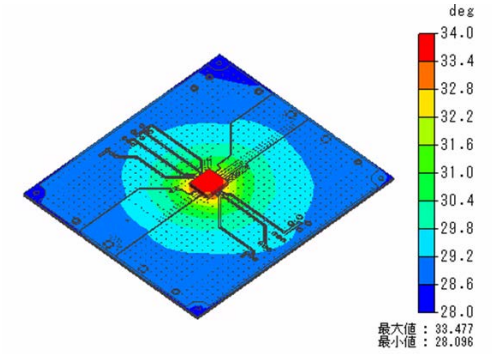
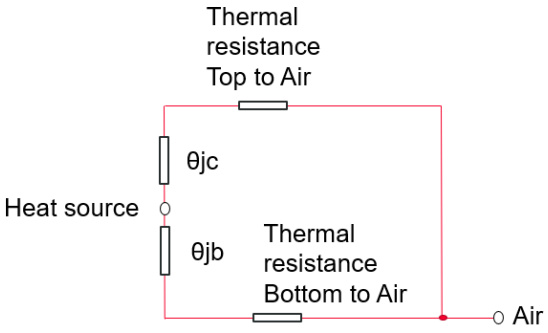
ABSTRACT

Thermal resistance model is useful to estimate thermal performance of the device and to design how to heat dissipate. Murata provide thermal resistance value of UltraCP in the datasheet.
In this paper how to calculate UltraCP Maximum temperature inside the module by thermal resistance.





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1. Definitions of Terms

To apply thermal resistance expression to a module there are standard terms. Most of them are defined in the JEDEC standard. This paper original terms below are noted inside after definition like (Only this paper)

Table 1. Definitions of Terms

Symbol	Meaning	Remark
Ta	Ambient temperature	Environment air temperature
Tj	Junction temperature	Maximum temperature of a module
Tc	Case temperature	Case temperature of the top side of the module
Tb	Case bottom temperature	Temperature of the hottest point of the PCB around module
θ ja	Junction to air thermal resistance	Thermal resistance between hottest point of a module and Ambient temperature
θ jc,	Junction to case thermal resistance	Thermal resistance between hottest point of a module and the top surface of a module
θ jct	Junction to bottom of the case thermal resistance	Thermal resistance between hottest point of a module and the bottom surface of a module
θ jb	Junction to bottom of the case thermal resistance	Thermal resistance between hottest point of a module and the top surface of a module
θ jcb	Junction to bottom of the case thermal resistance	Thermal resistance between hottest point of a module and the bottom surface of a module
Ptotal loss	Total loss of a module	Only this paper

2. Module Operation limit

There are limits to operation temperature because too much thermal stress makes specification error, reliability lost and in the worst case modules are down and stop their operation by their protection function. In the data sheet those thermal limitations are written in two sections.

One is “Absolute maximum rate”. Operation Over this condition makes modules damaged.

Two is “Recommended Operating Condition”. Inside this condition modules can operate little stressed.

Fig.1 is the image of the Module operation area and stress. Tj is the criteria to Thermal condition.

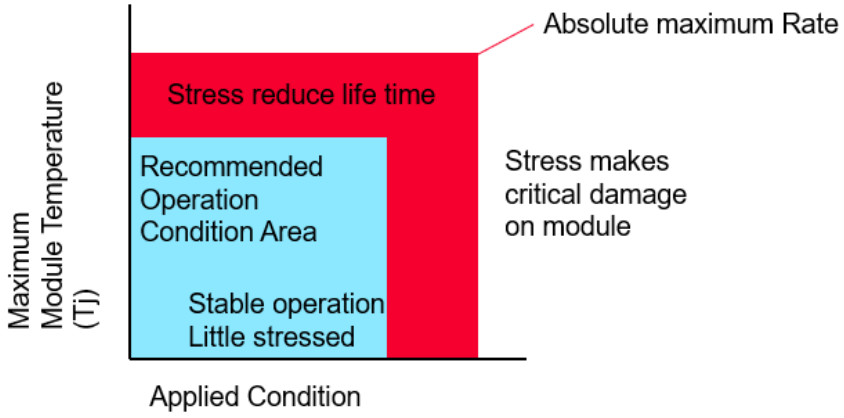

Figure 1. Operation area and Stress

3.Meaning of Thermal resistance

Thermal resistance is defined as below equation1.

$$Thermal\ resistance\ between\ A\ and\ b\ = \frac{Temperature\ difference\ A\ and\ B}{heat\ flow\ from\ A\ through\ B}$$

Equation 1

The functional expression of thermal resistance is left side picture in Fig.2 (If clearly recognize as thermal meaning, often use electrical resistance Z-shape symbol instead of white box symbol)
Right side of Fig.1 is an image of ideal 3Dim. model of thermal resistance.

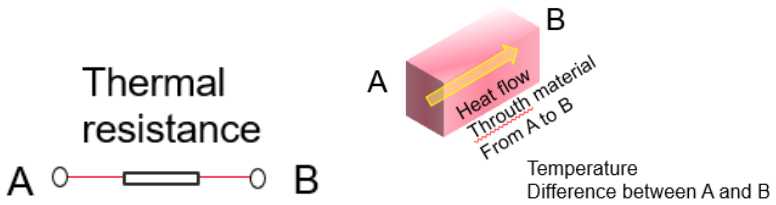

Figure 2. Thermal resistance model (left functional, right ideal model in 3Dim.)

The flamework is very simple but it is difficult to describe heat dissipation performance of the module by thermal resistance in detail. There are several devices as heat sources and PCB patterns as heat flow path and models become product by product. In this paper only two resistance model is explained for versatility.

Two resistance model is consist by two resistance(θ jc, θ jb) and one heat source (detail is in next section)

3.1 θjc(θjct) and θjb(θjcb)

Two thermal resistance model is consist by thermal resistance θjc(θjct) from heat source to top surface and thermal resistance θjb(θjcb) from heat source to bottom surface.Fig.3 is the image of the definition of θjc(θjct) and θjb(θjcb). In Fig.3 thermal resistance is expressed by blue Z-type resistance and heat source is expressed by red dot. As it is said It is necessary to be clear how much the heat flow from junction point (generate heat point) to other surface that out heat outside of the system.

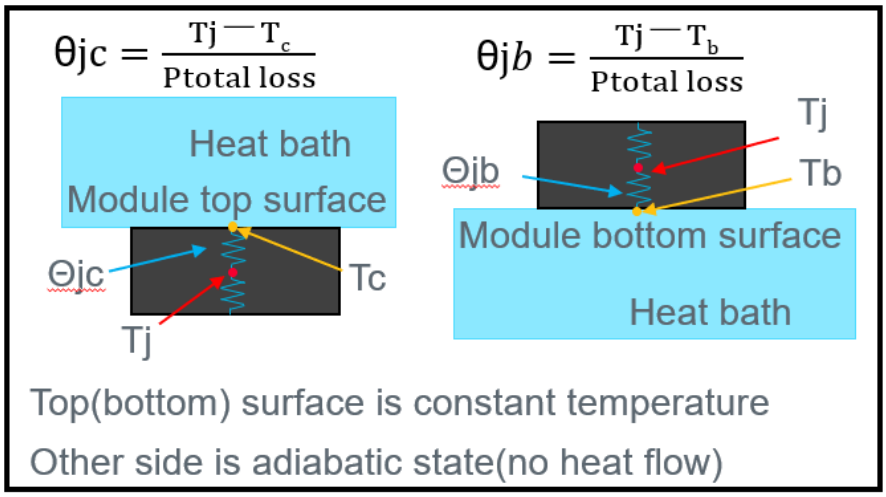

Figure 3. Thermal resistance difinition about θjc and θjb

To measure heat flow by minimize heat flow that go through a surface except heat bath and measuring heat source. Or subject heat flow that go through a surface except heat bath from total heat flow.

3.2 θja

θja is defined as Fig.4. As whole loss of the device flow away to air by radiation and convection of the air, θja is calculated by dividing temperature difference between heat source and far location air by total loss of heat source. The value θja is affected by the evaluation board heat dissipation performance.

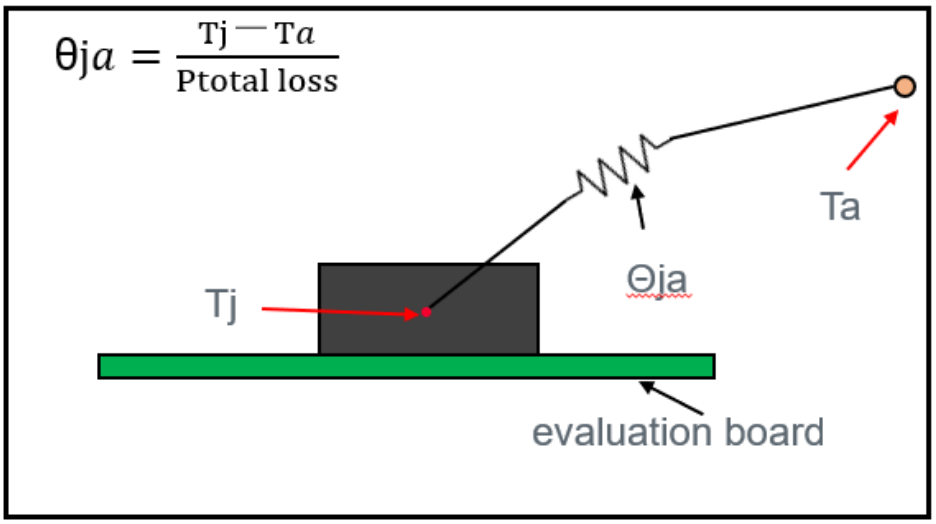

Figure 4. Thermal resistance difinition about θja

4. Calculation Method of Tj

1) Pick up Thermal resistance value from data sheet. (θjc, θjb)
2) Measure the loss of the module under the same condition as it is used, or calculate the loss from efficiency curve in the data sheet by equation2

$$"Ptotal\ loss" = \text{“Output power "} \times \frac{1 - \text{“Efficiency from datasheet”}}{\text{“Efficiency from datasheet”}}$$

Equation 2 Ptotal loss calculation

3) Calculate top surface Temperature and bottom side Temperature of the module by simulation or measurement. (Tt and Tb)
4) Calculate Tj from below equation by Thermal resistance value.

$$Tj = \theta\text{jb} * (\text{Ptotal loss} - Phf) + \text{Tb}$$

Here Phf is the heat flow from junction to module surface that exposed directory to the air.
If Top surface is the main path of the heat flow except bottom side. Phf can be simplified to below equation as rough estimation.

$$Phf = \frac{Tj - Tc}{\theta\ \text{jc}}$$

In that case Tj can be estimated by below equation

$$Tj = \frac{\theta\ \text{jb} * \text{Ploss} + \frac{\theta\ \text{jb}}{\theta\ \text{jc}} * \text{Tc} + \text{Tb}}{1 + \frac{\theta\ \text{jb}}{\theta\ \text{jc}}}$$

If need more accurate estimation, use simulation software that can calculate 1D model with thermal resistance value in the product data sheet

5.Example

Below is the Tj Calculation example.
Fig.5 is a module Thermal resistance value.
Table1 is a measurement result and a calculation result of this module under national convection condition.
(Calculation done by 4.4) equation)

- Thermal resistance

Θjc = 51.8degC/W
Θjb = 6.27 degC/W
Θja = 19.0 degC/W*1

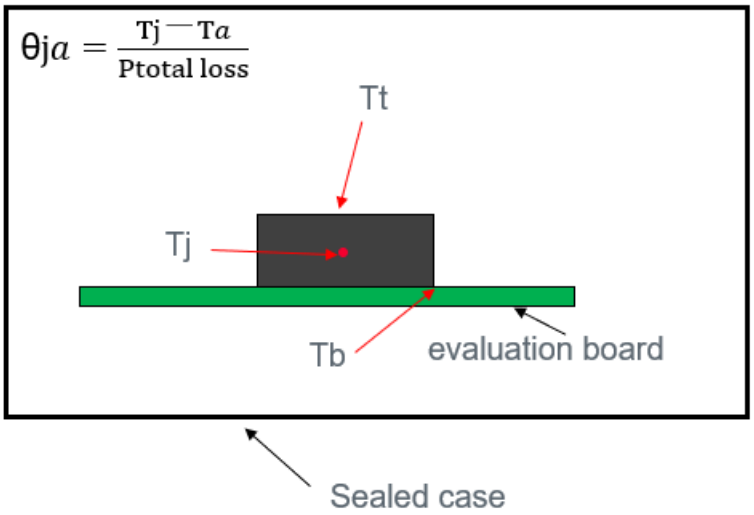

Figure 5. Thermal resistance value

Table 2. Measurement result

Item	Value	Unit
Top surface Temperature	43.81	degC
PCB Temperature near the module	37.4	degC
Ta	26.04	degC
Efficiency	92.5	%
Vin	11.9975	V
Iin	1.2138	A
Vout	1.7856	V
Iout	7.5454	A

Table 3. Calculation result

Item	Value	Unit
Ploss	1.09	W
Tj	44.2	degC
Θjb	6.27	degC/W
Θjc	51.8	degC/W
Θjb/Θjc	0.121	NA

6. Reference

Detail of terms definition
JEDEC JESD51-12 Page 6 to page 10

About real measurement (not mentioned this paper)
JEDEC JESD51-2A

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