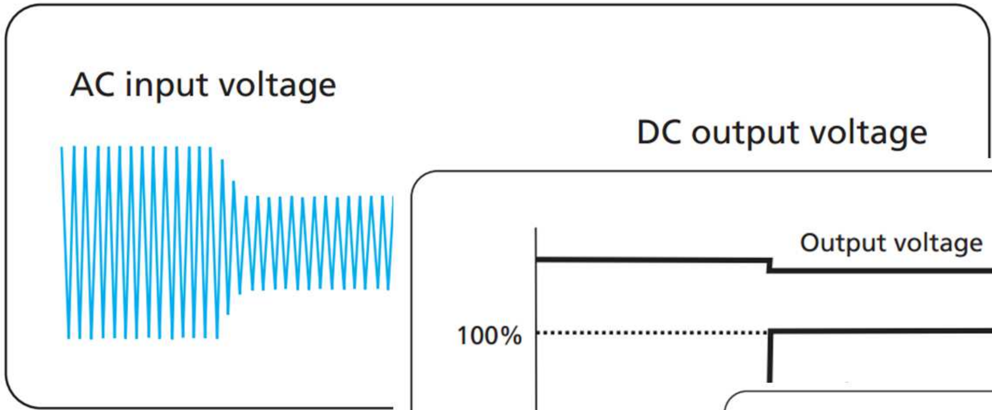
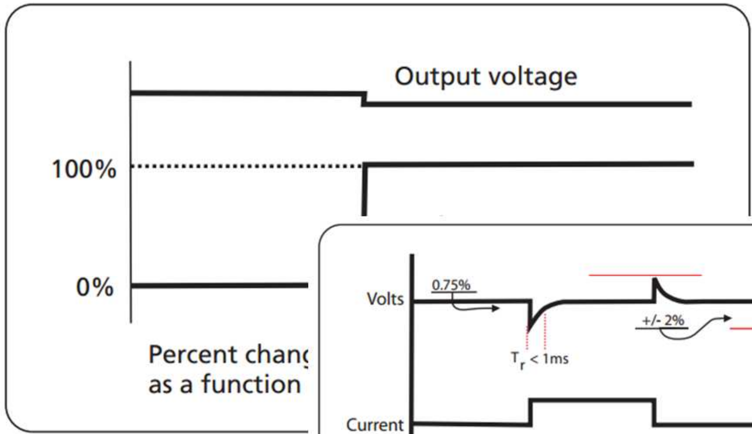
More Than Voltage and Current

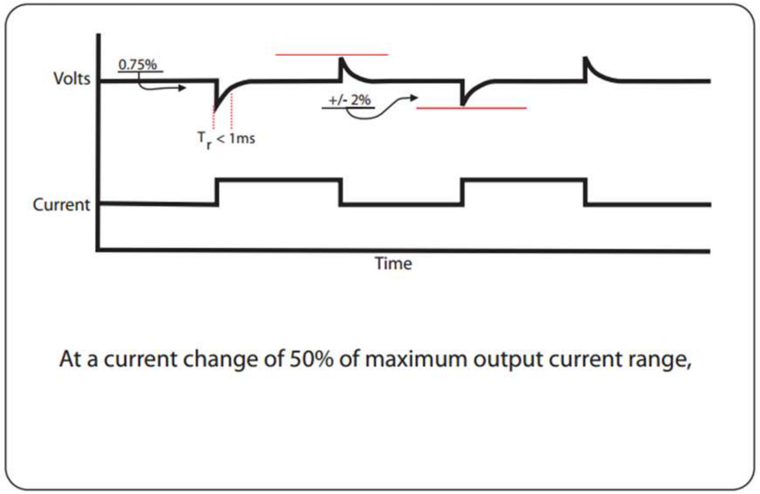
❑ Line Regulation



❑ Load Regulation



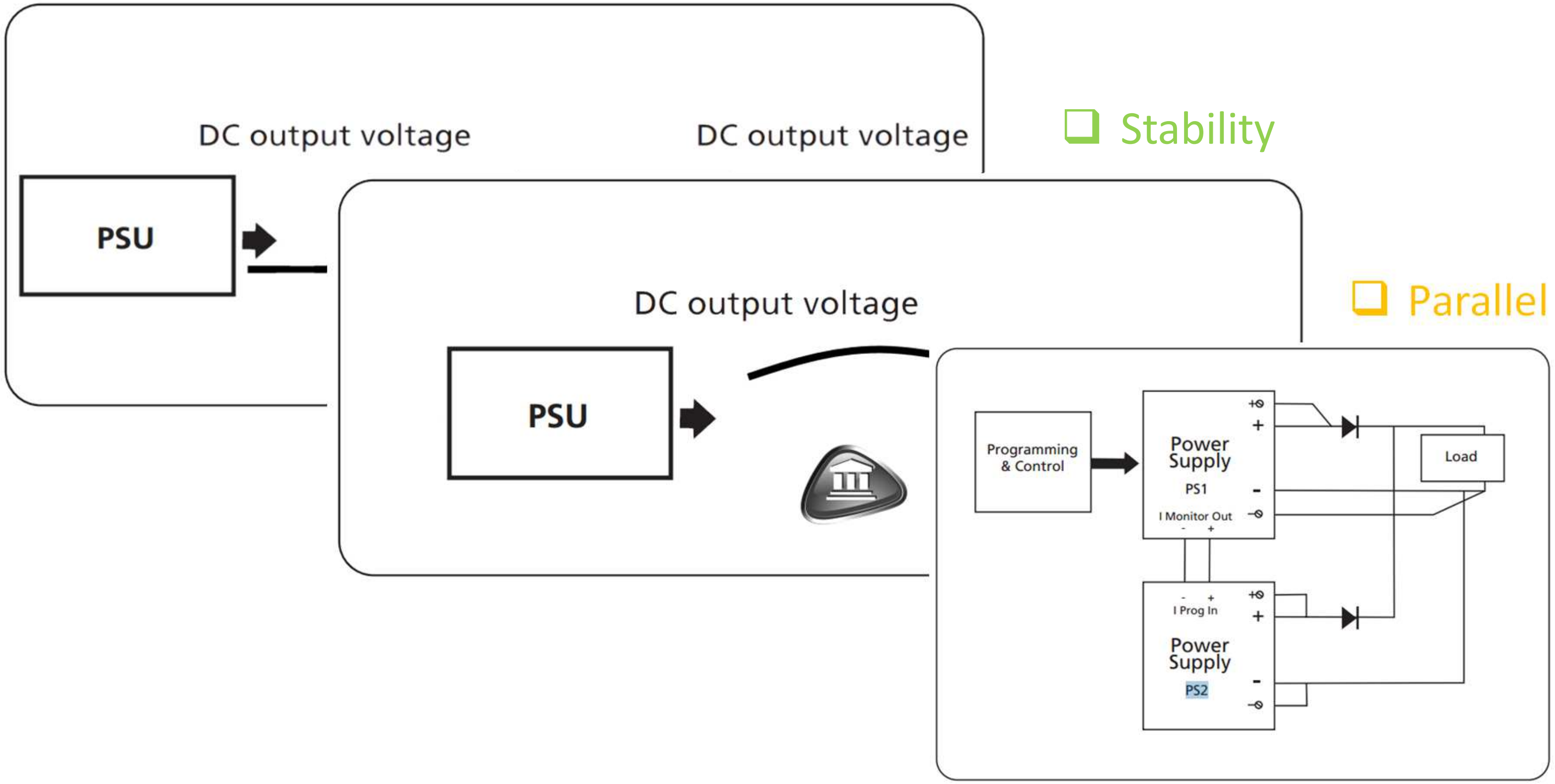
❑ Transient Response



ref. 6

More Than Voltage and Current

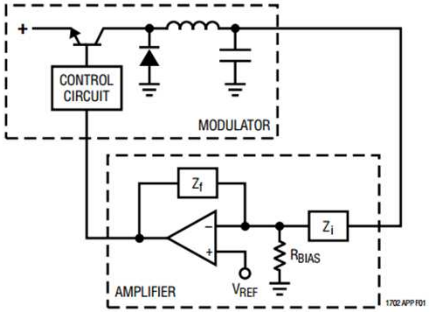
- Slew Rate (60% of the I_o)
- Stability
- Parallel Operation



ref. 6

Control Loop

- Stability and Phase Margin
- Keep phase shift from less than 360 degrees before the loop gain falls below unity
- Power supply should be silent



Closed Loop Circuit

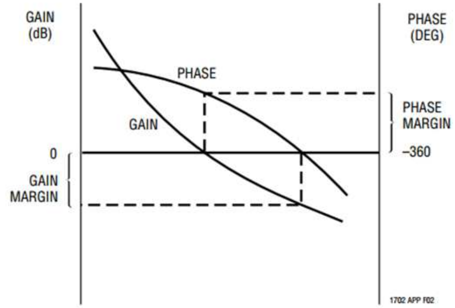


Figure A2. Stability Criteria

ref. 8

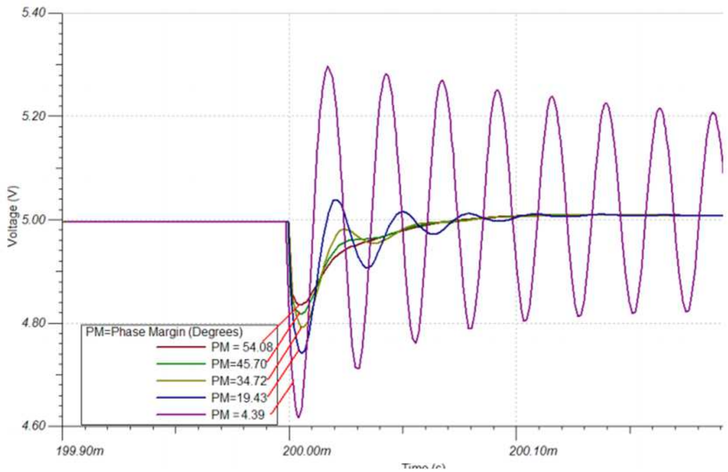


Table 1. Phase Margin vs Ringing in Load-Step Response

Phase Margin (Degrees)	Ringing (Bumps)
80.88	0
60.75	0
57.64	0
54.08	0
50.16	1
45.7	1.5
40.61	2
34.72	3
27.78	4
19.43	6
9.09	17

ref. 9

Good PSU Specification

Table 2. Performance Specification Summary

Specification	Test Conditions	Min	Typ	Max	Unit
V_{IN} voltage range		8	12	24	V
No Load Input Current	I_{OUT} = 0A, V_{IN} = 12V		6.3		mA
Output voltage set point					
Line regulation	I_{OUT}				
Operating frequency					
Output current range					
Output over current limit[1]	V_{IN} =				
Output over current limit[1]	V_{IN} =				
Load regulation	I_{OUT}				
	I_{OUT}				
Load transient response	I_{OUT}				
Loop bandwidth	I_{OUT} = 2.5A, V_{IN} = 12V		7.8		kHz
Phase margin	I_{OUT} = 2.5A, V_{IN} = 12V		56		°
Output ripple voltage	I_{OUT} = 2.5A, V_{IN} = 12V		75		mVpp
Peak efficiency	I_{OUT} = 0.9A, V_{IN} = 12V		87.9		%
Output current DCM threshold	V_{IN} = 12V		340		mA

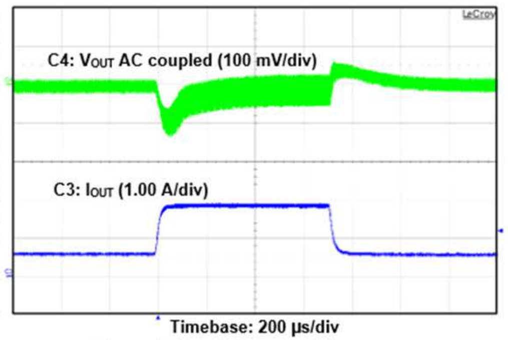


Figure 5. Load Transient Response

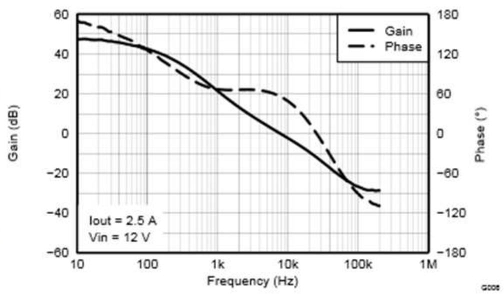


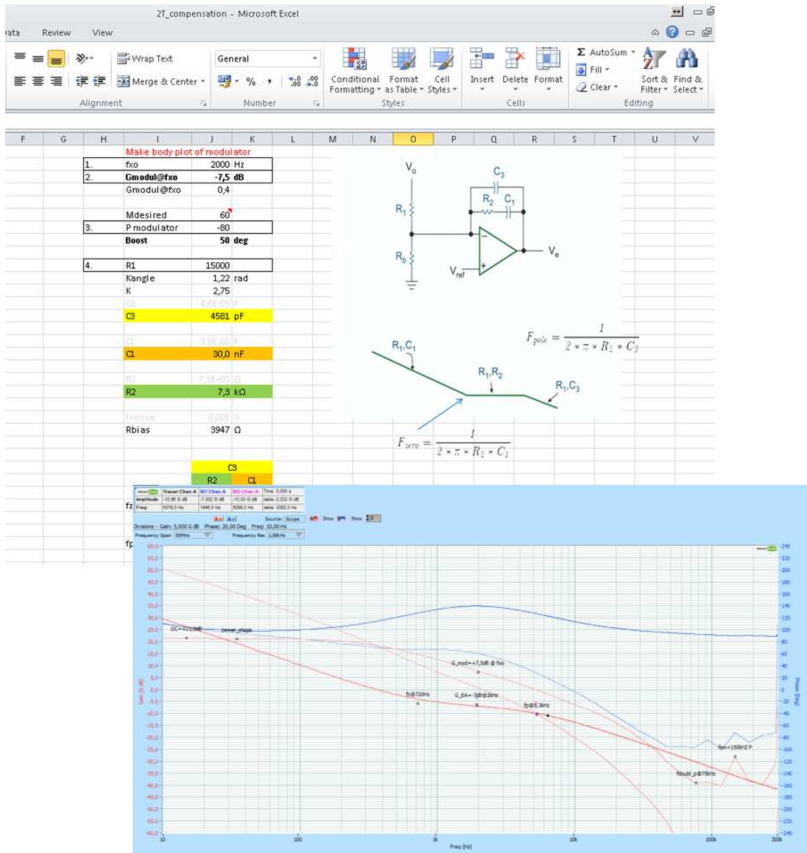
Figure 6. Loop Response

ref. 9

Agenda

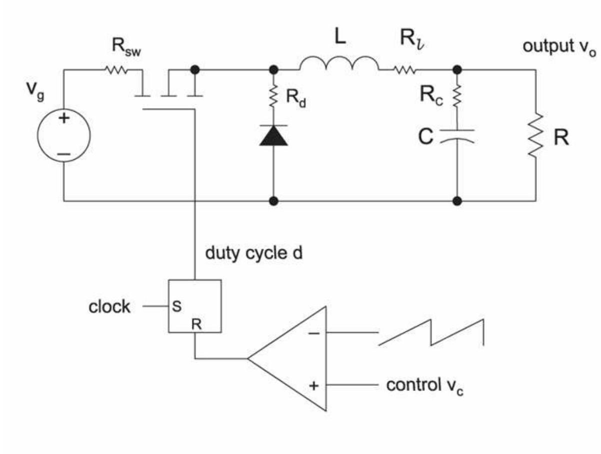
TOPICS:

- Power Supply Specification



Modelling Power Supplies

- The power electronics field is supposedly simple



$$\frac{\hat{v}_o}{\hat{d}} = V_g \frac{1 + sCR_c}{1 + \frac{s}{\omega_o Q} + \frac{s^2}{\omega_o^2}}$$

$$\omega_o = \frac{1}{\sqrt{LC}}$$

$$Q = \frac{1}{\frac{Z_o}{R} + \frac{DR_{sw} + D'R_d + R_c + R_l}{Z_o}}$$

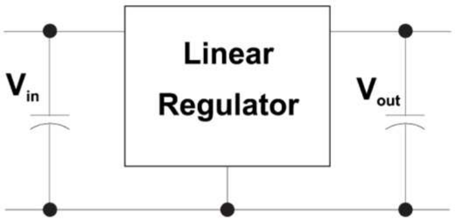
$$Z_o = \sqrt{\frac{L}{C}}$$

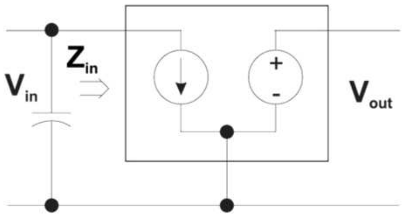
- Christophe Basso Switch-Mode Power Supply book
    - 1300 equations to cover the basics of operation

ref. 10

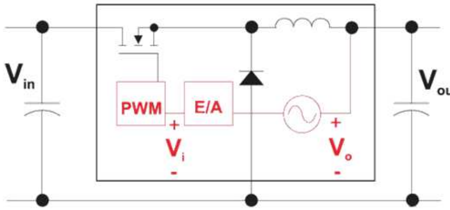
Small-Signal Model

- Linear Regulator

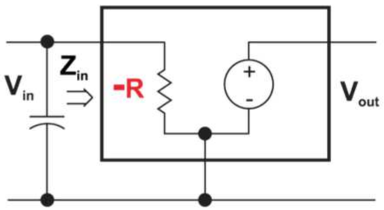




- Switching Mode Power Supply



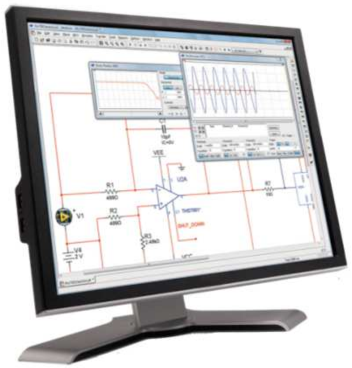
- Negative input impedance of SMPS



ref. 10

Simulation Tools

- Multisim - NI Instrument



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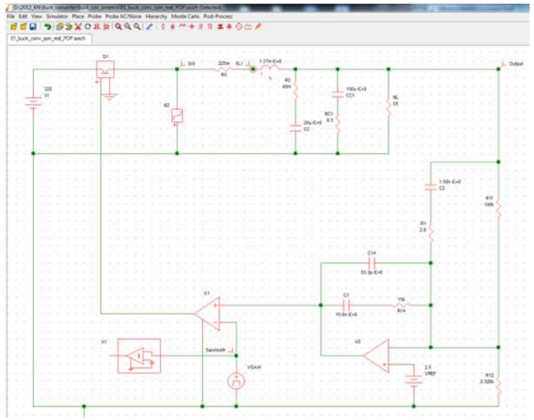
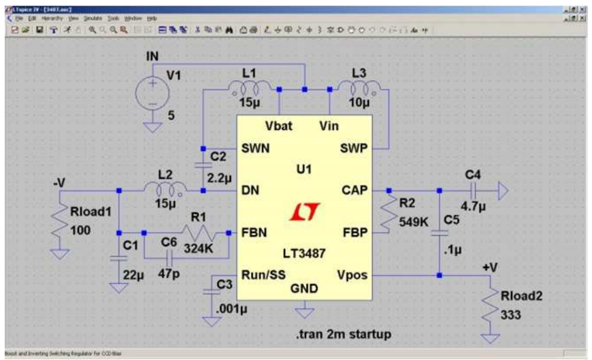
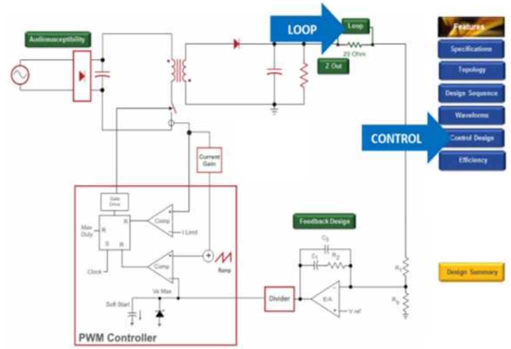
- Simplis - Simetrix Technologies



- LTspice - Linear Technology



- Power 456 – Ridley Engineering



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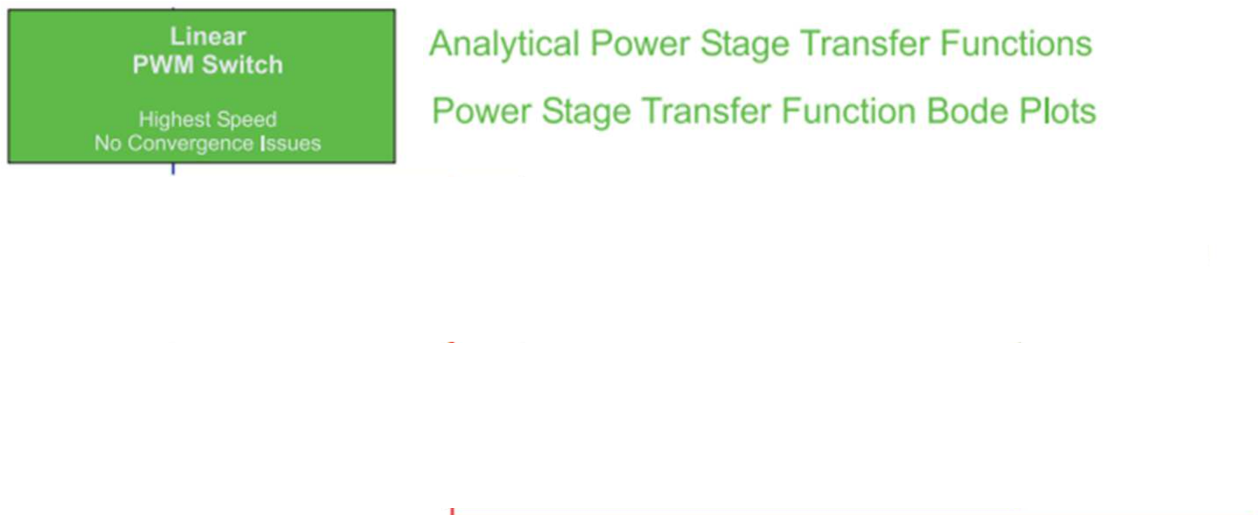
Modelling Approaches

- Four different ways to simulate power supplies



ref. 10

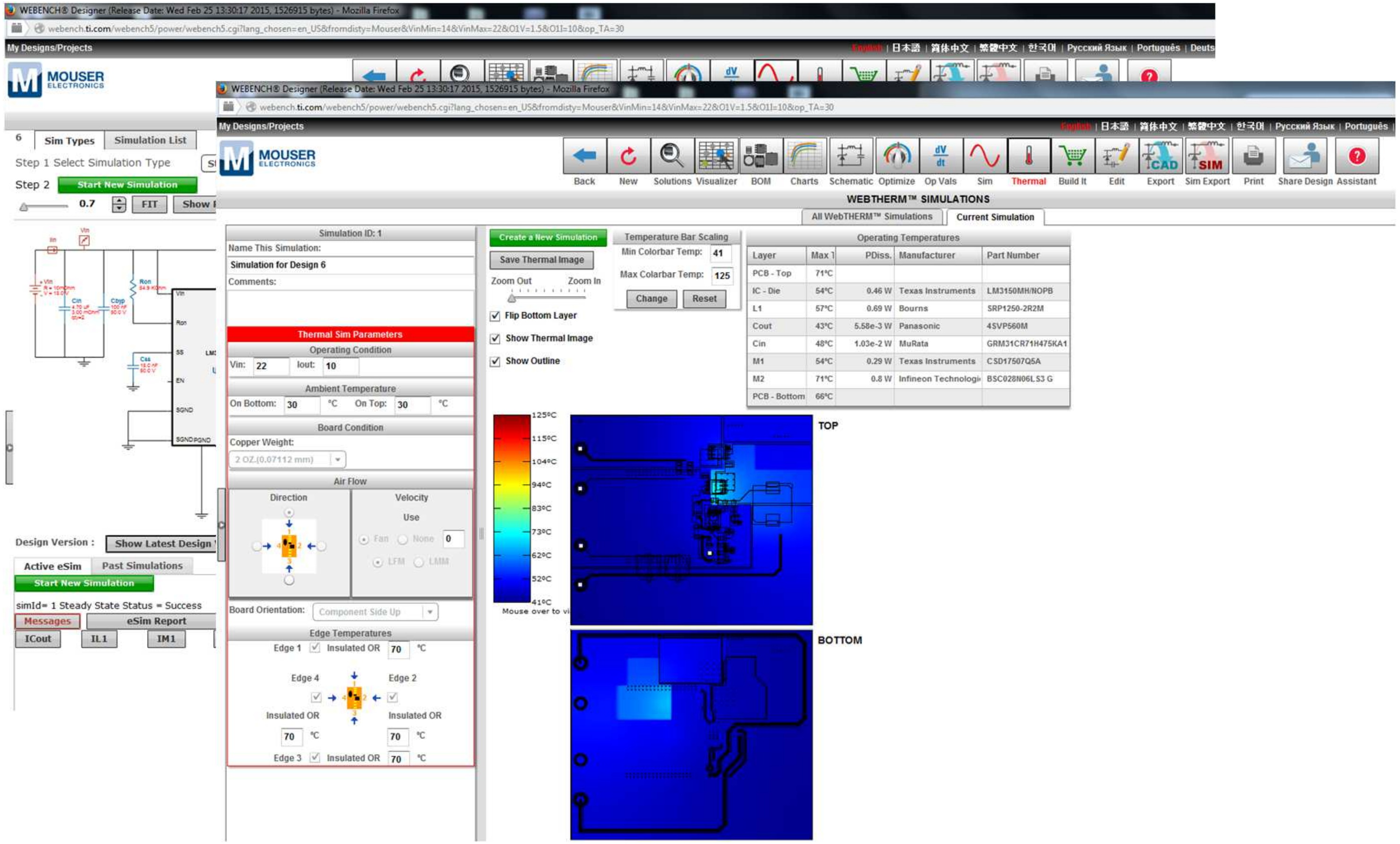
Design Tools from Linear Tech.

- LTpower CAD

ref. 12

Design Tools from Texas Instr.

- TI WebBench



ref. 9

References

- **List of references**

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Ref: 03 http://www.toroidy.pl/

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Ref: 07 http://www.tracopower.com/

Ref: 08 A NEW MATHEMATICAL TOOL FOR STABILITY ANALYSIS AND SYNTHESIS H. Venable

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Ref: 12 http://www.linear.com/solutions/LTPowerCAD

THANK YOU

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