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

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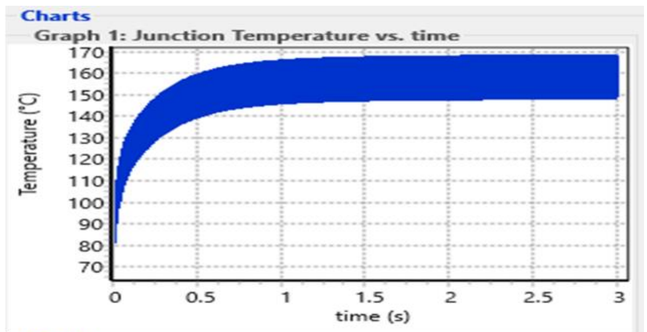
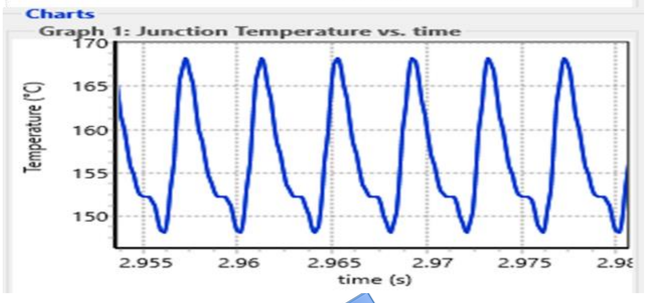
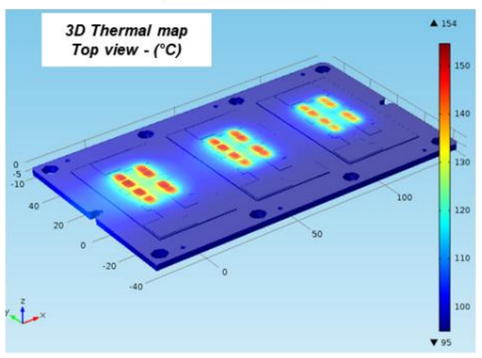
Research activity

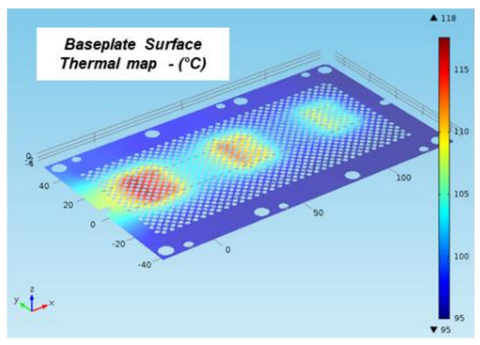
My research activity focuses on power devices used in converters, in the context of industrial and automotive applications. Both silicon and WBG materials, such as Silicon Carbide (SiC) and Gallium Nitride (GaN), are treated. A search line is on SiC power modules used in the main traction inverter of electric vehicles, focusing on all the issues arising in this framework. In this frame, it was treated the problem of the gate-source overvoltages in SiC modules, giving also guidelines to prevent this phenomenon. A second line of activity is related to the study of parasitic oscillations in Silicon MOSFETs in view of more electric aircrafts. The aforementioned activities have been developed in collaboration with STMicroelectronics. Finally, an activity was carried out in collaboration with the Sapienza University of Rome, on the power conversion for charging electric vehicles. In particular, a literature review of the charging modes has been done, and distribution and microgrid future topics related to charging electric vehicles were introduced.

SiC Power Modules for Traction Inverters







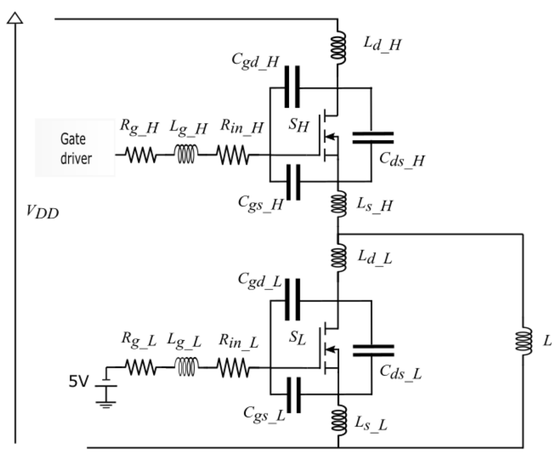


- SiC power modules play a key role for a widespread diffusion of electric vehicles
- The advantages and issues related to SiC traction modules are analysed
- Electrical and thermal problems, safety and reliability issues, challenges from device paralleling and module layout as well as power efficiency, have been investigated

AIMS OF THE ACTIVITY

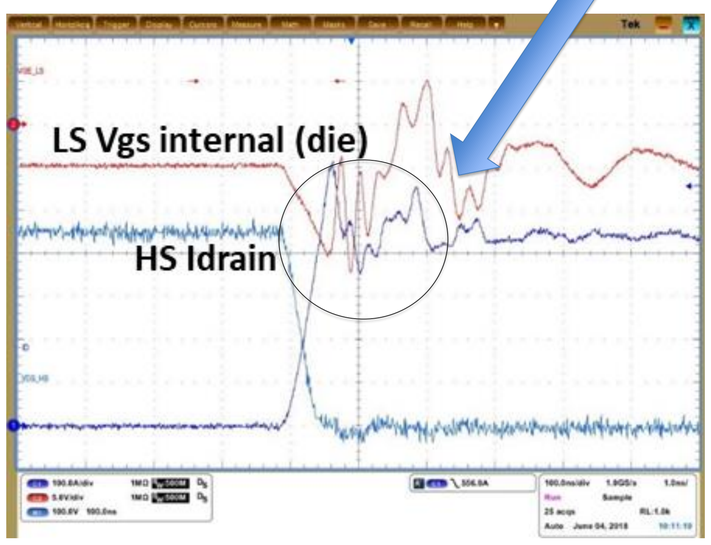
- The aim of this work is to collect all these aspects that must be carefully considered at the SiC power modules design stage.
- The main merit of this overview is that analysis performed by means of on field industrial experience

Gate-source overvoltage in SiC based modules



Positive and negative overvoltages occur in “passive” switch in half-bridge topology, due to parasitic elements such as inductances and capacitances

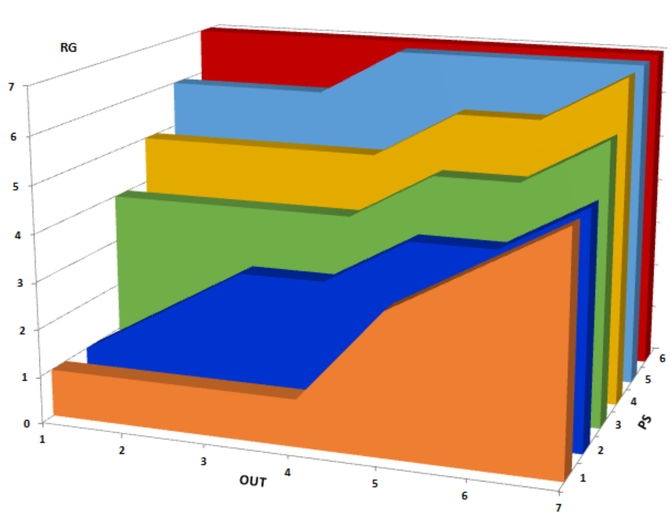
The design of a module layout, in terms of source inductance minimization, has to be considered as an aim to mitigate negative voltage spike



- The minimization is obtained bringing the kelvin pins as near as possible to the dice
- In such a way, there is a reduction of the inductance paths
- Parasitic inductance reduction can be also obtained making both HS and LS kelvin pins symmetric among the gate

Experimental traces for the negative overvoltage

Parasitic phenomena in half bridge with Super Junction MOSFETs suitable for drones (UAVs)



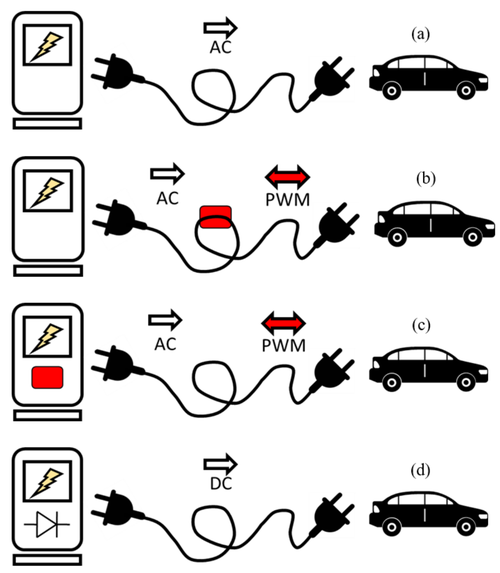
Minimum value of RG necessary to keep the V_{DS} overshoot below the MOSFET voltage breakdown when we are varying the power supply and half bridge phase output node path lengths

- Devices with high reliability level and robustness have to be adopted in Unmanned Aerial vehicles (UAVs)
- Automotive grade Super Junction MOSFET is a good choice in this field of applications

Effects of parasitic elements and gate resistance have been deeply investigated by means of extensive simulations

Design constraints of a leg of a three phase inverter feeding a motor of UAV are presented by using extensive numerical simulations

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



The four recharge modes for plug-in and battery electric vehicles

- Outline of electric vehicles types with recharge
- Review of the various charging modes
- Focus on wireless charging technology
- Distribution and microgrid new possible solutions

Possible adoption of TN-Island Grounding System for each local charging system by a separation transformer

ONGOING ACTIVITIES

- **Dynamic resistance in GaN power devices: evaluation of parameters sensitivity, dynamic resistance measurement methods**
- **Si MOSFET power losses in LLC resonant topologies: development of a model to evaluate the contribution of conduction and switching losses**