Cool solutions

Peter Davies of Warth explains how to get the most out of modern high-performance alternatives to the traditional mica and grease solution.

Good heat sink design is important since, quite simply, the cooler electronics components run, the longer they last. For heatsinks to perform optimally, the temperature difference between the heatsink and the surrounding air must be at a maximum. If there is a continual supply of new cooled air passing over the sink, the maximum temperature differential will be maintained.

It is equally important to ensure that the heat being generated in the device flows through to the heatsink efficiently so the heatsink temperature as closely as possible matches that of the device – again maximising the temperature differential between it and the surrounding air.

Historically, to provide electrical isolation, mica insulators were used with thermal grease to mount transistors to heatsinks – a time-consuming process which had several problems. The mica was prone to cracking and grease often migrated, causing contamination. The grease could also become age hardened. But the development of thermally conductive interface materials like *Kool-Pads*, from Warth International, has changed that.

Heat flow mechanisms

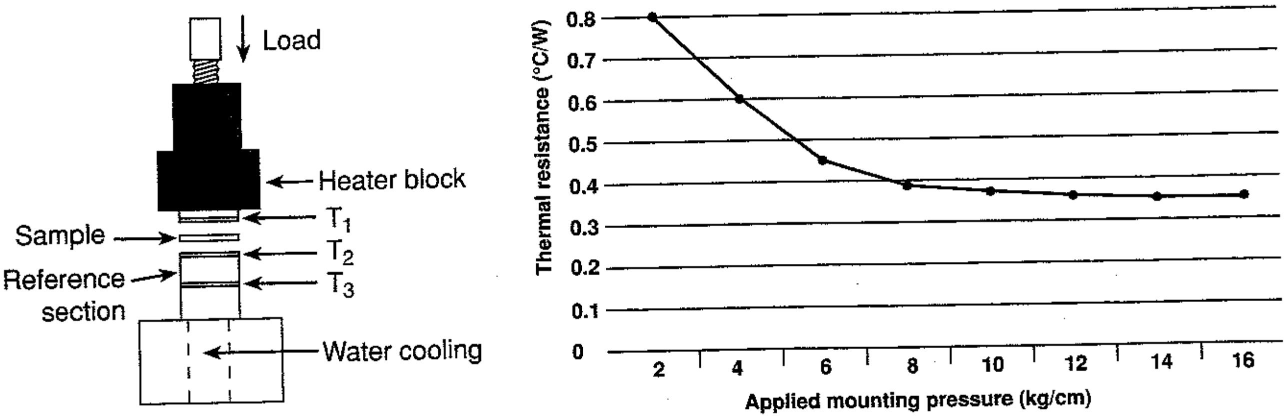
For thermal energy to be able to travel from the power dissipating device it has to cross several interfaces, each having its own resistance to this flow. These are:

- Device junction to case resistance. This is a function of the design of the device and will be specified by the manufacturer.
- Case-to-heatsink resistance. This is the point that the heatsink and the device meet and is variable.
- Heatsink-to-air resistance. This is the heatsink's ability to dissipate heat to air and is determined by the heatsink selected and is also variable.

Each one of these interfaces has its own thermal resistance figure.

The junction-to-case figure is predetermined by the device manufacturer and so can be only influenced by the device selection. Consequently, as the thermal performance of a device cannot be changed, the design engineer must focus on the other two interfaces. Both of these interfaces will have a critical effect on system reliability.

Fig. 1. Test jig for evaluating thermal conductivity of Warth Kool Pads, top, and curve showing how pressure affects thermal conductivity.



Often, the case of the device that needs cooling needs to be electrically insulated from the heat sink. The insulating material used to provide this insulation determines the second figure – case-to-heatsink resistance. Note that case-to-heatsink conductivity can also be improved by adding the right interface material since it removes thermally insulating air pockets.

The better the thermal interface, the easier the flow of thermal energy to the heatsink. It is vitally important to select a thermal interface pad with performance criteria matching the requirements of the application.

The third interface is determined by the heatsink selection. This is not as simple as it sounds. The obvious solution is to put the biggest heatsink available on the device, but space restriction becomes ever more important as electronic equipment continues to get smaller and smaller.

For design engineers, accurate calculation of thermal conductivity, thermal resistance and mounting pressure is crucial to optimum performance and product reliability. Warth has devised a series of formulae to be used in conjunction with its products to optimise accurate calculation.

Calculating thermal conductivity

Thermal conductivity is the measure of the ability of a material to allow heat to flow through it. It is normally expressed as $Wm^{-1}K^{-1}$. The higher the figure quoted, the better a material will perform.

All Warth calculated figures are achieved by clamping a 2.54cm^2 sample between two isothermal layers, as shown in the **Fig. 1**. Here, pressure is maintained accurately with a ram air cylinder.

The temperature differential across a calibrated stainless steel reference, T_1 and T_2, is compared to the differential across the sample T_2 and T_3 when the materials are in series and equilibrium is attained.

These figures are calculated from the ideal conditions with uniform pressure and one-dimensional heat flow, and are not effected by material thickness and other application variations.

Thermal resistance calculations

Thermal resistance is a measure of the resistance of a material to heat flow through it and is normally expressed in °C/W. The lower the quoted thermal resistance, the better the thermal conductivity.

For a given material, thermal resistance is also proportional to voltage breakdown; consequently high voltage breakdown material often has a higher thermal resistance due to increased thickness and material composition.

In general, thermal resistance is a more practical measure of thermal performance as it is proportional to the thickness of the material. This means that it can be more easily worked into thermal management calculations as heatsink and component thermal performance is normally expressed as a measure of thermal resistance.

Warth calculates its figures by using an aluminium heatsink and TO-3 transistor powered to 20W. An aluminium spacer is placed between the transistor and the heatsink which spreads the heat over the whole test area and distributes the pressure evenly. Thermocouples are embedded in all three components.

The transistor mounting screws are torqued to 0.7Nm giving a mounting pressure of 15kg/cm^2. Thermal resistance is calculated from the temperature difference across the insulator divided by the power dissipated, **Fig. 2**.

To calculate the thermal resistance of a Warth Kool-Pad used with any other component package style, the following equation should be used, **Fig. 3**.

Thermal resistance can be used to calculate the expected junction temperature of a device using, **Fig. 4** & 5.

Mounting pressure

The mounting pressure used in any application has a significant effect on the thermal resistance of the *Kool-Pads*. As the mounting pressure is increased, pockets of air are eliminated and the *Kool-Pad* fully conforms to the surface of the transistor and heatsink.

After this point, any further increase in pressure has no beneficial effect. In some instances, where packages styles like TO-220 and TO-3P are used, the thermal resistance could actually increase. This is due to the single mounting screw being located at one end of the transistor and causing a cantilever effect. These package styles are best mounted with a clip specially designed for use with the *Kool-Pads*.

For custom Kool-Pads, the following equation can be used to calculate the recommended mounting pressure, **Fig. 6**.

Take care when assessing the required pressure, as surfaces with rough finishes or burrs can cause cut-through and a breakdown in insulation.- ■

Figs 2-6. Equations needed for evaluating the performance of thermally-conductive component-mounting material.

Thermal resistance $\frac{T_S - T_R}{W}$

Where:

T_S is spreader temperature
T_R is heatsink Temperature
W is= power dissipated is watt

Selected Kool-Pad thermal resistance $\frac{\theta_{kp}=\theta_s \times K}{A}$

Where:

θ_s is thermal resistance of kool-pad material for standard TO-3 package
K is surface area conversion factor constant of 6.45)
A is component contact surface area (cm^2)

Junction temperature $T_j=(\theta_{jc}+\theta_{kp}+\theta_{sa})Q \times T_a$

Where: θ_{jc} is Junction-to-case Thermal Resistance
θ_{kp} = Kool-Pad thermal resistance
θ_{sa} is heatsink thermal resistance
Q is power dissipated in watts
T_a is Ambient temperature

TO-220 transistor with junction to case thermal resistance	$\theta_{jc}=1.5°C/W$
Heatsink thermal resistance	$\theta_{sa}=6°C/W$
Kool-Pad thermal resistance for standard TO-3 package	$\theta_s=0.07°C/W$
Ambient temperature	$T_a=30°C$
Mounting surface area of TO-220 case	$A=1.5cm^2$
Power dissipated	$Q=10W$
$\theta_{kp}=\frac{0.07 \times 6.45}{1.5}$	$\theta_{kp}=0.3$
$T_j=(1.5+0.3+6) \times 10+30$	$T_j=108°C$

$P=\frac{T \times N}{0.2 \times D \times A}$

P is pressure is N/m^2
D is fastener diameter
T is torque is Nm
A is contact surface area
N is number of fasteners
friction factor is 0.2.

Details of this month's free cover-mounted sample*

Warth's *K230* thermally-conductive insulating pads

K230 is made from silicone-coated fibreglass cloth in which the silicone is loaded with thermally conductive particles.

It is the type and concentration of the loading that dictates thermal and voltage performance. The greater the loading of particles, the better the thermal resistance and conversely, the lower the voltage breakdown. *K230* is loaded with thermally conductive particles including boron nitride which gives it very low thermal resistance while maintaining a high voltage breakdown. These characteristics make it ideal for applications which need to meet demanding VDE voltage specifications but still require very good thermal performance such as power transistors in high voltage power supplies.

Warth's conducting fillers give a more conformable product so that optimum performance can be achieved with low mounting pressures. This makes the material ideal for applications where transistor mounting clips can be used such as the Warth 'Gull wing' range.

Warth *K230* material attached to the front of this journal has been recently reformulated to give a 10% improvement in thermal performance whilst maintaining its high breakdown voltage.

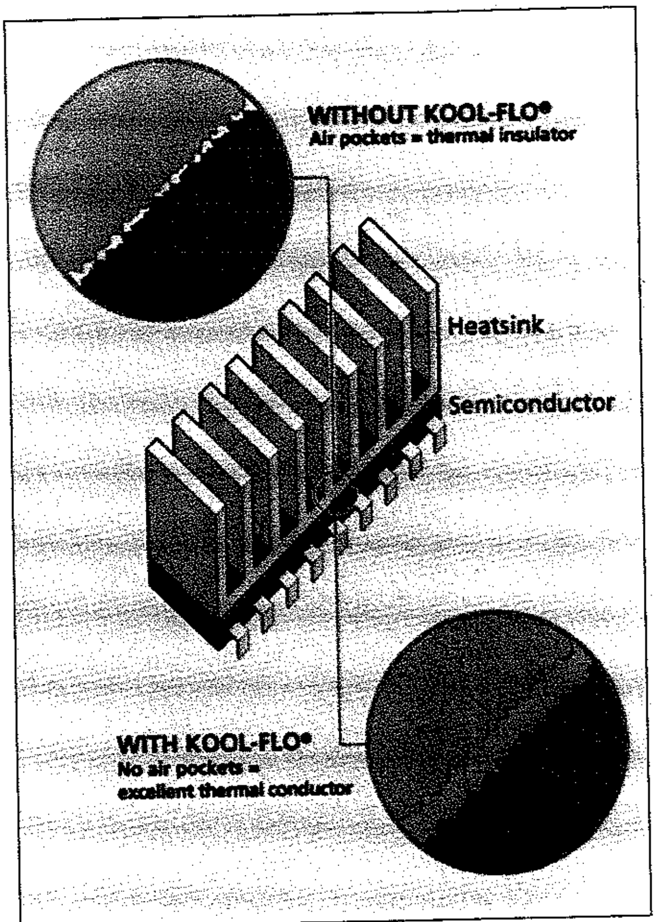
And where insulation isn't needed?

K230 and its family of products are ideal for applications that require electrical isolation. But for applications not requiring isolation, the interface material only needs to take up any irregularities and air gaps existing between the heat generating device and its heatsink. This is because air is a very poor heat-conducting medium and will have a detrimental effect on the performance of the device.

Historically, this type of application would be addressed using thermal grease. But Warth's *CM20* and *Kool-Flo* materials will give excellent consistent heat transfer without the difficulties and silicone contamination associated with using grease.

Kool-Flo – the latest grease replacement product from Warth – is a phase change material which at room temperature is a dry film. When heated to 50°C though, it softens – 'goes through a phase change' – allowing it to flow, filling any voids between the two surfaces.

CM20 is a soft, comfortable graphite sheet which again fills voids, giving a consistent, exceptionally low resistance heat path. It is ideal for high power applications.



Air is an excellent insulator. Adding a thermally-conductive pad improves heat transfer between the component and its heat sink by removing the air pockets.

Technical support

Based in East Grinstead, the British company Warth International manufactures a wide range of thermally conductive insulators and a multitude of rfi shielding solutions.

Whether for a clip mount processor type application, automotive, telecoms or medical equipment, Warth can solve most thermal interface problems wit standard or custom product.

Warth *Kool-Pads* are available in a comprehensive range of standard package profiles such as TO-3, TO-220 and TO-3Ps or can be quickly and easily cut to any shape required.

You can contact Warth on 01342 315044,

Visit Warth on the Web: http://www.warth.uk