Thermal Design

Thermal resistance and thermal characterization parameter

Contents

1. Scope

The definition and how to use thermal resistance and thermal characterization parameter of packages for ROHM's IC are described in this application note.

2. Normative references

The content of this application note complies with JEDEC standard JESD51.

3. Terms and definitions

3.1 T_A : Ambient temperature

3.2 T_J : Junction temperature

3.3 T_T : Top-center temperature on device package surface

3.4 θ_{JA} : Junction to ambient thermal resistance. Thermal radiation by plural paths.

3.5 Ψ_{JT} : Junction to top-center thermal characterization Parameter. This value varies depending on the heat radiation amount to other than the top center of the outside surface of the component package.

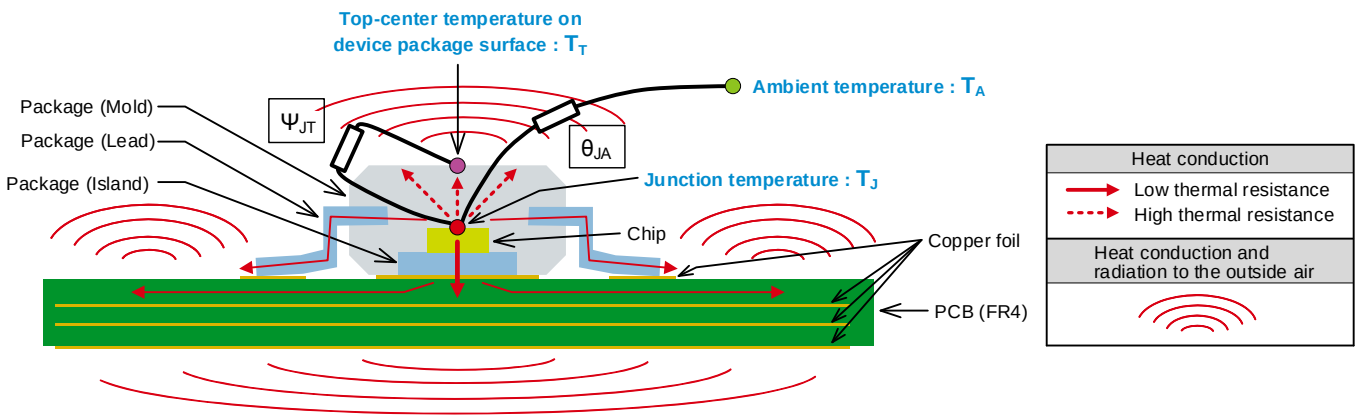


Figure1. The definition of thermal resistance θ_{JA} and thermal characterization parameter Ψ_{JT} (ex: HTSOP-J8)

●**Thermal Resistance**(*1)

Parameter	Symbol	Thermal Resistance (Typ)		Unit
		1s(*3)	2s2p(*4)	
HTSOP-J8				
Junction to Ambient	θ_{JA}	130	34	°C/W
Junction to Top Characterization Parameter(*2)	Ψ_{JT}	15	7	°C/W
TO252-3				
Junction to Ambient	θ_{JA}	136	23	°C/W
Junction to Top Characterization Parameter(*2)	Ψ_{JT}	17	3	°C/W
SOT223-4(F)				
Junction to Ambient	θ_{JA}	164	71	°C/W
Junction to Top Characterization Parameter(*2)	Ψ_{JT}	20	14	°C/W

(*1)Based on JESD51-2A(Still-Air).
(*2)The thermal characterization parameter to report the difference between junction temperature and the temperature at the top center of the outside surface of the component package.
(*3)Using a PCB board based on JESD51-3.

Layer Number of Measurement Board	Material	Board Size
Single	FR-4	114.3mm x 76.2mm x 1.57mmt

Top	
Copper Pattern	Thickness
Footprints and Traces	70μm

(*4)Using a PCB board based on JESD51-5, 7.

Layer Number of Measurement Board	Material	Board Size	Thermal Via(*5)	
			Pitch	Diameter
4 Layers	FR-4	114.3mm x 76.2mm x 1.6mmt	1.20mm	Φ0.30mm

Top		2 Internal Layers		Bottom	
Copper Pattern	Thickness	Copper Pattern	Thickness	Copper Pattern	Thickness
Footprints and Traces	70μm	74.2mm x 74.2mm	35μm	74.2mm x 74.2mm	70μm

Figure2. Data sheet description example

4. Test method environmental conditions（JESD51-2A）

Thermal test method environmental conditions comply with JESD51-2A (Still-Air) as below.

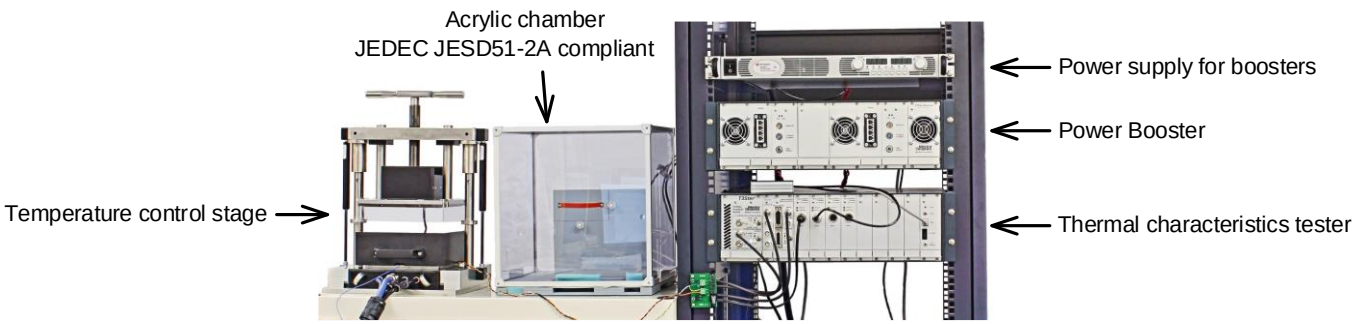


Figure3. Thermal test method environmental conditions

Table1. Measurement equipment for thermal resistance

Measurement equipment	Supplier	Type	Note
Thermal characteristics tester	Mentor Graphics	T3Ster	-
Temperature control stage	Keenus Design	PELNUS	-
Thermocouple (NOTE1)	Ninomiya Electric Wire	0.1×1P K-1-G-J1	Class1 / Φ 0.1 mm

(NOTE1) By fixing the thermocouple to the top center of the outside surface of the component package, the temperature at the top center of the outside surface of the component package is measured.

5. Test board

Thermal test board complies with JESD51-3,5,7,9,10 as below.

Table2. Specified parameters and values used for PCB design. (Package size is specified by a maximum body length.)

Package type	PCB	Material	Board Size	Thermal via(NOTE1)		Through-hole via(NOTE2)
				Pitch	Diameter	Diameter
SMD (Package size < 27mm)	1s	FR-4	114.3mm x 76.2mm x 1.57mmt	-	-	
	2s2p		114.3mm x 76.2mm x 1.6mmt	1.20mm	Φ 0.30mm	-
BGA, THD (Package size ≦ 40mm)	1s	FR-4	114.5mm x 101.5mm x 1.6mmt	-	-	Φ 0.85mm
	2s2p			1.20mm	Φ 0.30mm	Φ 0.85mm

Package type	PCB	Component trace		Plane		Backside trace	
		Copper pattern	Thickness	Copper pattern	Thickness	Copper pattern	Thickness
SMD (Package size < 27mm)	1s	Component mounting and trace fan-out region	70µm	-	-	-	-
	2s2p			74.2×74.2mm	35µm	74.2×74.2mm	70µm
BGA, THD (Package size ≦ 40mm)	1s	Component mounting and trace fan-out region	70µm	-	-	-	-
	2s2p			99.5×99.5mm	35µm	99.5×99.5mm	70µm

(NOTE1) Thermal via: This is a penetrating via, connected to 1, 2 and 4 layers of copper foil. Placement conforms to the land pattern.

(NOTE2) Through-hole via: Through-hole vias for THD mounting, connected to the first layer of copper foil. Arrangement and dimensions conform to the land pattern.

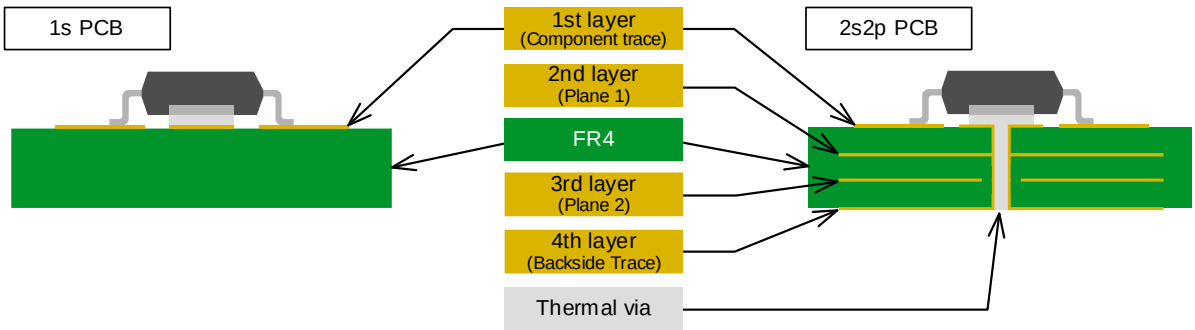


Figure4. Sectional view of the thermal test board (SMD with heat sink)

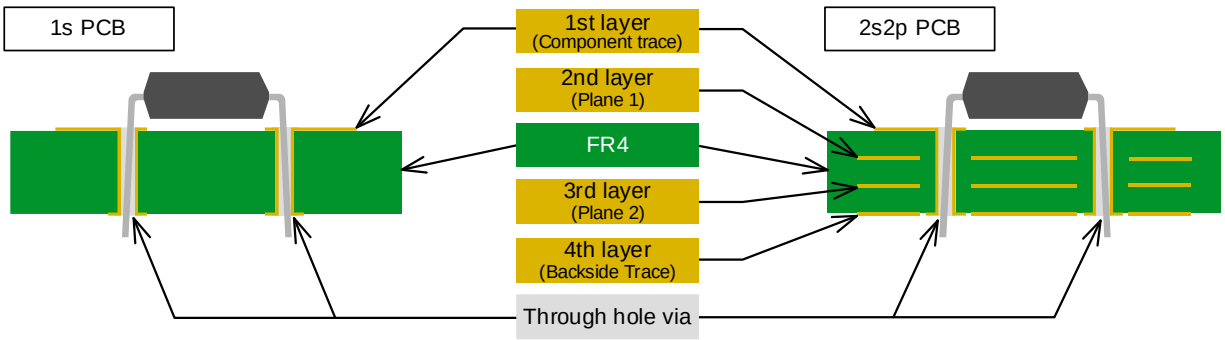


Figure5. Sectional view of the thermal test board (THD: DIP type)

6. Thermal measurement procedure

Below are two methods of thermal measurement for semiconductor.

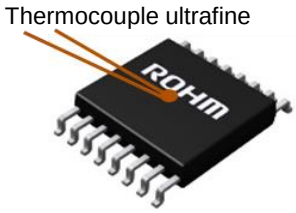
-Thermal measurement at the surface of the package (connected measurement / unconnected measurement)

-Thermal measurement at the pn junction of the chip

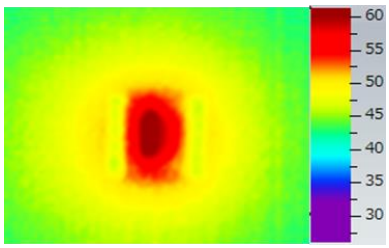
The advantages and disadvantages of each method are written in the table below.

Table3. The advantages and disadvantages due to differences in measurement method

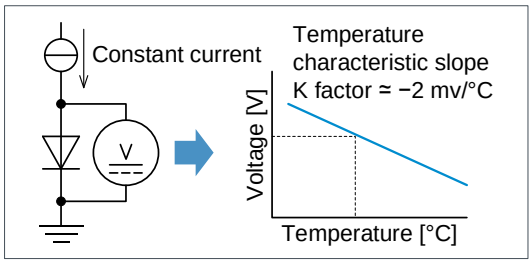
Measurement method	Advantages	Disadvantage
Thermal measurement at the surface of the package	Measurement is easy.	It is likely to contain some errors due to environment because it is not directly monitored.
Thermal measurement at the PN junction of the chip	Junction temperature is directly measured, resulting in a good accuracy.	The terminal for thermal measurement is needed for semiconductor.



Thermal measurement at the surface
Thermocouple (Connected)



Thermal measurement at the surface
Thermoviewer (Unconnected)



Thermal measurement
at the pn junction of the chip

Figure6. Images of each measurement

If surface temperature measurement is used in performing the semiconductor temperature measurement, thermal characterization parameter Ψ_{JT} will be used for the calculation.

An accurate junction temperature can be calculated by using thermal characterization parameter if temperature T_T is measured while the thermalcouple is firmly contacted with the top center of the package. However, it must be considered that thermal characterization parameter changes depending on heat dissipation performance of the board.

$T_J = T_T + \Psi_{JT} \times P$ (T_J : Junction temperature , T_T : the temperature at the top center of the outside surface of the component package , P : Power consumption)

In addition, junction temperature can be easily calculated by using thermal resistance θJ_A. However, it is likely to be influenced by the difference with JEDEC environment rather than thermal characterization parameter

$T_J = T_A + \theta_{JA} \times P$ (T_J : Junction temperature , T_A : Ambient temperature , P : Power consumption)

In case of checking the margin to the temperature limit from the package surface temperature, by assuming that $T_C \approx T_T$, maximum temperature T_{CMAX} at the top surface of the component package can be calculated as below.

$T_{CMAX} = T_{JMAX} - \Psi_{JT} \times P$ (T_{CMAX} : Maximum temperature at the top surface of the component package , T_{JMAX} : Maximum junction temperature , P : Power consumption)

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