

# Operation notes

## ●Selecting semiconductor devices

The reliability of semiconductor devices is determined primarily by conditions of use. When using semiconductors, pay careful attention to any changes in conditions and be aware of the specifications of each device. Absolute maximum ratings and related precautions are explained in the following. A good understanding of the absolute maximum ratings is necessary for selection of appropriate devices.

### (1) Maximum ratings

Absolute maximum ratings are used to specify the maximum temperature, voltage, and other limiting conditions under which a device can be used. The absolute maximum ratings are maximum values for operating and environmental conditions which apply to all products, and they must never be exceeded, regardless of the circumstance. We have determined absolute maximum ratings for our products, and as long as a semiconductor device is used within the ratings, we guarantee its performance and characteristics. When designing a device, it is necessary for the user of the semiconductor to take into consideration fluctuations in supply voltage, deviations in components, load fluctuations and environmental changes, and design the device so that the absolute maximum ratings are not exceeded even under the worst conditions. If the absolute maximum ratings are exceeded, it is possible that immediate deterioration and / or damage to the semiconductor device may occur, and even if it still operates, a considerable shortening of its life is likely. Furthermore, semiconductor ratings are not independent entities. Temperature, voltage, current, and power all are closely interrelated, and none may be exceeded.

### (2) Maximum allowed voltages

Maximum allowed voltages are the maximum voltages that can be applied between the emitter and base, collector and base, and collector and emitter without damaging the transistor. If a maximum allowed voltage is exceeded, transistor damage may result. ROHM regards the breakdown voltage to be the maximum allowed voltage of a device, and we guarantee that the breakdown voltage is higher than the rated voltage. For this reason, applying a voltage higher than the rated voltage may not cause transistor damage. However, taking into consideration device deviations, it is essential that the rated voltage not be exceeded. The emitter-base and collector-base junctions are both PN junctions. However, the collector-emitter junction interacts with both, and thus its maximum allowed voltage will differ depending on whether it is forward biased or reverse biased. In general the following relation holds, and there is not a large difference between  $BV_{CBO}$ ,  $BV_{CEX}$ , and  $BV_{CES}$ . The actual breakdown voltage is in a region in which the current increases very rapidly, and the voltage measured is that at which the current reaches a certain value. The absolute maximum rating has been fixed so that the entire transistor has margin with respect to the breakdown voltage. This margin varies by product such that the absolute maximum voltage falls within 50% to 80% of the breakdown voltage.

$$BV_{CBO} > BV_{CEX} > BV_{CES} > BV_{CER} > BV_{CEO}$$

The absolute maximum voltage is rated at an ambient temperature of 25°C. Therefore, when the junction temperature approaches the absolute maximum temperature, the absolute maximum voltage for 25°C cannot be applied. If it is, poor stability will result and there will be a danger of thermal runaway. Thermal runaway is a condition in which the current gain and cutoff current ( $I_{CBO}$ ) rise together with the temperature and the base voltage ( $V_{BE}$ ) decreases. If for any reason the temperature of the collector junction rises, the collector current increases, and this results in a further increase in the collector junction temperature. This cycle continues with the final result being damage to the transistor. In actual use considerable margin must be established with respect to the rated values. A device should normally be used at a maximum of 80% of the rated values for 25°C.

### (3) Maximum allowed current

As a transistor is a 3-terminal device, an absolute maximum current should be fixed for each of the terminals. However, normally only the emitter or collector current is rated. The maximum collector current is normally rated to be the current at which the DC current gain ( $h_{FE}$ ) falls to 50% of its maximum value. The maximum peak current is

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rated at a value which ensures reliability within the maximum allowed junction temperature. In the case of a transistor by itself, the maximum base current is normally rated to be 1 / 3 the collector current.

### (4) Maximum allowed junction temperature

The junction temperature is limited by the relationship between temperature and life, and the characteristics of the materials composing the transistor. Furthermore, transistors use minority carriers and thus are easily affected by temperature. In particular, if the temperature rises in a reverse-biased collector-base junction, carriers are generated without relation to the signal, the operating point shifts, and in the worst case thermal runaway occurs and the transistor becomes damaged. For this reason, the circuit must be designed so as to prevent the junction temperature from rising. Transistor deterioration occurs quickly when the junction temperature rises. The following relationship exists between average life (h) and junction temperature  $T_J$  (°K).

$$\log L = A + \frac{B}{T_J}$$

To obtain high reliability, it is necessary to keep the junction temperature as low as possible. The maximum temperature of ROHM transistors is normally 150°C, however, we recommend usage at less than 100°C.

### (5) Maximum allowed power dissipation

The junction temperature rises due to consumption of electrical power within the transistor and increases in ambient temperature. The maximum allowed power dissipation is the amount of power consumption needed to raise the junction temperature to the maximum allowed rating.

$$P_{CMax} = \frac{T_{jMax} - T_a}{R_{th}(j - a)}$$

$T_{jMax}$  is the maximum allowed junction temperature,  $T_a$  is the ambient temperature, and  $R_{th}(j - a)$  is a thermal resistance where  $(j - a)$  includes all thermal resistance from the junction to the external air. By using a heat sink for improved heat dissipation, the thermal resistance can be reduced and allowed power dissipation improved. Also, only DC allowed power dissipation is normally indicated. When a transistor is used for switching, the rating can sometimes be exceeded. In the case of saturated switching, the transistor moves between the saturated region and the cutoff region. In both regions power dissipation is low, and if the power dissipation of the transient state which moves along the load curve can be ignored, it can sometimes be acceptable for the operating point to move into the

$$V_{CE} \times I_C > P_{CMax}$$

region provided the voltage and current ratings are not exceeded. The maximum allowed power dissipation has been determined based on repeated reliability and damage tests, however, we recommend use at 75% of the rated value.

### (6) Maximum allowed storage temperature range

As an environmental condition for storage of a semiconductor product, temperature in particular is rated. The maximum temperature is determined by the maximum junction temperature and the package material. The minimum temperature is based on the package. ROHM normally rates the temperature range at -55° to 150°C.

### (7) Secondary breakdown (S / B) and safe operation area (SOA)

The explanations to this point have been of ratings under normal conditions, however, if the operation involves inductive loads or sudden voltage and current increases, damage may occur which cannot be explained simply based on the average maximum allowed junction temperature. This is principally secondary breakdown, and is caused by fly-back pulses, load shorts, or large load fluctuations. Secondary breakdown further increases the current after primary breakdown, and once a certain voltage or current level is reached, operation suddenly moves to a low impedance region, a high current flows, and transistor damage occurs. The area in which the transistor can be used without damage or deterioration and with high reliability is called the safe operation area, (SOA) and it is determined by the maximum voltage, the maximum current, the maximum collector power dissipation, and secondary breakdown.

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(8) Deviation of characteristics

Strict quality standards and control points are established for each stage of the transistor manufacturing process and transistors are produced in very large numbers. However, characteristics can change due to deviations in raw materials and slight changes in processing conditions, and deviations may appear not only among lots, but within one lot and even within the same wafer. It is not possible to correct these deviations by later adjustments. Principal factors affecting deviations include the thickness, diffusion density, depth, and resistivity of the wafer, and deviations appear in almost all of the characteristics, including  $h_{FE}$ ,  $BV_{CBO}$ ,  $C_{ob}$ , and  $f_t$ . Deviations in the characteristics appearing in the data sheets are held within a certain range through lot inspections and 100% inspection.

●Testing and inspection

Take special care with regard to noise produced by testing and inspection instruments. Voltage surges in commercial power supplies can cause deterioration or damage to semiconductor devices. Make sure that measuring instruments are sufficiently grounded. Breakdown voltages are frequently measured using a curve tracer or similar method. As the voltage is gradually applied make sure that the limit resistance setting is appropriate, and ensure that the rated voltage is not exceeded. Also, avoid bad contacts with measuring instrument terminals as a bad contact can cause surges.

●Moving and storage

Observe the following precautions when moving or storing transistors.

- (1) Avoid high humidity and high temperature.
- (2) Avoid static electricity. (do not store in Styrofoam boxes) Store in containers in which there is little generation of static electricity.
- (3) Do not store in a location where harmful gases are produced. Store in a location where there is little dust.
- (4) Make sure that no heavy loads are placed on devices in storage.
- (5) Do not store for a prolonged time after forming leads. (rust may form due to slight damages caused by forming)
- (6) Avoid sudden temperature changes during storage and when removing from storage.

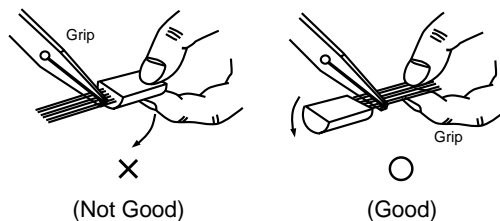
●Handling transistors during the manufacturing process

When handling transistors during manufacturing, take care not to subject them to mechanical, thermal, electrical, or chemical stresses.

(1) Forming leads

When forming leads, make sure that the force applied to the lead is not transmitted to the package. Also, when applying force only to the lead, make sure the stress is released.

- 1) Do not hold the package when bending a lead. (maximum load of 250g)



- 2) Do not pull a lead.(maximum load of 500g)
- 3) Bend the lead at a point at least 1.0mm from its base. Do not bend the lead at the base.
- 4) Do not repeatedly bend a lead.

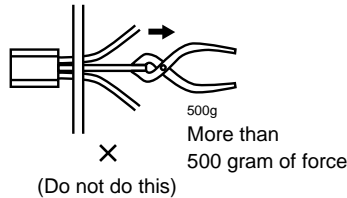
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- 5) Do not damage a lead. The surface of the lead is solder, and if the metal underneath becomes exposed it will oxidize and impair soldering.

(2) Mounting on the board

Observe the same precautions as for forming leads.

- 1) Make sure that the distance between the leads is the same as the distance between the insertion holes in the board. If not, form the leads before insertion.
- 2) Do not pull hard on the leads when inserting them in the board. (maximum load of 500g)



(3) Soldering

1) Flux

Use a rosin based flux. Do not use a highly acidic or alkaline flux.

2) Soldering

Semiconductor devices do not tolerate heat well, thus soldering must be completed as quickly possible.

Ground the solder bath and iron and eliminate leaks.

3) Cleaning

Some detergents may dissolve the package, weaken the seal, or efface the inscription. If the transistors are cleaned by ultrasonic cleaning, make sure the output is at a level which will not subject the transistors to stress.

Solvents which can be used : Methyl alcohol (Recommended conditions for ultrasonic cleaning)

Ultrasonic output : 15W / liter, 25 to 28kHz

Time : 60 seconds maximum

Do not allow the board or device to come in contact with the vibration source.

●Layout of components

Heating of semiconductor devices must be avoided as much as possible, and they must be protected from surge damage. For this purpose,

- 1) Do not place a heat source near a device.
- 2) Dust collects on high-voltage circuits. Make sure dust does not collect on devices.
- 3) Exercise caution with high-voltage wiring, high frequency wiring, and winding. These kinds of wiring can cause device damage through surges.

●Handling digital transistors

Surge voltages, electrostatic discharge and noise are problems which affect all semiconductor devices. As shown in the pellet cross-section of Fig.1, the inputs (bases) of ROHM digital transistors are a type of MOSFET structure, and therefore require particular care to prevent electrostatic discharge.

To prevent damage due to electrostatic discharge, understand and observe the following precautions.

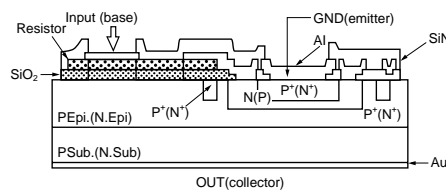


Fig.1 Cross-section of digital transistor pellet

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(1) Storage precautions

Use conductive containers to store digital transistors.

(2) Moving precautions

- 1) Use moving containers which not allow a buildup of charge due to vibration or other causes during moving. Conductive containers and aluminum foil are effective means of preventing electrostatic discharge.
- 2) To prevent damage due to discharge of charge built up on the human body or clothing, people handling transistors should be grounded through a high resistance, such as a wrist band.
- 3) Similar precautions should be observed when moving digital transistors mounted on boards. Terminals should be shorted keep them at the same electric potential.

(3) Precautions when measuring and handling digital transistors

When measuring and mounting digital transistors, the likelihood increases that open-circuited terminals will individually come in contact with the human body, measuring instruments, the work stand, soldering iron, or other equipment. In addition to electrostatic discharge, leakage from electrical equipment will damage the transistors, therefore, care must be taken that no current leakage from an AC power source occurs through the terminals of the measuring instrument.

### ●Using power transistors

(1) Temperature ratings

To ensure normal operation, allowed temperature ranges for operation and storage have been established.

(2) Power rating

Maximum collector power dissipation ratings ( $P_c$ ) have been respectively established both for a fixed ambient temperature ( $T_a$ ) and a fixed case temperature ( $T_c$ ), and for use with and without heat sinks. Based on these values, the thermal resistances from the junction to the free area ( $R_{th}(j-a)$ ) and the junction to the case ( $R_{th}(j-c)$ ) can be calculated as follows :

$$R_{th}(j-a) = \frac{T_j - T_a}{P_{c1}}$$

$$R_{th}(j-c) = \frac{T_j - T_c}{P_{c2}}$$

$T_a$  : Ambient temperature

$T_c$  : Case temperature

$P_{c1}$  : Collector dissipation at ambient temperature = 25°C

$P_{c2}$  : Collector dissipation at case temperature = 25°C

(3) Safe operating area

In addition to allowed ranges for  $V_{CE}$ ,  $I_c$ , and  $P_c$ , power transistors also have voltage, current and pulse width restrictions. This is due to the fact that excessive voltage, current and pulse width can cause secondary breakdown, leading to a weakening of the breakdown voltage and a damaged transistor.

1) Testing method

ROHM conducts a 100% inspection based on the transient thermal resistance method and guarantees the safe operating area (SOA). A bias with a specified pulse is applied and the forward voltage ( $V_{BE(ON)}$ ) is used to detect indications of increased temperature due to current hot spots which cause secondary breakdown. The test circuit and applied pulse are shown in Fig.3 and Fig.4. The base-emitter voltage ( $V_{BE(ON)}$ ) used for temperature detection (Fig.5) has a negative temperature coefficient, and the temperature rise at the time of the pulse is measured based on the following equation.

$$\Delta T_j = \frac{V_{BE1} - V_{BE2}}{\alpha} \text{ (}^\circ\text{C)}$$

$V_{BE1}$  :  $V_{BE}$  before pulse

$V_{BE2}$  :  $V_{BE}$  immediately after pulse

$\alpha$  : Temperature coefficient ( $\approx 2\text{mv} / ^\circ\text{C}$ )

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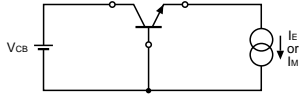


Fig.3

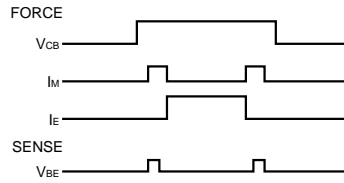


Fig.4

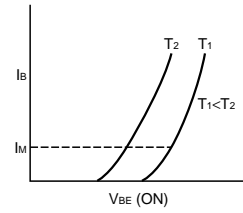


Fig.5

2) Rating the safe operating area

Ranges I through IV of the safe operating area shown in Fig.6 are determined based on the following factors.

1. Range I

This is limited by the maximum collector current.

The maximum collector current is determined as an actual allowed range of use of  $h_{FE}$ .

2. Range II

This is limited by the thermal resistance,

$$\text{with the limit being the line} = P_{CMax.} = I_c \times V_{CE}$$

3. Range III

This is limited by secondary breakdown.

4. Range IV

This is limited by the collector-emitter breakdown voltage.

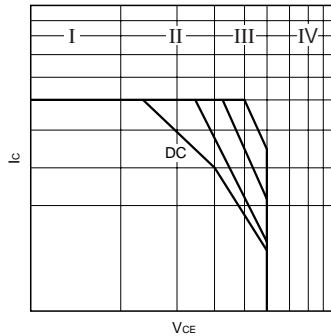


Fig.6

(4) Attachment to heat sink fins

The use of heat sink fins with power transistors will dissipate the heat generated by the transistor and lower the temperature of the junction. However, an inappropriate method of attachment will result not only in a failure to dissipate heat, but may damage the transistor as well. Observe the following precautions when attaching transistors to heat sink fins.

- 1) If the fin is warped or there are burrs in the insertion holes, not only will insufficient heat dissipation result, but the transistor may be damaged as well. For this reason, observe the following :
  1. The heat sink should not be more than 0.05mm out of true.
  2. The insertion holes should be beveled.
  3. The holes should be an appropriate size.
  4. Ensure that no foreign matter is trapped between the transistor and the heat sink.
- 2) If the transistor is not attached with sufficient torque, full heat dissipation will not be obtained. At the same time, excessive torque may damage the transistor or break leads. Table1 shows recommended torque ranges.

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Table1 Recommended torque

Package	Torque (N · cm)
TO-126FP	39.2 to 49
TO-220FP	49 to 68.6
TO-220FN	49 to 68.6
TO-220FM	49 to 68.6

- 3) Use self-tapping screws to attach the transistor to the heat sink. Do not use fiat or round head screws as they may apply abnormal stress to the transistor.
- 4) Silicon grease applied between the transistor and the heat sink to reduce thermal resistance should be thin and even. Also, some types of silicon grease can damage the transistor or impair its performance, therefore, select the type of grease carefully. We recommend G746 (Shin-etsu Chemical Co., Ltd.), SC101 (Toray Industries, Inc.) or an equivalent product.
- 5) Attach the transistor to the heat sink before soldering it. If the transistor is attached after being soldered, the leads and package may be damaged due to excessive stress.

(5) Power reduction (derating)

Derating of the allowable power dissipation ( $P_c$ ) is required for use in higher ambient temperatures ( $T_a$ ). Referring to the graph in Fig.7 below, reduce the power consumed by the transistor according to the ambient temperature.

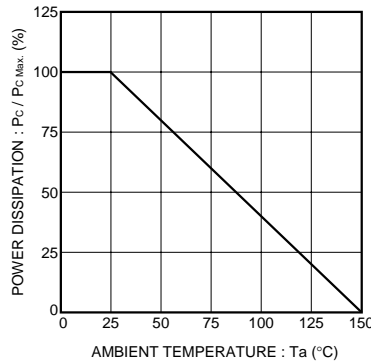


Fig.7 Power dissipation curve

(6) Land pattern example

For power transistors, the power dissipation ( $P_c$ ) will differ depending on the area of the collector land. As shown in the graph in Fig.8 below, the actual power consumed by the transistor is limited by the area of the collector land (copper foil), so be sure to design the land as large as acceptable. Below shows the examples of the MPT3, CPT3, and PSD3.

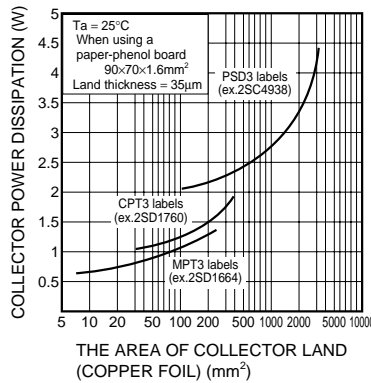


Fig.8 Collector power dissipation vs. the area of collector land

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