TR

ROHM

Things to be noted before calculating the TR die temperature.

Normally, a transistors gets heated when in use.

We can not ignore its heat.

Therefore, it is required to carefully calculate the heat of TR before use, in order to drive it safely and stably.

This is why this material has been prepared and offered here.
We hope this material becomes any help to the users.

Let' s figure out the temperature of transistor die !

TR Methods to calculate the die temperature

The followings are procedures to make judgement as to whether a transistor can be used or not.

Verification 1. (Usability judgement 2.)

Aren’t current or voltage exceeded beyond the absolute maximum rating even for a moment?

Verification 2. (Usability judgement 3.),(Usability judgement 4.)

Isn’t Safe Operating Area (SOA) violated?

Verification 3. (Usability judgement 6.)

Isn’t the die temperature beyond 150 deg.?

Here, an explanation is given in details as to “Verification?” (Mainly about “heat” .)
As for “Verification 1.,2.” , please refer to the different sheet [sable or Not Judgement Method]

Junction Temperature Calculation Method 1
: From the ambient temperature (basic)

Junction Temperature Calculation Method 2
: From the ambient temperature (transient thermal resistance)

Junction Temperature Calculation Method 3
: From the case temperature

Relevant page : About Junction-to-Case Thermal Resistnace Rth (j-c) (detailed)

Relevant page : About Resistance value of standard packages (reference)

Isn’ t the die temperature beyond 150 deg.?

The die of transistor need to be below 150 deg. always. (Below 100 deg. recommended.) The life becomes extremely short if beyond 150 deg. and the device may be deteriorated or destroyed in the worst case.

First of all, it is necessary to consider the junction temperature (Tj), since the junction between P layer and N layer generates the highest temperature in case of bipolar transistor. (The same applies to Digital Transistor too.)
As “channel” area gets heated most in case of MOSFET, Channel Temperature : Tch must be considered first for MOSFET.
Tj and Tch can be considred as the same paramater in terms of thermal rating, so that “Tj” will be used as representative herein after. (As such, “Tj” can be taken as “Tch” likewise.)

Junction Temperature Calculation Method 1 : From the ambient temperature (basic)

Junction temperature (or Channel Temperature) can be calculated from the ambient temperature or consumption current as following: i.e. from the theory of thermal resistance.

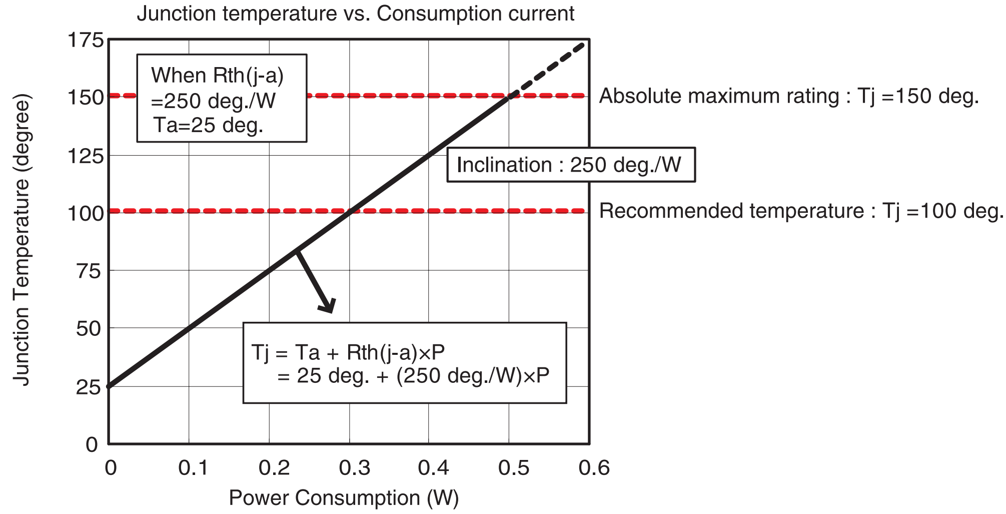
$$Tj = Ta + Rth(j\text{-}a) \times P$$

Ta : Temperature of ambient atmosphere (= room temperature where the measurement was done)
Rth(j-a) : Thermal resistance inbetween Junction and Ambient atmosphere *
P : Power dissipation **

*Rth(j-a) : Thermal resistance of “junction-to-ambient” varies depending on the types of circuit board. For reference, we are also providing “Table of Thermal Resistance by Package” based on the use of our standard circuit board separately.
Rth(j-a) value differs per each part number, but the values will be close if the package is the same.

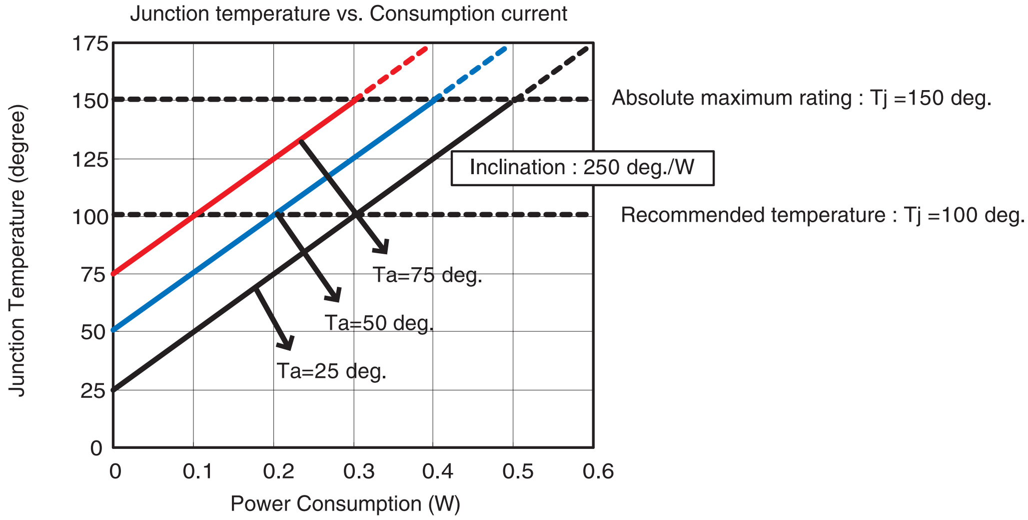
**If the current consumption is not stable and changing time to time, then the averaged values of consumption current shall be assigned in the calculation formula to get the approximate value. (See “Usable or Not Judgement Method” provided separately for getting the value of average current consumption.)

As an example, we list below the correlation between the current consumption and the junction temperature when Rth (j-a) is 250 deg./W , the ambient temperature is 25 deg..



Junction temperature rises in proportion to current consumption. The proportionality constant for this is Rth(j-a).
Since Rth(j-a) is 250 deg./W, the junction temperature rises by 25 deg. per each increment of 0.1W of current consumption. This means, the junction temperature becomes 150 deg. when the current consumption is 0.5W, and the graph in this case suggests that the current beyond 0.5W can not be applied to TR.

Nextly, we explain about the case that the ambient temperature changes while Rth(j-a) is the same 250 deg./W as above.



Junction temperature becomes 150 deg., when...

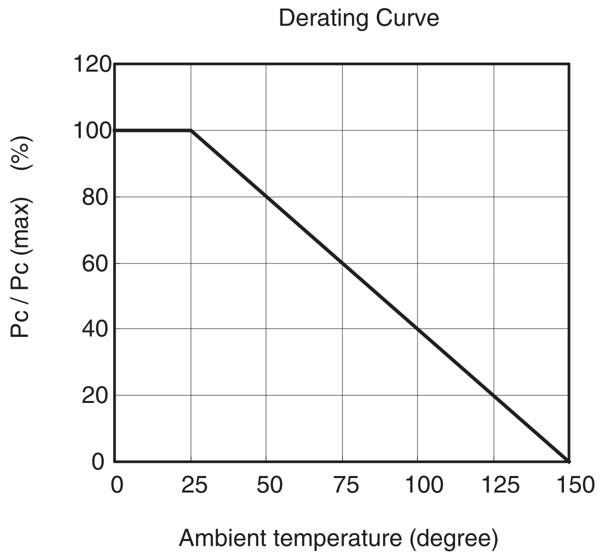
- Power consumption is 0.5W at the ambient temp. 25 deg.
- Power consumption is 0.4W at the ambient temp. 50 deg.
- Power consumption is 0.3W at the ambient temp. 75 deg.

That is tosay, even the same current is applied, the junction temperature also rises as the ambient temperature goes up and this diminishes the applicable current subsequently.
Maximum current consumption is influenced not only by thermal resistance but also by the ambient temperature also.
Since the applicable current will be 0 (zeron) when the ambient temperatrure is 150 deg. ,

$\boxed{100\% \div (150 \text{ deg.} - 25 \text{ deg.}) = 0.8 \text{ \%/deg.}}$

The maximum current consumption decreases with the above ratio.

The following graph is “Derating curve” to show this relationship.



Derating curve illustrates the ratio of current attenuation by percentage and we can apply the percentage to all the packages. For example, in case of MPT3 package (SOT89), the maximum applicable power is 0.5W at 25 deg. and the applicable current is getting reduce at the rate of 0.8%/deg..

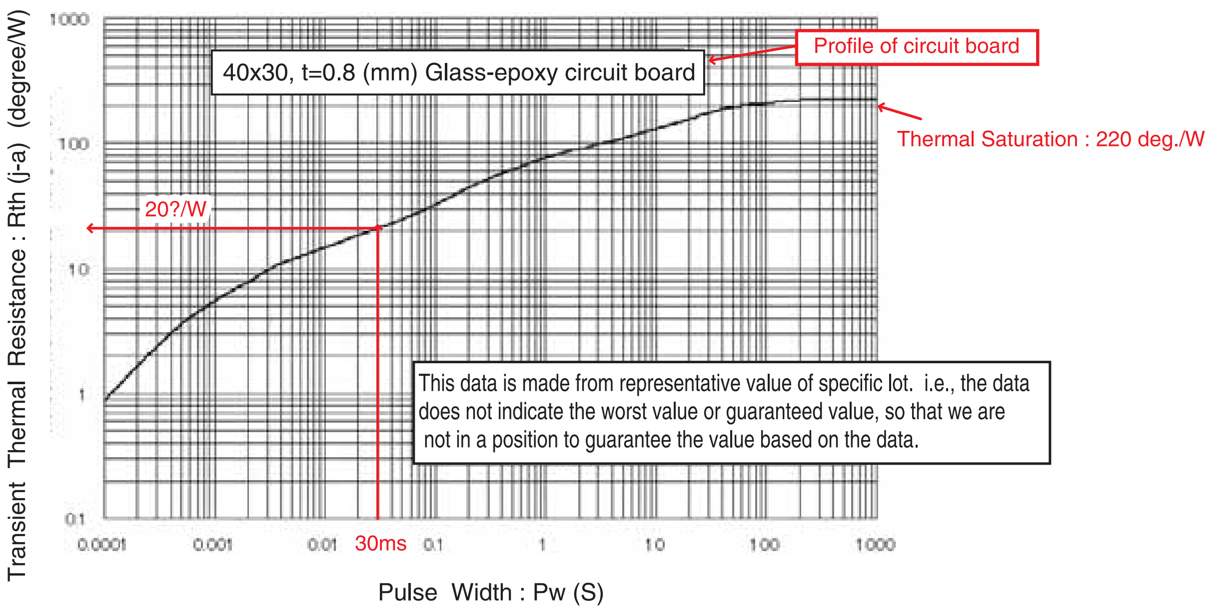
This means, the value goes down to 0.4W which is 80% from 100% of its initial (20% down), and down to 0.2W which is 40% (60% down).

Junction Temperature Calculation Method 2
: From the ambient temperature (transient thermal resistance)

With those examples aforementioned, we illustrated about the cases where the current is applied to device continuously.

Nextely, we will discuss about the case that the temperature rise by momentary current application.

An example of Tarnsient Thermal Resistance on part no. (2SD2675)



The above graph shows the thermal resistance at momentary time (Transient Thermal Resistance), plotting the pulse width on X-axis and Rth(j-a) is on Y-axis.

It is known from this graph that the junction temperature rose as the current application time lasts longer and it reached the plateau state (=called thermal saturation) after 200 sec. had passed.

For example, Rth(j-a) is 20 deg./W when the current application time is 30ms, so that the junction temperature can be claculated when 3W is applied for 30ms under the ambient temperature 25 deg..

Tj = Ta + Rth(j-a)×P

= 25 deg. + (20 deg./W)×3W

= 85 deg.

We can use this calculation formula to obtain the junction temperature when the current is applied momentarily as single pulse.

Junction Temperature Calculation Method 3
: From the case temperature

The junction temperature can be calculated from the temperature of case as below.
i.e., we assign Rth(j-c) in the formula in place of Rth(j-a) we did before,

$$Tj = Tc + Rth(j\text{-}c) \times P$$

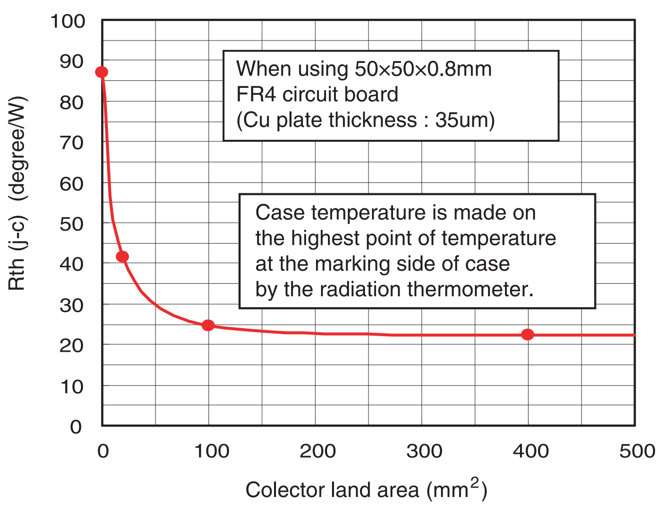
Tc : Case temperature*
Rth(j-c) : Thermal resistance between Junction - Case
P : Current consumption **

n.b. * Case temperature is measured by the radiation thermometer as the maximum temperature on the surface of package where the marking is put.
Please note that the case temperature differs considerably by the measurement method/point.

** The value is considered approximate one when the applied current is not constant and shifting time to time by assigning the averaged current consumption figure.

However, since Rth(j-c) value DOES vary depending on the types of circuit board and also on the heat dissipation conditions including soldering state, it may not be all right to apply the above formula directly to your calculation since the the measured values on our circuit board may not mean the same on your circuit board likewise. For instance, the case temperature may be measured as lower by comparison even though the applied current is the same, when the circuit board has good heat dissipation characteristics.
An illustration below shows that Rth(j-c) becomes lower as the collector land pattern on the circuit board gets smaller. (Collector land area / thickness / mterials plus circuit board material, size circuit width will also bring different measurement results on Rth(j-c).

2SD2673 (TSMT3) Rth(j-c) vs Collector land area

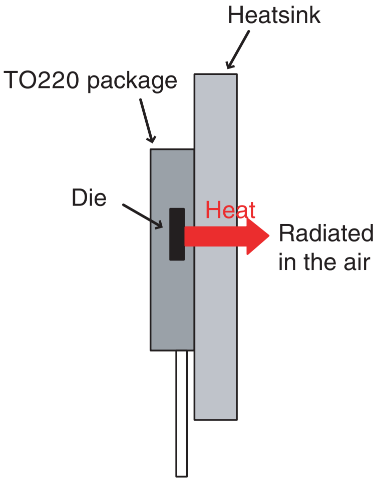


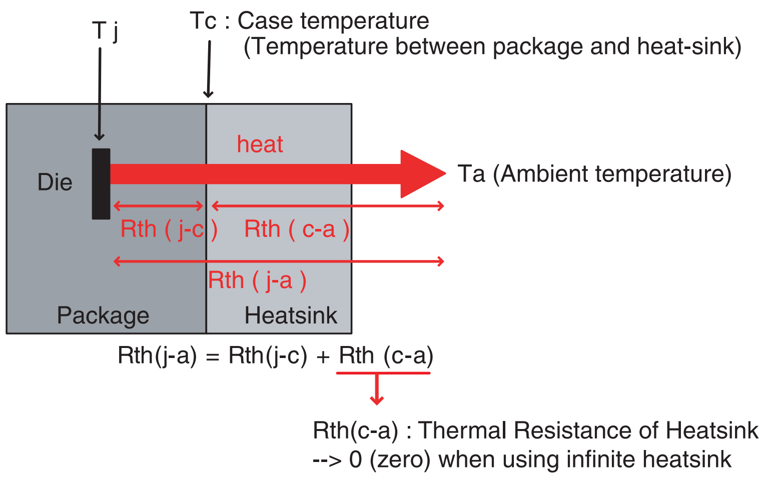
In this way, Rth(j-c) value can differ depending on the nature & conditions of circuit board and also it is difficult to spot the right place for measuring the case temperature precisely.
For these reasons, it is not so much recommended to approximate the junction temperature. from the case temperature.

(Please refer to the next page.)

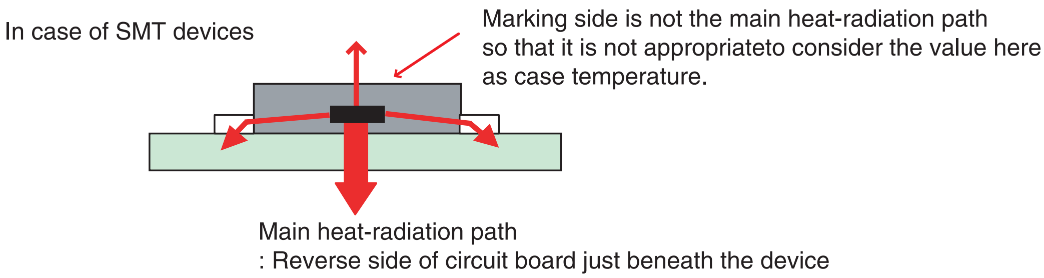
Relevant page : About Junction-to-Case Thermal Resistnace Rth (j-c) (detailed)

In principle, Junction-to-Case thermal resistance Rth(j-c) is an index basically used for TO220 packaged (=throughhole) devices by soldering it to the heatsink In this case, since Case-to-Heatsink is the heat-radiation path, it is possible to precisely calculate the junction temperature by measuring the case temperature at the point in the middle of such path. In particular, if the heatsink having the ideal heat dissipation performance is supposed to be used (e.g. infinite heatsink), the heat dissipation capability is considered as limitless and it is takenfor granted that "Case Temperature" = "Ambient Temperature" , Case temperature = 25 deg. (Tc = 25 deg.) is supplied in the calculation formula. (Thermal resistance of infinite heat-sink : Rth(c-a) = ; then Rth(j-a) = Rth(j-c))





However, for the surface-mount devices, heat-radiation path is mainly the part of circuit boad just beneath the device ; so that it is quite difficult to measure the case temperature at such location. Even if the temperature on marking side of device is measured, its portion of heat-dissipation in the entire heat-dissipation is rather small. Therefore, it is not suitable to use the temperature at such place in the formula to calculate the junction temperature either.



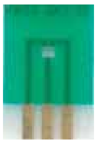
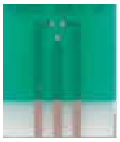
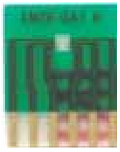
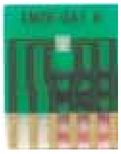
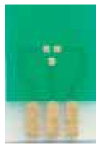
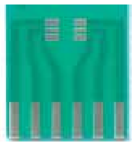
Nevertheless, since there are many requests from the customers about Rth(j-c) value for SMT devices also, ROHM provides in some cases Rth(j-c) value on the conditions that the temperature is measurement on the marking side of device being mounted on the aforementioned standard circuit board. Therefore, the Rth(j-c) value should be considered for reference as obtained from the customized conditions as described.

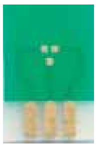
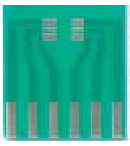
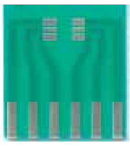
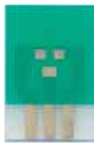
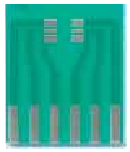
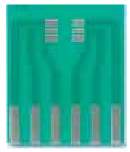
If the device is mounted on the circuit board different from ours, the portion of heat-dissipation in the entire heat radiaton shall differ so that it is not possible to figure out the junction temperature adequately.

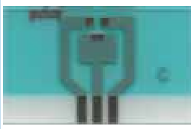
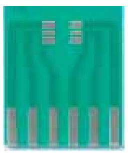
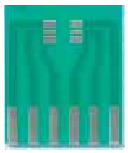
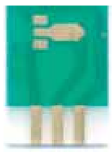
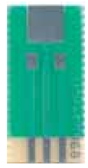
Relevant page : About Resistance value of standard packages (reference)

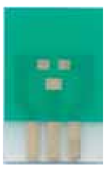
The values in following data are not the guaranteed values nor maximum / minimum values.
Please treat these only as reference data.

n.b.
- Data listed here came from the results of measuring a specific production lot.
- Rth (j-a) vary a lot depending on the circuit board, the heat-dissipation conditions involving soldering methods and the method of temperature measuring, .

Package	VMT3	EMT3	EMT5	EMT6	TUMT3	TUMT6
Circuit Board						
FR4 dimensions (unit : mm)	20×12×0.8	20×15×0.8	20×15×0.8	20×15×0.8	20×12×0.8	15×20×0.8
Rth (j-a) / Rth (ch-a)	833 deg. / W	833 deg. / W	1042 deg. / W	1042 deg. / W	313 deg. / W	313 deg. / W
Note	-	-	When driving 1-die	When driving 1-die	-	When driving 1-die

Package	UMT3	UMT5	UMT6	SMT3	SMT5	SMT6
Circuit Board						
FR4 dimensions (unit : mm)	20×12×0.8	20×15×0.8	15×20×0.8	20×12×0.8	20×15×0.8	20×15×0.8
Rth (j-a) / Rth (ch-a)	625 deg. / W	1042 deg. / W	1042 deg. / W	625 deg. / W	625 deg. / W	625 deg. / W
Note	-	When driving 1-die	When driving 1-die	-	When driving 1-die	When driving 1-die

Package	TSMT3	TSMT5	TSMT6	SOP8	MPT3	CPT3
Circuit Board						
FR4 dimensions (unit : mm)	30×15×0.8	20×15×0.8	20×15×0.8	20×20×0.8	12×20×0.8	12×30×0.8
Rth (j-a) / Rth (ch-a)	250 deg./ W	250 deg./ W	250 deg./ W	160 deg./ W	250 deg./ W	125 deg./ W
Note	-	When driving 1-die	When driving 1-die	When driving 1-die	-	-

Package	SST3					
Circuit Board						
FR4 dimensions (unit : mm)	20×12×0.8					
Rth (j-a) / Rth (ch-a)	625deg./ W					
Note	-					