SEMICONDUCTOR THERMAL MEASUREMENT PROCEDURE

The following general procedure is equally applicable to either JEDEC or SEMI thermal measurement standards for integrated circuits and thermal test die.

1. Determine Device Connection

One of the four connection configurations shown in TB-01 will usually be used in thermal measurements.

2. Determine Mounting Configuration

Usual practice is to mount the device package on either a JEDEC JESD51 or SEMI standard thermal test boards. This provides a uniform mounting configuration for comparing thermal data between measurements made with the same device package by different laboratories or for comparing thermal performance of different packages. It also provides a tool for validation of package thermal models.

(See TEA's TTB-1000 Series Thermal Test Board data sheet.)

3. Mount Device Packages and Wire Thermal Test Board

Using the information from 1. Above, appropriately wire the package contacts to the thermal test board edge connector.

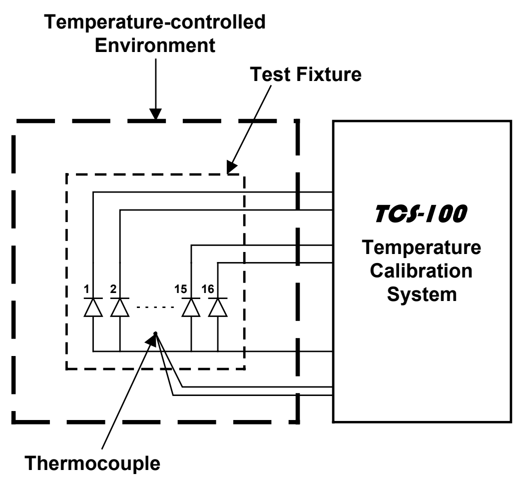
4. Determine appropriate value of Measurement Current (I_M)

Following the guideline provided by TB-02, determine the appropriate value of I_M. Typically this value in 1.0 mA but is dependent on the size of the actual diode used for temperature sensing. A curve tracer or constant current source/voltmeter combination can be used to determine the proper value of I

(See TEA's TCS-100 Temperature Calibration System data sheet.)

5. Calibrate the Diode Temperature Sensitive Parameter

This step requires three pieces of equipment - a temperature-controlled environment (i.e., oven); a test fixture to hold and provide electrical connection to the thermal test board-mounted device packages; and a calibration system that provides a constant current source for I_M, an accurate voltmeter for V_M measurement, and a thermocouple meter for T_A measurement.



Following the instructions in TB-02, measure V_M at two different values of T_A, then compute K Factor for each device and average the results.

SEMICONDUCTOR THERMAL MEASUREMENT PROCEDURE (cont'd)

6. Determine Heating Test Conditions

The Heating Power (P_H) applied to the device package should either approximate the operating condition of the application die housed in the package or set to some desired data point value using the following equation --

$$P_H = V_H \times I_H$$

where V_H is the voltage applied to the device and I_H is the current drawn by the device (or vice versa is the Substrate Isolation Diode is used for both heating and sensing).

7. Determine the Correction for Junction Cooling effect

Using the Thermal Test System (*TEA's TTS-4200*) in the automatic Cooling Curve mode with the I_M and V_H determined above, set Heating Time (t_H) to 300 ms and Measurement Delay Time (t_{MD}) to 30 µs. Initiate a Cooling Curve test and collect the ΔV_F data. Plot the data (or observe the data on the systems Chart mode display) and follow the procedure in JEDEC JESD51-1 to determine the "zero t_{MD}" correction ratio, then apply correction ratio to K Factor to determine the modified K Factor, K' (this procedure is automatically performed in *TEA* thermal test systems).

$$K' = \left(\frac{a}{b}\right) \times K$$

where K is the value determined in Step 5 above, b is the t_{MD} value to be used during the thermal tests, and a is the Y-axis incept value from a best-fit regression line extrapolated to the Y-axis on the Cooling Curve.

8. Thermal Resistance Junction-to-Case (θ_{JC}) Measurements

The object of this measurement is to determine the best-case heat flow condition by placing an "infinite" heat sink on the top surface of the package. The word "infinite" in this case implies an isothermal surface that doesn't exhibit a temperature change during the course of the measurement. As this is not practical in most cases, a large block of oxygen-free copper with a thermocouple imbedded just below the interface surface can be used instead, providing that any temperature rise in the block is accounted for in the data results as follows:

$$\theta_{JC} = \theta_{JC}\big|_{Measured} - \theta_{Block} = \theta_{JC}\big|_{Measured} - \left(\frac{\Delta T_{Block}}{P_H}\right)$$

where ΔT_{Block} is the temperature rise of the block from the beginning to the end of the measurement.

To help insure that most of the heat flow from the package to the ambient is through the heat sink block, the thermal test board is thermally isolated from it mounting surface (i.e., a thermal insulator is placed between the board and the surface it rests on during the measurement). If the Heating Curve data generation approach is used (a standard operation on *TEA* thermal test systems), the Heating Time (t_H) is usually set to 100 seconds. Once the Heating Curve data is plotted, the t_H value corresponding to the θ_{JC} point on the curve can be determined. This t_H value can be used for single-point measurements (i.e., non-Heating Curve multiple data point collection) and/or for package specification.

Although not required by the JEDEC standard, it sometimes advisable to monitor the thermal test board temperature either on the side-center package lead or on the board just at edge center of the package perimeter. The temperature can be used to compute a new thermal metric, Ψ_{JL} (lead) and Ψ_{JB} (board), which can be useful in estimating junction temperature for the chip/package combination in application environments. The general equation for this metric is:

$$\Psi_{JX} = \frac{T_J - T_X}{I_H \times V_H}$$

where subscript *X* is *B* for board or *L* for lead thermocouple mounting.

9. Mount Thermocouples

Common practice at this point is to mount a thermocouple on the package top surface in the center for Ψ_{JT} measurements. In the equation about, substitute *T* for *X* to compute Ψ_{JT}. Also mount the Ψ_{JL} or Ψ_{JB} thermocouple if not mounted as part of the last step.

10. Thermal Resistance Junction-to-Ambient (θ_{JA}) Measurements

The object of this measurement is to determine the worst-case heat flow condition by placing the thermal test board in a standard one cubic foot enclosure, as per JEDEC JESD51-2. The enclosure insures that only natural convection cooling occurs.

This measurement is best performed by either generating Heating Curve for some extended period of time (t_H in the range of 3,000 seconds is usually adequate for most packages ≤ 40 mm square) or by closely monitoring temperatures until a steady-state condition occurs. At steady state, the various temperatures are used to compute the desired θ and Ψ values.

11. Thermal Resistance Junction-to-Moving Air (θ_{JMA}) Measurements

The object of this measurement is to determine how well heat is transferred from the package to the air surrounding the package in a standard environment (JEDEC JESD51-6) when that air is moving at a set velocity. The package/test board combination is mounted in the forced convection environment with the long edge of the package facing the air flow. Measurements are made in this manner with air velocities in the 0.5 to 5 m/s range; 1 and 2 m/s are usually sufficient in most cases

This measurement is best performed by either generating Heating Curve for some extended period of time (t_H in the range of 2,000 seconds is usually adequate for most packages ≤ 40 mm square) or by closely monitoring temperatures until a steady-state condition occurs. At steady state, the various temperatures are used to compute the desired θ and Ψ values for the different air velocities.

SEMICONDUCTOR THERMAL MEASUREMENT PROCEDURE (cont'd)

12. Thermal Resistance Junction-to-Board (θ_{JB}) Measurements

The object of this measurement is to determine how well heat is transferred from the package into the thermal test board upon which the package is mounted. A pair of Ring Cold Plates, one on each side of the board, is clamped to board to establish a reference condition for the measurement. The size of the hollow center of the rings is determined by the package dimensions (refer to JEDEC JESD51-8). A thermocouple is mounted on the board at a specific distance from the package on the side of the board within the hollow area. The hollow section above and below the package is insulated to prevent convection cooling of the package top surface or of the bottom board area on the other side of the board. The Ring Cold Plates clamping pressure must be adequate to insure a good thermal interface to the board.

This measurement is best performed by either generating Heating Curve for some extended period of time (t_H in the range of 2,000 seconds is usually adequate for most packages ≤ 40 mm square) or by closely monitoring temperatures until a steady-state condition occurs. At steady state, the various temperatures are used to compute the desired θ_{JB} value.

SEMICONDUCTOR THERMAL MEASUREMENT PROCEDURE (cont'd)

Equipment Requirements

Step #	Operation	Equipment/Supplies	Comments
3	Mount Packages	Thermal Test Board (TEA TTB-1000 series or equivalent)	
4	Determine I_M	Curve Tracer or Constant Current Source and Voltmeter (TEA TCS-100 or equivalent)	Usually in 0.1 to 10 mA range depending on diode size
5	Calibrate Diode Temperature Sensitive Parameter	- Temperature-controlled environment - Thermocouple - Current Source, Voltmeter, & Thermocouple Meter (TEA TCS-100 or equivalent)	Data at two different temperatures usually sufficient; ΔT should be in 70 °C range for improved accuracy
6	Determine Heating Test Condition	- Current or Voltage Source - Voltage or Current Meter (Alternatively, use thermal test system [TEA TTS-4200 or equivalent])	P_H should be either desired characterization value or closely approximate actual application condition
7	Determine Junction Cooling Correction	Thermal Test System with transient test capability (TEA TTS-4200 or equivalent)	- Use P_H (or higher for greater measurement resolution) by setting I_H or V_H appropriately and I_M as determined above - Set t_H in 300 to 500 ms range; value should not cause significant package heating - Plot Cooling Curve, select t_{MD} test condition, then establish best-fit regression line and determine Correction Factor - Compute K'
8	θ_{JC} Measurements	- "Infinite" Heat Sink with embedded thermocouple (TEA DCP-100 or equivalent) - Low conductivity thermal interface material - Thermal Test System with Heating Curve capability (TEA TTS-4200 or equivalent)	- Use I_H or V_H, I_M, t_{MD}, K' as determined above - Set t_H to 100 seconds - Collect data and plot Heating Curve - Determine t_H value for θ_{JC} value
10	θ_{JA} Measurements	- Natural Convection environment (one cubic foot enclosure) with embedded thermocouple (TEA NC-100 or equivalent) - Thermal Test System with Heating Curve capability (TEA TTS-4200 or equivalent)	- Use I_H or V_H, I_M, t_{MD}, K' as determined above - Set t_H to 3000 seconds - Collect data and plot Heating Curve - Determine t_H value for θ_{JC} value
11	θ_{JMA} Measurements	- Forced Convection environment (wind tunnel) with embedded thermocouple (TEA WT-100 or equivalent) - Thermal Test System with Heating Curve capability (TEA TTS-4000 or TTS-4200 or equivalent)	- Use I_H or V_H, I_M, t_{MD}, K' as determined above - Set t_H to 2000 seconds - Collect data and plot Heating Curve - Determine t_H value for θ_{JC} value
12	θ_{JB} Measurements	- Forced Conduction environment with Ring Cold Plate (TEA DCP-100-03 or equivalent) clamped to test board. - Thermal Test System with Heating Curve capability (TEA TTS-4200 or equivalent)	- Use I_H or V_H, I_M, t_{MD}, K' as determined above - Set t_H to 2000 seconds - Collect data and plot Heating Curve - Determine t_H value for θ_{JB} value