# Efficient switching in SMPS

**Projectseminar**
Tutor: M.Sc. Muhammad Bilal Saif
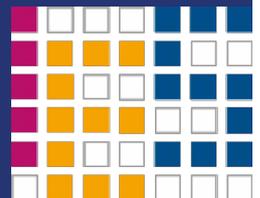By Mitja Stachowiak, July 2016
Integrated Electronic Systems          |          Univ.-Prof. Dr.-Ing. Klaus Hofmann

TECHNISCHE
UNIVERSITÄT
DARMSTADT

# Abstract

This work is a preparation for bachelorthesis on switching mode power suplies. Its aim is to prepare the tasks for bachelorthesis, to decide for a certain topology, to find required materials, and to get a simple prototype to work on.

# Contents

# 1   Situation

When designing a new SMPS, a lot of parameters have to be chosen, for example the topology, switching frequency, voltage control strategy or the type of semiconductor switches. For corresponding practical, a lot of different power supplies have been analyzed. The 180W models all have too large sizes and slightly worse efficiency, than the small 90W Hama power supply. There is also a defective HP Ultra Slim power supply. Because the Hama-model is pasted with thermal conductivity paste and the transformer's input connectors are unreachable, a new HP Ultra Slim power supply was bought and opened. This power supply is meant to be the archetype for the experimental prototype. Some special elements, required for the prototype, could be taken from the defective HP power supply. The first prototype will be built on a circuit board, later on, a PCB board should be designed.

## 1.1   Measurement conditions

The waveform measurements where done using digital oscilloscopes. For instrument protection, high voltage probes (factor 1:100) are used for all primary side measurements. This makes the measurement unprecise, especially if the probe is not descrewed perfectly. For current waveforms, simple (unprecise) resistors without temperature compensation are used. Furthermore, if there are more channels to be measured, than the oscilloscope has inputs, the measurements are done separatly using the same trigger. Sometimes, even if two channels are connected to the oscilloscope at once, there seems to be a delay in the signals. Maybe the oscilloscopes cannot take all channels synchronously.

# 2  Measurements on existing SMPS

## 2.1  Topology and Frequency

First, the device topology of the device has to be determined. There are two switching transistors at the Hama and HP power supply, which are inversly clocked with a frequency of about 120 KHz. Therefore it must be a halfbridge topology.
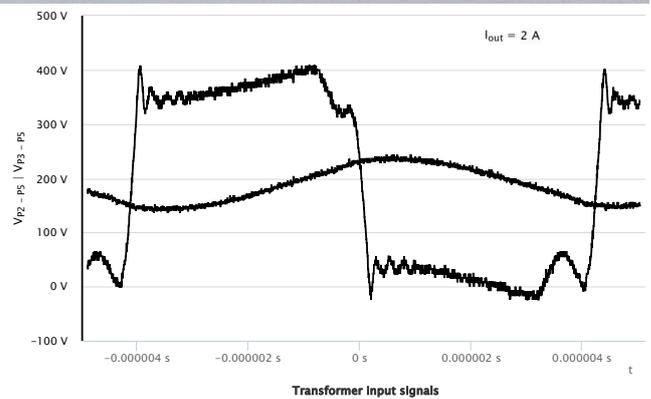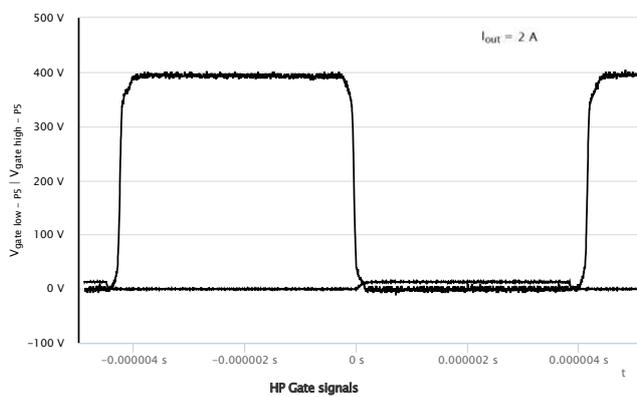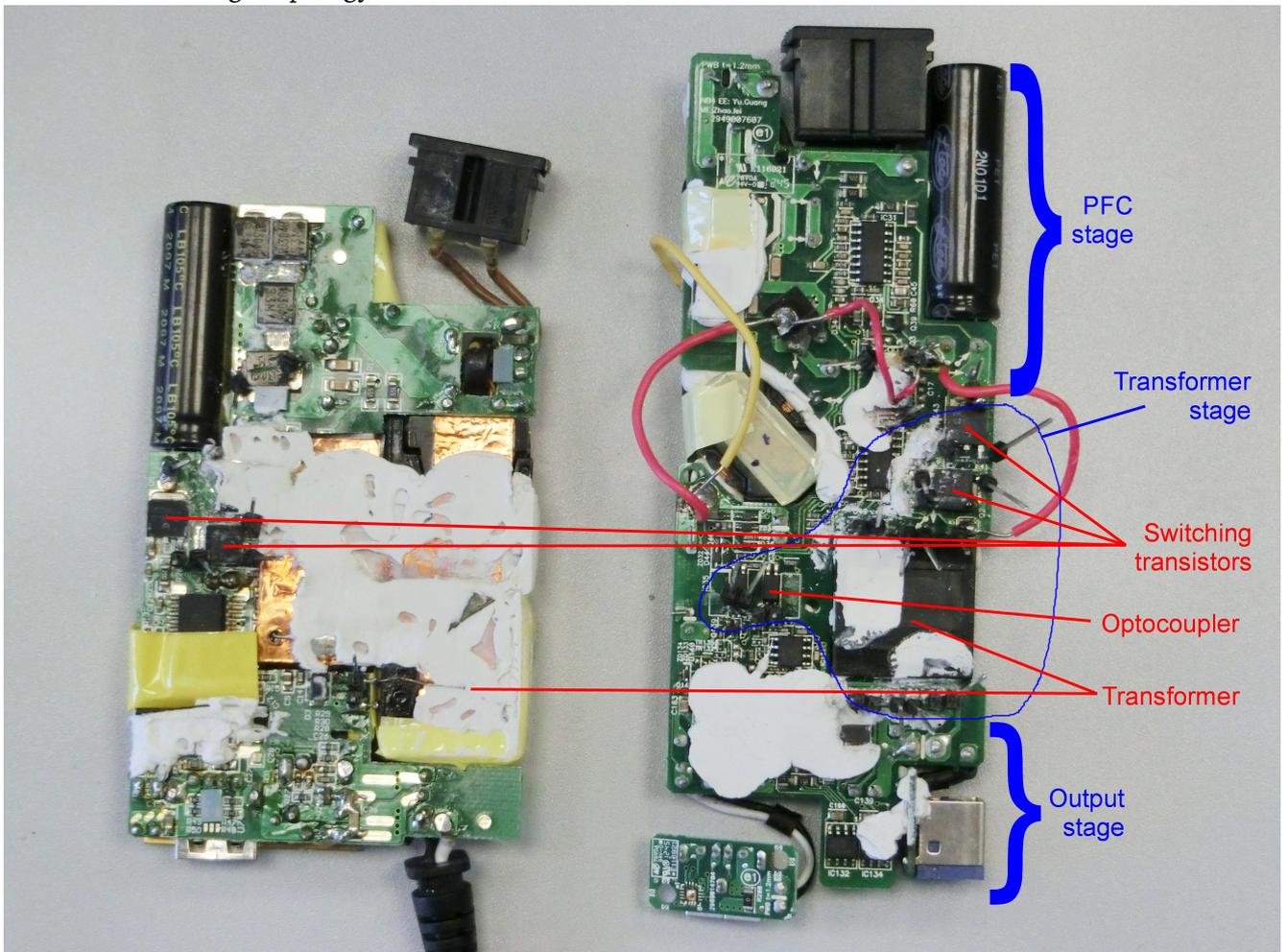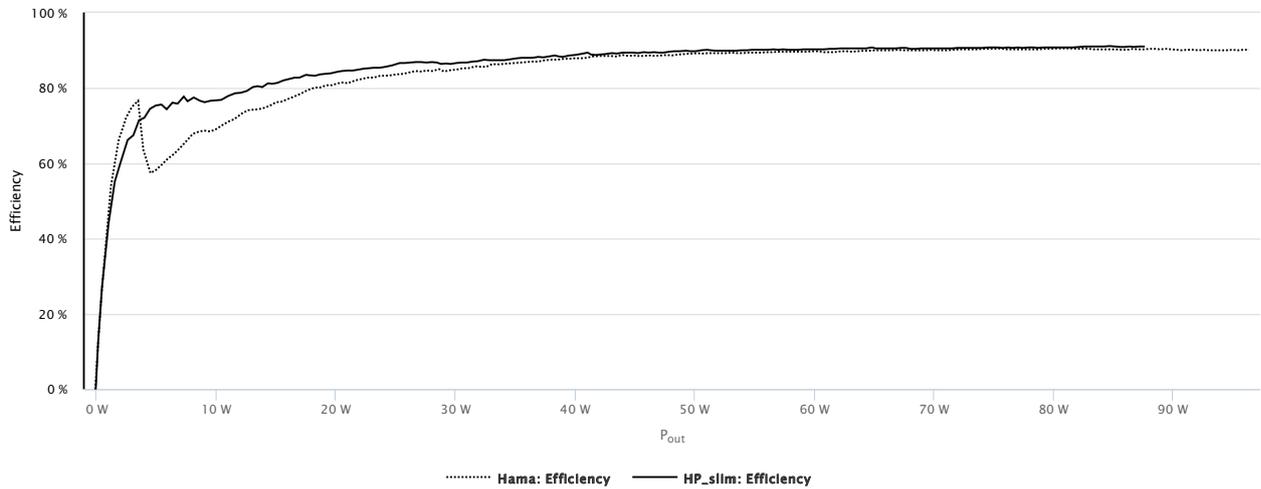
## 2.2 Voltage regulation and power saving

One important question is, how the output voltage is regulated. From corresponding practical, a breakdown in the efficiency of the Hama power supply for low powers is noted. For this work, the efficiency measurement was repeated for the HP power supply, which shows no breakdown:



The power supplies use on-off-control, to hold the efficiency high for low powers. Hama stopps this control at 0.3 A output current, HP continues the control until the on to off percentage reaches 100 % (0.8 A). When the output current becomes larger than 0.8 A, there is no significant change at the signals arround the transformer.
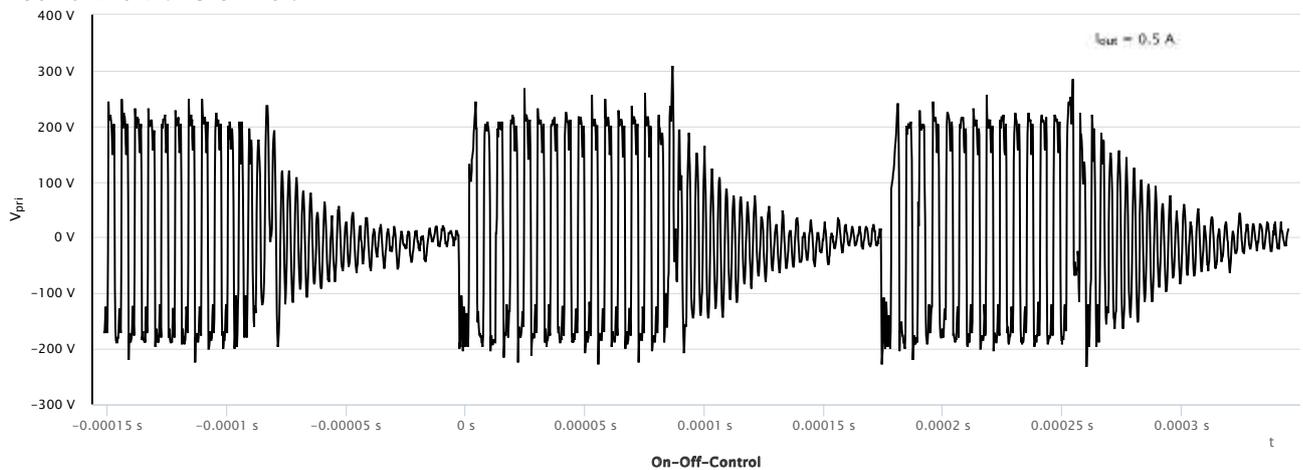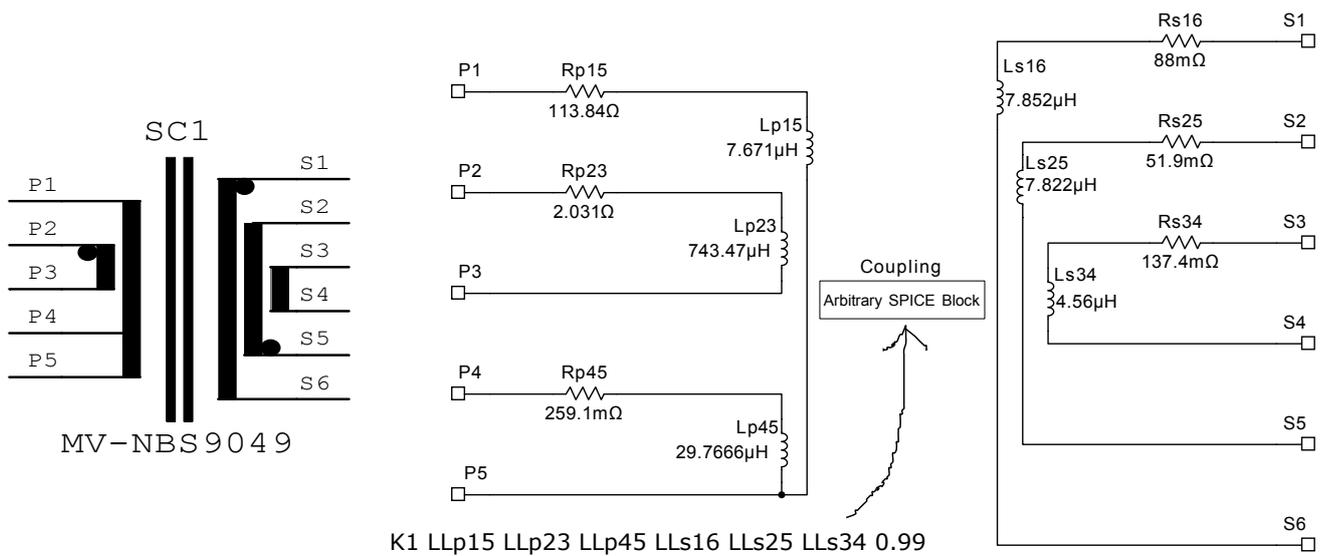


Both power supplies have a wide range input from 100 V - 250 V AC. Modulating this voltage using a controllable transformer has no influence on the signals arround the transformer, so the rough voltage control happens in the PFC.
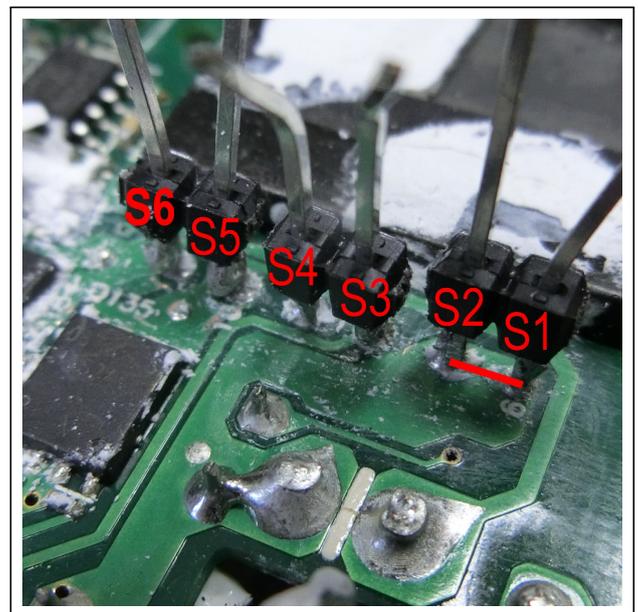
## 2.3 Transformer

From the defective HP ultra slim power supply, the transformer was cut out. It's a *Delta Tec MV-NBS 9049*. There is no technical datasheet or support for this transformer, so a Hameg LCR-Meter was used to determine the replacement circuit. The transformer has 5 input connectors and 6 output connectors which results in the following symbol and replacement circuit:

SC1

P1
P2
P3
P4
P5

MV-NBS9049

S1
S2
S3
S4
S5
S6

P1 — Rp15 113.84Ω — Lp15 7.671µH
P2 — Rp23 2.031Ω — Lp23 743.47µH
P3
P4 — Rp45 259.1mΩ — Lp45 29.7666µH
P5

Coupling
Arbitrary SPICE Block

Ls16 7.852µH — Rs16 88mΩ — S1
Ls25 7.822µH — Rs25 51.9mΩ — S2
Ls34 4.56µH — Rs34 137.4mΩ — S3
S4
S5
S6

K1 LLp15 LLp23 LLp45 LLs16 LLs25 LLs34 0.99

The coupling factor was not measured, the instrumentation was too unprecise. Some tests using this transformer in Flyback mode with open or shorted output resulted in unrealistic coupling factors anywhere between 50 % and 130 %.

The output windings S1-S6 and S2-S5 are connected in center tap mode and there must be an active rectifier on the secondary side.

The optocouplers just transfer DC-voltages from secondary to primary side, so the switching signals for the active rectifier are generated on the secondary side.
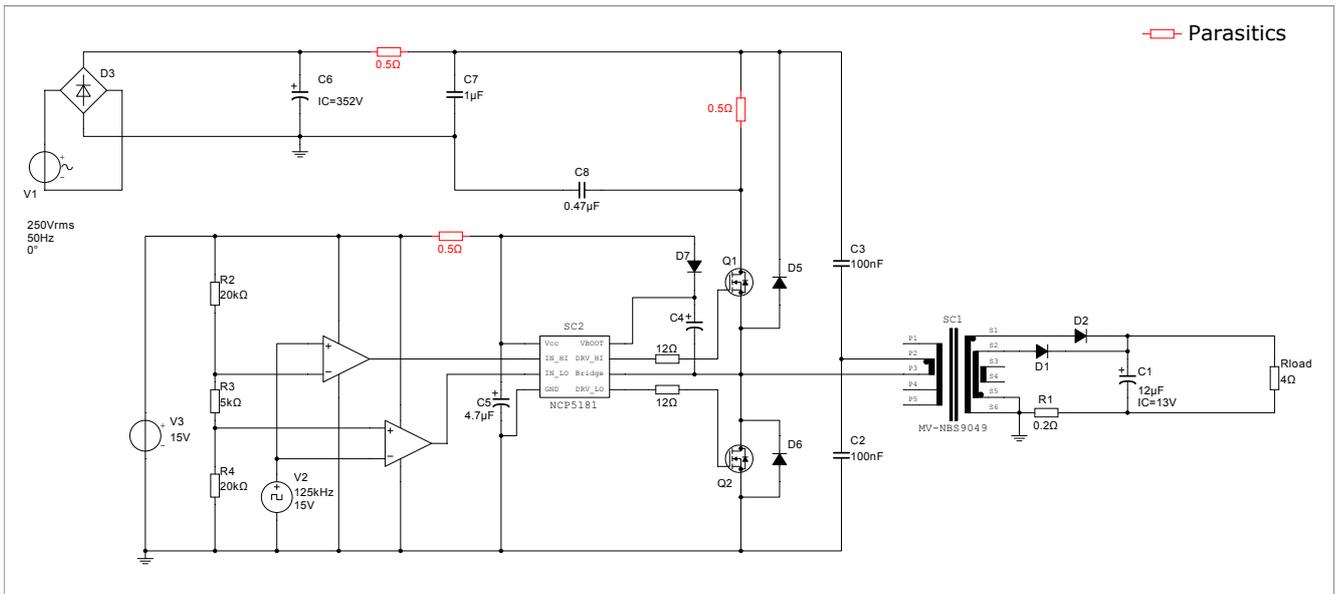
# 3 Construction of a halfbridge prototype

With the identified parameters, a simple half-bridge prototype was built on a circuit board, just existing of the transformer, the switching transistors and a passive two-diode rectifier.
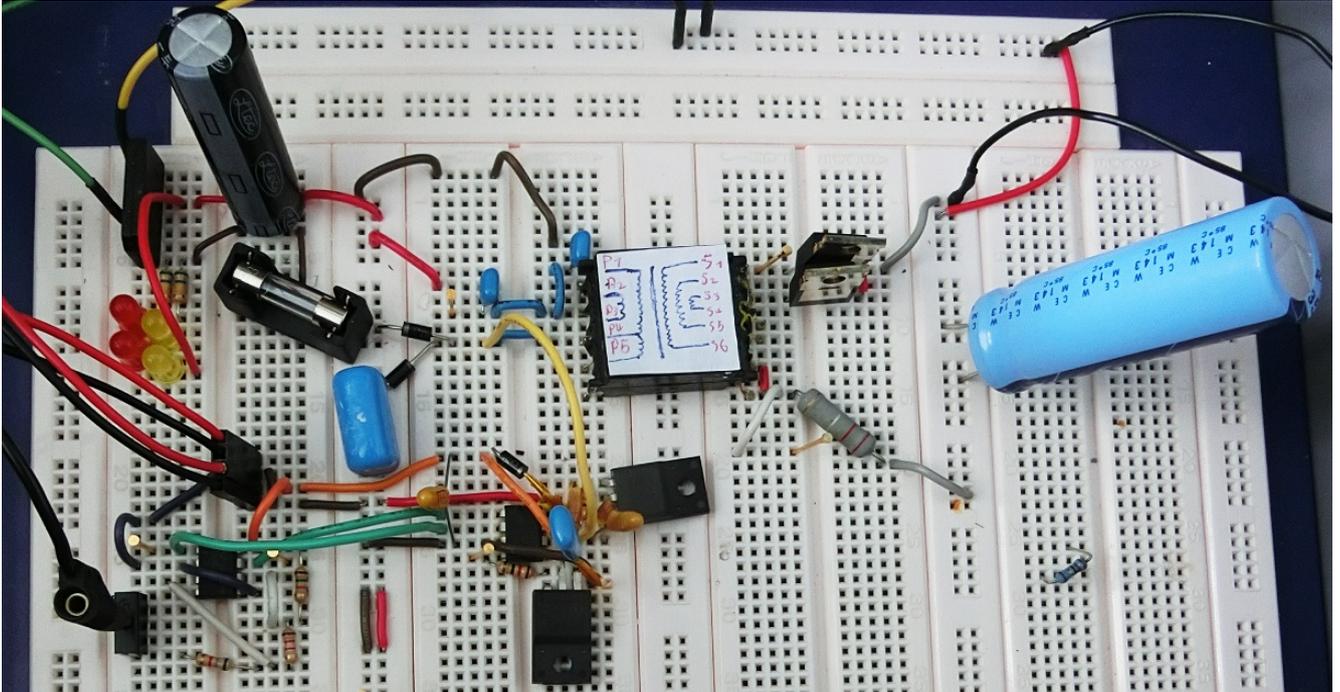


## 3.1 Simulation



One objective of this work was, to get not just the prototype but also a working simulation of it. The gate driver was only available as an encrypted PSPICE model, that works since Orcad 16. The free version of Orcad has a limit of 75 components but the driver consists of more than 80 sub-circuits and cannot

be simulated. Therefore this circuit plan was made with Multisim using ideal relais for the driver. The student version of Multisim have a component limit, too, so this plan has to be ported to LTSpice or an other free software to continue the work.

The resistors R2, R3, R4 and the opamps generate the signals for the driver, having a certain death time, which can be modulated by changing the rise and falltime of the clock.

## 3.2 Switching condition

Starting up the raw halfbridge circuit with full input voltage alwais resulted in destruction of the gate driver. When using a controlable source, it can be seen, that the ringing pushed the driver out of save operating area, even with voltages less then hundred volt. The ringing influences neighbour connections and the driver's supply voltage due to parasitic effects. If there is too much ringing, the gate driver doesn't do, what it is bounded for. The signals overshoots twice of the destination voltage.

An other problem in this first experiment was, that the duty cycle wasn't 50 % ($T_{on} = 5\,\mu s$, $f = 10\,KHz$).



When using Halfbridges, the duty cycle shoult be 50 %, because otherwise the capacitive voltage division won't work.
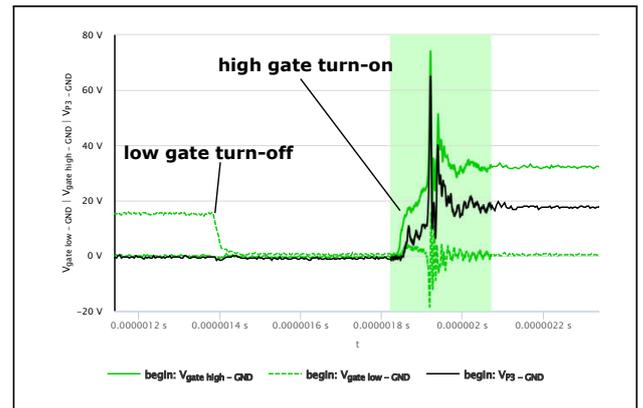
### First optimization

As a first optimizatrion, the duty cycle was set to 50 % ($T_{on} = 5\,\mu s$, $f = 100\,KHz$). The switching speed was reduced by adding a resistor ($27\,\Omega$) between gate and driver and the rectified input voltage was stabilized near the flyback diodes. There often is a large (and expensive) ceramic capacitor on switching mode power supplies. It seems, that electrolyte capacitors cannot buffer strong and high frequent ringing.

This optimizations significantly reduced the ringing on the bridge voltage, but the ringing on the gate signals and the transformer output current was still high.
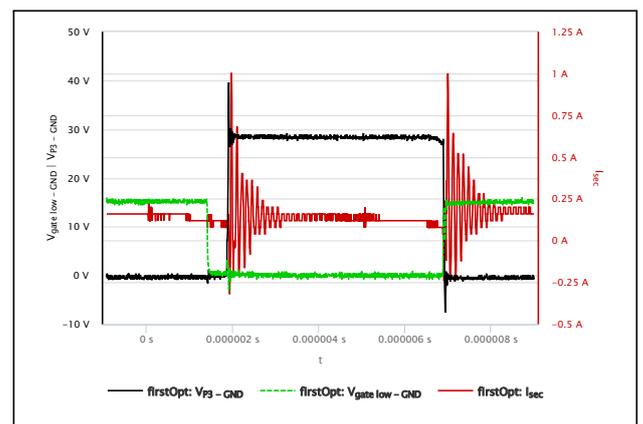


### Second optimization

For next step, a ceramic capacitor ($0.47\,\mu F$) was added to the input voltage near the gate driver. This reduced the ringing on the gate signals and allowed to reduce the gate-driver-resistor to $12\,\Omega$. Since now, the ringing reduced, when the input voltage or the output current increased. Under this conditions, the most important goal of efficient switching regarding halfbridges is fullfilled: Zero voltage switching.
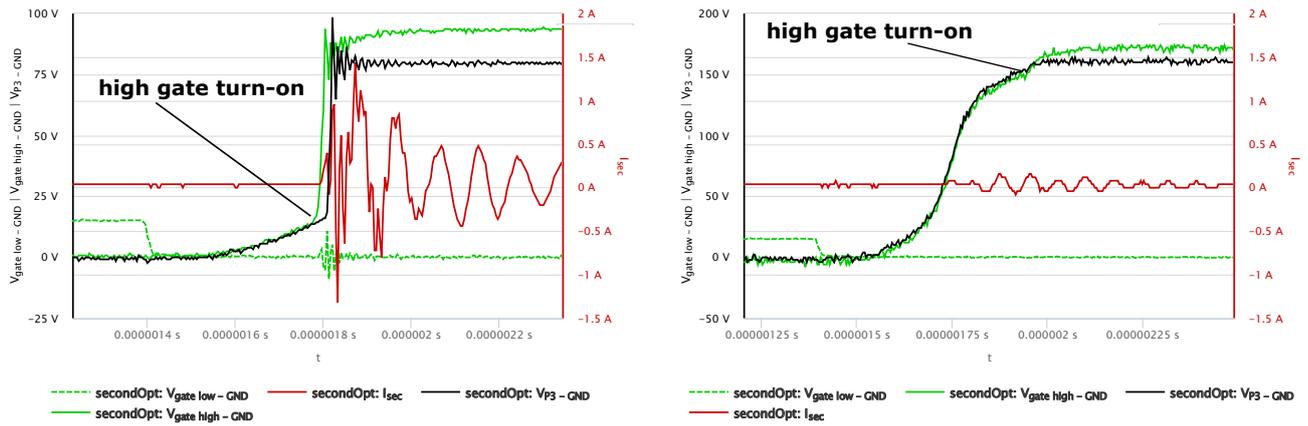
## 3.3 Zero voltage switching
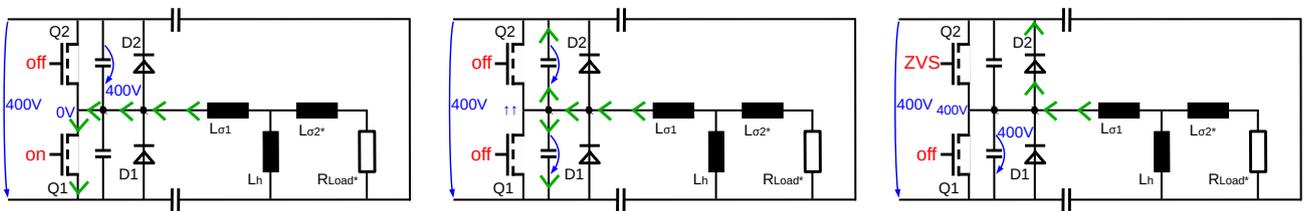


Zero voltage Switching (ZVS) means, that the voltage on the transistor is nearly zero, when the switching action occurs. After low gate turn-off, the transformer's inductances drive the current for a certain time, that shoult be long enough, to load the transistor's and wiring capacitances until the flyback diode becomes conductive. The high gate then should turn on, before this flyback current stopps.

Zero voltage switching is a powerfull soft switching technique, that comes for free on halfbridges, if the parasitic capacitances and - inductances are well coordinated with the dead-time. Regarding the previous measurements, it can be seen, that ZVS is not just a nice feature for efficiency maximization, but that it is absolutely necessary for high power applications.

## 3.4 Frequency stability

At least, the prototype was driven with the full rectified grid voltage and the frequency was modulated between 80 and 160 KHz, but there were no abnormalities.