TR Foreword to the customers before using ROHM transistors...

Whan a TR is operated, it naturally accompanies electric and thermal loads. The life of TR becomes short if such loads are too much and may be broken in the worst case. To avoi such events, it is highly recommended to check beforehand if the conditions of driving TR should have problem or not.
In this section, we explain as to the method of judging whether a selected TR can be used or not.
Please go through this over this material to avoid possible future trouble and use TRs in safety.

1. **Selection of transistor**

ROHM H.P. TR on Web.
http://www.rohm.com/web/global/groups/-/group/groupname/Transistors

(Search the possible candidate from web & short form catalogue.)

2. **Get samples and data-sheets**

ROHM H.P. TR on Web.
http://www.rohm.com/web/global/groups/-/group/groupname/Transistors

(Some sample can be purchase also from ROHM Website.)

3. **Mount a TR on the evaluation board for function check.**

Check points !

- if a chosen TR surely works safely on the actual circuit.
- if a chosen TR functions for a long time stably (=reliability) after its starting of work.
- if there are enough electrical margin for such TR drive.

THEREFORE,

Let' s check as to usable or not judgement of a TR!

TR Judgement : Usable or Not

Judgement as to whether it is OK to use a selected TR or not shall be done based on the following steps. (Details are referred in the next page and onwards.)

1. **Measure actual current and voltage waveform.**

2. **Is absolute maximum rating met all the time?** — No → **NG**

Yes

3. **Is the use of TR within S O A* ?** — No → **NG**

* Safety Oparation Area

Yes

4. **Is the use of TR within SOA derated per the ambient temperature?** — No → **NG**

Yes

5. **Single Pulse ?** or **ContinuousPulse ?**

Single Pulse ? — Yes → **OK**

ContinuousPulse ? — Yes →

6. **Is average current consumption within the rated wattage considered per the ambient temperature?** — No → **NG**

Yes → **OK**

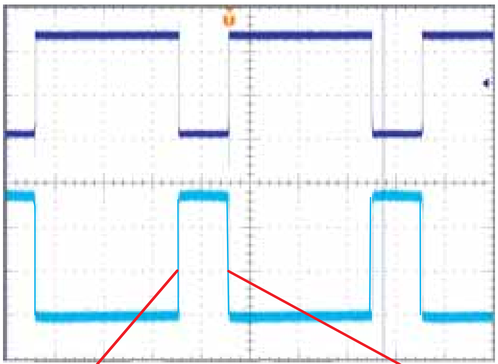
1. Measure the actual current & voltage waveform

Confirmation of current and voltage

First, check to see the current and the voltage applied to a TR with the oscilloscope. Although all the listed ratings on the data sheets need to match the measured values, the parameters listed below should be given priority.

Priority Items	Voltage	Current
Bipolar Transistor	Collector-Emitter Voltage : V_{CE}	Collector current : Ic
Digital Transistor	Output voltage : Vo (GND-OUT)	Output current : Io
MOSFET	Drain-Source Voltage : V_{DS}	Dorain current : I_D

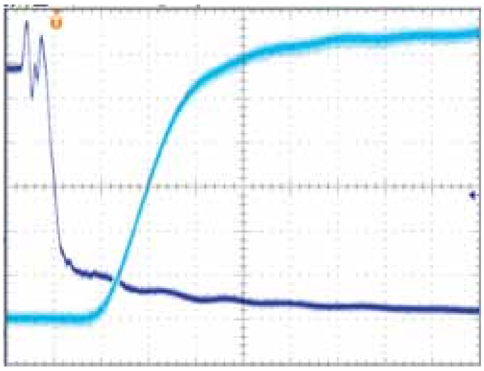
Example : Waveform when switching 2SD2673 (100μs / div)



<--- V_{CE} (5V/div)

<--- Ic (200mA/div)

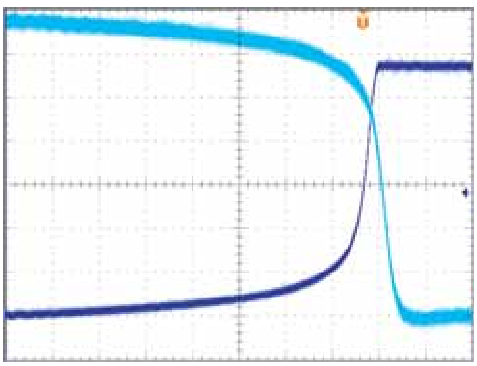
Enlarged image when OFF ---> ON (40ns/div)



<-- Ic (200mA/div) --->

<--- V_{CE} (5V/div) --->

Enlarged image when ON ---> OFF (200ns/div)



It is necessary to check in an enlarged size the waveforms when shifting OFF -> ON and ON -> OFF in order to calculate the current loss at switching.

2. Is the absolute maximum rating observed all the time ?

Confirmation of absolute maximum rating.

Check if the current and the voltage confirmed in (1.) are not exceeding the absolute maximum rating stipulated in the data sheet.

There are items not checked in (1.), but all such unchecked items also need to stay below the absolute maximum rating. The use of chosen TR is not possible if the peak current or the voltage surge could go beyond the absolute maximum rating range even for a moment. Otherwise, there is possibility of performance deterioration of destruction of device if driven beyond the absolute maximum rating.

Example : Data sheet of 2SD2673 (Description of absolute maximum rating)

4. Absolute maximum rating (Ta=25 deg.)

Collector - Base voltage V_{CEO} .. 30V <--- Check if V_{CBO} is beyond 30V or not.

Collector - Emitter voltage V_{CBO} ..30V <--- Check if V_{CE} is beyond 30V, from waveform in (1.)

Emitter - Base voltage V_{EBO} ...6V <--- Check if V_{EBO} is beyond 6V.

Collector current DC I_C ...3A
Pulse I_{CP} ...6A PW = 1ms - single pulse <--- Check if Ic is beyond 6A when the pulse is less than 1ms, from waveform in (1.)

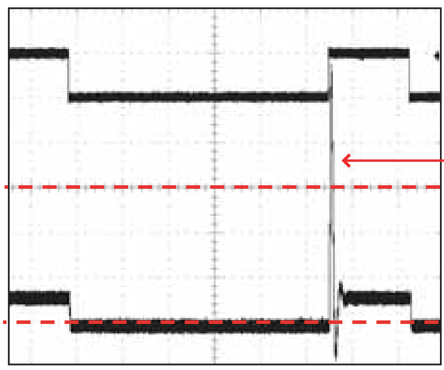
Collector loss P_C ..0.5W When each pin is mounted on the recommendedland pattern
1W When ceramic circuit board of 25x25, t=0.8 (mm) is used

Junction temperature Tj ..150 deg.

Calculation method of applied current / Junction temperature is explained in (6.)

Storage temperature Tstg .. -55 deg. to 150 deg.

Example A case the absolute maximum rating is violated momentarily (NG)



<--- VCE

It is no good (NG) to use the TR even if the exceeding above the absolute maximum rating is momentary.

Ic absolute maximum rating (pulse) : 6A

<--- Ic (2A/div)

3. Is the use of TR within SOA?

Confirmation of Safety Operating Area (SOA*1)

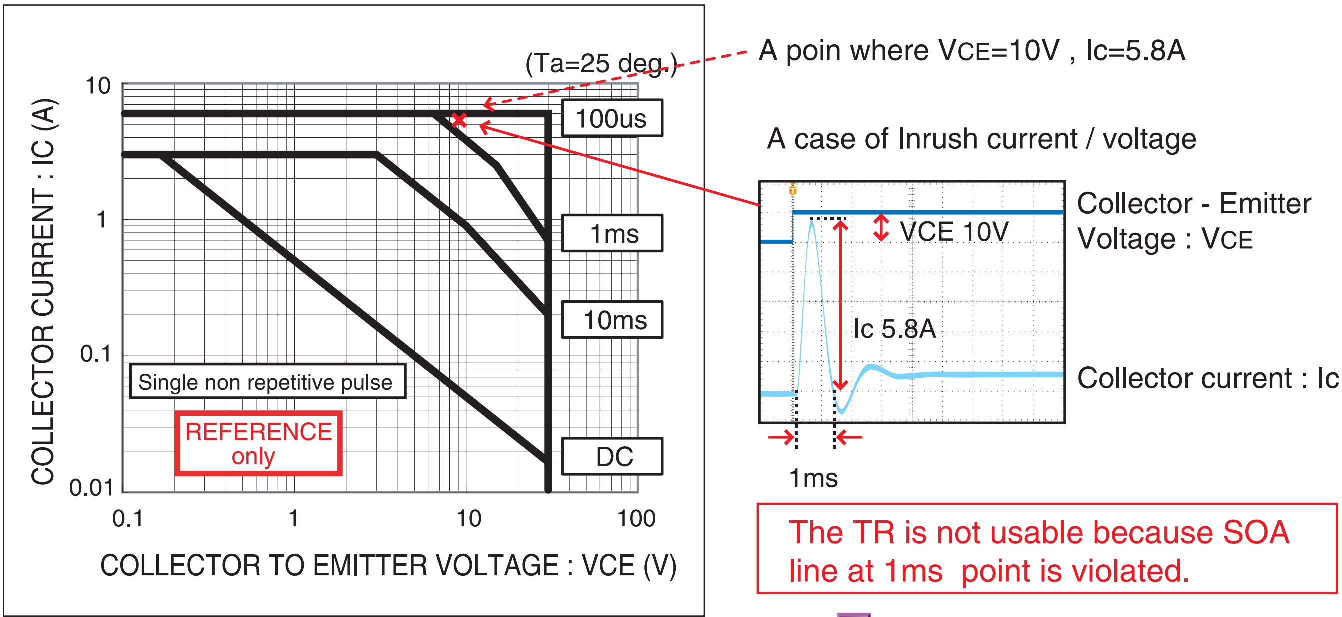
SOA specifies the area where a TR can be driven safely.
However, SOA is merely based on single (One) pulse alone. Therefore, it is necessary also to check if all the pulses stay within SOA if the TR is driven by repetitive pulses also the averaged applied current (to be calculated in ?) stays within the rated power.

*1 Also called ASO (Area of Safe Operating).

SOA compliance check

Check if waveform confirmed in (1.) stays withn SOA.
NG (TR Not Usable) judgement must be concluded if inrush / peak current or voltage surge goes beyond the absolute maximum rating even for a moment.
Also, please be careful that there are cases that SOA is violated even if the waveform observed in (2.) is within the absolute maximum rating. (See the example below.)

Example : 2SD2673 SAFETY OPERATING AREA



The TR is not usable because SOA line at 1ms point is violated.

Although the current waveform is not rectangular shape in the above case, more margin should be given for safe drive considering as if the waveform shape is rectangular type.
i.e.,

$$I_C=5.8A\ ,\ V_{CE}=10V\ ,\ P_W=1ms$$

The above values are below the absolute maximum rating, but the use of TR is NG because the values are above SOA.

4. Is the condition of driving a TR within SOA reflecting SOA?

*1 The ambient temperature where the TR is used or the temperature of die
when the temperature of TR is elevated by its heat.

Confirmation of Safety Operation Area (SOA) - Part.2

Normally, SOA is defined subject to the room temperature / 25 deg.
Therefore, SOA data needs modification reflecting the temperature derating curve if the temperature of die is elavated bythe heat of TR in use or the room temperature is above 25 deg.

-> Way to reflect derating into SOA graph

Bipolar TR / DIgital TR ---> See 4. addendum 1
MOSFET ---> See 4. addendum 2

*The temperature requiring derating is basically corresponds to the temperature of die.

When the TR is not heated such as when just after start of driving

Die temperature = Regarded as same as ambient temperature and the derating to be done per the ambient temperature.

Please refer to "Calculation method of die temperature" which is prepared separately for details of die temperature calculation.

4. Addendum 1 Temperature Derating Method of SOA

< Bipolar TR / Digital TR >

1.SOA (Safety Operating Area)

SOA(Safety Operating Area) need temperature derating when the ambient temperature is more than25 deg. or the tempearture of die is elavated by the heating of TR itself. Temperature of derating is the ambient temperature for the former, and the die temperature for the latter. To be specific, SOA line needs to be shifted toward the direction where the current is smaller. THe derating ratio varies depending on the area as per the Fig.1

1-1. Heat-restriction area

In this area, SOA line has 45°downward inclination. (Power constant line)

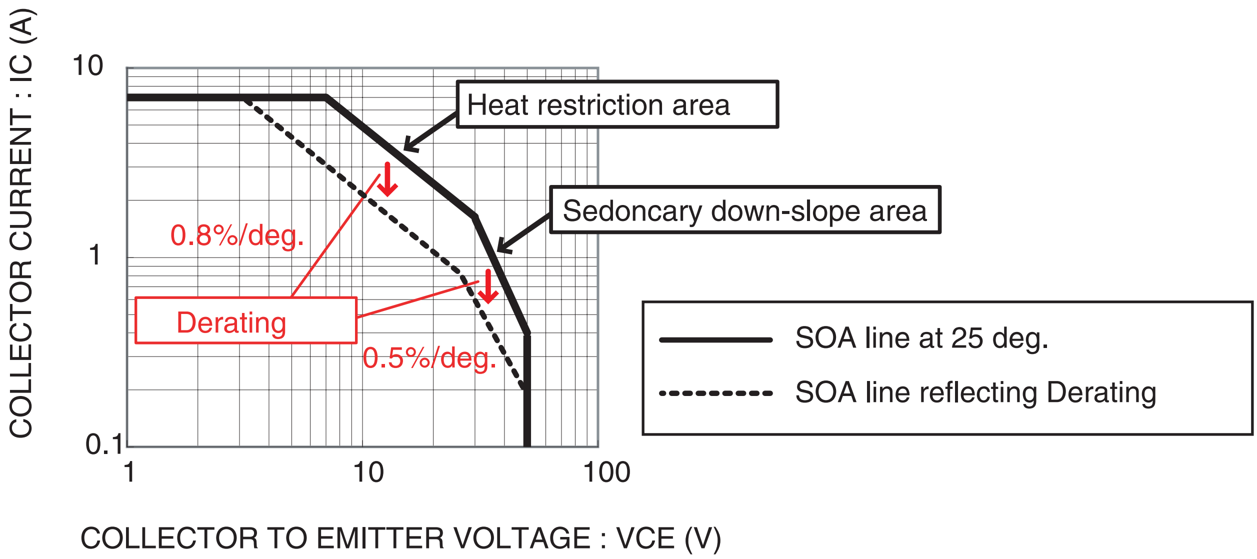
In this area, the derating ratio is 0.8% /deg.

1-2. Secondary down-slope area

For bipolar TR, there is secondary down-slope area due to thermal overdrive.

SOA in this area has the slope is more than at 45°and the derating ratio is 0.5% /deg.

Fig.1 Temperature derating of SOA



< Bipolar TR / Digital TR (continuation) >

2. Example Ta=100 deg.

2-1. Derating in the area of heat-restriction area

In case of ambient temperature of 100 deg.

Derating	= ⊿t × (Derating ratio)
	=(100 deg. - 25 deg.) × 0.8% / deg.
	=60%

Therefore, the judgement should be made by considering SOA line shift by 60% toward the smaller current direction.

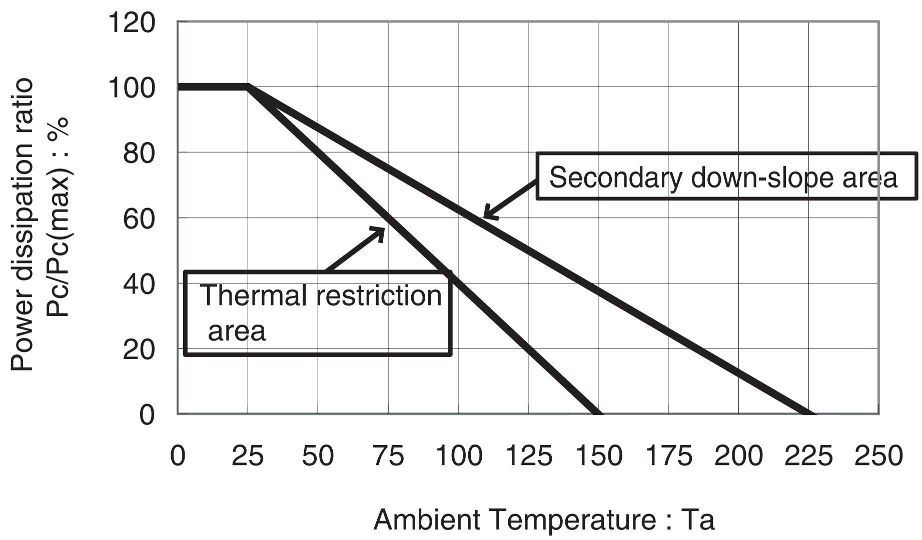
2-2. Derating in the area of secondary down-slope

Likewise as above, the calculation is done as below.

Derating	= ⊿t × (Derating ratio)
	= 100 deg. - 25 deg.) × 0.5% / deg.
	= 37.5%

Accordingly, the judgement should be made by considering SOA line shift by 37.5& toward the smaller current direction.

Fig. Temperature derating of SOA



4. Addendum 2 Temperature Derating Method of SOA

< MOSFET >

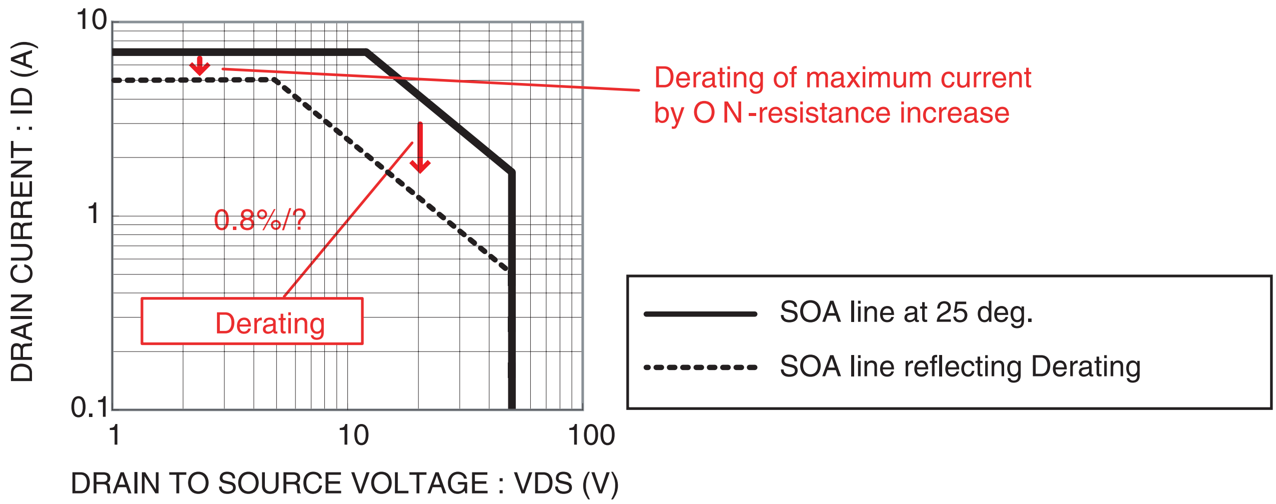
1.SOA (Safety Operating Area)

SOA of MOSFET does not have secondary down-slope line unlike SOA of bipolar TRs has, and there is lineof heat-restriction area (power constant line) only.

The derating ratio in this heat-restriction area is 0.8% / deg. like bipolar TR.

Incidentally, in case of MOSFET, the maximum current needs derating as well since ON-resistance goes up as the temperatur rises..

Fig.1 Temperature Derating for MOSFET



<About the maximum current derating by ON-resistance increase>

Current consumption “P” is express as below.

$$P = IV = I \cdot IR = I^2 R$$ (R : ON-resistance)

The maximum current consumption is constant even if the ambient temperature rised, but ON-resistance increases.

Therefore, if ON-resistance shifted from R1 to R2 upward per the ambient temperature rise, the maximum current I at 25 deg. will be derated as I ’ per the temperature increase, then the following formula / calculation can be applied.

$$I^2 R1 = I'^2 R2$$

$$I' = \sqrt{\frac{R1}{R2}}\, I$$

< MOSFET (continuation) >

2. Example Ta = 75 deg.

2-1. Derating per SOA line

In case the ambient temperature is 75 deg.,

$$\text{Derating} = \Delta t \times (\text{Derating ratio}) = (75\text{ deg.} - 25\text{ deg.}) \times 0.8\% / \text{deg.} = 40\%$$

Therefore, we should check the safety by considering SOA line shift by 40% horizontally toward the smaller current direction.

2-2. Derating of Maximum current

In case of RSS100N03,

Maximum current I_D = 10A, and ON-resistance is

10m ohm at 25 deg. (V_{GS} = 10V, I_D = 3A)

16m ohm at 75 deg. (V_{GS} = 10V, I_D = 3A) (each is typ. value) , so that the maximum current allowable at 75 deg. is,

$$I_D' = \sqrt{\frac{10\text{m ohm}}{16\text{m ohm}}}\ 10\text{A} = 7.9\text{A}$$

5. Continuous pulse? Single pulse?

Cofirmation of Power / Heat generation

Single pulse

When an Inrush current come only once like when the power is switched on or off, it is called “Single Pulse” (pulse not repetes), and in that case,

Check if the drive conditions are within SOA and the result is “yes”, then

OK

---> The TR can be used.

Continuous pulse

Unlike single pulse, it is called “continuous pulse” if the pulses are loaded repeatedly.
In that case, check if

Drive conditions are below the rated power
in consideration of the ambient temperature.

confirmation
is necessary

---> Go to (6.)

6. Is Averaged Power Consumption below the rated power at the ambient temperature?

Confirmation when below the rated power

Below the rated power under the ambient temperature

= Die temperature below the maximum rating 150 deg..

The rated power is decided as the power which heats up the die at 150 deg..

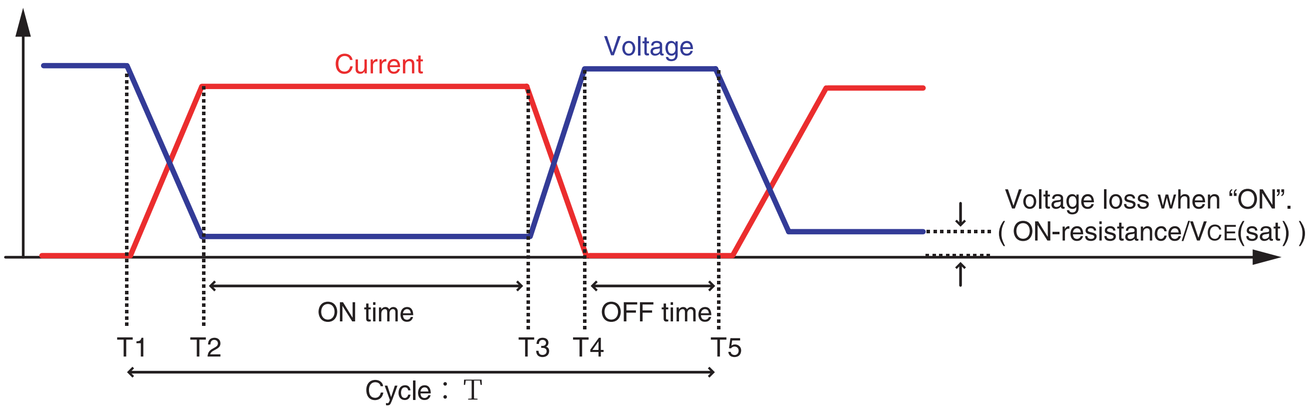
(For details, please refer to " Calculation method of die temperature" prepared separately.

Power calculation method

In principle, the averaged power is the value obtained as a result of dividing the integration of Current and Voltage by the time. i.e.,

$$P = \frac{\int_0^t I(t)V(t)dt}{T} \quad (W)$$

Now, thinking the following switching behavior for instance.



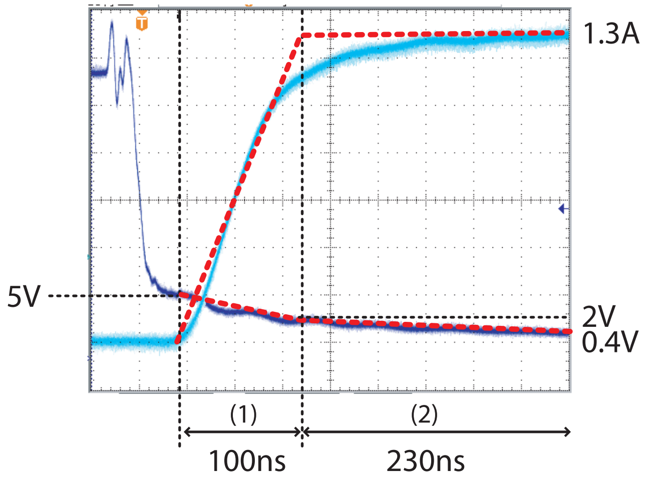
In this case, the calculation should be done by dividing one cycle in four.

$$P = \frac{\int_{t1}^{t2} IVdt + \int_{t2}^{t3} IVdt + \int_{t3}^{t4} IVdt + \int_{t4}^{t5} IVdt}{T} \quad (W)$$

In actual integration calculation, please refer to "Integration Formula" prepared separately.

Let’s make calculation for the waveform observed in (1.) as an example.

<1> When O FF ---> O N



First, put the approximation line along On-time waveform as drwaing on the left as

From the integration formula,

(1) Zone

$\int IVdt = (1/6)\times 100ns\times (2\ 0A\ 5V + 0A\ 2V + 1.3A\ 5V + 2\ 1.3A\ 2V)$ ・

$= 1.95\times 10^{-7}(J)$

(2) Zone

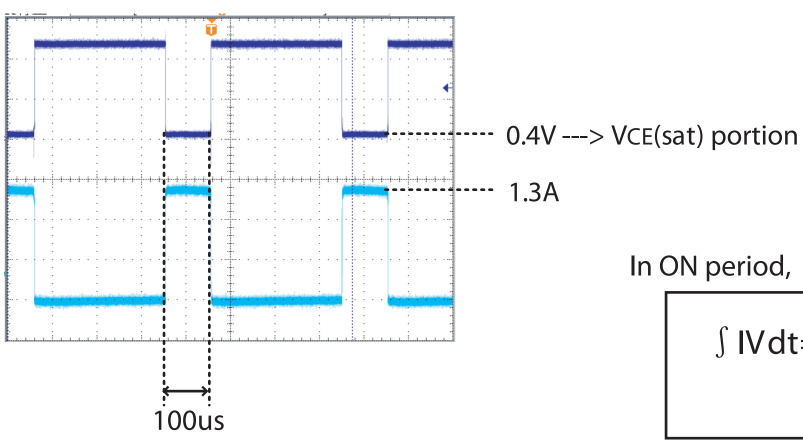
$\int IVdt = (1/6)\times 230ns\times (2\ 1.3A\ 2V + 1.3A\ 0.4V + 1.3A\ 2V + 2\ 1.3A\ 0.4V)$ ・

$= 3.59\times 10^{-7}(J)$

When OFF ---> ON

Total : $5.54\times 10^{-7}(J)$

<2> O N period

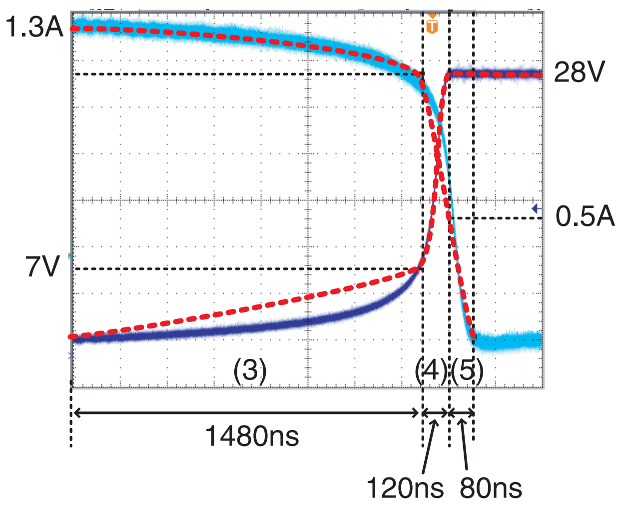


In ON period,

$\int IVdt = 100us \times 0.4V \times 1.3A$

$= 5.2\times 10^{-5}(J)$

<3> When O N ---> OFF



Zone (3)

$$\int IVdt = (1/6)\times 1480ns\times(2\cdot 1.3A\cdot 0V + 1.3A\cdot 7V + 1.15A\cdot 0V + 2\cdot 1.15A\cdot 7V) = 6.22\times 10^{-6} (J)$$

Zone (4)

$$\int IVdt = (1/6)\times 120ns\times(2\cdot 1.15A\cdot 7V + 1.15A\cdot 28V + 0.5A\cdot 7V + 2\ \ 0.5A\cdot 28V) = 2.1\times 10^{-6} (J)$$

Zone (5)

$$\int IVdt = (1/6)\times 80ns\times(2\cdot 0.5A\cdot 28V + 0.5A\cdot 28V + 0A\cdot 28V + 2\cdot 0A\cdot 28V) = 9.3\times 10^{-7} (J)$$

When ON ---> OFF | Total 9.25×10^{-6} (J)

(4) We can regard that there is almost no current when OFF (there should be some nA to 10nA level of leak current should exist in reality) and the current consumption as 0 (zero) while OFF state.

From the above calculation, if we divide all the total of integrattion result per each zone by 400μs which is the length of cycle, the the averaged current consumption is figured out as

$$P = \frac{\int_0^t I(t)V(t)dt}{T} = \frac{5.54\times 10^{-7}(J) + 5.2\times 10^{-5}(J) + 9.25\times 10^{-6}(J)}{400us} = 0.155\ (W)$$

We took an example of bipolar transistor 2SD2673 earlier in order to do integration calculation of collector current Ic and Collector-Emitter voltage V_{CE}.
The integration calculation in case of other TR types can be as below for obtaining the averaged current consumption.

-> Digital TR : Output Current Io and Outpout Voltage Vo
-> MOSFET : Drain Current I_D and Drain-Source Voltage V_{DS}

After getting the averaged current consumption, we should check with Pc (Collector-loss) for digital TR (Drain-loss for MOSFET).

Example : Data sheet of 2SD2673

4. Absolute maximum rating (Ta=25 deg.)

Collector - Base voltage		V_{CEO}	.. 30V	
Collector - Emitter voltage		V_{CBO}	..30V	
Emitter - Base voltage		V_{EBO}	..6V	
Collector current	DC	I_C	..3A	
	Pulse	I_{CP}	..6A	PW = 1ms - single pulse
Collector loss		P_C	...0.5W	When each pin is mounted on the recommendedland pattern
			1W	When ceramic circuit board of 25x25, t=0.8 (mm) is used
Junction temperature		Tj	..150 deg.	
Storage temperature		Tstg	.. -55 deg. to 150 deg.	

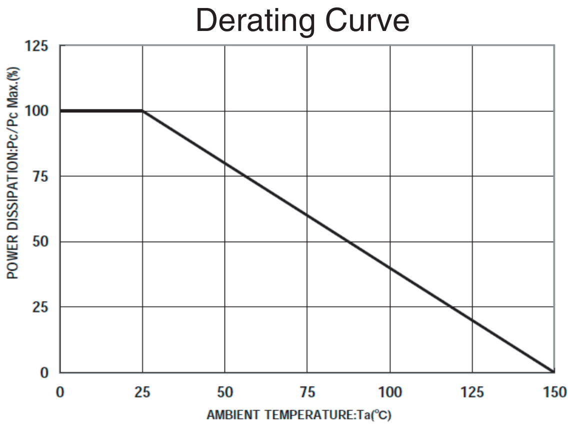
Check Collector-loss

In this case, the averaged applied power is 0.155W and Colloetor-loss is 0.5W (Recommended land : glassepoxy circuit board), so that the use of this TR under the ambient temperature of 25 deg. is OK. (In the strict sense, Pc should differ depending on the difference of heat dissipation conditions as from the types of circuit board or as from land-pattern area. However, we assume that the the recommended lnd-patterns are employed.)

When the ambient temperature is above 25 deg., please consider the temperature derating in designing per the derating curve.

For example, Pd (power dissipation) becomes 80% under ambient temprature 50 deg. compared with the one at 25 deg.. Therefore, Pd = 0.5W×80% = 0.4W

In this case, the averaged current consumption is considered as 0.155W which is not matching to the derating curve at the point of ambient temperature50 . Thus, the TR can be used.

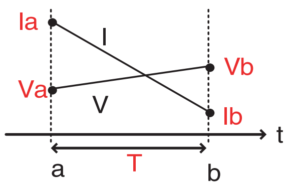


For the details of Die Temperature Calculation, please refer to the separate documents "Calculation method of die temperature".

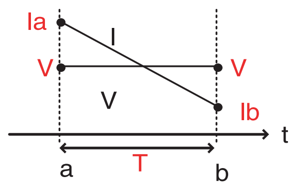
Power calculation integration formula

$$E=\int_a^b IV\,dt \quad (J)$$

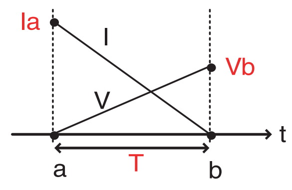
Calculation of power between a - b by integration with Current I and Voltage V.



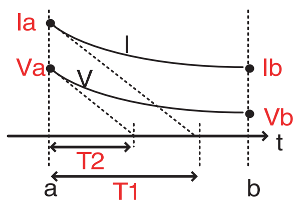
$E=1/6\cdot T(2I_aV_a+I_aV_b+I_bV_a+2I_bV_b)$



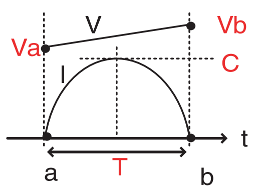
$E=1/2\cdot T\cdot V(I_a+I_b)$



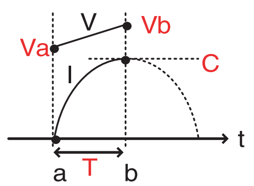
$E=1/6\cdot T\cdot I_aV_b$



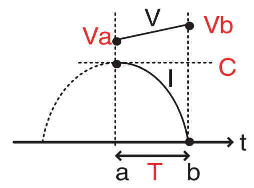
$E=T_1T_2/(T_1+T_2)\cdot(I_aV_a-I_bV_b)$



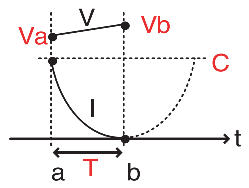
$E=1/3\cdot C\cdot T(V_a+V_b)$



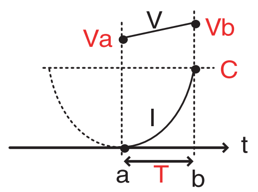
$E=1/12\cdot C\cdot T(3V_a+5V_b)$



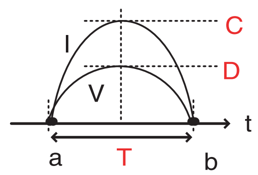
$E=1/12\cdot C\cdot T(5V_a+3V_b)$



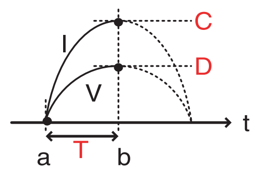
$E=1/12\cdot C\cdot T(3V_a+V_b)$



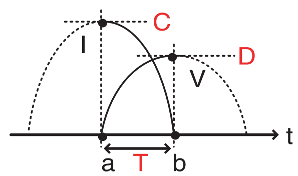
$E=1/12\cdot C\cdot T(V_a+3V_b)$



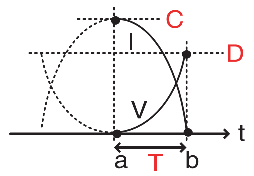
$E=8/15\cdot C\cdot D\cdot T$



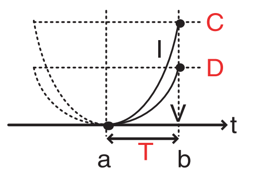
$E=8/15\cdot C\cdot D\cdot T$



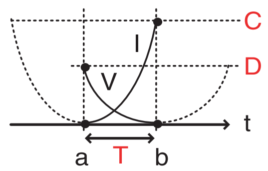
$E=11/30\cdot C\cdot D\cdot T$



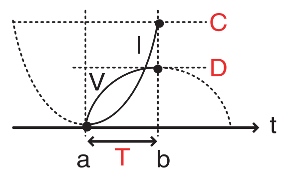
$E=2/15\cdot C\cdot D\cdot T$



$E=1/5\cdot C\cdot D\cdot T$



$E=1/30\cdot C\cdot D\cdot T$



$E=3/10\cdot C\cdot D\cdot T$

* These formulas are symmetrical to V and I, so that the formula can be use having V and I swapped.