To use transistor safely

Transistor is used for switching or amplifying, but may have failure when use in inappropriate condition.
Therefore, to use the transistor safely, it is necessary to verify whether condition is appropriate.
Here, we introduce three points about verification to be required to a minimum.

Verification1. Are there all conditions within the maximum ratings?
Verification2. Is there it within ASO (area of safety operation)?
Verification3. Is there junction temperature within the maximum ratings?
- 3-1.When use in DC
- 3-2.When use in single pulse
- 3-3.When use in continuous pulse

Verification1. Are there all conditions within the maximum ratings?

Please confirm the maximum ratings listing in the data sheet of the target part.

On this occasion please confirm to refer the following caution points.

・Collector to emitter voltage must be within the maximum ratings (following example 50V).

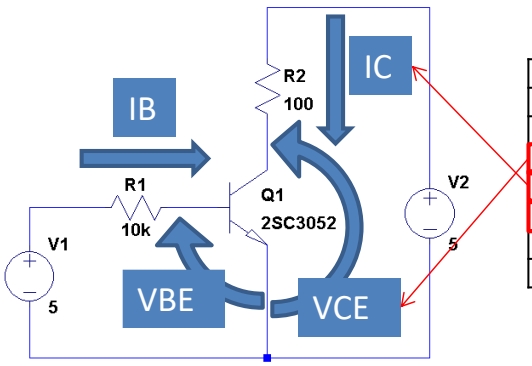
・Collector current must be within the maximum ratings (following example 200mA).

・Collector dissipation VCE×IC must be within the maximum ratings (following example 200mW).

・Base current IB ratings is not usually listed because it is smaller than collector current. When base current is large depending on use condition, it must satisfy the following condition.

VBE×IB + VCE×IC < PC (collector dissipation maximum ratings)

It is 1/3～1/10 of collector current.

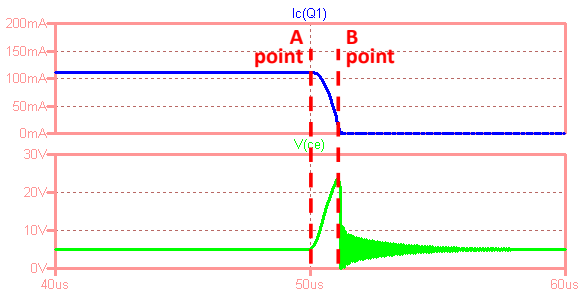


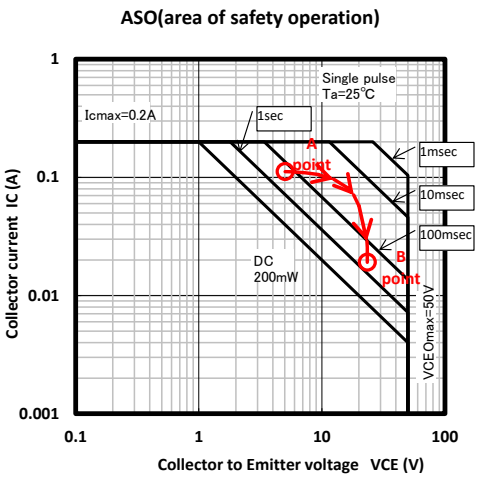
MAXIMUN RATINGS（Ta=25℃）

Symbol	Parameter	Ratings	Unit
VCBO	Collector to Base voltage	50	V
VEBO	Emitter to Base voltage	6	V
VCEO	Collector to Emitter voltage	50	V
IC	Collector current	200	mA
PC	Collector dissipation	200	mW
Tj	Junction temperature	+150	℃
Tstg	Storage temperature	-55～+150	℃

Verification2. Is there it within ASO (area of safety operation)?

Collector dissipation PC listing maximum ratings is for direct current. In case exceeding collector dissipation when use in pulse driving or inductive load, it is necessary to use within the area of safety operation to show as follows.





In addition, when a data sheet does not have the ASO (area of safety operation) by kind, sorry for inconvenience but, please ask to sales office.

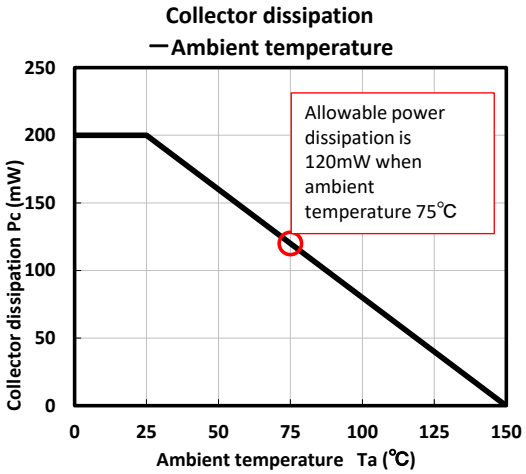
Verification3. Is there junction temperature within the maximum ratings? (direct current case)

Since maximum ratings of power dissipation and ASO (area of safety operation) are defined as the power when junction temperature reach maximum ratings(usual 150℃) in case ambient temperature is 25℃, it is necessary to consider to derate maximum ratings by the following derating curve in case ambient temperature is more than 25℃.

Since derating curve is the power when junction temperature reaches maximum ratings, we can consider as follows.

Tj=Ta+Rth(j-a)×Pc

※Tj: junction temperature、Ta: ambient temperature
Pc: applying power、Rth(j-a): thermal resistance between junction and ambient

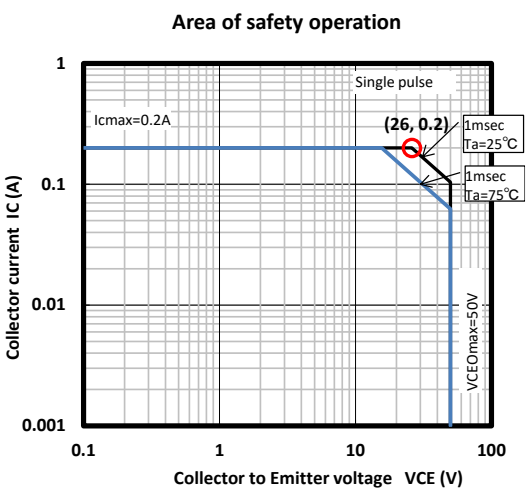


In case right graph,
when Ta=25℃, Pcmax=200mW, Tjmax=150℃,
then Rth(j-a)=(150-25)/200=625(℃/W)
In case Ta=75℃, power dissipation Pcmax is as follows.
Pcmax=(Tjmax-Ta)/Rth(j-a)=(150-75)/625=0.12(W)
In case Ta=75℃, applying power Pc=0.1(W),
Junction temperature Tj=Ta+Rth(j-a)×Pc=75+625×0.1=137.5(℃)
Since it is within maximum rating of junction temperature Tjmax=150℃, we can consider use condition has no problem .

Verification3. Is there junction temperature within the maximum ratings? (single pulse case)

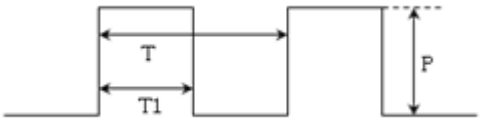
It is also necessary to consider to derate maximum ratings of ASO (area of safety operation) in case ambient temperature is 25℃.

When Ta=25℃,1msec, allowable power dissipation becomes 26V×0.2=5.2W from right figure .
When Ta=25℃, Pcmax=5.2W, Tjmax=150℃
then rth(j-a)=(150-25)/5.2=24(℃/W)
In case Ta=75℃,allowable power dissipation Pcmax becomes as follows.
Pcmax=(Tjmax-Ta)/Rth(j-a)=(150-75)/24=3.1(W)
Blue line in right figure shows the area limited by Pcmax=3.1(W). In case Ta=75℃, applying power Pc=2(W), junction temperature Tj=Ta+Rth(j-a)×Pc=75+24×2=123(℃). Since it is within maximum rating of junction temperature Tjmax=150℃, we can consider use condition has no problem.



Verification3. Is there junction temperature within the maximum ratings? (continuous pulse case)

For confirmation of junction temperature in continuous pulse, it is necessary to calculate power wave form from current wave form and voltage wave form in continuous pulse, and calculate junction temperature increasing according to the following equation. Let calculated junction temperature increasing as ΔTj, ambient temperature as Ta, we can consider use condition has no problem if Ta+ΔTj is within Tjmax .



$\Delta Tj = [\ D \times Rth\text{-}a + (1\text{-}D) \times rth(T1+T) + rth(T1) - rth(T)\ ] \times P$

where

D:duty

Rth-a: static thermal resistance between junction and ambient

rth(T1):transient thermal resistance at pulse width T1

rth(T): transient thermal resistance at pulse width T

rth(T1+T):transient thermal resistance at pulse width T1+T

P:peak power dissipation

Assuming continuous pulse as Icpeak=175mA,

VCE(sat)=0.6V, period T=3msec, D=50%,

then P=175mA×0.6V=105mW, T1=1.5msec

Rth-a=(Tjmax-Ta)/PT=(150-25)/0.2=625(℃/W)

From the transient thermal resistance graph of right figure,

rth(1.5msec)=17.4(℃/W)

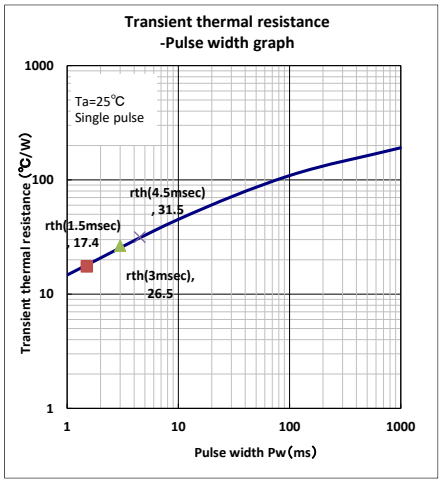
rth(3msec)=26.5(℃/W)

rth(4.5msec)=31.5(℃/W)

$\Delta Tj = [\ D \times Rth\text{-}a + (1\text{-}D) \times rth(T1+T) + rth(T1) - rth(T)\ ] \times P$

$= [0.5 \times 625 + (1\text{-}0.5) \times 31.5 + 17.4 - 26.5] \times 0.105$

$= 33.5(℃)$



Since Ta+ΔTj = 25 + 33.5 = 58.5(℃) < Tjmax(150℃), we can consider use condition has no problem.

Since maximum ratings are limit value of usable condition, the device has degradation or failure when use exceeding them. Please use within maximum ratings to prevent the degradation or failure of the devices, and to realize the high reliability of equipment.