Application Note No. 077
Thermal Resistance Calculation
LEGAL DISCLAIMER

THE INFORMATION GIVEN IN THIS APPLICATION NOTE IS GIVEN AS A HINT FOR THE IMPLEMENTATION OF THE INFINEON TECHNOLOGIES COMPONENT ONLY AND SHALL NOT BE REGARDED AS ANY DESCRIPTION OR WARRANTY OF A CERTAIN FUNCTIONALITY, CONDITION OR QUALITY OF THE INFINEON TECHNOLOGIES COMPONENT. THE RECIPIENT OF THIS APPLICATION NOTE MUST VERIFY ANY FUNCTION DESCRIBED HEREIN IN THE REAL APPLICATION. INFINEON TECHNOLOGIES HEREBY DISCLAIMS ANY AND ALL WARRANTIES AND LIABILITIES OF ANY KIND (INCLUDING WITHOUT LIMITATION WARRANTIES OF NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS OF ANY THIRD PARTY) WITH RESPECT TO ANY AND ALL INFORMATION GIVEN IN THIS APPLICATION NOTE.

Information

For further information on technology, delivery terms and conditions and prices please contact your nearest Infineon Technologies Office (www.infineon.com).

Warnings

Due to technical requirements components may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies Office.

Infineon Technologies Components may only be used in life-support devices or systems with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system, or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body, or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.
### Application Note No. 077

#### Revision History: 2007-01-08, Rev. 2.0

#### Previous Version:

<table>
<thead>
<tr>
<th>Page</th>
<th>Subjects (major changes since last revision)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>Document layout change</td>
</tr>
</tbody>
</table>
1 Thermal Resistance

The heat caused by the power loss $P_{\text{tot}}$ in the active semiconductor region during operation results in an increased temperature of the component. The heat is dissipated from its source (junction J or channel Ch) via the chip, the case and the substrate (pc board) to the heat sink (ambient A). The junction temperature $T_J$ at an ambient temperature $T_A$ is determined by the thermal resistance $R_{\text{thJA}}$ and the power dissipation $P_{\text{tot}}$.

$$T_J = T_A + P_{\text{tot}} \times R_{\text{thJA}}$$

(with $R_{\text{thJA}}$ in K/W or °C/W)

2 RF and AF Transistors an Diodes in SMD Packages

In SMD packages the heat is primarily dissipated via the pins. The total thermal resistance in this case is made up of the following components:

$$R_{\text{thJa}} = R_{\text{thJT}} + R_{\text{thJS}} + R_{\text{thSA}}$$

R_{\text{thJS}} = R_{\text{thJT}} + R_{\text{thTS}}

<table>
<thead>
<tr>
<th>Table 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{\text{thJa}}$</td>
</tr>
<tr>
<td>$R_{\text{thJS}}$</td>
</tr>
</tbody>
</table>
\[ T_J = T_S + P_{tot} \times R_{\text{thJS}} \]

The temperature of the soldering point \( T_S \) is determined by the application, i.e. by the substrate, heat produced by external component and the ambient temperature \( T_A \). These components combine to form the substrate thermal resistance \( R_{\text{thSA}} \) that is circuit-dependent and can be influenced by heat dissipation measures.

\[ T_S = T_A + P_{tot} \times R_{\text{thSA}} \]

If measurement of the temperature of the soldering point \( T_S \) is not possible, or if estimation of the junction temperature is sufficient, \( R_{\text{thSA}} \) can be read from diagrams below. Here we give an approximate value of the thermal resistance between the soldering point on an epoxy or ceramic substrate and still air as a function of the area of the collector mounting or ceramic. The parameter is the dissipated power, i.e. the heat \( T_S - T_A \) of the pc board. So in this case for the operating temperature:

\[ T_J = T_A + P_{tot} \times (R_{\text{thJS}} + R_{\text{thSA}}) \]

In the data sheets \( R_{\text{thJS}} \) is stated as a thermal reference quantity of the heat dissipation. The total thermal resistance \( R_{\text{thJA}} \) is started for comparison purposes. Depending on the typical component application, substrates of the following kinds are used for reference:

- **AF applications** epoxy circuit board: collector mounting area in \( \text{cm}^2 \) Cu (see data sheet), thickness 35 \( \mu \text{m} \) Cu.
- **RF applications** ceramic substrate: 15 mm \( \times \) 16.7 mm \( \times \) 0.7 mm (alumina) or epoxy circuit board with collector mounting area corresponding to 80 K/W.

The two diagrams below show, to an approximation, the thermal resistance as a function of the substrate area, assuming that the test device is located in the center of a virtually square substrate.

| \( R_{\text{thJT}} \) | Thermal resistance between junction and chip base (chip thermal resistance) |
| \( R_{\text{thTS}} \) | Thermal resistance between chip base and soldering point (package/alloy) |
| \( R_{\text{thSA}} \) | Thermal resistance between soldering point and ambient (substrate thermal resistance) |

---

**Table 1**

- \( R_{\text{thJT}} \): Thermal resistance between junction and chip base (chip thermal resistance).
- \( R_{\text{thTS}} \): Thermal resistance between chip base and soldering point (package/alloy).
- \( R_{\text{thSA}} \): Thermal resistance between soldering point and ambient (substrate thermal resistance).

\( R_{\text{thJS}} \) contains all type-dependent quantities. For a given power dissipation \( P_{tot} \) it is possible to use it to precisely determine the component temperature if the temperature \( T_S \) of the hottest soldering point is measured (for bipolar transistors typically the collector, for FETs the source lead).
2.1 Temperature Measuring og Components Leads

2.1.1 Measuring with temperature indicators (e.g. thermopaper)
Temperature indicators do not cause heat dissipation and thus allow an almost exact determination of temperature. A certain degree of deviations can only result from rough grade indication of the temperature indicators. This method is quite easy and provides sufficient accuracy. It is particularly suitable for measurement in pc boards.

2.1.2 Measuring with thermocouple elements
Measurement with thermocouple elements is not advisable because the functioning of the circuit can be influenced by electrical conduction and heat dissipation at the soldering point. This corrupts the results of the measurement, unless the measurement is carried out with appropriate effort.
2.2 Permissible Total Dissipation in DC Operation

The total power dissipation $P_{\text{tot}}$ defines the maximum thermal gradient in the component. As a result of the heating of components, the maximum total power dissipation $P_{\text{tot max}}$ stated in the data sheets is only permissible up to limits of $T_{\text{S max}}$ or $T_{\text{A max}}$. These critical temperatures describe the point at which the maximum permissible junction temperature $T_{J \text{ max}}$ is reached. The maximum permissible ambient or soldering-point temperature is calculated as follows:

\begin{equation}
T_{\text{S max}} = T_{J \text{ max}} - P_{\text{tot max}} \times R_{\text{thJS}}
\end{equation}

\begin{equation}
T_{\text{A max}} = T_{J \text{ max}} - P_{\text{tot max}} \times R_{\text{thJA}}
\end{equation}

In diodes the power dissipation is for the most part caused by internal resistance. So the diagram has to be translated into the form $I_F=f(T_S; T_A)$, resulting in the bent shape of the curve. For $R_{\text{thJA}}$ the appropriate standard substrate was taken in each case. The diagrams shown here are intended as examples. For the application the curve given in the data sheet is to be taken. Exceeding the thermal max. ratings is not permissible because this could mean lasting degradation of the component’s characteristics or even its destruction.

Total Power Dissipation $P_{\text{tot}}=f(T_S; T_A)$

Forward Current $I_F=f(T_S; T_A)$

1) $\text{Al}_2\text{O}_3$-Substrate $15 \text{ mm} \times 16.7 \text{ mm} \times 0.7 \text{ mm}$ / Package mounted on alumina $15 \text{ mm} \times 16.7 \text{ mm} \times 0.7 \text{ mm}$
2.3 Permissible Total Power Dissipation in Pulse Operation

In pulse operation, under certain circumstances, higher total power dissipation than in DC operation can be permitted. This will be the case when the pulse duration \( t_p \), i.e. the length of time that power is applied, is small compared to the thermal time constant of the system. This time constant, i.e. the time until the final temperature is reached, depends on the thermal capacitances and resistances of the component’s chip, case and substrate. The thermal capacitance utilized in the component is a function of the pulse duration.

Here we describe this through the transient thermal resistance. The pulse-load thermal resistance, or the permissible increase in \( P_{tot} \) that can be derived from it, is shown by way of examples in the following curves. For the application the particular data sheet should be taken.

\[
P_{tot\text{max}} / P_{tot\text{DC}} = f(t_p)
\]

The duty factor \( t_p / T \) is given as a parameter for periodic pulse load with a period of \( T \). For long pulse durations the factor \( P_{tot\text{max}} / P_{tot\text{DC}} \) approaches a value of 1, i.e. \( P_{tot} \) in pulsed operation can be equated with the DC value. At extremely short pulse widths, on the other hand, the increase in temperature as a result of the pulse (residual ripple) becomes negligible and a mean temperature is created in the system that corresponds to DC operation with average pulse power.