

SEMI G43-87

TEST METHOD FOR JUNCTION-TO-CASE THERMAL RESISTANCE MEASUREMENTS OF MOLDED PLASTIC PACKAGES

1 Purpose

The purpose of this test is to determine the thermal resistance of molded plastic packages using thermal test chips. This test method deals only with junction-to-case measurements of thermal resistance and limits itself to fluid bath testing environments. For this test, conduction through the leads is minimized, thus providing information on the ability of the plastic package material to dissipate heat. Due to the thermophysical properties of the heat transfer fluids used and the effects of the variable nature of the fluid-stirring and package-mounting procedures, this test method should only be used for comparing the thermal characteristics of plastic packages in the same fluid bath system.

2 Applicable Documents

2.1 SEMI Specification

SEMI G32 — Guideline for Unencapsulated Thermal Test Chip

3 Definitions

The following definitions and symbols shall apply for the purpose of this test:

case temperature, T_C — in degrees Celsius. The case temperature is the temperature at a specified accessible reference point on the package in which the microelectronic chip is mounted.

junction temperature, T_J — in degrees Celsius. The term is used to denote the temperature of the semiconductor junction in the microcircuit in which the major part of the heat is generated. For purposes of this test, the measured junction temperature is only indicative of the temperature in the immediate vicinity of the element used to sense the temperature.

power dissipation, P_H — in watts, is the heating power applied to the device causing a junction-to-reference point temperature difference.

thermal resistance, junction to specified reference point, $R_{\theta JR}$ — in degrees Celsius/watt. The thermal resistance of the microcircuit is the temperature difference from the junction to some reference point on the package divided by the power dissipation P_H .

temperature-sensitive parameter, TSP — the temperature-dependent electrical characteristic of the junction under test which can be calibrated with respect

to temperature and subsequently used to detect the junction temperature of interest.

4 Apparatus

The apparatus required for these tests shall include the following as applicable to the specified test procedures:

- Thermocouple material shall be copper-constantan (type T) or equivalent, for the temperature range -100 to + 300°C. The wire size shall be no larger than AWG size 30. The junction of the thermocouple shall be welded to form a bead rather than soldered or twisted. The accuracy of the thermocouple and associated measuring system shall be $\pm 0.5^\circ\text{C}$.
- Suitable electrical equipment as required to provide controlled levels of conditioning power and to make the specified measurements. The instrument used to electrically measure the temperature-sensitive parameter shall be capable of resolving a voltage change of 0.5 mV.
- Controlled temperature chamber or fluid bath capable of maintaining the specified reference point temperature to within $\pm 0.5^\circ\text{C}$ of the preset (measured) value. A typical temperature-controlled fluid bath assembly is presented for illustrative purposes only.

4.1 Fluid Bath Assembly — A typical temperature-controlled fluid bath for thermally characterizing the microelectronic device under test is shown in Figure 1. In this figure, the package is mounted in a fluid bath separate from the fluid circulator, although it can be immersed directly in an integrated fluid circulator/bath unit. The fluid in the bath should be continuously stirred or agitated to ensure the required temperature stability and uniformity. Since this working fluid is being used as an infinite heat-sink, the case-to-fluid (ambient) temperature difference at the case temperature reference point of interest should be minimized, i.e., $\leq 20^\circ\text{C}$. For case-to-fluid temperature differences $> 20^\circ\text{C}$, accuracy and repeatability difficulties may occur due to a large variable temperature gradient in the fluid film boundary layer at the package-fluid interface. The case-to-fluid temperature difference can be minimized by increasing the fluid velocity and by decreasing the power density seen by the fluid.

The device under test should be mounted such that heat transfer to the fluid is not impeded. For leaded devices, the leads should be oriented in such a manner so as not to interfere with the heat transfer to the fluid and provide freedom to any thermal currents caused by the power dissipation within the package. The microcircuit package shall be mounted such that conduction cooling through the leads or test socket or both shall be small compared to the other cooling mechanisms. To minimize conduction through the leads, a special socket jig that connects No. 36 AWG wire to the device socket should be used.

The case temperature of the device under test should be measured with a thermocouple that is attached to the package/lead and should not be assumed to be at the fluid temperature. The working fluid should have a thermal conductivity at 25°C of at least 0.0006 W/cm°C. Working fluids such as inert fluorocarbon liquids and silicone oils are suitable as cooling media.

5 Procedure

5.1 Direct Measurement of Reference Point Temperature, $T_R = T_c$ — For the purpose of measuring a microelectronic device thermal resistance, the reference point temperature shall be measured at the package location of highest temperature which is accessible from outside the package. This reference point location is determined with the device operating in free air and with no external heat-sinking. In general, this reference point is found to be on the surface of the body of the package, or on a lead near the body, in the major path of heat flow from the chip heating surface to the ambient fluid. The package surface may be altered to facilitate this measurement provided that such alteration does not affect the original heat transfer paths and, hence, the thermal resistance, within the package by more than a few percent.

5.1.1 Case Temperature, T_c — The microelectronic device under test shall be mounted under specified conditions so that the case temperature can be held at the specified value. A thermocouple shall be attached on the surface of the device package directly under the chip (i.e., on the base plane of the package). A conducting epoxy may be used for this purpose. The thermocouple bead should be in direct mechanical contact with the package of the microelectronic device under test. Care should be taken to minimize exposure of the thermocouple bead to the high temperature gradient in the fluid film boundary layer at the package-fluid interface.

If it is found that attaching the thermocouple directly to the case is impractical, an alternate approach using a thermocouple welded to one side of a thin metal disk should be used. This can be accomplished by parallel

gap welding the crossed thermocouple wires to one side of a 0.25 cm (0.094 in) diameter, 0.02 cm (0.008 in) thick beryllium-copper disk and then, with a thin layer of adhesive, bonding the other side of the disk to the case at the point of interest. The exposed thermocouple bead/wire on the disk shall be covered with epoxy or silicone rubber. The attached thermocouple should not unduly interfere with heat transfer to the fluid.

5.2 Thermal Resistance, Junction-to-Specified Reference Point, $R_{\theta JR}$

5.2.1 General Considerations — The thermal resistance of a semiconductor device is a measure of the ability of its carrier or package and mounting technique to provide for heat removal from the semiconductor junction. The thermal resistance of a microelectronic device can be calculated when the case temperature and power dissipation in the device and a measurement of the junction temperature are known.

When making the indicated measurements, the package shall be considered to have achieved thermal equilibrium when halving the time between the application of power and the taking of the reading causes no error in the indicated results within the required accuracy of measurement.

5.2.2 Indirect Measurement of Junction Temperature for the Determination of $R_{\theta JR}$ — The purpose of the test is to measure the thermal resistance of integrated circuits by using particular semiconductor elements on the chip to indicate the device junction temperature. In order to obtain a realistic estimate of the operating junction temperature, the whole chip in the package should be powered in order to provide the proper internal temperature distribution. During measurement of the junction temperature, the chip heating power (constant voltage source) shall remain constant while the junction calibration current remains stable. It is assumed that the calibration current will not be affected by the circuit operation during the application of heating power.

The temperature-sensitive device parameter is used as an indicator of an average (weighted) junction temperature of the semiconductor element for calculations of thermal resistance. The measured junction temperature is indicative of the temperature only in the immediate vicinity of the element used to sense the temperature.

The temperature-sensitive electrical parameters generally used to indirectly measure the junction temperature are the forward voltage of diodes and the emitter-base voltage of bipolar transistors. Other appropriate temperature-sensitive parameters may be used for indirectly measuring junction temperature for