USER GUIDE

UG011 | Thermal Gap Filler Pad – WE-TGF

Sebastian Mirasol-Menacho

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 versatility 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 features 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.

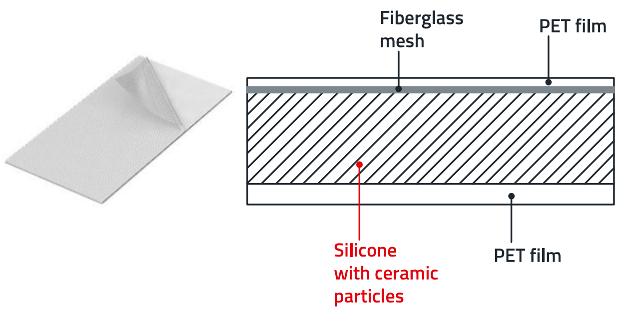

Figure 1: WE-TGF cross-section.

- **PET Film:**
  The WE-TGF is protected by two PET film layers. The one on the bottom is thicker and acts as a carrier, while the top film protects any foreign particles from adhering to the tacky surface of the pad. These film layers 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, filling gaps and removing air. The main body of the part is made with silicone or vinyl for silicone-free applications and is doped with ceramic particles to increase thermal conductivity.
- **Fiberglass mesh:**
  Pads under 2 mm thickness have a fiberglass mesh layer, 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.

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						
Bulk Thermal Conductivity	1 W/m·K	2 W/m·K	3 W/m·K	4 W/m·K	5 W/m·K	6 W/m·K
Color	Light Grey	Light Blue	Blue	Purple	White	Grey
Thickness	0.5 - 18 mm	0.5 - 18 mm	0.5 - 18 mm	0.5 - 4 mm	0.5 - 3 mm	0.5 - 3 mm
Specific Gravity	2.35 g/cm³	2.8 g/cm³	3.01 g/cm³	3.12 g/cm³	3.2 g/cm³	3.2 g/cm³
Hardness (5 mm pad thickness)	45 Shore 00	45 Shore 00	35 Shore 00	60 Shore 00	60 Shore 00	75 Shore 00
Temperature	-50 - +180 °C	-50 - +180 °C	-50 - +180 °C	-50 - +180 °C	-50 - +150 °C	-50 - +150 °C
Elongation	≥80%	≥70%	≥60%	≥60%	≥60%	≥50%
Tensile Strength	≥0.3 MPa	≥0.25 MPa	≥0.15 MPa	≥0.15 MPa	≥0.15 MPa	≥0.15 MPa
Compression Ration @ 35.5 N/cm²	≥25%	≥25%	≥20%	≥15%	≥15%	≥15%

Table 1: Material properties of WE-TGF.

Thermal Properties						
Bulk Thermal Conductivity	1 W/m·K	2 W/m·K	3 W/m·K	4 W/m·K	5 W/m·K	6 W/m·K
Thermal Impedance (Initial pad thickness of 2 mm @ 17.25 N/cm²)	17 K·cm²/W	7.7 K·cm²/W	4.9 K·cm²/W	4.7 K·cm²/W	2.7 K·cm²/W	1.6 K·cm²/W

Table 2: Thermal properties of WE-TGF.

Electrical Properties						
Bulk Thermal Conductivity	1 W/m·K	2 W/m·K	3 W/m·K	4 W/m·K	5 W/m·K	6 W/m·K
Breakdown Voltage	8 kV/mm	8 kV/mm	8 kV/mm	8 kV/mm	5 kV/mm	3 kV/mm
Volume Resistivity	10^{10} Ω·cm	10^{10} Ω·cm	10^{10} Ω·cm	10^{10} Ω·cm	10^{10} Ω·cm	10^{10} Ω·cm
Permittivity	7.8	11	13	13	13	13

Table 3: Electrical properties of WE-TGF.

3. DESIGN CONSIDERATIONS

3.1 Selecting the right thickness

Selecting the appropriate thickness and size of silicone elastomer pads is a critical design consideration. The thickness of the pad significantly affects the thermal conductivity and overall thermal performance. Thicker pads provide a softer and more compliant surface, but the thicker they are the higher the thermal resistance is. Thinner pads, on the other hand, are ideal for situations where minimal thermal resistance is required. Designers must consider the specific requirements of their application, such as available space, heat dissipation needs, and pressure constraints to choose the right thickness.

We can easily observe the impact of the thickness in the performance of the pad in Figure 2. The bar graph represents the thermal impedance of different thicknesses of a WE-TGF 3 W/m·K under a compressing force of 6.9 N/cm^2.

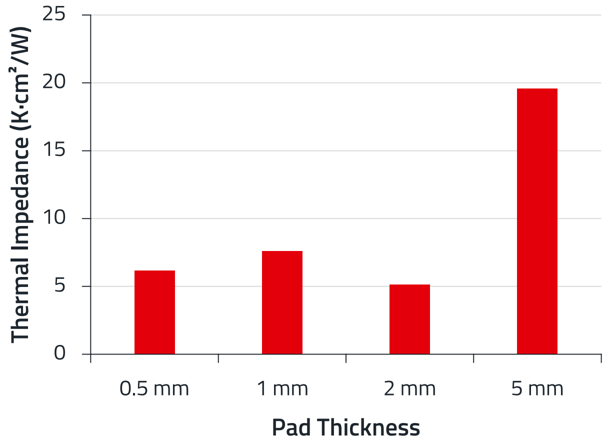

Figure 2: Thermal impedance vs. pad thickness.

In the graph, the effect of the fiberglass reinforcement is also represented. This reinforcement is standard and recommended for any pad with a height under 2 mm. Its purpose is to help the pad maintain its mechanical structure under compression, however it comes with the drawback of a slightly higher thermal impedance.

3.2 Recommendations for pad shape and dimensions

Determining the correct pad size involves evaluating the contact area between the electronic component and the heat sink. Ensuring full coverage while avoiding unnecessary material waste is pivotal for a cost-effective and efficient thermal solution.

The shape and dimensions of silicone elastomer pads should align with the geometry of the heat source. Whether the components have irregular shapes or standardized forms, customizing the pad shape to match the components' contours will ensure a cost-effective solution by avoiding material waste. After all, keep in mind that the pads have good through-plane thermal conductivity while worse in-plane.

Figure 3: Functionality of a gap filler on an IC.

Covering multiple components is also an option thanks to the non-conductive electrical properties of the elastomer. Although this is not the most cost-effective use, it can simplify device assembly.

For example, in applications where there are height variations between components, higher thickness and softer pads should be used to ensure uniform pressure distribution. By tailoring the shape and dimensions of silicone elastomer pads to the specific requirements of the application, designers can optimize thermal contact and maximize heat transfer efficiency.

3.3 How to design in the WE-TGF

In this section, we will follow the process on how you can design in the WE-TGF as a thermal interface material in your own design.

Identify thermal requirements

The first step in your thermal design is to determine the heat dissipation requirements of the components in your application, including power ratings, maximum operating temperatures, and final ambient temperature. Registering this data on a table, as shown in Table 4, can help you define different case scenarios and determine your thermal budget. It is a good habit to design for the worst-case scenario.

	Scenario 1		Scenario 2	
	Component A	Component B	Component A	Component B
Surface area	600 mm²			
Thermal losses	1.5 W	1.5 W	2 W	2.5 W
R_{thJC}	1 K/W	1 K/W	1 K/W	1 K/W
T_A	40 °C		45°C	
$T_{j\,MAX}$	120 °C			
Air flow	400 FPM		350 FPM	

R_{thJC} = Thermal resistance junction to case, T_A = Ambient temp., $T_{j\,MAX}$ = Max. junction temp.

Table 4: Comparison of different thermal management challenges.

In this example, the worst-case scenario is "Scenario 2", both components are running a higher load, and the expected ambient temperature is higher. For this example, we will focus on Component B.

Thermal Modelling

Heat always transfers from high to low temperatures. In this context, it flows from the hot component to the air surrounding the cooling assembly, which is commonly defined as ambient temperature. Anything that lays between the two will add a resistance to the flow of heat, and where there is a resistance there is a rise-above temperature.

By now, this has likely sparked an idea: thermal systems are analogous to Ohm's law. This analogy is visualized in Figure 4.

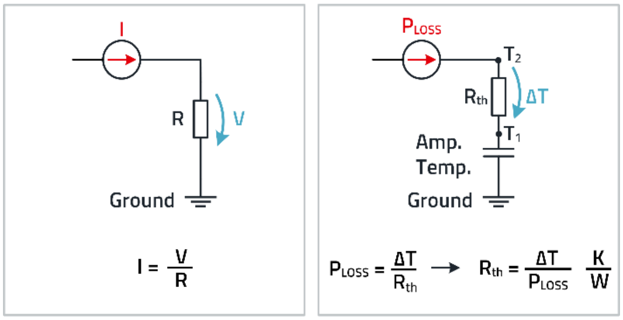

Figure 4: Electrical analogy of systems.

Of course, this is a simplified and unidimensional analysis, but often it's enough to validate your concept design. You can make it more detailed by considering additional paths for heat flow, such as emissions and package convection as shown in Figure 5. If your design contains a switching component, a transient analysis can be performed by adding thermal capacitances such as the ones considered in the Foster or Cauer thermal models.

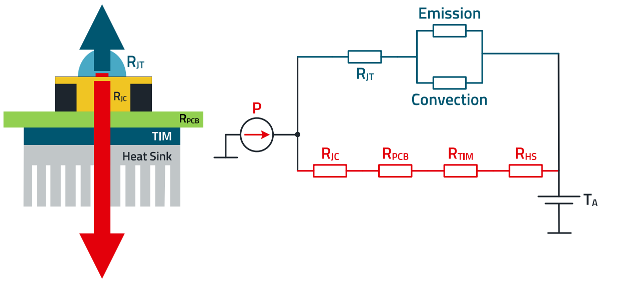

Figure 5: Thermal calculation considering dissipation through heat sink and packaging.

For this example, we will focus on a static analysis of component B in scenario 2 where we have a dissipation of 2.5 Watts of energy as thermal losses and has a junction-to-case thermal resistance of 1 K/W. We now have most of the information required to calculate our component's junction temperature.

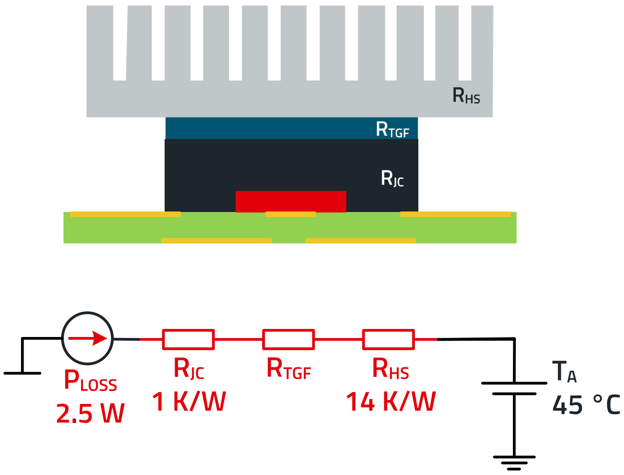

Figure 6: Thermal resistance network.

Our design requires that we fill a gap of approximately 2 mm. Now we can evaluate different WE-TGF options to find the optimal solution to keep our components junction temperature within operating limits. You can calculate the thermal resistance of the pad as follows if you know the thermal conductivity (λ), thickness (L) and contact area (A).

$$R_{th\text{-}TIM} = \frac{L}{\lambda \cdot A} \left(\frac{K}{W}\right) \quad (1)$$

Since we know the surface area of our component, the thickness and thermal conductivity of the WE-TGF, we can estimate that the thermal resistance of a 1 W/m·K pad is:

$$R_{th\text{-}TIM} = \frac{0.002\ \text{m}}{1\ \frac{\text{W}}{\text{m} \cdot \text{K}} \cdot 0.0006\ \text{m}^2} = 3.3\ \frac{\text{K}}{\text{W}} \quad (2)$$

Now we would have everything we need to estimate the junction temperature of our component under the conditions.

$$T_2 = P_{LOSS} \cdot R_{th} + T_1 \qquad (3)$$

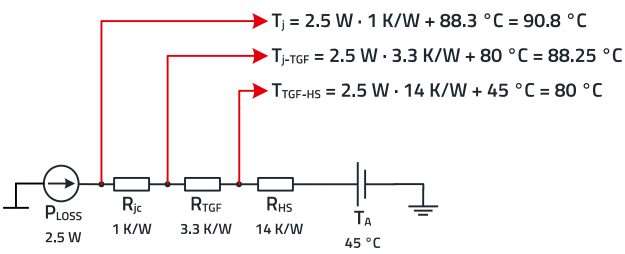

Figure 7: Junction temperature calculation.

The resulting junction temperature of 90.8 °C in our component is well within its maximum operating temperature. By repeating the calculations with different WE-TGF conductivity values, we can estimate the junction temperature and assess if we have selected the most cost-effective solution.

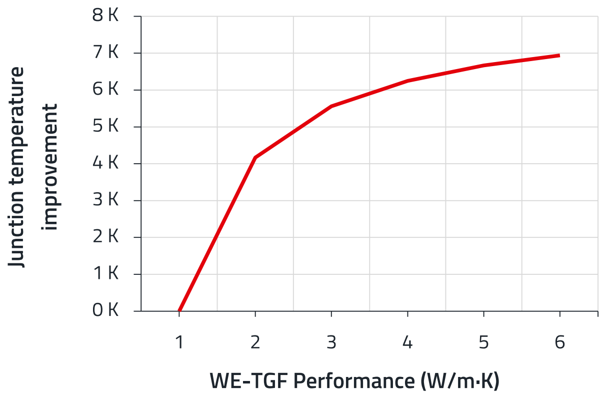

Figure 8: Junction temperature improvement based on WE-TGF performance.

In Figure 8 we can observe that the improvement of the junction temperature based on the performance of the WE-TGF for this application is significantly noticeable up to 3 W/m·K, thus we can conclude that a 3 W/m·K WE-TGF is the optimal TIM selection. Using a higher performing interface is not a cost-effective solution, considering the low decrease of junction temperature it will create. If we wanted to decrease the junction temperature further, it would be more effective to use a better performing heatsink rather than higher performing TIM.

If we would like to perform a more detailed analysis of the 3 W/m·K solution that has an estimated thermal resistance value of 1.1 K/W, we could also use the thermal impedance values in Figure 9 resulting from measurements following the ASTM D5470 standard. For more information about the measurement setup please have a look at appendix A.2.

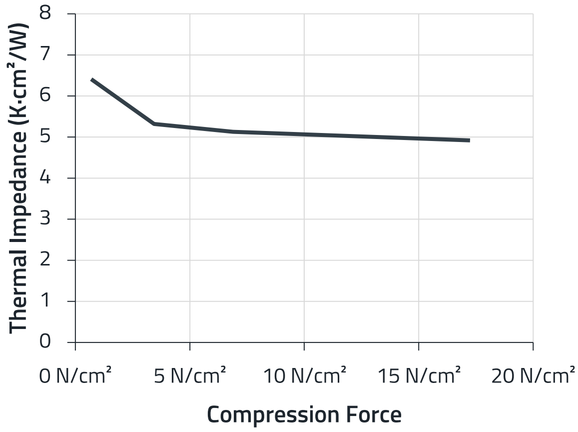

Figure 9: Thermal impedance values as per ASTM D5470.

For a compression force of 6.89 N/cm^2 we see an impedance value of 5.1 $K{\cdot}cm^2/W$. Based on our component surface area, which in this example is 6 cm^2, we can calculate that our final thermal impedance is:

$$R_{th\text{-}TIM} = \frac{5.1\ \frac{K{\cdot}cm^2}{W}}{6\ cm^2} = 0.85\ \frac{K}{W} \qquad (4)$$

As it can be observed, there is a slight difference between calculated and measured thermal resistance. The reason for this difference is that the measurement is performed under compression. Thermal impedance measurements also represent thermal contact resistance as well as the heat capacity of the material. Therefore, we can consider thermal impedance measurements as a more "real application" value.

Thermal Simulations

With current electronic design trends, the power density on a board is quite high. This density effects how heat sources interact with each other, complicating analytical models such as the one presented in the previous section. This is where electronic thermal simulators come in, which take more first and second order effects into account and provide results closer to an experimental measurement.

Würth Elektronik provides the thermal models for ANSYS of the WE-TGF series, which can be downloaded for free from the online catalog.

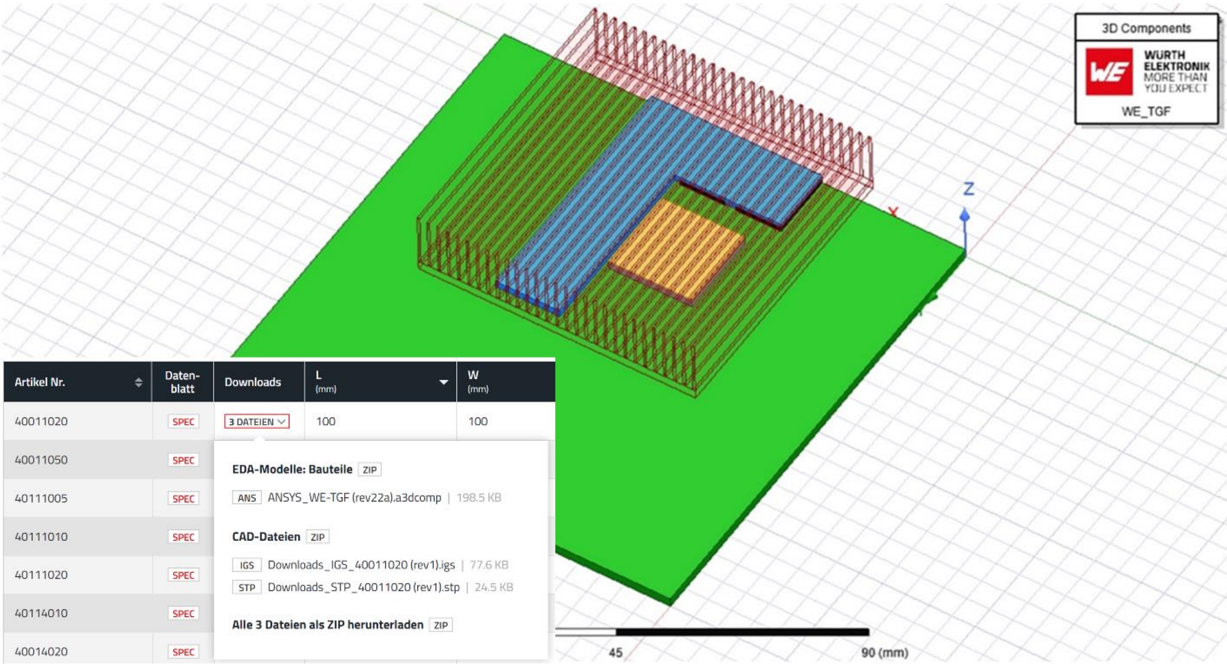

Figure 10: Ansys simulation with WE-TGF.

Validation through prototyping

The last step in any thermal design is the validation through prototyping. It is recommended to perform thermal tests under different operating conditions, including temperature variations and load fluctuations. We can see in fig.10 an Ansys Icepak thermal simulation with WE-TFG in blue and WE-PCM in yellow interfacing the heat sources and a heatsink in red. Thermal performance can be evaluated using thermal imaging or thermocouples.

4. INSTALLATION AND HANDLING

The correct installation of elastomeric pads is crucial for ensuring optimal thermal performance and long-term reliability of electronic devices. During installation, it is essential to ensure that the pads are clean and properly aligned with the components they are intended to cool. Proper alignment guarantees maximum surface contact, minimizing thermal resistance. Additionally, applying an appropriate amount of pressure while installing the pads is vital. Adequate pressure helps in squeezing out air pockets and ensures a tight bond between the pad, the electronic component, and the heat sink. However, excessive pressure should be avoided as it might lead to pad deformation, damage or the appearance of silicone oil droplets if working with a silicone pad.

In order to ensure correct application, the following steps are recommended:

1. The surface of the component and cooling assemblies must be clean and dry. It is recommended to use isopropyl alcohol applied with a lint-free wipe or swab to remove any particles on contact surfaces.
2. Remove the pad from the matrix and place it on the component. If the part contains a fiberglass mesh, make sure the surface of the mesh faces that of the cooling assembly.
3. Remove the remaining protective film before installing the cooling assembly
4. Apply the recommended compression.

Cutting

To fit the WE-TGF to your application it can be cut with any sharp object to any shape. Laser cutting is discouraged because it can decrease the thermal performance of the pad by increasing its hardness around the edges.

Compression

As a rule of thumb, a compression between 10 % and 30 % of the pad's height is recommended. This depends on the thickness of the part. Thinner pads are harder to compress. Generally, 6.9 N/cm² (10 PSI) ensures a good thermal performance.

Reworking

The pads are designed to be used once. Rework can allow foreign particles to attach themselves to the contact surfaces decreasing the thermal performance of the pad.

5. MODIFICATION AND PROTOTYPING SERVICE

Würth Elektronik provides a shape modification service that accompanies you from prototyping to manufacturing offering no MOQ or tooling costs.

Modified shapes are performed by die-less cutting. This technique allows a knife to cut through the top protective film and the material itself, leaving the bottom carrier intact as a carrier for the pads. Die-less cutting allows the parts to be delivered as a sheet.

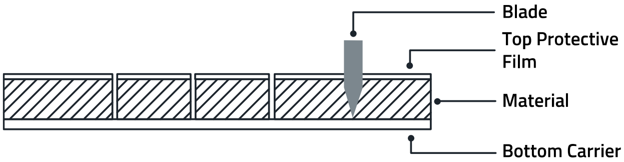

Figure 11: Die-less cutting of parts.

Reach out to your Würth Elektronik representative with the following information and they will reply with a personalized quotation:

- Desired thermal conductivity
- Gap height
- Number of parts needed
- Technical drawing of desired part
- Any special requests you may have

A APPENDIX

A.1 Thermal performance

Elastomeric pads conduct heat through a combination of thermal conductivity and physical conformability.

Thermal conductivity is a fundamental material property that describes how well a material conducts heat. It quantifies the rate at which heat energy is transferred through a material per unit area and per unit temperature gradient. In simpler terms, thermal conductivity reflects a material's ability to conduct or transfer heat from one contact surface to another.

When a material is subjected to a temperature gradient (meaning one side is hotter than the other), heat naturally flows from the hotter region to the cooler region. The rate at which this heat transfer occurs depends on the material's thermal conductivity. Materials with high thermal conductivity allow heat to move quickly through them, while materials with low thermal conductivity impede the flow of heat, making them good insulators.

Thermal conductivity is typically expressed in units of watts per meter-kelvin (W/m·K). The thermal conductivity of a material can be mathematically represented as follows:

$$\lambda = \frac{Q \cdot L}{A \cdot (T_2 - T_1)} \qquad (5)$$

Where:

- λ is the thermal conductivity of the material (W/m·K)
- Q is the heat transfer rate (W).
- L is the thickness of the material (m)
- A is the surface area (m²)
- $T_1 - T_2$ is the temperature difference between two surfaces (K)

The **physical conformability** of the WE-TGF is characterized by their elastomeric nature, which enables them to conform to surface irregularities of both the component and the heat sink. This conformability ensures very close contact and reduces the thermal interfacial resistance. When the pad is compressed between the component and the cooling assembly, it fills microscopic gaps and air voids, providing a path with low thermal resistance for heat to flow through.

Another factor that affects the performance of the pads is the temperature difference between the heat source and the ambient.

Lowering the thermal resistance by using a higher performing pad in an application where the temperature difference is small will have no effect on the overall system cooling.

Thermal resistivity and resistance

Silicone elastomer pads are also characterized by their thermal resistivity values, which quantify how much they impede the transfer of heat under a specific temperature difference. Thermal resistivity is a material property and refers to the material's ability to resist the flow of heat. It is analogous to electrical resistance in electrical circuits. Just as electrical resistance limits the flow of electric current, thermal resistivity limits the flow of heat energy.

Thermal resistivity is the reciprocal of the heat transfer rate:

$$R = \frac{T_2 - T_1}{Q} \qquad (6)$$

Where:

- R is the thermal resistivity (K/W)
- $T_2 - T_1$ is the temperature difference between two surfaces (K)
- Q is the heat transfer rate (W)

The thermal resistance on the other hand is influenced by various factors, including pad thickness, pressure, and operating temperature. Thicker pads generally have higher thermal resistance due to increased material volume for heat conduction. Applying appropriate pressure during installation is crucial, as it reduces the thermal interfacial resistance by maximizing surface contact between the pad and the components. When this is applied to the field of thermal interface materials a lower thermal resistance implies that the component will be able to transfer more heat to the ambient.

Thermal impedance

Thermal impedance is the temperature gradient per unit of heat flux that flows through a material. Therefore, it can be defined as the material’s opposition to the flow of thermal energy per cm². Consider a thermal impedance value of 0.5 K·cm²/W, it implies that for every watt of power dissipated through a pad with an area of one centimeter square, there is a 0.5 °C temperature difference between the contact surfaces. This value is measured in-house by Würth Elektronik following the standard ASTM D5470.

It is expressed as thermal resistivity per area in K·cm²/W:

$$Z = \frac{T_2 - T_1}{Q / A} = R \cdot A \qquad (7)$$

Where:

- Z is the thermal impedance (K·cm²/W)
- R is the thermal resistance (K/W)
- $T_2 - T_1$ is the temperature difference between two surfaces (K)
- Q is the heat transfer rate (W)
- A is the surface area (cm²)

Lower thermal impedance indicates better responsiveness to temperature changes, ensuring quick dissipation of heat spikes and maintaining stable operating temperatures. In Figure 12 the thermal impedance values of 2 mm pads with thermal conductivity values from 1 to 6 W/m·K are shown. It clearly represents the relationship between thermal impedance, the thermal conductivity of the pads and the compression force. The greater the thermal conductivity, the lower the thermal impedance. The compression force also contributes to a lower thermal impedance, but its influence is relatively small.

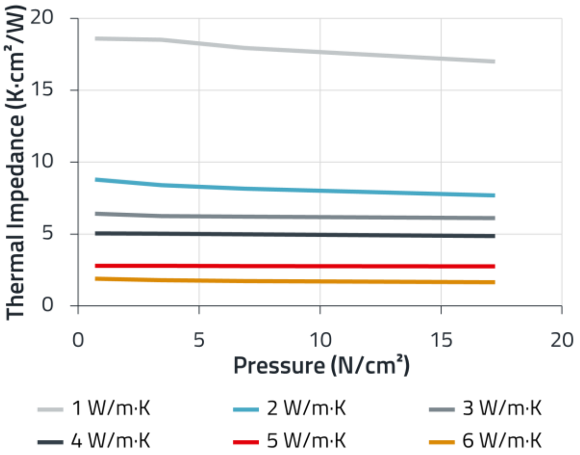

Figure 12: Thermal Impedance of 2 mm WE-TGF pads of different performance.

A.2 Thermal measurement setup

All thermal parameters mentioned in this guideline have been performed in-house following ASTM D5470 - Standard Test Method for Thermal Transmission Properties of Thermally Conductive Electrical Insulation Materials.

The standard focuses on steady-state heat transfer conditions. During testing, a constant heat source is applied to one side of the TIM specimen, while a cooling assembly ensures a temperature difference to create a heat flow though the material under test. This setup, shown in Figure 13 allows for the measurement of thermal conductivity and impedance under different temperature and mechanical conditions.

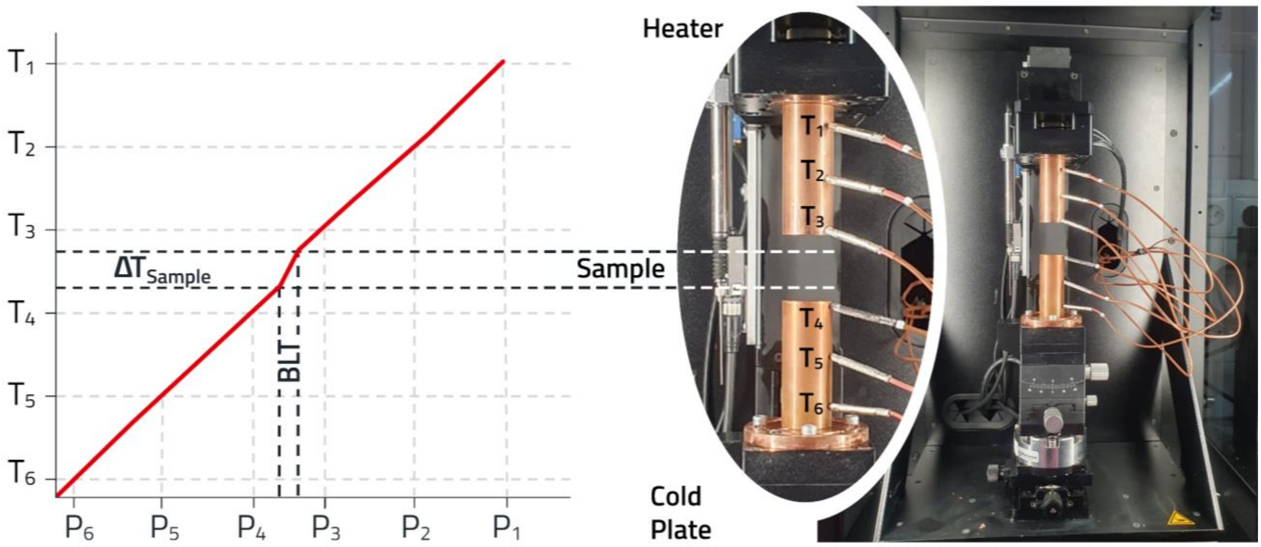

Figure 13: ASTM D5470 testing setup

IMPORTANT NOTICE

USEFUL LINKS

Application Notes
www.we-online.com/appnotes

REDEXPERT Design Platform
www.we-online.com/redexpert

Toolbox
www.we-online.com/toolbox

Product Catalog
www.we-online.com/products

CONTACT INFORMATION

appnotes@we-online.com
Tel. +49 7942 945 - 0

Würth Elektronik eiSos GmbH & Co. KG
Max-Eyth-Str. 1 74638 Waldenburg Germany
www.we-online.com