3M

Technical Bulletin

Heat Flow Calculation for 3M™ Thermally Conductive Tapes 9882, 9885, 9890

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General Information

The function of thermally conductive tape is to mechanically bond the hot component to the heat sink and provide a thermal path from the chip or case of the package to the cooling air in the box. The important number in this calculation is the operating temperature of the chip or case when in use. The system must provide sufficient thermal outflow to keep the chip or case below its maximum rated temperature. The examples and worksheet provided are supplied to help the user determine the applicability of 3M tapes to their heat sink attachment application.

The chip manufacturer can provide either the maximum operating temperature of the chip or the maximum temperature allowed at the package case surface. The chip or case temperature $T_{\text{chip/case}}$ is calculated knowing the T_{air}, temperature of the air in the box, the power dissipation of the chip, P, and all the thermal resistance between the chip and the air, R_{total}

(Eq 1.) $$T_{\text{chip/case}}\ (°\text{C}) = T_{\text{air}} + (P \bullet R_{\text{total}})$$

The total resistance is the thermal resistance from the chip to the air and it is the sum of the thermal resistance of the various components that make up the assembly:

(Eq. 2) $$R_{\text{total}}\ (°\text{C/W}) = R_{\text{chip-case}} + R_{\text{case-sink}} + R_{\text{sink-air}}$$

$R_{\text{chip-case}}$ is the thermal resistance of the package holding the chip, $R_{\text{sink-air}}$ is the thermal resistance of the heat sink to air interface. The $R_{\text{case-sink}}$ is equal to the thermal resistance of the 3M Thermally Conductive Adhesive Transfer Tape which bonds the package case to the heat sink, R_{adhesive}:

(Eq. 3) $$R_{\text{adhesive}}\ (°\text{C/W}) = \frac{\text{thermal impedance } (°\text{C in}^2/\text{W})}{\text{contact area } (\text{in}^2)}$$

As noted in equation 3, the resistance of the adhesive will be controlled by the inherent thermal impedance of the material divided by the area of the tape. Theoretically, the contact area equals the physical area of the tape utilized in making the bond; in practice one never gets 100% contact between the tape and the substrates, so some loss in thermal performance is expected relative to the theoretical maximum. Wet-out (percent contact) is optimized by using very flat substrates and applying the tape in the prescribed manner. In these examples we have arbitrarily chosen a percent wet-out. This wet-out percent should be estimated for each combination of substrates in each application.

Example 1

Example 1 shows a typical calculation where the user knows the maximum operating temperature of the chip. In this example we have chosen a piece of 10 mil 3M™ Tape 9890, which has relatively high thermal impedance.

<u>Known quantities:</u>

$T_{air} = 50°C$

$R_{chip\text{-}case} = 1.75°C/W$

$R_{sink\text{-}air} = 1.5°C/W$

Thermal impedance of 3M Tape = 0.9°C in^2/W, tape area is 0.75 in^2

Power dissipation of chip = 5W

Chip maximum operating temperature = 90°C

<u>Calculations:</u>

From equation 3, $R_{adhesive} = 0.9°C\ in^2/W/0.75\ in^2 = 1.2°C/W$. Recall that one does not get 100% wet-out between the adhesive and the substrates, so let us bump this value up to 2.0°C/W (approximately 60% wet-out assumed).

From equation 2, $R_{total} = R_{chip\text{-}air} = 1.75 + 2.0 + 1.5 = 5.25°C/W$

So we can now calculate the chip operating temperature from equation 1.

$$T_{chip} = 50°C + (5W \bullet 5.25°C/W) = 50°C + 26.25°C = 76.25°C$$

We can see that the calculated temperature of the chip surface (76.25°C) is less than the recommended operating temperature of the chip (90°C). If, on the other hand, the power dissipation for this chip were 10 W, our calculation would be:

$$T_{chip} = 50°C + (10W \bullet 5.25°C/W) = 50°C + 52.5°C = 102.5°C$$

i.e. and this chip would run too hot in this design.

Example 2

Example 2 shows a typical calculation where the user has been provided the maximum operating temperature of the case by the manufacturer. In this example we have chosen a piece of 2 mil 3M™ Tape 9882, which has relatively low thermal impedance. In this example there is no $R_{chip\text{-}case}$ in the calculation. The power dissipation of this chip is 10 W.

Now equation 1 can be written as: $T_{case} = T_{air} + (P \bullet R_{total})$

And equation 2 is given as: $R_{total} = R_{case\text{-}sink} + R_{sink\text{-}air}$

As before the $R_{case\text{-}sink}$ is equal to $R_{adhesive}$ given in equation 3 above.

<u>Known quantities:</u>

$T_{air} = 50°C$

$R_{sink\text{-}air} = 1.5°C/W$

Thermal impedance of tape = 0.2°C in^2/W, tape area is 0.75 in^2

Power dissipation of chip = 10W

Maximum case temperature = 80°C

<u>Calculations:</u>
From equation 3, $R_{adhesive}$ = 0.2°C in^2/W/0.75 in^2 = 0.27°C/W. Recall that one does not get 100% wet-out between the adhesive and the substrates, so let us bump this value up to 0.6°C/W (approximately 50% wet-out assumed; the thinner the tape, the more difficult it is to obtain complete wet out of the substrate.).

From modified equation 2, $R_{total} = R_{case\text{-}air} = 0.6 + 1.5 = 2.1°C/W$

So we can now calculate the chip operating temperature from equation 1.

$$T_{case} = 50°C + (10W \bullet 2.1°C/W) = 50°C + 21°C = 71°C$$

We see in example 2 with the thin tape 9882 the case temperature is below the specified maximum.

Customer Worksheet:

Information Required (units):

T_{air} - typical expected air temperature in the device (°C)	
Information from Material Suppliers:	
$R_{chip\text{-}case}$ (if needed) (°C/W)	
$R_{sink\text{-}air}$ (°C/W)	
P, power dissipation of chip (W)	
Chip maximum operating temperature (°C) or	
Maximum case temperature (°C)	
Thermal impedance of 3M™ Tapes (see product data page for most up-to-date values)	
Tape 9882 = 0.2°C in^2/W	
Tape 9885 = 0.5°C in^2/W	
Tape 9890 = 0.9°C in^2/W	

1. Calculate $R_{adhesive}$:

   $R_{adhesive}$ = (Thermal impedance of 3M tape/area of tape) / wet out % estimate

   ______________ (°C/W) = (______________ / ______________) / ______________

2. Calculate R_{total} from equation 2:

   $R_{total} = R_{chip\text{-}case}$ (if applicable) $+ R_{adhesive} + R_{sink\text{-}air}$

   ______________ (°C/W) = ______________ + ______________ + ______________

3. Calculate the chip or case temperature:

   $T_{chip\ or\ case} = T_{air} + (P \bullet R_{total})$

   ______________ (°C) = _________ + (_____ x _________)

4. Compare this calculated chip/case temperature with the chip manufacturer's recommendations.

For Additional Information

To request additional product information or to arrange for sales assistance, call toll free 1-800-362-3550 or visit www.3M.com/conductives. Address correspondence to: 3M Engineered Adhesives Division, 3M Center, Building 220-7E-01, St. Paul, MN 55144-1000. Our fax number is 651-733-9175. In Canada, phone: 1-800-364-3577. In Puerto Rico, phone: 1-787-750-3000. In Mexico, phone: 52-70-04-00.

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