

TECHNICAL REPORT



**Thermal standardization on semiconductor packages –
Part 1: Thermal resistance and thermal parameter of BGA, QFP type
semiconductor packages**

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semiconductor packages**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

THERMAL STANDARDIZATION ON SEMICONDUCTOR PACKAGES –**Part 1: Thermal resistance and thermal parameter of BGA,
QFP type semiconductor packages**

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The text of this Technical Report is based on the following documents:

Draft	Report on voting
47D/928/DTR	47D/935/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 63378 series, published under the general title *Thermal standardization on semiconductor packages*, can be found on the IEC website.

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THERMAL STANDARDIZATION ON SEMICONDUCTOR PACKAGES –

Part 1: Thermal resistance and thermal parameter of BGA, QFP type semiconductor packages

1 Scope

This part of IEC 63378 specifies the terms and definitions that are commonly used for thermal characteristics of BGA and QFP type semiconductor packages, and guidelines to use these thermal characteristics.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60191-4, *Mechanical standardization of semiconductor devices – Part 4: Coding system and classification into forms of package outlines for semiconductor device packages*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60191-4 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 Terms and letter symbols related to temperature (unit [°C or K])

3.1.1 ambient air temperature

T_A

temperature of ambient air at location adequately distant from the package (see Figure 1)

Note 1 to entry: Conceptually, it refers to an ambient air temperature at a location that is not affected by the semiconductor package to be measured.

3.1.2 junction temperature

T_J

temperature of at an arbitrary position of the chip (see Figure 1)

Note 1 to entry: Especially when there is no specification, it is considered as the centre of a chip.

Note 2 to entry: Junction refers to the junction area of a semiconductor. Assuming that heat is generated at the junction of p-type and n-type, temperature at the junction becomes high and is used as representing temperature for semiconductor devices. Because there are many junctions built into a real chip, the term junction is used synonymously as the chip. The location is commonly placed at the centre of the circuit surface of the chip, although location dependence may be taken into consideration for chips requiring high power consumption.

3.1.3

case temperature

T_C

temperature at an arbitrary position on the surface of a package (see Figure 1)

Note 1 to entry: Especially when there is no specification, it is considered as the centre of a chip upper part.

3.1.4

top temperature

T_T

temperature at the centre of the package's upper surface (see Figure 1)

Note 1 to entry: Defined as T_T due to T_C used as definition for special surface at back of package of power device, etc. For normal package such as BGA, T_C and T_T are used synonymously.

3.1.5

board temperature

T_B

temperature of the board which is distant from an arbitrary end of a package 1 mm (see Figure 1)

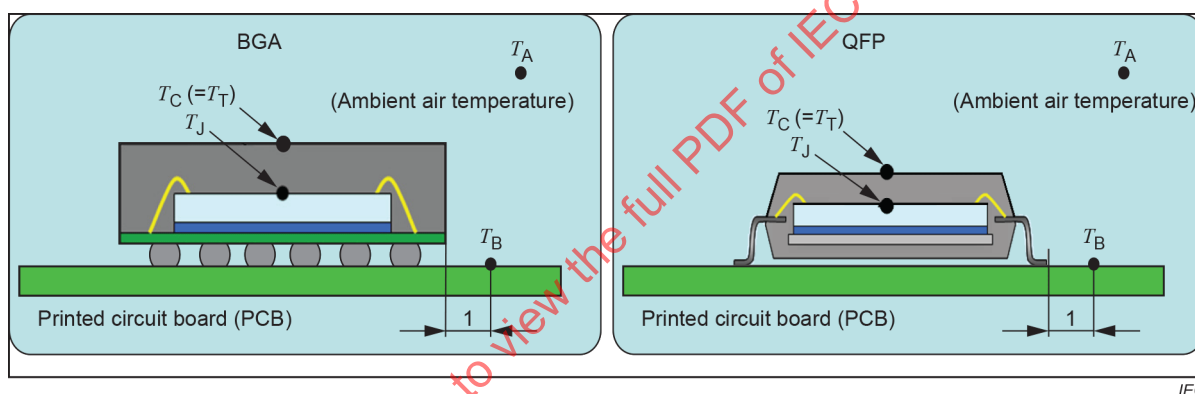


Figure 1 – Definition of temperature

3.2 Terms and letter symbols related to thermal characteristics

3.2.1

thermal resistance

quotient of the difference between the virtual temperature of the device and the temperature of a stated external reference point, by the steady-state power dissipation in the device (see Figure 2)

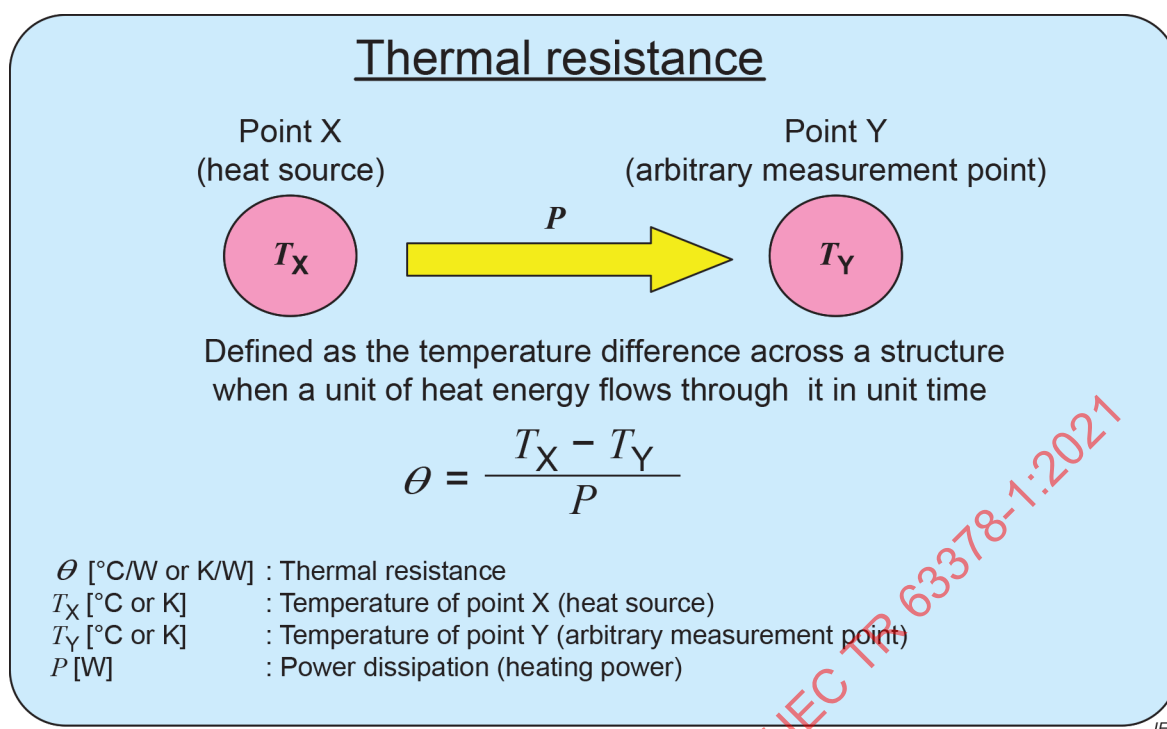


Figure 2 – Definition of thermal resistance

Note 1 to entry: It is the reciprocal of thermal conductance. Thermal resistance is the temperature difference across a structure when a unit of heat energy flows through it in a unit time.

[SOURCE: IEC 60050-521:2002, 521-05-13, modified – Figure 2 and Note 1 to entry have been added.]

3.2.1.1

thermal resistance from junction-to-ambient

$R_{th(j-a)}$

θ_{JA}

thermal resistance between chip (junction) and ambient air (see Figure 1)

$$\theta_{JA} = \frac{T_J - T_A}{P}$$

where

P is the power dissipation

3.2.1.2

thermal resistance from junction-to-case top

$R_{th(j-c)}$

θ_{JCTOP}

thermal resistance between chip (junction) and package surface (see Figure 3)

Note 1 to entry: Value in an ideal environment in which all heat dissipation from the chip goes towards the package top surface. (It is also shown simply as θ_{JC}).

3.2.1.3

thermal resistance from junction-to-board

$R_{th(j-b)}$

θ_{JB}

thermal resistance between chip (junction) and board surface (see Figure 3)

Note 1 to entry: Value in an ideal environment in which all heat dissipation from the chip goes towards the package board side only.

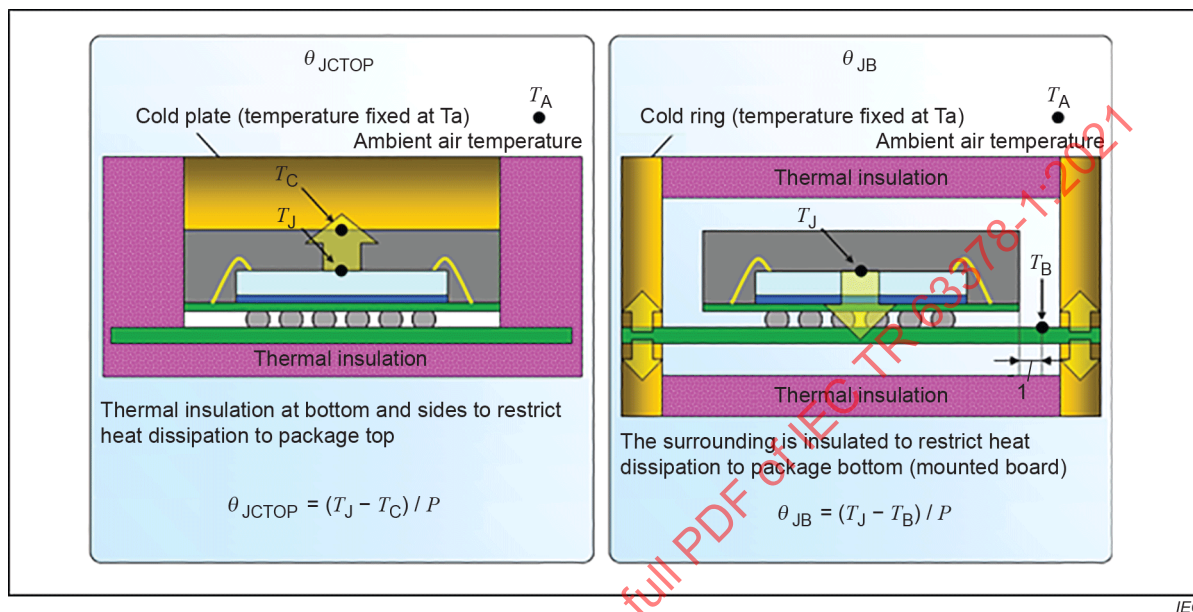


Figure 3 – Thermal resistance

3.2.2

thermal characterization parameter

quotient of the difference between the virtual temperature of the device and the temperature of a stated external reference point, by the total heat quantity of steady-state power dissipation in the device

Note 1 to entry: As is shown in Figure 4, thermal resistance is defined as the value dividing the temperature gap between X and Y by the heat volume from X to Y like the left hand figure, and thermal characterization parameter is defined as the value dividing the temperature gap between X and Y by the total heat quantity like the right hand figure. Since thermal characterization parameter cannot be strictly called thermal resistance, it was distinguished from thermal resistance by calling it thermal characterization parameter.

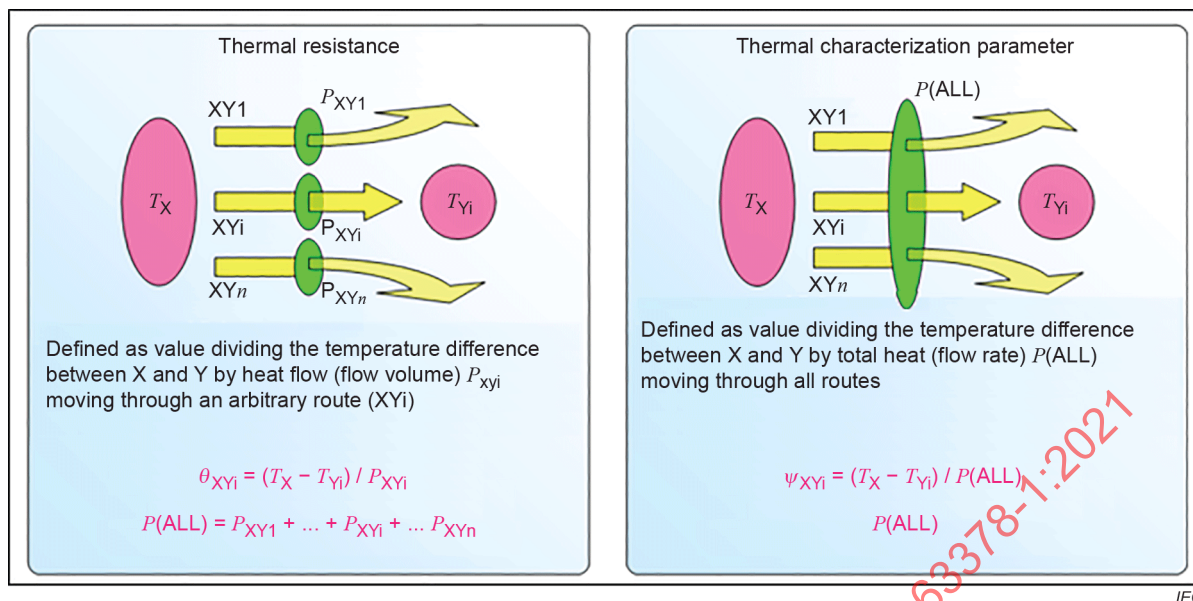


Figure 4 – Thermal resistance and thermal characterization parameter

3.2.2.1

thermal characterization parameter from junction-to-top centre of package

ψ_{JT}

thermal characterization parameter between chip (junction) and surface of package centre (see Figure 5)

3.2.2.2

thermal characterization parameter from junction-to-board

ψ_{JB}

thermal characterization parameter between chip (junction) and board surface (see Figure 5)

Dimensions in millimetres

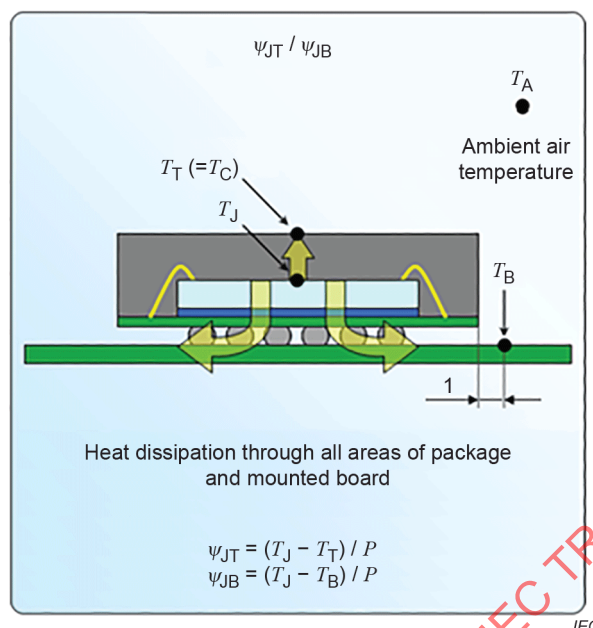


Figure 5 – Thermal characterization parameter

4 Accuracy of θ_{JA}

4.1 Variation of θ_{JA}

4.1.1 General

Measurements and simulations of thermal characteristic are commonly conducted in compliance with evaluation environment regulations that are used commonly in the semiconductor industry. However, there are some items not specified clearly and defined individually by each semiconductor manufacturer. These individually defined items may cause confusion in thermal characteristic value.

In this 4.1, variation of θ_{JA} has been examined by simulation, using 2 types of packages for example. In these simulations, ψ_{JT} is also listed as references.

4.1.2 Analysis model

Model (1)

Package:	35 mm × 35 mm BGA 544 pins (Total thickness = 2,33 mm)
Chip:	Material Si 10,5 mm × 10,5 mm thickness = 0,3 mm
Heat spreader:	None
Soldering:	Lead-free soldering

Model (2)

Package:	20 mm × 20 mm LQFP 144 pins (Total thickness = 1,5 mm)
Chip:	Material Si 8,4 mm × 8,4 mm thickness = 0,3 mm
Soldering:	Lead-free soldering

4.1.3 Simulation conditions (typical values)

Power consumption: 1 W

Ambient air temperature: 25 °C (room temperature)

Board: 4 Layers, FR4

Remaining copper rate: L1 = 20 % L2 = 90 % L3 = 90 % L4 = 20 %
(equivalent thermal conductivity set to correspond to remaining copper rate per layer)

Other: See Figure 6

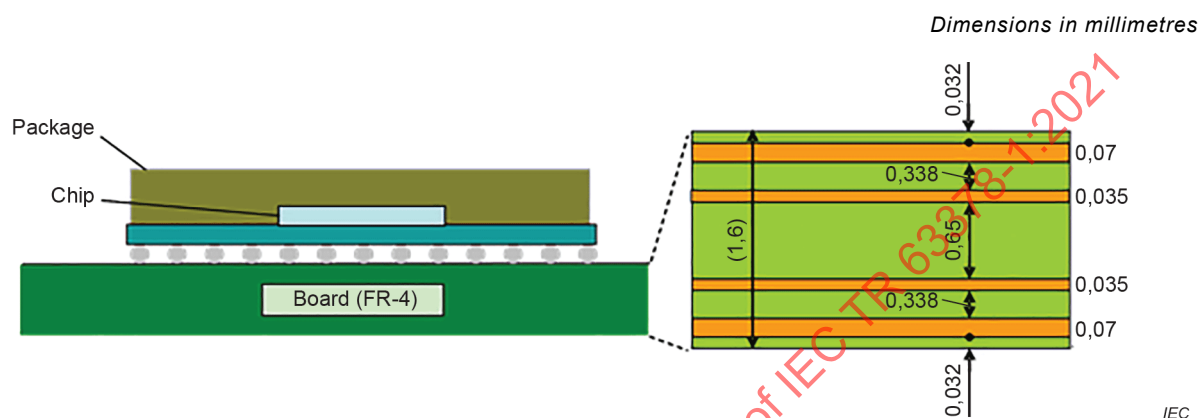


Figure 6 – Simulation conditions

4.1.4 Evaluation items and standards

Among the items that affect thermal resistance, three items shown in Table 1 were evaluated.

Table 1 – Evaluation items and evaluation parameters

Evaluation items	Evaluation parameters
Remaining copper rate	25 %/25 %/25 %/25 % 20 %/90 %/90 %/20 % (Typical value) 50 %/50 %/50 %/50 % 20 %/100 %/100 %/20 % 75 %/75 %/75 %/75 % 50 %/90 %/90 %/2 % 100 %/100 %/100 %/100 % 50 %/90 %/90 %/50 %
Ambient Air temperature	0 °C 25 °C (Typical value) 85 °C 125 °C
Power consumption	0,1 W 1 W (Typical value) 2 W 10 W

4.1.5 Evaluation results

4.1.5.1 θ_{JA} dependence on remaining copper rate (BGA)

θ_{JA} dependence on remaining copper rate (BGA) is shown in Figure 7. θ_{JA} is reduced by increasing the board's remaining copper rate.

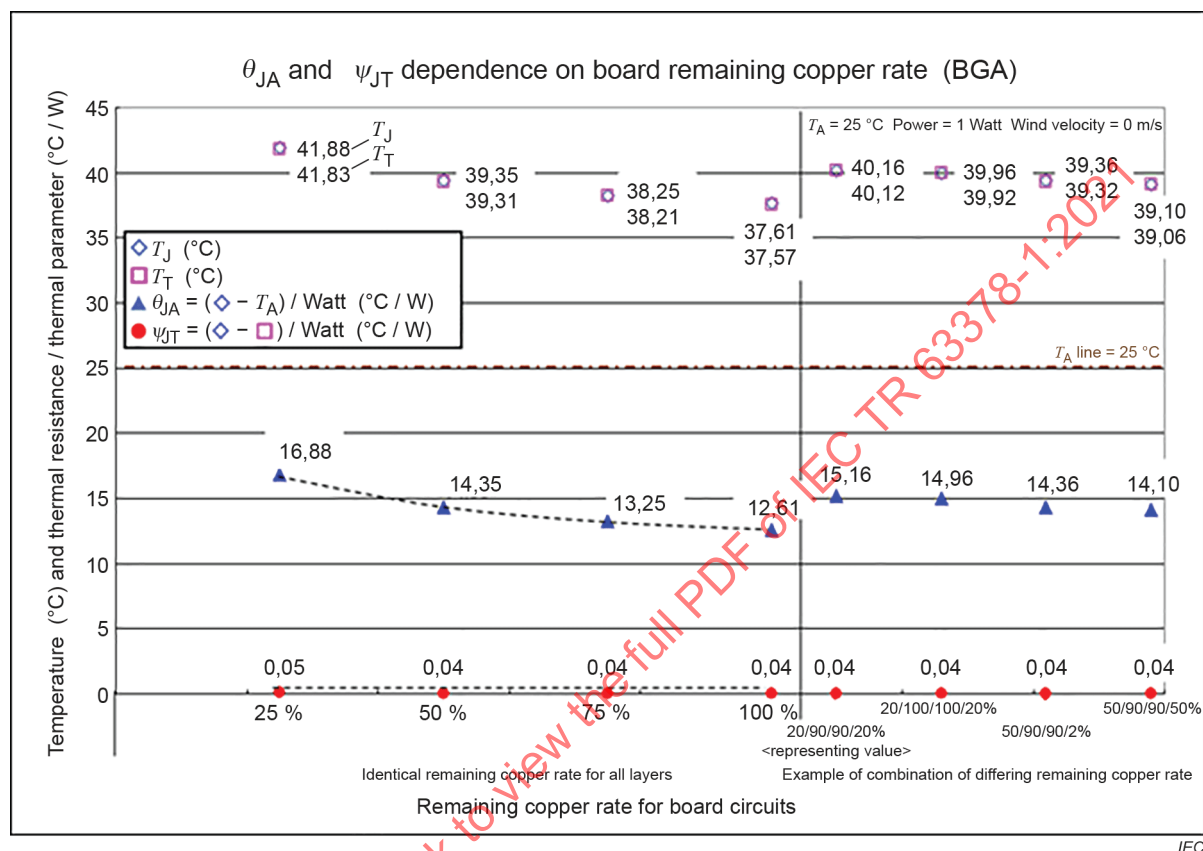


Figure 7 – θ_{JA} dependence on board remaining copper rate (BGA)

4.1.5.2 θ_{JA} dependence on remaining copper rate (LQFP)

θ_{JA} dependence on remaining copper rate (LQFP) is shown in Figure 8. θ_{JA} is reduced by increasing the board's remaining copper rate.

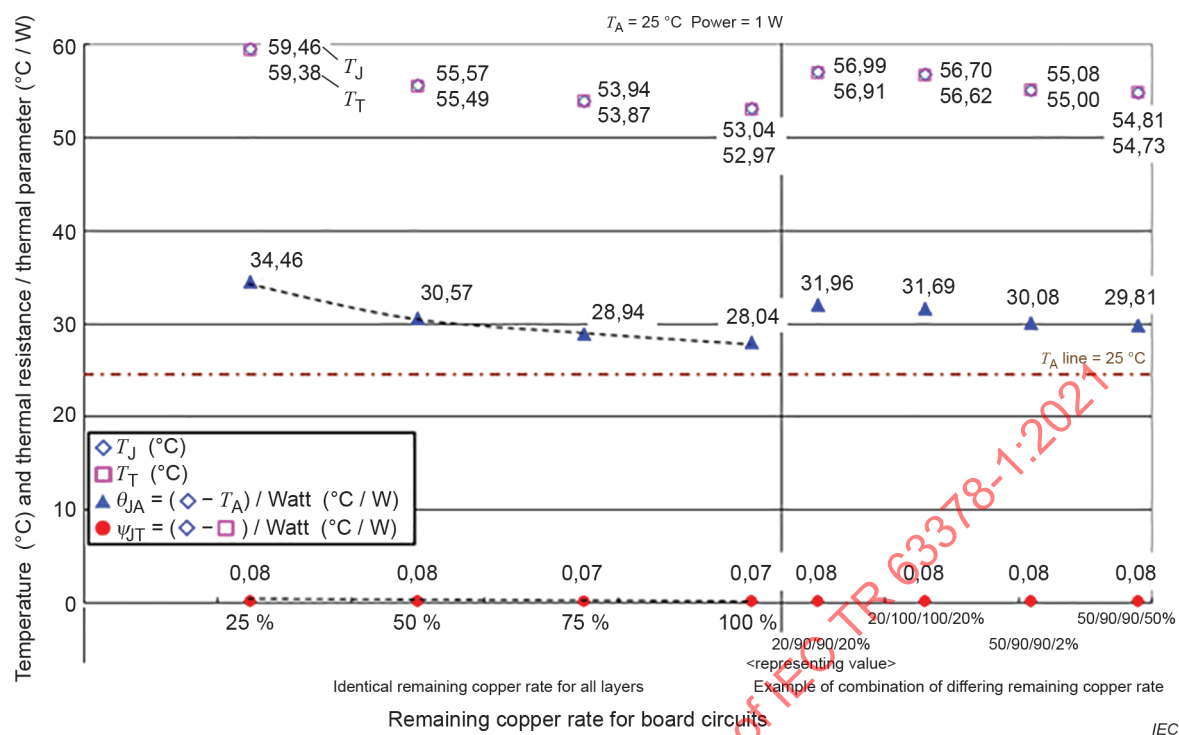


Figure 8 – θ_{JA} dependence on remaining copper rate (LQFP)

4.1.5.3 θ_{JA} dependence on ambient air temperature T_A (BGA)

θ_{JA} dependence on ambient air temperature T_A (BGA) is shown in Figure 9. θ_{JA} falls, proportional to the rise in temperature. This is due to radiation heat (thermal energy radiating as electromagnetic waves) from the package and board surface.

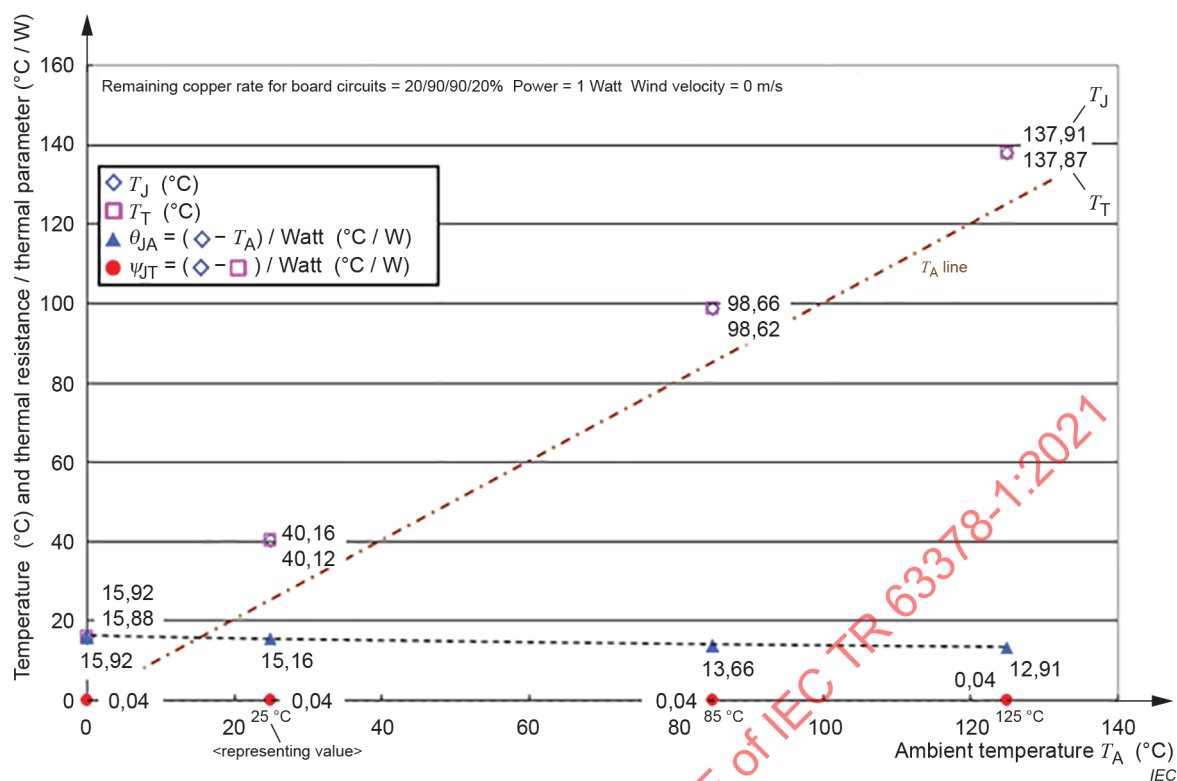


Figure 9 – θ_{JA} dependence on ambient air temperature T_A (BGA)

4.1.5.4 θ_{JA} dependence on ambient air temperature T_A (LQFP)

θ_{JA} dependence on ambient air temperature T_A (LQFP) is shown in Figure 10. θ_{JA} falls in proportional to the rise in temperature. This is to be caused by radiation heat, the same as in the case of BGA.

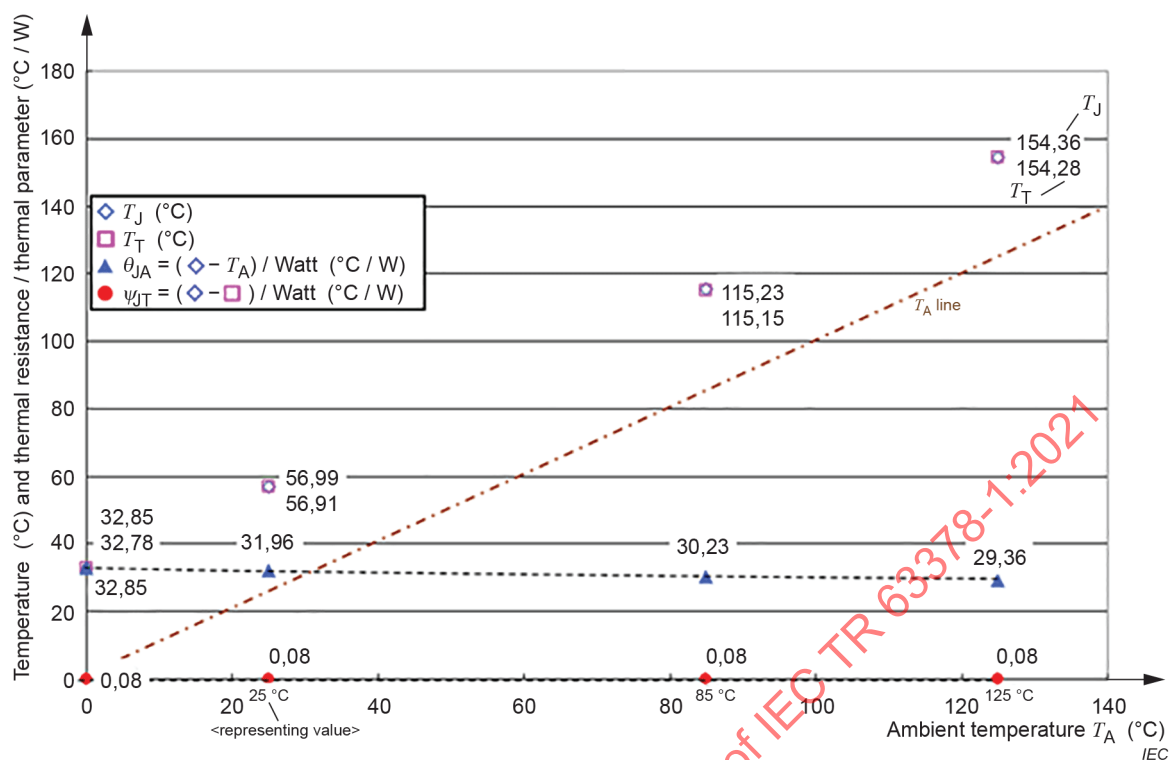


Figure 10 – θ_{JA} dependence on ambient air temperature T_A (LQFP)

4.1.5.5 θ_{JA} dependence on power dissipation (BGA)

θ_{JA} dependence on power dissipation (BGA) is shown in Figure 11. θ_{JA} falls in proportion to the rise in power dissipation. This is to be chiefly caused by increase in radiation heat from the package and board surface.

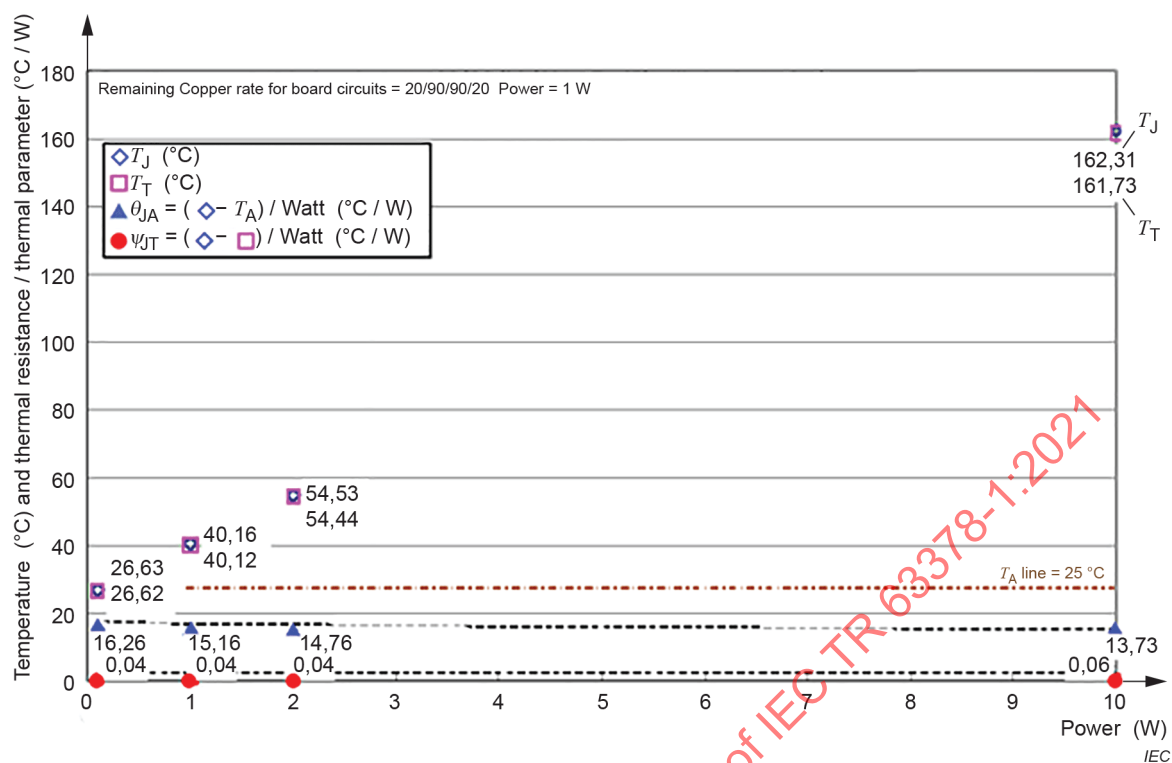
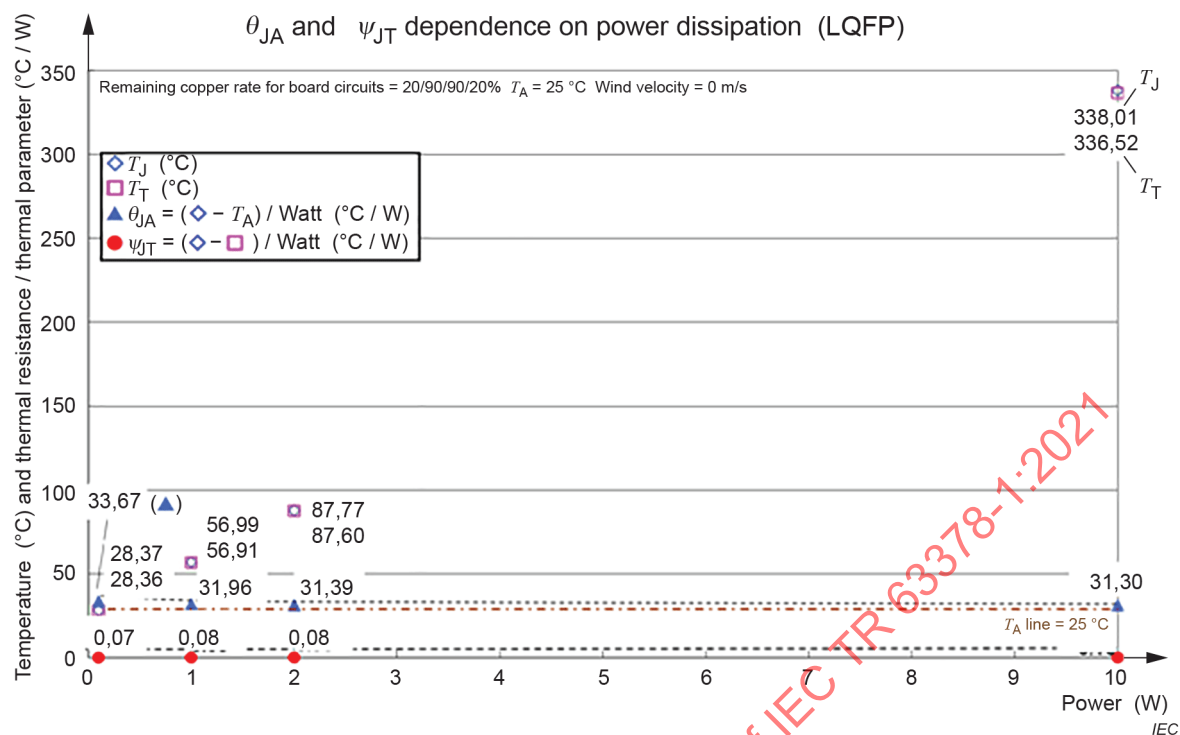


Figure 11 – θ_{JA} dependence on power dissipation (BGA)

4.1.5.6 θ_{JA} dependence on power dissipation (LQFP)

θ_{JA} dependence on power dissipation (LQFP) is shown in Figure 12. θ_{JA} falls in proportion to the rise in power dissipation. This is also to be mainly caused by increase in radiation heat from the package and board surface.

Figure 12 – θ_{JA} dependence on power dissipation (LQFP)

4.1.6 Summary

The summary of Clause 4 is shown in Figure 13.

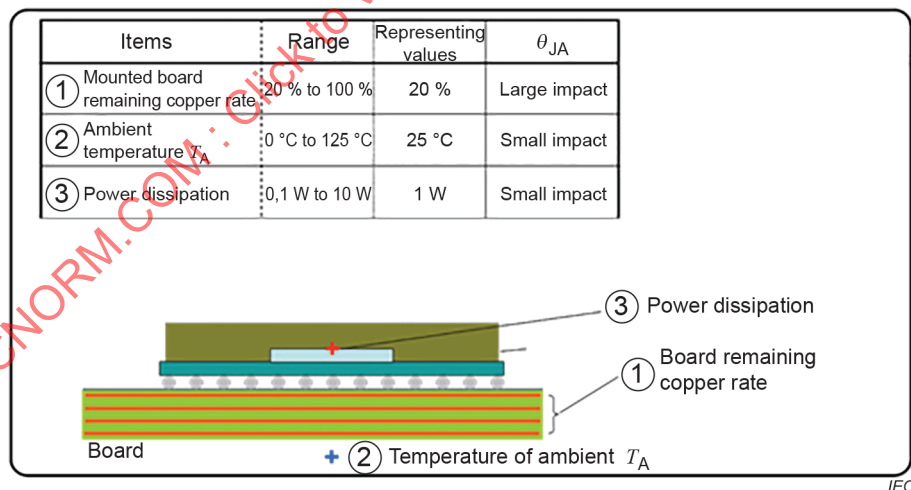
Figure 13 – Influence items and their impact on θ_{JA}

Figure 13 shows the level of impact in case the representing values change.

“Large impact” means the change is basically more than 10%, “Small change” means it is within 10% respectively.