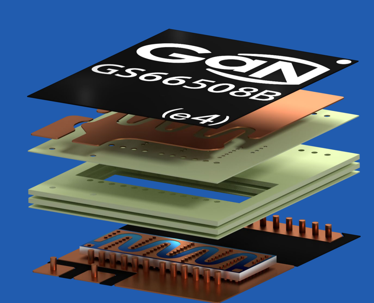
Loss Characterization of Wide Bandgap Semiconductor Devices



Rui Qiang[1], Thiago Batista Soeiro[1], Gert Rietveld[1]

[1]Power Electronics and Electromagnetic Compatibility (PE), EEMCS, University of Twente, Enschede, The Netherlands

Introduction

- Intelligent power electronic systems that acquire key metrics such as losses and temperature of main components enable the systematic optimization, assessment of reliability, and state-of-health.
- Adaption of wide bandgap (WBG) semiconductor devices e.g., SiC and GaN transistors poses great measurement challenges.
- Measurement techniques satisfying new requirements are the foundation for comprehensive condition monitoring and help gain insights into WBG devices.

Dynamic Characterization Methodology

1. Electrical measurement e.g., Double Pulse Test (DPT) can be used to obtain quantities such as power loss, switching time, dv/dt, and di/dt.
The obtained data can be used to estimate device junction temperature and degradation.

- Accuracy is defined by bandwidth and intrusiveness of voltage and current sensors.
- Measurement time is short (tens of us)
- Accuracy is susceptible to probe offsets and misalignment, leading to a significant error of up to 200% under soft-switching operations [1].

2. Calorimetric meas. is based on observing thermal quantities.

- The measurement time is longer (hrs/mins).
- Careful calibration is required with extra experimental efforts.
- Accuracy is higher than electrical if well-calibrated.

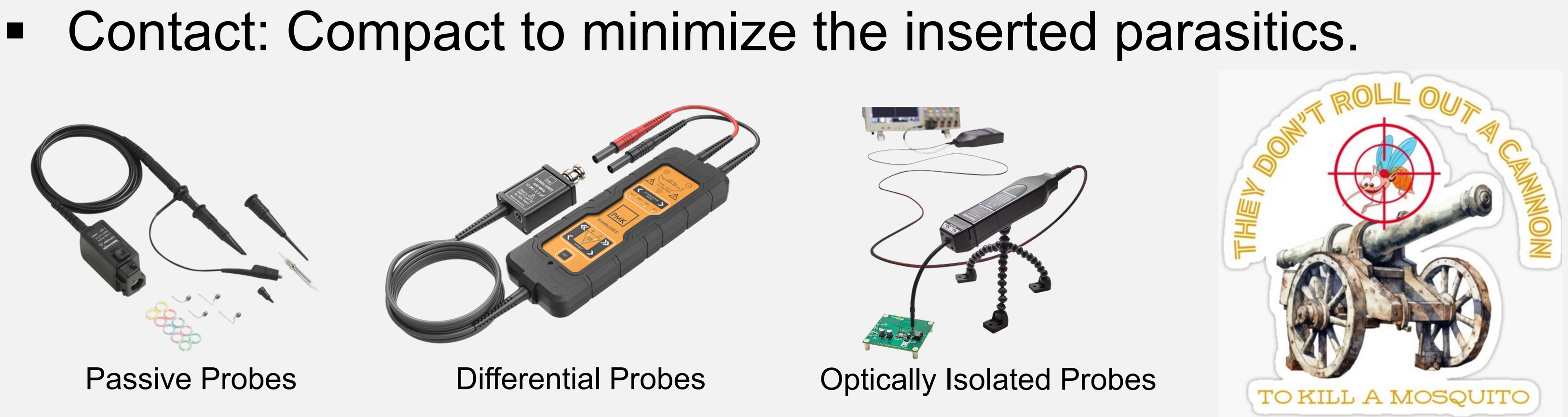
Voltage Sensors

ONE SIZE DOES NOT FIT ALL

The most crucial voltage measurements are the gate-source V_{GS} and drain-source V_{DS}.

Requirements on voltage sensors:

- BW: 100 MHz for SiC (15 ns t_{rise}); 350 MHz for GaN (5ns t_{rise}).
- CMRR: Probes with high CMRR, e.g., optically isolated probes are recommended. Common mode noise with high dv/dt (>100 V/ns) can cause distortion due to the non-ideality of the differential amplifier.
- Contact: Compact to minimize the inserted parasitics.



Passive Probes | Differential Probes | Optically Isolated Probes

Takeaway: An optically isolated probe is a suitable technology for measuring the voltage transient (in a few ns).

Sensor	Mfr.	Type	Bandwidth Quoted (MHz)	Dynamic Range (V)	CMR Quoted (dB)	Contact
TPP1000	Tektronix	Passive	1000	300	N/A	Compact
TPP0850	Tektronix	Passive	800	2500	N/A	Compact
PP0001A	Keysight	Passive	1000	300	N/A	Compact
PP0002A	Keysight	Passive	800	1200	N/A	Compact
BumbleBee	PMK	Differential	400	±2000	DC: 80 400 MHz: 35	Poor
DP0001A	Keysight	Differential	400	±2000	DC: 90 400 MHz: 70	Poor
MOIP1000P	Micsig	Optical Isolated	1000	±5000	DC: 180 500 MHz: 114	Compact
TIVP1	Tektronix	Optical Isolated	1000	±2500	DC: 160 500 MHz: 35	Compact

Current Sensors

ONE SIZE DOES NOT FIT ALL

The most crucial current meas. is the drain-source current I_{DS}.

Requirements on current sensors:

- BW: 100 MHz for SiC (15 ns t_{rise}); 350 MHz for GaN (5ns t_{rise})
- Inserted inductance (if any): Minimized to prevent a voltage overshoot on the device turn-off.
- DC capability: Particularly for DC/DC converters.
- Galvanic Isolation: Preferred. However, inductive-type sensors with isolation generally have lower BW.

Takeaway: Compensated SMD shunt is a suitable technology for measuring the transient current of WBG devices.

Current Clamp | Rogowski Coil | Vertical SMD Shunt [3] | Coaxial Shunt | Infinity Sensor [4]

Sensor	Mfr.	Type	BW Quoted (MHz)	Inserted Inductance (nH)	Dynamic Range (A)	DC Capability	Galvanic Isolation
SDN-414-10	T&M	Coaxial Shunt	2000	5-7	N/A	Yes	No
CS1202	Cleverscope	Compensated SMD Shunt	1000	0.04	50	Yes	No
CWT Mini50HF	PEM	Rogowski Coil	50	App. Dep.	30 - 3k	No	Yes
N2783B	Keysight	Hall effect + transformer	100	0	30	Yes	Yes
Ultra Fast Current Shunt	Cambridge University	Compensated SMD Shunt	1480	0.26	N/A	Yes	No
SMD Coaxial Shunt	University of Tennessee	SMD Shunt PCB inserted	Up to 2230	0.12	N/A	Yes	No
Infinity Sensor	University of Bristol	Planar Rogowski	1000	0.2	20	No	No

Future Directions

- To make a compensated SMD current shunt prototype.
- To assemble and test a DPT prototype setup.
- To evaluate the loss measurement on magnetic components and capacitors.

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