Application Report
SPRA953C – December 2003 – Revised April 2016

Semiconductor and IC Package Thermal Metrics

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ABSTRACT

Many thermal metrics exist for semiconductor and integrated circuit (IC) packages ranging from $R_{\theta JA}$ to Ψ_{JT}. Often, these thermal metrics are misapplied by those who try to use them to estimate junction temperatures in their systems. This document describes traditional and new thermal metrics and puts their application in perspective with respect to system-level junction temperature estimation.

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1 $R_{\theta JA}$ Junction-to-Ambient and $R_{\theta JMA}$ Junction-to-Moving Air

The junction-to-ambient thermal resistance, $R_{\theta JA}$, is the most commonly reported thermal metric and is the most often misused. $R_{\theta JA}$ is a measure of the thermal performance of an IC package mounted on a specific test coupon. The intent of $R_{\theta JA}$ is to give a metric by which the relative thermal performance of a package can be compared. Thus, the thermal performance of a TI device can be compared to a device from another company. This is true when both companies use a standardized test to measure $R_{\theta JA}$, such as that specified by JEDEC in the EIA/JESD51-x series of documents. Sometimes, however, JEDEC conditions are not followed and the excursions from the standards are not documented. These test variations can have a dramatic effect on the measured values of $R_{\theta JA}$. Therefore, unless test conditions are reported with the $R_{\theta JA}$ value, they should be considered suspect.

The measurement of $R_{\theta JA}$ is performed using the following steps (summarized from EIA/JESD51-1, -2, -5, -6, -7, and -9):

Step 1. A device, usually an integrated circuit (IC) package containing a thermal test chip that can both dissipate power and measure the maximum chip temperature, is mounted on a test board.

Step 2. The temperature sensing component of the test chip is calibrated.

Step 3. The package- and test-board system is placed in either a still air ($R_{\theta JA}$) or moving air ($R_{\theta JMA}$) environment.

Step 4. A known power is dissipated in the test chip.

Step 5. After steady state is reached, the junction temperature is measured.

Step 6. The difference in measured ambient temperature compared to the measured junction temperature is calculated and is divided by the dissipated power, giving a value for $R_{\theta JA}$ in °C/W.

1.1 *Usage*

Unfortunately, $R_{\theta JA}$ has often been used by system designers to estimate junction temperatures of their devices when used in their systems. The equation usually assumed to be valid for calculating junction temperature from $R_{\theta JA}$ is:

$$T_J = T_A + \left(R_{\theta JA} \times \text{Power}\right) \tag{1}$$

This is a misapplication of the $R_{\theta JA}$ thermal parameter because $R_{\theta JA}$ is a variable function of not just the package, but of many other system level characteristics such as the design and layout of the printed circuit board (PCB) on which the part is mounted. In effect, the test board is a heat sink that is soldered to the leads of the device. Changing the design or configuration of the test board changes the efficiency of the heat sink and therefore the measured $R_{\theta JA}$. In fact, in still-air JEDEC-defined $R_{\theta JA}$ measurements, almost 70%–95% of the power generated by the chip is dissipated from the test board, not from the surfaces of the package. Because a system board rarely approximates the test coupon used to determine $R_{\theta JA}$, application of $R_{\theta JA}$ using Equation 1 results in extremely erroneous values.

Table 1 lists factors that can influence $R_{\theta JA}$ for a given package outline when all materials are held constant. The first column lists the factor while the second column gives a *rule of thumb* estimate as to the impact of the factor.

Table 1. Factors Affecting $R_{\theta JA}$ for a Given Package Outline

Factors Affecting $R_{\theta JA}$	Strength of Influence (rule of thumb)
PCB design	Strong (100%)
Chip or pad size	Strong (50%)
Internal package geometrical configuration	Strong (35%)
Altitude	Strong (18%)
External ambient temperature	Weak (7%)
Power dissipation	Weak (3%)