HOT OFF THE PRESS: THERMAL MANAGEMENT SOLUTIONS AND IMPLEMENTATION

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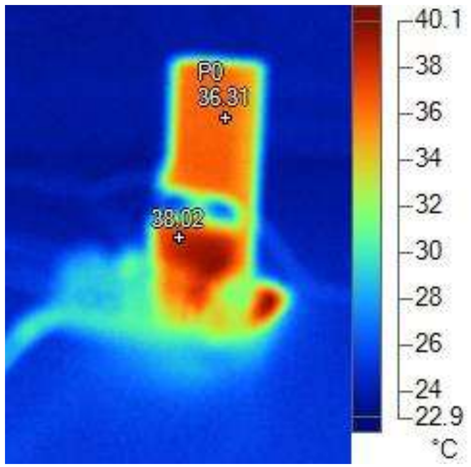
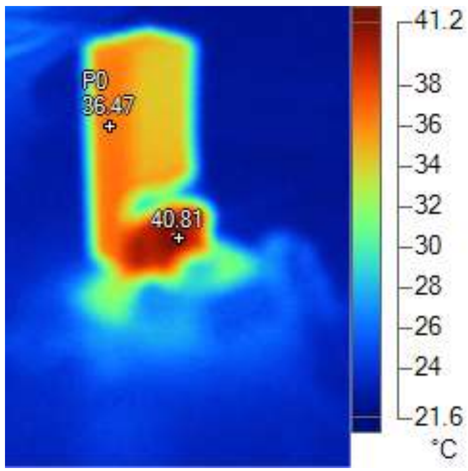
WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

TODAY'S AGENDA

- Hot Topic
- Thermal Management Basics
- Thermal Calculations
- Thermal Management Solutions
- Resources and Services



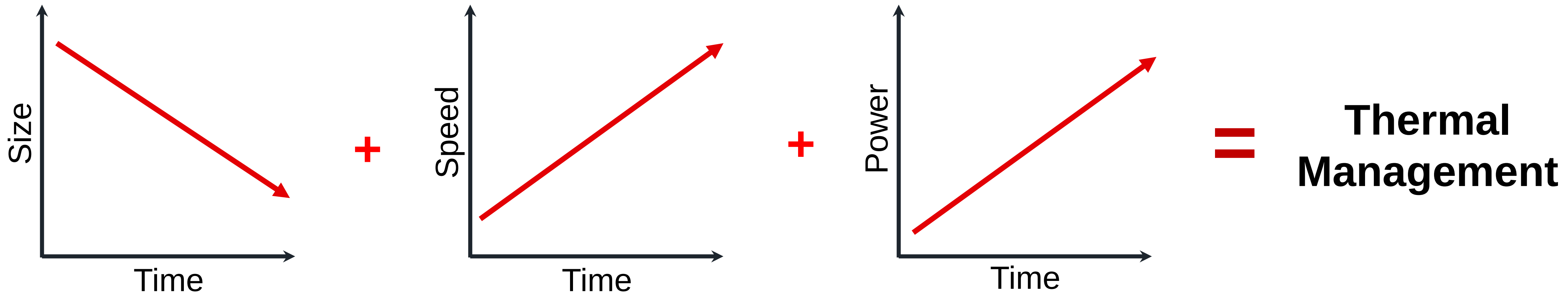


HOT TOPIC

HOT TOPIC

- Thermal Management; The need:
  - Component miniaturization
  - Compact designs
  - Increase in power density

- Electronic design tendencies:

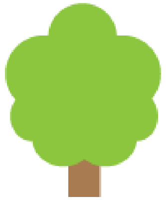


HOT TOPIC

- It’s not about just about keeping it cool, it’s about keeping it reliable!
  - Rule of thumb between thermal designers:

10ºC **Temperature decrease** = **x2 Component reliability**

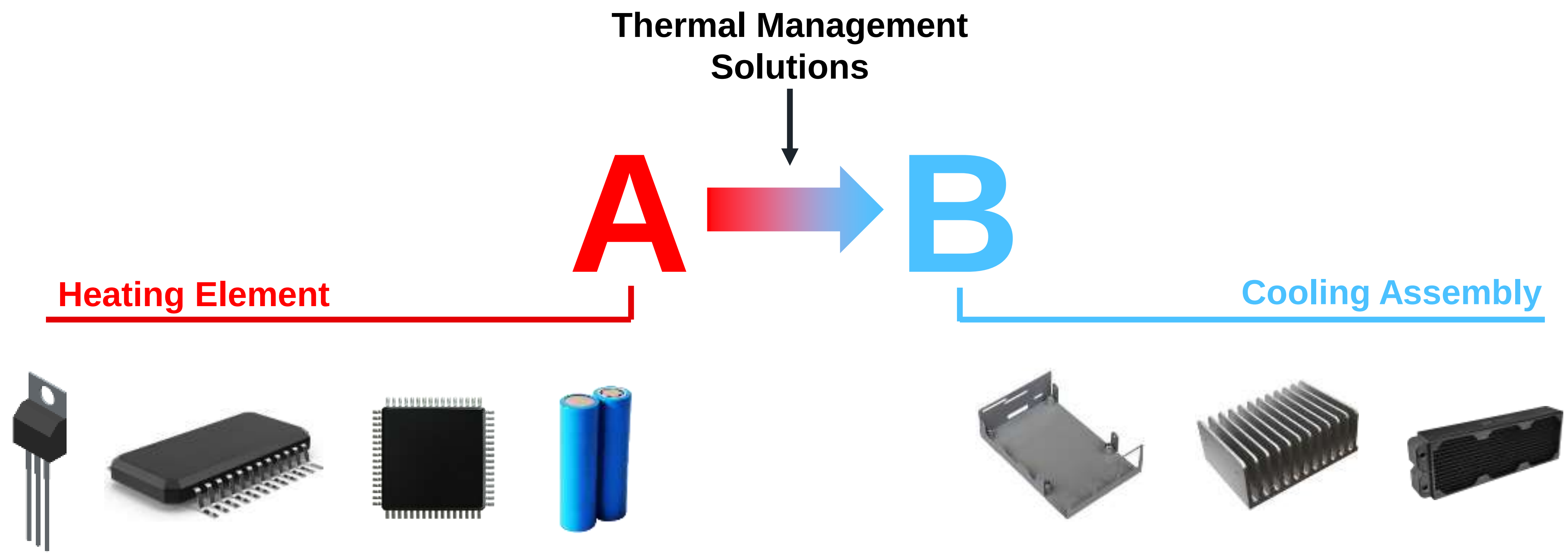
  - We all benefit!

 **Robust devices** = **Customers** &  **Less e-waste**

- Products need to comply to certain standards, which influence the product boundaries:
  - **IEC 60950** Safety of Information Technology Equipment
  - **IEC 60721-2-1** Classification of Environment Conditions, Part 2: Environmental Conditions Appearing in Nature –Precipitation and wind

THERMAL MANAGEMENT BASICS

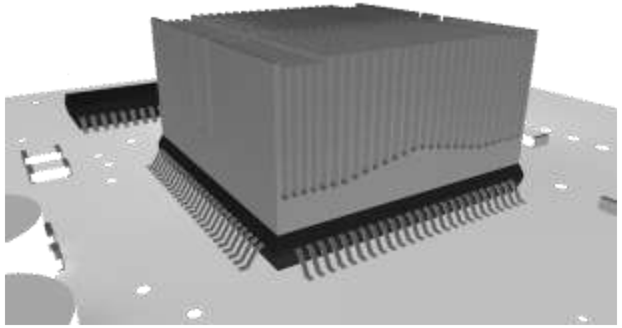
THERMAL MANAGEMENT

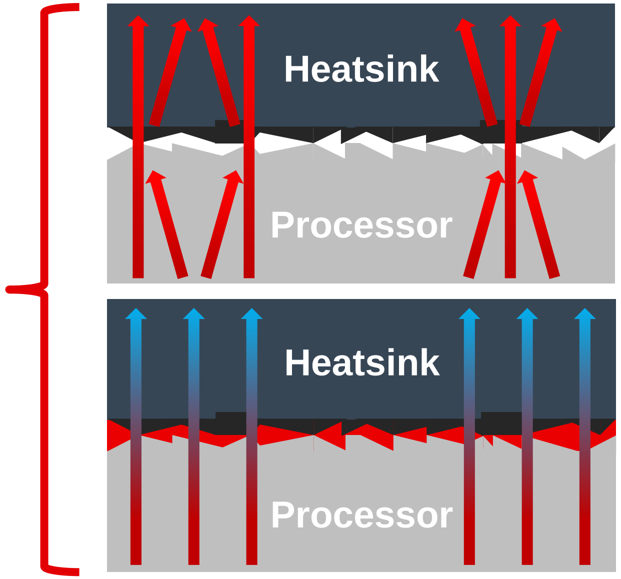


THERMAL MANAGEMENT

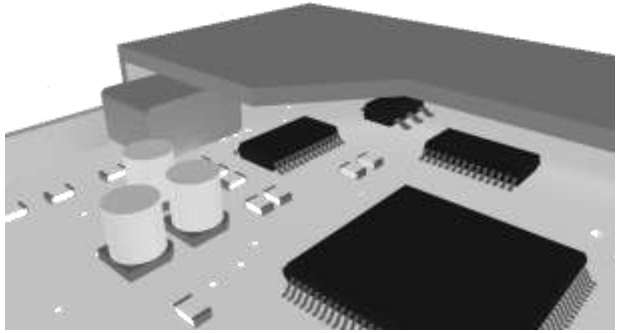
- We can provide a path for heat to flow by:
  - Filling a gap

Small Gap



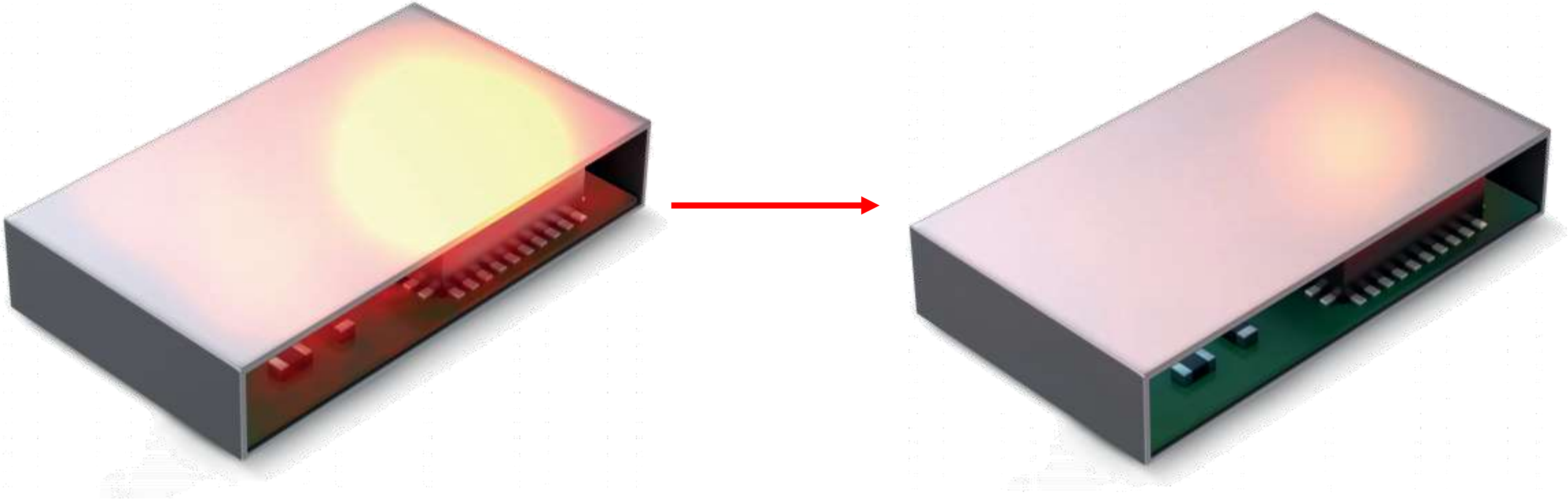


Large Gap



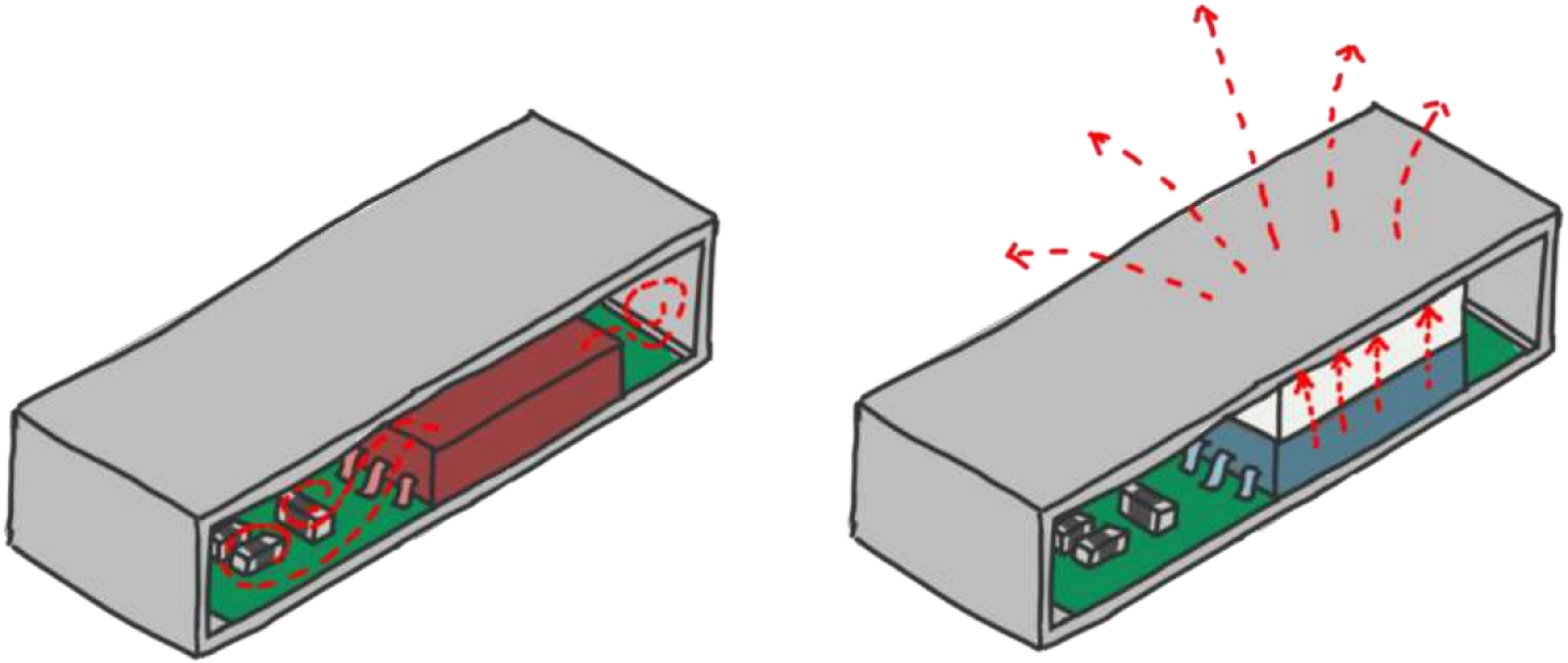
THERMAL MANAGEMENT

- We can provide a path for heat to flow by:
  - Filling a gap
  - Spreading the heat



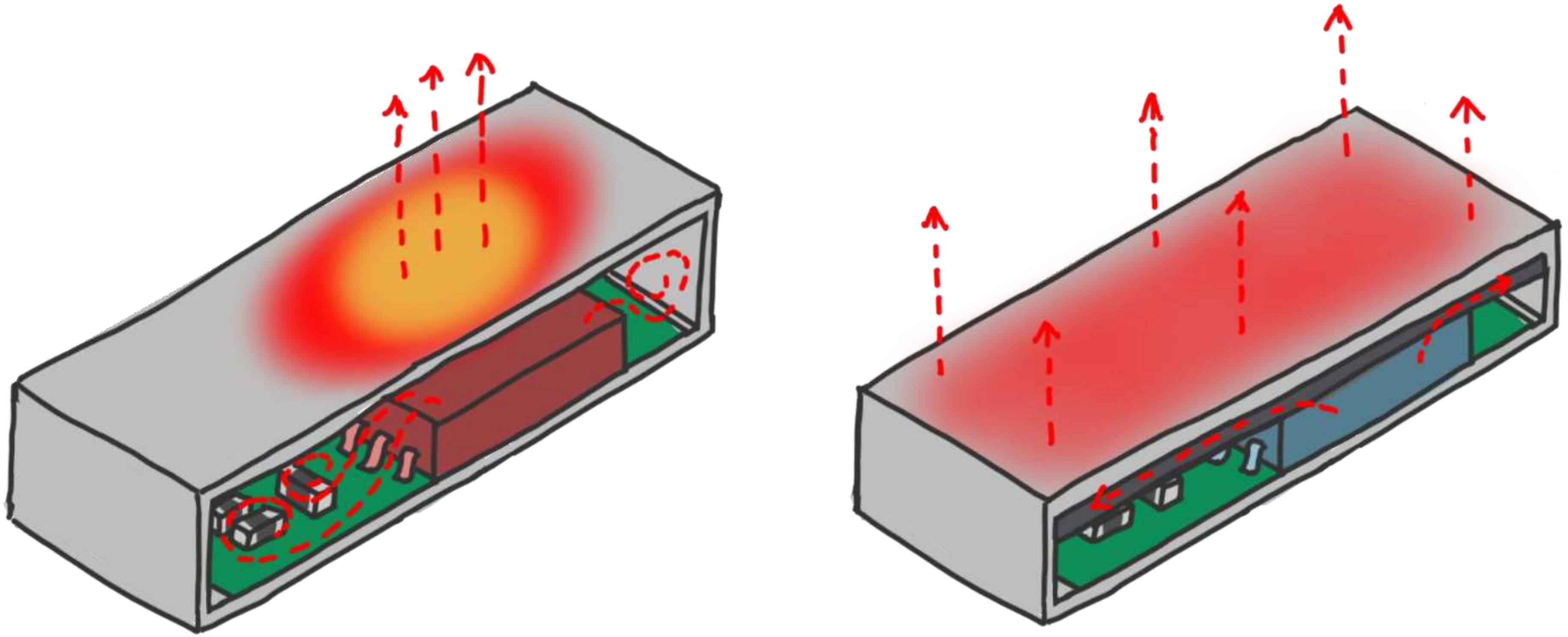
TIMS

- **Vertical Transportation: known as Thermal Interface Materials (TIMs for short) or Gap Fillers**



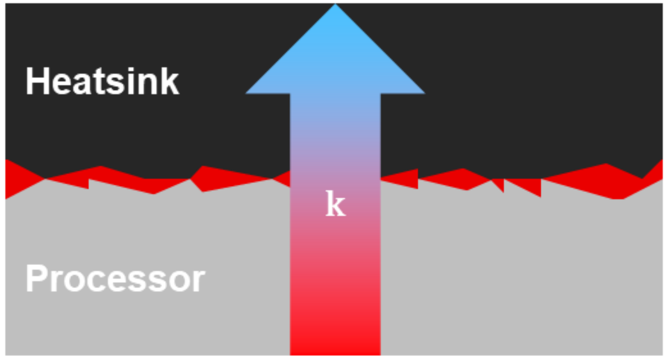
HEAT SPREADERS

- **Horizontal Transportation: known as Heat Spreaders**



PARAMETERS

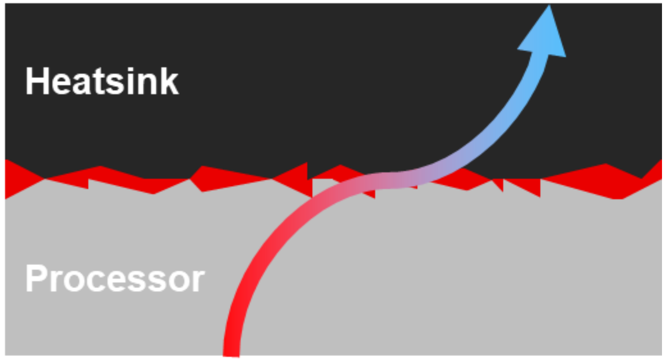
Thermal Conductivity



$$k = \frac{W}{mK}$$

Maximum amount of heat energy that can go through the material, independent of dimensions & thickness. It is a material constant.

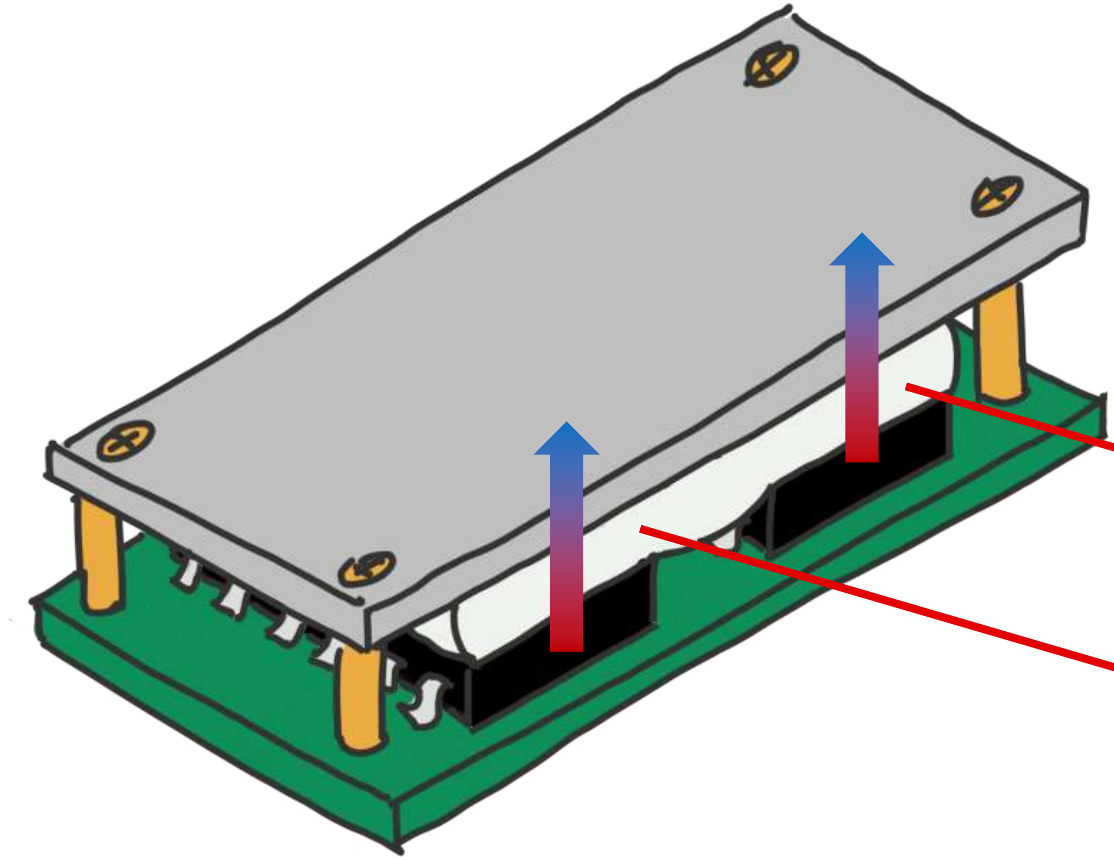
Thermal Resistance



$$R = \frac{{}^{o}C}{W}$$

Resistance of the material to the flow of heat. It is a property of a particular component, which has defined geometry (thickness – L, area – A and shape)

PARAMETERS

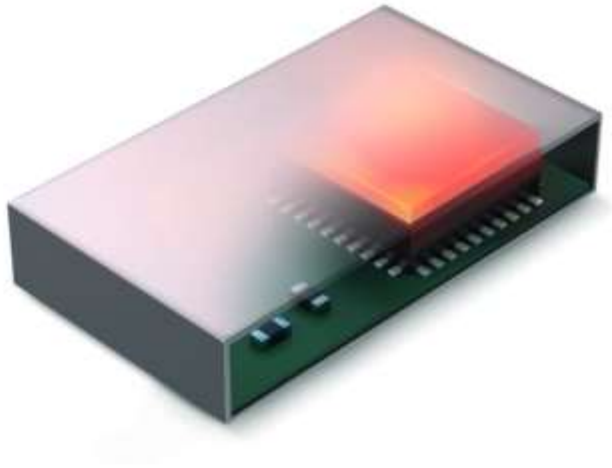


Hardness (Shore)
How soft and formable the material is

Electrical Breakdown E_{BR} (kV/mm)
Up to what voltage the material remains non-conductive or insulating

APPLICATION SPECIFIC REQUIREMENTS

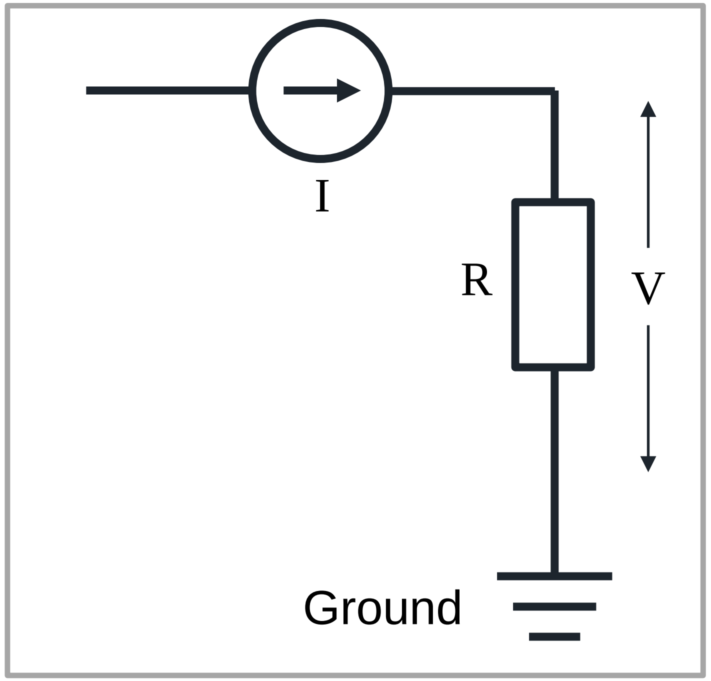
- Adhesive contact surfaces
- Electrically insulating
- Use of some materials not allowed
- Mechanical limitations
- High operating temperatures

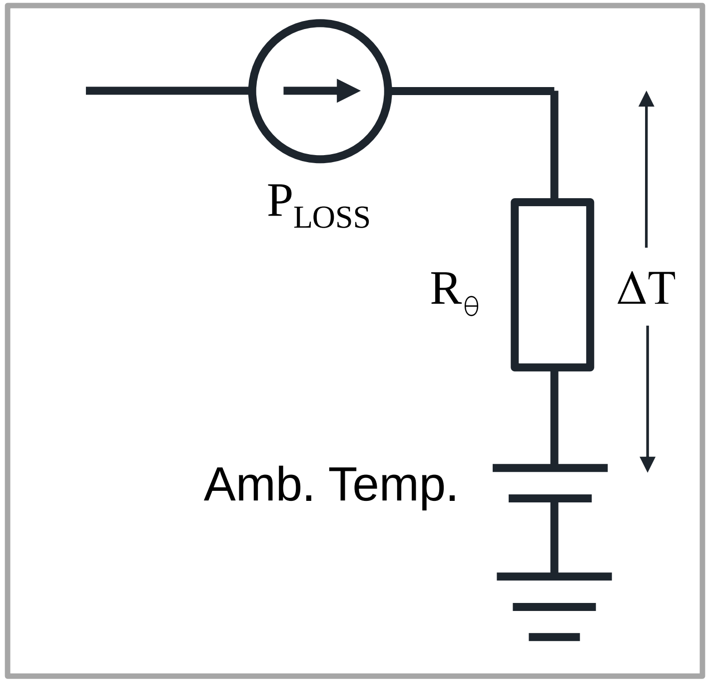


THERMAL CALCULATIONS

THERMAL MODELING

- **Understanding thermal properties**

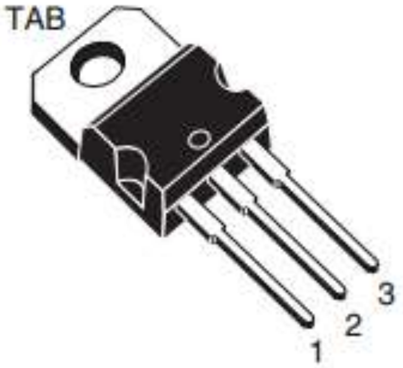




$$I = \frac{V}{R} \longleftrightarrow P_{LOSS} = \frac{\Delta T}{R_\theta} \longrightarrow R_\theta = \frac{\Delta T}{P_{LOSS}} \quad \frac{°C}{W}$$

THERMAL MODELING

- **Let’s say we are a Designer who wants to use a MOSFET:**
  - PN: STB24N60DM2
  - TO-220 Package
  - Vertically mounted
  - Three cases:
    1. Can I use it without a heatsink?
    2. If I need a heatsink, can it be convection cooled?
    3. Or should it have active cooling?



THERMAL MODELING

- **Case 1: no heatsink used**
  - Lets look at the datasheet

Table 3. Thermal data

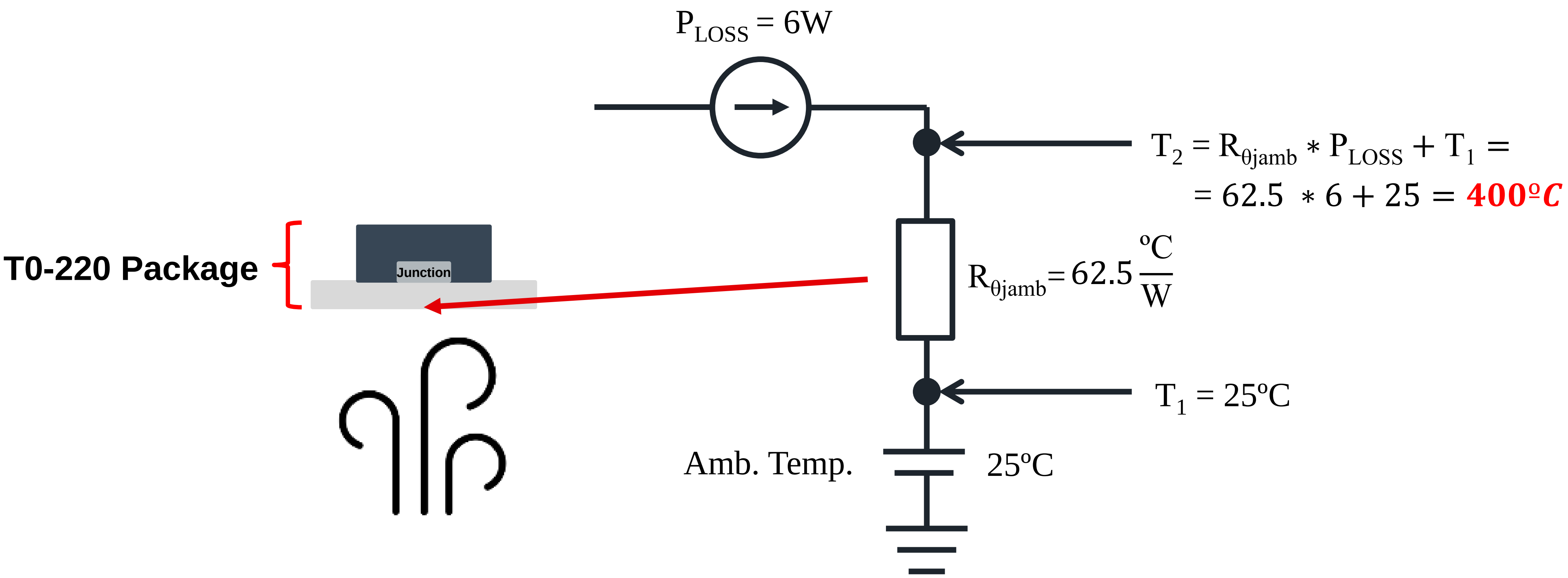
Symbol	Parameter	Value			Unit
		D^2PAK	TO-220	TO-247	
$R_{thj\text{-}case}$	Thermal resistance junction-case max	0.83			°C/W
$R_{thj\text{-}pcb}$	Thermal resistance junction-pcb max(1)	30			°C/W
$R_{thj\text{-}amb}$	Thermal resistance junction-ambient max		62.5	50	°C/W

1. When mounted on 1 inch² FR-4, 2 Oz copper board

Without a heatsink: $R_{\theta jamb} = 62.5\,\frac{^{o}C}{W}$

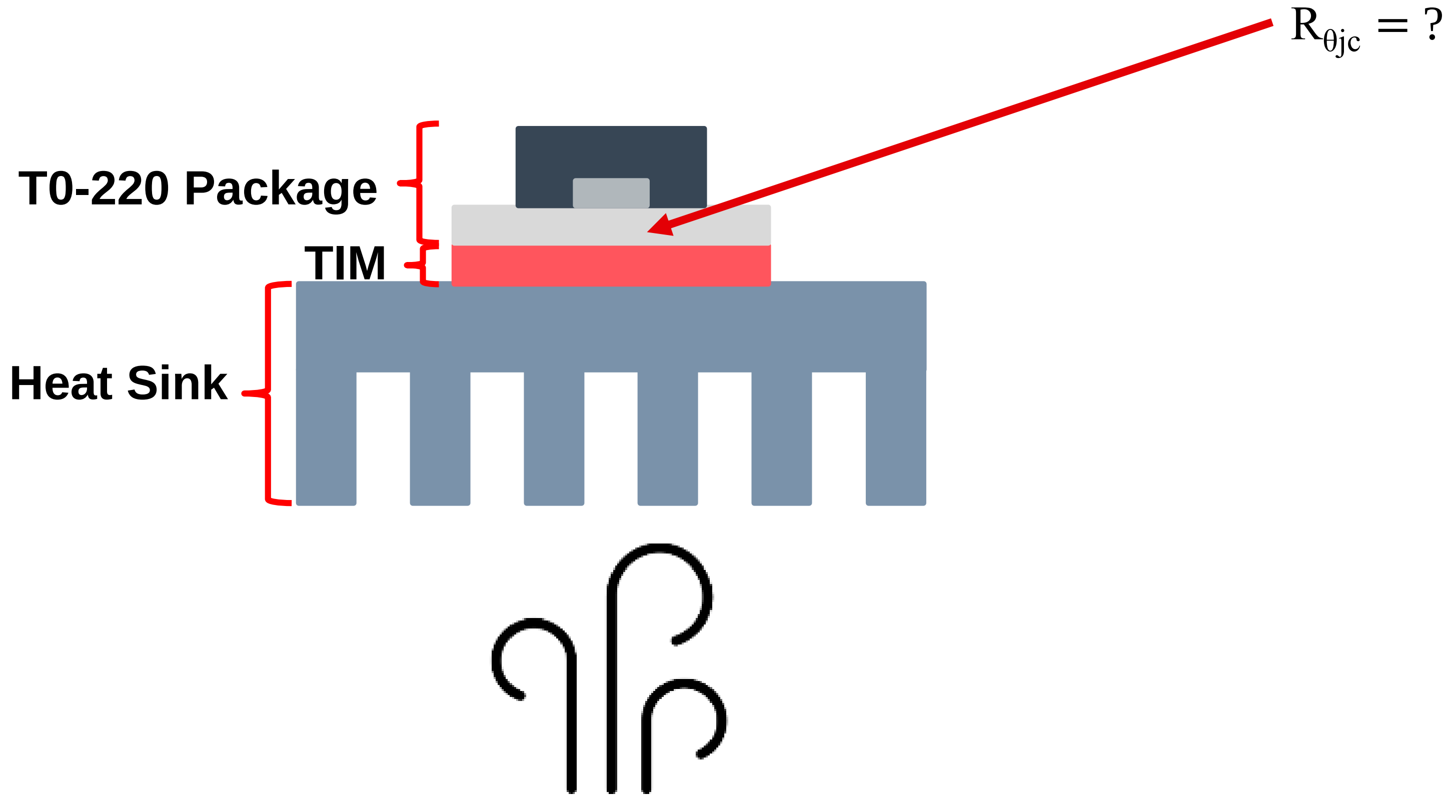
THERMAL MODELING

- **Case 1: no heatsink used**



THERMAL MODELING

- **Case 2: let's add a convection cooling heatsink!**



THERMAL MODELING

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With a heatsink: $R_{\theta jamb} = 0.83 \frac{^{\circ}C}{W}$

THERMAL MODELING

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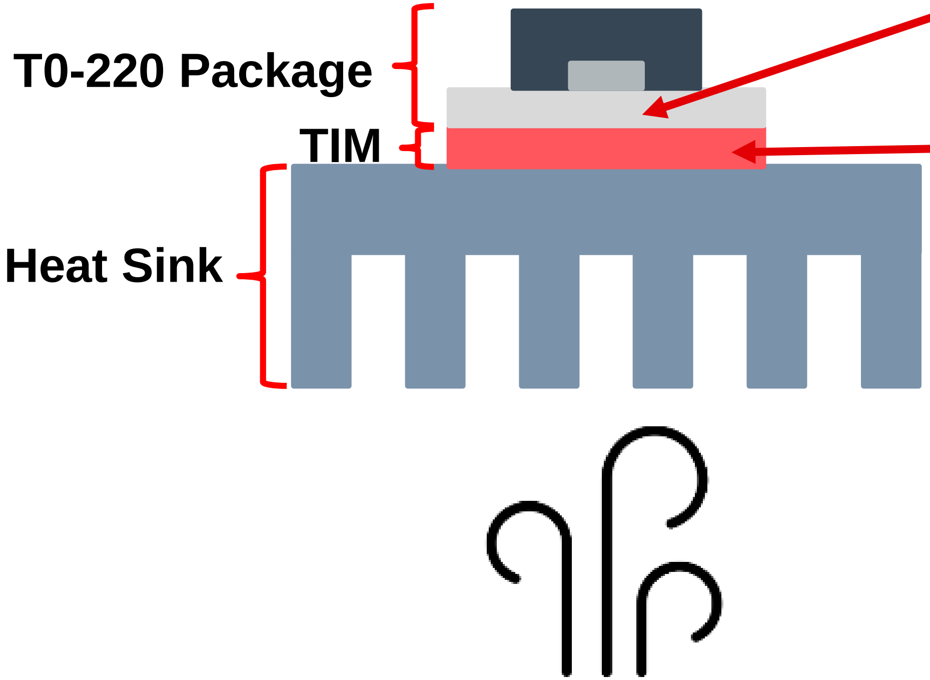


$$R_{\theta jc} = 0.83\,\frac{^{o}C}{W}$$

$$R_{\theta cs} = ?$$

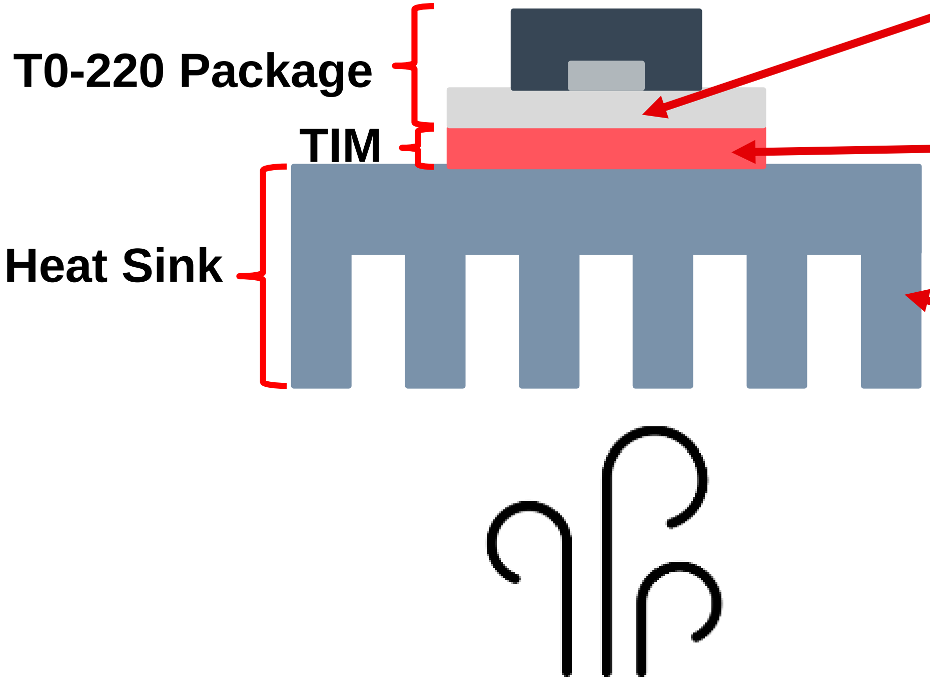
THERMAL MODELING

- **Case 2: let’s add a convection cooling heatsink!**

Thermal Resistance of an Insulator Pad: $R_{\theta cs} = 1.1\,\frac{^{\circ}C}{W}$

THERMAL MODELING

- **Case 2: let’s add a convection cooling heatsink!**



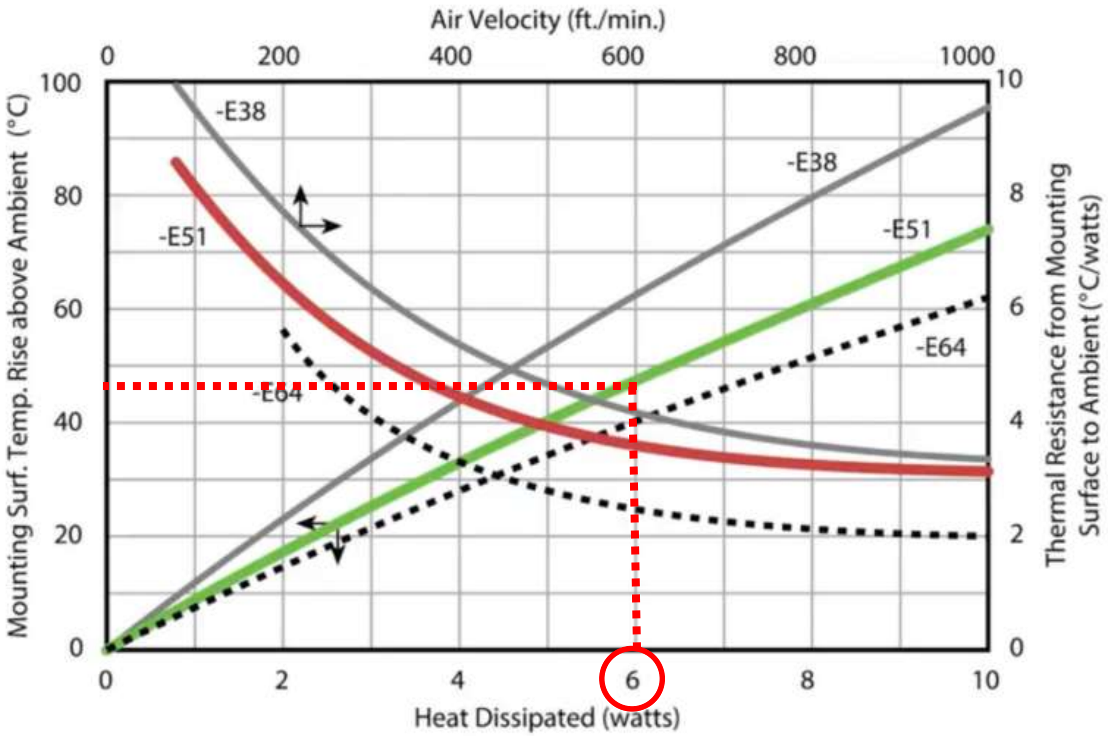
$R_{\theta jc} = 0.83 \frac{^{o}C}{W}$

$R_{\theta cs} = 1.1 \frac{^{o}C}{W}$

$R_{\theta sa} = ?$

THERMAL MODELING

- **Case 2: let's add a convection cooling heatsink!**



$P_{LOSS} = 6W$

Temperature rise $= 49ºC$

To calculate Thermal Resistance:

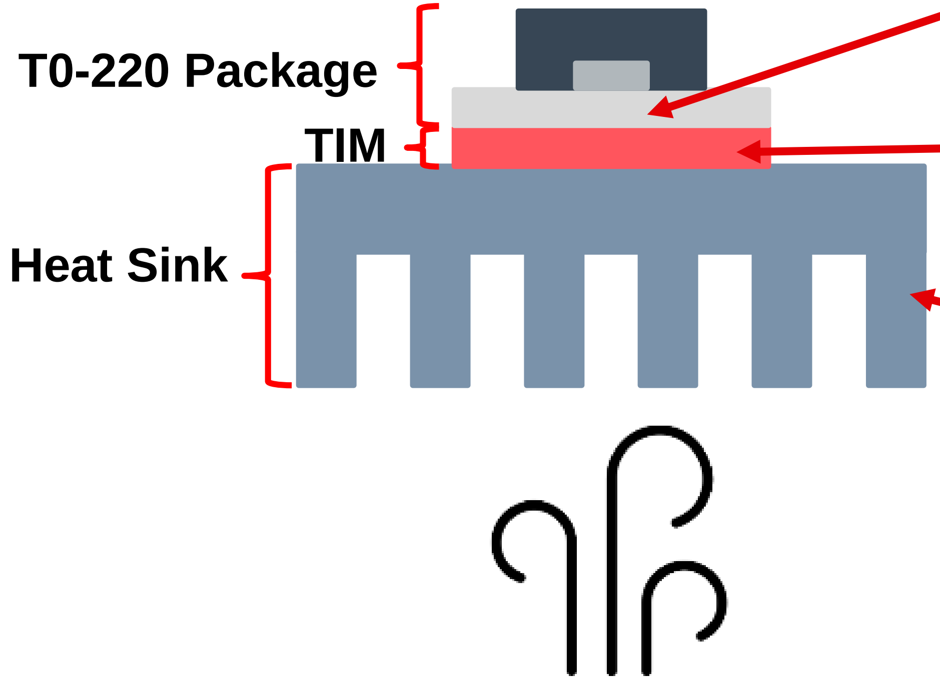
$R_{\theta sa} = \frac{49ºC}{6W} = 8.16\frac{ºC}{W}$ (In ideal conditions)

In reality: 20 to 30% safety margin

$R_{\theta sa} = 8.16 * 1.3 = 10.62\frac{ºC}{W}$

THERMAL MODELING

- **Case 2: let's add a convection cooling heatsink!**



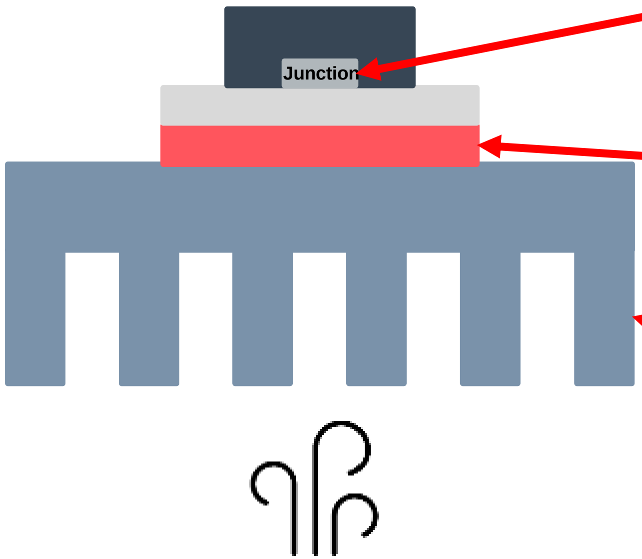
$$R_{\theta jc} = 0.83 \frac{^{o}C}{W}$$

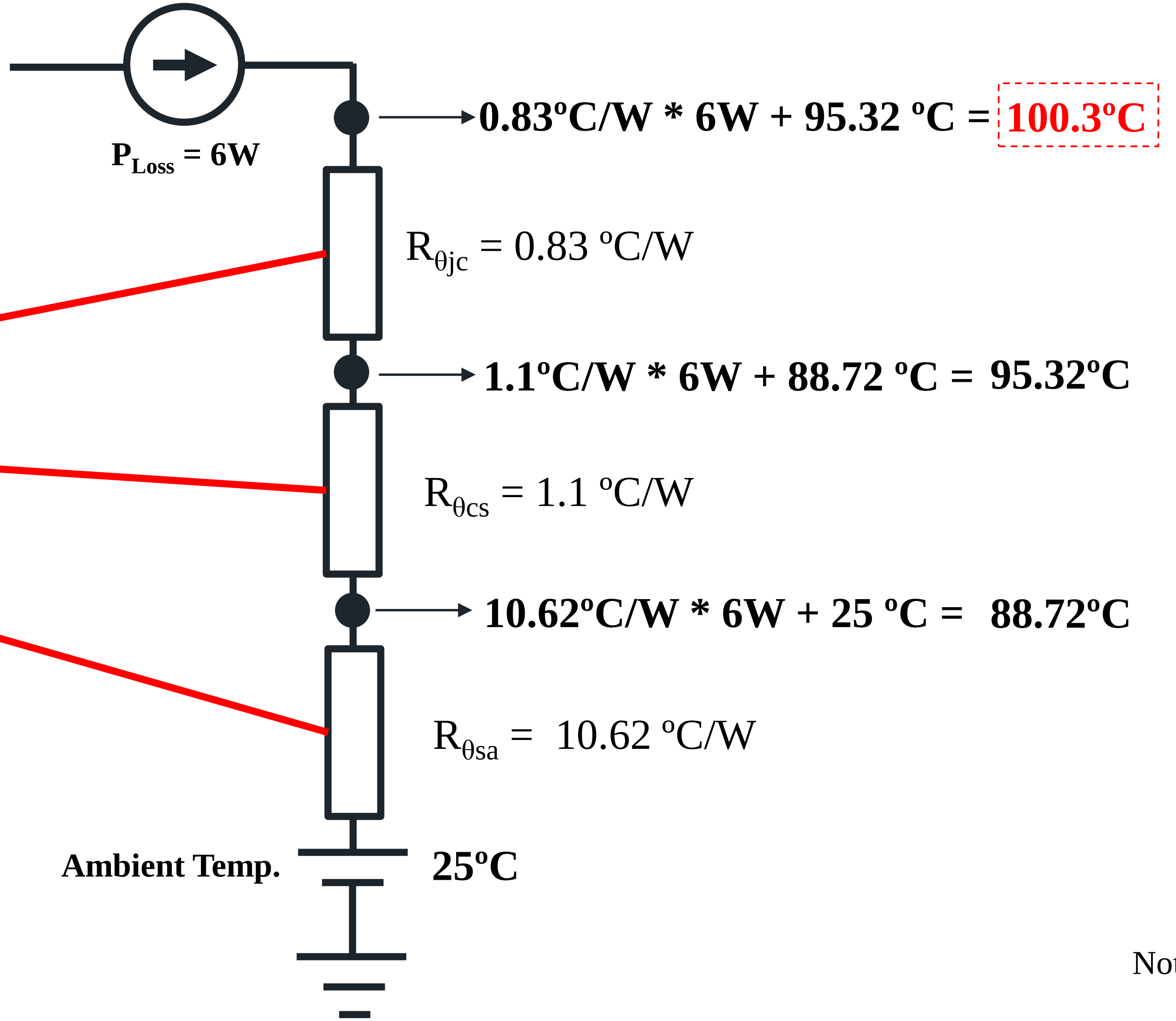
$$R_{\theta cs} = 1.1 \frac{^{o}C}{W}$$

$$R_{\theta sa} = 10.62 \frac{^{o}C}{W}$$

THERMAL MODELING

- **Case 2: passive heatsink**

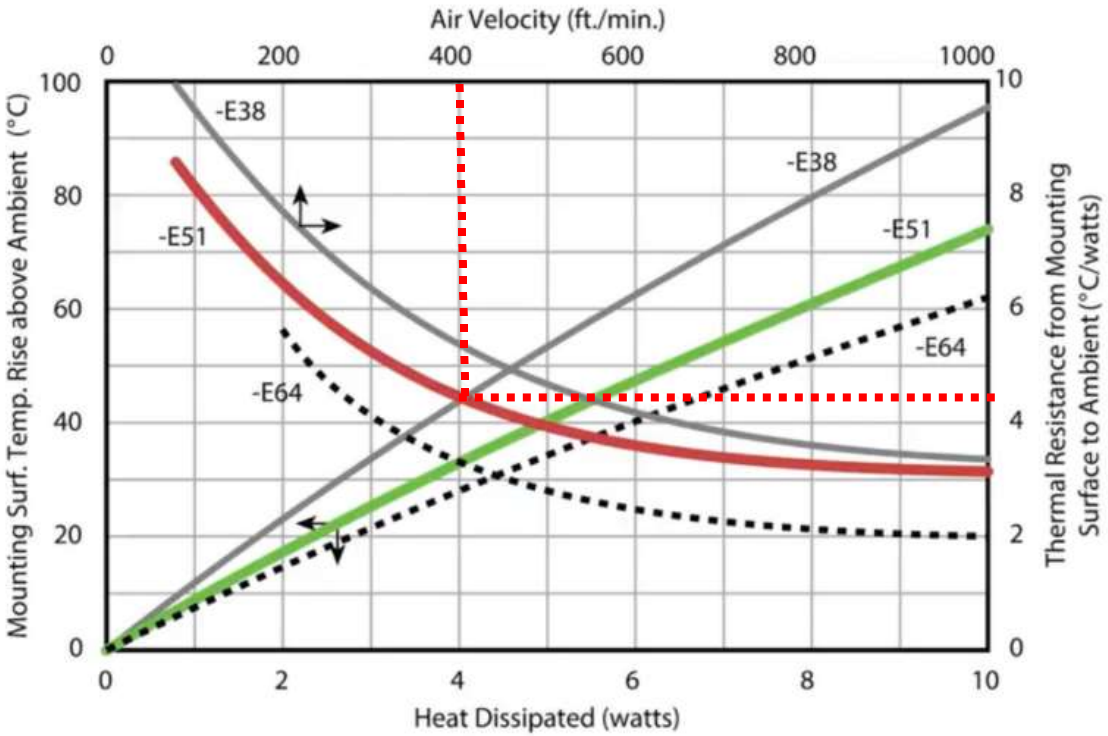




Note: $T_2 = R * P_{LOSS} + T_1$

THERMAL MODELING

- **Case 3: Active cooling heatsink!**



The fan has an average air velocity of 400 ft./min

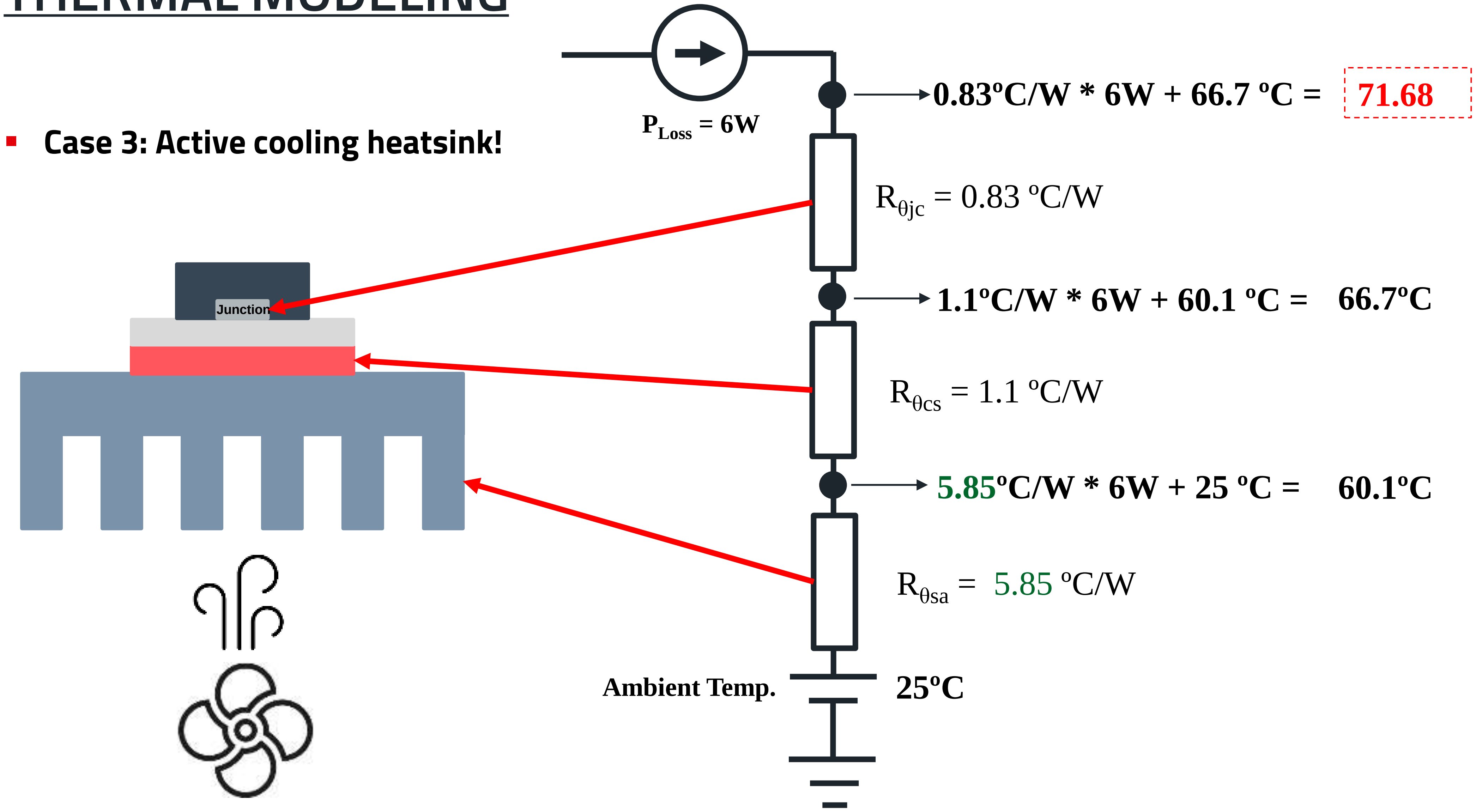
$$R_{\theta sa} = 4.5\,\frac{^{\circ}\mathrm{C}}{\mathrm{W}}\ \text{(In ideal conditions)}$$

In reality: 20 to 30% safety margin

$$R_{\theta sa} = 4.5 * 1.3 = 5.85\,\frac{^{\circ}\mathrm{C}}{\mathrm{W}}$$

THERMAL MODELING

- **Case 3: Active cooling heatsink!**

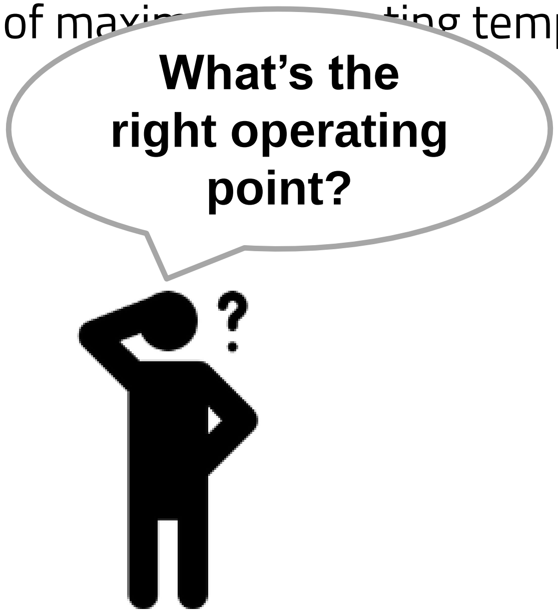


THERMAL MODELING

- **Which of my three cases gives me the results I want?**
  - **Case1 No heatsink**: Junction temperature of 400°C
  - **Case 2 passive heatsink**: Junction temperature of 103°C ≈ 68% of maximum operating temperature
  - **Case 3 active heatsink**: Junction temperature of 71.6°C ≈ 47% of maxi[illegible]ting temperature

-

T_{stg}	Storage temperature	- 55 to 150	°C
T_j	Max. operating junction temperature		



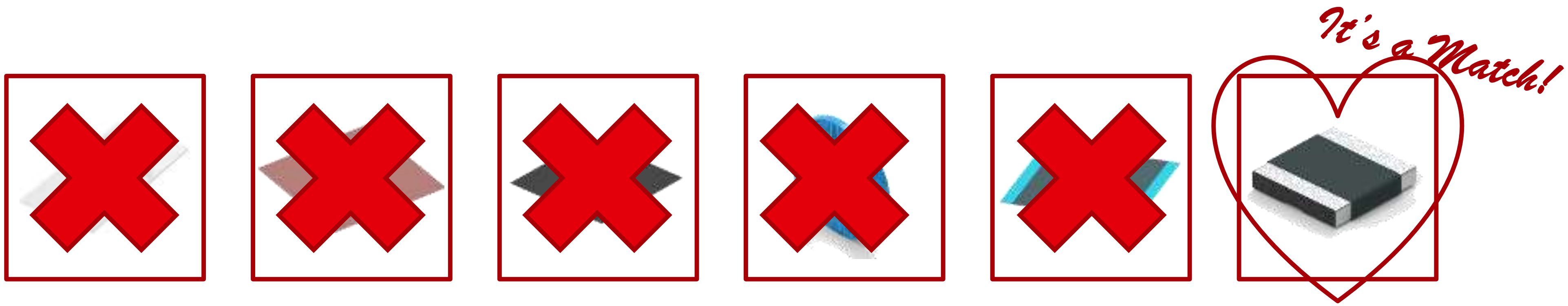
THERMAL MODELING

- **What's the right operating point?**
  - Sometimes there will be a specification of the thermal derating of all the components on the board
  - If there isn't any, a judgement call needs to be made:
    - **Rule of thumb:** For every 10 degrees Centigrade rise in temperature, the average reliability is decreased by 50 percent
    - If we look at it from the Quality POV: if we can lower the temperature by 10 degrees, we'll double the reliability.

FIND YOUR SOLUTION

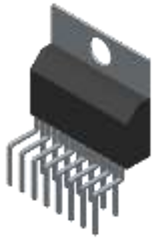
- Every application is different

Gap Size? → Material Performance? → Cooling assembly fixation? → Special Requirements?



CASE STUDY

- DC Motor driver
  - Dissipated power: 2.5 W
  - Passive cooling with heatsink
- Select a TIM



Gap Size? → Thin bond line, < 0.5 mm

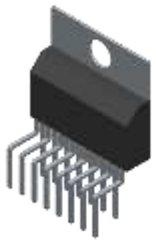
Material Performance? → Low – mid range performance

Cooling assembly fixation? → Heatsink screwed to driver

Special Requirements? → Electrical insulation

CASE STUDY

- DC Motor driver
  - Dissipated power: 2.5 W
  - Passive cooling with heatsink



- Select a TIM:
  - Thin bond line, < 0.5mm
  - Low – mid range performance
  - Heatsink screwed to driver
  - Electrical insulation

Insulator Pad!

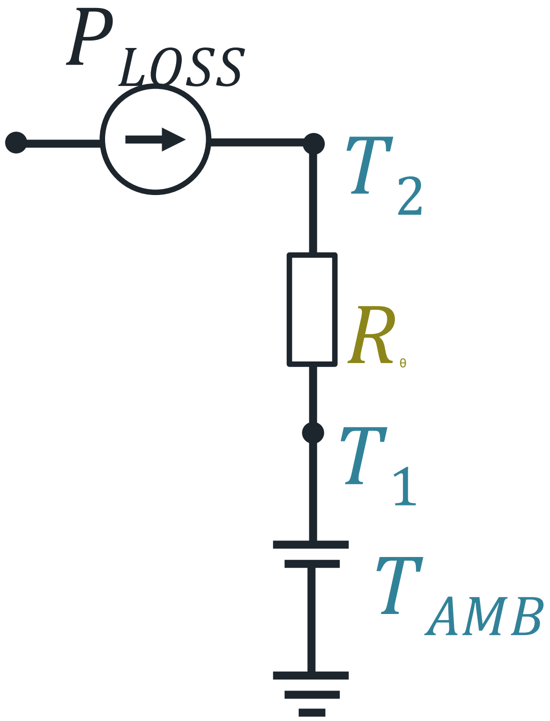
- Before committing, how do I know I've made the right choice?

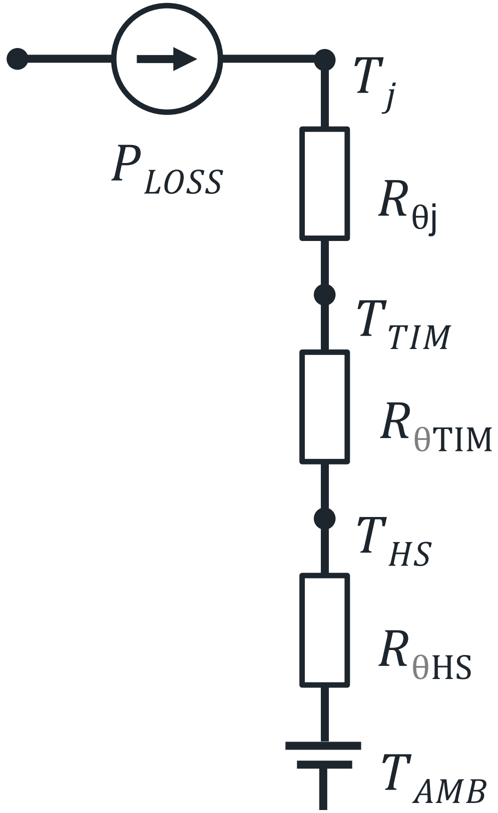
Mathematical Model → Simulation → Experimental

CASE STUDY

Mathematical Model → Simulation → Experimental

- Mathematical Model:
  - All material between the junction of the driver and the ambient adds a thermal resistance to the system





CASE STUDY

Mathematical Model → Simulation → Experimental

- Mathematical Model:
  - All material between the junction of the driver and the ambient adds a thermal resistance to the system
  - We need all the data to calculate junction temperature:
    - Power loss = **2.5W**
    - Maximum junction temperature = **130°C**
    - Thermal resistance from junction - case = **3 °C/W**
    - Insulator pad thermal resistance = **2.25 °C/W**
    - Heatsink thermal resistance = **10.08 °C/W**

ST L298 Dual Full-Bridge Driver

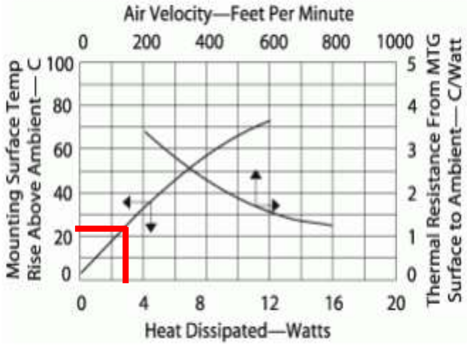
ABSOLUTE MAXIMUM RATINGS

T_{op}	Junction Operating Temperature	–25 to 130	°C

THERMAL DATA

Symbol	Parameter		PowerSO20	Multiwatt15	Unit
$R_{th\ j\text{-}case}$	Thermal Resistance Junction-case	Max.	–	3	°C/W
$R_{th\ j\text{-}amb}$	Thermal Resistance Junction-ambient	Max.	13 (*)	35	°C/W

Part Number: 6396BG & 6396B-P2G



Temperature rise = 21ºC

$$R_{\theta HS} = \frac{21^{\circ}\mathrm{C}}{2.5\mathrm{W}} = 8.4\,\frac{^{\circ}\mathrm{C}}{\mathrm{W}} \text{ (ideal conditions)}$$

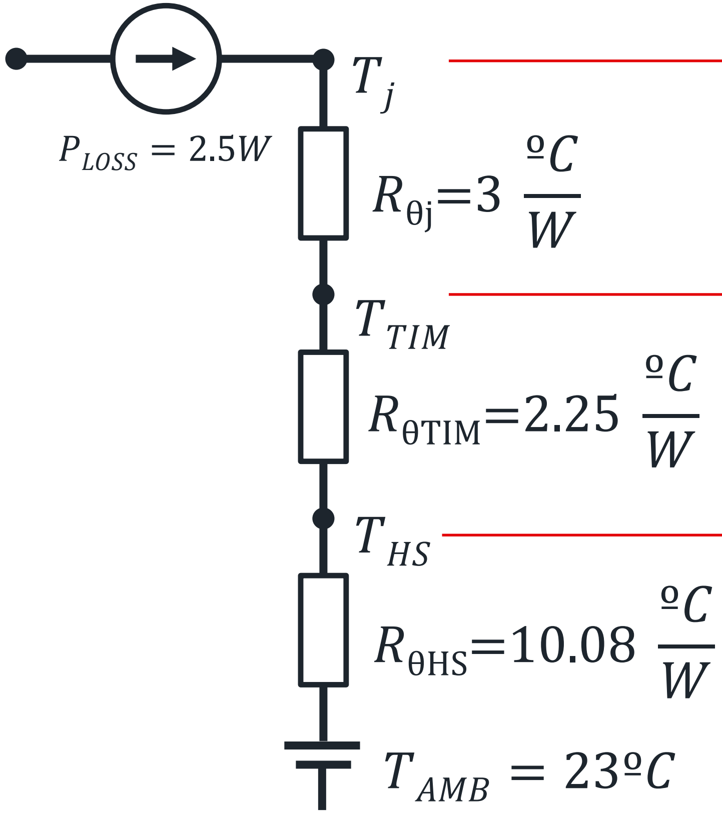
In reality: 20 to 30% safety margin

$$R_{\theta HS} = 8.4 * 1.3 = 10.08\,\frac{^{\circ}\mathrm{C}}{\mathrm{W}}$$

CASE STUDY

Mathematical Model → Simulation → Experimental

- Mathematical Model:
  - All material between the junction of the driver and the ambient adds a thermal resistance to the system
  - We need all the data to calculate junction temperature



$$T_{j = 3} \frac{ºC}{W} \cdot 2.5W + 53.82ºC = \mathbf{61.32ºC} \quad \ll 130ºC$$

$$T_{TIM = 2.25} \frac{ºC}{W} \cdot 2.5W + 48.2ºC = 53.82ºC$$

$$T_{HS = 10.08} \frac{ºC}{W} \cdot 2.5W + 25ºC = 48.2ºC$$

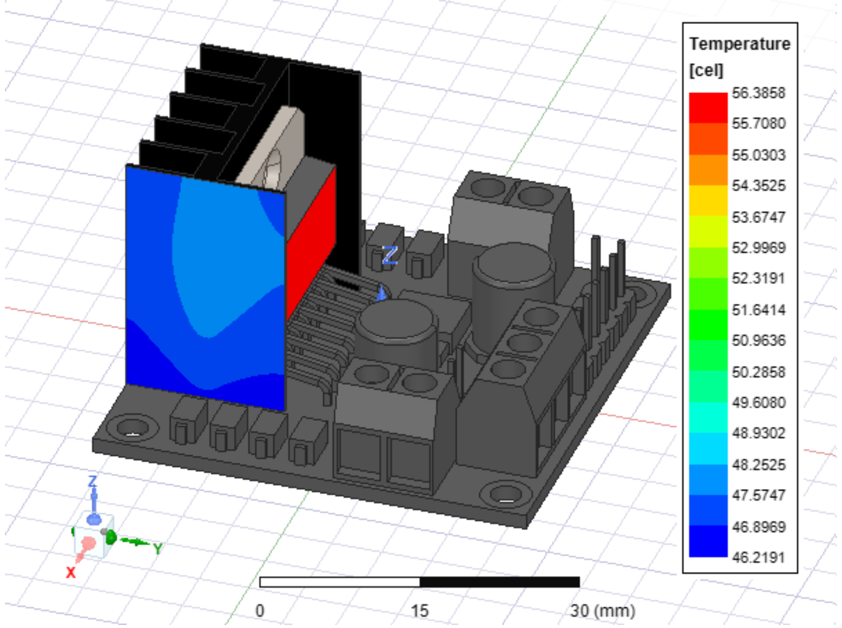
$$\boxed{T_2 = R * P_{LOSS} + T_1}$$

CASE STUDY

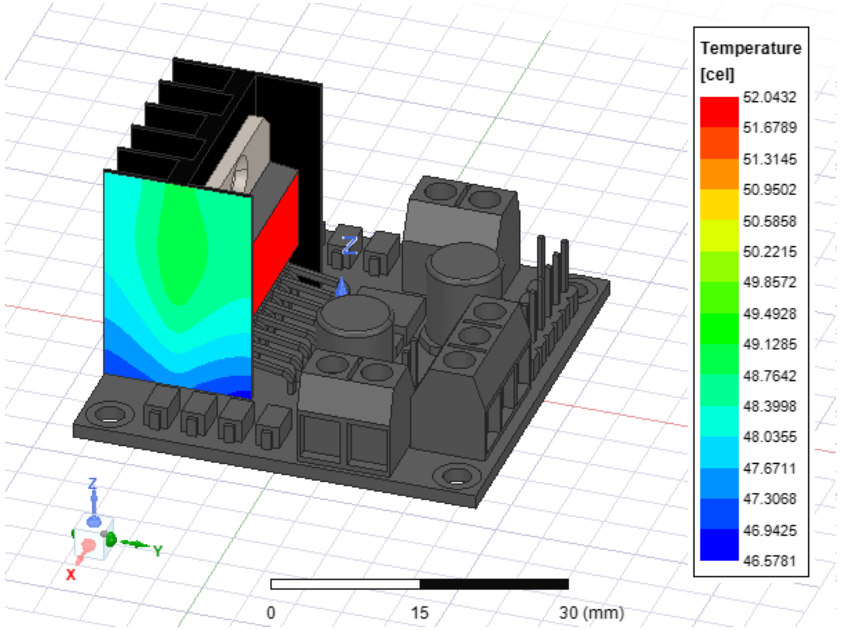
Mathematical Model → **Simulation** → Experimental

- Simulation:
  - Even more similar to the real life application
  - ANSYS Icepak

No TIM



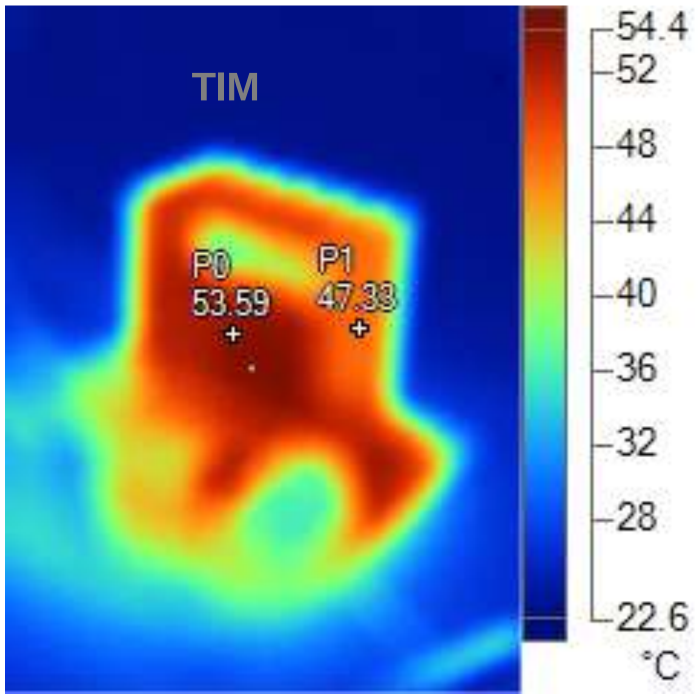
Insulator Pad



CASE STUDY

Mathematical Model → Simulation → Experimental

- Experimental:
  - Let's verify the data with experimental results: benchmark with a load to dissipate target power
  - Measure temperatures with Fluke IR handheld camera



CASE STUDY

Mathematical Model → Simulation → Experimental

- Lets look at all the data:

Insulator Pad

	Mathematical Model	Simulation	Experimental
	T(°C)	T(°C)	T(°C)
Driver	53.8	52	53.59
Heatsink	48.2	49.3	47.33

Gap Size? → Material Performance? → Cooling assembly fixation? → Special Requirements?

THERMAL MANAGEMENT SOLUTIONS – ONE STOP SHOP

	WÜRTH ELEKTRONIK
Gap Filler Pad	✓
Insulator Pad	✓
Thermal Transfer Tape	✓
Phase Changer	✓
Graphite Foil	✓
Graphite Foam Gasket	✓

SELECTION GUIDE

Thickness			Thermal Conductivity				Electric Insulation
x < 0.1 mm	0.1 mm > x < 0.5 mm	0.5mm > x > 25 mm	Low	Medium	High	Super High	If requiered
✓ ✓	✓ ✓	✓ ✓	✓	✓ ✓	✓ ✓	✓ ✓	✓ ✓ ✓ ✓ ✓ ✓

Gap Filler Pad

Thermally Conductive Insulator

Phase Changer

Thermal Transfer Tape

Graphite Foam Gasket

Graphite Sheet

PORTFOLIO
WE-TGF: GAP FILLER PAD

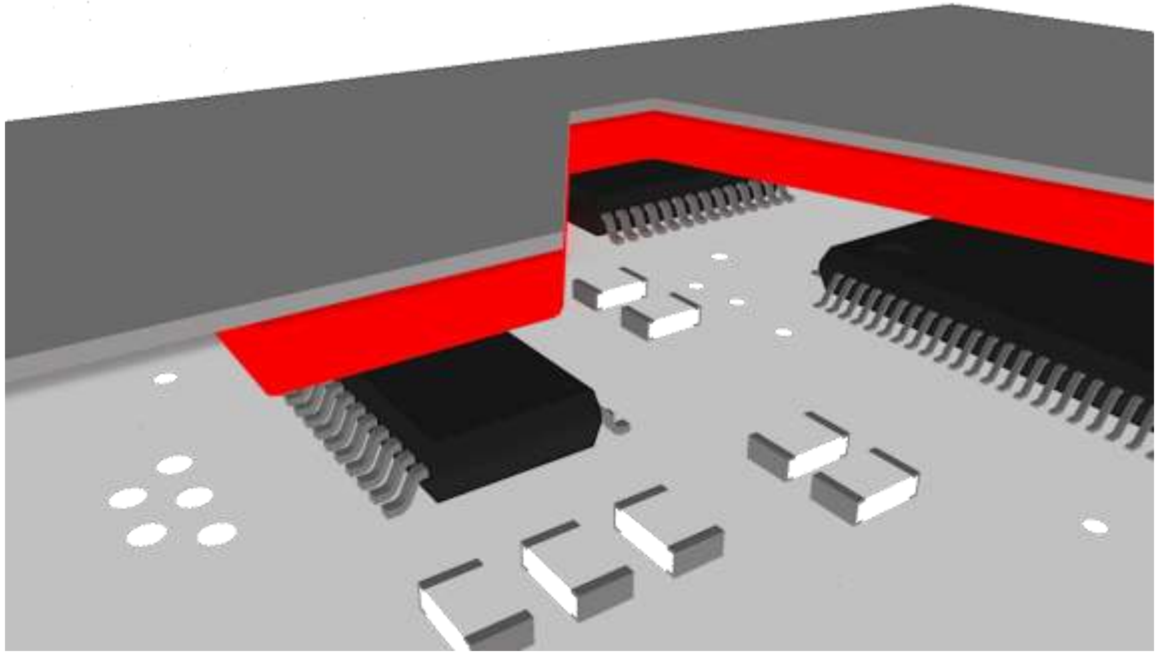
- Characteristics
  - Thermal Conductivity: from 1 to 10 W/m·K
  - Thicknesses:
    - 0.5 - 18mm for thermal conductivities of 1 to 3W/m·K
    - 0.5 – 3mm for higher thermal conductivities
  - Electrically insulating
  - 200x400mm & 100x100mm sheets

- Features
  - Soft and conformable
  - Naturally tacky, self adhesive
  - Optimal performance: compression 10-30%

General purpose gap filling

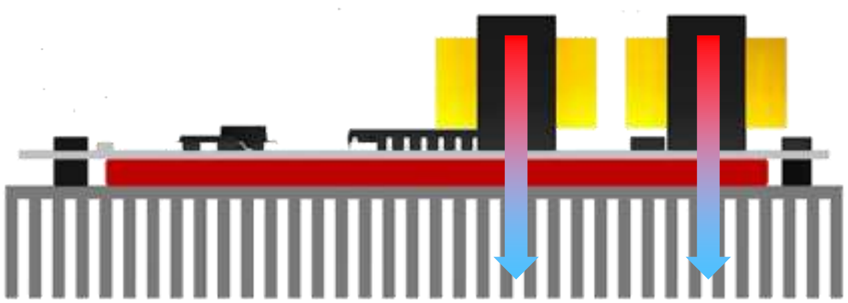
PORTFOLIO
WE-TGF: GAP FILLER PAD

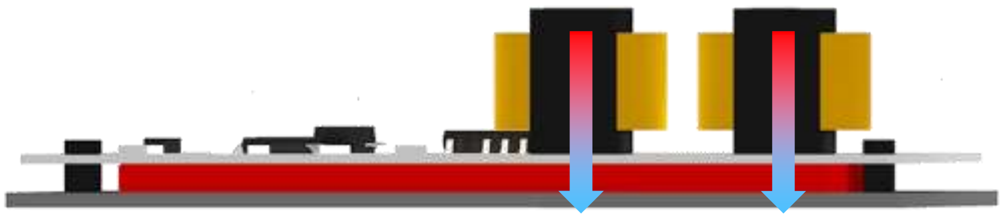
- Fills large gaps between hot components and cooling assemblies
- Cover multiple components without worrying about short circuits



PORTFOLIO
WE-TGF: GAP FILLER PAD

- Cool components with uneven contact surfaces with thermal traces to the back of the PCB
- Transfer the heat to the cooling assembly with a gap filler





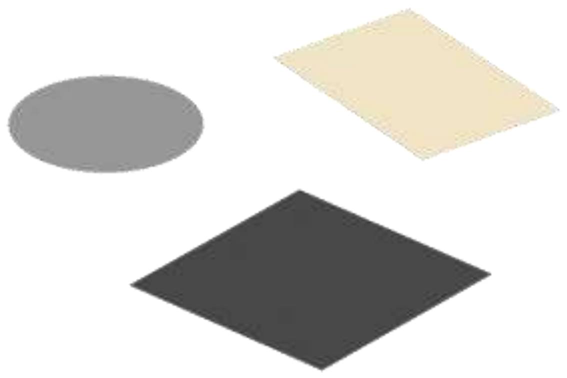
PORTFOLIO
WE-PCM: PHASE CHANGING MATERIAL

- 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
  - 300x400mm & 100x100mm sheets

- Features
  - Comparable to thermal pastes and greases
  - Removes microscopic unevenness in contact surfaces
  - Easy to handle in manufacture environments
  - Can be pre-applied

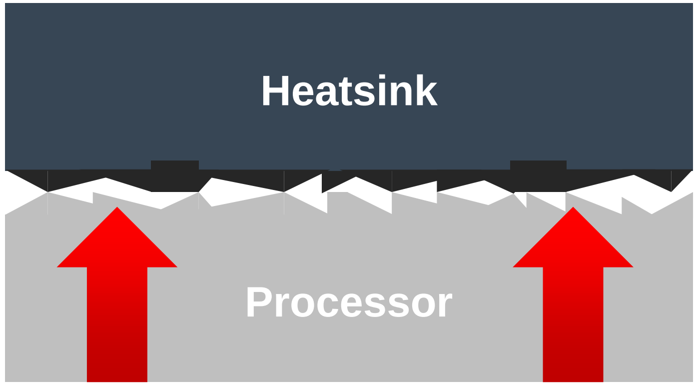
Seamless Thermal Interface

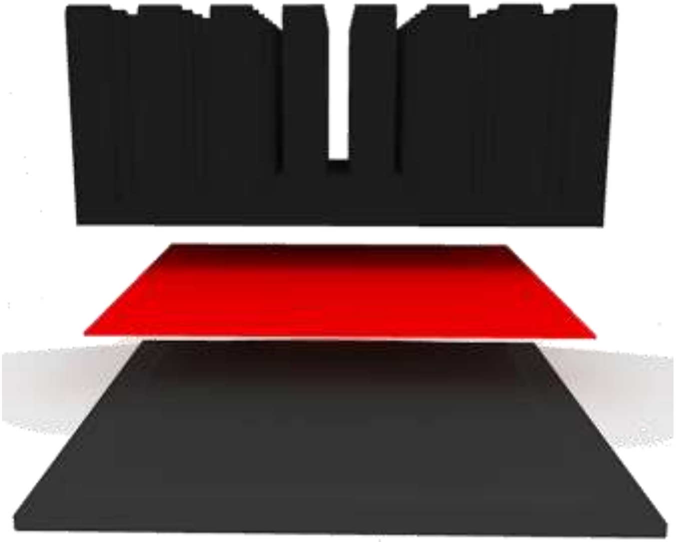
Alternative to thermal pastes

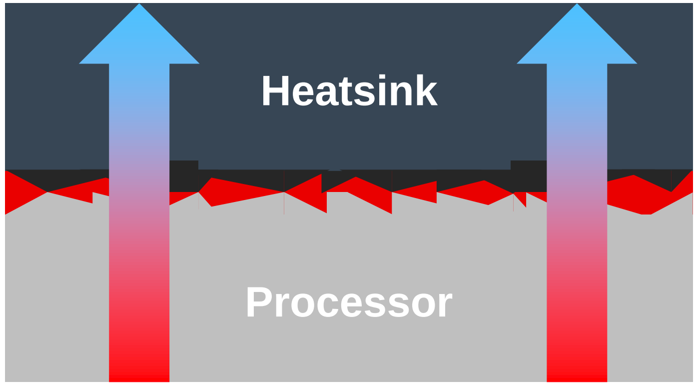


PORTFOLIO
WE-PCM: PHASE CHANGING MATERIAL

- Thin thermal interface, fills microscopic gaps



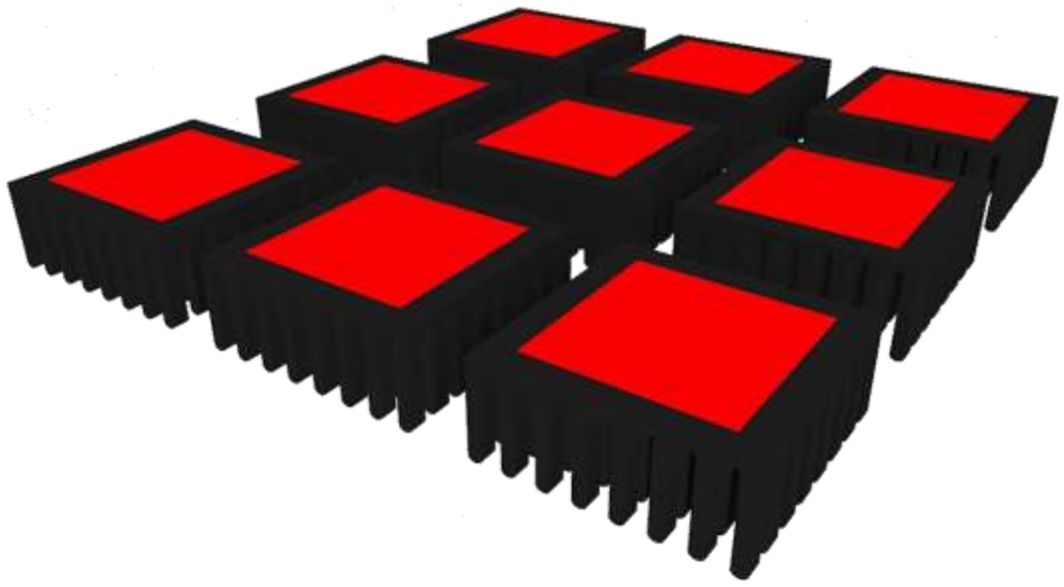




PORTFOLIO
WE-PCM: PHASE CHANGING MATERIAL

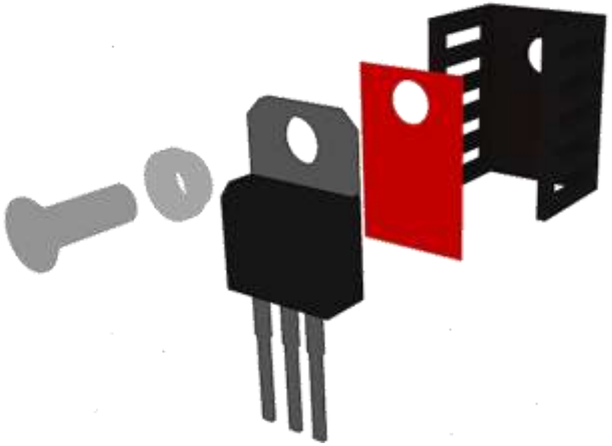
- Thermal pastes and greases can be difficult to handle:
  - Special storage conditions
  - Liquids in production lines can be a hassle

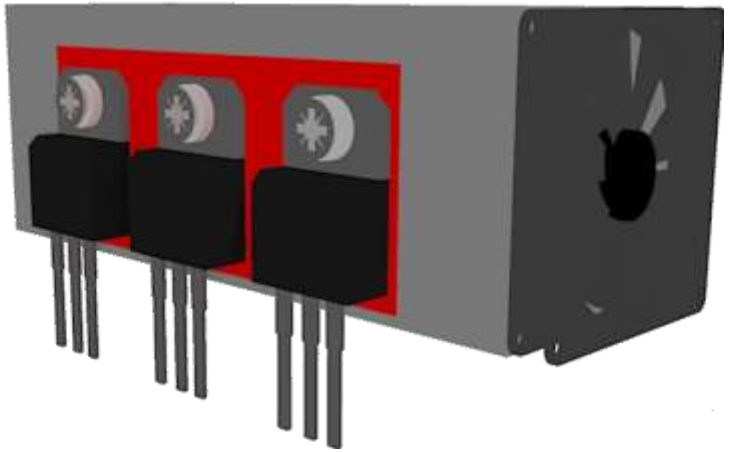
- WE-PCM can be pre-applied on cooling assemblies for ease of use



PORTFOLIO
WE-TINS: INSULATOR PAD

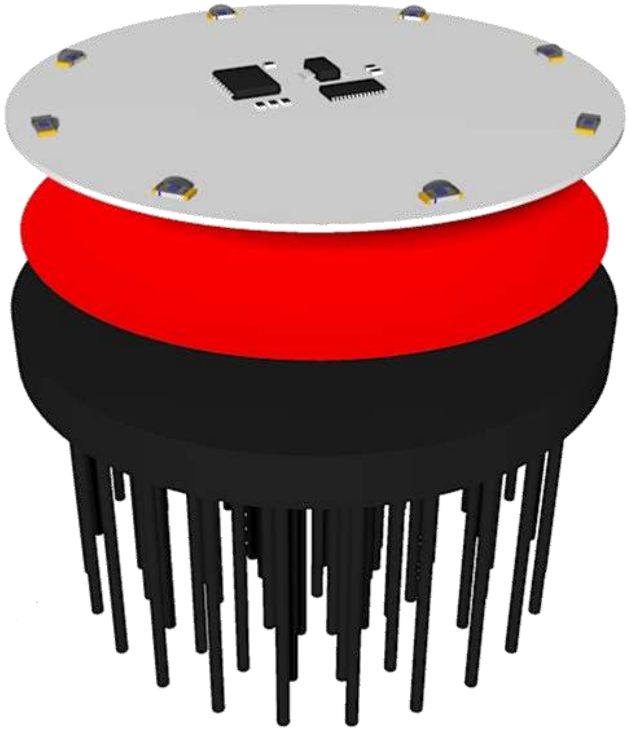
- Simple interface with eclectic insulation
- Used mainly in power applications





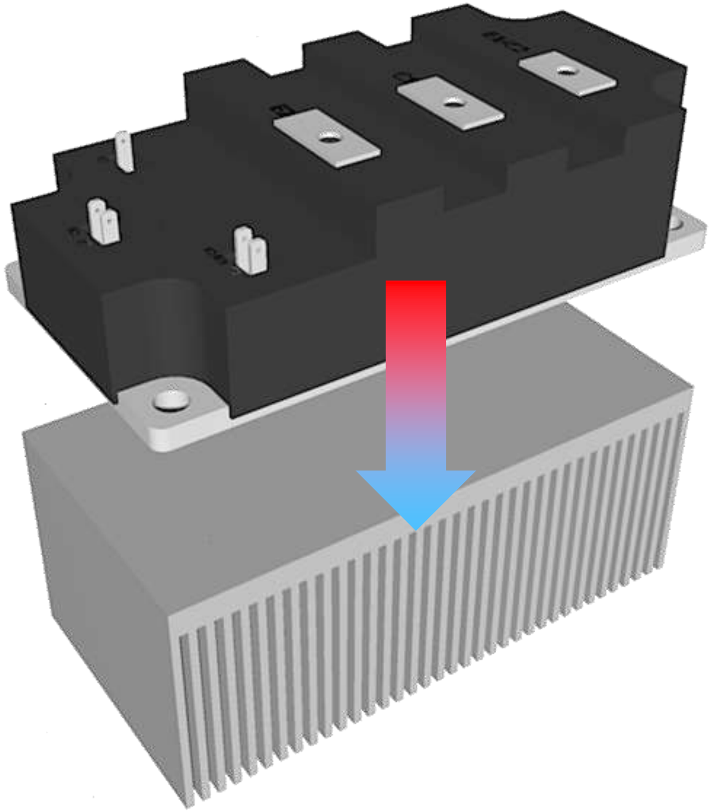
PORTFOLIO
WE-TTT: THERMAL TRANSFER TAPE

- When mechanical fixation of the cooling assembly with screws or clips is not possible



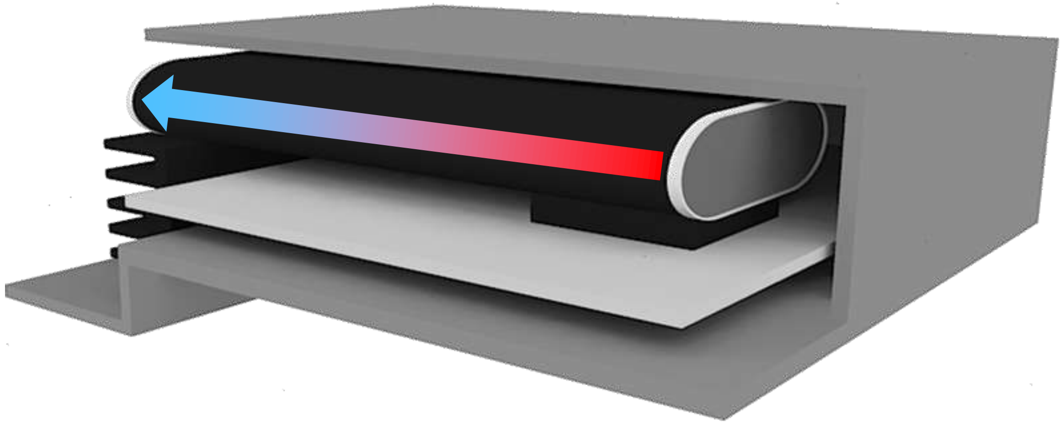
PORTFOLIO
WE-TGS: GRAPHITE SHEET

- Components may not provide enough surface for cooling



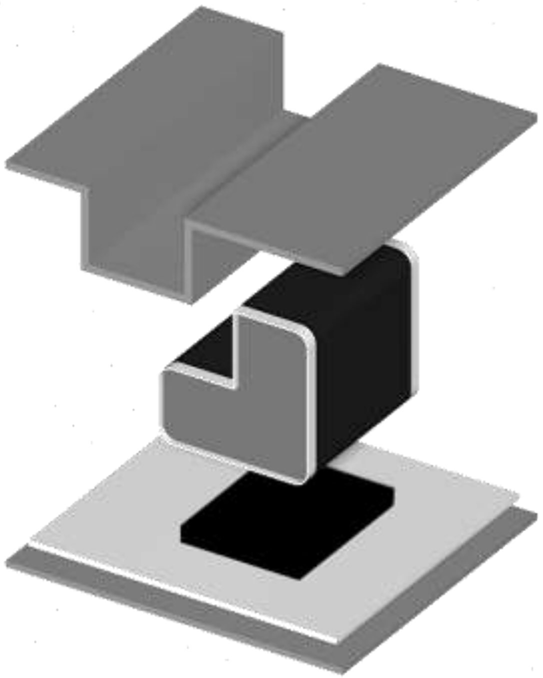
PORTFOLIO
WE-TGFG: GRAPHITE FOAM GASKET

- Some times mounting a cooling assembly on top of a component is not possible (plastic housing, no holes for ventilation, no space for heat sink).
- Heat needs to be transfer to a place where a cooling assembly can be mounted



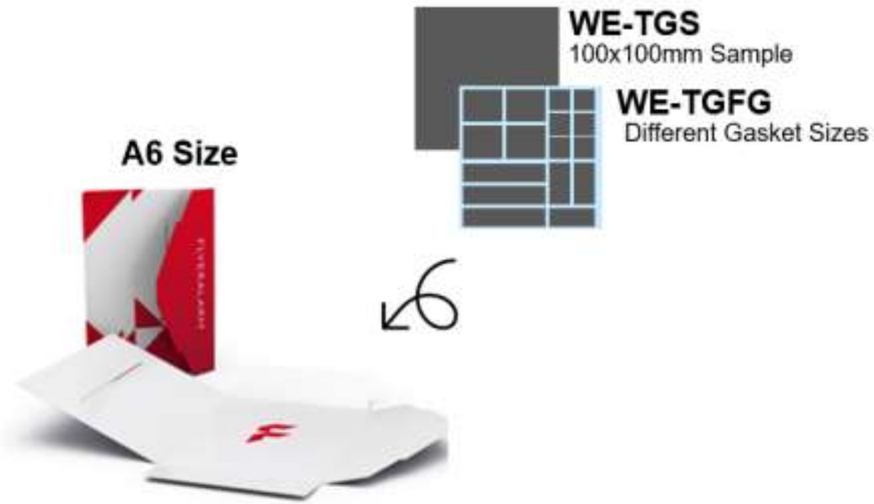
PORTFOLIO
WE-TGFG: GRAPHITE FOAM GASKET

- Mechanical design can make difficult the use of a traditional gap filler.
- The WE-TGFG adds vast versatility by being able to have it's profile customized.

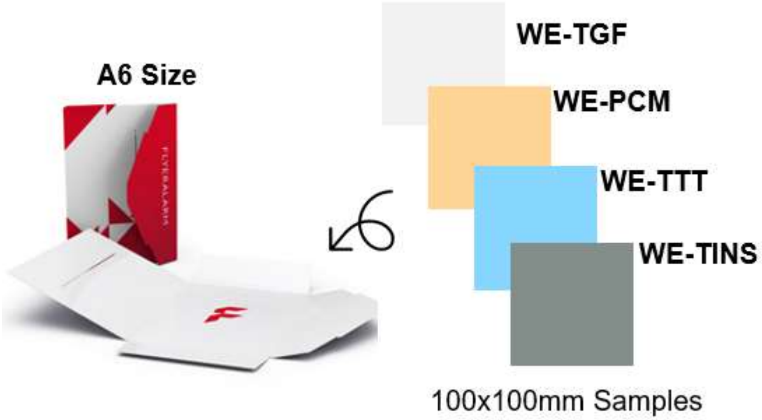


RESOURCES AND SERVICES

DESIGN KITS



Graphite Heat Spreaders



Thermal Interface Materials

DESIGN GUIDELINES

- Information about each product series
- Application recommendations
- FAQs
- Services provided
- Thermal Management properties & glossary
- [WE-TGF](); [WE-TTT](); [WE-TINS](); [WE-PCM]()
- [WE-TGFG](); [WE-TGS]()

WE-TGF Design Guideline

WE-TGF Design Guideline

Silicone Elastomer Gap Filler Pad

Thermal Management is the term used to describe all the methods used take care of all the excess heat that electronic devices and components generate. It is a field of upmost importance in order to guarantee reliability of electronic devices and components as well as to prevent premature failure.

1. What is the WE-TGF used for?

The WE-TGF is a silicone elastomer gap filler pad, designed to fill a gap between one or multiple electronic components and a cooling assembly, such as a heating, cooling plate or metal housing.

The pad itself is composed by three main components:

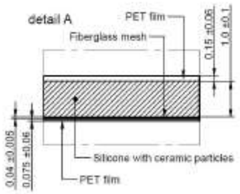


Fig. 1: WE-TGF components

- **PET film:** the WE-TGF is protected by two PET films, a thicker one at the bottom that acts as a carrier and a thinner one on top to protect the material from foreign particles.
- **Thermally conductive silicone elastomer:** this is the main part of the component. Silicone allows the product to be soft and to conform with ease to contact surfaces, allowing the material to fill out the gap completely and remove any air. The silicone is doped with ceramic particles that are the thermally conductive component. The mixing ratio of both elements determine the overall thermal conductivity of the material.
- **Fiberglass mesh:** this component brings mechanical stability to the part in its thinner versions (under 2mm).

2. Where can the WE-TGF be used?

The WE-TGF is designed to be used in low-pressure applications between a component and a cooling assembly. Because it is designed to be used between two mechanically mounted surfaces, the pad does not have any additional adhesive layer beside its natural tackiness.

Since it is a general purpose solution it covers a wide range of application requirements:

- **Thermal Conductivity:** wide range from 1 up to 10 W/mK.
- **Thickness:** from 0.5 to 18mm in the lower range of thermal conductivities, between 1 and 3 W/mK. For higher performance materials the thickness range is from 0.5 up to 5mm.
- **Electric Insulation:** since the product is based on a silicone matrix, there is complete electric insulation between the component's contact surfaces.
- **Low pressure applications:** the WE-TGF is designed to be compressed between 10% and 30% of its thickness for optimal performance and to ensure proper contact on both surfaces.

Thanks to its soft and electrically insulating nature the WE-TGF can be used to fill a gap between one or multiple electronic components and a cooling assembly without the need to worry about any shorts or unwanted contacts.

Fig. 2: Multiple components cooled by a heat sink

When working with compact designs that use thermal vias to redirect heat to the back of a PCB, the WE-TGF is a great choice to provide a thermal interface with a heat sink or a metal housing.

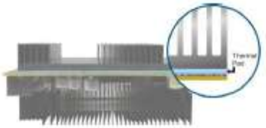


Fig. 3: Backside of a PCB interfaced with a heat sink

Fig. 4: Backside of a PCB interfaced with a metal housing

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SERVICES / CUSTOMIZATION

- Technical Support
- Standard parts in stock
- Free Samples

- Customization service
  - No MOQ
  - No Tooling Costs

- Web Form for customized solutions e.g. WE-TGS: https://www.we-online.com/web/en/electronic_components/extra_pbs/thermal_forms/wetgsgrequestform.php

NEXT BIG EVENT

- F2F Event
- Birmingham, UK
- Large Venue
- Registration link

Thank you