

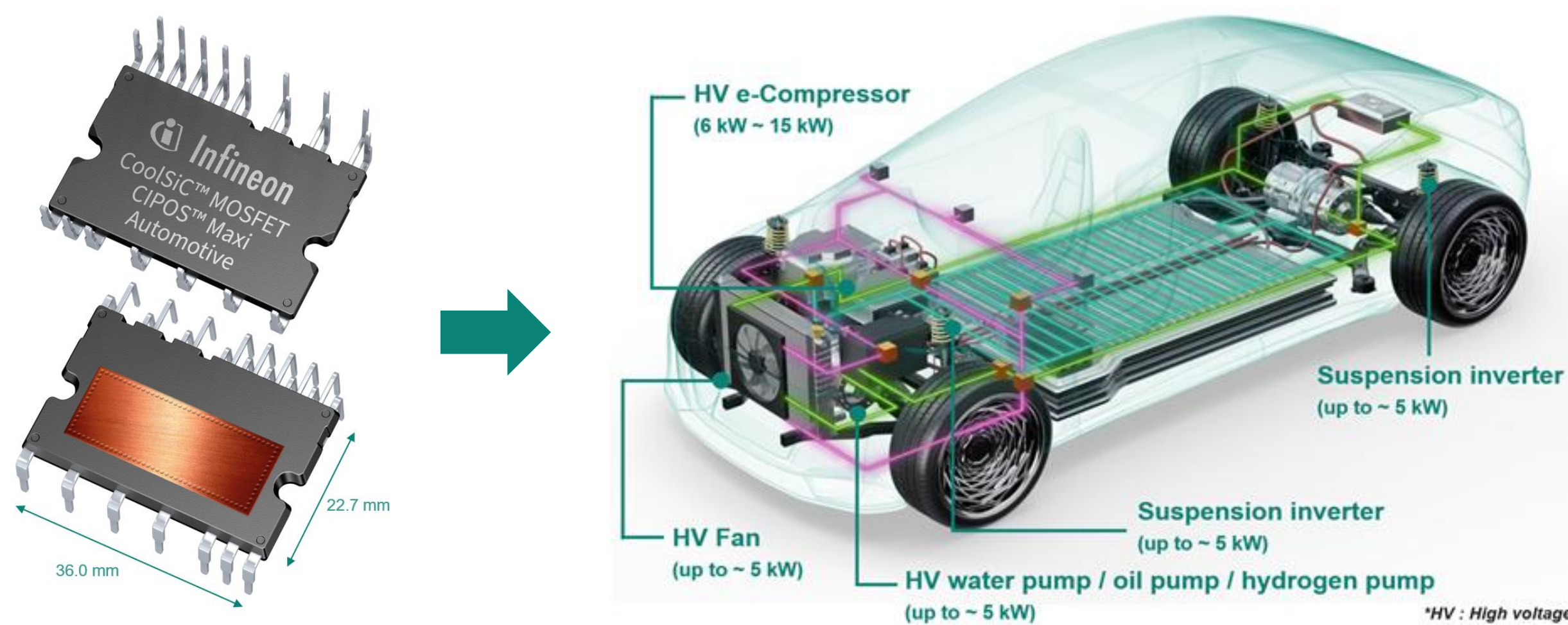
Thermal correlation among junction, NTC, and heatsink in 1200 V automotive-grade CIPOS™ Maxi IPM for automotive auxiliary motor drives

Hyoungsub Jo, Jungdoo Kim, Jinhyeok Kim, Kihyun Lee, Soohyuk Han, Bokkeun Song
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Introduction

Automotive auxiliary motor drives operate under prolonged operation cycles and severe ambient conditions, leading to excessive junction temperature (T_J) of intelligent power module (IPM). Elevated T_J increases power losses and may trigger thermal runaway, resulting in critical reliability and safety issues. Therefore, strict thermal management of power devices is essential. However, in actual system environments, direct T_J measurement via thermocouples or infrared cameras (IR) is impractical. Instead, T_J must be tracked using the embedded NTC and heatsink temperature. This paper presents the thermal correlation among T_J , NTC, and heatsink using the new automotive-grade 1200 V CIPOSTM Maxi IPM under realistic operating conditions.

Why Auto-grade CIPOS™ Maxi IPM



Auto-grade CIPOS™ Maxi IPM

Auxiliary motor drive applications on EV

Why Tier1, 2 and OEMs go High Voltage

- The possibility to charge the vehicle faster
- Weight saving
- Increasing efficiency
- Positive effect on battery aging
- Less competition

Why thermal management is important

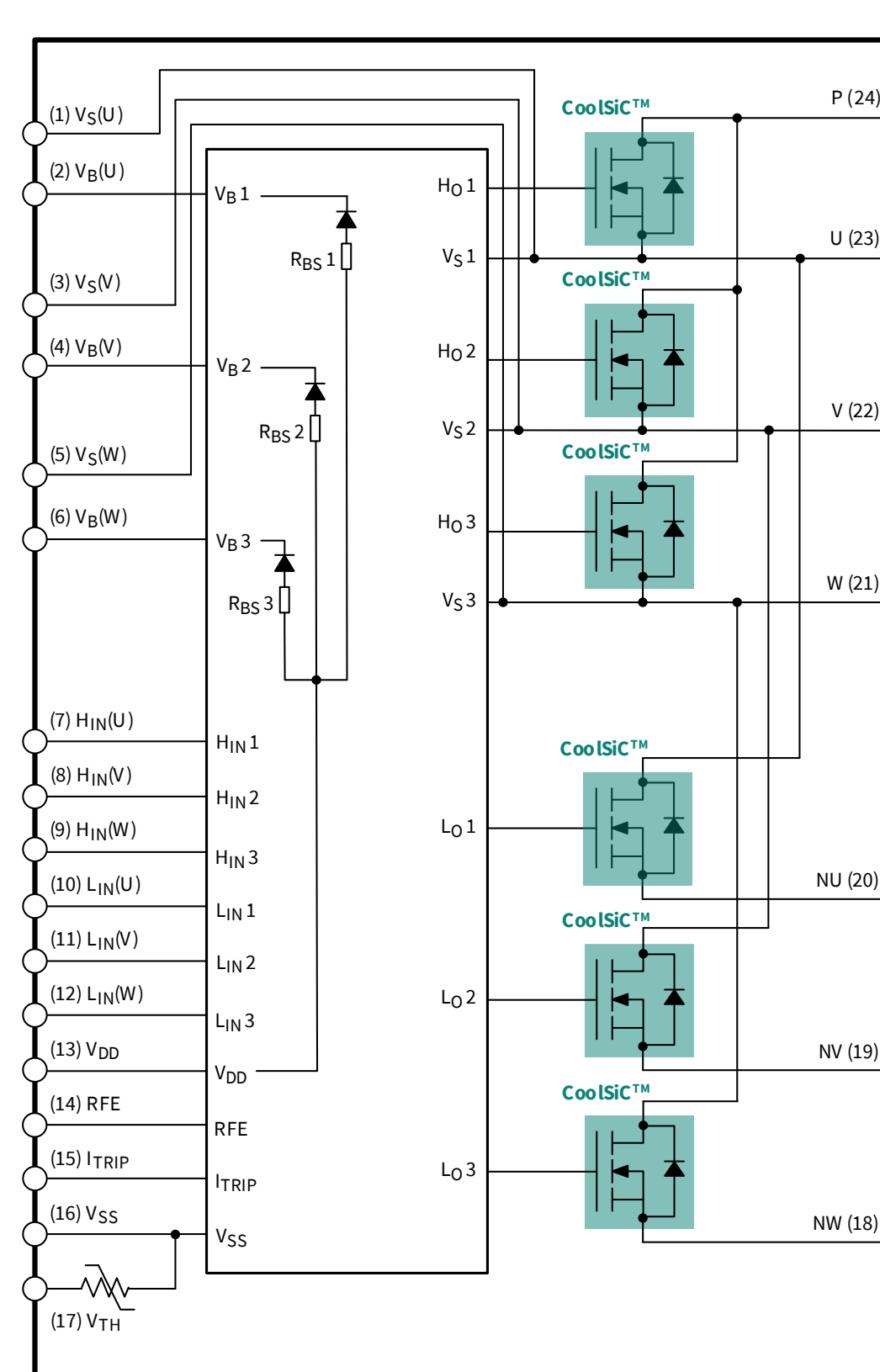
- EV auxiliary motor drives often run prolonged operation cycles and severe ambient temperature conditions.
- High T_J increases power loss, reducing efficiency and EV driving range.
- Thermal cycling and high heat damage the package (solder, DBC, bond wires), increasing failure risk and shortening lifetime.

Auto-grade Maxi IPM Product overview

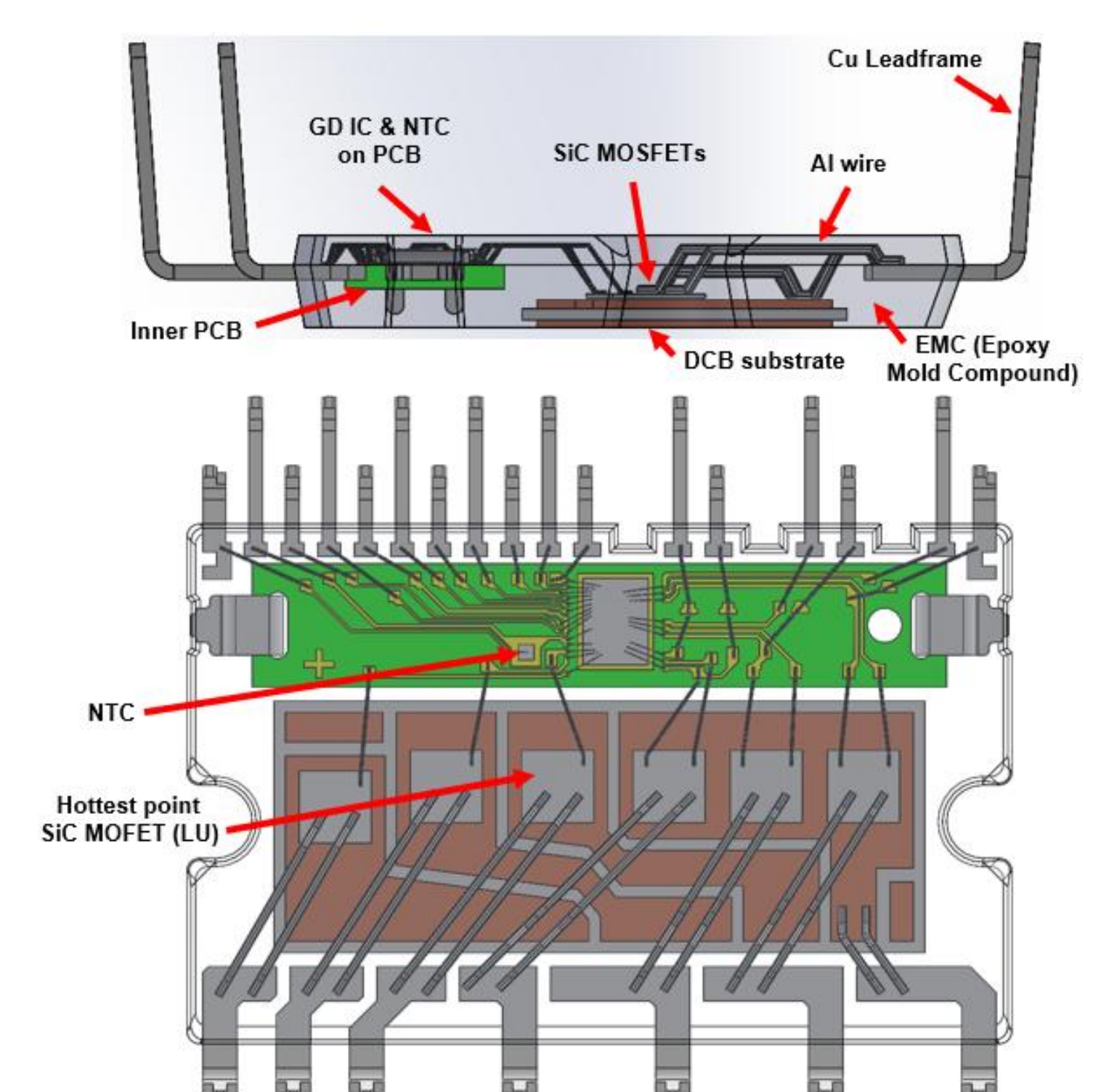
External outline overview

- Six Gen2 CoolSiC™ MOSFETs
- Rugged 1200 V six-channel silicon-on-insulator (SOI) gate drive IC with integrated bootstrap functionality
- An AEC-Q200-qualified negative temperature coefficient (NTC) thermistor for temperature monitoring

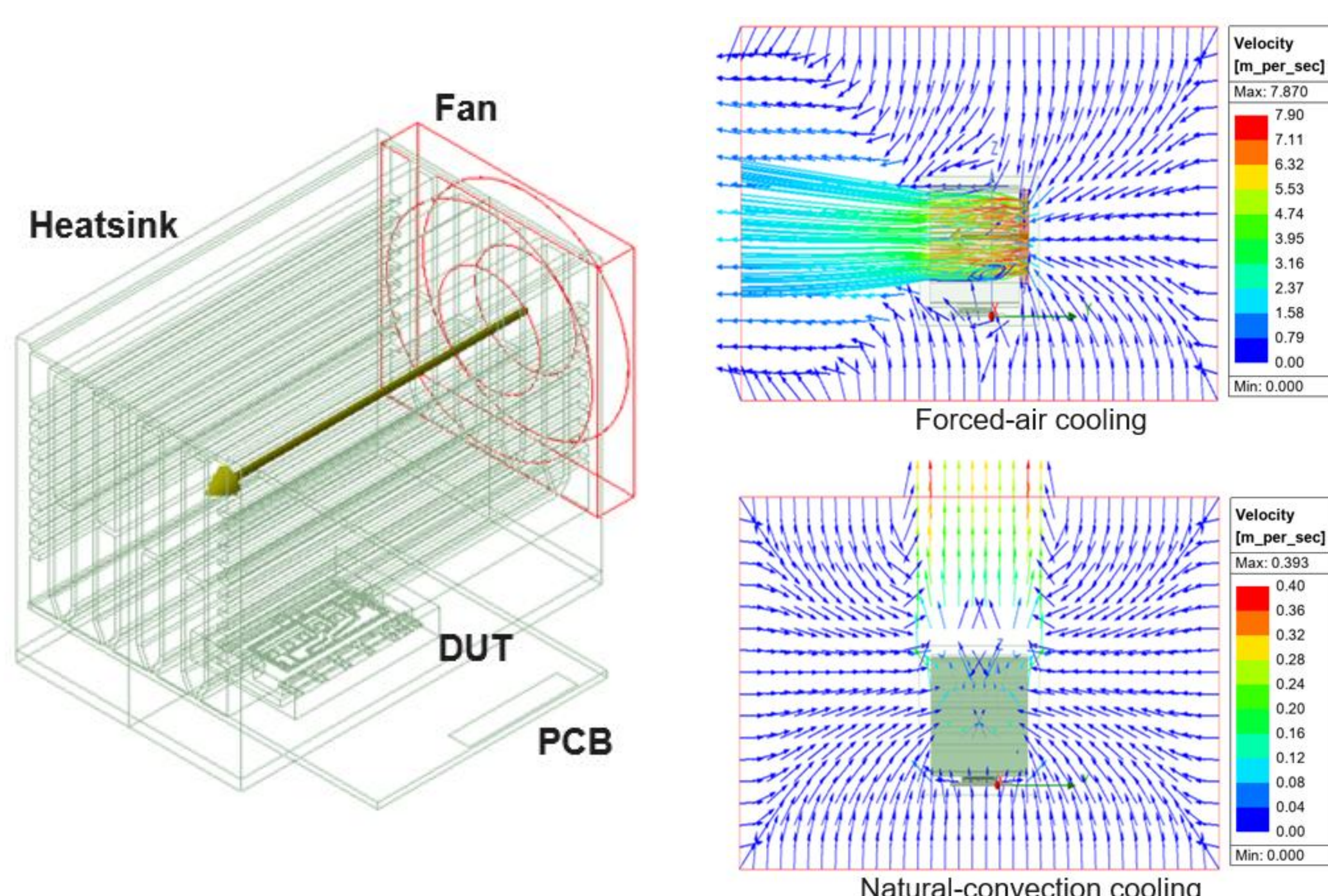
Internal block diagram



PKG structure

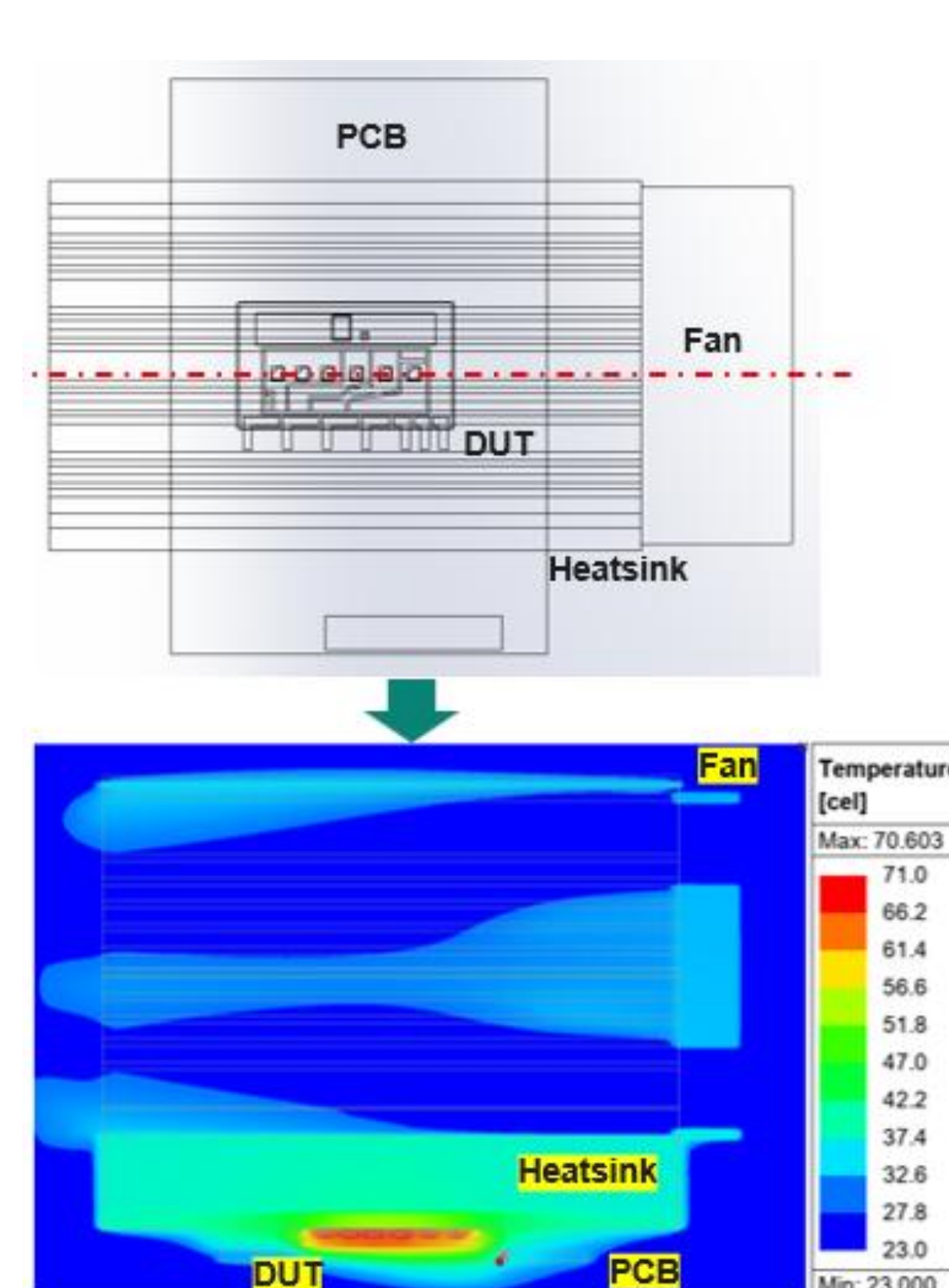


Package thermal simulation

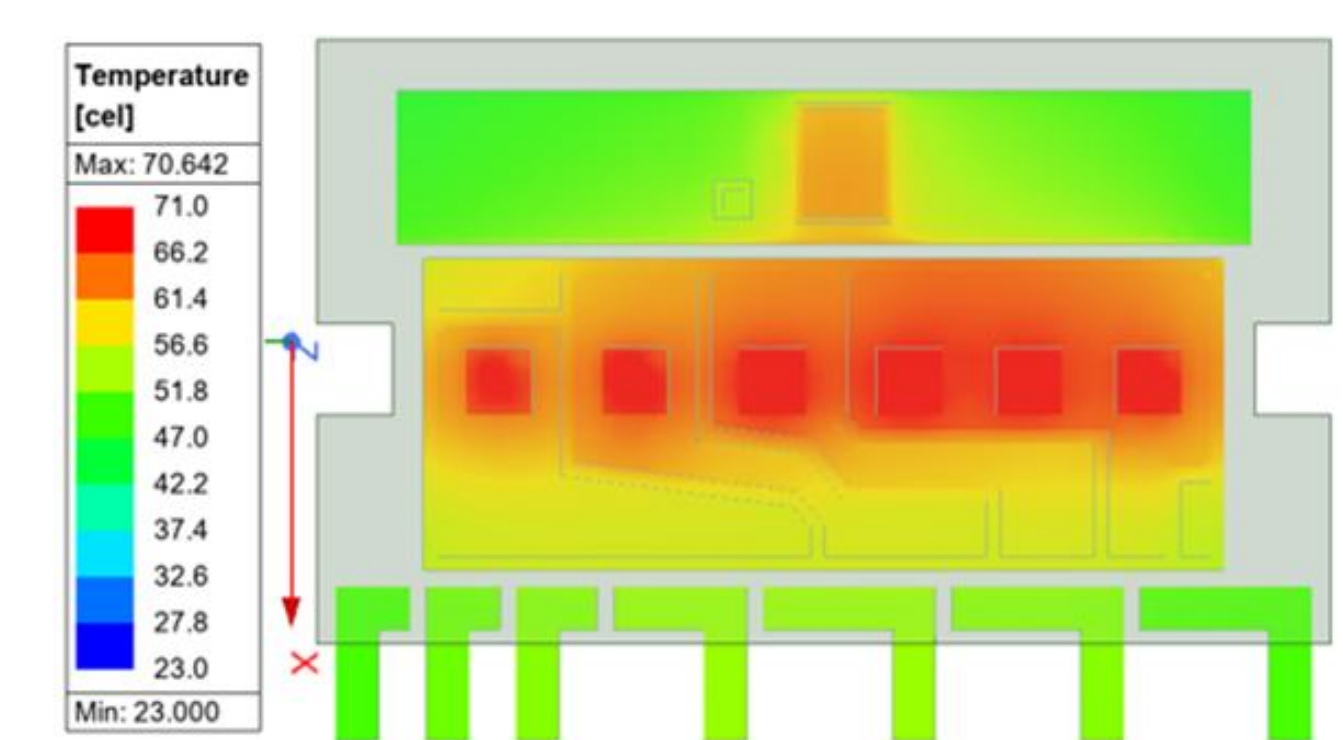


(a) 3D image of simulation model

(b) Air flow according to cooling conditions



(c) Cross-section of thermal distribution



(d) Layout view of thermal distribution

I_o [A _{rms}]	Cooling method			
	Forced-air cooling		Natural-convection cooling	
I_o [A _{rms}]	7	10.6	7	10.6
Single chip P_D [W]	5.29	9.39	5.55	10.51
T_A [°C]	23	23	23	23
T_H [°C]	40.0	51.3	64.5	99.4
T_{NTC} [°C]	40.3	52.1	65.2	98.8
Simulation T_J (LU) [°C]	49.3	69.8	75.5	120.6

(e) Results of package thermal simulation

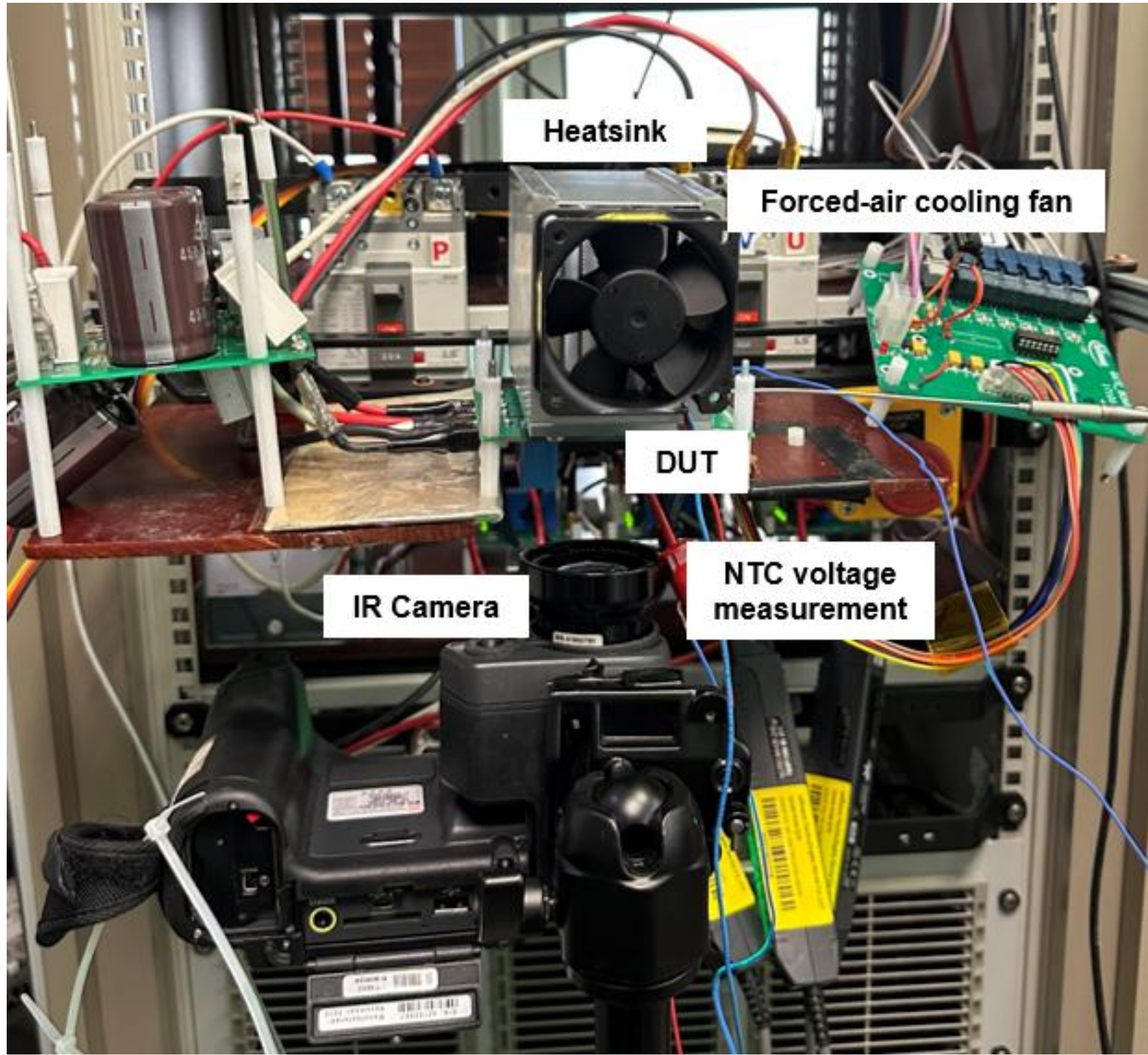
Package thermal simulation results:

- To analysis the thermal correlation among SiC MOSFET T_J , NTC, and heatsink temperatures, thermal model of CIPOSTM Maxi IPM was simulated by using Ansys ICEPAK AEDT.
- Under forced-air and natural-convection cooling, T_{NTC} and T_H were nearly identical, and their temperature differences relative to T_J were likewise nearly the same.
- Therefore, T_J can be estimated from either T_{NTC} or T_H measurements.

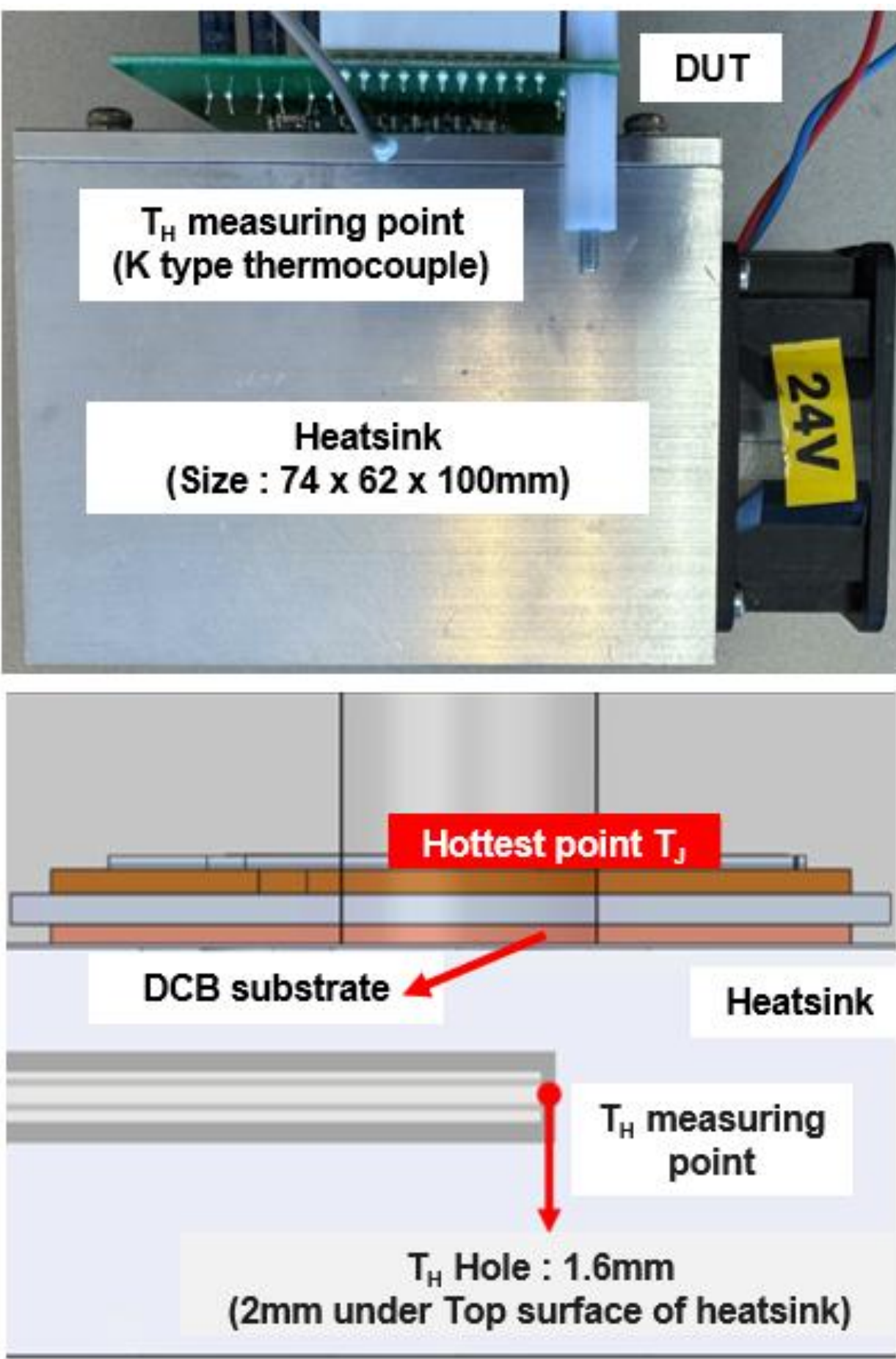
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Thermal correlation test environment



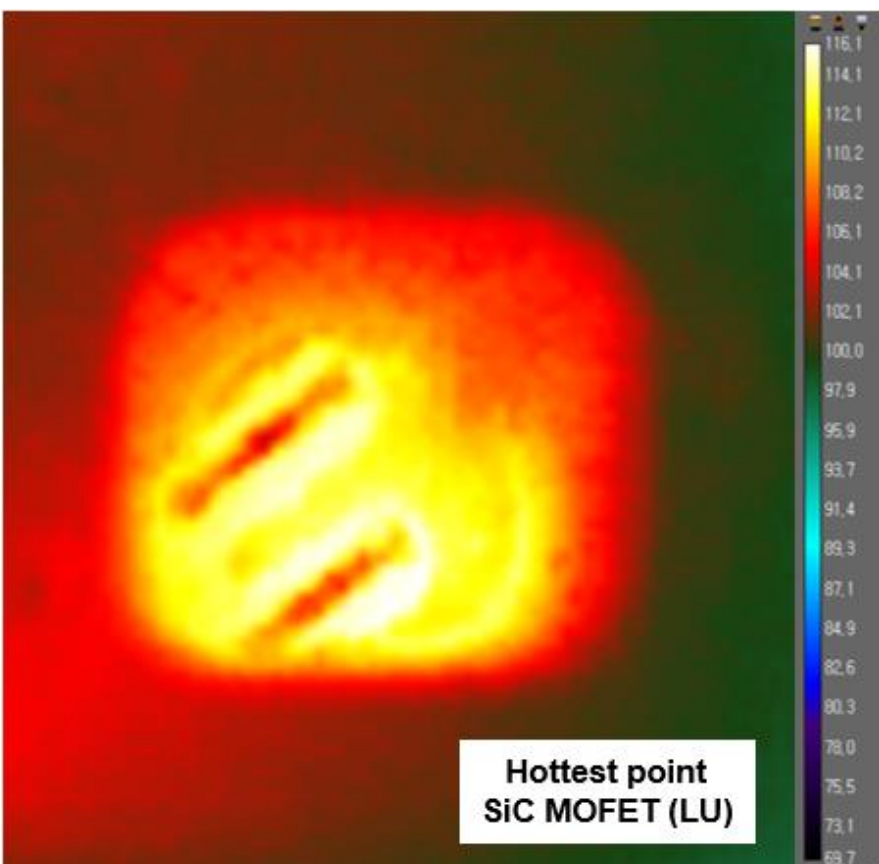
(a) Thermal correlation test set-up



(b) Heatsink information



(c) Test board with de-cap sample

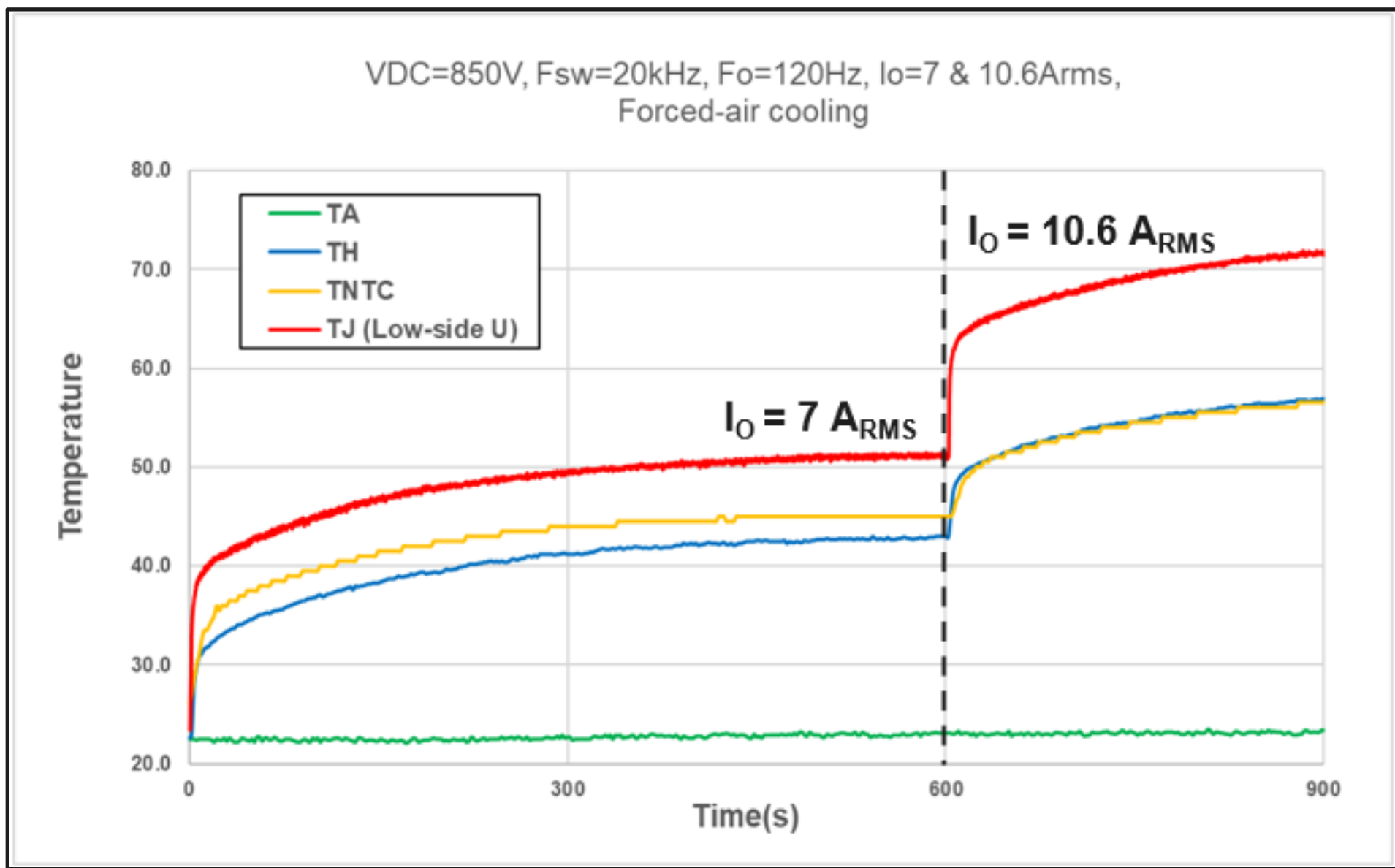


(d) Thermal photo by an IR camera

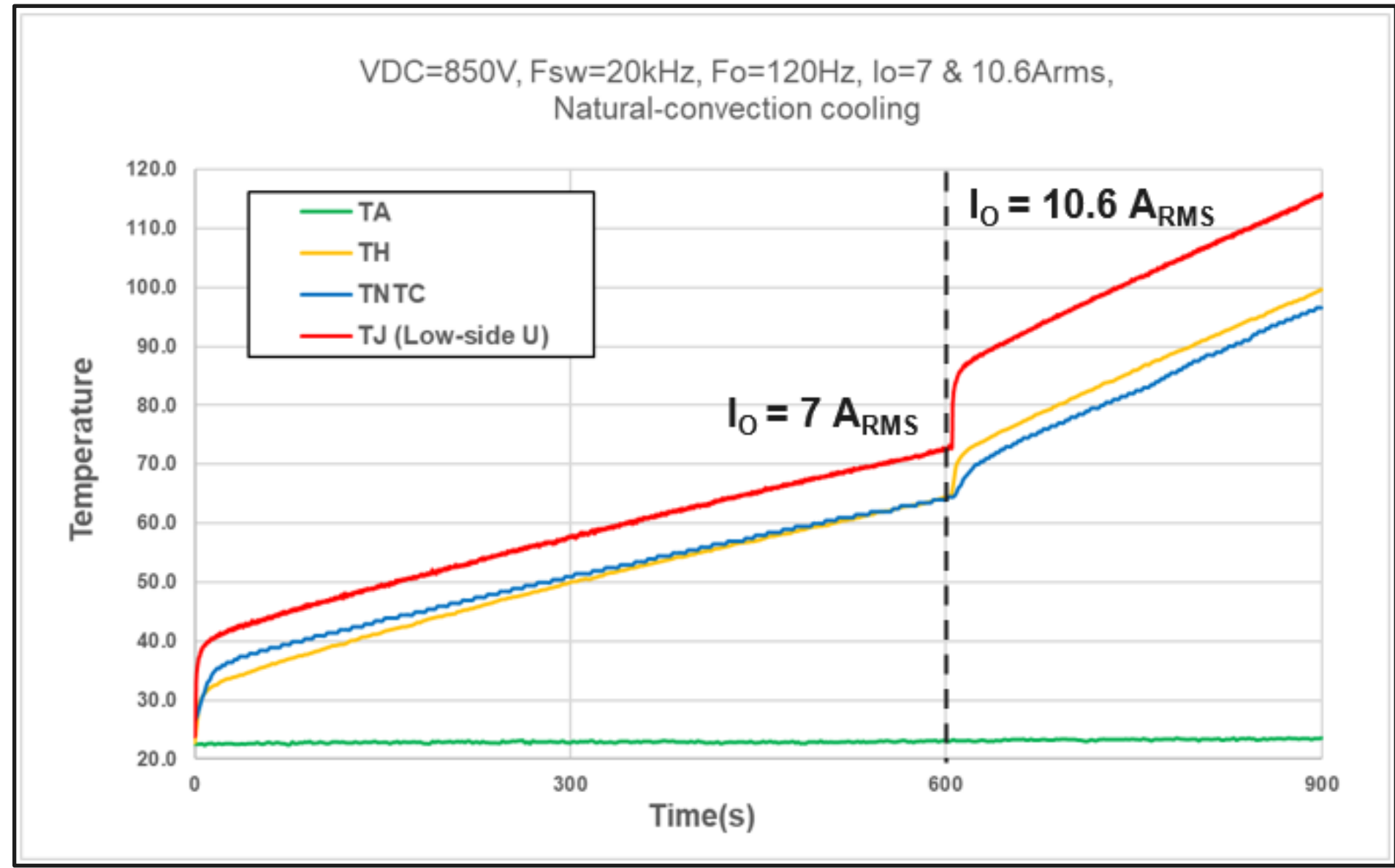
Thermal evaluation set-up

- For the T_J measurement, the low side U phase SiC MOSFET in the IPM was selected, as it represents the hottest device within the module during operation.
- The T_H was measured at the point on the heatsink that corresponds to the location of the low side U phase SiC MOSFET when the IPM is mounted to the heatsink.
- Additionally, T_H was measured with a K type thermocouple inserted into a 1.6 mm diameter hole at a depth of approximately 2 mm from the top surface of the heatsink.

Thermal correlation test results



(a) Thermal test under forced-air cooling



(b) Thermal test under natural-convection cooling

I _O [A _{RMS}]	Cooling method			
	Forced-air cooling		Natural-convection cooling	
I _O [A _{RMS}]	7	10.6	7	10.6
Single chip P _D [W]	5.29	9.39	5.55	10.51
T _A [°C]	23.1	23.4	23.2	23.6
T _H [°C]	43	56.9	64.4	99.7
T _{NTC} [°C]	45	56.5	64	97
Simulation T _J (LU) [°C]	50.1	70.2	71.9	114.6
Measured T _J (LU) [°C]	51.4	71.8	72.7	115.8

(c) Results of thermal correlation test

Test condition:

- $V_{DC} = 850 \text{ V}$, $V_{DD} = 18 \text{ V}$, $F_{SW} = 20 \text{ kHz}$, $T_A = 23^\circ\text{C}$, SVPWM, $I_O = 7 \text{ \& } 10.6 \text{ A}_{RMS}$, with forced cooling fan (forced-air cooling) & without forced cooling fan (natural-convection cooling)
- Simulation $T_J = T_H + R_{thJH} \cdot P_D$ (T_H is measured heatsink temperature, R_{thJH} is the measured junction to heatsink thermal resistance and P_D is SiC MOSFET single chip power loss)

Test results:

- It was confirmed consistent with the package thermal simulation results that under two different operating conditions, T_{NTC} and T_H were similar.
- Measured T_J was verified to be close to the simulation T_J .
- This indicates that T_J can be effectively tracked using T_{NTC} and T_H measurements.

Summary

This paper presented an experimental and simulation based thermal correlation study among T_J , T_{NTC} , and T_H for the new automotive-grade 1200 V CIPOSTM Maxi IPM under automotive auxiliary motor drive conditions.

- Across forced air and natural convection cooling with varying output power, T_{NTC} and T_H showed close agreement, and T_H based thermal simulations yielded T_J values in close accord with the measured T_J .
- Therefore, the T_J of the hottest SiC MOSFET in this IPM can be reliably tracked using either T_{NTC} or T_H measurements, providing a practical in vehicle thermal monitoring approach when direct T_J measurements are impractical.