Structuring a SMPS Course, Part II: Laboratory

THUAS Delft, The Netherlands
Prof oP. dr.ir. P.J. van Duijsen(presenter), ing D.C. Zuidervliet

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Introduction SMPS

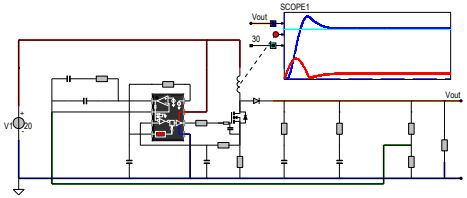
Switched Mode Power Supply Laboratory
What to teach?

- Basic converter topology(Buck, Boost,.....)
- Components(Inductor, Capacitor, Mosfet, Diode)
- Control(Voltage Mode, Peak Current Mode, Constant on time,...)
- Measurements(Learn how to measure)

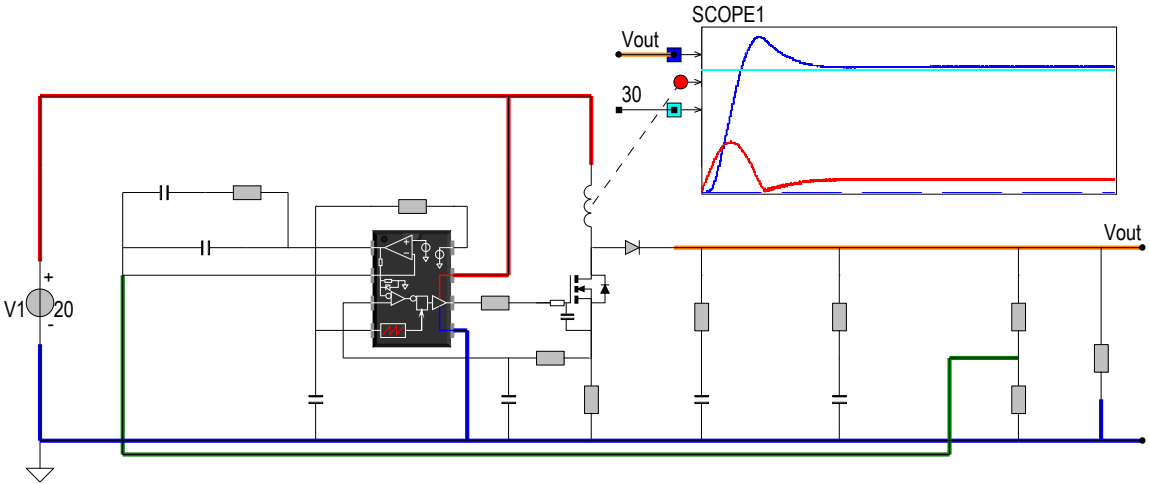
SMPS What to teach?

Boost converter

- Topology
  Most important components
- Components
  Basic design
- Control
  Dedicated IC
- Measurements
  Detailed Current shape measurement

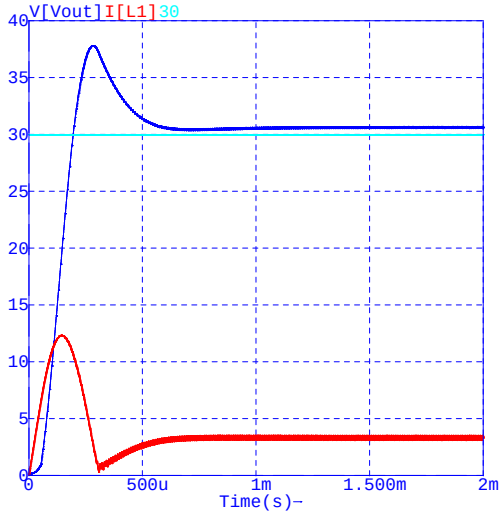


Boost Converter



Figuur: Boost converter simulation in Caspoc. Peak current mode control using the uc3842.

Boost Converter



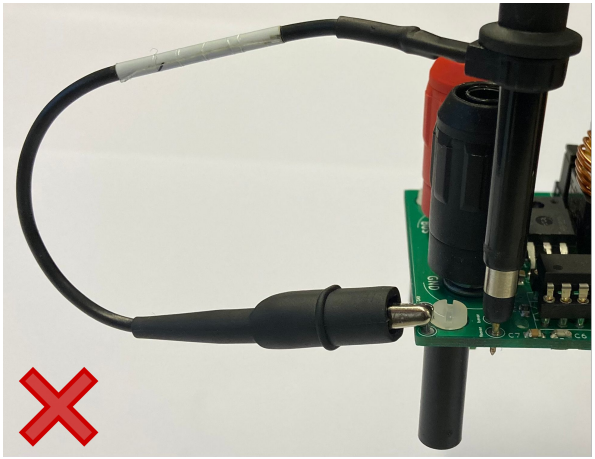
Boost converter simulation results. Output voltage(blue) and inductor current(red).

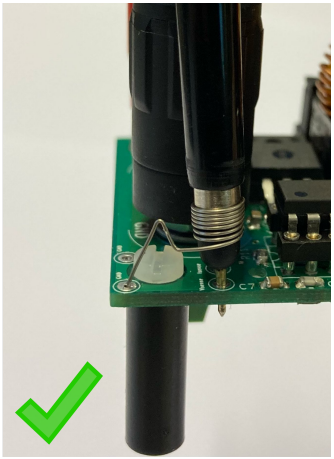
Lecture and Laboratory Objectives

Lecture	Week	Topic	Lecture objective	Laboratory objective
1	1	Basic converters	Switching Cell	Build pwm generator
2	2-3	Operation Principles	Input-output relations and inductor ripple current calculation	Building a breadboard boost converter
3	4	Waveforms	Voltage and current waveforms for continuous and discontinuous mode	Debugging and performing measurements on the breadboard converter
4	5-6	Components	Sizing all main components for storage and filtering	Assembling a Boost converter on PCB(SMD or Through Hole)
5	7	Constraints	Understanding the datasheet parameters for mosfet and magnetic cores	Measuring the real waveforms on the constructed PCB
6	1-2	Magnetic	Design of magnetic components	Winding and testing a self made inductor
7	3-4-5	Layout and Thermal	Origin of Electromagnetic conducted and radiated interference, Efficiency and loss calculation	PCB design and EMI, measuring the losses and heating of the inductor and Mosfet
8	6-7	Control	Closed loop control	Measuring converter stability

Tabel: Lecture and week number with topic and lecture and laboratory objectives.

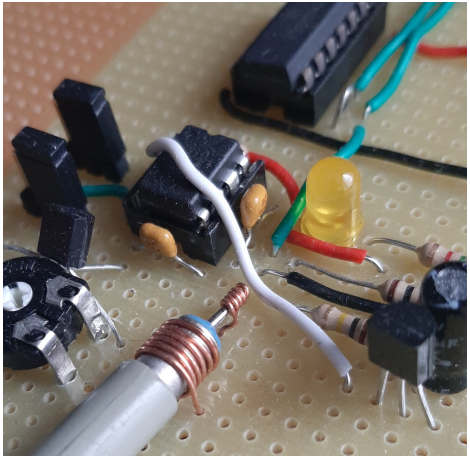
Topics: Ground loop





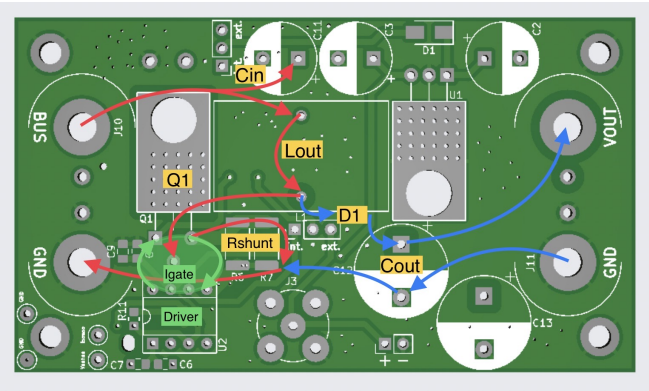
A long ground wire of the probe may give false signals on the oscilloscope. Proper connection using a pig tail reduces ground loops and give better measurements.

Topics: Pigg Tail



Low cost pigtail soldered on a perfboard for measuring the oscillator frequency signal on a UC3842 control IC.

Topics: PCB: SMD design



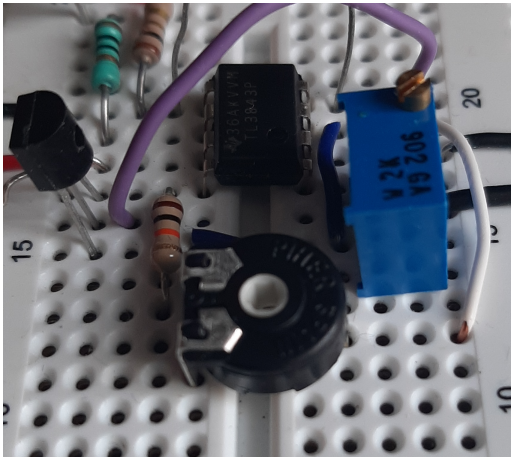
Boost converter using SMD components on printed circuit board. The layout is optimized and the loop area is minimized. Current paths during continuous mode. During T_{on} the current flows through the inductor, Mosfet and sense-resistors, see the red arrows. During the freewheeling period T_{off}, the current stored in the inductor, flows via the diode over the output capacitors to the output, see the blue arrows.

Methods

Methods

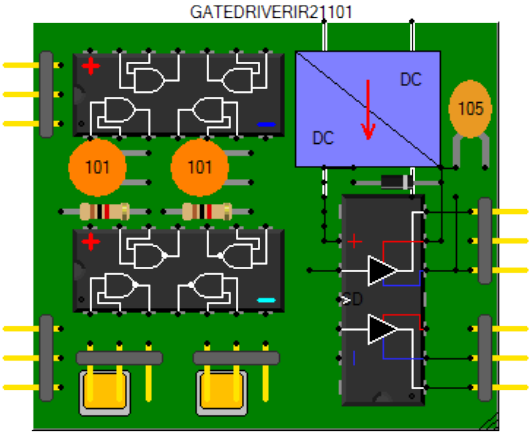
- Breadboard
- Hardware trainer
- Assembled PCB

Breadboard



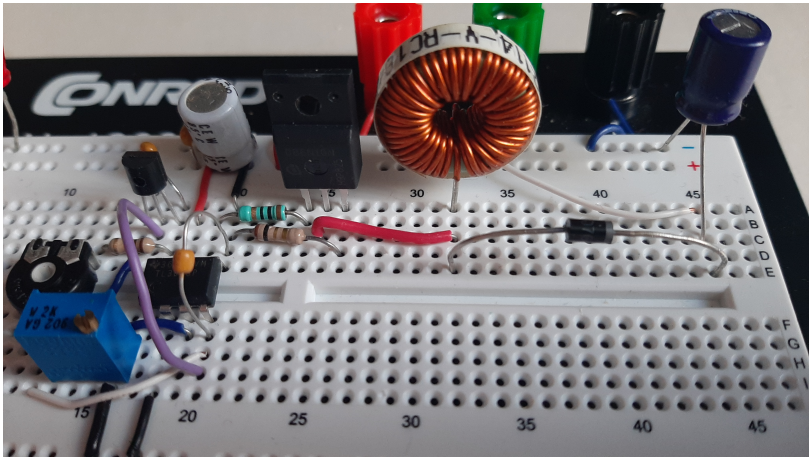
Single uc3842 power management IC to create pulse width modulator with variable frequency and duty cycle, to demonstrate and experiment with a general current mode control IC.

Hardware Trainer



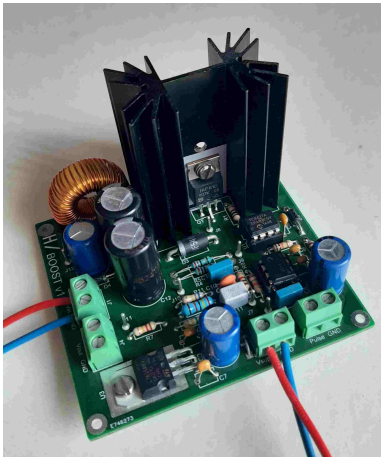
Gatedriver circuit board, that can be interchanged to study the impact of various gate driver ICs on the U2L board.

Boost assembled on breadboard



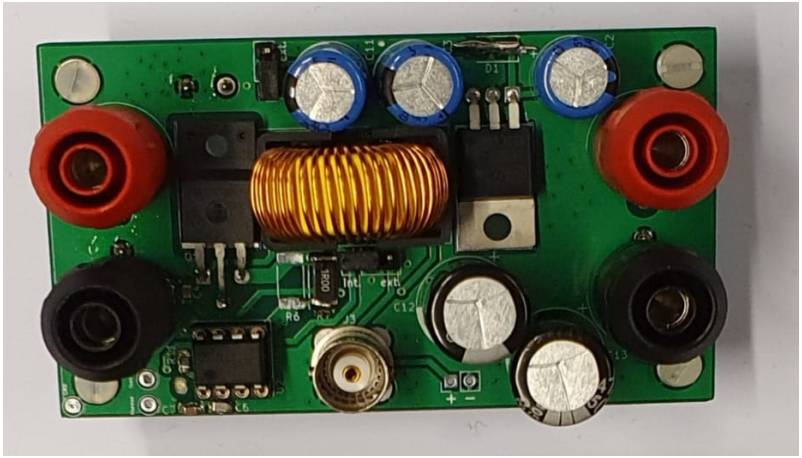
Low cost set up of a boost converter with limited power capabilities, but allowing to demonstrate the basic waveforms and principles.

Boost assembled on PCB through-hole



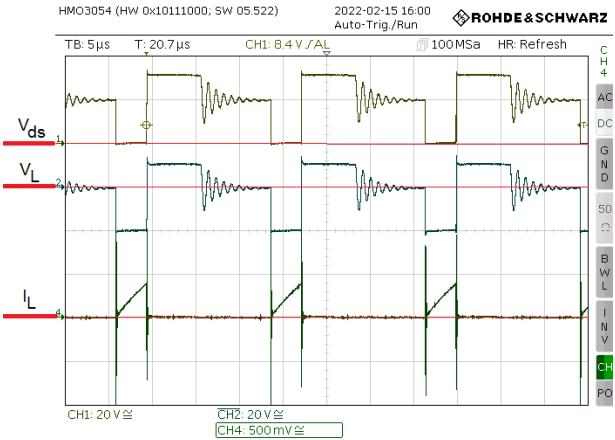
Fully assembled boost converter on a through hole PCB.

Boost assembled on PCB using SMD components



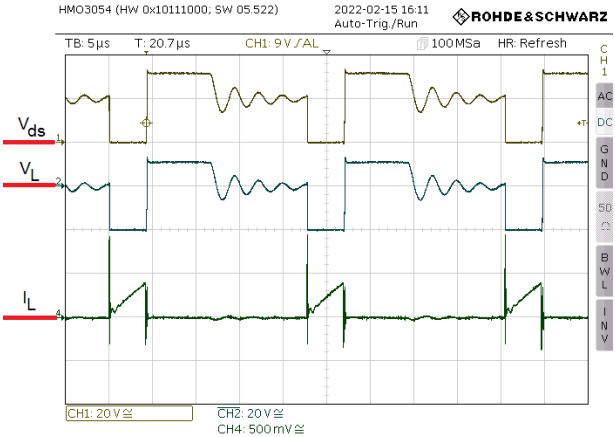
Fully assembled boost converter on an optimized PCB using SMD components.

Measurements PCB through-hole



Through Hole Boost converter measurement. From top to bottom, *Vds*, V_L, V_{Rsense}

Measurements PCB using SMD components



SMD Boost converter measurement. From top to bottom, *Vds*, V_L, V_{Rsense}

Basic Objectives

Basic objectives

B PWM
Build a basic pulse width generator using an industry standard power management IC.

M Converter
Extend the pulse width generator with a Boost converter on a breadboard, to understand the switching cell principle. Use a constant duty cycle only. Measure input and output voltage and current waveforms, as well as the inductor current.

B Assembling
Assemble a Boost converter on PCB either Through Hole or SMD.

D Component ratings
Measure all voltage and current waveforms and compare for various design methods (Breadboard, Through Hole PCB or SMD PCB). Verify component ratings, for example maximum V_{DS} for the Mosfet, or maximum current through the Mosfet, inductor and diode.

M PCB design
Understand the difference in PCB design and measure the conductive EMI by measuring the ringing on the Mosfet. Add a second output capacitor and observe the reduction of the output voltage ripple.

Tabel: Basic Objectives(B:Build, D:Design, M:Measure)

Extended Objectives

Extended objectives

D Magnetic design and switching frequency
Design a custom inductor using ferrite cores and make a trade-off between losses and size.

D Thermal design
Losses and heat sink design. Calculate the thermal resistors in the thermal path from the Mosfet into the heat sink. Design the size of the heat sink and estimate the losses losses and final semiconductor temperature.

M Control
Measure the bandwidth of the control and by changing components in the control feedback loop, see the functioning and influence of each component in the control. For example, adding slope compensation, by adding a single resistor to avoid subharmonic oscillations. Increase output capacitor ESR to reduce overshoot during load changes. Load the boost converter with a variable pulsating load and observe the bandwidth of the control loop.

Tabel: Extended Objectives(D:Design, M:Measure)

Conclusion

- Course outline
- Topics that should be included
- Methods(Breadboard, Hardware Trainer, PCB)
- Objectives (Basic and Extended)

Thank you!
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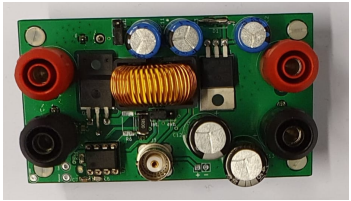

Thanks to Christian Nagy, Koen de Bruin and Holly Engelbrecht for designing and constructing the SMD-PCB board.