THERMAL RESISTANCE – DEFINITIONS & EXPLANIATIONS

The physical definition of thermal resistance is the temperature difference along a heat flow path divided by the power dissipated along that path; in equation form -

$$\theta_{AB} = \left[\frac{T_A - T_B}{P_{AB}} \right]$$

where A is the path point of highest temperature and B is the path point of lowest temperature.

For the purposes of semiconductor device (i.e., a chip mounted either in a package or directly attached to a hybrid substrate or printed circuit board (pcb)), the A path point is almost always the junction area of the chip. The B path point can be anyone of several different path reference points. The JEDEC JESD51 thermal standards currently define four different path reference points and provide a format for user-defined conditions; the thermal resistance symbols are shown below:

Symbol	Definition of path end point temperature	Application
θ_{JC}	Case – temperature of outside package surface immediately adjacent to chip attachment area within package	Necessary for estimating performance with heat sink
θ_{JA}	Ambient – air temperature within enclosed natural convection environment	Useful for estimating performance in an enclosure without internal air circulation
θ_{JMA}	Moving Air – a forced convection environment with a specified air velocity and inlet temperature	Useful for estimating performance in an enclosure with internal air circulation
θ_{JB}	Board – temperature at a defined location on a thermal test board with the board set up to maximize het flow into the board	Useful for estimating junction temperature if board temperature adjacent to chip/package combination is known
θ_{JX}	User must define in detail the environment conditions and temperature point for which the thermal resistance applies	Actual thermal resistance for a given chip/package combination in a non-standard, application-orient environment; provides actual junction temperature value

θ_{JC} is one of the two oldest defined standard thermal resistances. Originally intended for power semiconductor devices (i.e., diodes and bipolar transistors) with high thermal conductivity environment mounting capability, this parameter has gained increased importance in the integrated circuit (IC) world as power dissipation in these device have increased to levels exceeding 4 watts, making heat sinks a necessity in many applications. θ_{JC} provides an indication of the best thermal performance possible from a given chip/package/standard environment combination. The test environment is setup to maximize heat flow through the top surface of the package and minimize heat flow through any other package surfaces or contacts. This is accomplished by placing an isothermal heat dissipating surface in thermal contact with the package top surface. After chip/package/test board/environment temperature equilibrium has occurred, Heating Power (P_H) is applied to the chip and junction and package top surface temperature (T_J and T_P, respectively) are monitored until a steady-state condition occurs. The value of θ_{JC} is then computed as follows:

THERMAL RESISTANCE – DEFINITIONS & EXPLANIATIONS (cont'D)

$$\theta_{JC} = \frac{\Delta T_J}{P_H} - \frac{T_{Pfinal} - T_{Pinitial}}{P_H}$$

If T_P does not change during the measurement, then the second term in this equation drops out.

θ_{JA} is the other oldest defined standard thermal resistance. The original intent of θ_{JA} was to provide a thermal resistance value from junction-to-environment for an environment extreme in which there was a minimal heat removal mechanism. A sealed one-cubic-foot enclosure is used for this measurement. The equation for θ_{JA} is the same as the one for θ_{JC} except that T_P is replaced with T_A, which is the air temperature at a defined position within the enclosure. The θ_{JA} values is useful in estimating T_J in application-oriented environments that have only natural convection (i.e., free air) cooling.

θ_{JMA} is a more recent thermal resistance standard and represents the performance of the chip/package combination mounted on a standard thermal test board with air flow into the thin cross-section of the package. Because the θ_{JMA} is highly dependent on the air flow rate and turbulence, the industry standard for the measurement of this parameter carefully spells out the mounting of the thermal test board within the air flow and how the air flow is to be measured. This parameter is useful for estimating T_J in forced convection (i.e., moving air) environments in which the air velocity and turbulence is reasonably well known. θ_{JMA} applies to the chip/package/test board combination only; adding a heat sink on top of the package produces a thermal resistance value that requires a different symbol.

θ_{JB} is a new thermal resistance standard that has developed into a worthwhile addition because of its usefulness in estimating T_J in real-life applications. It is a measure of the junction-to-board thermal resistance when most of the heat generated within the chip/package combination is forced into the pcb upon which the package is mounted. Heat flow from other package surfaces is minimized by thermally isolating these surfaces from the environment; there is no heat sink or other heat dissipating contact made with the top of the package. Use of θ_{JB} to estimate T_J is simple -

$$T_J = T_B + \frac{\theta_{JB}}{P_H}$$

where T_B is the board mounting surface temperature at center of the package length immediately adjacent to the package footprint and P_H is the power applied to the chip/package combination. This simple estimate of T_J is only applicable in natural convection environments with minimal heat leaving the package top surface (i.e., no heat sink); in actual practice, this approach produces a very conservative value of T_J.

θ_{JX} is the "catch-all" symbol for thermal resistance values obtained in non-standard environments. The "X" indicates that the thermal resistance value must be accompanied with a full description of the test environment and conditions. For example, this parameter might describe the results of putting 4.65 W into a chip/package combination mounted on a specified application board in a specified application enclosure with a specified heat sink on top and 100 lfpm and 60 cfm of air flow, a situation in which the exact heat flow path is unknown.

THERMAL ENGINEERING ASSOCIATES, INC.
www.thermengr.com

612 National Avenue
Mountain View, CA
94025-2222 USA

Phone: 650-961-5900
FAX:: 650-323-9237
E-mail: info@thermengr.com
page 2 of 2

001016