Product Document

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The thermal measurement point of LEDs

Application Note

Valid for:
OSLON® Black Flat / OSLON® Compact / SYNIOS® P2720 / OSRAM OSTAR® Compact / OSRAM OSTAR® Headlamp Pro /OSLON® Sub-mount CL / OSLON® Boost

Abstract

When current passes through the junction area of a chip, light is emitted. Not only light is generated, but also a lot of heat. Good thermal management is a major factor for the stable performance of LEDs in applications. However, a high junction temperature has a negative effect on the lifetime and the reliability of LEDs.

Defining the junction temperature poses a challenge because it cannot be measured directly. However, the junction temperature can be calculated by measuring the solder point.

In the large portfolio of different LEDs OSRAM Opto Semiconductors offers, the measuring point varies. The recommended measuring points for selected designs are described in this document.

Further information:
- Reliability and lifetime of LEDs
- Package-related thermal resistance of LEDs
- Temperature measurement with thermocouples

Author: Retsch Stefanie / Huber Rainer

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A. Technical basics

The temperature of the light emitting layer represents one of the major factors which influence the lifetime of an LED. The lower the junction temperature T_j, the higher the expected lifetime. The maximum allowed value for T_j can be found in the product data sheet.

Influencing factors on the junction temperature are the environmental temperature and the operating current. An increase in the operating current leads to an increase in the junction temperature. Further information on the factors influencing the lifetime and reliability of LEDs can be found in the application note “Reliability and lifetime of LEDs”.

Measurement point

Ideally the junction temperature T_j is measured directly on the chip, but this is limited. Therefore it is necessary to measure the temperature at defined reference points and to calculate the junction temperature with these values.

OSRAM Opto Semiconductors defines this reference point as the solder point temperature T_S. It represents the transition from the active thermal path from the LED package to the soldering surfaces of the circuit board and is dependent on the package technology.

T_j can be calculated in different ways, based on the different input variables. Detailed information is given in the application note “Package-related thermal resistance of LEDs”.

In most cases the measurement point represents the solder point temperature T_S. The junction temperature is calculated according to the following equation:

$T_j = T_S + P_{Heat} \cdot R_{th\ JS\ real}$

$P_{Heat} = P_{el} - \Phi_e = (1\text{-}\eta) \cdot P_{el}$

T_j = Junction temperature of the LED [°C]

T_S = Solder Point temperature [°C]

$P_{el} = I_F \cdot V_F$ [W]

I_F = Forward current of the LED [A]

V_F = Forward voltage of the LED [V]

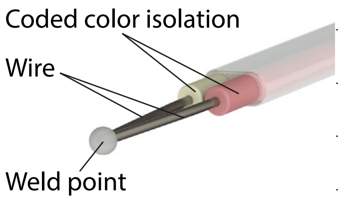
$R_{th\ JS\ real}$ = Thermal resistance of the LED according to the data sheet [K/W]

η = Efficiency of the LED according to the data sheet

Measurement equipment

Thermocouples are the most commonly used temperature sensors for temperature measurements. In order to measure the LED solder point temperature (T_S) a type K thermocouple is recommended, since the thermal conductivity for this type is the lowest and therefore less heat is conducted away than with other types (see Table 1).

Table 1: Recommended thermocouple



Designation	i.e. OMEGA thermocouple
Type:	5TC - Type K
Isolation:	PTEE
Accuracy:	± 1.5 °C
Length:	1000 mm
Conductor diameter:	AWG 40 (Order No.: 5TC-TT-KI-40-1M)
Conductor diameter:	AWG 36 (Order No.: 5TC-TT-KI-36-1M)

To minimize the occurrence of systematic errors, the dimensions of the thermocouple should be as small as possible. In terms of accuracy thermocouples with wire diameters AWG 36 (φ 0.13 mm) or AWG 40 (φ 0.08 mm) are recommended. Further information on temperature measurement with thermocouples can be found in the application note “Temperature measurement with thermocouples”.

Thermal simulations

This application note provides thermal simulations for the different packages. They do not represent the exact temperature distribution for the LEDs because this always depends on the boundary conditions. But it provides an idea of the temperature distribution and the difference between the junction temperature, the temperature at the solder point and the recommended measured temperature.

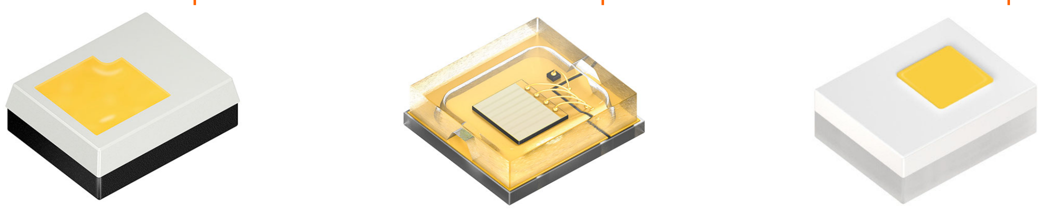
All thermal simulations were performed with an aluminum heat sink. Furthermore, it was assumed that the components are placed on a PCB with a 35 µm copper layer, a 38 µm or 75 µm dielectric (depending on the LED) and a 1.5 mm aluminum base. Further boundary conditions were an ambient temperature of 20 °C, still air and a conjugate heat transfer.

B. The thermal measurement point of specific LEDs

OSLON® Compact, OSRAM OSTAR® Compact family, OSLON® Boost

The design of the OSLON® Compact, OSRAM OSTAR® Compact family and OSLON® Boost (Figure 1) is based on a ceramic base with solder contacts.

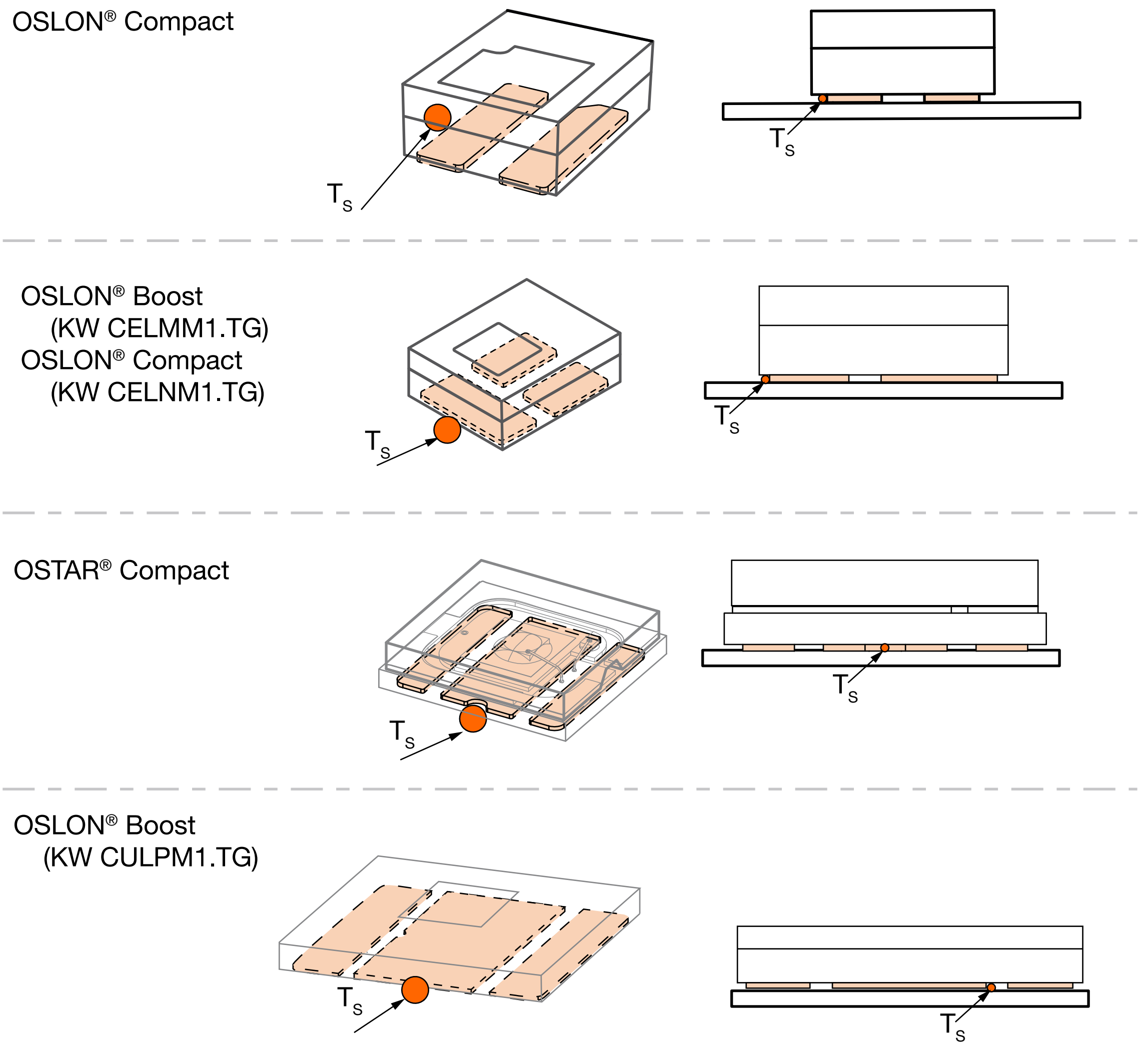
Figure 1: Product pictures: OSRAM OSLON Compact and OSRAM OSTAR Compact



OSRAM OSLON® Compact | OSRAM OSTAR® Compact | OSRAM OSLON® Boost

To calculate the junction temperature for these products, the contact leads should be used as a reference for the solder point T_S. Therefore the thermocouple should be mounted onto the solder contacts under the LED, as near as possible to the chip, as shown in Figure 2.

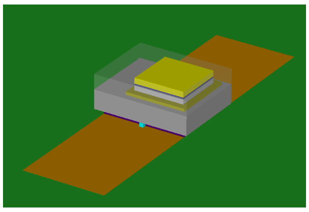
Figure 2: Ideal mounting position of a thermocouple for the OSLON® Compact, the OSRAM OSTAR® Compact and the OSLON® Boost



For the OSLON® Compact the thermal simulation (Figure 3) shows that with a P_{Heat} of 1.55 W the junction temperature rises to 72.4 °C. The solder point temperature heats up to an average temperature of 65.7 °C. If the thermocouple is placed as recommended, it measures 63 °C. The difference between the temperature at the solder point and the measured temperature is negligible.

Figure 3: Thermal simulation of the solder point temperature for the OSRAM OSLON® Compact (LUW CEUP.CE)

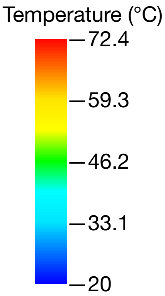
Simulation model:

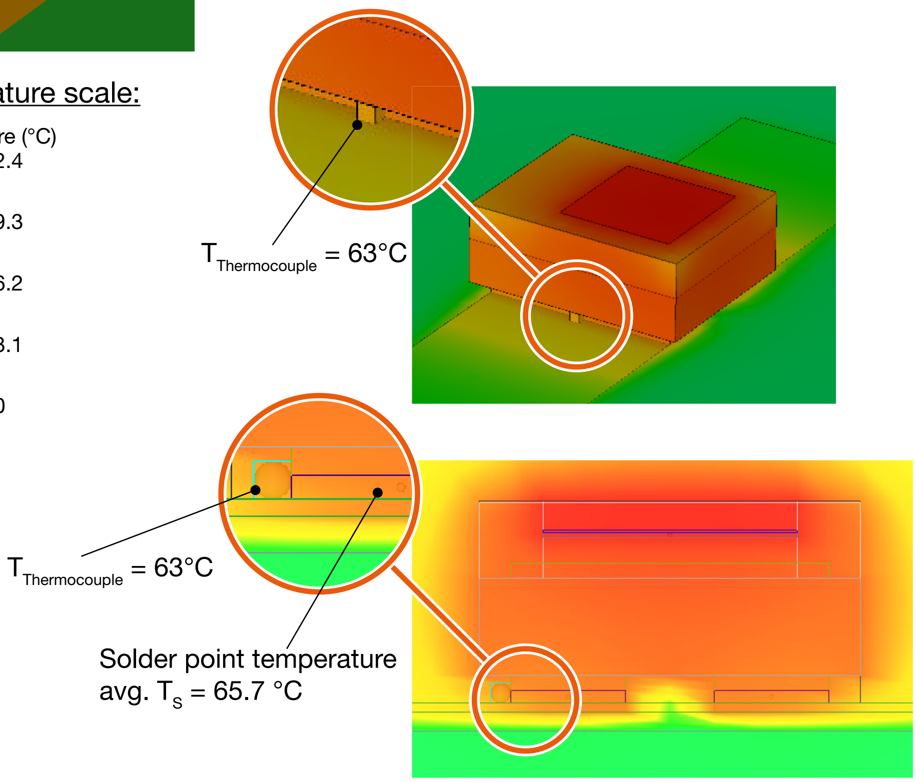


Boundary conditions:

- P_{Heat} = 1.55 W (I_F = 700 mA; typ. V_F = 3.13 V; η = 28%)
- Ambient temperature T_{amb} = 20 °C
- Still air
- Conjugate heat transfer

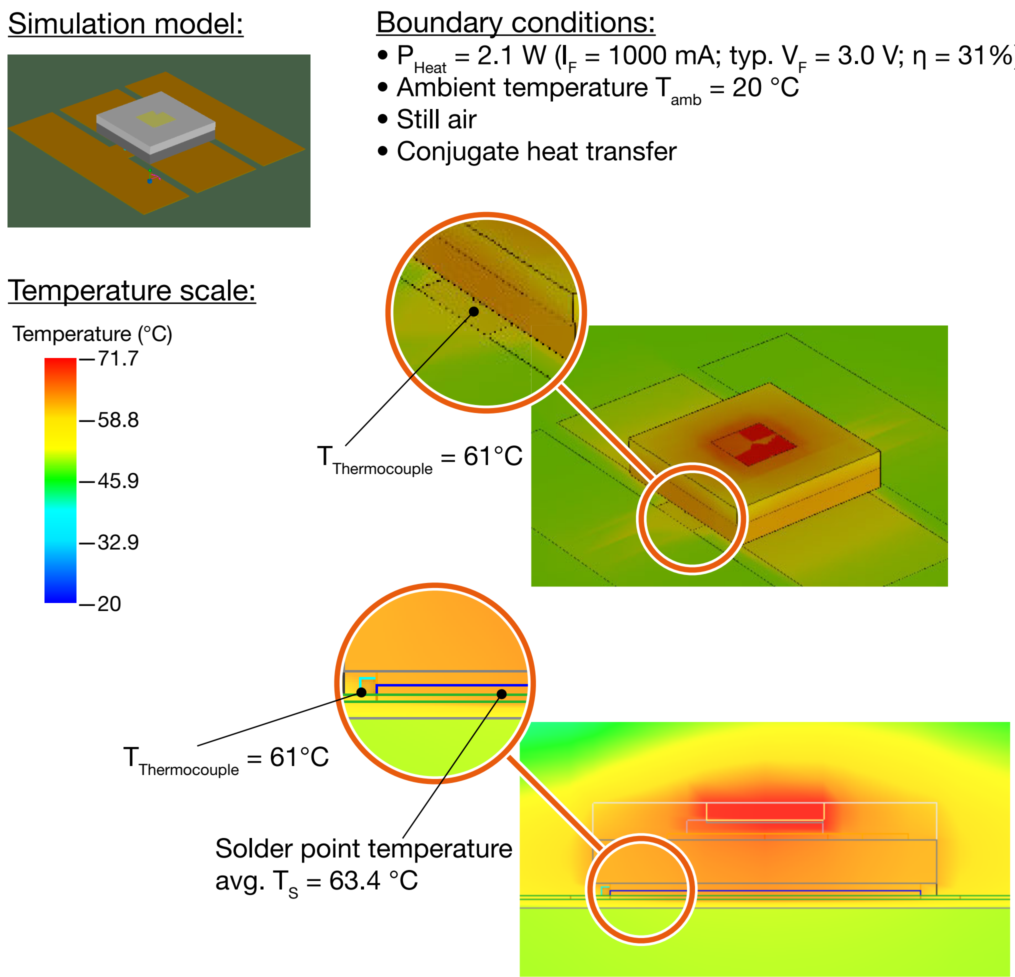
Temperature scale:





The thermal simulation for the OSRAM OSTAR® Compact (Figure 4) shows that with a P_{Heat} of 2.1 W the junction temperature rises to 71.7 °C. The solder point temperature heats up to an average temperature of 63.4 °C. If the thermocouple is placed as recommended, it measures 61 °C. The difference between the temperature at the solder point and the measured temperature is negligible.

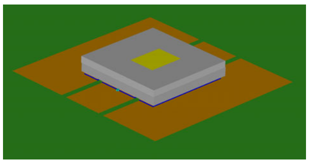
Figure 4: Thermal simulation of the solder point temperature of the OSRAM OSTAR® Compact (KW CSLNM1.TG)



For the thermal simulation of the OSLON® Boost (Figure 5) it was assumed that the device was soldered to a thin FR4 laminate on a Cu plate with micro via array. This was mounted on a aluminum heat sink with a fan. The simulation result shows that with a P_{Heat} of 14.1 W the junction temperature rises to 77 °C. The solder point temperature heats up to an average temperature of 52.5 °C. If the thermocouple is placed as recommended, it measures 48 °C. The difference between the temperature at the solder point and the measured temperature is in an acceptable range.

Figure 5: Thermal simulation of the solder point temperature of the OSLON® Boost (KW CELMM1.TG)

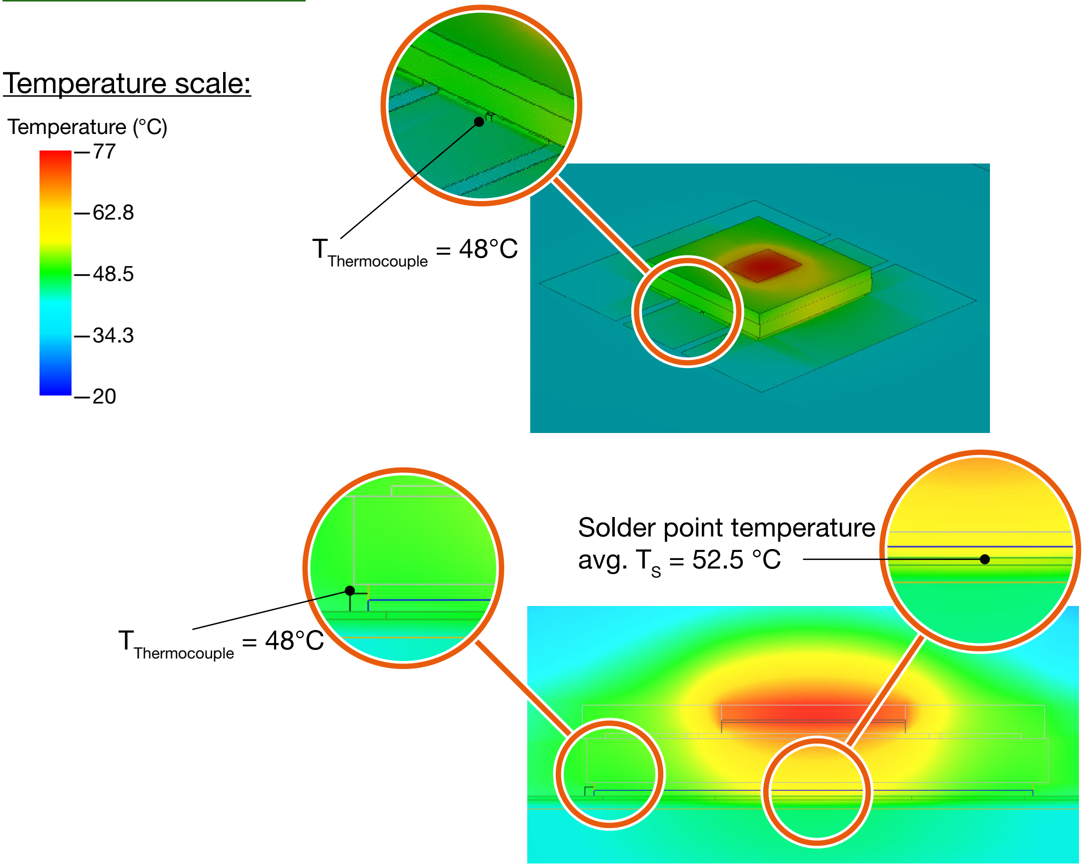
Simulation model:



Boundary conditions:

- P_{Heat} = 14.1 W (I_F = 6000 mA; typ. V_F = 3.35 V; η = 30%)
- Ambient temperature T_{amb} = 20 °C
- Still air
- Conjugate heat transfer

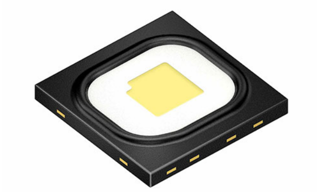
Temperature scale:



OSLON® Black Flat family

The package concept of the OSLON® Black Flat family (Figure 6) is based on a molded body. The chip is soldered to the lead frame and covered with a ceramic layer converter above the die.

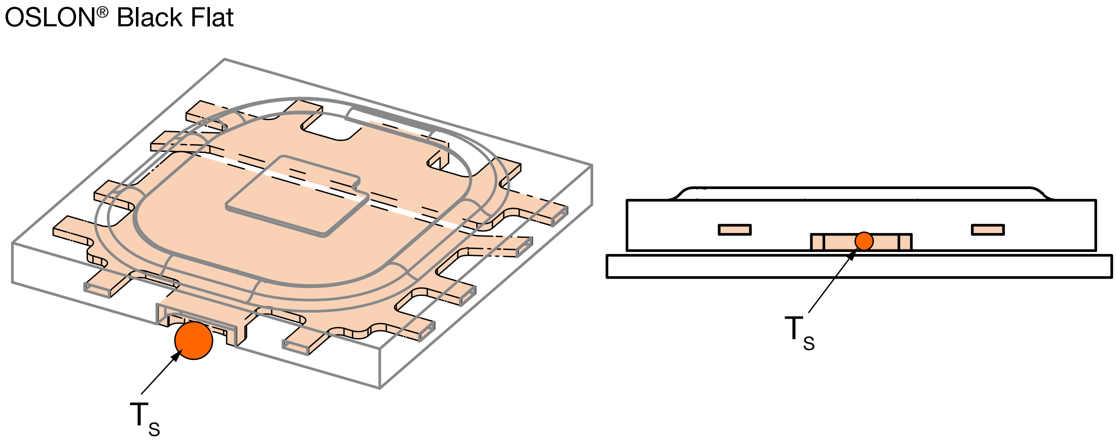
Figure 6: Product picture of the OSLON® Black Flat Family



OSLON® Black Flat

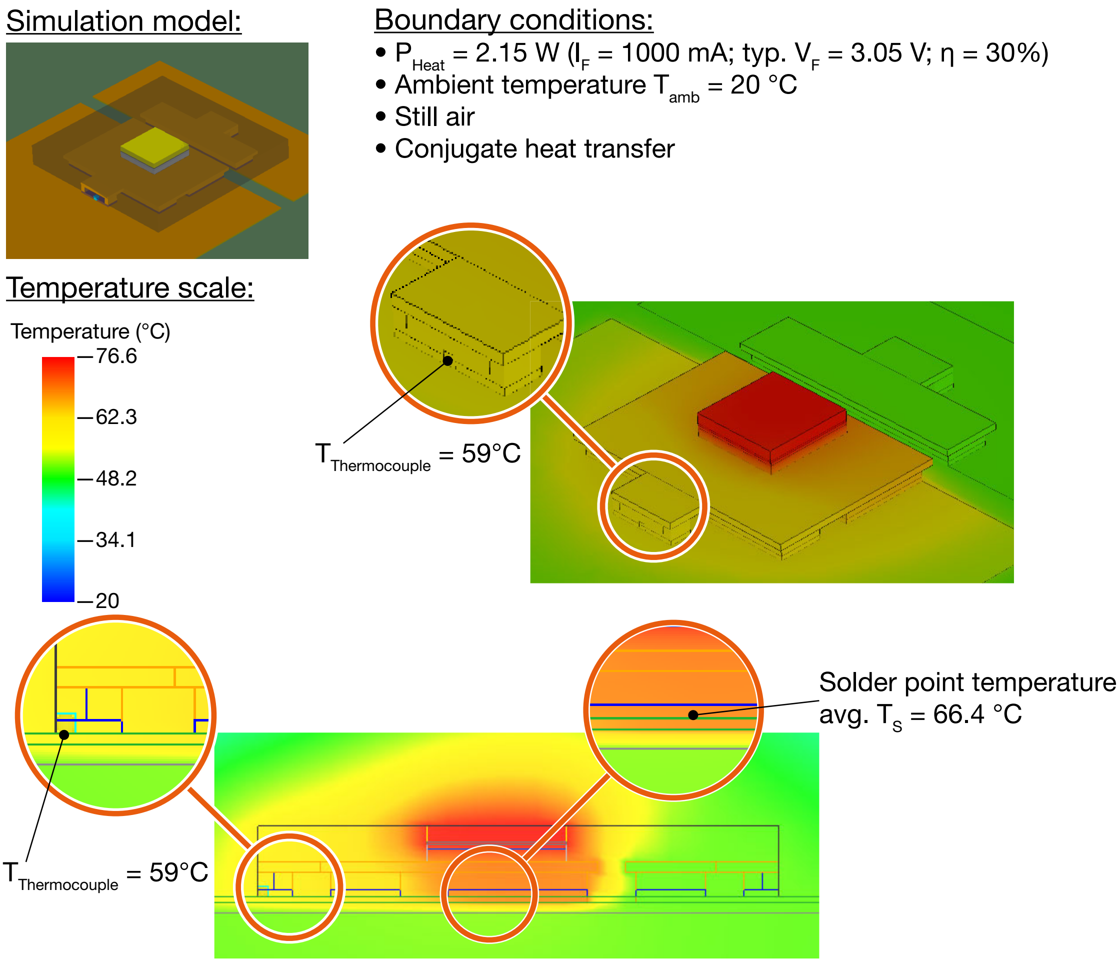
It is recommended to use the solder inspection cavity for measuring T_S as shown in Figure 7. To place the thermocouple as close as possible, the cavities needs to be free of solder paste. Therefore attention must be paid that the cavities are not filled with solder paste during the solder past printing process.

Figure 7: Ideal mounting position of a thermocouple for the OSLON® Black Flat



When simulating the OSLON® Black Flat (Figure 8) with a P_{Heat} of 2.15 W the junction temperature reached 76.6 °C. The solder point temperature underneath the chip heats up to an average temperature of 66.4 °C. As the solder inspection cavity for the measure point of T_S is not centered on the chip, the simulation shows that a lower temperature of 59 °C is measured. But with the calculation based on the equation specified in chapter "Measurement point" on page 2 this temperature difference is in an acceptable range.

Figure 8: Thermal simulation of the solder point temperature of the OSLON® Black Flat (LW HWQP)



OSLON® Black Flat Multichip family

The OSLON® Black Flat Multichip family (Figure 9) features a molded body where the chips are soldered to the lead frame. The chips are covered with a ceramic layer converter above the die.

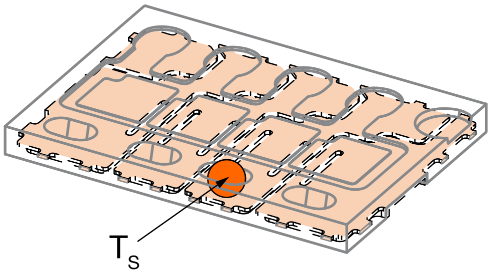
Figure 9: Product picture of the OSLON® Black Flat Multichip Family

OSLON® Black Flat Multichip

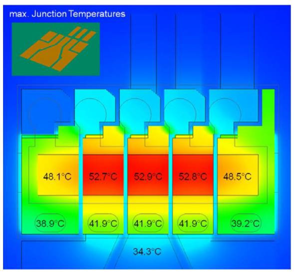
For estimating the solder point, the thermocouple should be mounted in the openings of the molding, as shown in Figure 10. The thermal analysis model shows that it is recommended to use the centered opening, as the temperature distribution is higher there.

Figure 10: Ideal mounting position of a thermocouple for the OSLON® Black Flat Multichip

OSLON® Black Flat Multichip



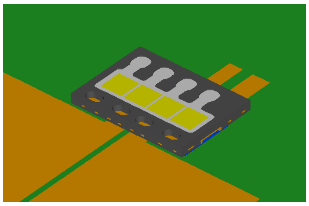
Temperature distribution



The thermal simulation for the OSLON® Black Flat Multichip shows that with a P_{Heat} of 2.15 W the junction temperature rises to 62.5 °C. The solder point temperature heats up to an average temperature of 53.6 °C. If the thermocouple is placed as recommended, it measures 49.3 °C. The difference between the temperature at the solder point and the measured temperature is acceptable.

Figure 11: Thermal simulation of the solder point temperature of the OSLON® Black Flat Multichip (KW H4L531.TE)

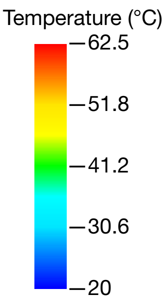
Simulation model:

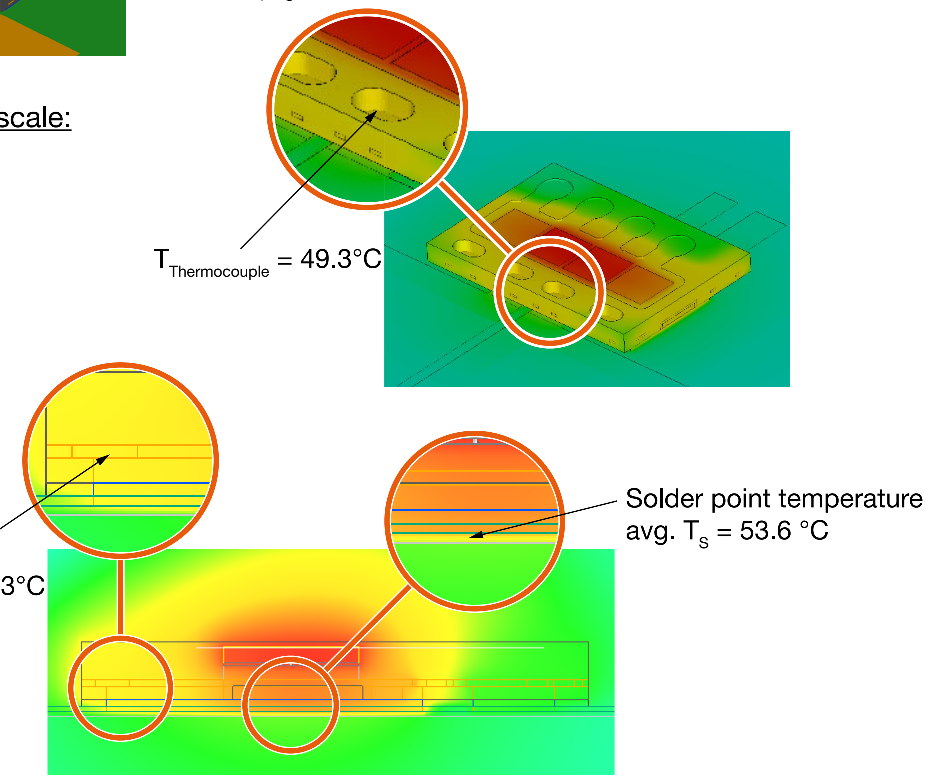


Boundary conditions:

- total P_{Heat} = 8.6 W (I_F = 1000 mA; typ. V_F = 12.3 V; η = 30%)
- P_{Heat} = 2.15 W per die
- Ambient temperature T_{amb} = 20 °C
- Still air
- Conjugate heat transfer

Temperature scale:





SYNIOS® P2720

The common package of the SYNIOS® P2720 (Figure 12) consists of a lead frame and a white epoxy mold compound in which a semiconductor chip is mounted and electrically connected.

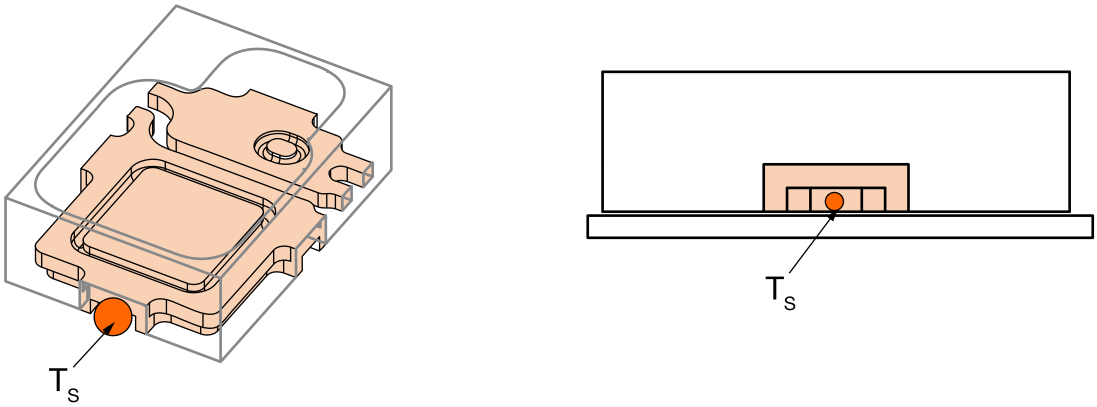
Figure 12: Product picture of the SYNIOS® P2720

SYNIOS® P2720

It is recommended to use the solder inspection cavity for measuring T_S (Figure 13). To place the thermocouple as close as possible, the cavities needs to be free of solder paste. Therefore attention must be paid that the cavities are not filled with solder paste during the solder past printing process.

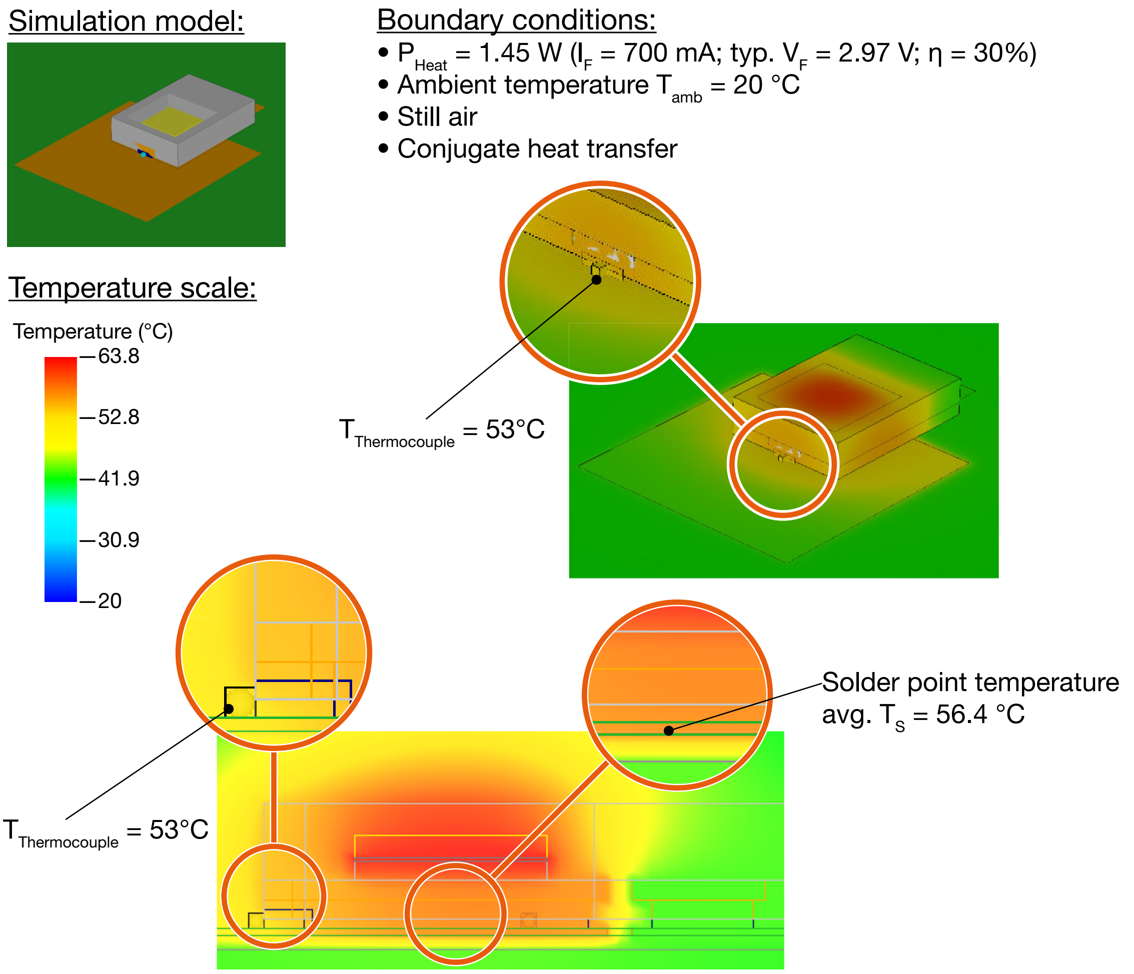
Figure 13: Ideal mounting position of a thermocouple for the SYNIOS® P2720

SYNIOS® P2720



The SYNIOS® P2720 simulated with a P_{Heat} of 1.45 W shows that the junction temperature rises to 63.8 °C (Figure 14). The average temperature of the solder point temperature heats up to 56.4 °C. If the thermocouple is placed as recommended, it measures 53 °C. The difference between the temperature at the solder point and the measured temperature is negligible.

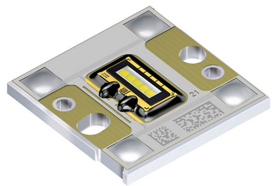
Figure 14: Thermal simulation of the solder point temperature of the SYNIOS® P2720 (KW DMLS31.SG)



OSRAM OSTAR® Headlamp Pro

In the OSRAM OSTAR® Headlamp Pro (Figure 15) between two and a maximum of five semiconductor chips are mounted and wired as a light source on a ceramic substrate surrounded by a black frame. The assembled diodes and wire bonds are embedded into a white compound material. The ceramic carrier is mounted directly onto the aluminum element of the metal-core substrate for optimized heat dissipation. The metal core of the substrate serves for heat distribution and provides a surface of sufficient dimensions for simple thermal connection to the system heat sink.

Figure 15: Product picture of the OSRAM OSTAR® Headlamp Pro



OSRAM OSTAR® Headlamp Pro

As these special product designs are not soldered when implementing them in an application, no solder point is available. Therefore the solder point temperature is replaced by the board temperature T_B.

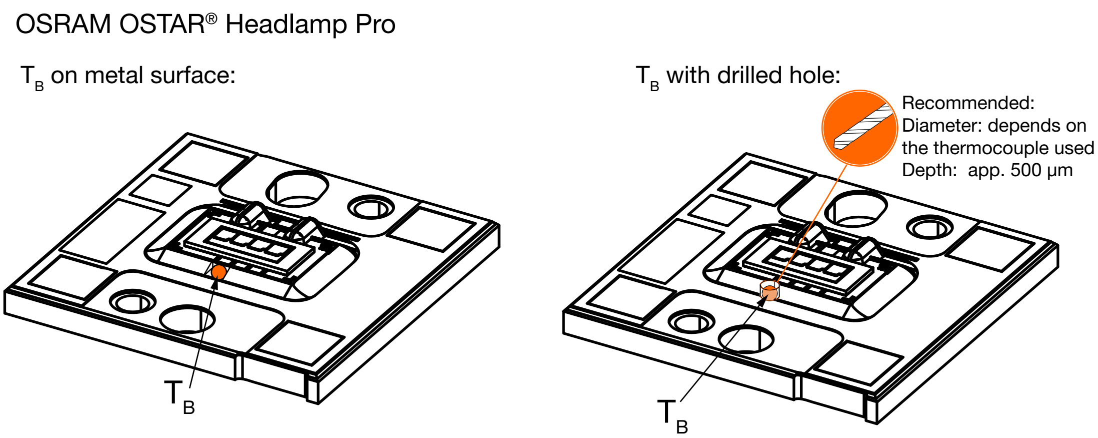
The following equation should be used in order to calculate the junction temperature T_j:

$$T_j = T_B + P_{Heat} \cdot R_{th\ JB\ real}$$

P_{Heat} can be calculated as described in the chapter "Measurement point" on page 2. $R_{th\ JB\ real}$ is the thermal resistance of the board as specified in the data sheet. T_B can be measured with a thermocouple.

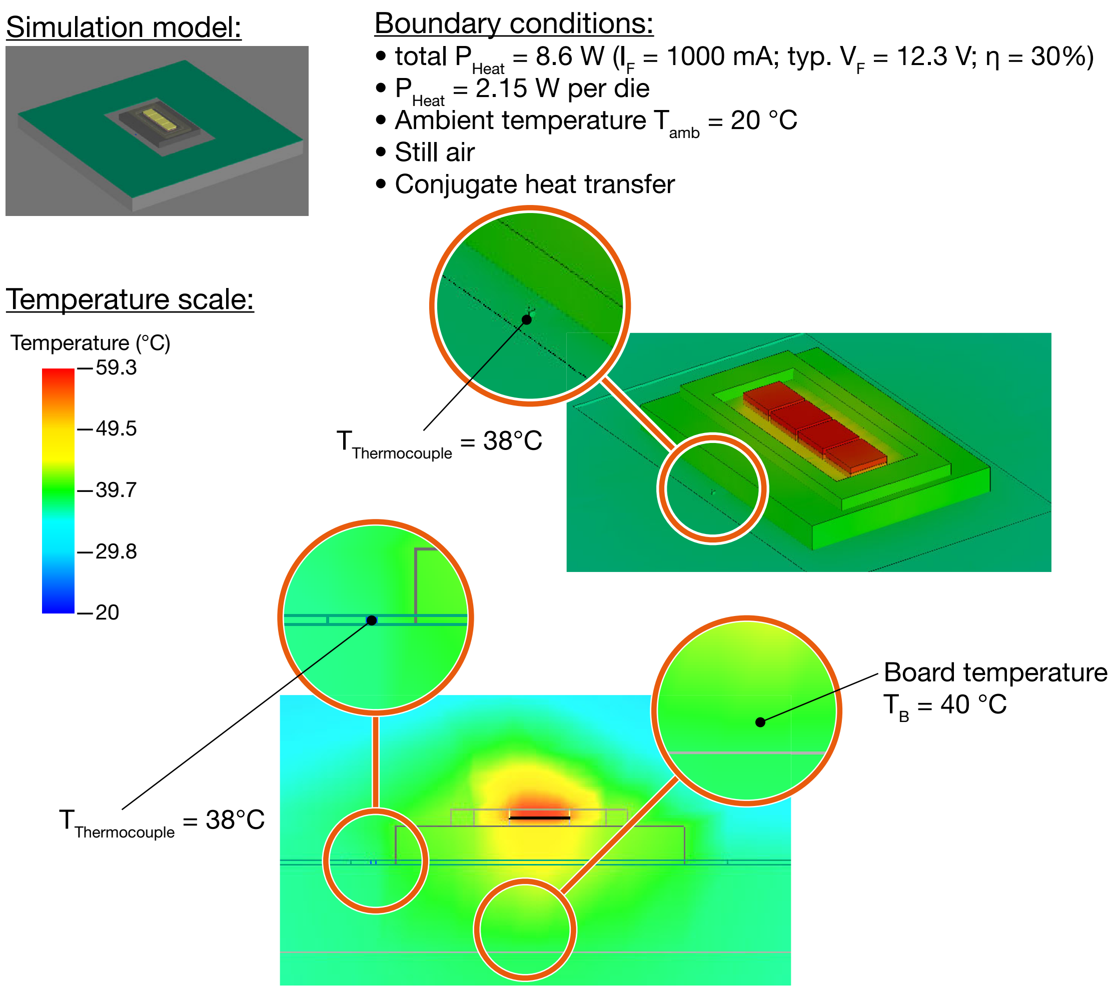
Since the recommended measurement point is located on the bare metal surface next to the ceramic substrate, the black silicone needs to be removed. Alternatively the thermocouple can be placed in a drilled hole with adapted diameter and depth (see Figure 16).

Figure 16: Ideal mounting position of a thermocouple for the OSRAM OSTAR® Headlamp Pro



The thermal simulation (Figure 17) with a P_{Heat} of 2.2 W shows that the temperature detected at the recommended measuring point on the surface is 38 °C. It almost matches the board temperature T_B which is simulated at 40 °C. Therefore it can be used for the calculation of the junction temperature.

Figure 17: Thermal simulation of the board temperature of the OSRAM OSTAR® Headlamp Pro (LW UW U1A4 O1)



OSLON® Submount CL

In the OSRAM OSLON® Submount CL (Figure 18) two or three semiconductor chips are mounted on a ceramic substrate. The assembled diodes and wire bonds are embedded into a white compound material. The ceramic carrier is designed for gluing to a heat sink for optimized heat dissipation.

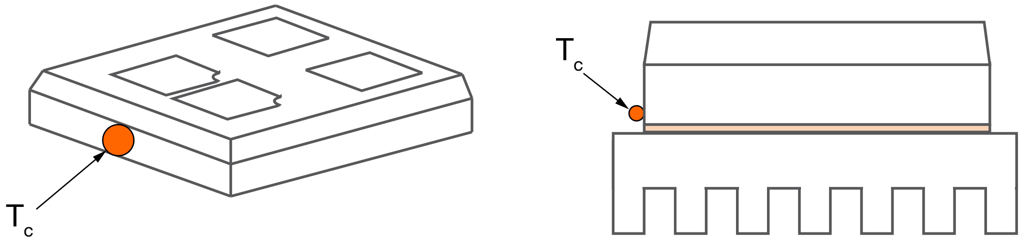
Figure 18: Product picture: OSRAM OSLON® Submount CL

OSRAM OSLON® Submount CL

As these special product designs are not soldered when implementing them in an application, no solder point is available. Instead, T_{case} (T_C) is introduced. For measuring T_c the thermocouple can be placed directly onto the ceramic at the side of the device where the chips are located (see Figure 19).

Figure 19: Ideal mounting position of a thermocouple for the OSRAM OSLON® Submount CLt

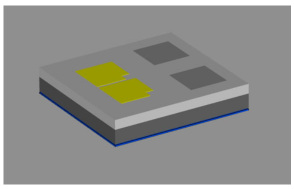
OSRAM OSLON® Submount CL



The thermal simulation (Figure 20) with a P_{Heat} of 4.3 W shows that the temperature detected at the recommended measuring point on the surface is 54.2 °C. It almost matches the board temperature T_c which is simulated at 53.4 °C. Therefore, it can be used for the calculation of the junction temperature.

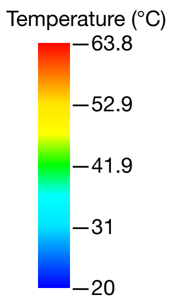
Figure 20: Thermal simulation of the board temperature for the OSRAM OSLON® Submount CL (KW C2L5L1.TE)

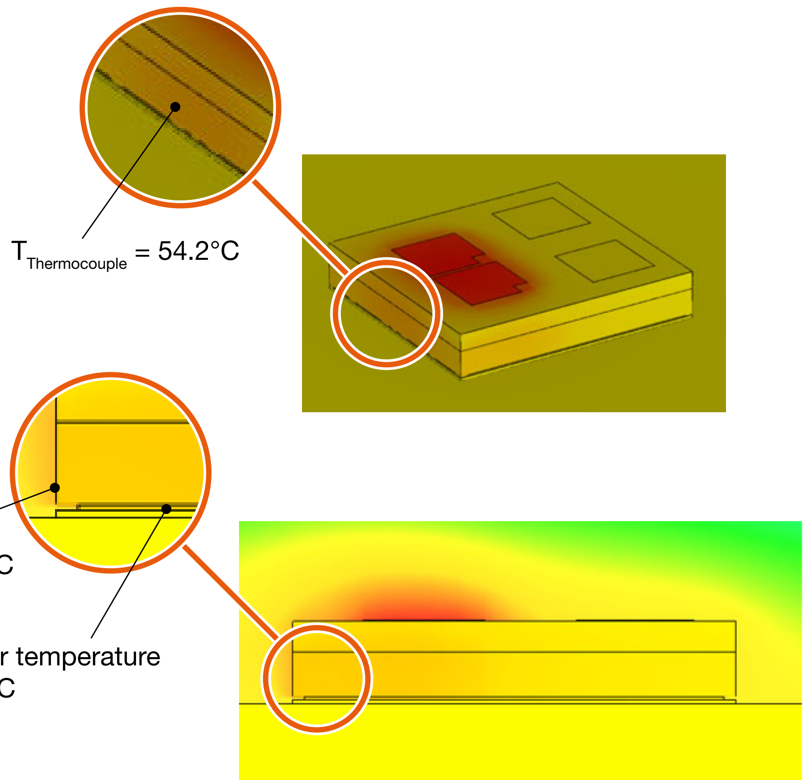
Simulation model:



Boundary conditions:
- P_{Heat} = 4.3 W (I_F = 1 A; typ. V_F = 6.3 V; η = 34%)
- Ambient temperature T_{amb} = 20 °C
- Still air
- Conjugate heat transfer

Temperature scale:





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OSRAM Opto Semiconductors GmbH

Head office:

Leibnizstr. 4
93055 Regensburg
Germany
www.osram-os.com