Thermal Design

Thermal resistance and thermal characterization parameter

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1. Scope
The definition and how to use thermal resistance and thermal characterization parameter of packages for ROHM’s IC are described in this application note.

2. Normative references
The content of this application note complies with JEDEC standard JESD51.

3. Terms and definitions
3.1 $T_A$: Ambient temperature
3.2 $T_J$: Junction temperature
3.3 $T_T$: Top-center temperature on device package surface
3.4 $\theta_{JA}$: Junction to ambient thermal resistance. Thermal radiation by plural paths.
3.5 $\Psi_{JT}$: Junction to top-center thermal characterization Parameter. This value varies depending on the heat radiation amount to other than the top center of the outside surface of the component package.

![Figure1. The definition of thermal resistance $\theta_{JA}$ and thermal characterization parameter $\Psi_{JT}$ (ex: HTSOP-J8)](image)

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Thermal resistance and Thermal characterization parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Thermal Resistance (Typ)</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction to Ambient</td>
<td>( \theta_{JA} )</td>
<td>130</td>
<td>34°C/W</td>
</tr>
<tr>
<td>Junction to Top Characterization Parameter((^2))</td>
<td>( \psi_{JT} )</td>
<td>15</td>
<td>7°C/W</td>
</tr>
<tr>
<td>TO252-3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junction to Ambient</td>
<td>( \theta_{JA} )</td>
<td>136</td>
<td>23°C/W</td>
</tr>
<tr>
<td>Junction to Top Characterization Parameter((^2))</td>
<td>( \psi_{JT} )</td>
<td>17</td>
<td>3°C/W</td>
</tr>
<tr>
<td>SOT223-4(F)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junction to Ambient</td>
<td>( \theta_{JA} )</td>
<td>164</td>
<td>71°C/W</td>
</tr>
<tr>
<td>Junction to Top Characterization Parameter((^2))</td>
<td>( \psi_{JT} )</td>
<td>20</td>
<td>14°C/W</td>
</tr>
</tbody>
</table>

"(1) Based on JESD51-2A (Still-Air)"

Figure 2. Data sheet description example

4. Test method environmental conditions (JESD51-2A)

Thermal test method environmental conditions comply with JESD51-2A (Still-Air) as below.

![Figure 3. Thermal test method environmental conditions]

Table 1. Measurement equipment for thermal resistance

<table>
<thead>
<tr>
<th>Measurement equipment</th>
<th>Supplier</th>
<th>Type</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal characteristics tester</td>
<td>Mentor Graphics</td>
<td>T3Ster</td>
<td></td>
</tr>
<tr>
<td>Temperature control stage</td>
<td>Keenus Design</td>
<td>PELNUS</td>
<td></td>
</tr>
<tr>
<td>Thermocouple ((\text{NOTE1}))</td>
<td>Ninomiya Electric Wire</td>
<td>0.1 x 1P K-1-G-J1</td>
<td>Class 1 / (\Phi 0.1 \text{ mm})</td>
</tr>
</tbody>
</table>

(\(\text{NOTE1}\)) By fixing the thermocouple to the top center of the outside surface of the component package, the temperature at the top center of the outside surface of the component package is measured.
5. Test board
Thermal test board complies with JESD51-3,5,7,9,10 as below.

<table>
<thead>
<tr>
<th>Package type</th>
<th>PCB</th>
<th>Material</th>
<th>Board Size</th>
<th>Thermal via (NOTE1)</th>
<th>Through-hole via (NOTE2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pitch</td>
<td>Diameter</td>
</tr>
<tr>
<td>SMD (Package size &lt; 27mm)</td>
<td>1s</td>
<td>FR-4</td>
<td>114.3mm x 76.2mm x 1.57mm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2s2p</td>
<td></td>
<td>114.3mm x 76.2mm x 1.6mm</td>
<td>1.20mm</td>
<td>Φ 0.30mm</td>
</tr>
<tr>
<td>BGA, THD (Package size ≤ 40mm)</td>
<td>1s</td>
<td>FR-4</td>
<td>114.5mm x 101.5mm x 1.6mm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2s2p</td>
<td></td>
<td></td>
<td>1.20mm</td>
<td>Φ 0.30mm</td>
</tr>
</tbody>
</table>

(NOTE1) Thermal via: This is a penetrating via, connected to 1, 2 and 4 layers of copper foil. Placement conforms to the land pattern.
(NOTE2) Through-hole via: Through-hole vias for THD mounting, connected to the first layer of copper foil. Arrangement and dimensions conform to the land pattern.

Figure 4. Sectional view of the thermal test board (SMD with heat sink)

Figure 5. Sectional view of the thermal test board (THD: DIP type)
6. Thermal measurement procedure

Below are two methods of thermal measurement for semiconductor.
- Thermal measurement at the surface of the package (connected measurement / unconnected measurement)
- Thermal measurement at the PN junction of the chip

The advantages and disadvantages of each method are written in the table below.

<table>
<thead>
<tr>
<th>Measurement method</th>
<th>Advantages</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal measurement at the surface of the package</td>
<td>Measurement is easy.</td>
<td>It is likely to contain some errors due to environment because it is not directly monitored.</td>
</tr>
<tr>
<td>Thermal measurement at the PN junction of the chip</td>
<td>Junction temperature is directly measured, resulting in a good accuracy.</td>
<td>The terminal for thermal measurement is needed for semiconductor.</td>
</tr>
</tbody>
</table>

If surface temperature measurement is used in performing the semiconductor temperature measurement, thermal characterization parameter $\Psi_{JT}$ will be used for the calculation.

$\Psi_{JT}$ is a parameter which defines the temperature difference between junction temperature $T_J$ and the temperature at the top center of the outside surface of the component package $T_T$, and it is same as ROHM previously used notation $\theta_{JC}$.

An accurate junction temperature can be calculated by using thermal characterization parameter if temperature $T_T$ is measured while the thermocouple is firmly contacted with the top center of the package. However, it must be considered that thermal characterization parameter changes depending on heat dissipation performance of the board.

$$T_J = T_T + \Psi_{JT} \times P$$  \hspace{1cm} (T_J : Junction temperature, T_T : the temperature at the top center of the outside surface of the component package, P : Power consumption)

In addition, junction temperature can be easily calculated by using thermal resistance $\theta_{JA}$. However, it is likely to be influenced by the difference with JEDEC environment rather than thermal characterization parameter

$$T_J = T_A + \theta_{JA} \times P$$  \hspace{1cm} (T_J : Junction temperature, T_A : Ambient temperature, P : Power consumption)

In case of checking the margin to the temperature limit from the package surface temperature, by assuming that $T_C \approx T_T$, maximum temperature $T_{CMAX}$ at the top surface of the component package can be calculated as below.

$$T_{CMAX} = T_{JMAX} - \Psi_{JT} \times P$$  \hspace{1cm} (T_{CMAX} : Maximum temperature at the top surface of the component package, T_{JMAX} : Maximum junction temperature, P : Power consumption)
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