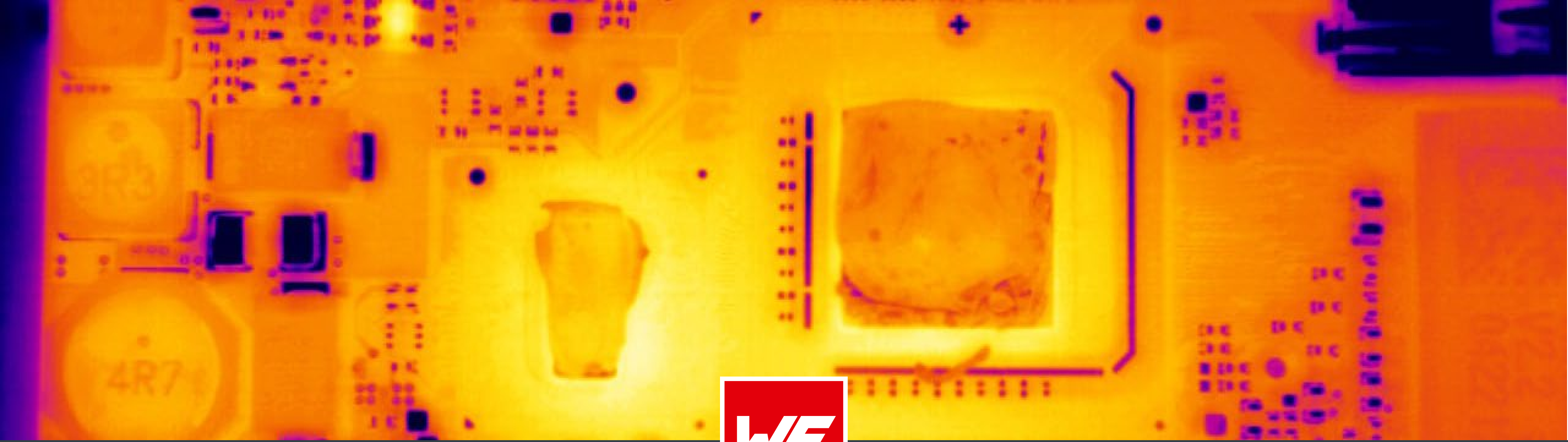
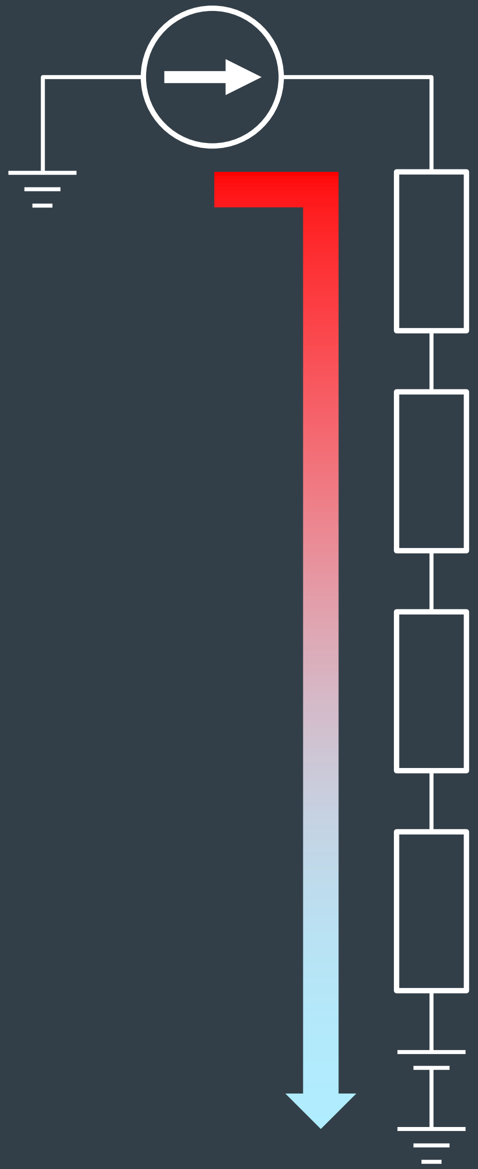


THERMAL MANAGEMENT IN ELECTRONIC DESIGN

Maria Cuesta Martín
Product Manager

Frank Gräber
Field Application Engineer

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

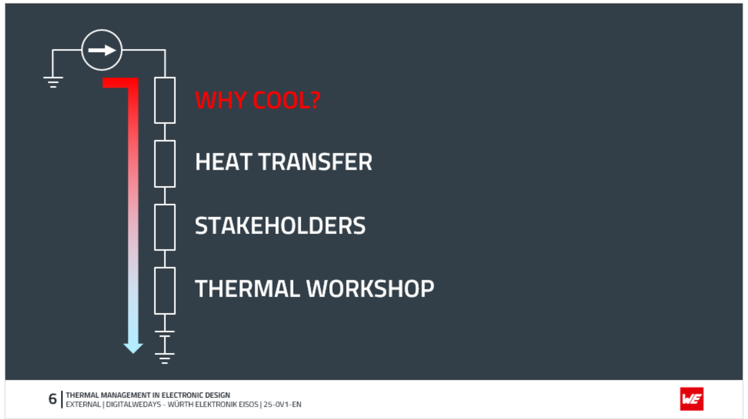


WHY COOL?

HEAT TRANSFER

STAKEHOLDERS

THERMAL WORKSHOP


WHY COOL?
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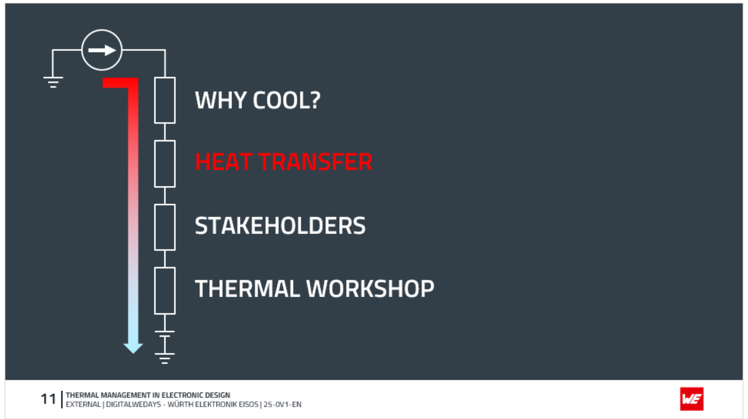
THERMAL MANAGEMENT IN ELECTRONIC DESIGN
EXTERNAL | DIGITALWEDAYS - WÜRTH ELEKTRONIK EISOS | 25-0V1-EN


WHY COOL?
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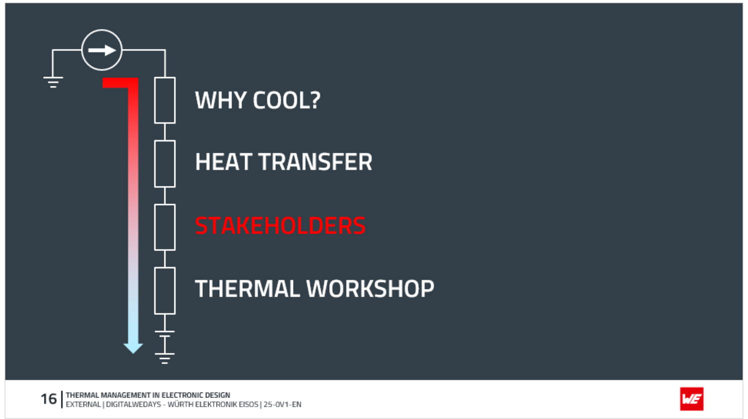
THERMAL MANAGEMENT IN ELECTRONIC DESIGN
EXTERNAL | DIGITALWEDAYS - WÜRTH ELEKTRONIK EISOS | 25-0V1-EN


WHY COOL?
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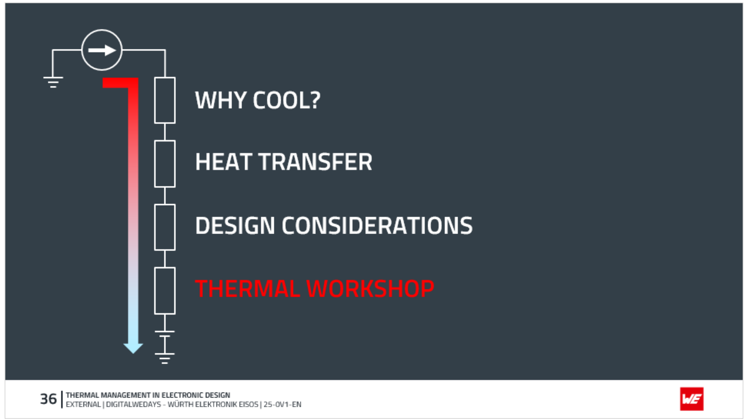
THERMAL MANAGEMENT IN ELECTRONIC DESIGN
EXTERNAL | DIGITALWEDAYS - WÜRTH ELEKTRONIK EISOS | 25-0V1-EN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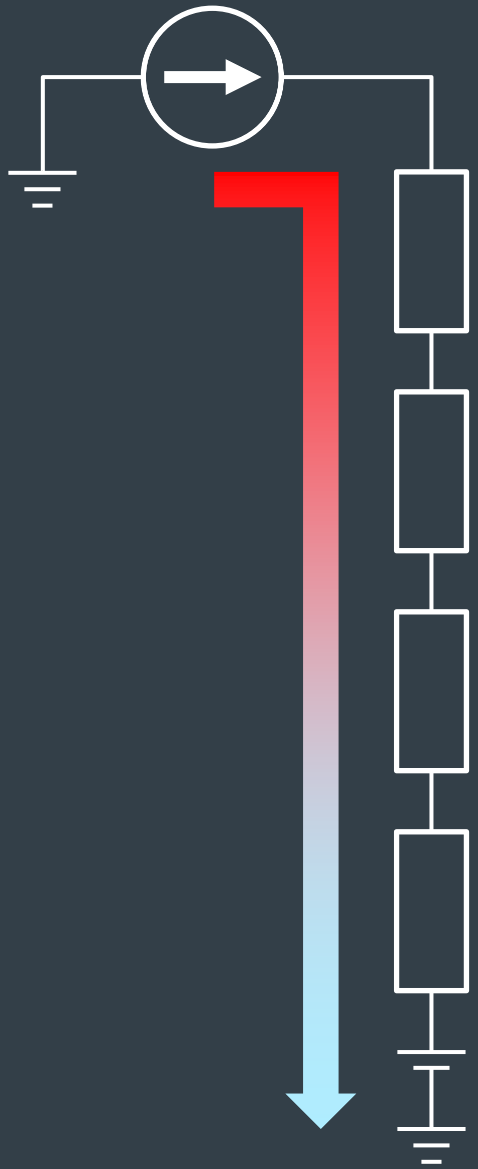
THERMAL MANAGEMENT IN ELECTRONIC DESIGN
EXTERNAL | DIGITALWEDAYS - WÜRTH ELEKTRONIK EISOS | 25-0V1-EN



WHY COOL?

HEAT TRANSFER

STAKEHOLDERS

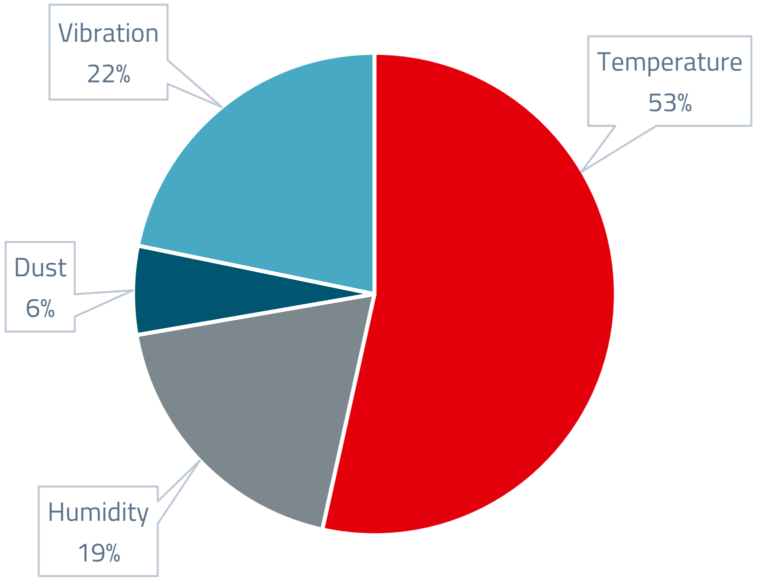
THERMAL WORKSHOP

WHY COOL?

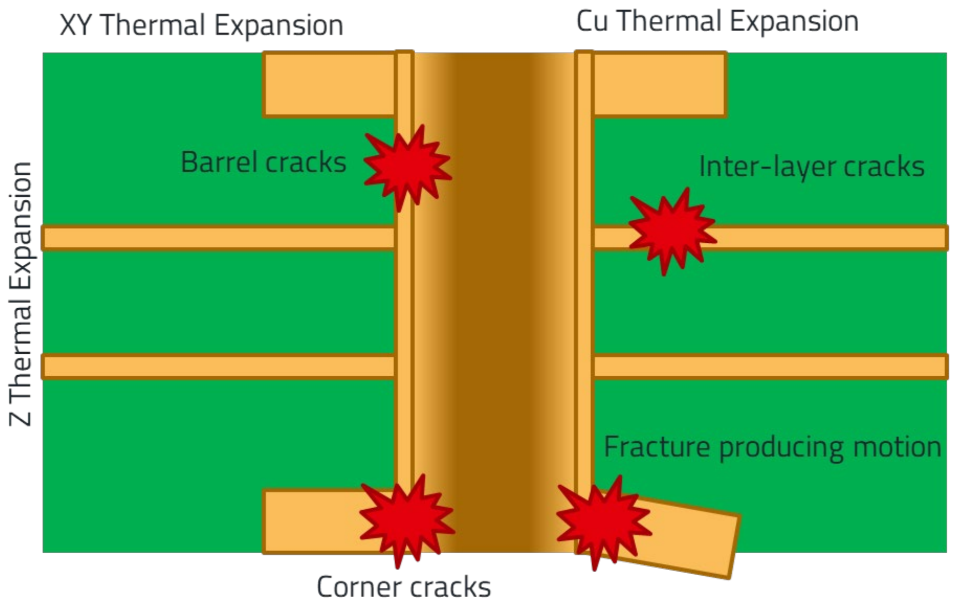
Problem Statement

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

Device Failure



Mechanical Stress Failure

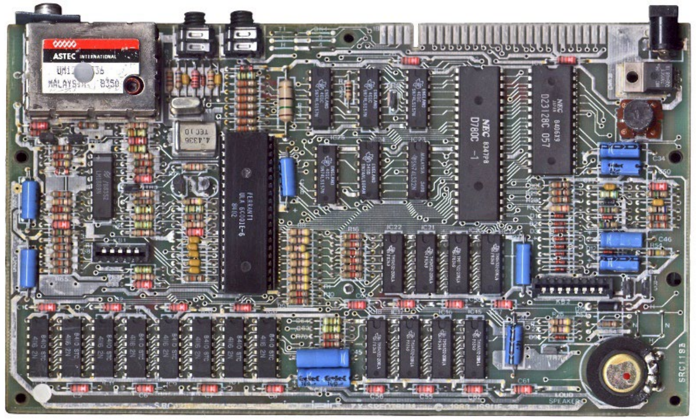


WHY COOL?

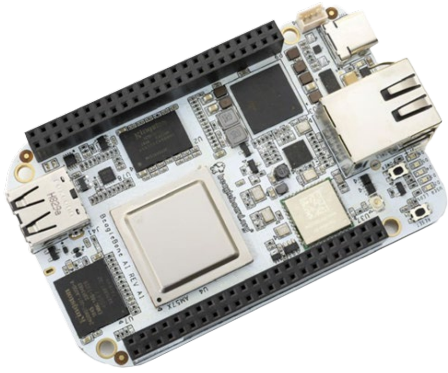
Problem Statement

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

ZX Spectrum
1980s



Beaglebone
2010s



22 W/cm^2 ⟷ 43 W/cm^2

WHY COOL?

Problem statement

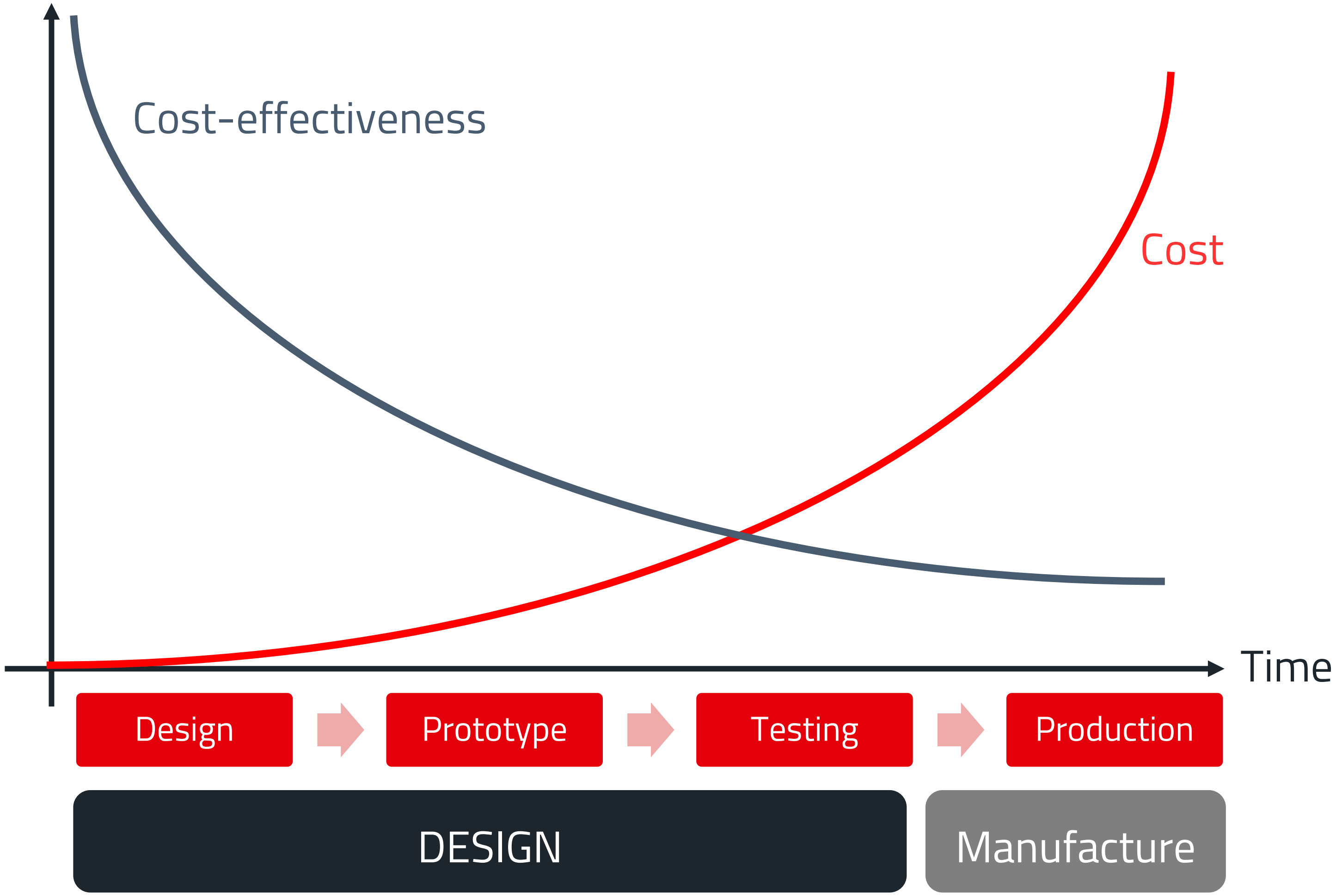
- Placement & PCB layout:
  - **Single & most important thermal design decision**

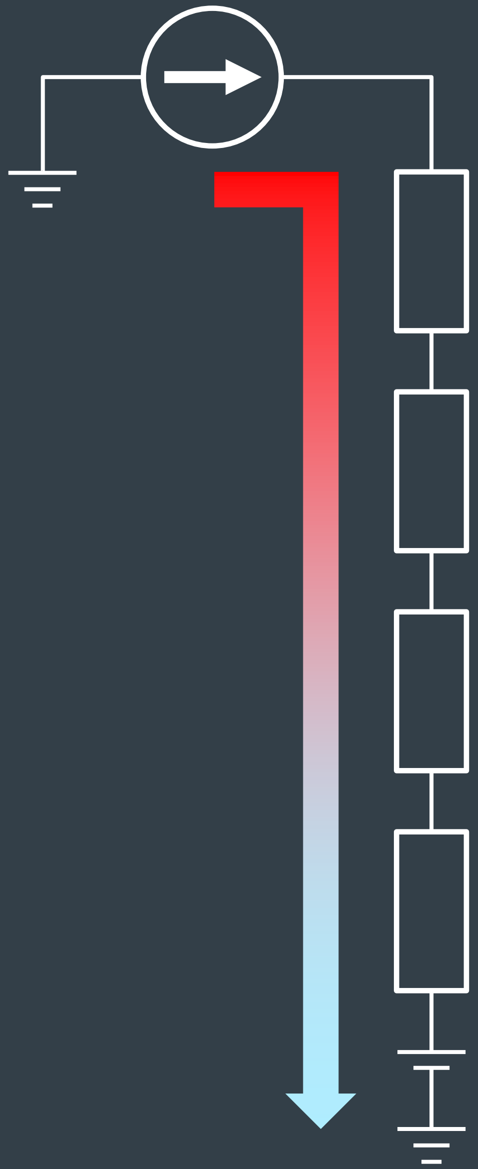
Best layout according to thermal criteria

Best layout according to electronic criteria

WHY COOL?

Development Impact





WHY COOL?

HEAT TRANSFER

STAKEHOLDERS

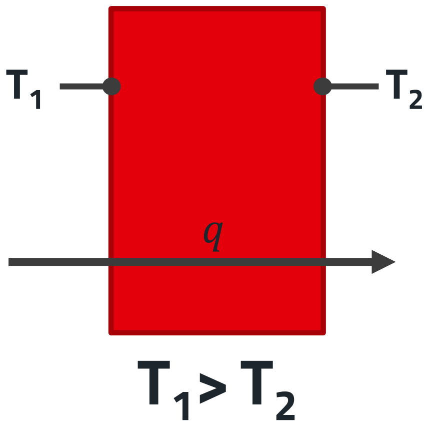
THERMAL WORKSHOP

HEAT TRANSFER

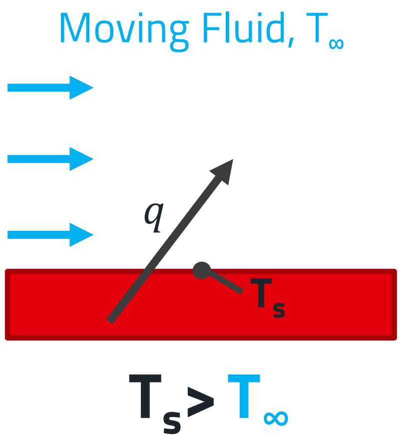
How Heat Behaves

- 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:

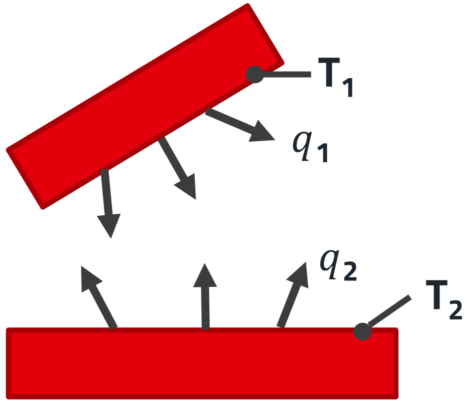
Conduction



Convection



Radiation



HEAT TRANSFER

Conduction

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

Contact Area

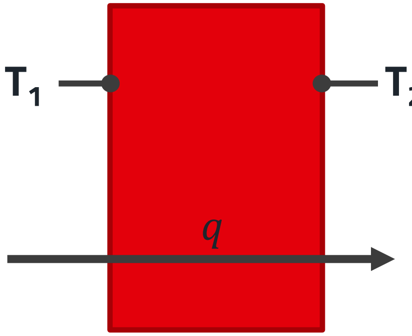
$$P = k \cdot \frac{A}{L} \cdot \Delta T$$

Thickness

Thermal Conductivity

Source: Depositphotos

Conduction



$T_1 > T_2$

Fourier's Law

HEAT TRANSFER

Convection

- Heat flow from solid to fluid proportional to temperature difference

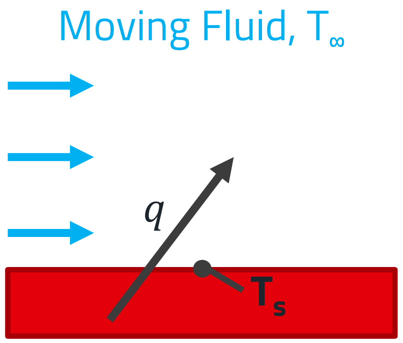
Convection Coefficient
h_vacuum=0
h_ambient=1
h_fan=10

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

Surface Area

Source: lne.es

Convection



$T_s > T_\infty$

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

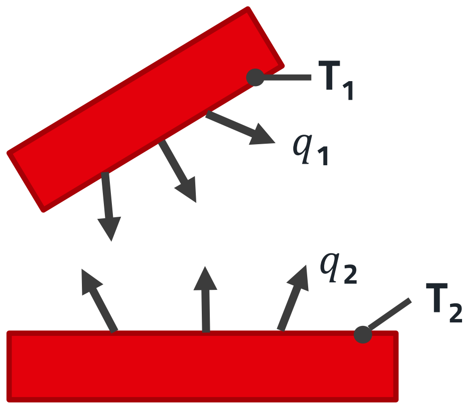
$$P = \varepsilon \cdot A_s \cdot \sigma \cdot (T_s^4 - T_{ent}^4) \cdot f_v$$

Geometric Factor

Emissivity

Boltzmann's Constant

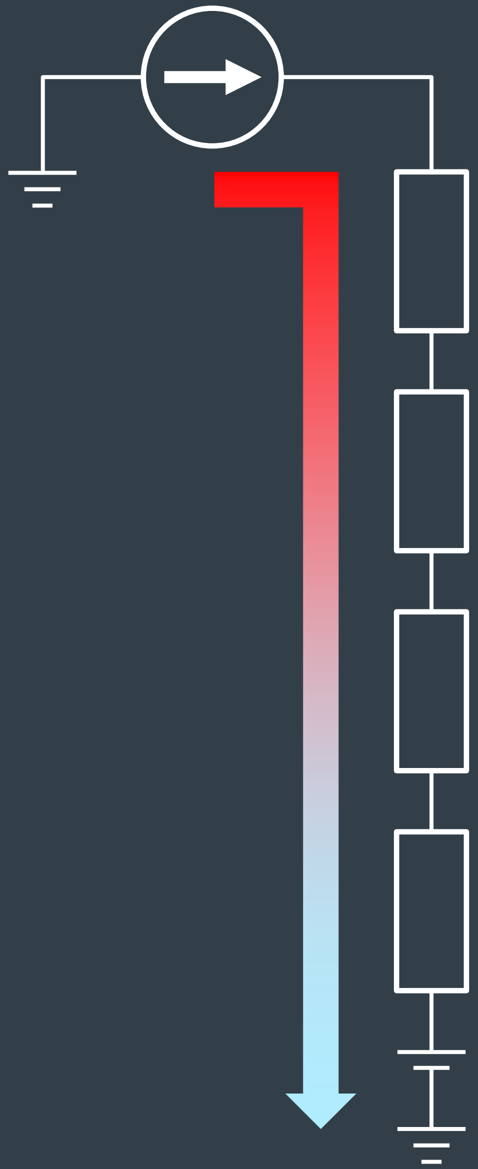
Radiation



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



WHY COOL?

HEAT TRANSFER

STAKEHOLDERS

THERMAL WORKSHOP

DESIGN CONSIDERATIONS

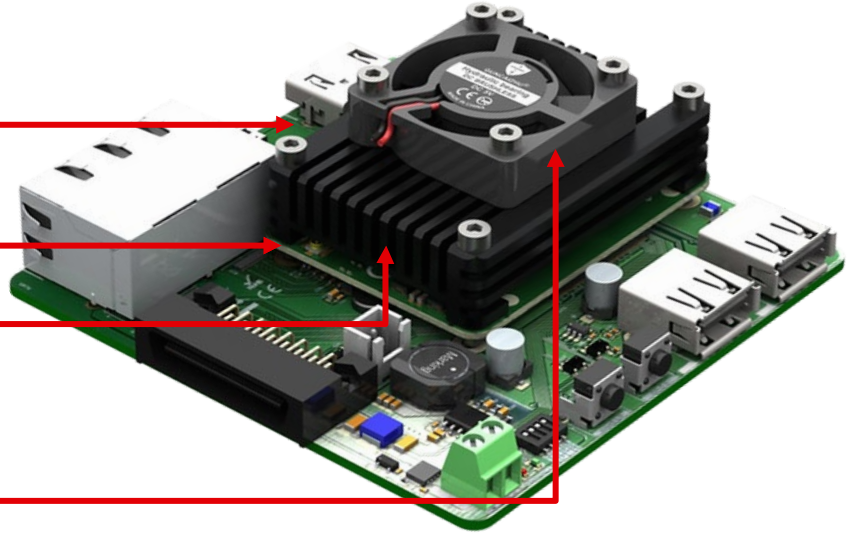
Thermal Management “Stakeholders”

PCB Level

Thermal Interface Materials

Heat Sinks

Cooling



DESIGN CONSIDERATIONS

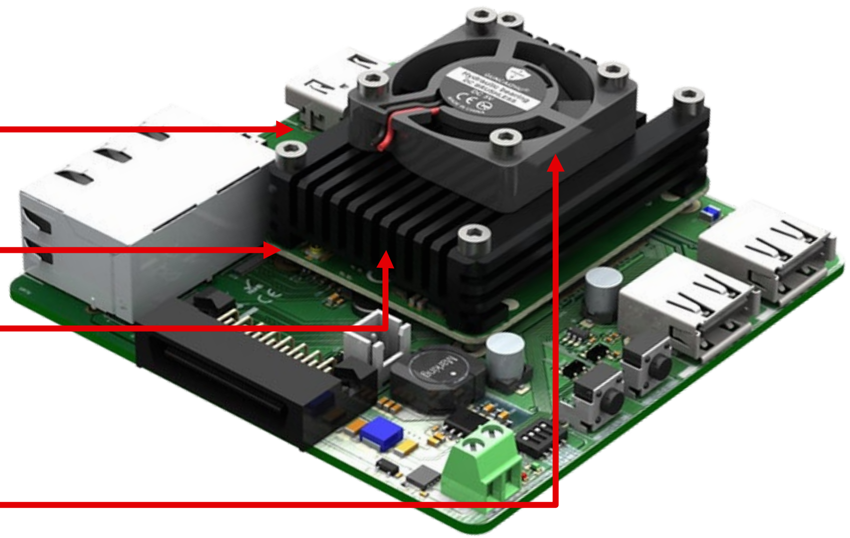
Thermal Management “Stakeholders”

PCB Level

Thermal Interface Materials

Heat Sinks

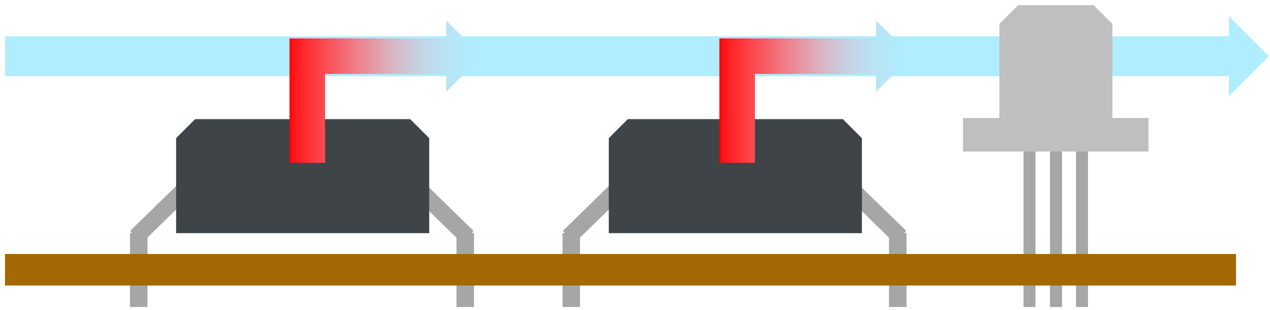
Cooling



DESIGN CONSIDERATIONS

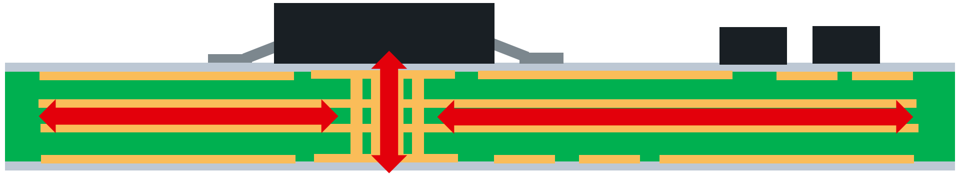
Thermal Management "Stakeholders": PCB Level

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



$$T_j = T_a + P \cdot R_{ja}$$

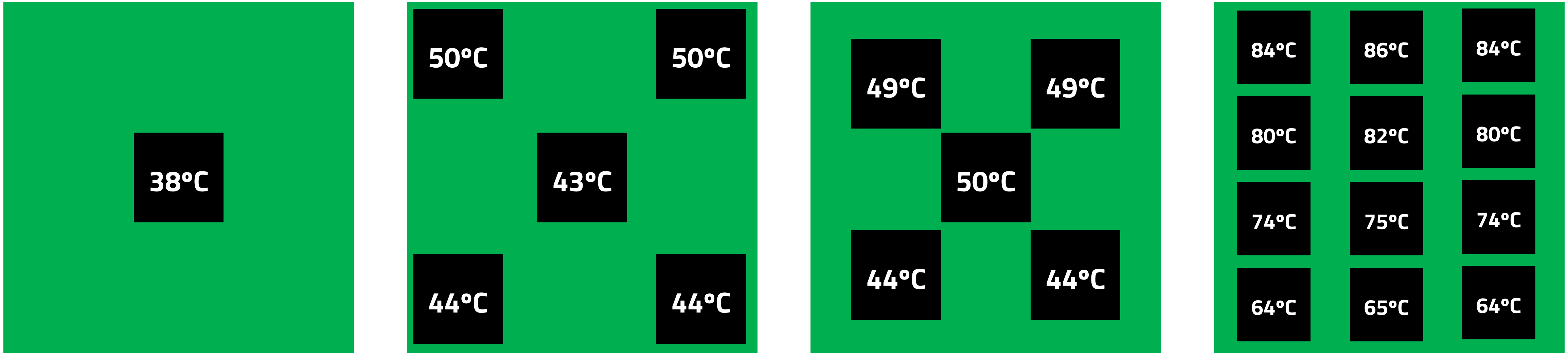
  - Due to miniaturization now 80-90 % of heat flows to the ambient through the PCB



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”

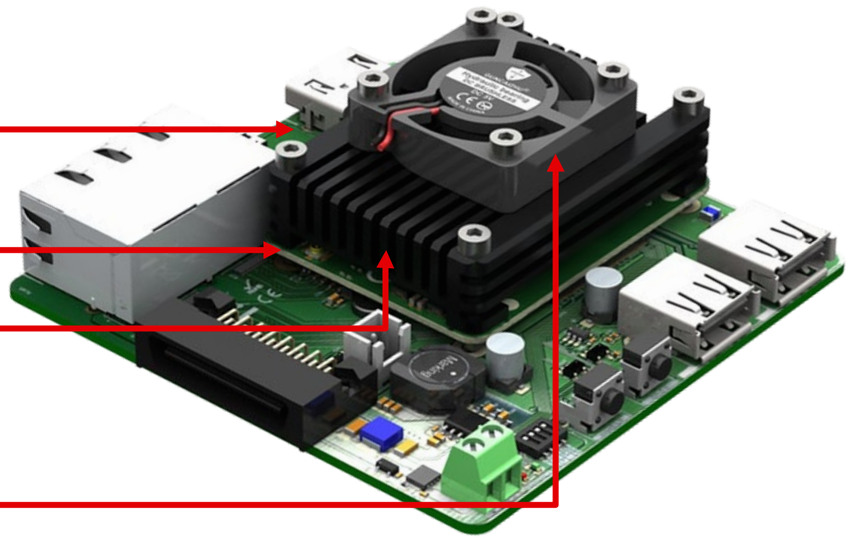
WÜRTH ELEKTRONIK
MORE THAN YOU EXPECT

PCB Level

Thermal Interface Materials

Heat Sinks

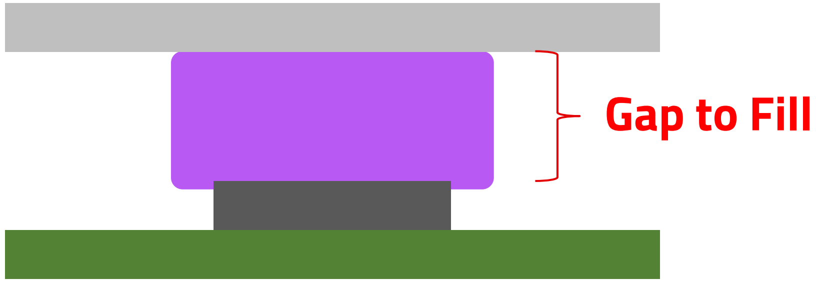
Cooling

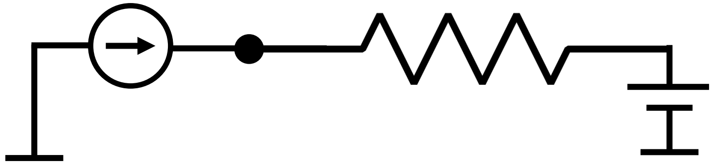


DESIGN CONSIDERATIONS

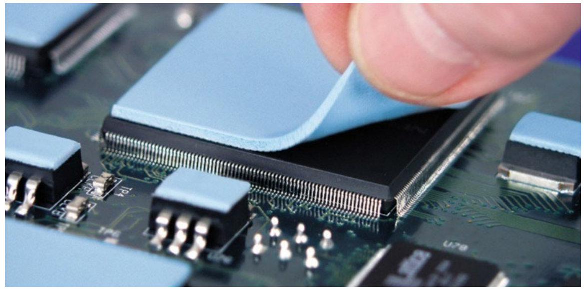
Thermal Management “Stakeholders”: Thermal Interface Materials

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





- When **using** a TIM:



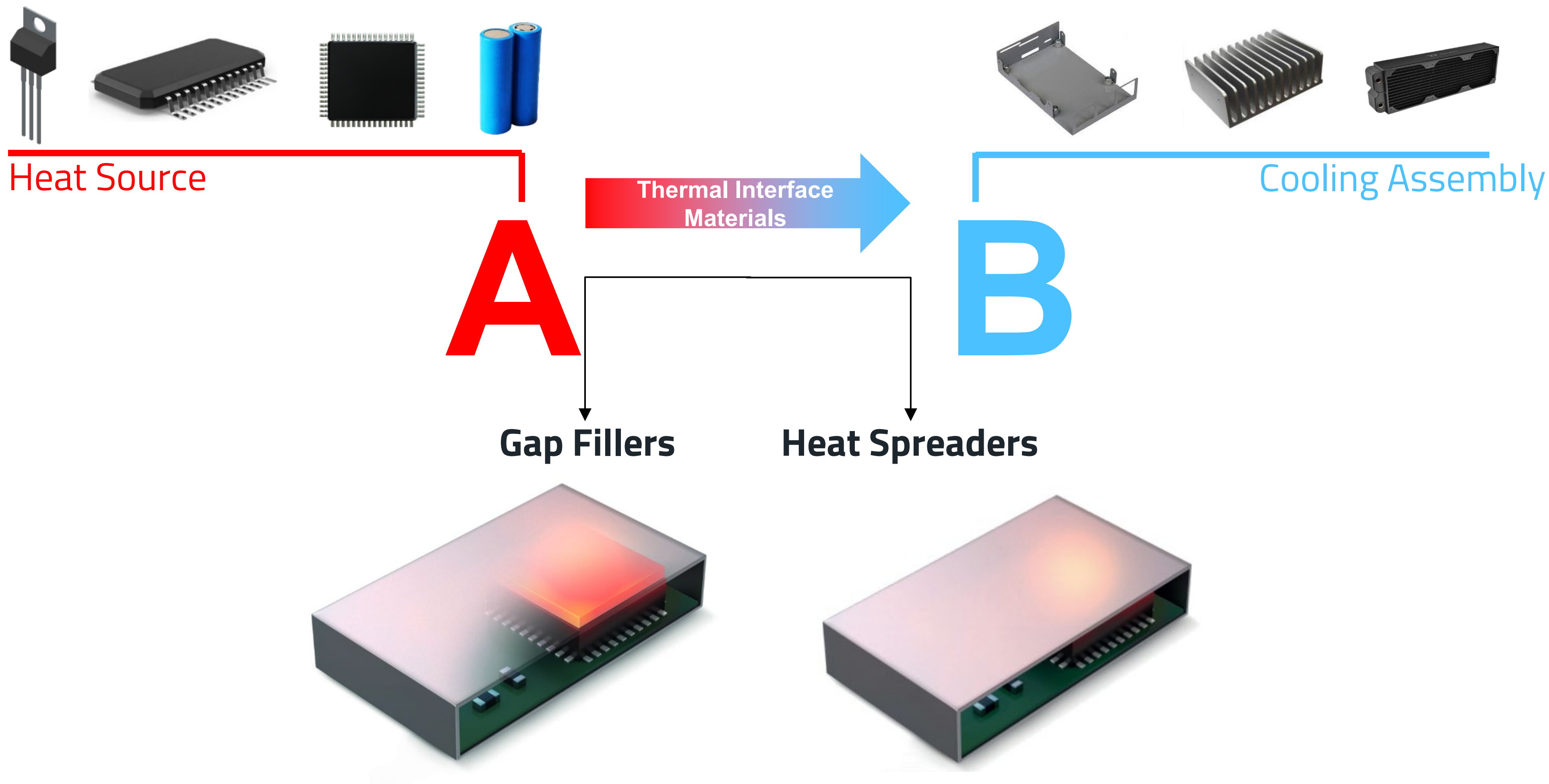
Source: *KVB reseaarch*

Optimize Processing

Optimize Cost-effectiveness

DESIGN CONSIDERATIONS

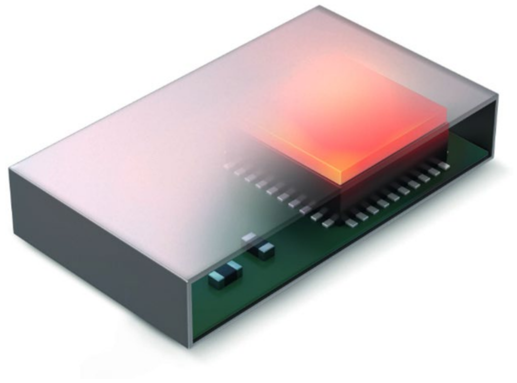
Thermal Management “Stakeholders”: Thermal Interface Materials



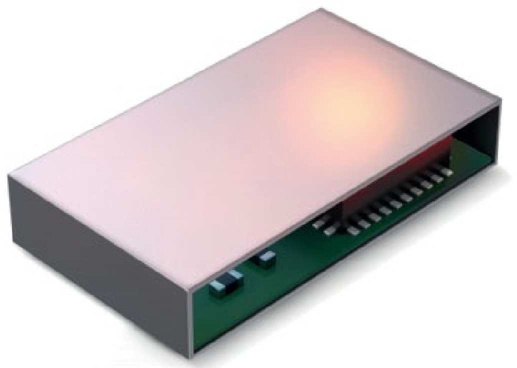
IMPORTANT NOTE!

Before explaining our portfolio…

- Thermal interface materials **are for:**
  - Giving a path to the heat *between two surfaces*
  - Ensure good contact *between two surfaces*

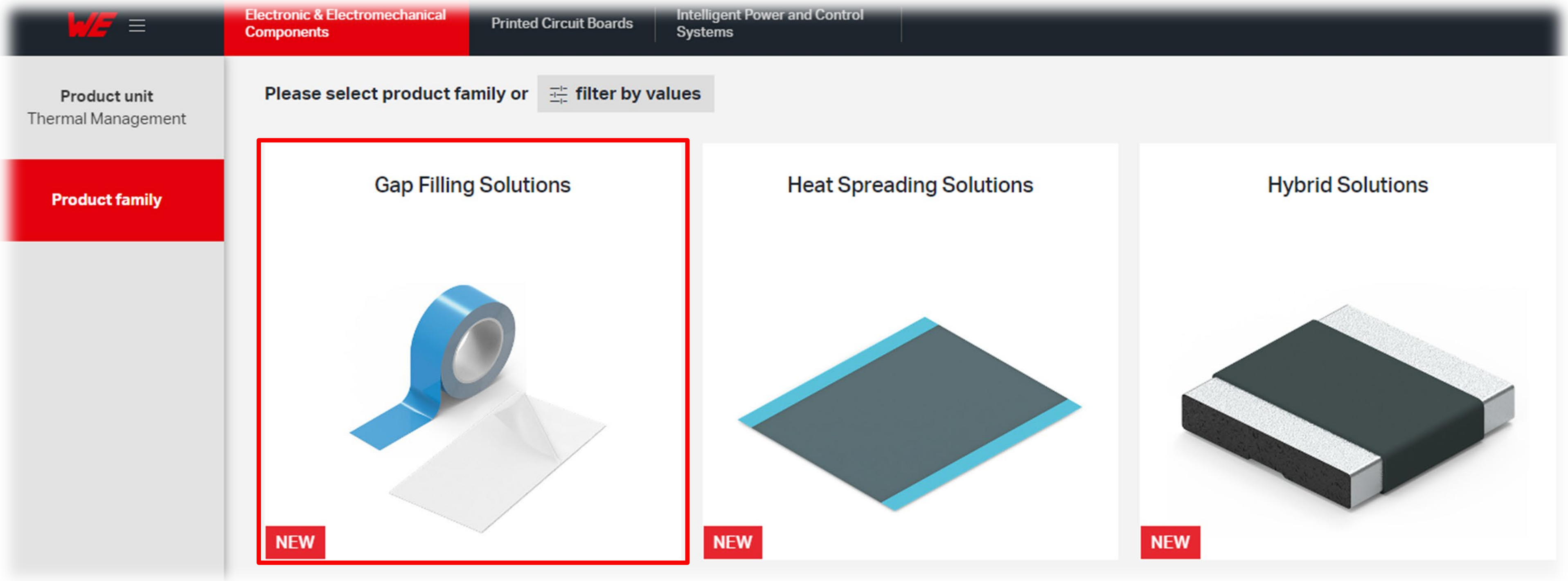


- Thermal interface materials **are not for:**
  - Apply on a material *without contact with another surface*



OUR TIM PORTFOLIO

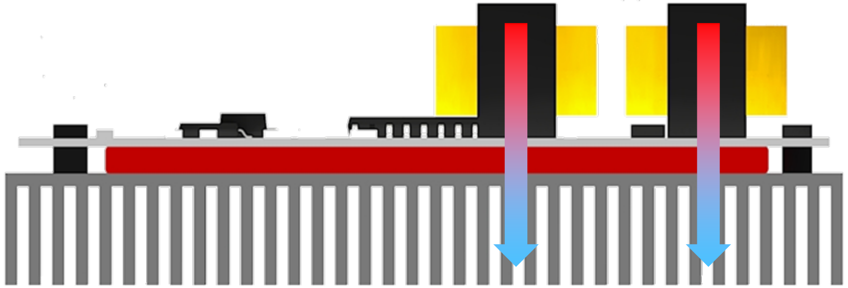
3 Main Categories



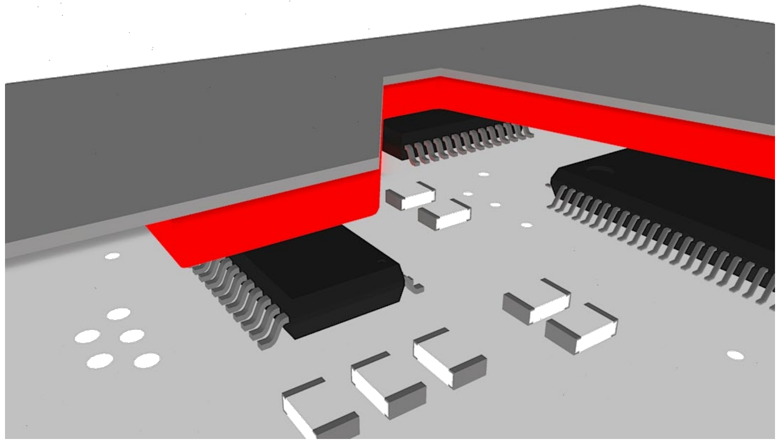
OUR TIM PORTFOLIO

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 %**

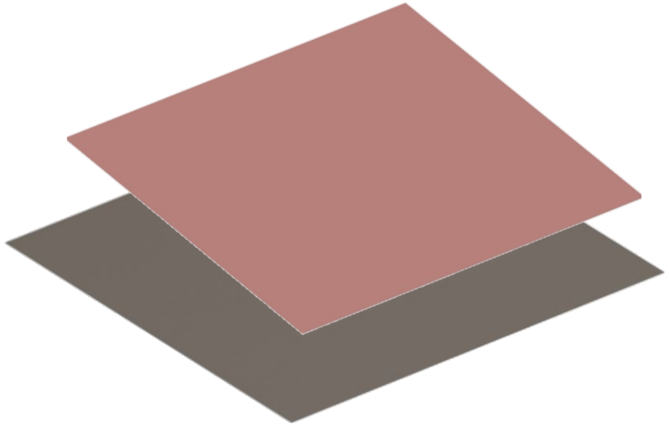


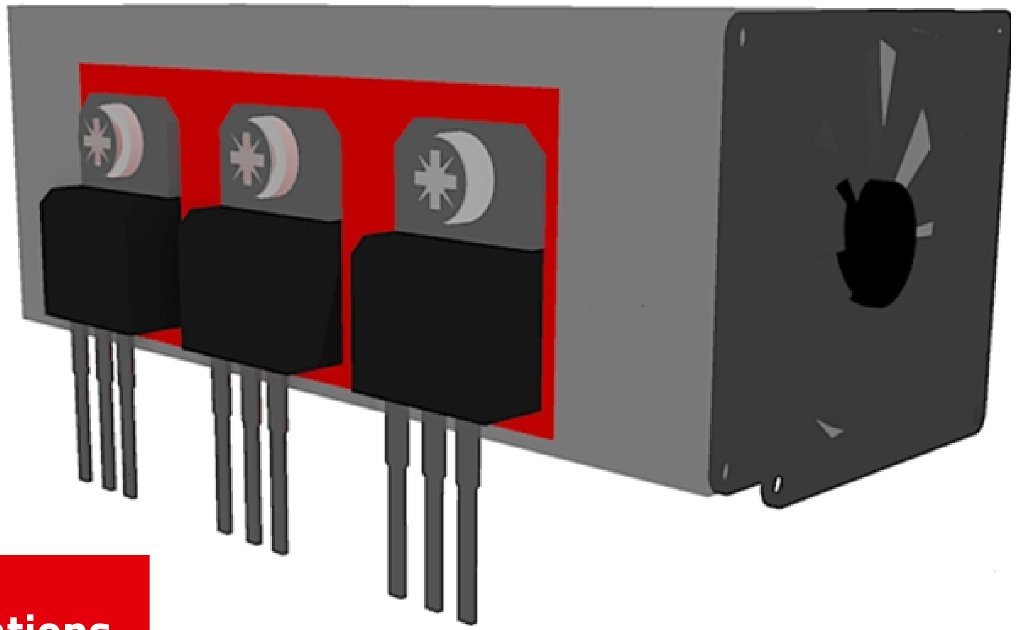
OUR TIM PORTFOLIO

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

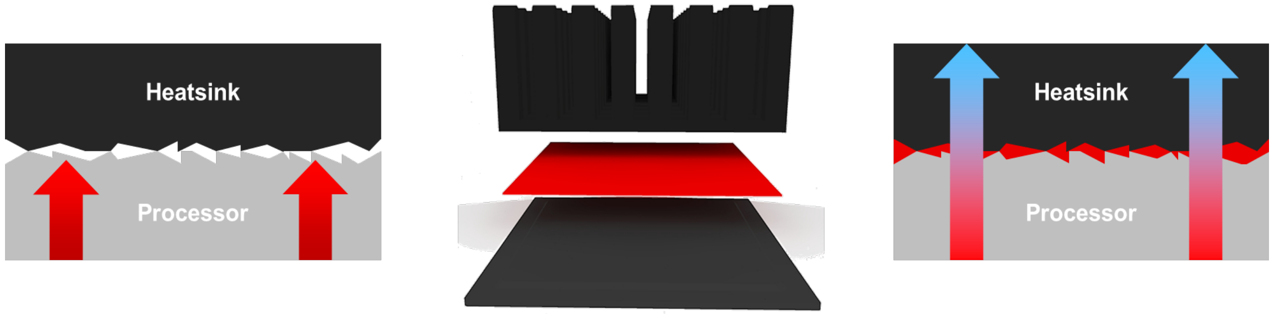




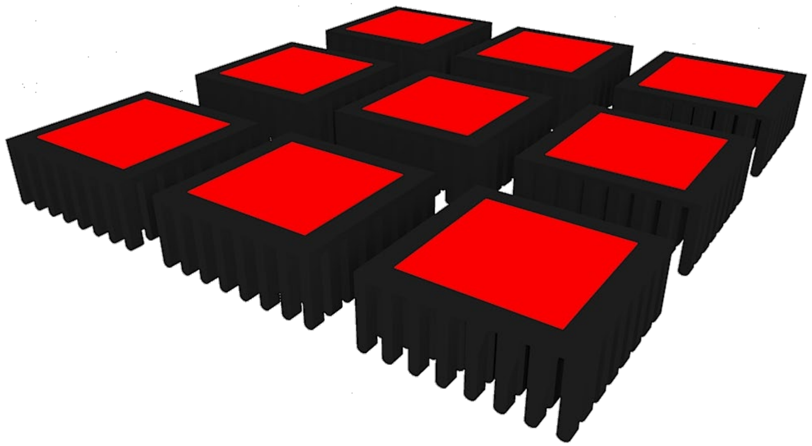
High Mechanical Stress Applications

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

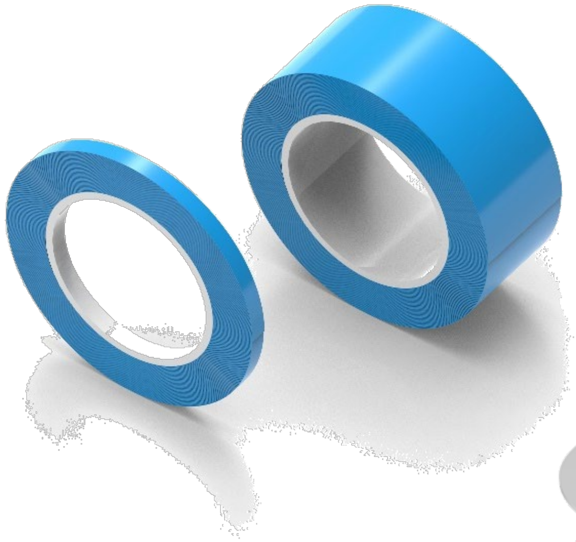
Alternative to Thermal Pastes

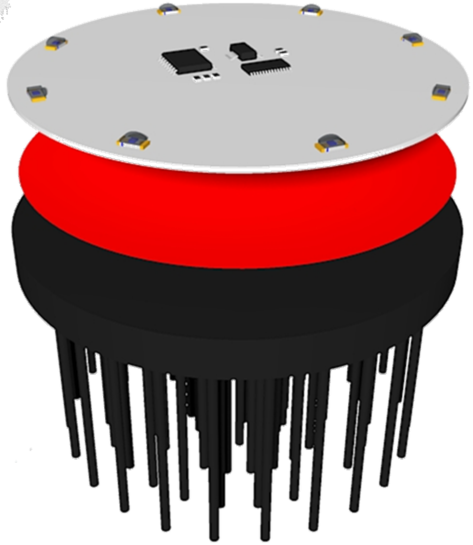
OUR TIM PORTFOLIO

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

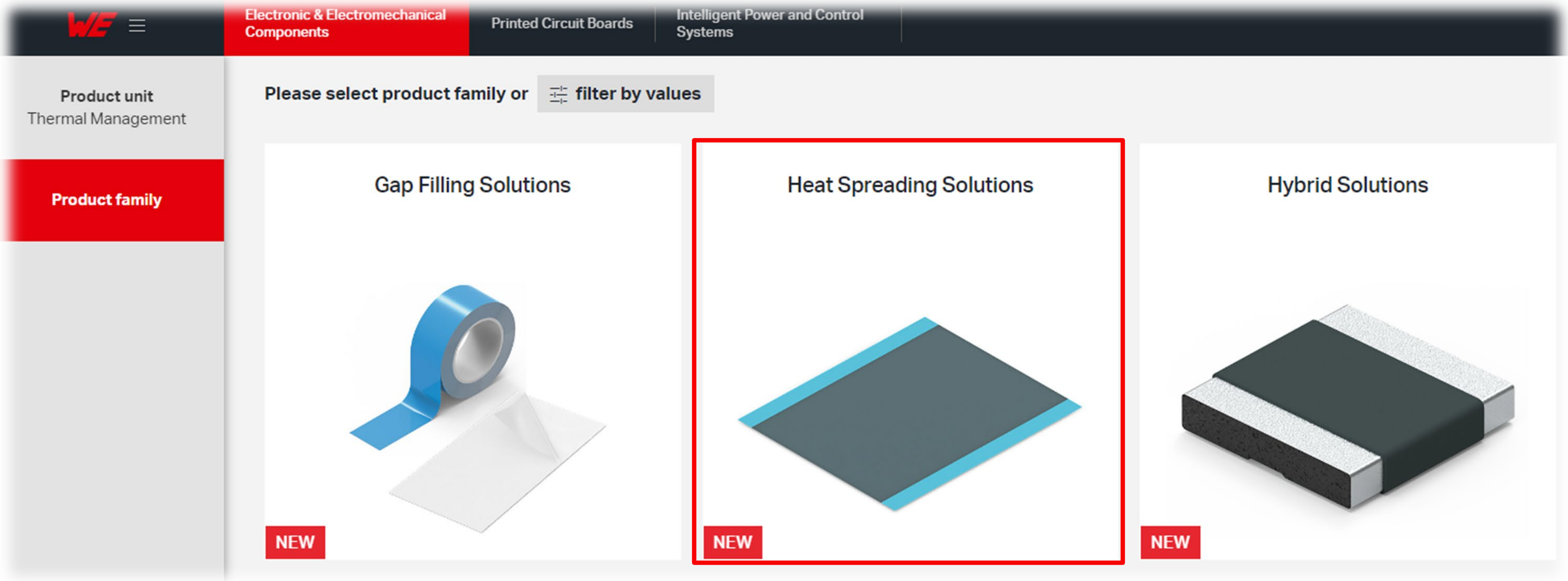




Adhesive Solution

OUR TIM PORTFOLIO

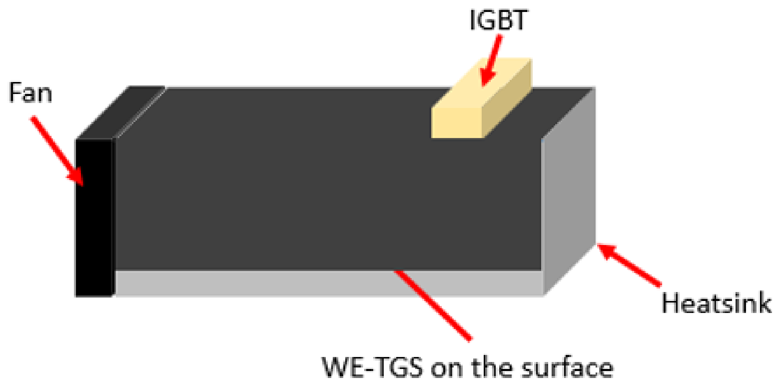
3 Main Categories

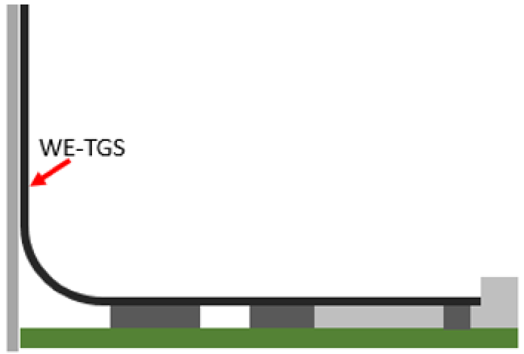


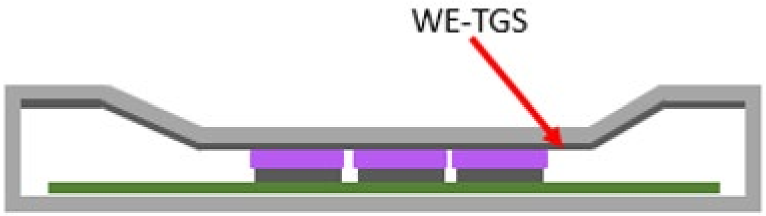
OUR TIM PORTFOLIO

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



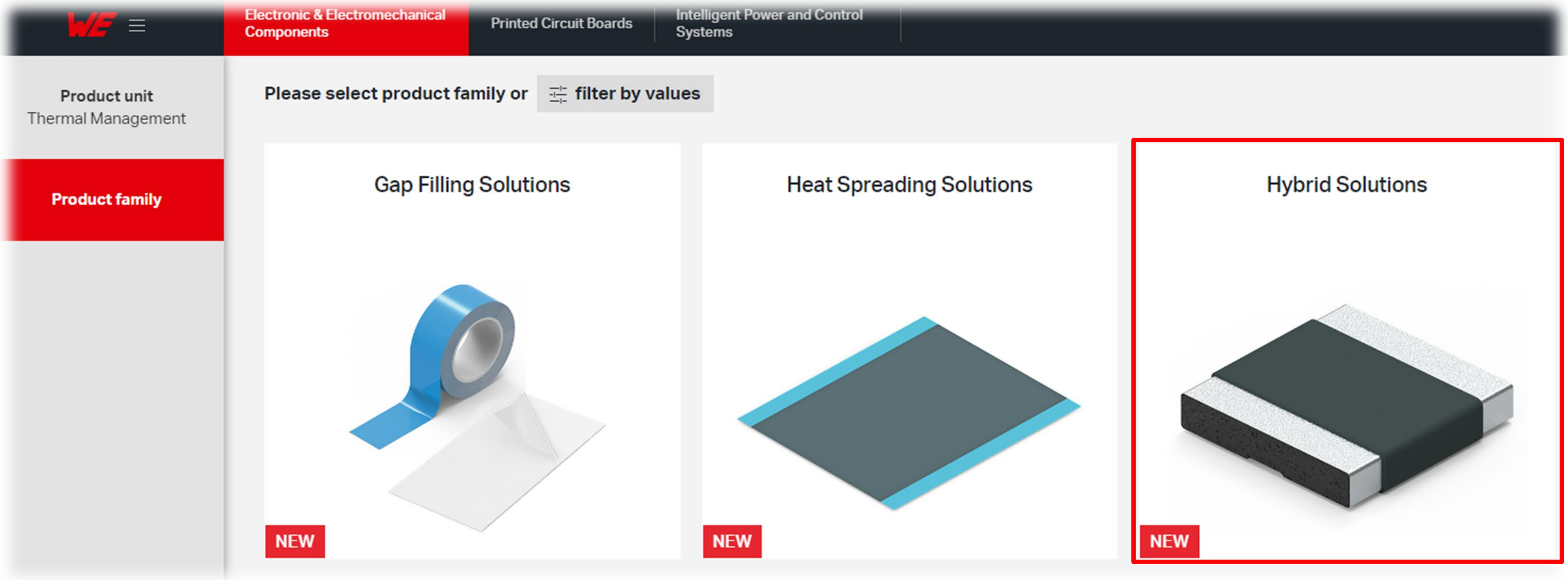




Heat Spreading Solution

OUR TIM PORTFOLIO

3 Main Categories

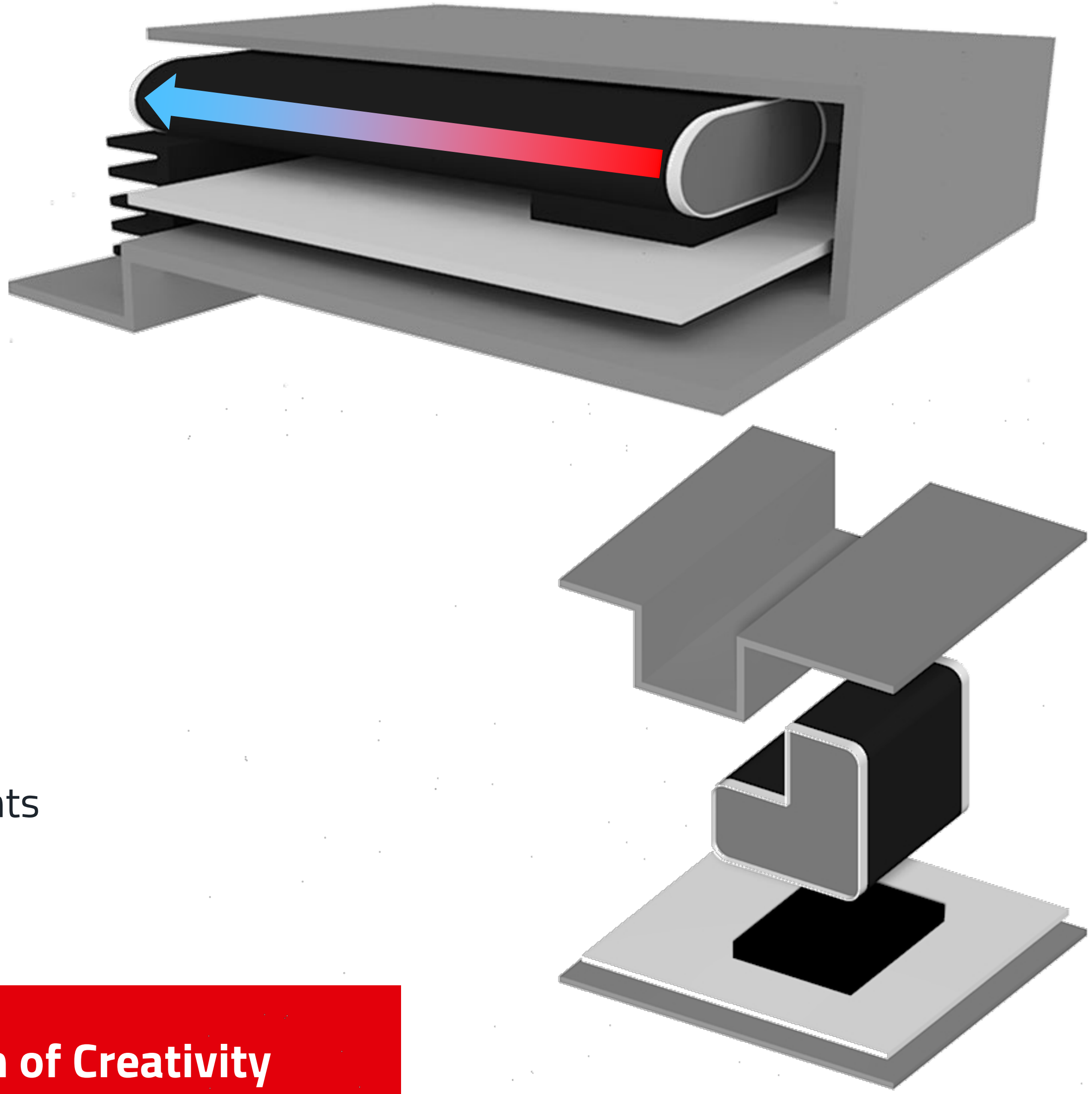


OUR TIM PORTFOLIO

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

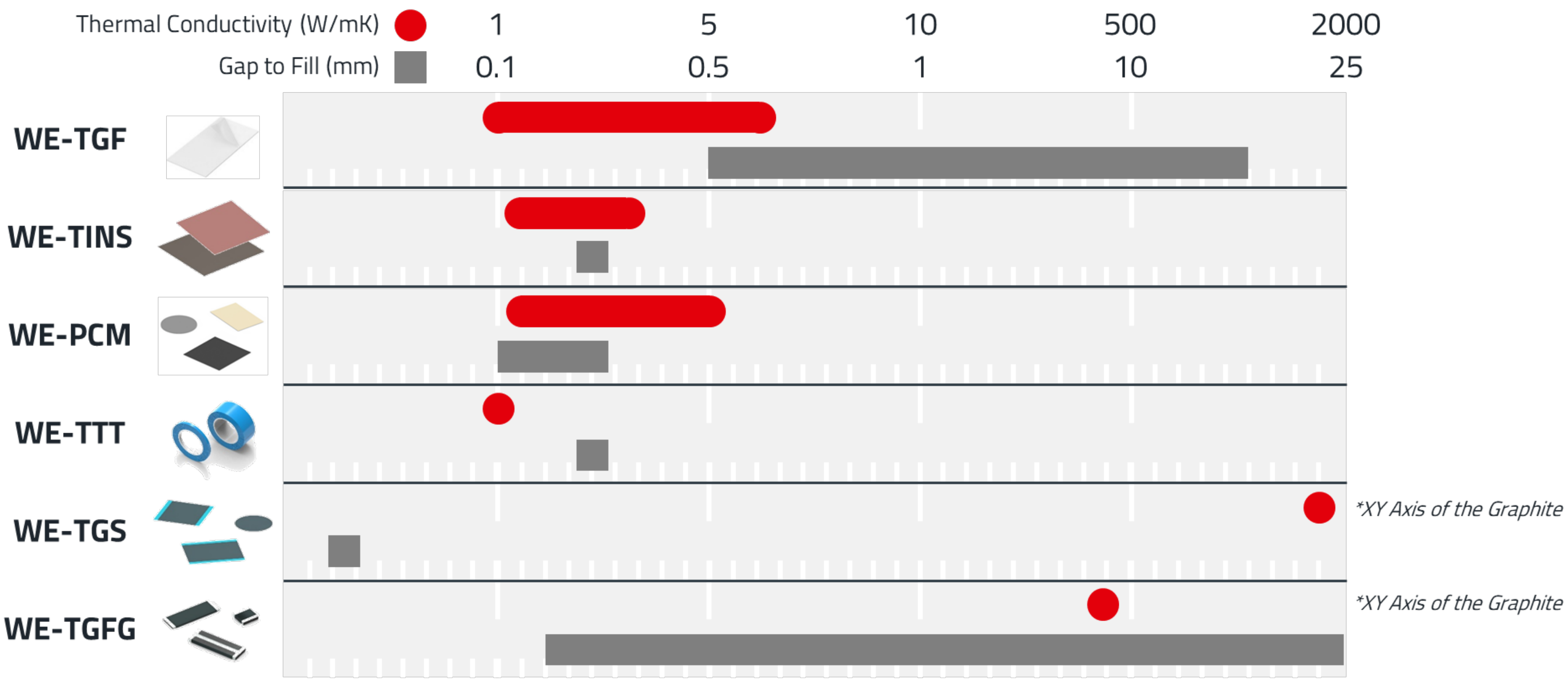
- Features
  - Highly versatile solution: profiles for particular applications
  - Can be used as a gap filler for high thicknesses
  - Can transfer heat to cooling assemblies away from components



More Freedom of Creativity

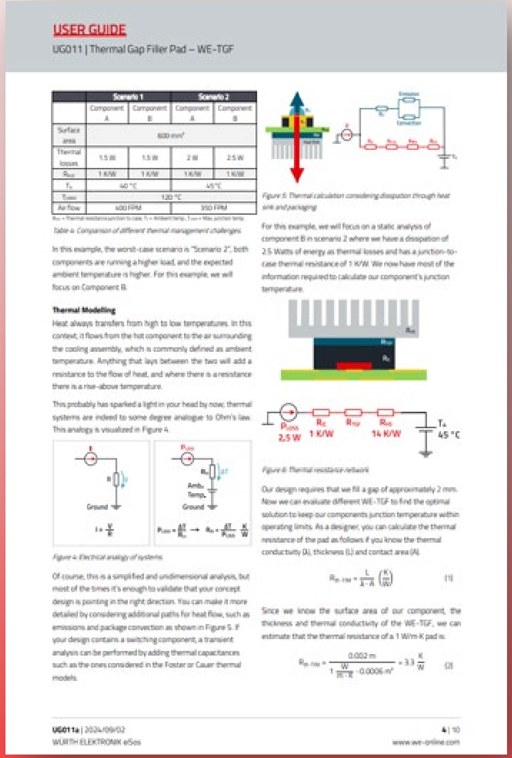
OUR TIM PORTFOLIO

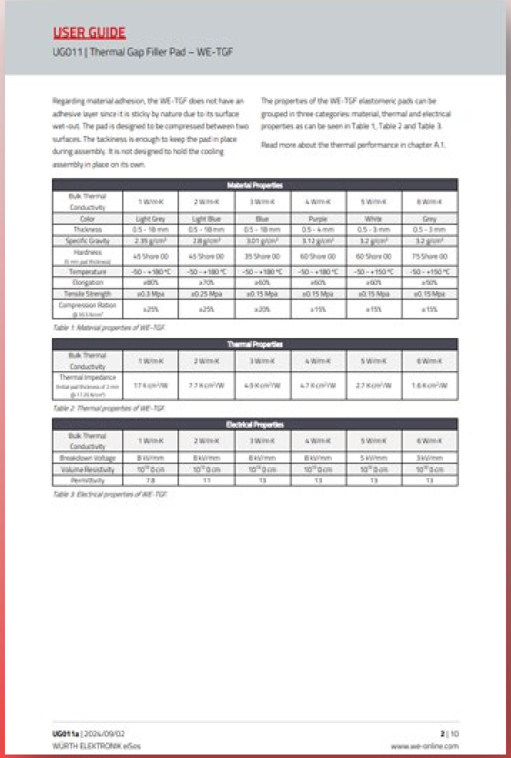
Summary

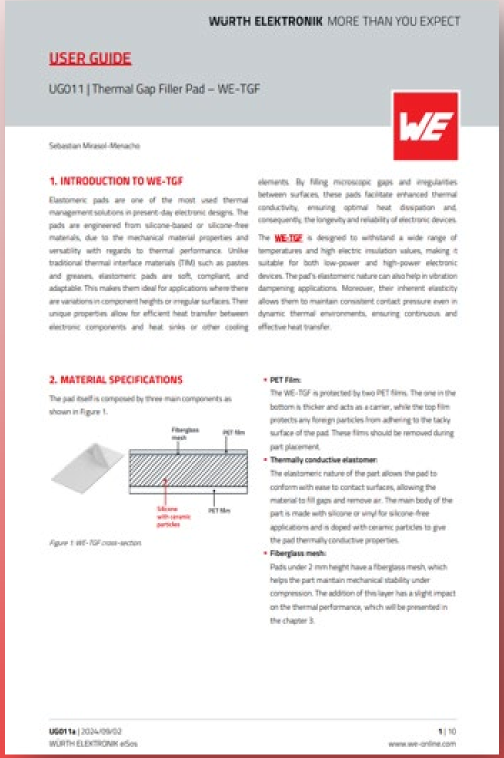


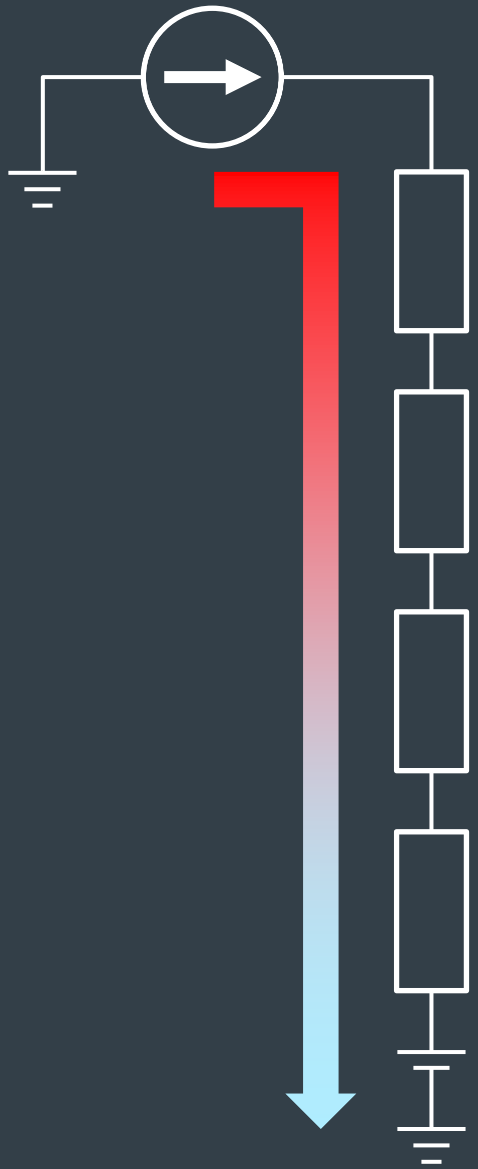
OUR TIM PORTFOLIO

For More Information see our User Guideline









WHY COOL?

HEAT TRANSFER

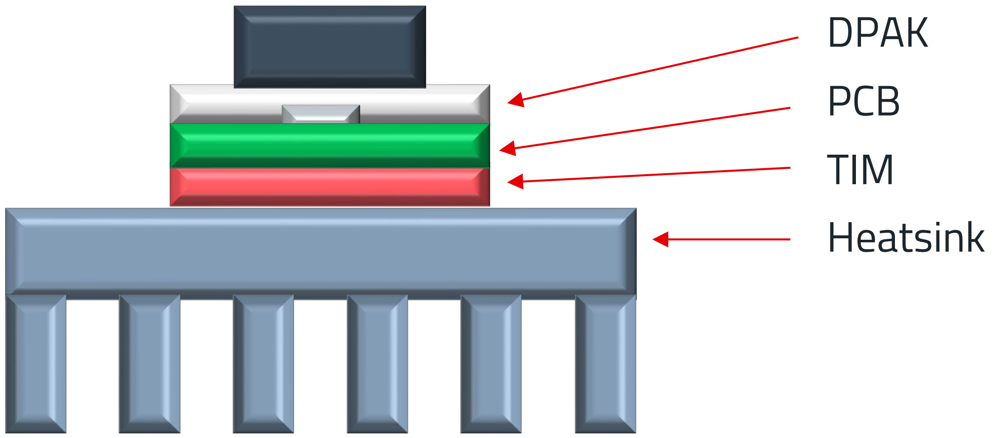
DESIGN CONSIDERATIONS

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

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

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

$$l = Material\ thickness\ of\ TIM\ [m]$$

$$A = Contact\ surface\ area\ of\ TIM\ [m^2]$$

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

- 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

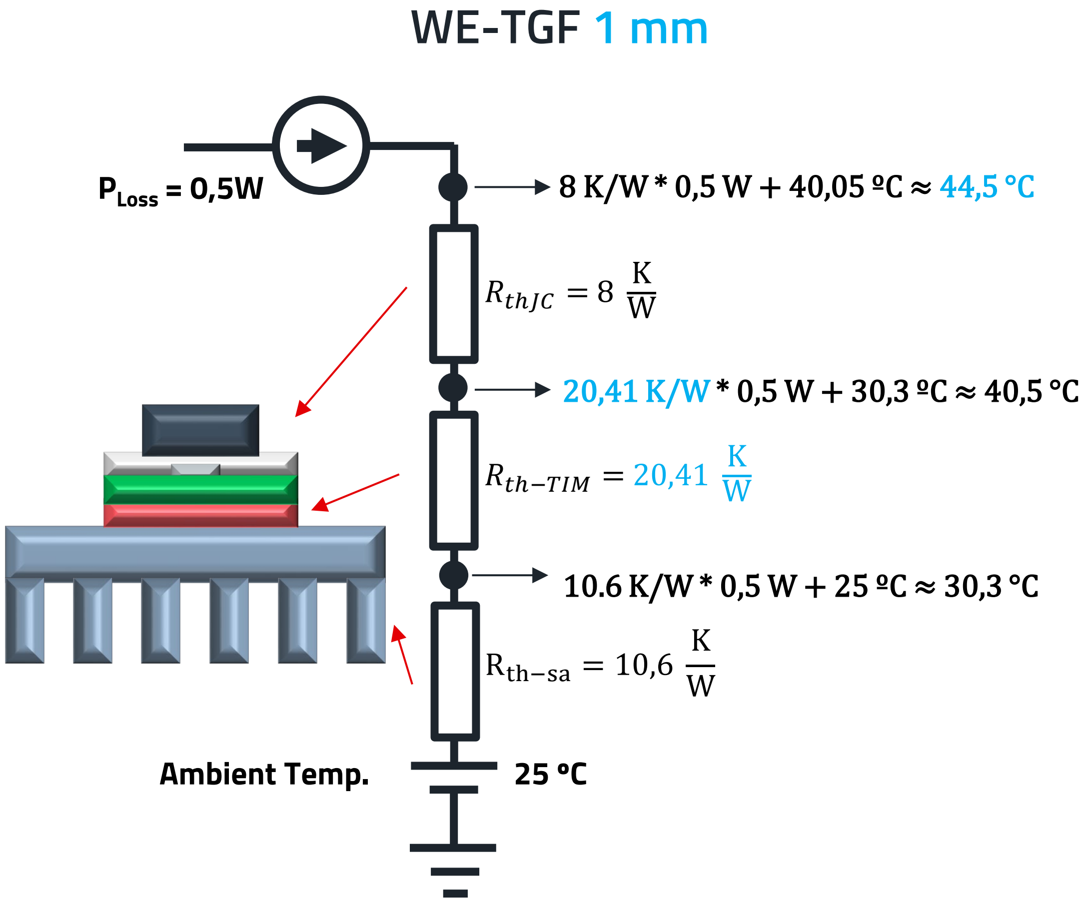
RthJC – Datasheet information

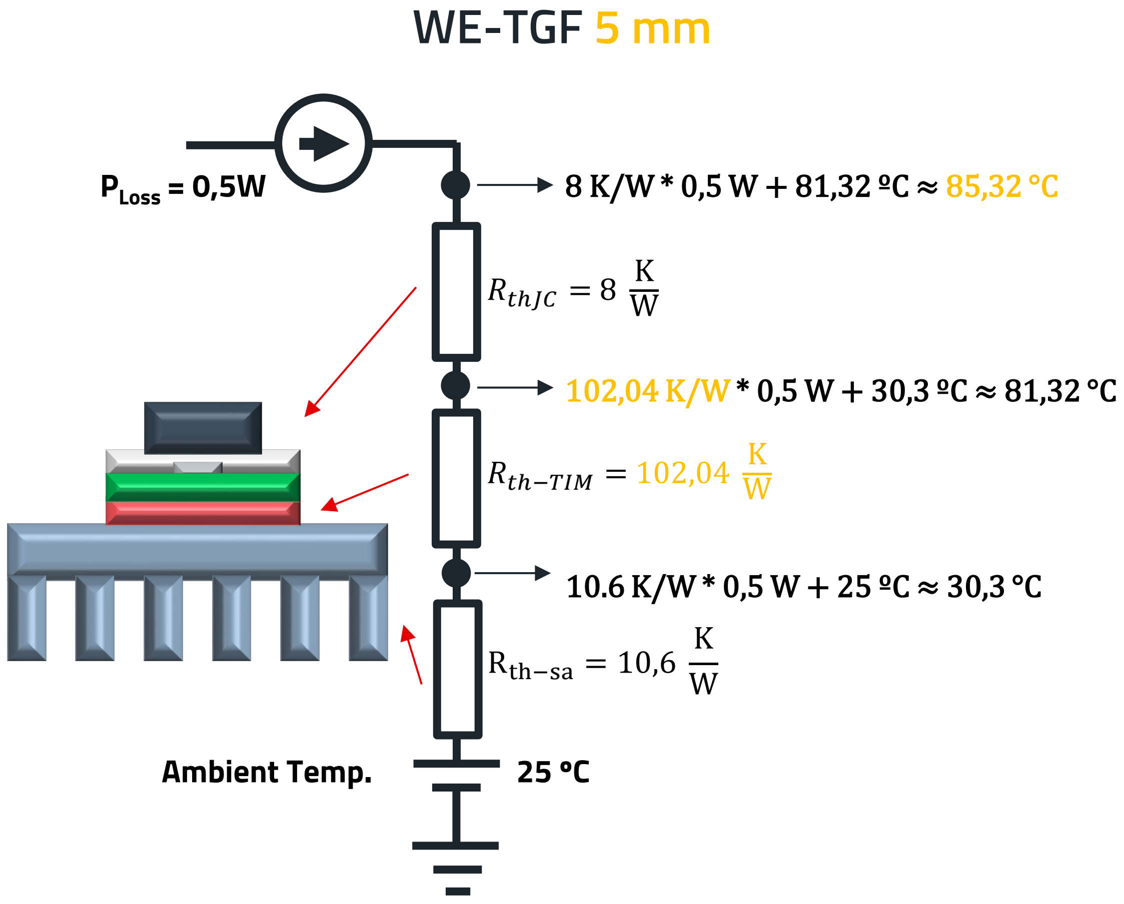
Table 2: Thermal data

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: $R_{th-Jc} = 8\ \frac{\mathrm{K}}{\mathrm{W}}$

THERMAL MEASUREMENT EXAMPLE





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

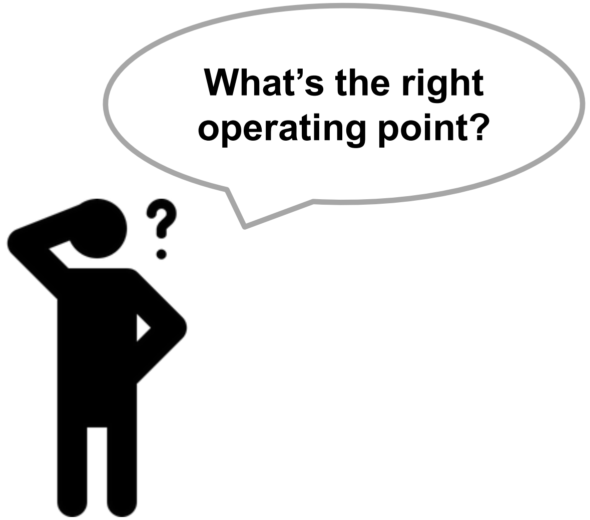
THERMAL MEASUREMENT EXAMPLE

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.