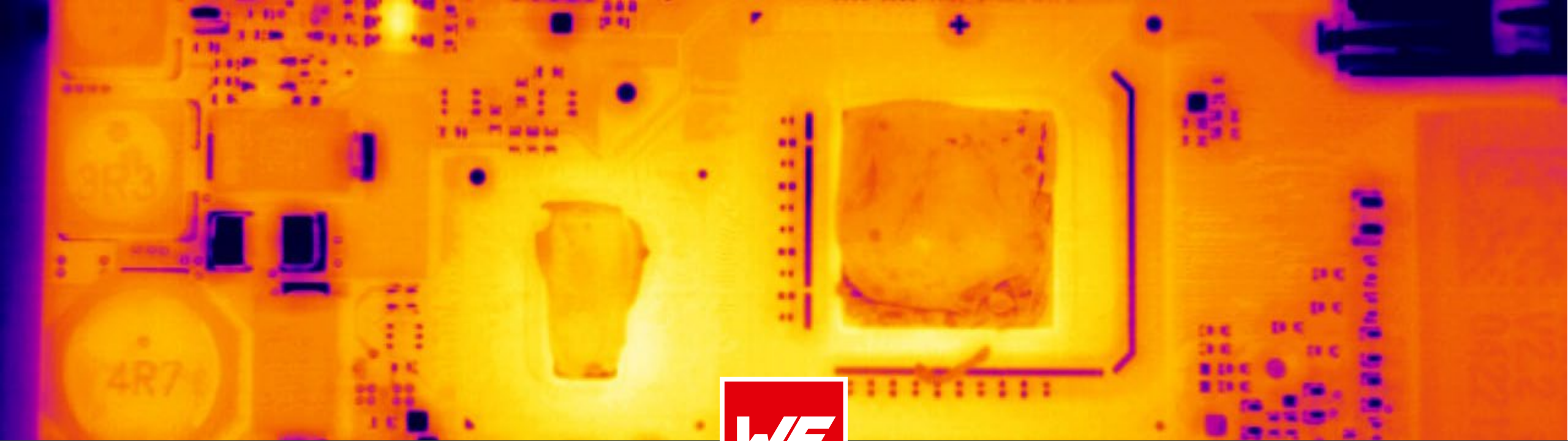


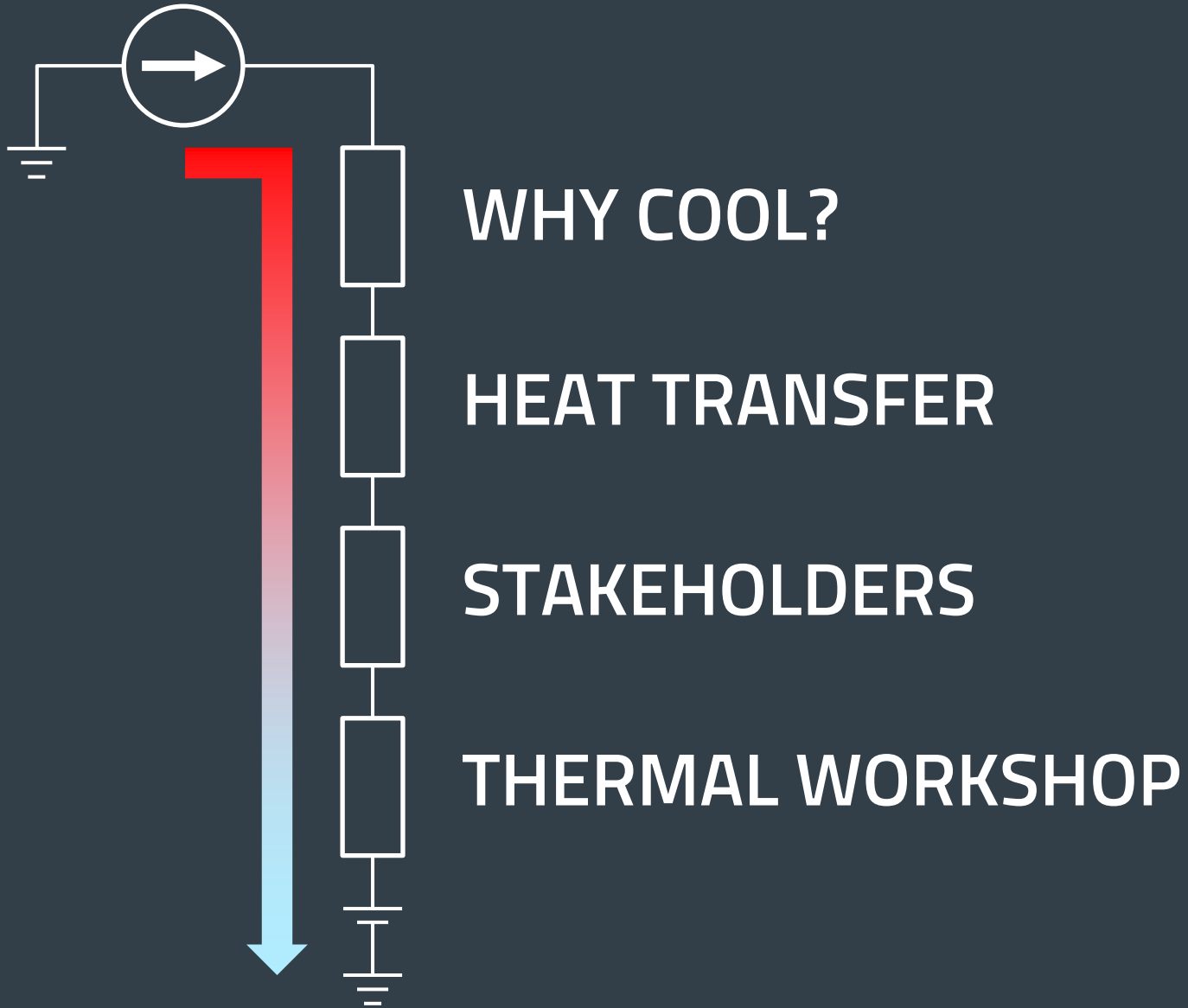


THERMAL MANAGEMENT IN ELECTRONIC DESIGN

Maria Cuesta Martín
Product Manager

Frank Gräber
Field Application Engineer

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

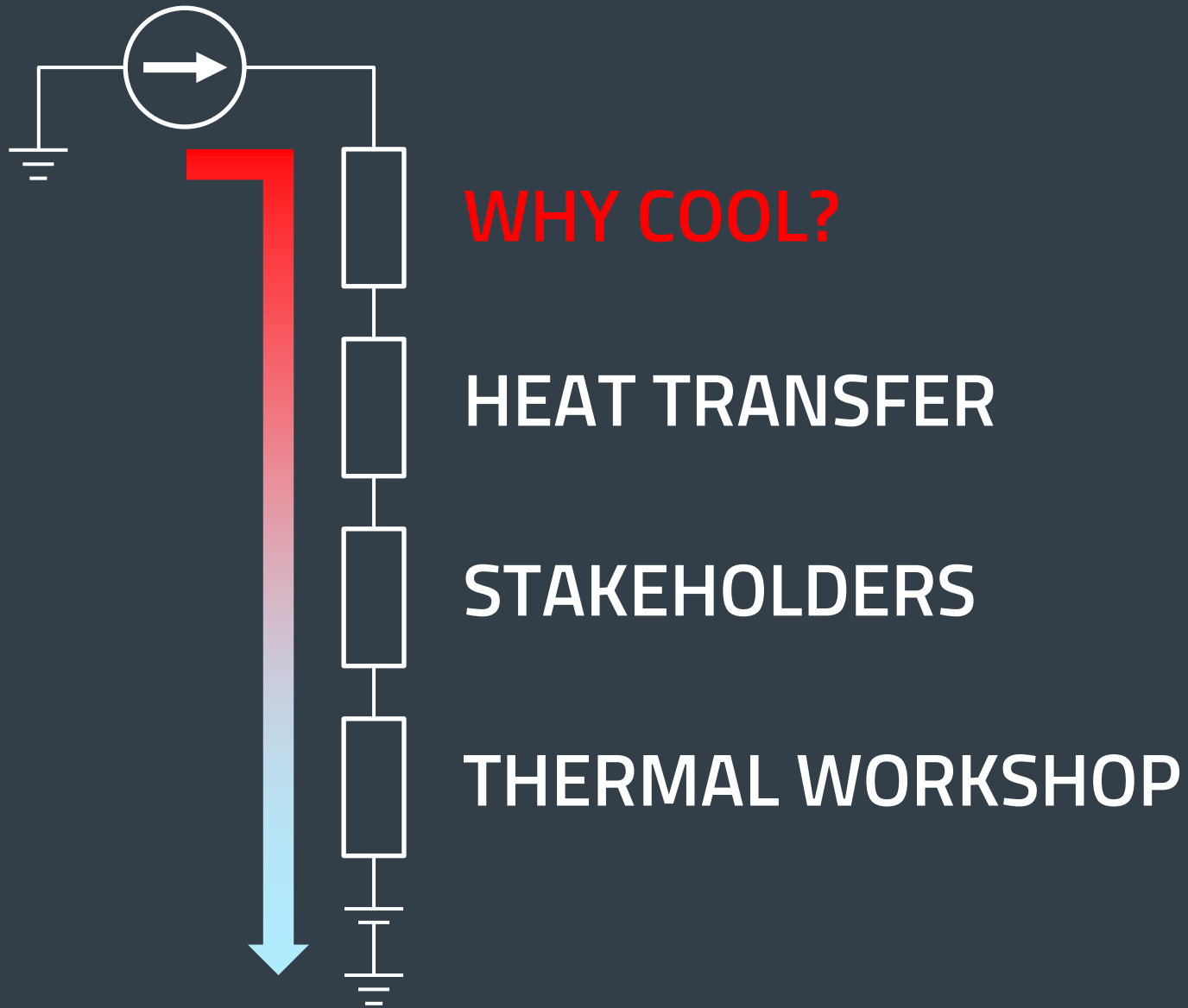


6 | THERMAL MANAGEMENT IN ELECTRONIC DESIGN
EXTERNAL | DIGITALWEDDAYS - WÜRTH ELEKTRONIK EISOS | 25-0V1-EN

11 | THERMAL MANAGEMENT IN ELECTRONIC DESIGN
EXTERNAL | DIGITALWEDDAYS - WÜRTH ELEKTRONIK EISOS | 25-0V1-EN

16 | THERMAL MANAGEMENT IN ELECTRONIC DESIGN
EXTERNAL | DIGITALWEDDAYS - WÜRTH ELEKTRONIK EISOS | 25-0V1-EN

36 | THERMAL MANAGEMENT IN ELECTRONIC DESIGN
EXTERNAL | DIGITALWEDDAYS - WÜRTH ELEKTRONIK EISOS | 25-0V1-EN

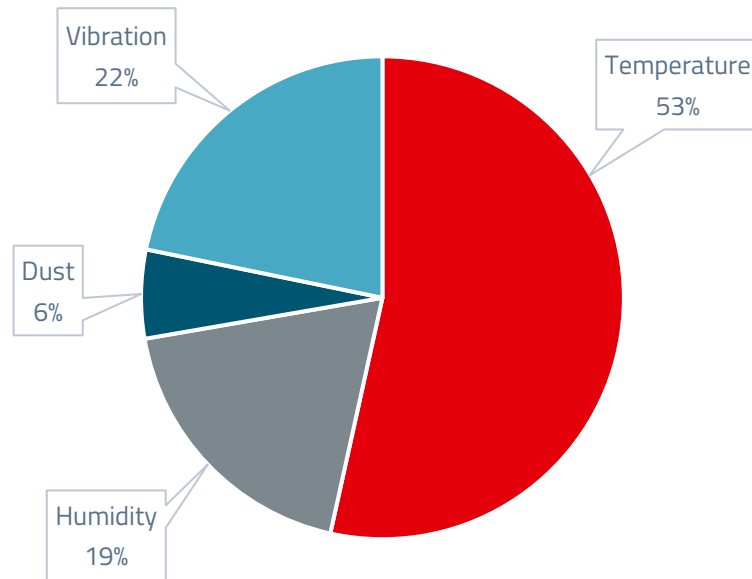


WHY COOL?

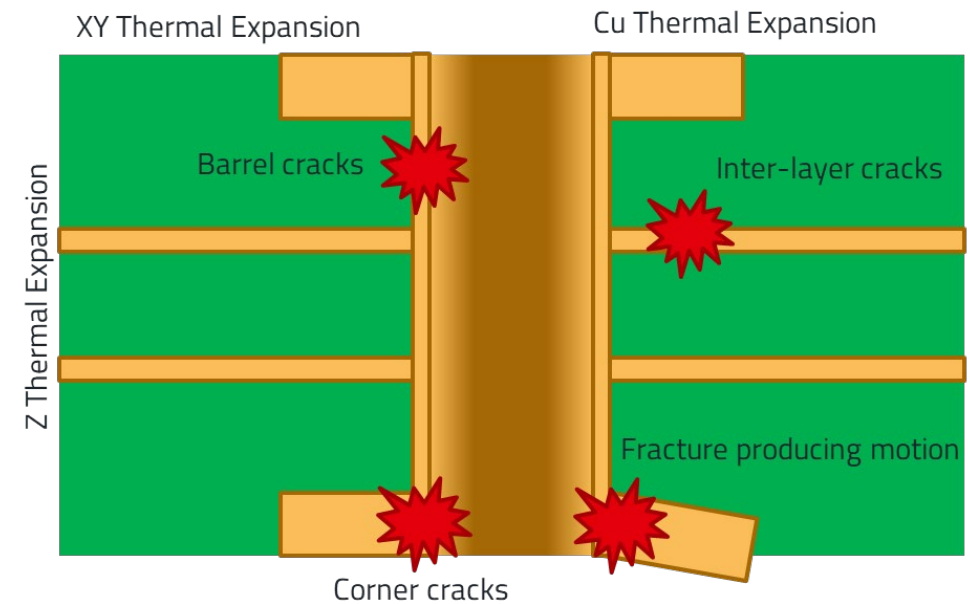
Problem Statement

Every 10 degrees we decrease the temperature of a component, we double its lifetime

Device Failure



Mechanical Stress Failure

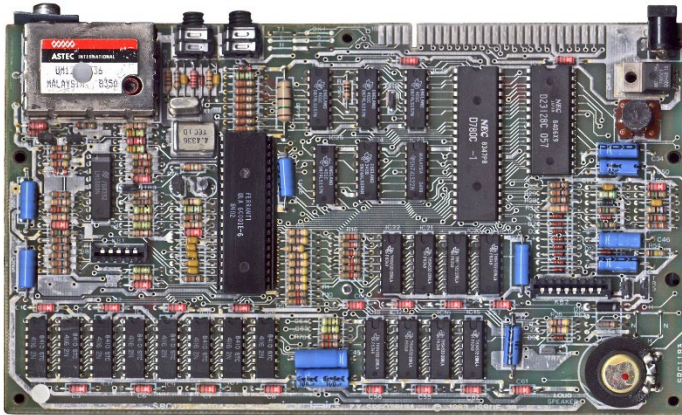


WHY COOL?

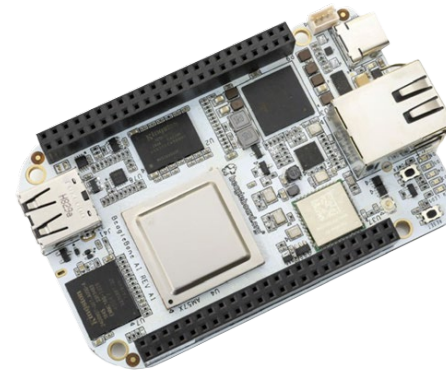
Problem Statement

- As an electronic designer, why should you care about Thermal Design?
 - Miniaturization & Power Density

**ZX Spectrum
1980s**



**Beaglebone
2010s**



22 W/cm² ← → 43 W/cm²

WHY COOL?

Problem statement

- Placement & PCB layout:
 - **Single & most important thermal design decision**



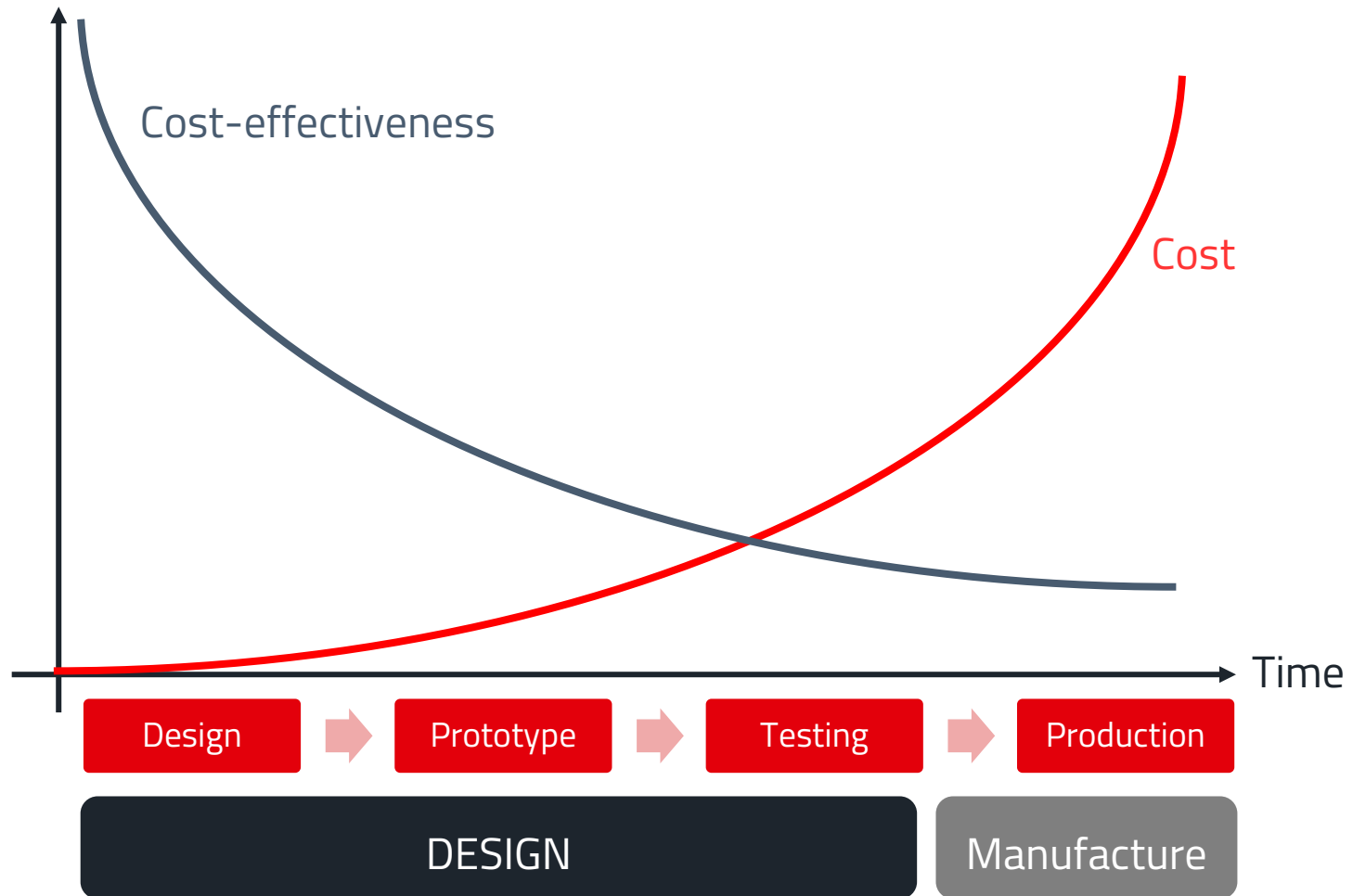
Best layout according to thermal criteria

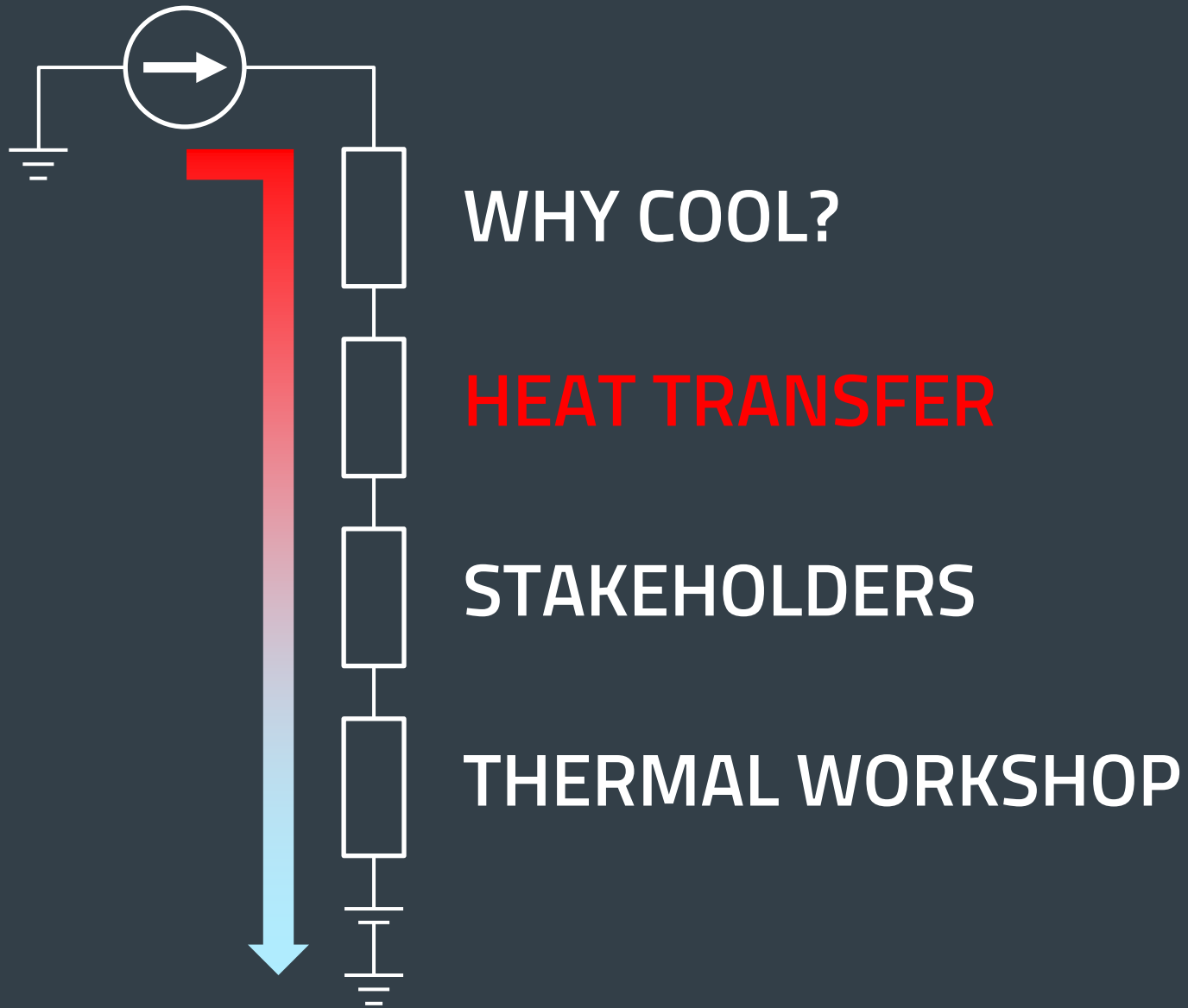


Best layout according to electronic criteria

WHY COOL?

Development Impact



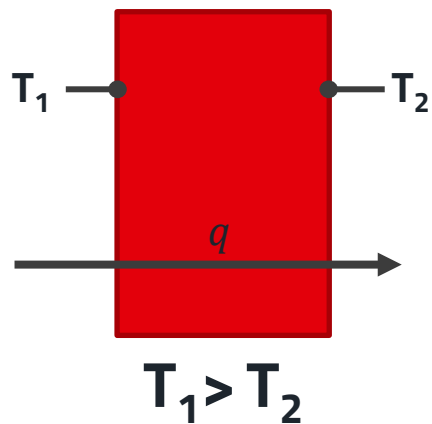


HEAT TRANSFER

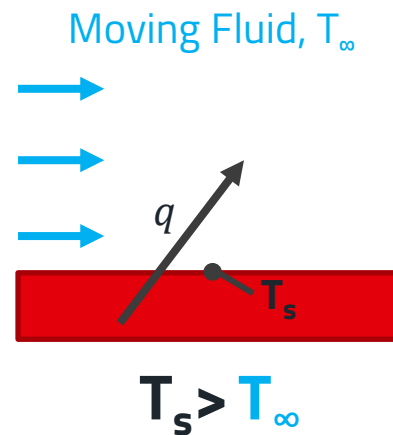
How Heat Behaves

- The goal of Thermal Management in Electronics is to manage **Heat Transfer**
 - Heat Transfer is **energy** in transit due to a **temperature difference**
- There are 3 main types of transfer:

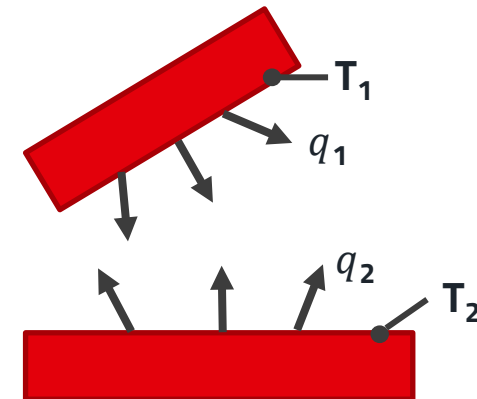
Conduction



Convection



Radiation



HEAT TRANSFER

Conduction

- Heat flow through a solid is directly proportional to a temperature difference

$$P = k \cdot \frac{A}{L} \cdot \Delta T$$

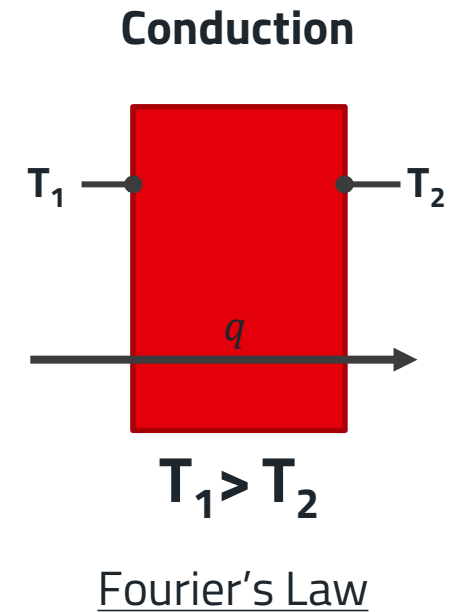
Thermal Conductivity

Thickness

Contact Area



Source: *Depositphotos*



HEAT TRANSFER

Convection

- Heat flow from solid to fluid proportional to temperature difference

$$P = h_{conv} \cdot A_s \cdot (T_s - T_{fluid})$$

Convection Coefficient
 $h_{vacuum}=0$
 $h_{ambient}=1$
 $h_{fan}=10$

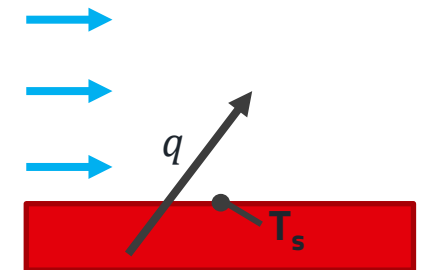
Surface Area



Source: [Ine.es](https://ine.es)

Convection

Moving Fluid, T_∞



$$T_s > T_\infty$$

Newton's Law

HEAT TRANSFER

Radiation

- When an object is surrounded by other of less temperature, a heat transfer equivalent to that of natural convection occurs

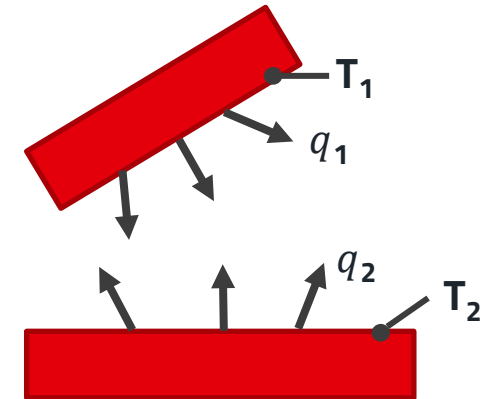
$$P = \epsilon \cdot A_s \cdot \sigma \cdot (T_s^4 - T_{ent}^4) \cdot f_v$$

Geometric Factor f_v

Emissivity ϵ

Boltzmann's Constant σ

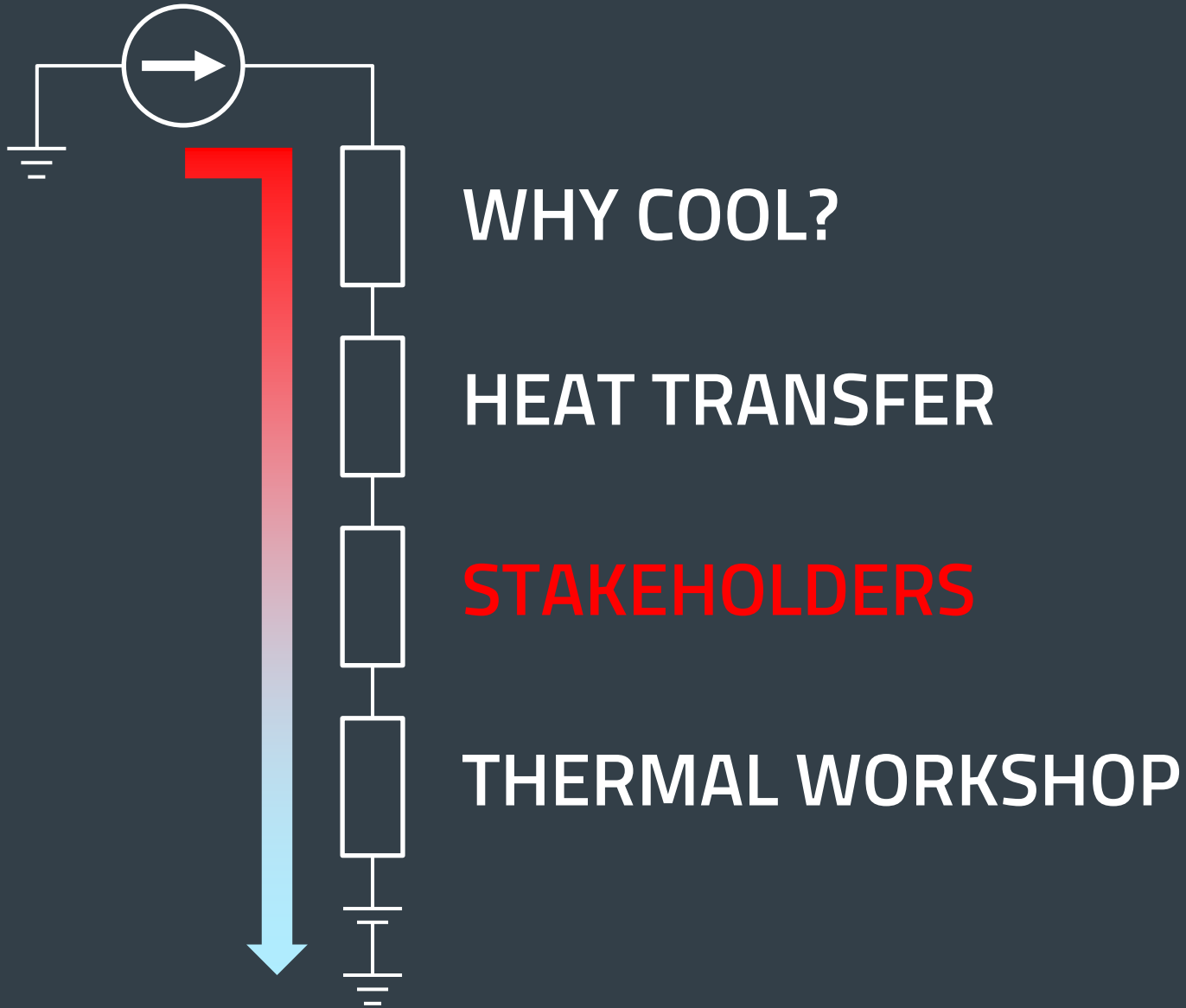
Radiation



Boltzmann's Law

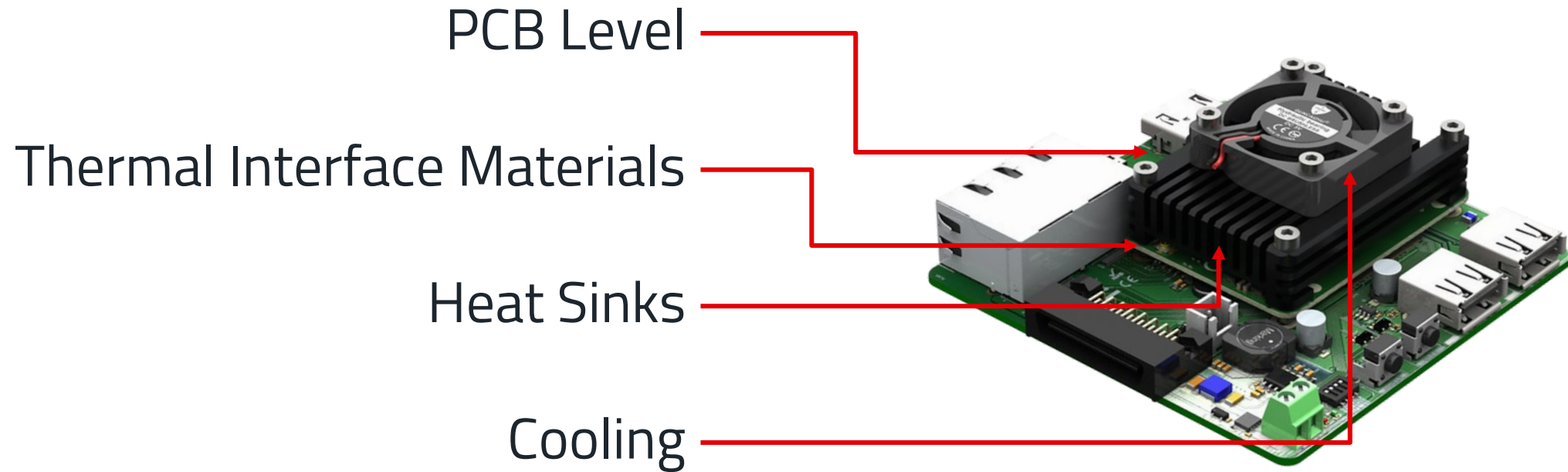
Material	ϵ
Copper	0.03
Polished Al	0.04
Anodized Al	0.9
Mold Compound	0.8

Surface Emissivity of Common Electronic Materials



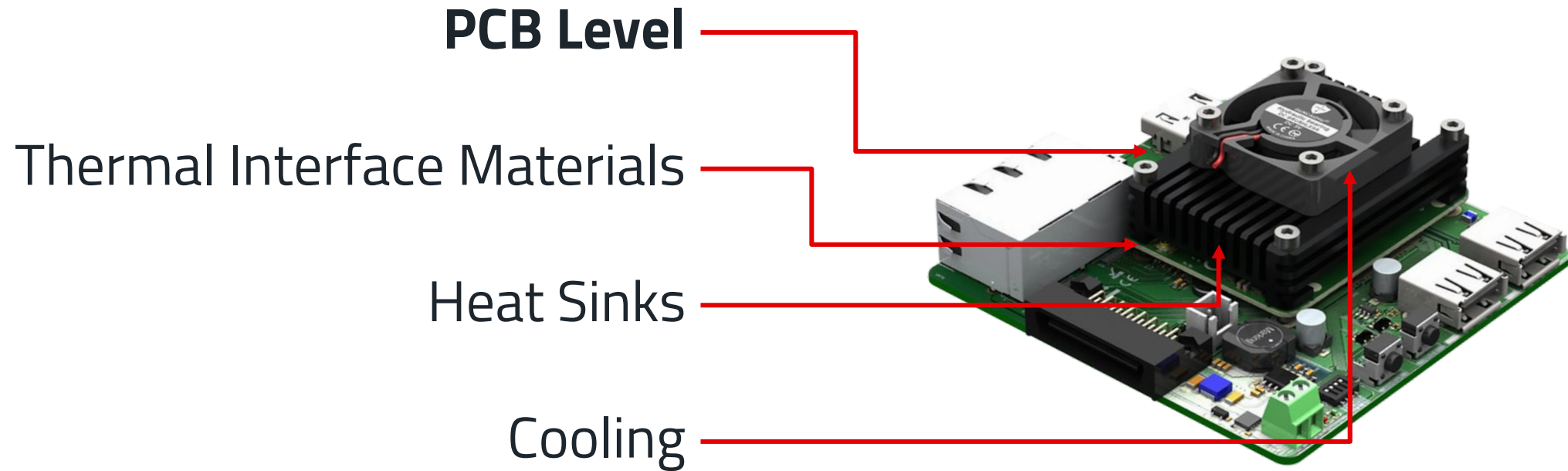
DESIGN CONSIDERATIONS

Thermal Management "Stakeholders"



DESIGN CONSIDERATIONS

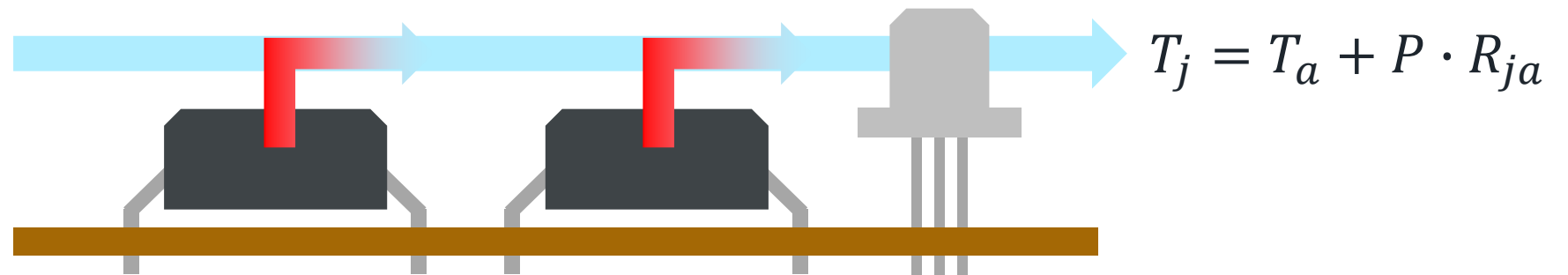
Thermal Management "Stakeholders"



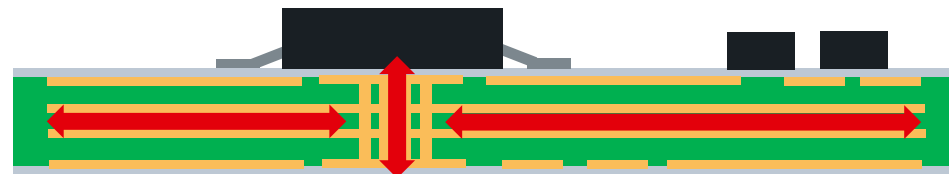
DESIGN CONSIDERATIONS

Thermal Management "Stakeholders": PCB Level

- The THT to SMD transition
 - Circuit boards started as a physical support that allowed the mounting & interconnection of components



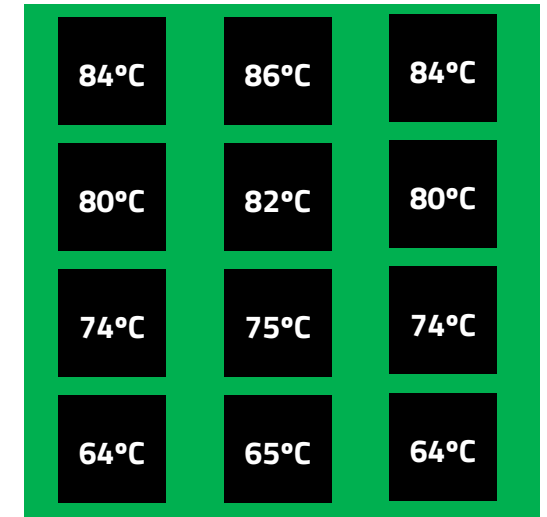
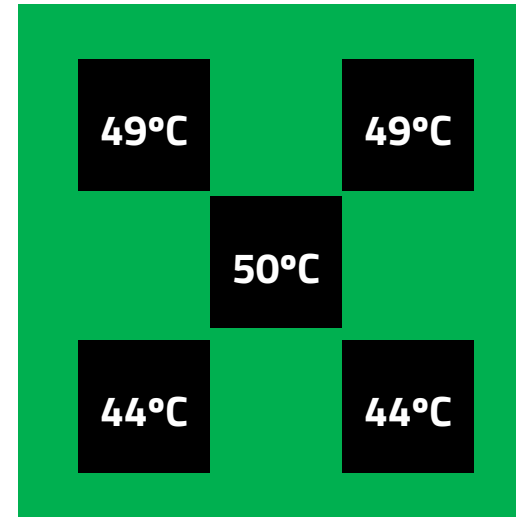
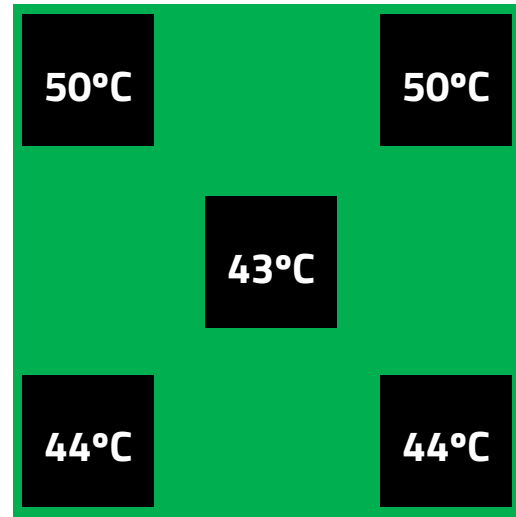
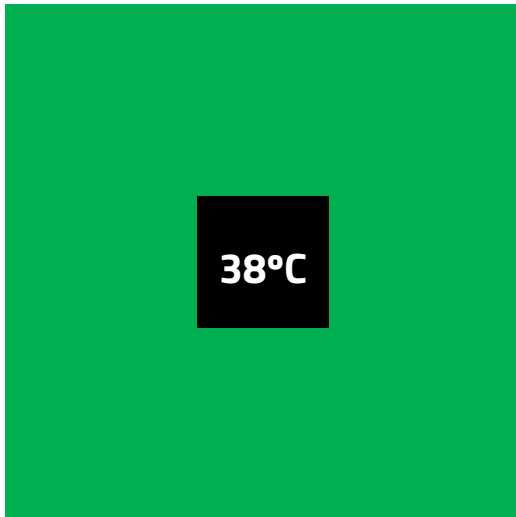
- Due to miniaturization now 80-90 % of heat flows to the ambient through the PCB



DESIGN CONSIDERATIONS

Thermal Management "Stakeholders": PCB Level

- Placement & PCB layout:
 - **Single & most important thermal design decision**
 - Same IC, same operating criteria & same ambient can have different temperatures depending on PCB placement



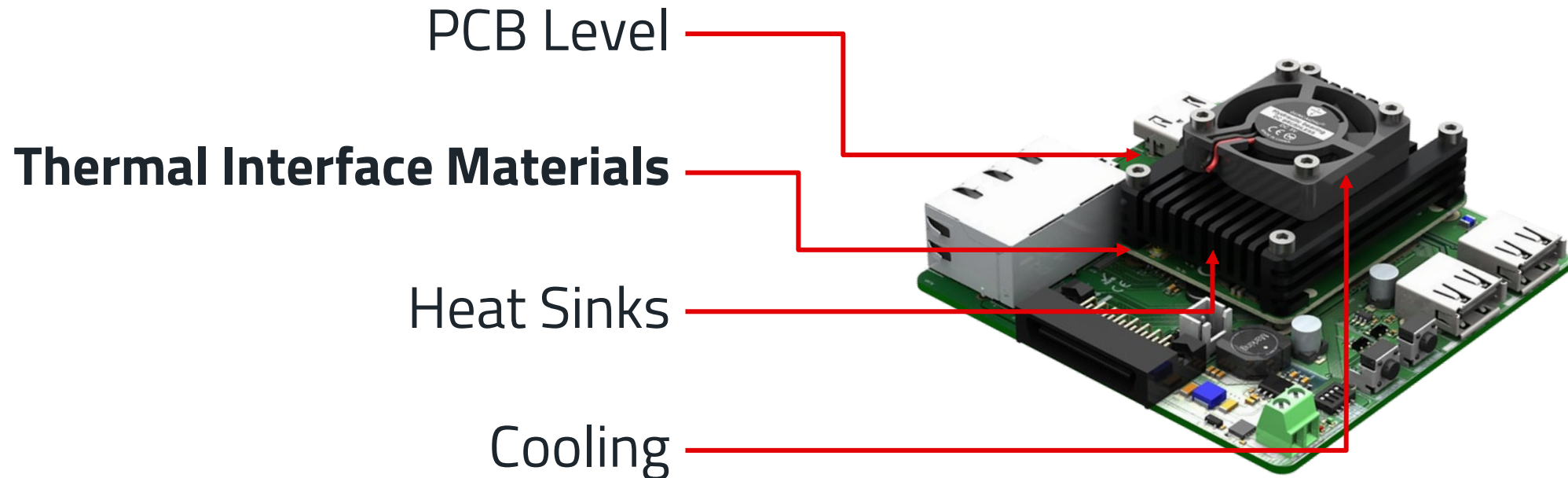
1W IC, Vertical Placement, Ambient Temperature: 20°C

DESIGN CONSIDERATIONS

Thermal Management "Stakeholders"



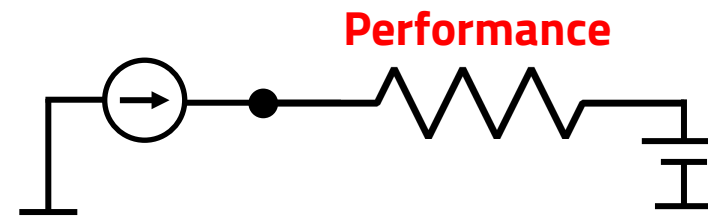
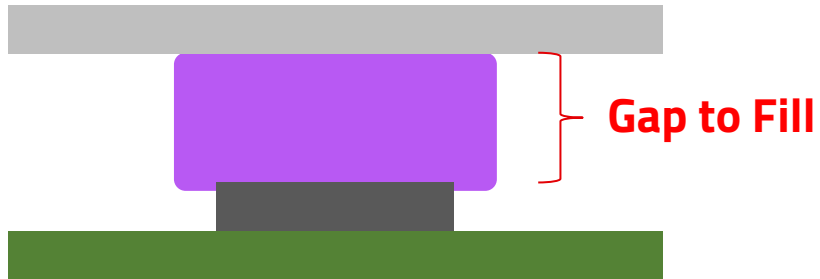
**WÜRTH
ELEKTRONIK**
MORE THAN
YOU EXPECT



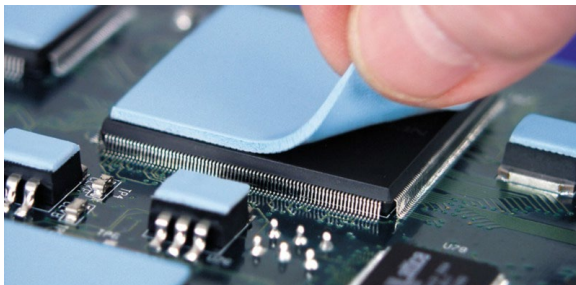
DESIGN CONSIDERATIONS

Thermal Management “Stakeholders”: Thermal Interface Materials

- When **looking** for a TIM there are two main factors:



- When **using** a TIM:



Source: KVB research

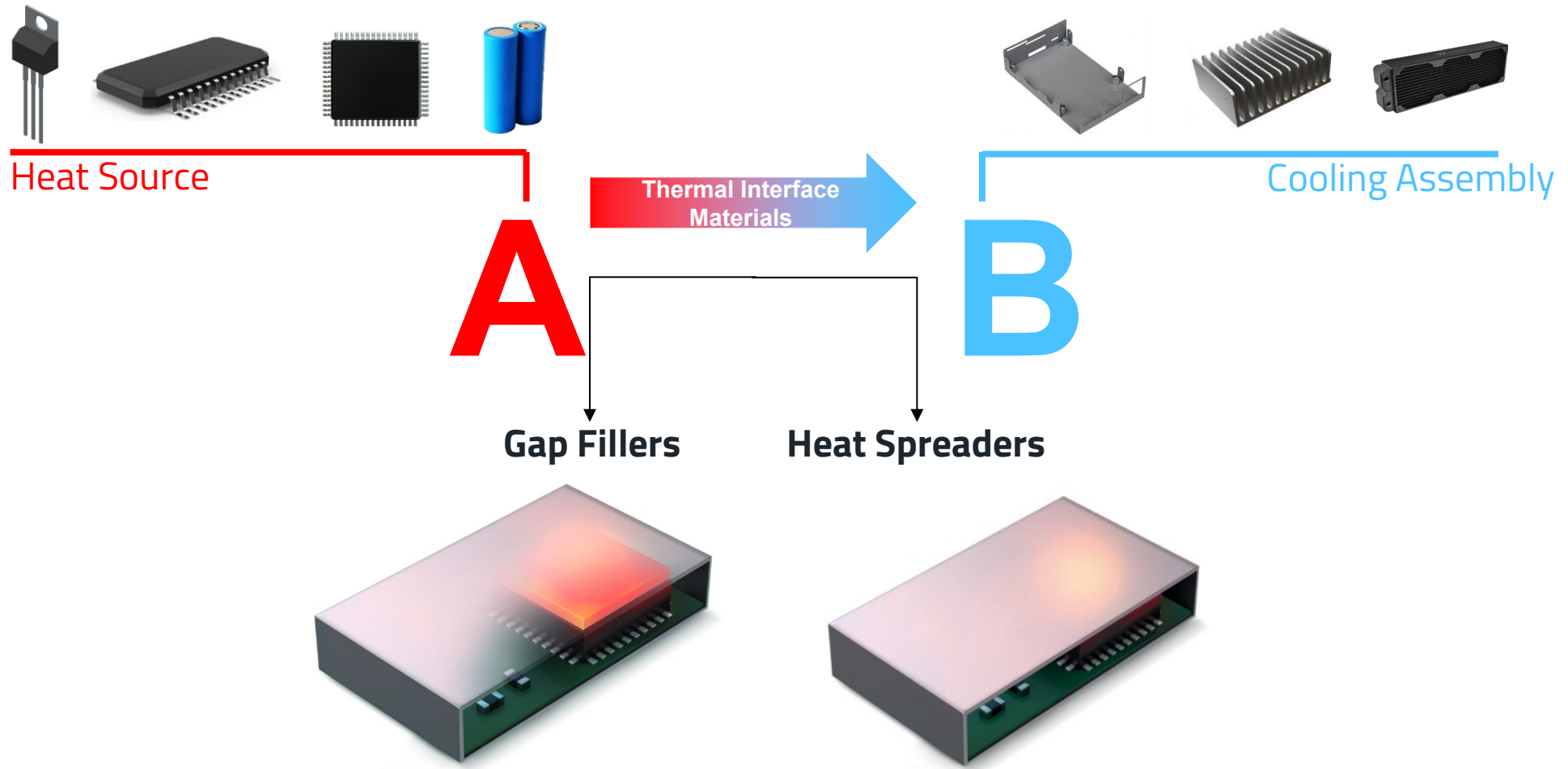
Optimize Processing



Optimize Cost-effectiveness

DESIGN CONSIDERATIONS

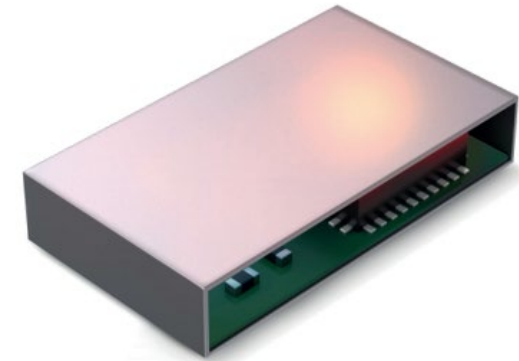
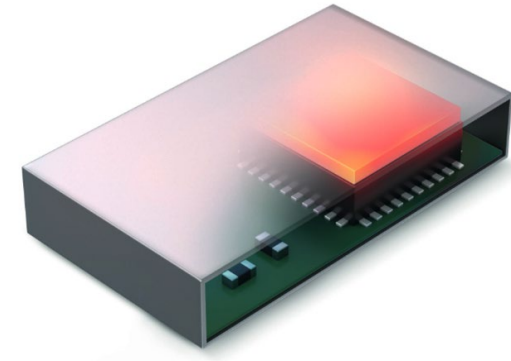
Thermal Management "Stakeholders": Thermal Interface Materials



IMPORTANT NOTE!

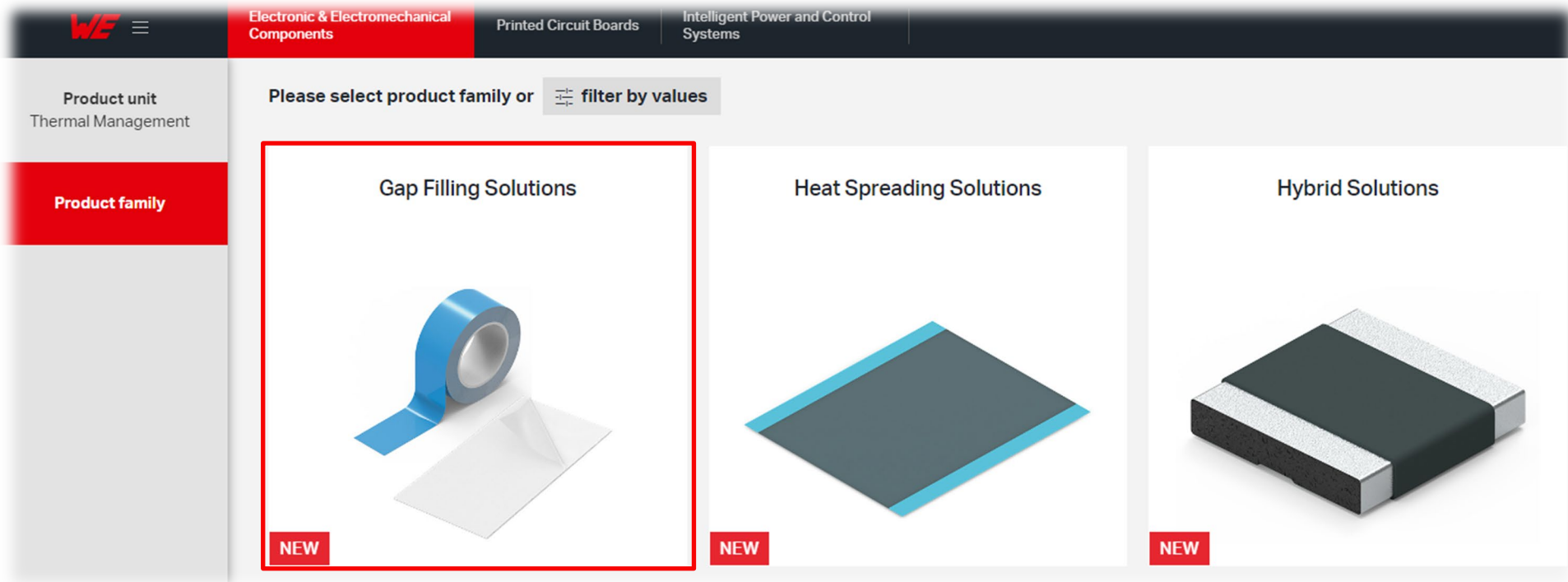
Before explaining our portfolio...

- Thermal interface materials **are for:**
 - o Giving a path to the heat *between two surfaces*
 - o Ensure good contact *between two surfaces*
- Thermal interface materials **are not for:**
 - o Apply on a material *without contact with another surface*



OUR TIM PORTFOLIO

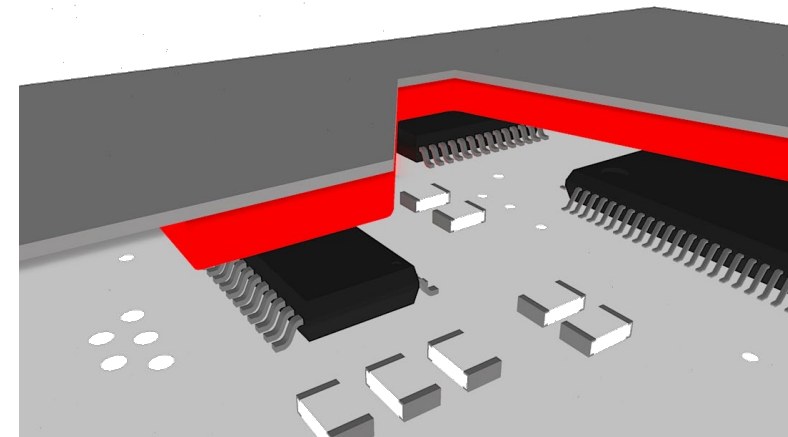
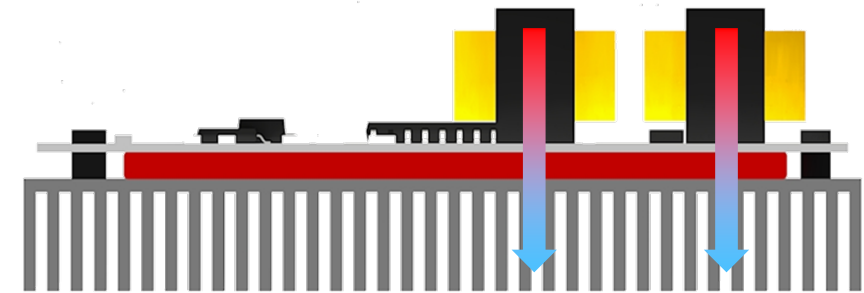
3 Main Categories



OUR TIM PORTFOLIO

Gap Filling Solutions: **WE-TGF**

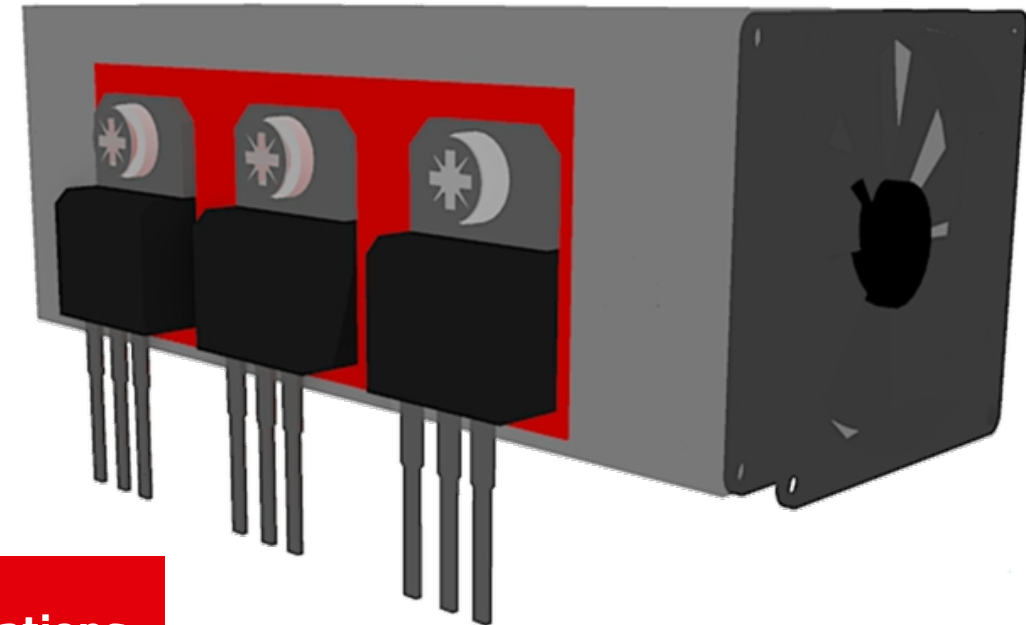
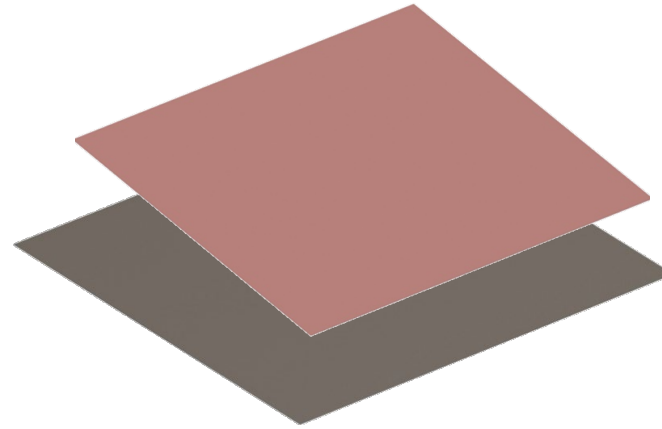
- Characteristics
 - Thermal Conductivity: from 1 to 6 W/m·K
 - Thicknesses:
 - 0.5 – 18 mm for thermal conductivities of 1 to 3 W/m·K
 - 0.5 – 3 mm for higher thermal conductivities
 - Electrically insulating
- Features
 - Soft and conformable
 - Naturally tacky, self adhesive
 - **Optimal performance: compression 10-30 %**



OUR TIM PORTFOLIO

Gap Filling Solutions: **WE-TINS**

- Characteristics
 - Thermal Conductivity: from 1.6 to 3.5 W/m·K
 - Thickness:
 - 0.23 - 0.25 mm
 - Electrically insulating
- Features
 - Withstands high mechanical stress
 - Flexible and conformable
 - Puncture and shear resistant

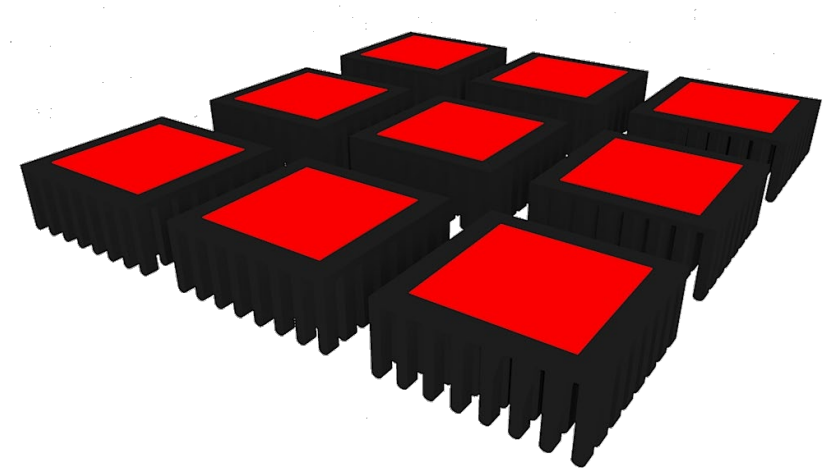
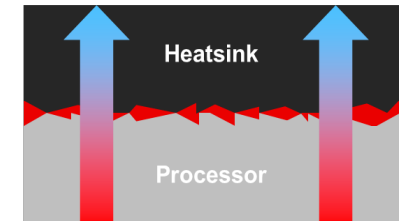
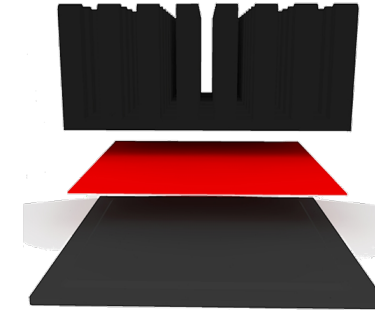
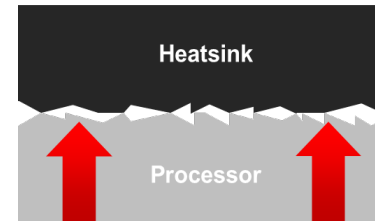


High Mechanical Stress Applications

OUR TIM PORTFOLIO

Gap Filling Solutions: **WE-PCM**

- Characteristics
 - Phase change temperature: 50 – 60 °C
 - Thermal Conductivity: from 1.6 to 5 W/m·K
 - Low thermal resistance
 - Polyimide film for electrical insulation
- Features
 - Comparable to thermal pastes and greases
 - Removes microscopic unevenness in contact surfaces
 - Easy to handle in manufacture environments
 - **Can be pre-applied**



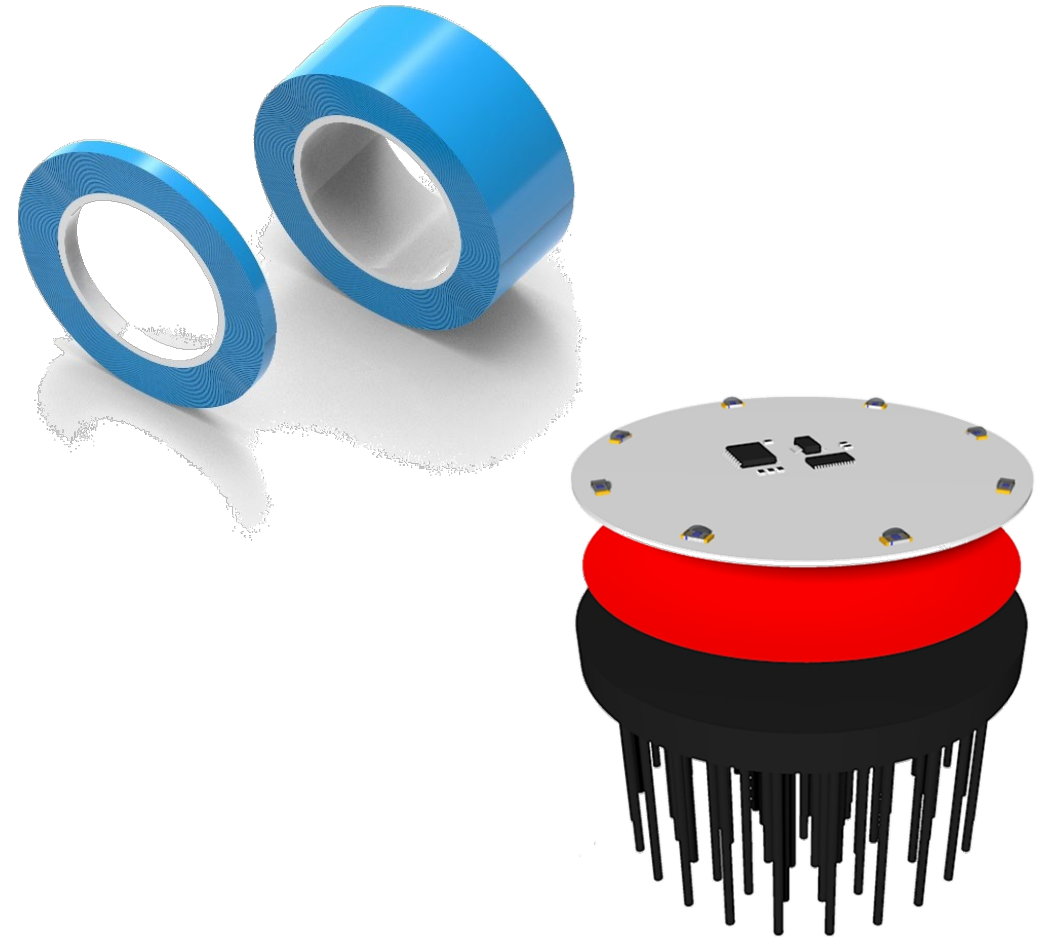
Seamless Thermal Interface

Alternative to Thermal Pastes

OUR TIM PORTFOLIO

Gap Filling Solutions: **WE-TTT**

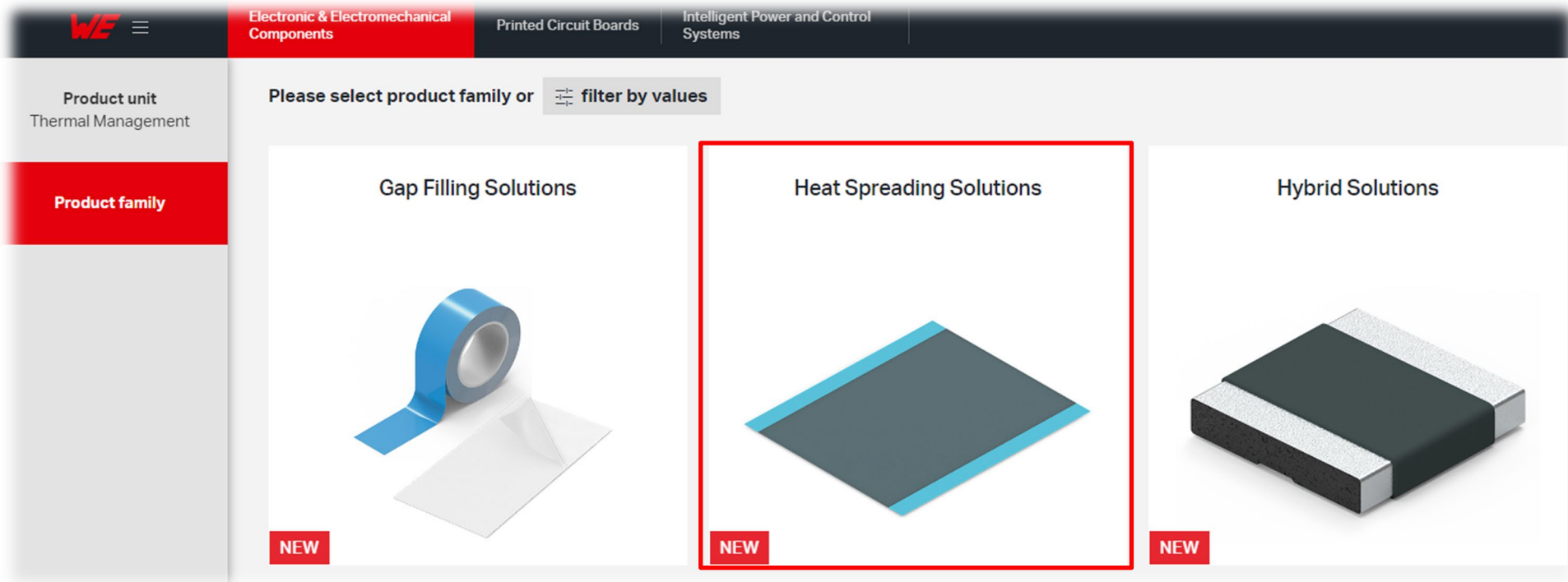
- Characteristics
 - Thermal Conductivity: 1 W/m·K
 - Thickness: 0.2 mm
 - Adhesive Strength: 5.8 N/cm
 - Electrically insulating
 - 25 m roll with a width of 8 or 50 mm
 - 250 x 250 mm & 100 x 100 mm sheet
- Features
 - Pressure sensitive adhesive
 - Eliminates the need for mechanical mounting points



Adhesive Solution

OUR TIM PORTFOLIO

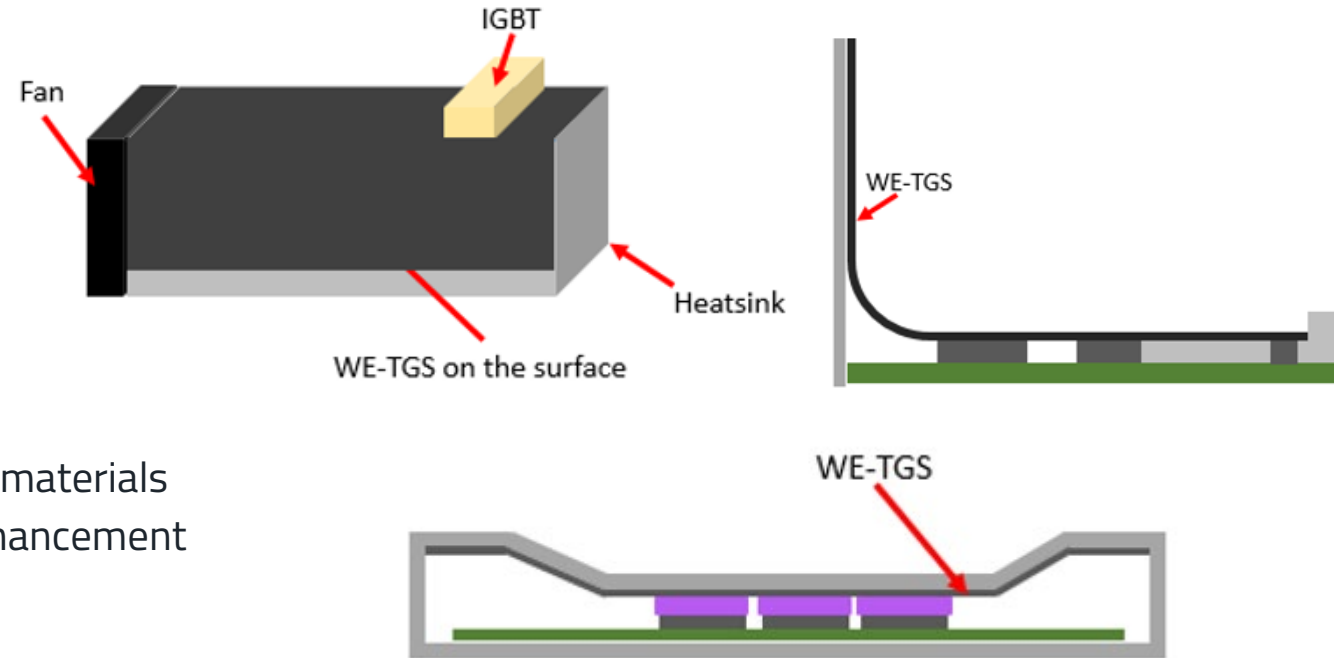
3 Main Categories



OUR TIM PORTFOLIO

Heat Spreading Solutions: **WE-TGS**

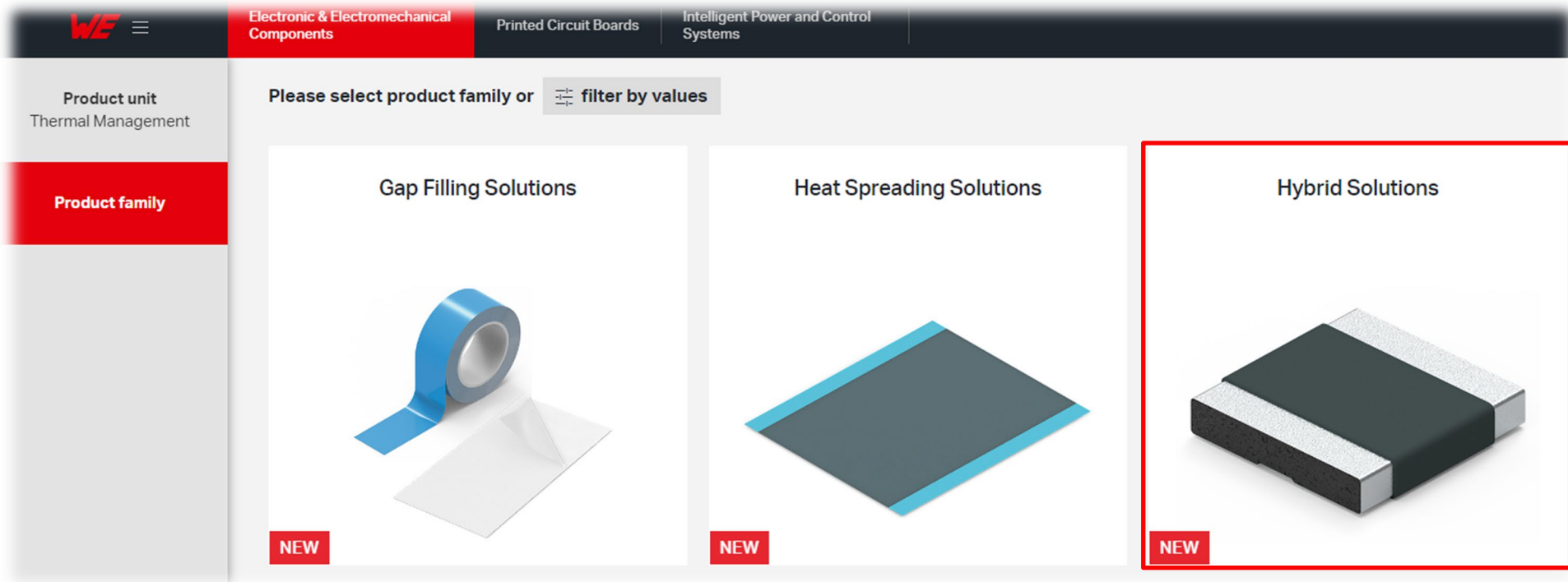
- Characteristics
 - Horizontal Thermal Conductivity: 1800 W/m·K
 - Thickness: 17 μm
 - Electrically insulating: acrylic top and bottom layer
 - Adhesive layer
 - 210 x 297 mm & 100 x 100 mm sheet
- Features
 - Enhance heat dissipation of other lower-performing materials
 - Can be combined with other solutions for further enhancement



Heat Spreading Solution

OUR TIM PORTFOLIO

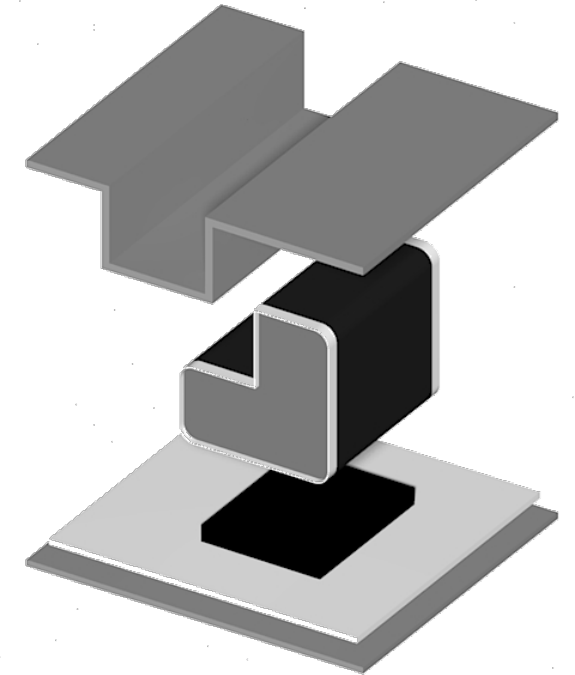
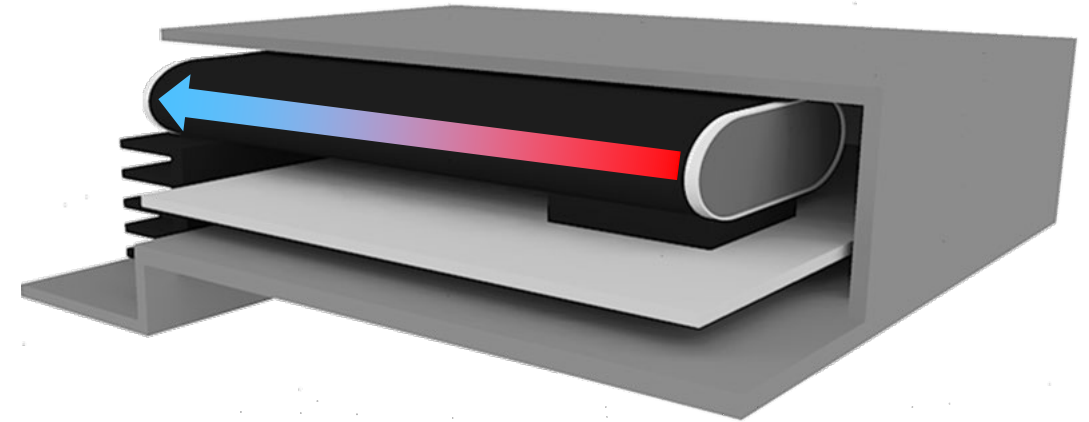
3 Main Categories



OUR TIM PORTFOLIO

Hybrid Solutions: **WE-TGFG**

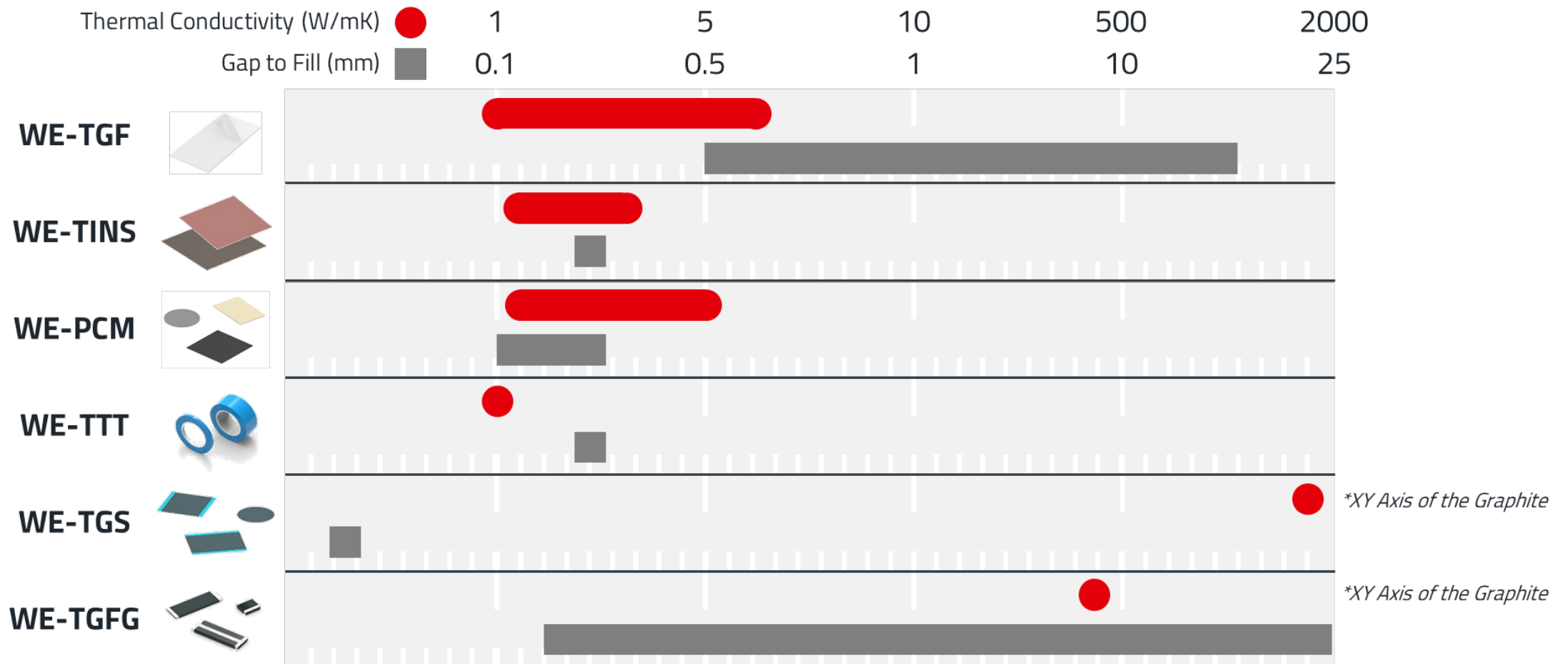
- Characteristics
 - Thermal Conductivity: up to **400 W/m·K**
 - Thicknesses: **1.5 – 25 mm**
 - Electrically insulating
 - Adhesive contact surfaces
 - Many different sizes and profiles
- Features
 - Highly versatile solution: profiles for particular applications
 - Can be used as a gap filler for high thicknesses
 - Can transfer heat to cooling assemblies away from components



More Freedom of Creativity

OUR TIM PORTFOLIO

Summary



OUR TIM PORTFOLIO

For More Information see our User Guideline

USER GUIDE
UG011 | Thermal Gap Filler Pad – WE-TGF

Scenario 1		Scenario 2	
Component A	Component B	Component A	Component B
Surface area	600 mm ²		
Thermal losses	15.36 W	15.36 W	2.16 W
R _{thJA}	1.676 K/W	1.676 K/W	1.676 K/W
T _A	40 °C	40 °C	45 °C
T _{max}	120 °C	120 °C	120 °C
Power flow	400 W	400 W	400 W

Figure 5: Thermal calculation considering dissipation through heat sink and packaging

Figure 6: Thermal resistance network

Figure 7: Electrical analogy of systems

UG011a | 2024/09/02
WÜRTH ELEKTRONIK eSOS

USER GUIDE
UG011 | Thermal Gap Filler Pad – WE-TGF

Regarding material adhesion, the WE-TGF does not have an adhesive layer since it is sticky by nature due to its surface wet-out. The pad is designed to be compressed between two surfaces. The tackiness is enough to keep the pad in place during assembly. It is not designed to hold the cooling assembly in place on its own.

The properties of the WE-TGF elastomeric pads can be grouped in three categories: material, thermal and electrical properties as can be seen in Table 1, Table 2 and Table 3.

Read more about the thermal performance in chapter A.1.

Material Properties					
Color	Light Grey	Light Blue	Blue	Purple	White
Thickness	0.5 - 10 mm	0.5 - 10 mm	0.5 - 10 mm	0.5 - 10 mm	0.5 - 10 mm
Specific Gravity	2.80 g/cm ³	2.80 g/cm ³	3.00 g/cm ³	3.12 g/cm ³	3.2 g/cm ³
Hardness (Shore OO)	45 Shore OO	45 Shore OO	35 Shore OO	60 Shore OO	75 Shore OO
Temperature	-60 +180 °C	-60 +180 °C	-60 +180 °C	-60 +180 °C	-60 +180 °C
Dielectric	>100	>100	>100	>100	>100
Tensile Strength	>1.5 MPa	>0.25 MPa	>0.15 MPa	>0.15 MPa	>0.15 MPa
Compression Setback	<25%	<25%	<25%	<15%	<15%

Thermal Properties					
Bulk Thermal Conductivity	1.50 W/mK	2.50 W/mK	3.50 W/mK	4.50 W/mK	5.50 W/mK
Thermal Impedance (max. power dissipation at 1 cm x 1 cm x 1 cm)	17.8 K/(W/m ²)	7.7 K/(W/m ²)	4.9 K/(W/m ²)	4.7 K/(W/m ²)	2.7 K/(W/m ²)

Electrical Properties					
Bulk Thermal Conductivity	1.50 W/mK	2.50 W/mK	3.50 W/mK	4.50 W/mK	5.50 W/mK
Breakdown Voltage	8 kV/mm	8 kV/mm	8 kV/mm	8 kV/mm	8 kV/mm
Volume Resistivity	10 ¹² Ω·cm	10 ¹² Ω·cm	10 ¹² Ω·cm	10 ¹² Ω·cm	10 ¹² Ω·cm
Permittivity	7.8	11	13	13	13

UG011a | 2024/09/02
WÜRTH ELEKTRONIK eSOS

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

USER GUIDE
UG011 | Thermal Gap Filler Pad – WE-TGF

Sebastian Mrazek-Menache

1. INTRODUCTION TO WE-TGF

Elastomeric pads are one of the most used thermal management solutions in present-day electronic designs. The pads are engineered from silicone-based or silicone-free materials, due to the mechanical material properties and suitability with regards to thermal performance. Unlike traditional thermal interface materials (TIM) such as pastes and greases, elastomeric pads are soft, compliant, and adaptable. This makes them ideal for applications where there are variations in component heights or irregular surfaces. Their unique properties allow for efficient heat transfer between electronic components and heat sinks or other cooling elements. By filling microscopic gaps and irregularities between surfaces, these pads facilitate enhanced thermal conductivity, ensuring optimal heat dissipation and, consequently, the longevity and reliability of electronic devices.

The **WE-TGF** is designed to withstand a wide range of temperatures and high electric insulation values, making it suitable for both low-power and high-power electronic devices. The pad's elastomeric nature can also help in vibration dampening applications. Moreover, their inherent elasticity allows them to maintain consistent contact pressure even in dynamic thermal environments, ensuring continuous and effective heat transfer.

2. MATERIAL SPECIFICATIONS

The pad itself is composed by three main components as shown in Figure 1.

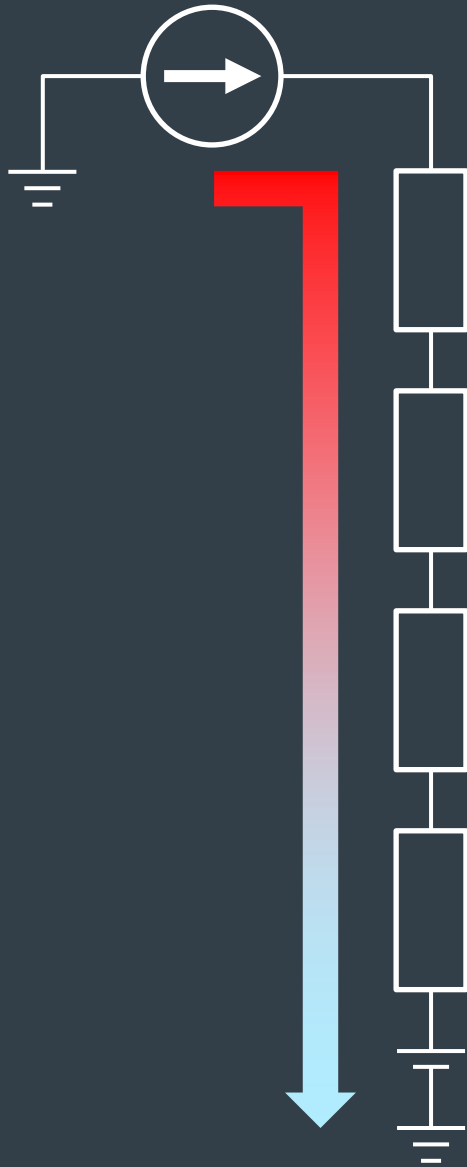
• PET film:
The WE-TGF is protected by two PET films. The one in the bottom is thicker and acts as a carrier, while the top film protects any foreign particles from adhering to the back surface of the pad. These films should be removed during part placement.

• Thermally conductive elastomer:
The elastomeric nature of the part allows the pad to conform with ease to contact surfaces, allowing the material to fill gaps and remove air. The main body of the part is made with silicone or vinyl for silicone-free applications and is doped with ceramic particles to give the pad thermally conductive properties.

• Fiberglass mesh:
Pads under 2 mm height have a fiberglass mesh, which helps the part maintain mechanical stability under compression. The addition of this layer has a slight impact on the thermal performance, which will be presented in the chapter 3.

Figure 1: WE-TGF cross-section

UG011a | 2024/09/02
WÜRTH ELEKTRONIK eSOS



WHY COOL?

HEAT TRANSFER

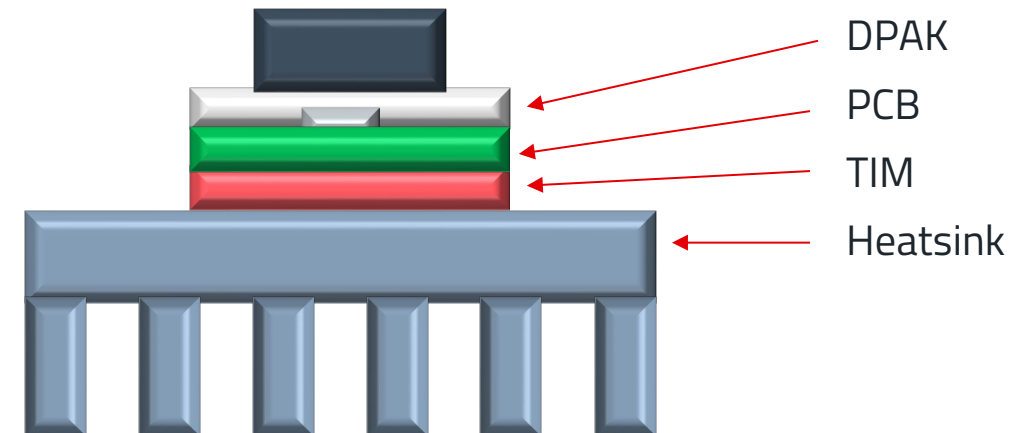
DESIGN CONSIDERATIONS

THERMAL WORKSHOP

THERMAL MEASUREMENT EXAMPLE

General Information

- Let's have a look on our following thermal measurement:
 - PN: ST LF33CDT-TR
 - DPAK
 - Horizontal mounted
 - Two cases:
 1. Thermal Interface Material "WE-TGF" 1 W / mK 1 mm
 2. Thermal Interface Material "WE-TGF" 1 W / mK 5 mm



THERMAL MEASUREMENT EXAMPLE

Calculation thermal resistance of TIM

$$R_{th-TIM} = \frac{l}{\lambda \cdot A} = \frac{0,001 \text{ m}}{1,0 \frac{W}{m \cdot K} \cdot (0,007m \cdot 0,007m)} = 20,41 \frac{K}{W}$$

$$R_{th-TIM} = \frac{l}{\lambda \cdot A} = \frac{0,005 \text{ m}}{1,0 \frac{W}{m \cdot K} \cdot (0,007m \cdot 0,007m)} = 102,04 \frac{K}{W}$$

l = Material thickness of TIM [m]

A = Contact surface area of TIM [m²]

λ = Thermal conductivity coefficient of TIM [$\frac{W}{m \cdot K}$]

- Modeling thermal resistance of an insulator pad
- WE-TGF
7 mm x 7 mm; 1 mm; 1 W / mK
- WE-TGF
7 mm x 7 mm; 5 mm; 1 W / mK



THERMAL MEASUREMENT EXAMPLE

RthJC – Datasheet information

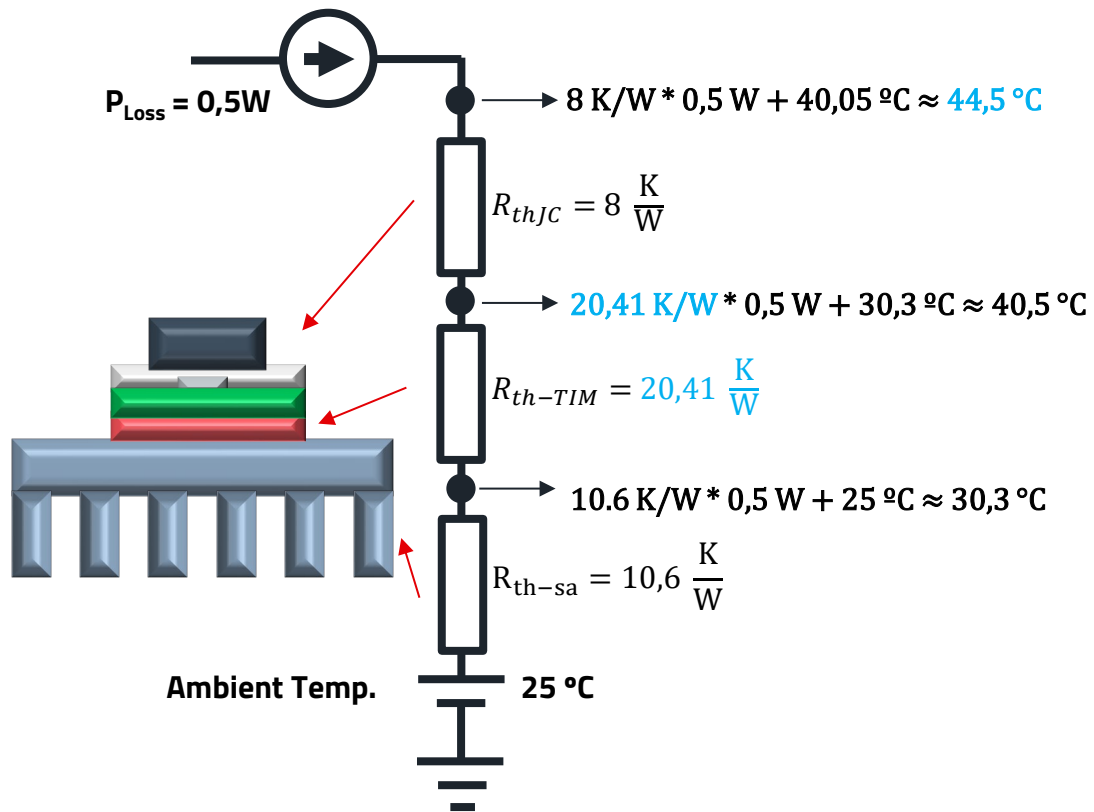
Table 2: Thermal data

Symbol	Parameter	TO-220	TO-220FP	DPAK/PPAK	Unit
R _{thJC}	Thermal resistance junction-case	5	5	8	°C/W
R _{thJA}	Thermal resistance junction-ambient	50	60	100	°C/W

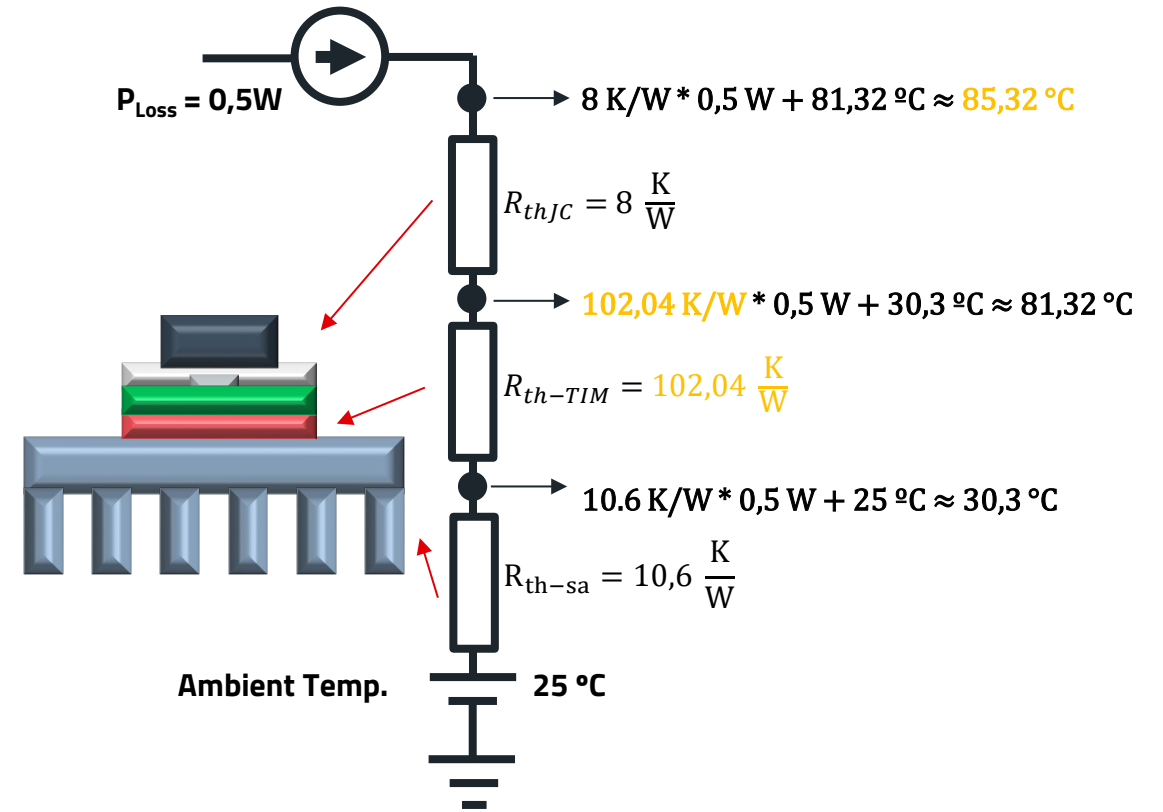
With DPAK / PPAK: $R_{th-Jc} = 8 \frac{K}{W}$

THERMAL MEASUREMENT EXAMPLE

WE-TGF 1 mm



WE-TGF 5 mm



Note: $T_2 = R * P_{Loss} + T_1$

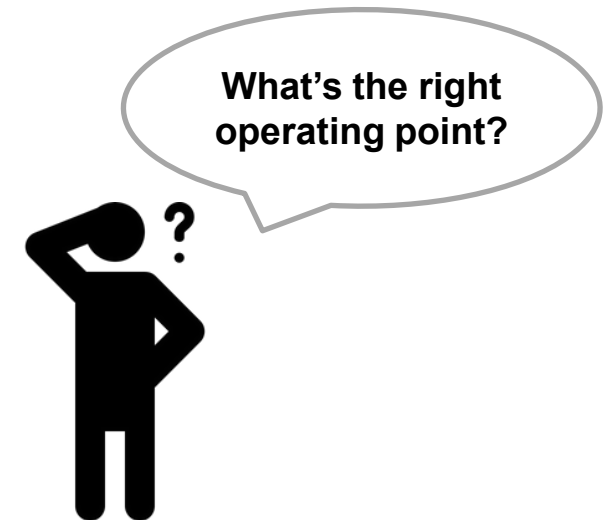
THERMAL MEASUREMENT EXAMPLE

Comparison

- Which of my three cases gives me the results I want?
 - **Case I:** Thermal Interface Material “WE-TGF” 1 W / mK 1 mm: Junction temperature of 44,5 °C
 - **Case II:** Thermal Interface Material “WE-TGF” 1 W / mK 5 mm: Junction temperature of 85,3 °C

Table 1: Absolute maximum ratings

Symbol	Parameter	Value	Unit
V _I	DC input voltage	-0.5 to 40 ⁽¹⁾	V
I _O	Output current	Internally limited	A
P _{TOT}	Power dissipation	Internally limited	W
T _{STG}	Storage temperature range	-40 to 150	°C
T _{OP}	Operating junction temperature range	-40 to 125	°C



THANK YOU FOR YOUR ATTENTION!

We are now at your disposal for any questions you may have.