DIPARTIMENTO DI
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Power devices in Si, SiC and GaN, switching converters and their applications

Catania, October 29, 2019

Tutor: Prof. Angelo Raciti

Overview

- **SiC Power Modules for Traction Inverters**
- **Gate-source overvoltages in SiC modules**
- **Parasitic phenomena in half bridge with Super Junction (SJ) MOSFETs suitable for drones (UAVs)**
- **E-mobility: Safety, Service Continuity and Penetration of Charging Systems**
- **Ongoing activities and other activities**
- **Scientific publications**

SiC Power Modules for Traction Inverters

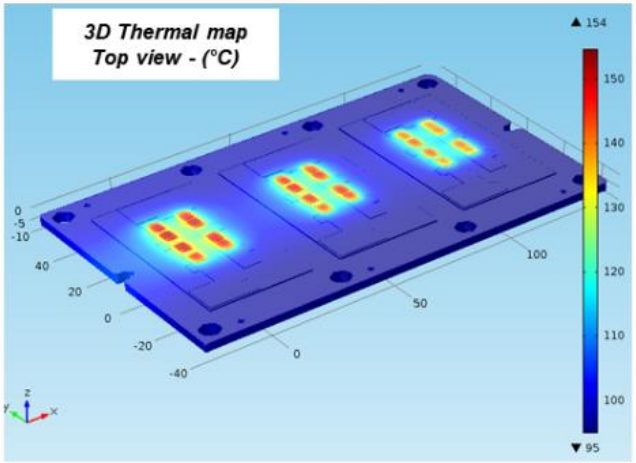
In collaboration with STMicroelectronis

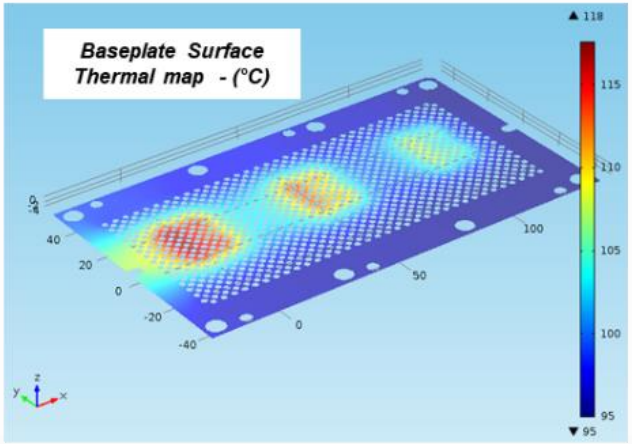
- SiC power modules for traction inverters in electric vehicles are treated in this activity

Main topics:

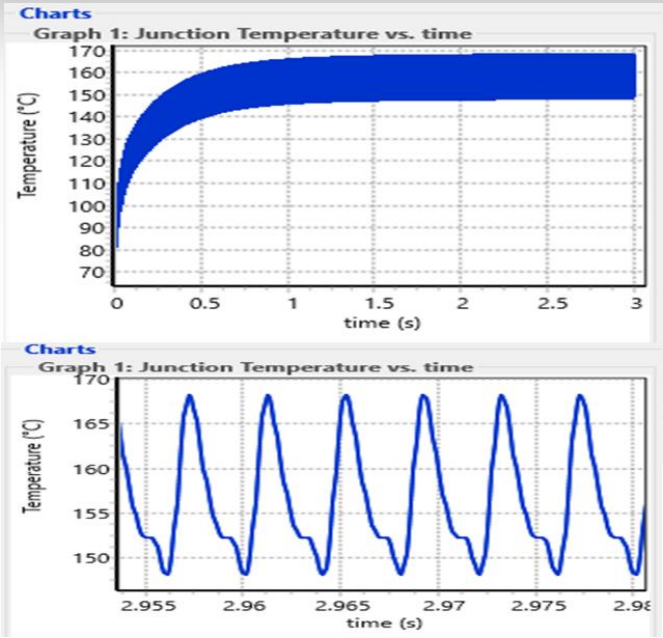
- Electro-thermal Issues
- Unbalance Problems From Paralleled Dice
- Reliability Issues: UIS And Short-circuit
- Layout Issues

Several issues, descriptions, solutions, experimental and numerical results have been reported





SiC Power Modules for Traction Inverters



Input Data

		Limits	
t_sim:	Simulation time (s)	0.001 ÷ 30	3.000
Iph:	RMS Phase Current (A)	0.01 ÷ 600	340.00
Pout:	Output Power (W)	0.1 ÷ 20000	219259.6
Vdc:	DC Link Voltage (V)	20 ÷ 960	800.0
fsw:	Switching Frequency (kHz)	1 ÷ 40	8
fsine:	Output Frequency (Hz)	0.1 ÷ 500	250.00
PF:	Power Factor	0.1 ÷ 1	0.8
MI:	Modulation Index	0.01 ÷ 1	0.95
Tflu:	Fluid Temperature (°C)	25 ÷ 100	50
Ths:	Heatsink Temperature (°C)	25 ÷ 125	65.0
Vgs OFF:	Vgs OFF Voltage (V)	-5 ÷ -1	-5
Rg (Ω) 1.2 ÷ 9			
ON/OFF		3.3	3.3

Output Data

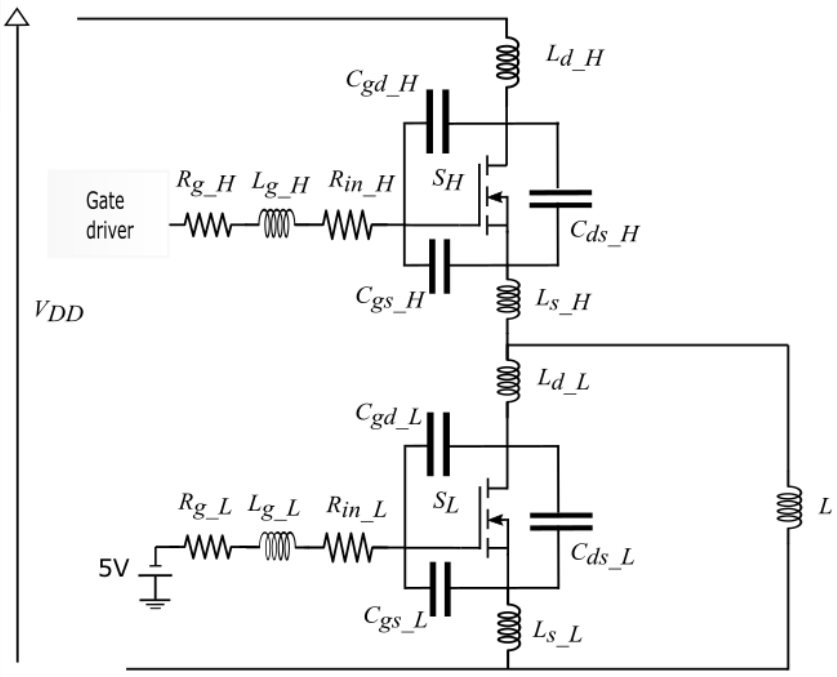
	T1	D1
Conduction Loss (avg) (W)	433.06	91.61
Switching Loss (avg) (W)	123.30	35.01
Total Loss (avg) (W)	556.37	126.63
Junction Temp. (Max) (°C)	168.24	168.24
Junction Temp. (avg) (°C)	151.44	151.44
T1+D1 Total Loss (avg) (W)	682.99	
System Total Loss (avg) (W)	4097.96	
Heatsink Temperature (Max)	65.00	
Heatsink+TIM Rth (°C/W)	0.0037	

Electro-thermal simulations

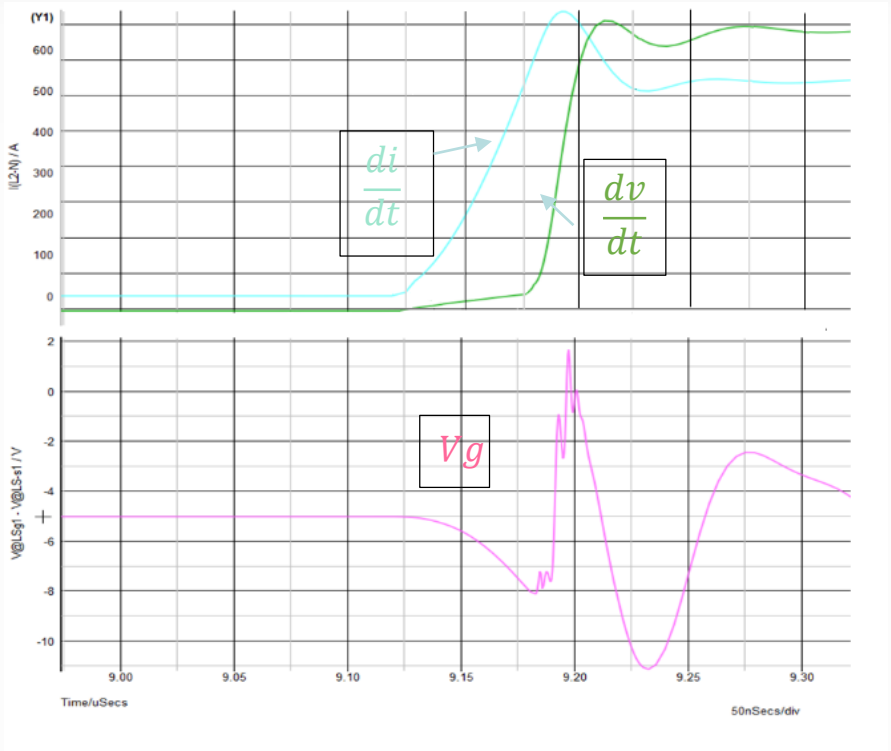
- Real cases, from on-field experience, are treated
- This work may help the designers to pay attention to all these issues when they deal with SiC power modules

Gate-source overvoltage in SiC based modules

In collaboration with STMicroelectronis

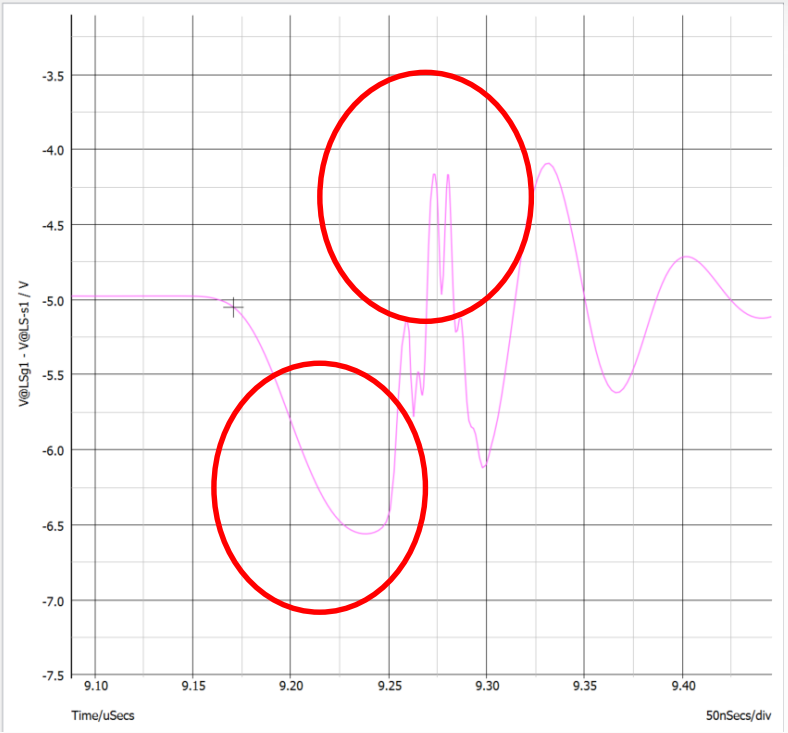


Half-bridge configuration



Simulated waveforms, non-optimized layout of the power module (LS: $V_{GS} = -5V$ with $R_{g(off)} \cong 0\ \Omega$. HS: turn on)

Gate-source overvoltage in SiC based modules

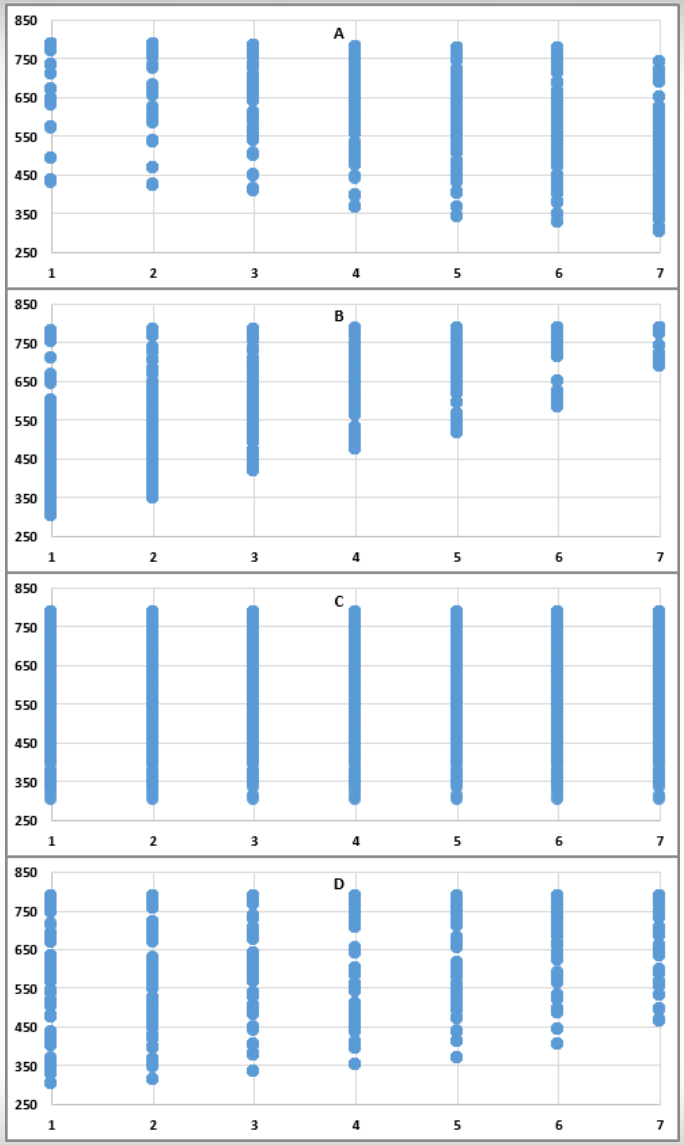


Simulated v_{GS} waveform, optimized PCB layout (LS: $V_{GS} = -5V$ with $R_{g(off)}$ ≅0 Ω, HS: turn on)

<u>A pinout reshaping has been done to optimize the module</u>

- The purpose is to optimize the layout in order to reduce the source inductance for each die
- Making the sensing pin the same for both HS and LS, and removing the HS gate wire
- Locating the Kelvin source pin close to the dice

Parasitic phenomena in half bridge with SJ MOSFETs suitable for Drones (UAVs)



In collaboration with STMicroelectronis

Overshoots and oscillations of the voltage and current in power switches are considered in this activity

AIM OF THE SIMULATIONS

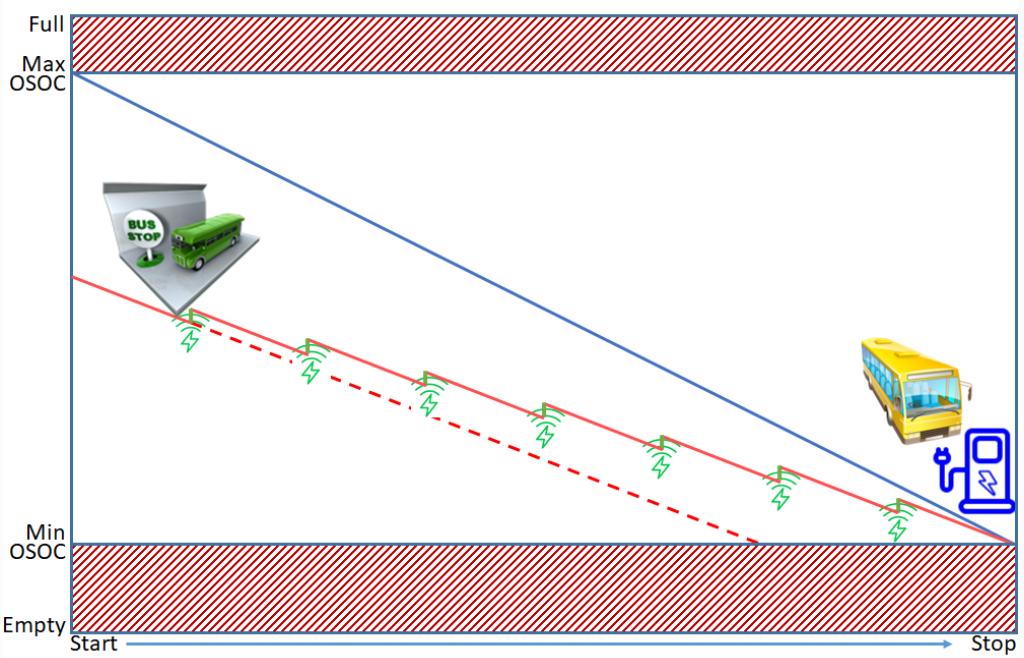
To understand the impact of the various device and board parameters on the global switching transient behavior

E-mobility: Safety, Service Continuity and Penetration of Charging Systems

In collaboration with Sapienza University of Rome

- Outline of electric vehicles types with recharge
- Review of the various charging modes

  On board At charging station
- Focus on wireless charging technology
- Distribution and microgrid new possible solutions



Wireless Power Transfer Technology

Ongoing activities

- **Dynamic on state resistance in GaN power devices:**
  - Evaluation of parameters sensitivity
  - Dynamic resistance measurement methods

- **Silicon Super Junction MOSFET power losses in LLC resonant topologies:**
  - Development of a model to evaluate the contribution of conduction and switching losses

<u>Other activities</u>

- **Participation to the European Phd School - Power Electronics, Electrical Machines, Energy Control and Power Systems, Gaeta, Italy, May 20-24 2019**

Scientific publications

1. **G. Mauromicale**, A. Raciti, S. A. Rizzo, G. Susinni, L. Abbatelli, S. Buonomo, V. Giuffrida, A. Raffa, "Improvement of SiC power module layout to mitigate the gate-source overvoltage during switching operation," 2019 AEIT International Conference of Electrical and Electronic Technologies for Automotive (AEIT AUTOMOTIVE), Torino, Italy, 2019, pp. 1-6.
2. **G. Mauromicale**, A. Raciti, S. A. Rizzo, G. Susinni, G. Parise and L. Parise, "E-mobility: Safety, Service Continuity and Penetration of Charging Systems," 2019 AEIT International Conference of Electrical and Electronic Technologies for Automotive (AEIT AUTOMOTIVE), Torino, Italy, 2019, pp. 1-6**. Also speaker at the conference.**
3. **G. Mauromicale**, A. Raciti, S.A. Rizzo, G. Susinni, L. Abbatelli, S. Buonomo, V. Giuffrida, "SiC Power Modules for Traction Inverters in Automotive Applications," 45th Annual Conference of the IEEE Industrial Electronics Society (IECON), Lisbon, Oct. 14-17, 2019. **Also speaker at the conference.**
4. **G. Mauromicale**, A. Raciti, S.A. Rizzo, G. Susinni, F. Fusillo, A. Palermo, F. Scrimizzi, "Efficiency of available GaN devices in a synchronous-rectifier buck converter," 45th Annual Conference of the IEEE Industrial Electronics Society (IECON), Lisbon, Oct. 14-17, 2019.
5. L. Abbatelli, A. Raciti**,** R. Scollo, **G. Mauromicale**, S. A. Rizzo, A. Scuto, D. Nardo, N. Salerno, G. Susinni, "Effects of parasitic components on SJ MOSFET suitable for UAV," 2019 AEIT International Annual Conference, Firenze, September 18-20, 2019. **Also speaker at the conference.**
6. G. Susinni, **G. Mauromicale**, A. Raciti, S.A. Rizzo, F. Fusillo, A. Palermo, R. Scollo, F. Scrimizzi, "Si and GaN Devices in Quasi Resonant Flyback converters for Wall Charger Applications", 2019 IEEE Energy Conversion Congress and Exposition (ECCE), Baltimore, Maryland (USA), 2019.

Thank you
for the attention