# Package Thermal Characteristics in a Space Environment

Space Products

Technical Note

## 1. Introduction

The thermal performance of semiconductor packages is a very important parameter to be taken in consideration when designing an application board. Indeed, the reliability and functional life of the device is directly related to its junction operating temperature. As the temperature of the device increases, the stability of its junctions decline, as does its reliable life. The necessary taking into account of the thermal performances introduces constraints into the design of the boards: limitation of the board density, limited freedom for the location of high power dissipating devices on the board, or requirement of expensive cooling method for the system. As devices have become more complex and boards have become denser, the need of taking into account for the thermal characteristics of packages has shifted from being a minor consideration to being a necessary consideration.

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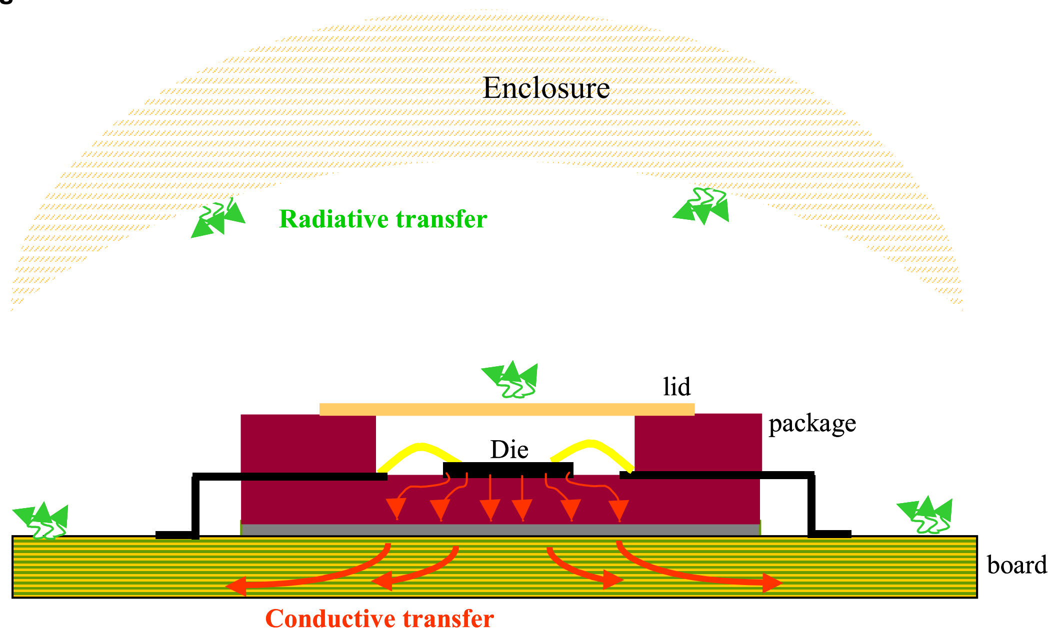
## 2. Characteristics

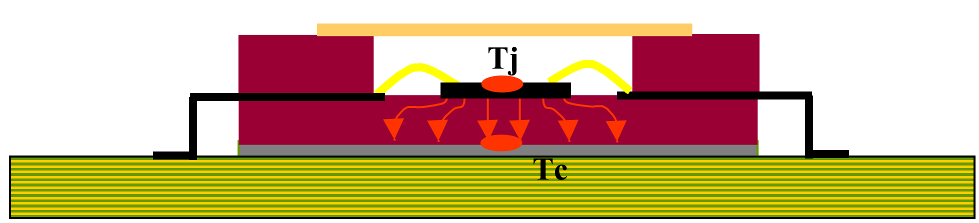
The thermal performance of a package is measured by its ability to dissipate the power required by the device into its surroundings. The electrical power drawn by the device generates heat on the top surface of the die. This heat is conducted through the package to the surface and then dissipated by radiative transfer and conductive transfer to the board. In space environment, no convective transfer occurs (Figure 2-1).

**Figure 2-1.** Heat Transfer in a device




It may be easily shown that the thermal resistance of the cavity and of the surrounding between the lid and the enclosure is very high compared to the thermal resistance of the package. So, we assume that nearly all the heat flow is dissipated by conduction through the board.
The capability of a package to transfer the heat flow is defined by its resistance junction-to-case Rjc. This parameter represents the resistance between the die's active surface (junction) and a specified reference point (board, bottom or top of package). In our calculation or measurement, as we assume that all or nearly all the heat flux spreads out to the board through the bottom of the package, the reference point has been defined as the bottom of the case (Figure 2-2).

**Figure 2-2.** Reference points and heat path



## 3. Model

In thermal steady-state, the resistance junction-to-case is defined by the following equation:

$$R_{jc} = \frac{T_j - T_c}{P}$$

Where:

- Tj is the junction temperature of the device (K)
- Tc is the case temperature at the bottom of the package (K)
- P is the dissipated power nearly equivalent to the operating power (W)
- Rjc is the resistance junction to case (K/W)

It has to be noticed that Rjc is independent on the dissipated power, but depends on package and die characteristics as:

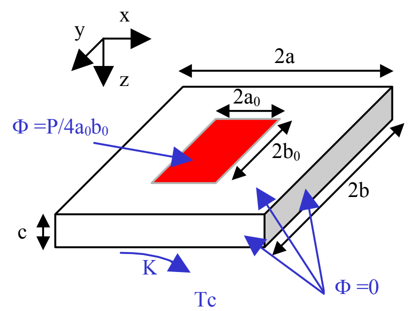
- the thermal conductivities of die attach, package ceramic and thermal join between package and board.
- Die, cavity and package sizes.

# 4. Analytical Calculation

The thermal resistance of the package is calculated by resolving the heat transfer equation in the simplified following system *(Figure 5-1)*:

**Figure 4-1.** Simplified geometry of the package

$$
\begin{cases}
\dfrac{\partial^2 T}{\partial x^2} + \dfrac{\partial^2 T}{\partial y^2} + \dfrac{\partial^2 T}{\partial z^2} = 0 \\
x = 0 \text{ and } 2a \quad \dfrac{\partial T}{\partial x} = 0 \\
y = 0 \text{ and } 2b \quad \dfrac{\partial T}{\partial y} = 0 \\
z = 0 \quad -\lambda \dfrac{\partial T}{\partial z} = \begin{cases} \dfrac{P}{4a_0 b_0} \text{ if } x \in [a - a_0, a + a_0] \text{ and } y \in [b - b_0, b + b_0] \\ 0 \quad \text{elsewhere} \end{cases} \\
z = c \quad -\lambda \dfrac{\partial T}{\partial z} = K(T - T_c)
\end{cases}
$$




K represent the thermal interface between package and board.
For instance, in the case of a MCGA, K is the equivalent thermal conductance of the leads (K/m².K)

The thermal resistance Rjc may be expressed by a double Fourier serie as follow:

$$R_{jc} = \frac{1}{\lambda} \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} F_{m,n}\left(n, m,, a, b, a_0, b_0, \frac{Kb}{\lambda}, \frac{Ka}{\lambda}\right)$$

$F_{m,n}$ depends on package dimension (a,b) and die dimension ($a_0$,$b_0$), thermal property of package ($\lambda$) and interface property (K).

# 5. Thermal Data

Following tables present calculated resistance junction to case.

## 5.1 ASIC's results

Please note that thermal information is provided as a guideline, the data cover specific cavities and die sizes (MH1RT or ATC18RHA) only corresponding to the worst case for each package. For specific thermal data, contact your local sales representative.

| Package type | lead | | | | $R_{jc}$ (K/W) |
|---|---|---|---|---|---|
| | count | form | pitch (inch) | material | |
| Multilayer ceramic quad flat pack - MQFP | 132 | F | 0,025 | Alloy42 / Kovar | 5 |
| | 160 | F | 0,0256 | Alloy42 / Kovar | 8 |
| | 196 | F | 0,025 | Kovar | 8 |
| | 256 | F | 0,02 | Kovar | 5 |
| | 352 | T | 0,02 | Kovar | 5 |
| Multilayer column grid array - MCGA | 349 | Columns | 0,05 | PbSn 90/10 | 3 |
| | 472 | Columns | 0,05 | PbSn 90/10 | 2 |

## 5.2 Standard products

| Product | Package | lead | | | | Rjc (K/W) |
|---|---|---|---|---|---|---|
| | | count | form | pitch (inch) | material | |
| 65608 | MFP | 32 | F | 0,05 | Alloy 42 / Kovar | 2.5 |
| 65609 | MFP | 32 | F | 0,05 | Alloy 42 / Kovar | 5.5 |
| AT60142 | MFP | 36 | F | 0,05 | Alloy 42 / Kovar | 3 |
| AT17LV010 | MFP | 28 | F | 0,05 | Alloy 42 / Kovar | 12.5 |
| AT28C010 | MFP | 32 | F | 0,05 | Alloy 42 / Kovar | 3.5 |
| 67025 | MQFP | 84 | F | 0,05 | Kovar | 7 |
| 67204 | MFP | 28 | F | 0,05 | Alloy 42 / Kovar | 4.5 |
| 67206(1) | MFP | 28 | F | 0,05 | Alloy 42 / Kovar | 4.5 |
| AT68166 | MCM | 68 | F | 0,05 | Kovar | 2.5 |
| AT40KEL040 | MQFP | 160 | F | 0,0256 | Alloy42 / Kovar | 2.5 |
| AT40KEL040 | MQFP | 256 | F | 0,02 | Kovar | 2.5 |
| ATF280 | MCGA | 472 | Columns | 0,05 | PbSn90/10 | 1 |
| TSC21020 | MQFP | 256 | F | 0,02 | Kovar | 3.5 |
| TSC695 | MQFP | 256 | F | 0,02 | Kovar | 3 |

| Product | Package | lead count | lead form | lead pitch (inch) | lead material | Rjc (K/W) |
|---|---|---|---|---|---|---|
| AT697 | MQFP | 256 | F | 0,02 | Kovar | 5 |
| | MCGA | 349 | Columns | 0,05 | PbSn90/10 | 2.5 |
| 29C516 | MQFP | 100r | F | 0,0256 | Alloy 42 | 7 |
| TSS901 | MQFP | 196 | L | 0,025 | Alloy 42 | 5 |
| T7906 | MQFP | 100 | F | 0,025 | Alloy42 / Kovar | 6 |
| AT7910 | MQFP | 196 | F | 0,025 | Alloy42 / Kovar | 5.5 |
| AT7911 | MQFP | 196 | L | 0,025 | Alloy42 / Kovar | 3 |
| AT7912 | MQFP | 100 | F | 0,025 | Alloy42 / Kovar | 6 |
| AT7913 | MCGA | 349 | Columns | 0,05 | PbSn90/10 | 2.5 |

## Document revision change

| | |
|---|---|
| **Changes from Rev.**<br>**7544A to 7544B** | 1. Update Rjc valueswith new packaging conditions (die attach change)<br>2. Remove experimental setup |

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