Ciro Scognamillo

Analysis of electrothermal effects in electronic devices, circuits, and systems

Tutor: prof. Vincenzo d'Alessandro

Cycle: XXXV

Year: 2020/2021

My background

M.Sc. in **Electronic Engineering** – 24th Oct 2019
Microelectronics, Prof. **Vincenzo d'Alessandro**

*Analysis of thermal and electrical issues of
state-of-the-art double-sided cooling power modules*

Ph.D. started in Nov 2019 (XXXV cycle)

*Electrothermal effects in electronic
devices, circuits, and systems*
Tutor: Prof. **Vincenzo d'Alessandro**

RF devices characterization lab, building 2, via Claudio

Scholarship

The funding for my Ph.D. was generously donated by the Rinaldi family **in the memory of Prof. Niccolò Rinaldi**.

Research field of interest

Study and modeling of thermal and **electrothermal** (ET) **effects** in **electronic devices** and **circuits.**

Problem

ET effects hinder the **adoption of new technologies** that may improve the devices electrical performances. ET analyses are **time-demanding**, **prone-to-errors**, and **resource-hungry**.
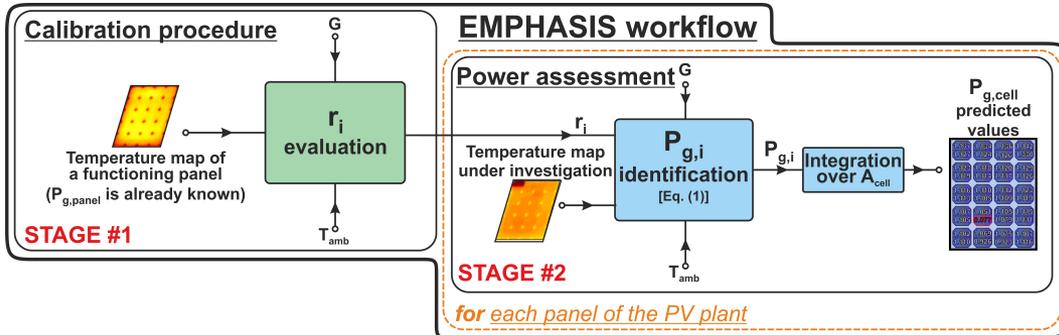
Objective

To build compact models and to carry out **highly-efficient ET numerical investigations**.

Intended contribution

To **improve the trade-off** between **accuracy** and **computational efforts in ET simulations** of state-of-the-art devices.
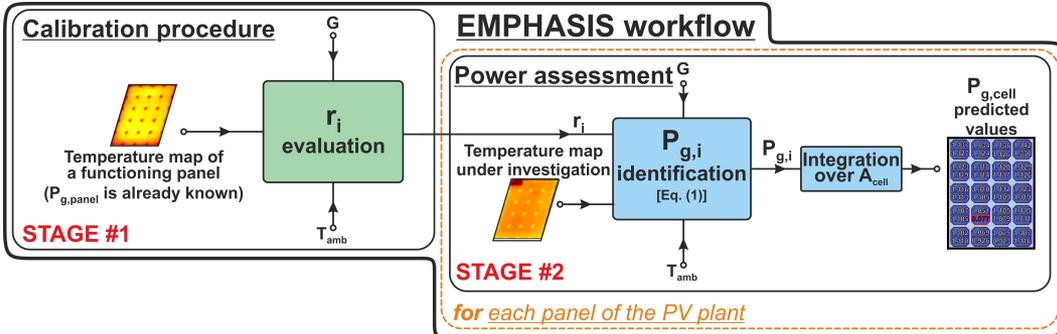
Research activity during 2nd year
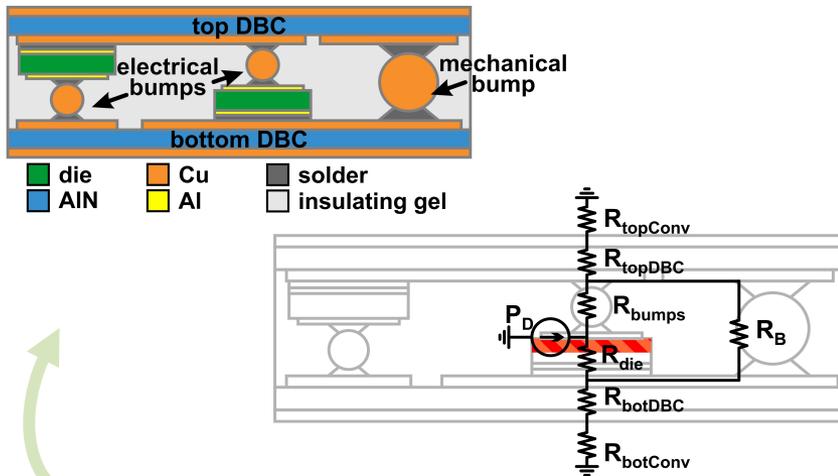

EMPHASIS

➢ Analytical method for fast and non-invasive fault detection in PV panels
➢ Tested under nonuniform environmental conditions
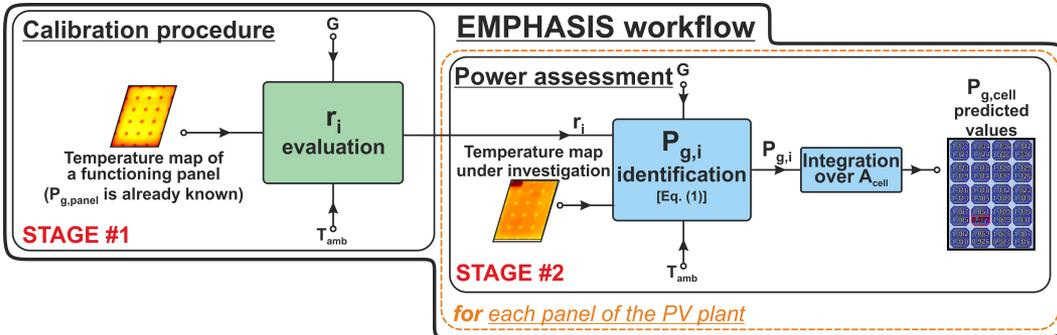
Research activity during 2ⁿᵈ year

EMPHASIS
- Analytical method for fast and non-invasive fault detection in PV panels
- Tested under nonuniform environmental conditions

Power module modeling
Stationary thermal network describing the 3-D heat flow taking place in the assembly

Research activity during 2nd year

Calibration procedure / EMPHASIS workflow

Temperature map of a functioning panel ($P_{g,panel}$ is already known)

STAGE #1

r_i evaluation

G, T_{amb}

Power assessment

Temperature map under investigation

r_i

$P_{g,i}$ identification [Eq. (1)]

$P_{g,i}$

Integration over A_{cell}

$P_{g,cell}$ predicted values

STAGE #2

G, T_{amb}

for *each panel of the PV plant*

EMPHASIS
➢ Analytical method for fast and non-invasive fault detection in PV panels
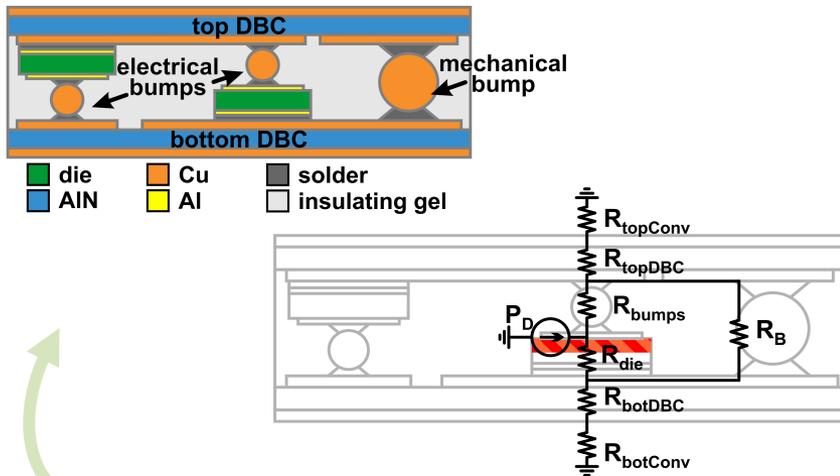➢ Tested under nonuniform environmental conditions

Power module modeling

top DBC

electrical bumps, mechanical bump

bottom DBC

- 🟩 die 🟧 Cu ⬛ solder
- 🟦 AlN 🟨 Al ⬜ insulating gel

$R_{topConv}$, R_{topDBC}, R_{bumps}, R_B, P_D, R_{die}, R_{botDBC}, $R_{botConv}$
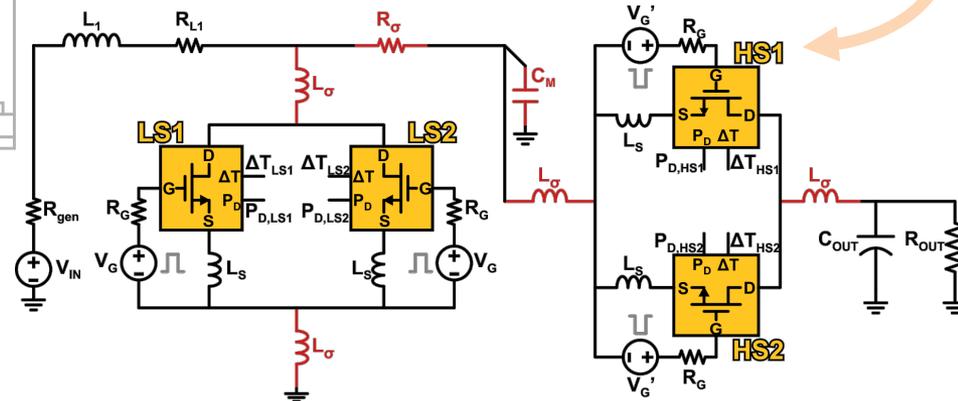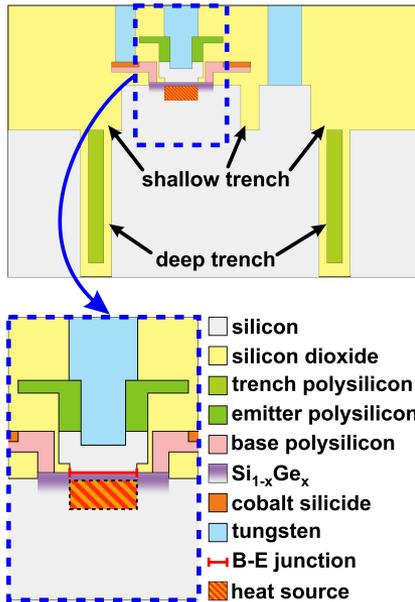
Power module modeling
Stationary thermal network describing the 3-D heat flow taking place in the assembly

DC-DC converter ET macrocircuit
➢ Easy testing of design strategies (no prototypes needed)
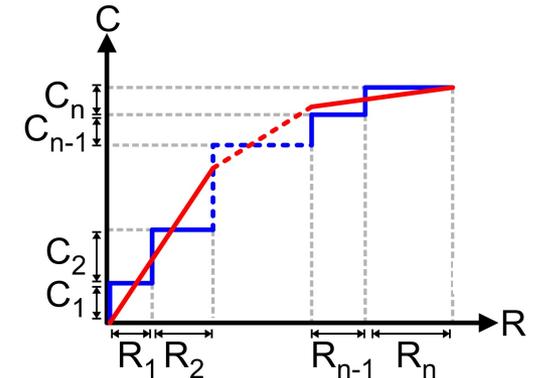➢ Experimentally-calibrated parasitics (in red)

L_1, R_{L1}, R_σ, L_σ, C_M

R_{gen}, R_G, V_{IN}, V_G, L_S

LS1: ΔT_{LS1}, P_D, $P_{D,LS1}$
LS2: ΔT_{LS2}, P_D, $P_{D,LS2}$, R_G, V_G

HS1: P_D ΔT, $P_{D,HS1}$, ΔT_{HS1}, V_G', R_G, L_S
HS2: $P_{D,HS2}$, ΔT_{HS2}, P_D ΔT, V_G', R_G
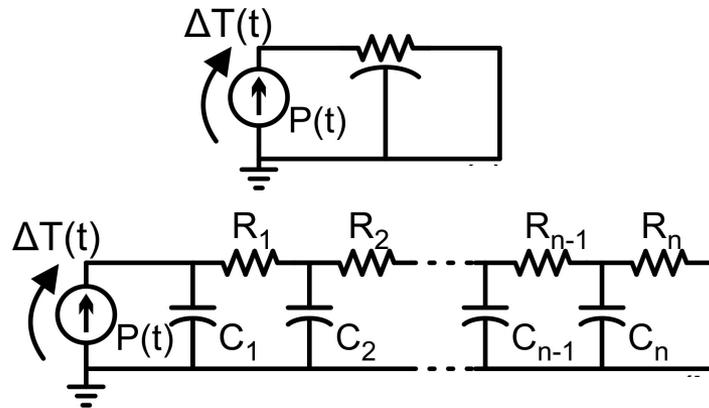
C_{OUT}, R_{OUT}
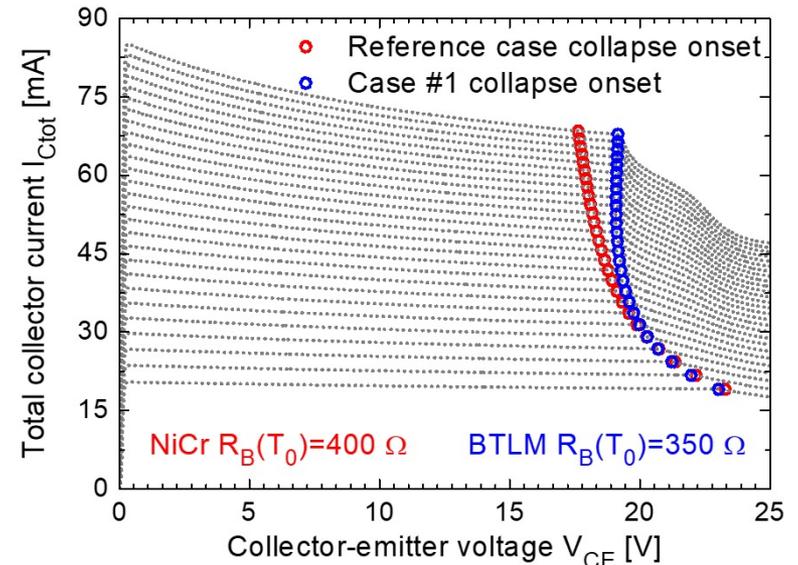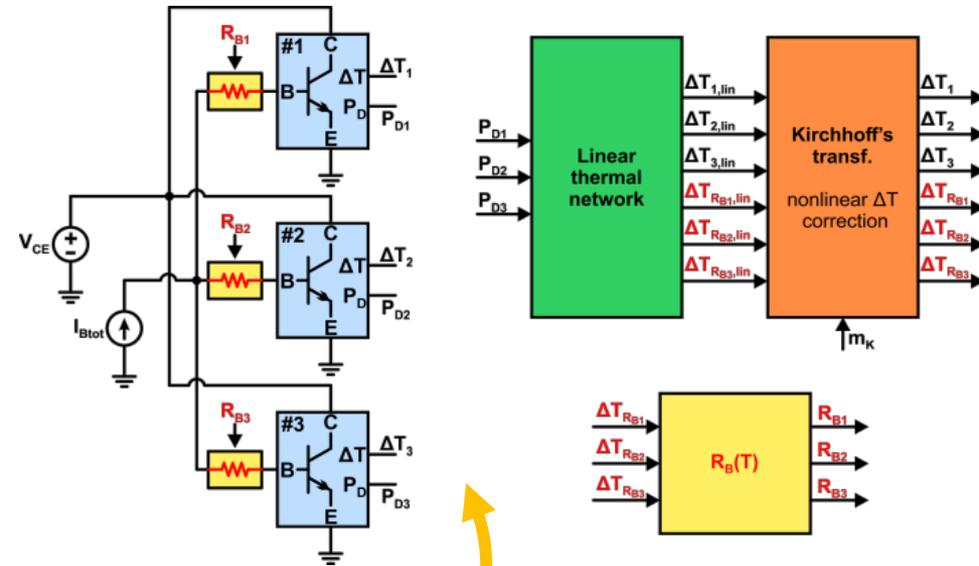
Research activity during 2nd year

Structure functions
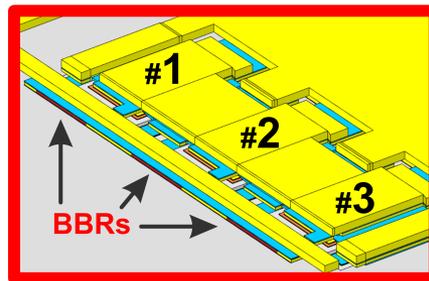Algorithm applied to dynamic thermal response in order to investigate the internal structure of any electronic device.
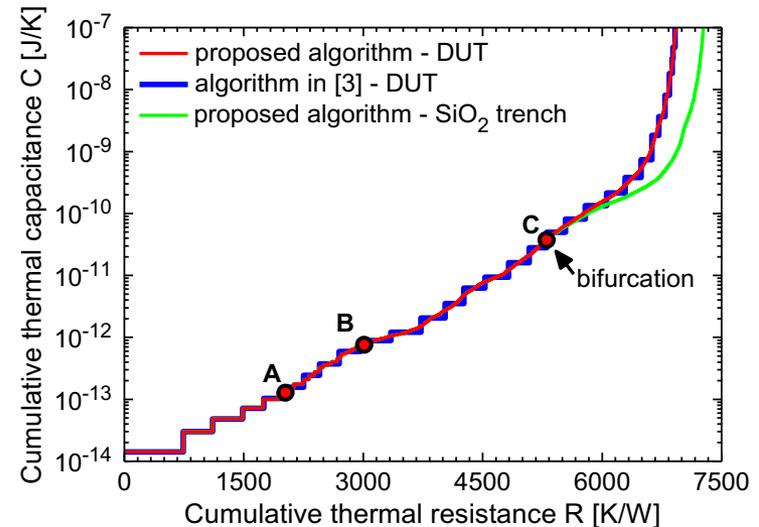
Research activity during 2nd year

Ballasting networks
Temperature-dependent base ballasting resistors (benefits from the safe operating area point of view)

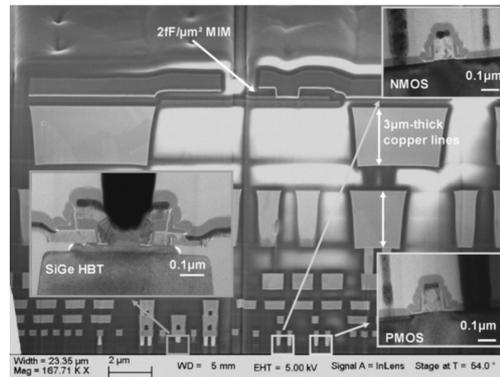**SOA increased** by using ballasting resistor with **resistivity having a positive and high temperature coefficient**

Plans for 3rd year: hands on!

Research period abroad
I will be spending six months at the *Universitè de Bordeaux* (FR)

Research topics
➢ Experimental RF characterization of SiGe HBTs (up to 40 GHz)
➢ Investigation of nonlinear thermal effects in SiGe HBTs

Products
Journal contributions

[1.j]	V. d'Alessandro, A. P. Catalano, **C. Scognamillo**, L. Codecasa, and P. J. Zampardi, "Analysis of electrothermal effects in devices and arrays in InGaP/GaAs HBT technology," *Electronics*, vol. 10, no. 6, 757, 2021.
[2.j]	L. Codecasa, V. d'Alessandro, A. P. Catalano, **C. Scognamillo**, D. D'Amore, and K. Aufinger, "Accurate and efficient algorithm for computing structure functions from the spatial distribution of thermal properties in electronic devices," *IEEE Transactions on Electron Devices, vol. 68, no. 11, pp. 5386–5393, 2021. (**invited paper**)*
[3.j]	**C. Scognamillo**, A. P. Catalano, M. Riccio, V. d'Alessandro, L. Codecasa, A. Borghese, A. Castellazzi, G. Breglio, and A. Irace, "Compact modeling of a 3.3 kV SiC MOSFET power module for detailed circuit-level electrothermal simulations including parasitics," *Energies*, vol. 14, no. 15, 4683, 2021.

Conference contributions

[1.c]	**C. Scognamillo**, A. P. Catalano, A. Borghese, M. Riccio, V. d'Alessandro, G. Breglio, A. Irace, R. N. Tripathi, A. Castellazzi, and L. Codecasa, "Electrothermal modeling, simulation, and electromagnetic characterization of a 3.3 kV SiC MOSFET power module," *Proc. International Symposium on Power Semiconductor Devices and ICs (ISPSD),* Jun. 2021.
[2.c]	A. P. Catalano, **C. Scognamillo**, A. Castellazzi, L. Codecasa, and V. d'Alessandro, "Study of the thermal behavior of double-sided cooled power modules," *Proc. IEEE International Workshop on Thermal Investigations of ICs and Systems (THERMINIC)*, 2021.
[3.c]	**C. Scognamillo**, A. P. Catalano, P. Guerriero, S. Daliento, L. Codecasa, and V. d'Alessandro, "PV fault detection through IR thermography: using EMPHASIS under uneven environmental conditions," *Proc. IEEE International Workshop on Thermal Investigations of ICs and Systems (THERMINIC)*, 2021.

itee PhD
information technology
electrical engineering

Summary of activities

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	0	2.6	6.8	0	9.4
Bimonth 2	0	2.6	5.0	0	7.6
Bimonth 3	0	2.6	7.0	0	9.6
Bimonth 4	0	0.8	7.2	0	8.0
Bimonth 5	5.5	0	8	0	13.5
Bimonth 6	0	0	10	0	10
Total	5.5 (+ 21.6 first year)	8.6 (+ 11.1 first year)	44.0 (+ 40.9 first year)	0 (+ 0 first year)	58.1 (+ 73.4 first year)
Expected	30 - 70	10 - 30	80 - 140	0 – 4.8	

Ad-hoc courses and certifications

- *MATLAB Associate Certification*, 13/07/21
- *Real Time Embedded Systems*, 13/05–15/07/21

Conferences

- *International Symposium on Power Semiconductor Devices and ICs (**ISPSD**), online conference, Jun. 2021. I presented one contribution: [1.c].*
- *International Workshop on Thermal Investigations of ICs and Systems (**THERMINIC**), online conference, Sep–Oct 2021. I presented one contribution: [3.c].*

Thank you for your kind attention