Overcoming Measurement Challenges In High-Speed GaN Power Devices

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Making WBG Designs Happen

GaN

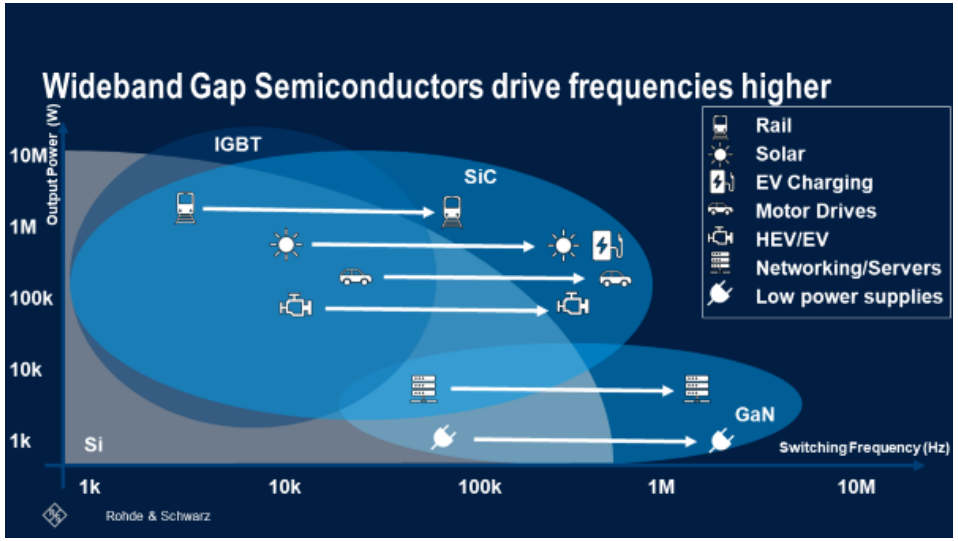
Why New Measurement Methods?

- Wideband Gap With Focus On GaN
  - GaN Transistor Switches At Higher Speed
  - Lower Power and Intermediate Voltage Level

Benefits Are Efficiency And Compact Designs!!!

- Looking At the WBG Technology From A Measurement Perspective
  - What Are the Challenges With GaN Designs?
    - Higher System Bandwidth Is Required
    - Common Mode Noise (high dV/dt) Appears At Higher Frequencies
    - Probing Itself Becomes A Challenge

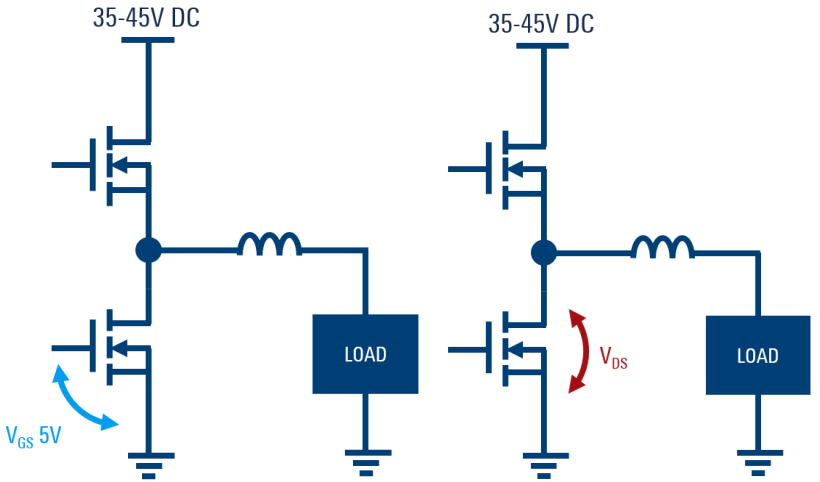
    - Very Low Drive Voltage of GaN Transistor
    - Higher Impact Of Probes On The (DUT) Device Under Test
    - EMI Emissions Due To Fast Rising And Falling Edges

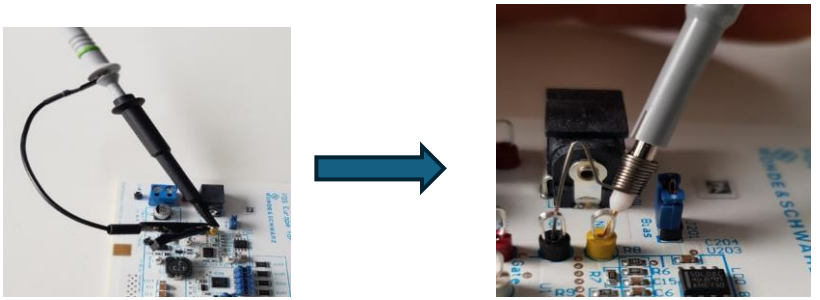


A Lot Of Measurement challenges Are Valid Also For Silicon Carbide Technology

Standard Measurements In Hard-Switching Converter/Inverter Designs

- Single Ended Voltage Measurements (Ground Reference)
  - Low-Side Gate-Source Voltage Validation
    - Minimum and Maximum Gate Voltage)
    - Gate Threshold Voltage (Miller Plateau) & Ringing
    - Gate Resistor Validation (Ensure Dead Time / EMI Related)
    - Ensure That Low-Side Is Off To Prevent Shot-Through
  - Switch-Node Voltage Validation
    - Minimum and Maximum Drain-Source Voltage (No Avalanche Capability With GaN)
    - Ringing
    - Rising and Falling Edges (Impact On EMI)

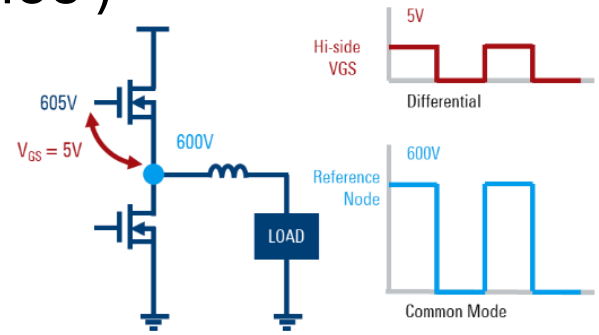


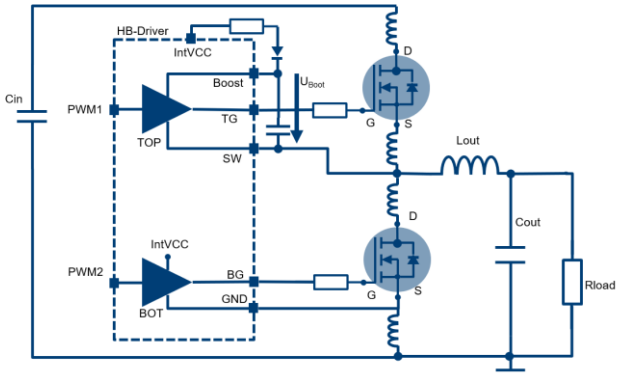


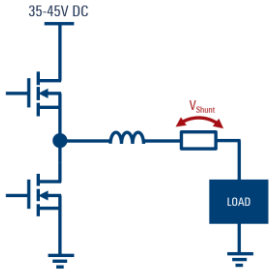
How To Minimize Ground Loop?

Extended Measurements In Hard-Switching Converter/Inverter Designs

- Differential Voltage Measurements (No Ground Reference)
  - High-Side Gate-Source Voltage Validation
    - Minimum and Maximum Gate Voltage
    - Gate Threshold Voltage
    - Ringing
    - Gate Resistor Validation (Ensure Dead Time / EMI Related)
  - HS-Driver Supply Validation
    - Bootstrap Circuit Voltage / Auxiliary PSU
    - Voltage Level Validation
      (Minimum, Maximum and Ripple)
  - Current Shunt Measurement
    - Small Voltage Measurement
      On Higher Voltage (e.g. DC-Bus)







Technology Comparison With Impact On Measurement Methods & Tools

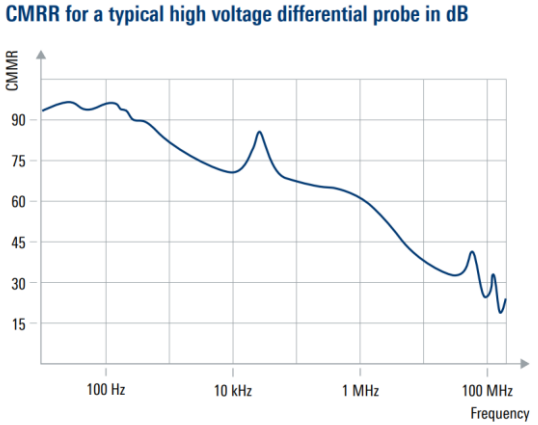
	Rise Time	Gate Voltage Maximum	Gate Voltage Typical	Threshold Voltage	RDSon	Avalanche Capability	Break Down Voltage	Package
GaN Enhancement Mode	1,5ns (>200MHz)	-4 .. +6V	0V (off) 5V (on)	1V	4mΩ	No	100V	LGA 2x3mm
Silicon	40ns (>8MHz)	±20V	0V (off) 12V (on)	3V	40mΩ	275mJ (Single Pulse)	100V	D2PAK 10mm x10mm

Main Problems Using Old Measurement Tools And Methods In WBG-Designs

- High-Side Gate Voltage Measurement
  - Conventional HV-Differential Probes
    - Bandwidth Up To **200MHz** HV-Differential Probes
    - Common Mode Rejection Ratio (CMRR) At Higher Frequency

  - High-Speed Differential Probes (<60V)
    - Bandwidth Up To At Least 1GHz
    - Common Mode Rejection Ration At Higher Frequency

    48V Design with 30dB CMMR Shows 1,4V Measurement Error

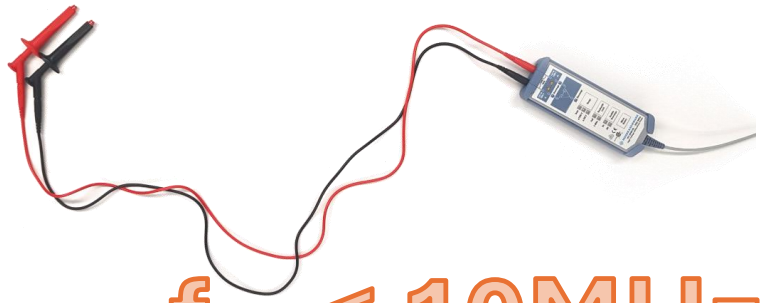


30dB @ 100MHz

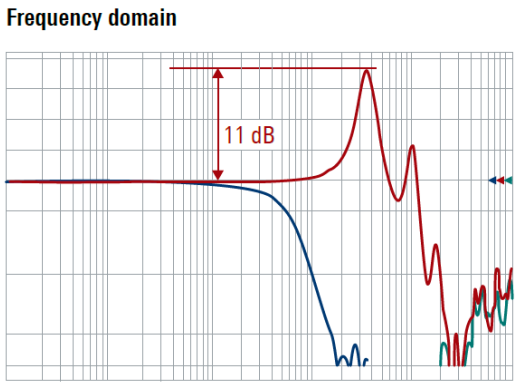
Good CMRR At Higher Frequency (e.g. 500MHz) Is Not Only About The Measurement Tool / Instrument!

Problems With Standard Probing Methods

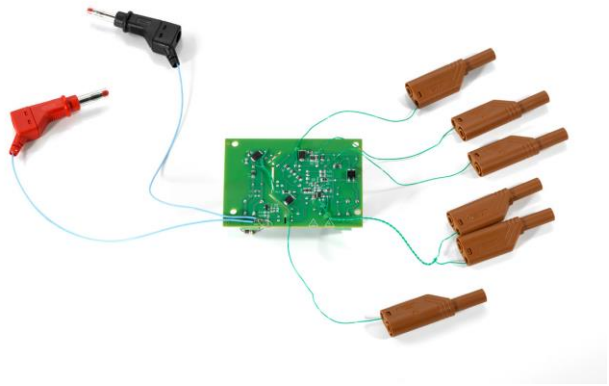
- HV-Differential (200MHz) Probe Example (1m Cable)
  - Leads Are Not Shielded
    Or Twisted (Immunity)
  - Lead Length Is Critical
  - Connection To DUT



$f_{bw} < 10MHz$



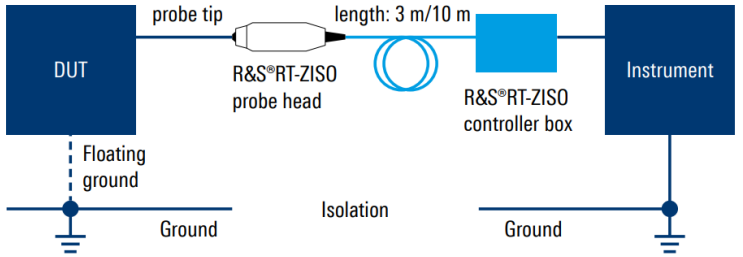
- Improvements
  - Use Twisted Cable
  - Use Soldered In
  - Keep The Cable Length To 10cm (Compensated)

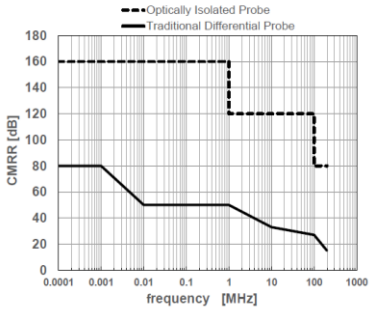


GaN Technology Requires A Different Solution!

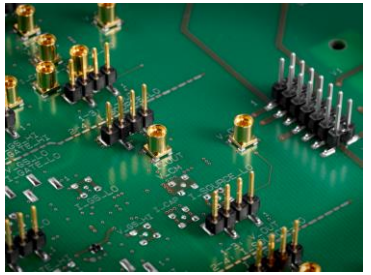
New Measurement Tools & Methods

- Fully Optical Isolated Probing System
  - An Analog Frontend Of The Oscilloscope Is Built Inside The Probe Head
    - High Bandwidth Of 1GHz Is Possible
    - The Frontend Solution Also Provides Low Voltage Measurement At high frequency With Low Noise (Current Shunt)
    - CMMR of 75dB Is Possible Due To Isolation





- Coax System Is Part Of The Probing Solution
  - MMCX Connection Is The Best Trade-Off between Electrical Performance And Space
  - Coax System Also Helps To Suppress External Noise And Transients
  - Max Voltage of 300V Is Allowed
  - Design In Into The PCB Is Required
  - Space On The PCB Is Required >> Power Loop Gets Larger



- Single Channel Approach Is Beneficial Because It Can Not Couple Between Two Channels

Case Study Of Synchronous GaN Buck Converter Design

High-Side Gate Voltage Measurement With Different Probes

- High Voltage Differential Probe (f_{BW}=200MHz / CMRR = 30dB)
- High Bandwidth / Low Voltage Differential Probe (f_{BW}=1GHz / CMRR = 30dB)
- Isolated Probing System (f_{BW}=1GHz / CMRR =75dB)

Shows All Details And High Signal Fidelity

Summary

- Standard High Voltage Probes Do Not Provide Enough Bandwidth & CMRR
- High Frequency Low Voltage Differential Probes Do Not Provide Enough Common Mode Rejection Ratio At High Frequency
- If The Probing Is Not Based On Coax (MMCX), This Will Degrade The CMRR Significantly
- Coax Systems Like The MMCX Requires Design-In And Space In The Layout