

Interactions between blocking and overshoot voltages of LLC SR MOSFETs

International Workshop on Power Supply On Chip (PwrSoC)

October 3-5 2016, Madrid, Spain

Authors: Sylvain Leomant, Olivier Guillemant, Roesch Maximilian, Anita Risteska, Martin Poelzl



Large portfolio covering 4 segments:



Automotive (ATV)

- > 32-bit automotive microcontrollers for powertrain, safety and driver assistance systems
- > Discrete power semiconductors
- > IGBT modules
- > Industrial microcontrollers
- > Magnetic and pressure sensors
- > Power ICs
- > Radar
- > Transceiver (CAN, LIN, Ethernet, Flex Ray™)
- > Voltage regulators



Industrial Power Control (IPC)

- > Bare die business
- > Discrete IGBTs
- > Driver ICs
- > IGBT modules (high-power, medium-power, low-power)
- > IGBT module solutions incl. IGBT stacks



Power Management & Multimarket (PMM)

- > Control ICs
- > Customized chips (ASICs)
- > Discrete low-voltage and high-voltage power transistors
- > GPS low-noise amplifier
- > Low-voltage and high-voltage driver ICs
- > MEMS and ASICs for silicon microphones
- > RF antenna switches
- > RF power transistors
- > TVS (transient voltage suppressor) diode



Chip Card & Security (CCS)

- > Contact-based security controllers
- > Contactless security controllers
- > Dual-interface security controllers (contact-based and contactless)



Villach site, 1979



Villach site, 2015, around 3000emp



*FlexRay is a trademark licensed by FlexRay Consortium GbR

Market Position*

<p>Automotive</p> <p># 2</p> <p>Strategy Analytics April 2016</p>	<p>Power</p> <p># 1</p> <p>IHS Inc. September 2015</p>	<p>Smart card ICs</p> <p># 2</p> <p>IHS Inc. July 2015</p>
---	--	--

*Details see page 8

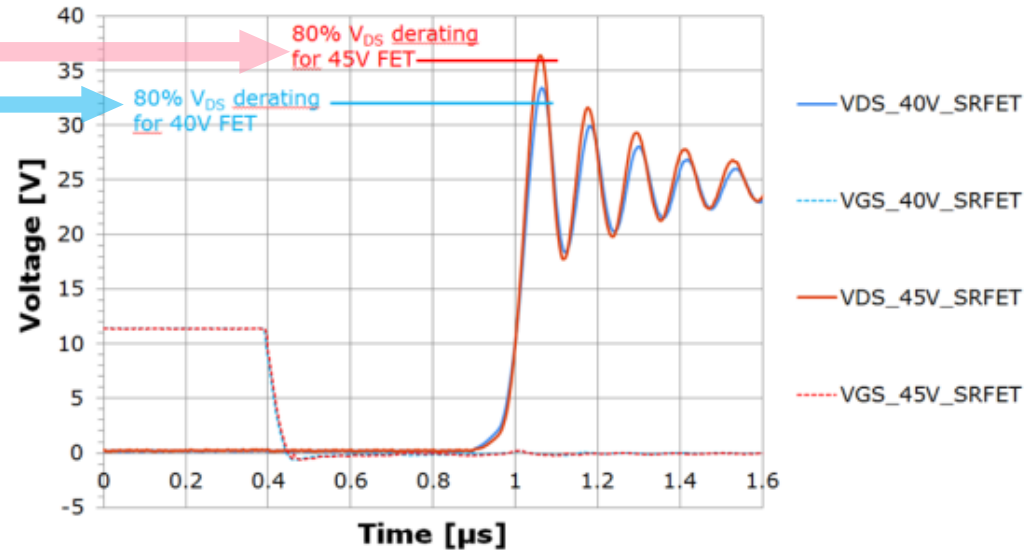
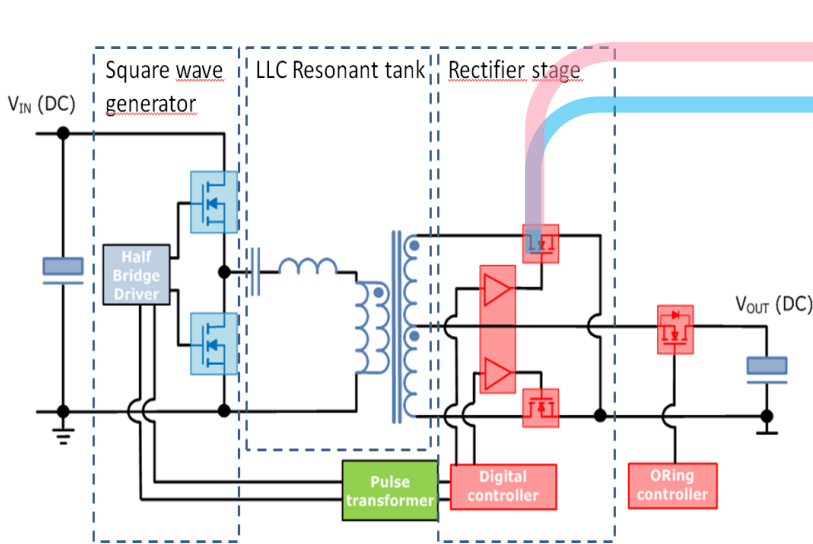
About 35,400 employees worldwide (as of Sep. 2015)



32 R&D locations
20 manufacturing locations

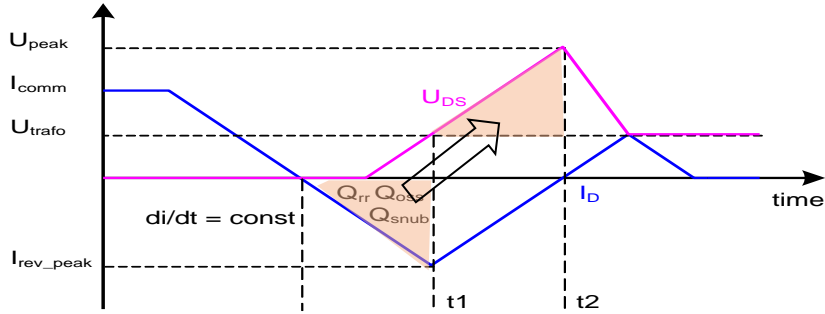
1970	Founding Siemens diode production facility in Villach
1979	Formation Development Center for microelectronics in Villach Start chip production on 100 mm Wafers: Villach becomes a front end site
1997	Villach becomes Competence Center and leading site for power electronics
1998	Founding Development Center Graz
1999	Siemens Semiconductors becomes Infineon Technologies Joint Venture Development Center DICE-JKU Linz
2000	Stock market launch Infineon Group
2004	Founding IT-Services in Klagenfurt
2006	Opening Competence Center for Automotive and Industrial Electronics (KAI)
2013	Pioneer in chip production on 300 mm thinwafers
2015	Formation new building for R&D and production with pilot area Industry 4.0

□ **This work:** Rectifier stage for Server Power supply with efficiency levels >94%



- Safe operation when overshoot voltage < 80% of the device rating (i.e. **32V** for a 40V MOSFET)
- !!! Replacing the 40V rated MOSFET by a 45V MOSFET can lead to a higher overshoot!!!
-> **Safety margin still not fulfilled!**

Voltage overshoot @Turn-off -> energy transfer from loop inductance to output capacitance.



Simplified overshoot model (Ref):

$$U_T \cdot \left(\frac{1}{2} Q_{oss_L} + Q_{rr} \right) = \frac{1}{2} C_{oss_H} \cdot (U_{pk}^2 - U_T^2)$$

$$U_{pk} = \sqrt{\frac{U_T \cdot \left(\frac{1}{2} Q_{oss_L} + Q_{rr} \right)}{\frac{1}{2} C_{oss_H}} + U_T^2}$$

Q_{oss} @ V_{DS} < U_T
C_{oss} @ V_{DS} > U_T

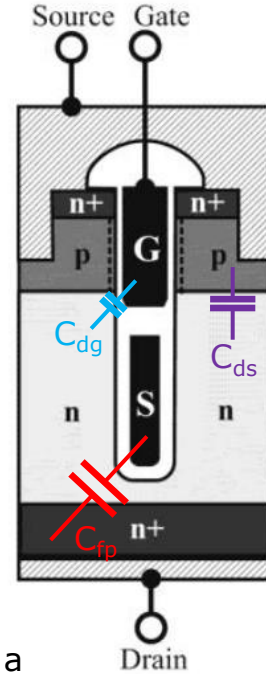
- Q_{rr} negligible (for 40V-45V MOSFETs and application in focus)

Ref: Mösslacher C. et I. "Improving Efficiency of Synchronous Rectification by Analysis of the Mosfet Power Loss Mechanism" PCIM2009

Field Plate Trench MOSFET:

Output capacitance

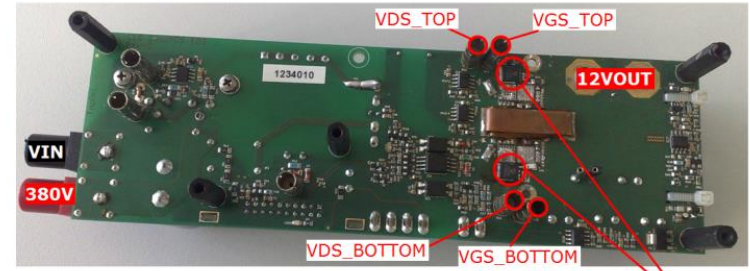
- $C_{oss} = C_{dg} + C_{ds} + C_{fp}$
- C_{fp} depends on Field oxide, Trench depth, Epi Doping (high interactions with the device voltage rating)
- C_{ossL}/C_{ossH} new metric introduced (see next slide)
- 45V with non optimized C_{ossL}/C_{ossH} has a higher overshoot than a 40V



Interactions between blocking and overshoot voltages of LLC SR MOSFETs

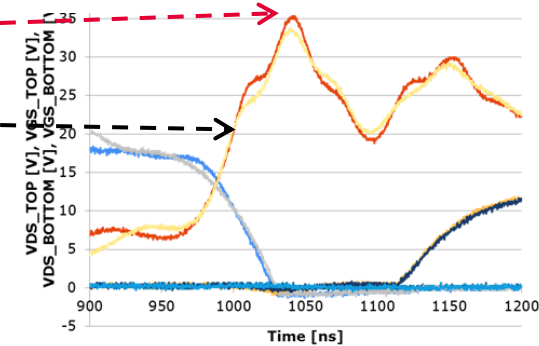
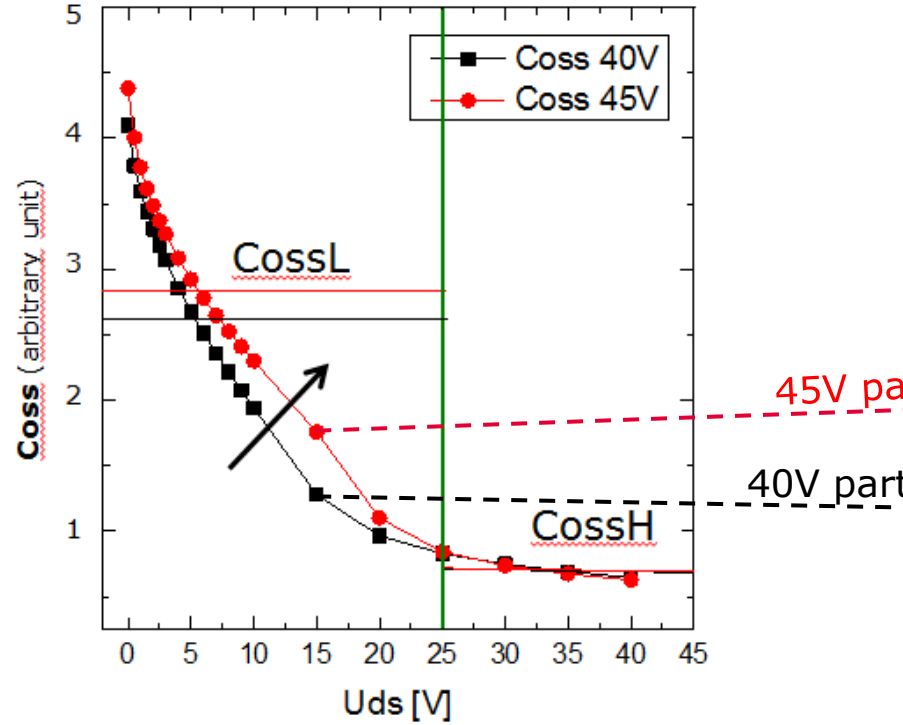
□ In-house application tests & Characterization:

(C_{ossL}/C_{ossH}) optimization possible due to U_T fixed to ~25V within our application



Devices Under Test

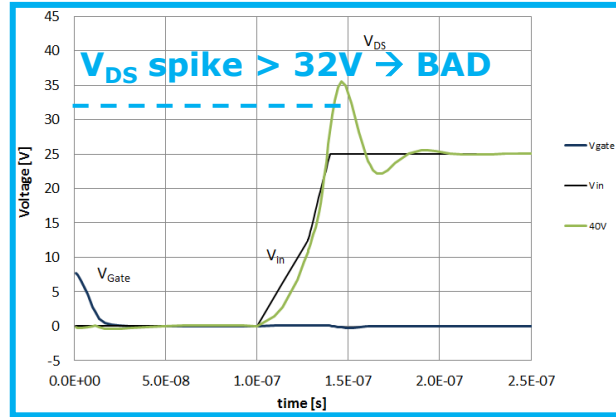
- Platform: DC/DC stage of a server power supply
 - 380VIN (set value for tests), 12VOUT
- Topology : LLC + center-tap
- $V_{GS(Sync Rec FETs)} = 12V$
- Output current up to 50A (600W)
 - But, for tests, only up to 20A due to only 1 FET of high $R_{DS(on)}$ per Sync Rec branch



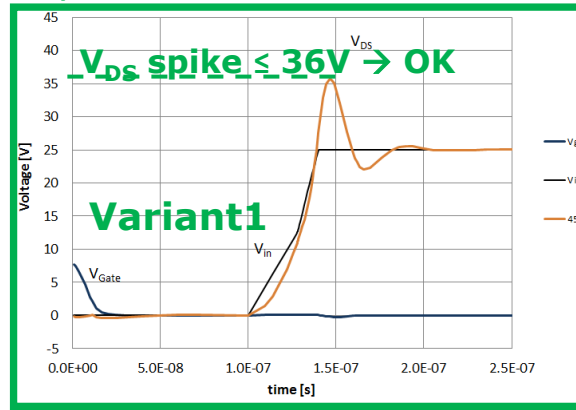
Higher Overshoot For the 45V Correlating with Coss curves

Simulation results:

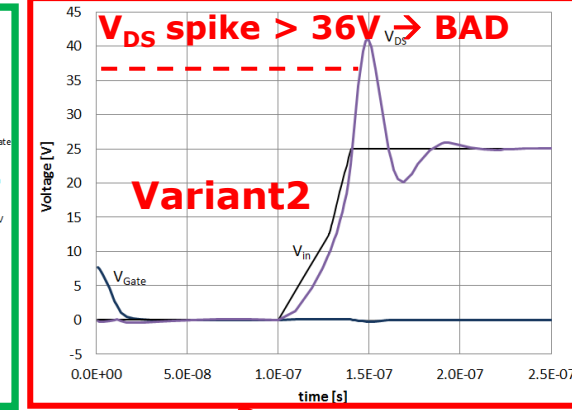
„Reference 40V FET“



„Optimized 45V FET“



„Low effort/scaling 45V FET“



Coss shaping successfully employed: same overshoot voltage for a 45V rated device as for the reference technology (40V).

Parameters	Variant1	Variant2
Ron10.A (mΩ.mm ²)	+13%	+14%
FOMg (mΩ.nC)	+9%	+10%
CossL/CossH	+5%	+10%
Sim. V _{DS} overshoot	<3%	+19%

NB: 45V technology variants compared to 40V

Conclusion:

- Overshoot is application specific (Q_{rr} , Q_{oss} ..)
- In-depth analysis with electrical charac. and simulation data.
- C_{ossL}/C_{ossH} metric defined
- 45V cell-level geometry fine-tuned(no add. passives integrated) allowing overshoot optimization with low area penalty.



Reliable, Efficient and Cost-driven system