

# **TOSHIBA**

## **Toshiba Memory Corporation Semiconductor Handling Precautions and Requests**

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# Chapter 1 Usage Notes for Semiconductor Products

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Even though we make a continuous effort to improve the quality and reliability of our products, semiconductor products can malfunction or fail.

When using our semiconductor products (hereinafter called “Product”), please consider safety design for the customer’s hardware, software, and systems and their responsibilities to prevent loss of human life, bodily injury or damage to property due to a malfunction or failure of Product.

Before starting designing or using the Product, customers must read and comply with the latest information of the Product (this document, specifications, data sheets, application notes, and technical references for the Product) and the product instruction manuals and operation manuals for the application in which the Product will be used.

When using any technical contents, including product data, diagrams, and tables and information including program code, algorithms, and sample application circuits described in the above documents, for customers’ products, customers must thoroughly evaluate their own products independently as well as whole systems and determine the applicability of the information in relation to the customers’ responsibilities.

# Chapter 2 Safety Precautions

This section lists important precautions which users of semiconductor products should observe in order to avoid injury to the user or anyone else and damage to property, and to ensure safe and correct use of our products. Please be sure that you understand the meanings of the labels and graphic symbols described below before you move on to the detailed descriptions of the precautions, and comply with the precautions stated.

## [Explanation of Labels]

 <b>DANGER</b>	 <b>WARNING</b>	 <b>CAUTION</b>	<b>NOTICE</b>
Indicates a hazardous situation which, if not avoided, will result in death or serious injury <sup>1</sup> .	Indicates a hazardous situation which, if not avoided, could result in death or serious injury <sup>1</sup> .	Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury <sup>2</sup> .	Indicates practices that may cause property damage <sup>3</sup> and other problems, but not personal injury.

1. Serious injury includes blindness, wounds, burns (low and high temperature), electric shock, fractures, and poisoning, etc. with long-lasting effects or that require hospitalization and/or long-term hospital visits for treatment.
2. Minor or moderate injury includes wounds, burns, electric shock, etc. not requiring hospitalization and/or long-term hospital visits for treatment.
3. Property damage means damage to customer or third party machines and equipment.

## [Explanation of Graphic Symbols]

 <b>Prohibited</b>	 <b>Instructions</b>
Indicates prohibited actions.	Indicates actions that must be undertaken for safety purposes.

# Chapter 2 Safety Precautions

## 2-1. General Precautions Regarding Semiconductor Products

<b>⚠ CAUTION</b>	
 <b>Prohibited</b>	The absolute maximum ratings of a semiconductor device are a set of ratings that must not be exceeded, even for a moment. Do not exceed any of these ratings. Exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.
 <b>Prohibited</b>	Do not insert devices in the wrong orientation or incorrectly. Make sure that the positive and negative terminals of power supplies are connected properly. Otherwise, the current or power consumption may exceed the absolute maximum rating, and exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion. In addition, do not use any device that is applied the current with inserting in the wrong orientation or incorrectly even just one time.
 <b>Prohibited</b>	Do not touch the semiconductor product and its heat sink while the semiconductor product is on or immediately after it has been turned off. Devices and Heat sinks become hot. Contact to the heat sink may result in a burn.
 <b>Prohibited</b>	Do not touch the lead tips of a device. Some devices have leads with sharp tips. Contact to sharp tips may result in a puncture wound.
 <b>Instructions</b>	Check that there is no electrical leakage before grounding measuring equipment or a solder iron. Electrical leakage may cause electric shock or the device you are testing or soldering to electrically break down.
 <b>Instructions</b>	On the evaluation, inspection or test, be sure to connect the test equipment's electrodes or probes to the pins of the device before turning the power on. When you have finished, discharge any electrical charge remaining in the device. Failure to do so may cause electric shock, resulting in injury.
 <b>Instructions</b>	Always wear safety glasses when cutting the leads of a device with clippers or a similar tool. Failure to do so may result in eye damage from the small shavings that fly off the cut ends.

# Chapter 3 General Usage Considerations

This section provides information that will help you gain a better understanding of semiconductor products so as to ensure product safety, quality and reliability.

## 3-1. From Incoming to Shipping

### 3-1-1. Electrostatic Discharge (ESD)

Semiconductor products are very sensitive to electrostatic charges. If a high voltage electricity caused by electrostatic discharge flows through a semiconductor product, the product may be destroyed. Especially, for MOS type semiconductors, as little as several tens of voltage can destroy the devices. Humans feel a discharge of two to three kV, which indicates how only a trace amount of voltage can destroy semiconductor products. Therefore, countermeasures against electrostatic charges are required.

When handling semiconductor products, be sure that the environment is protected against static electricity. Operators should wear anti-static clothing, anti-static shoes, and a wrist strap. In addition, containers and other objects that come in direct contact with semiconductor products should be made of materials that do not produce static electricity that would cause damage.

Control anti-static equipment at all times to ensure that it works correctly.

Please follow the precautions below. This is particularly important for those semiconductor products marked “Be careful of ESDS\*.”

\*: ElectroStatic Discharge Sensitive products



# Chapter 3 General Usage Considerations

## 3-1-1-1. Work Environment Control

- (1) When humidity decreases, static electricity readily occurs due to friction. Taking into consideration the fact that moisture-proof-packed products absorb moisture after unpacking, the advisable relative humidity is 40 to 70%.
- (2) Be sure that all equipment such as jigs and tools installed in the work area are grounded.
- (3) Place a conductive mat over the floor of the work area or take other measure to ensure that the floor is protected against static electricity and is grounded to the earth.  
(Resistance between the floor surface and ground:  $1 \times 10^9 \Omega$  or less)
- (4) Place a conductive mat over the surface of worktables to ensure that the tables are grounded. (Resistance between surface and ground:  $7.5 \times 10^5$  to  $1 \times 10^9 \Omega$ ) Do not construct worktable surfaces of metallic materials. Metallic materials are low in resistance, allowing rapid discharge when a charged semiconductor product comes in contact with them directly.
- (5) Observe the following when using automated equipment:
  - (a) When picking up a semiconductor product with a vacuum, use conductive rubber in sections which come into contact with the product surface to protect against electrostatic charge.
  - (b) Avoid friction on the semiconductor-product surface to the extent possible. If rubbing is unavoidable due to the product's mechanical structure, minimize the friction plane or use material with a small friction coefficient and low electrical resistance. Also, prevent electrostatic charge by using an ionizer.
  - (c) Use a material which dissipates static electricity in sections which come in contact with semiconductor-product leads or terminals.
  - (d) Ensure that no statically charged bodies (such as work clothes or the human body) come in contact with the semiconductor products.
  - (e) Use a tape carrier that employs a low-resistance material on sections that come in contact with electrical machinery.
  - (f) Make sure that jigs and tools used in the manufacturing process do not touch the semiconductor products.

# Chapter 3 General Usage Considerations

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- (g) In processing associated with package electrostatic charge, use an ionizer to neutralize the ions in the ambient environment.
- (6) Ensure that the work chairs are protected by a conductive cover and grounded to the floor by conductive castors. (Resistance between seat surface and ground:  $1 \times 10^{10} \Omega$  or less)
- (7) Install anti-static mats on storage shelf surfaces and ground the mat surface. (Resistance between surface and ground:  $7.5 \times 10^5$  to  $1 \times 10^9 \Omega$ )
- (8) For semiconductor-product transport and temporary storage, use containers (boxes, jigs or bags) that are made of a material which does not produce static electricity that could damage the semiconductor product.
- (9) Make sure that cart surfaces which come in contact with product packaging are made of materials which conduct static electricity, and ground the cart surfaces to the floor surface using conductive castors.
- (10) In static electricity control areas, install anti-static dedicated ground wires. Use a transmission line circuit ground wire [Type D or above], or a trunk line ground wire. In addition, separate and ground the various devices individually.
- (11) Make sure that CRT displays in the work area are protected against static charge by employing a filter, for example. Avoid turning displays on and off to the extent possible. Neglecting to do so can cause electrostatic induction in semiconductor products.
- (12) Periodically measure the charged potential of semiconductor products, systems and fixtures located in the work area to ensure that the area is free of any charge.

# Chapter 3 General Usage Considerations

## 3-1-1-2. Controlling Operation

- (1) Operators must wear anti-static clothing and anti-static shoes (or a toe or heel strap).
- (2) Operators must wear a wrist strap grounded to earth via a resistor.  
(Resistance between surface and earth when worn:  $7.5 \times 10^5$  to  $3.5 \times 10^7 \Omega$ )



- (3) Soldering irons must be grounded from the iron tip to earth, and must be used at low voltages (6 to 24 V).
- (4) If the tweezers you use are likely to touch the semiconductor-product terminals, use anti-static tweezers. Do not use metallic tweezers since they are low in resistance and may cause rapid discharge when a charged semiconductor product comes in contact with them.  
When using a vacuum tweezers, attach a conductive chucking pat to the tip, and connect it to a dedicated anti-static ground. In addition, follow the manufacturer's methods of use and maintenance.
- (5) Do not place semiconductor products or their containers near sources of strong electrical fields (such as above a CRT).
- (6) Place boards with mounted semiconductor products in anti-static board containers separated from one another, and do not stack them directly on top of one another. Stacking them directly on top of one another may cause frictional charge or discharge.
- (7) Ensure, to the extent possible, that any articles (such as clipboards) which are brought to a static electricity control area are constructed of anti-static materials.
- (8) When the human body is to come in direct contact with a semiconductor product, wear anti-static finger covers or gloves.

# Chapter 3 General Usage Considerations

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- (9) The material of equipment safety covers located near semiconductor products should have a resistance value of  $1 \times 10^9 \Omega$  or less.
- (10) If a wrist strap cannot be used and there is a possibility of imparting friction to semiconductor products, use an ionizer.
- (11) The transport film used in tape carrier products is manufactured from materials in which static electricity readily builds up. When using these products, use an ionizer to prevent the film from being charged. Also, to ensure that no static electricity will be applied to the copper foil area, take measures to prevent electrostatic discharge failure of peripheral equipment.

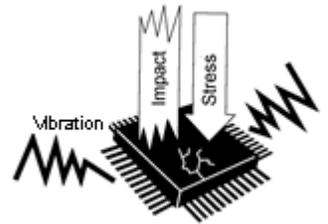
## 3-1-2. Transportation

- (1) Handle exterior fiberboard boxes carefully.  
Note that a physical shock or dropping the product can cause product damage.
- (2) Handle interior boxes with extra care.  
If you drop the box, products may fly out of a magazine or a tray inside, deforming their leads.
- (3) Protect products from water.  
Do not let products become wet from rain or snow while carrying them.
- (4) Minimize mechanical vibration and shock during transportation.  
Especially for wafer shipping, take special care not to cause vibrations and shock during transportation.

# Chapter 3 General Usage Considerations

## 3-1-3. Vibration, Impact and Stress

Handle individual or packed semiconductor products with care. Dropping or applying impact to semiconductor products or packaging causes semiconductor-product damage. Ensure that they are not subjected to mechanical vibration or impact to the extent possible. Hollow canister-type and ceramic sealed semiconductor products contain unsecured wires, making them more susceptible to vibration and impact than plastic sealed semiconductor products.

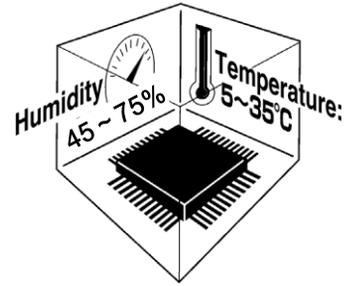


When the body or a connecting part of a semiconductor product is subjected to vibration, impact or stress in actual equipment, bonding fault or device destruction may result. Therefore, be sure to keep this in mind at the time of structural design.

If a semiconductor product is subject to especially strong vibration, impact or stress, the package or chip may crack. If stress is applied to a semiconductor chip through the package, changes in the resistance of the chip may result due to piezoelectric effects, resulting in fluctuation in element characteristics.

Furthermore, if a stress that does not instantly result in damage is applied continually for a long period of time, product deformation may result, causing defects such as disconnection or element failure. Thus, at the time of structural design, carefully consider vibration, impact and stress.

# Chapter 3 General Usage Considerations



## 3-2. Storage

### 3-2-1. General Packaged Products

- (1) Avoid storage locations where semiconductor products may be exposed to water (wet, rain, dew condensation, etc.) or direct sunlight.
- (2) Follow the precautions printed on the packing label for transportation and storage.
- (3) Also refer to “3-1-2. Transportation” for transporting packed products.
- (4) Keep the storage location at temperature and relative humidity within a range of 5°C to 35°C and 45% to 75%, respectively.
- (5) Do not store the products in locations with poisonous gases (especially corrosive gases) and/or in dusty conditions.
- (6) Store the products in locations with minimal temperature fluctuations. Rapid temperature changes during storage can cause dew condensation, resulting in lead oxidation or corrosion, which will deteriorate the solderability of leads.
- (7) When restoring semiconductor products after removal from their packing, use anti-static containers.
- (8) Do not allow loads to be applied directly to semiconductor products while they are in storage.
- (9) If semiconductor products have been stored for more than two years under normal storage conditions, it is recommended that you check the leads for ease of soldering prior to use.

# Chapter 3 General Usage Considerations

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## 3-2-2. Moisture-Proof Packing

Moisture-proof packing should be used while taking into careful consideration the handling methods specified for each packing type. If the specified procedures are not followed, the quality and reliability of the semiconductor products may be deteriorated. This section describes the general precautions for handling moisture-proof packing. Since the details may differ depending on the semiconductor products, please follow the specific delivery specification for handling packed products. If no delivery specification is designated, please seek guidance from our sales contact.

### 3-2-2-1. Moisture-Proof Packing General Precautions

Follow the precautions printed on the packing label for transportation and storage. To transport packed products, also refer to “3-1-2. Transportation.” For chip products, follow the respective specifications.

- (1) Do not toss or drop product packing. The aluminum laminated bag may be damaged, resulting in a loss in airtightness.
- (2) Follow the specific delivery specification for storage environment and storage temperature. If no delivery specification is designated, please seek guidance from our sales contact.

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- (3) If the storage period has been exceeded, or if the 30% humidity indicator is pink when the package is opened, remove any moisture under the conditions described in the table below. The effective usage period without moisture removal after the packing has been opened and the product has been stored at 5°C to 30°C and relative humidity at 70% or less is listed on the moisture-proof package. If the effective usage period has been exceeded, or if the packing has been stored in a high-humidity environment or an environment that produces dew condensation, remove any existing moisture.
- (4) When removing the moisture from semiconductor products, protect the products from breakdown from static electricity.
- (5) Moisture indicators (for your reference)

Moisture indicators detect the approximate ambient humidity level at a standard temperature of 25°C.

Figure 3-2-1 shows a 1-point indicator.

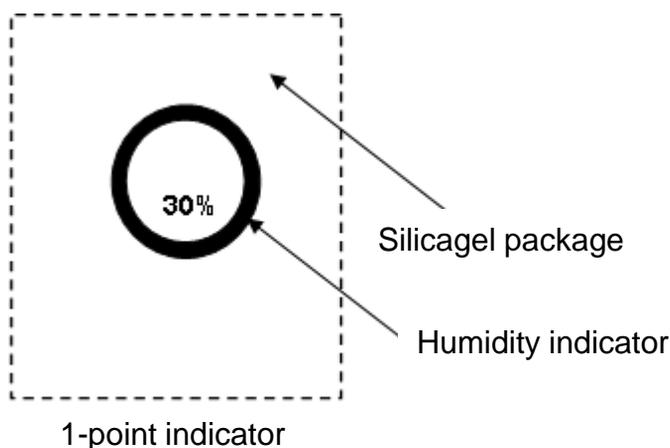


Figure 3-2-1 Humidity Indicator

- (6) Do not allow loads to be applied directly to semiconductor products while they are in storage.

# Chapter 3 General Usage Considerations

Table 3-2-1 Feasibility and Conditions of Moisture Removal by Packaging Forms of Semiconductor Products

Semiconductor-Product Packing Type	Feasibility and Conditions for Moisture Removal
Tray Type	<p>Since moisture-proof packing bags are not heat resistant, do not perform the baking process on them as they are.</p> <p>(1). For heat resistant trays (when there is a “Heatproof” or temperature indication) Please observe the following conditions regarding the baking process. ① Remove the tray from the moisture-proof packing bag. ② Perform the baking process according to the instructions written on the moisture-proof bag.</p> <p>(2). For trays that are not heat resistant (when there is not a “Heatproof” or temperature indication) Please observe the following conditions regarding the baking process. ① Remove the tray from the moisture-proof packing bag. ② Transfer the product to another heat-resistant container with static electricity measures. ③ Perform the baking process according to the instructions written on the moisture-proof bag.</p>
Magazine Type	<p>Since moisture-proof packing bags are not heat resistant, do not perform the baking process on them as they are.</p> <p>Please observe the following conditions regarding the baking process. ① Remove the magazine from the moisture-proof packing bag. ② Transfer the product to another heat-resistant container with static electricity measures. ③ Perform the baking process according to the instructions written on the moisture-proof bag.</p>
Taping Type	<p>Since moisture-proof packing bags are not heat resistant, do not perform the baking process on them as they are.</p> <p>Taping products are not heat-resistant with respect to all packing components (embossed tape, cover tape, and reel), so do not perform the baking process as they are. (Some products can be baked as they are, but for baking conditions please follow the instructions written on the moisture-proof bags.)</p> <p>Please observe the following conditions regarding the baking process. ① Remove the reel from the moisture-proof packing bag. ② Transfer the product to another heat-resistant container with static electricity measures. ③ Perform the baking process according to the instructions written on the moisture-proof bag.</p>

# Chapter 3 General Usage Considerations

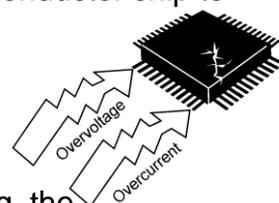
## 3-3. Design

To achieve the reliability required by an electronic device or system, it is important not only to use the semiconductor product in accordance with specified absolute maximum ratings and operating ranges, but also to consider the environment in which the equipment will be used, including factors such as the ambient temperature, humidity, vibration, impact, stress, transient noise and current surges, as well as mounting conditions which affect semiconductor-product reliability. This section describes general design precautions. Be sure to refer to the respective technical datasheets of each product at the time of design.

### 3-3-1. Absolute Maximum Ratings

<b>⚠ CAUTION</b>	
 <b>Prohibited</b>	The absolute maximum ratings of a semiconductor device are a set of ratings that must not be exceeded, even for a moment. Do not exceed any of these ratings. Exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.

If the voltage or current on any pin exceeds the absolute maximum rating, the overvoltage or overcurrent causes the semiconductor product's internal circuitry to deteriorate. In extreme cases, heat generated in internal circuitry can fuse wiring or cause the semiconductor chip to break down.



If the storage or operating temperature exceeds the absolute maximum rating, the semiconductor-product internal circuitry may deteriorate and the bonded areas may open or the package airtightness may deteriorate due to the differences between the thermal expansion coefficients of the materials from which the semiconductor product is constructed.

Although absolute maximum ratings differ from product to product, they essentially concern the voltage and current at each pin, the allowable power dissipation, the connecting area temperatures, and storage temperatures.

Note that the term “maximum rating” which appears in the respective technical datasheets and the like refers to “absolute maximum rating.”

# Chapter 3 General Usage Considerations

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## 3-3-2. Operating Range

The operating range is the range of conditions necessary for the semiconductor product to operate as specified in the respective technical datasheets. Care must be exercised in the design of the equipment. If a semiconductor product is used under conditions that do not exceed absolute maximum ratings but exceed the operating range, the specifications related to semiconductor-product operation and electrical characteristics may not be met, resulting in a decrease in reliability.

If greater reliability is required, derate the semiconductor product's operating ranges for voltage, current, power and temperature before use.

## 3-3-3. Derating

The term “derating” refers to ensuring greater semiconductor-product reliability by setting operating ranges reduced from rated values and taking into consideration factors such as current surges and noise.

While derating generally applies to electrical stresses such as voltage, current and power, and environmental stresses such as ambient temperature and humidity. Power devices in particular have relatively large self-heating, therefore the level of junction temperature ( $T_j$ ) derating greatly affects reliability.

For your reference, details are provided in the appendix. Be sure to read the appendix carefully.

# Chapter 3 General Usage Considerations

## 3-3-4. Unused Pins

If unused pins are left open, some semiconductor products exhibit input instability, resulting in faulty operation such as a sudden increase in current consumption. In addition, if unused output pins on a semiconductor product are connected to the power supply, GND or other output pin, the IC may malfunction or break down.

Since the treatment of unused input and output pins differs for each product and pin, please follow the explanation in the respective technical datasheets. If no treatment method is described in the respective technical datasheet, please seek guidance from our sales contact.

CMOS logic IC inputs, for example, have extremely high impedance. If an input pin is left open, it can readily pick up noise and become unstable. In this case, if the input reaches an intermediate level, both the P-channel and N-channel transistors will become conductive, allowing unnecessary power supply current to flow. It is therefore necessary to ensure that the unused input gates of a semiconductor product are connected to the power supply pin or ground (GND) pin of the same product. For treatment of heat sink pins, refer to the respective technical datasheets.

## 3-3-5. Latch-Up

Semiconductor products sometimes transition to an inherent condition referred to as “latch-up.” This condition mainly occurs in CMOS semiconductor products. This happens when a parasitic PN-PN junction (thyristor structure) built in the semiconductor product itself is turned on, causing a large current to flow between the power supply voltage and GND, eventually causing the semiconductor product to break down.

Latch-up occurs when the voltage impressed on an input or output pin exceeds the rated value, causing a large current to flow in the internal element, or when the voltage impressed on the power supply voltage pin exceeds its rated value, forcing the internal element to breakdown. Once the element falls into the latch-up state, even though the excess voltage may have been applied only for an instant, the large current continues to flow between the power supply voltage and GND, potentially causing product explosion or combustion. To avoid this problem, observe the following:

# Chapter 3 General Usage Considerations

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- (1) Do not allow the voltage levels on the input and output pins to rise above the power supply voltage or decrease below GND. Consider the timing during power supply activation as well.
- (2) Do not allow any abnormal noises to be applied to the semiconductor product.
- (3) Set the electrical potential of unused input pins to the power supply voltage or GND.
- (4) Do not create an output short.

## 3-3-6. Input/Output Protection

Wired-logic configurations in which outputs are connected together directly cannot be used since the outputs short-circuit with the configurations. Outputs should, of course, never be connected to the power supply voltage or GND. In addition, products with tri-state outputs can undergo product deterioration if a shorted output current continues for a long period of time. Design the circuit so that the tri-state outputs will not be enabled simultaneously.

## 3-3-7. Load Capacitance

Certain semiconductor products exhibit an increase in delay times and a large charging and discharging current if a large load capacitance is connected, resulting in noise. In addition, since outputs are shorted for a long period of time, wiring can become fused. Use the load capacitance recommended for each product.

## 3-3-8. Thermal Design

The failure rate of semiconductor products largely increases as the operating temperatures increase. As shown in Figure 3-3-1, the thermal stress applied to semiconductor-product internal circuitry is the sum of the ambient temperature and the temperature rise caused by the power consumption of the semiconductor product.

# Chapter 3 General Usage Considerations

Please refer to the considerations for thermal design in the respective technical datasheets. To achieve even higher reliability, take into consideration the following thermal design points:

- (1) Conduct studies to ensure that the ambient temperature ( $T_a$ ) is maintained as low as possible, avoiding the effects of heat generation from the surrounding area.
- (2) If the semiconductor product's dynamic power consumption is relatively large, conduct studies regarding use of forced air-cooling, circuit board composed of low thermal resistance material, and heat sinks. Such measures can lower the thermal resistance of the package.
- (3) Derate the semiconductor product's absolute maximum ratings to minimize thermal stress from power consumption.

$$\Theta_{ja} = \Theta_{jc} + \Theta_{ca}$$

$$\Theta_{ja} = (T_j - T_a)/P$$

$$\Theta_{jc} = (T_j - T_c)/P$$

$$\Theta_{ca} = (T_c - T_a)/P$$

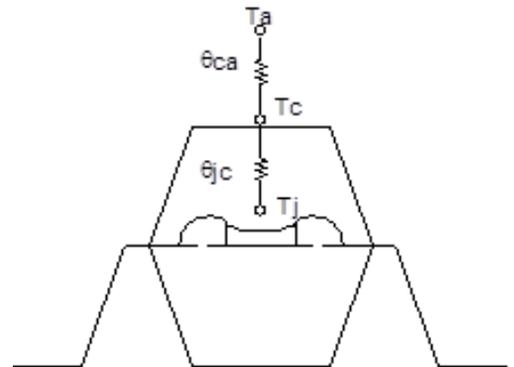


Figure 3-3-1 Thermal Resistance of Package

$\Theta_{ja}$ : Thermal resistance between junction and ambient air ( $^{\circ}\text{C}/\text{W}$ )

$\Theta_{jc}$ : Thermal resistance between junction and package surface, or internal thermal resistance ( $^{\circ}\text{C}/\text{W}$ )

$\Theta_{ca}$ : Thermal resistance between package surface and ambient air, or external thermal resistance ( $^{\circ}\text{C}/\text{W}$ )

$T_j$ : Junction temperature or chip temperature ( $^{\circ}\text{C}$ )

$T_c$ : Package surface temperature or case temperature ( $^{\circ}\text{C}$ )

$T_a$ : Ambient temperature ( $^{\circ}\text{C}$ )

$P$ : Power consumption (W)

# Chapter 3 General Usage Considerations

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## 3-3-9. Mechanical Stress

Applying mechanical stress to packages can degrade the adhesion strength of the packages and allow moisture and contaminants to seep into the packages, thereby degrading the quality of the semiconductor products.

## 3-3-10. Interfacing

When connecting semiconductor products with different input and output voltage levels, make sure that the input voltage ( $V_{IL}/V_{IH}$ ) and output voltage ( $V_{OL}/V_{OH}$ ) levels match. Otherwise, the semiconductor products may malfunction.

To transfer data between two pins, make the input setup/hold times and the output transmission delay consistent. Otherwise, the semiconductor products may malfunction. In addition, when connecting semiconductor products with different power supply voltages, such as in a dual power supply system, semiconductor-product breakdown may result if the power-on and power-off sequences are incorrect.

For semiconductor-product interface details, refer to the respective technical datasheets. In addition, if you have any questions about interfacing, contact your nearest Toshiba office or distributor.

# Chapter 3 General Usage Considerations

## 3-3-11. Decoupling

Spike currents generated during switching can cause power supply voltage and GND voltage levels to fluctuate, causing ringing in the output waveform or a delay in the response speed. (The power supply and GND wiring impedance is normally 50 to 100  $\Omega$ .) For this reason, the impedance of the power supply lines with respect to high frequencies must be kept low.

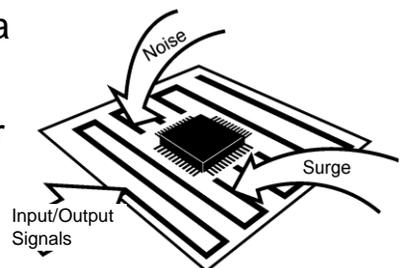
Specifically, this is ideally accomplished by routing thick and short power supply and GND lines and by inserting decoupling capacitors (of approximately 0.01 to 1  $\mu\text{F}$ ) as high-frequency filters between the power supply and GND into each required location on the circuit board.

For low-frequency filtering, it is appropriate to insert a 10 to 100  $\mu\text{F}$  capacitor in each circuit board. However, conversely if the capacitance is excessively large (such as 1000  $\mu\text{F}$ ), latch-up may result. An appropriate capacitance value is therefore required.

On the other hand, in the case of high-speed logic ICs, noise is caused by reflection, crosstalk or common power supply impedance. Reflections cause increased signal delay, ringing, overshoot and undershoot, thereby reducing the semiconductor product's noise margin. One effective wiring measure for preventing reflections is to reduce the wiring length by increasing the mounting density so as to lower the wiring inductance (L) and capacitance (C). This measure, however, also requires consideration with regard to crosstalk between wires. In actual pattern design, both of these factors must be considered.

## 3-3-12. External Noise

When externally induced noise or surges are applied to a printed circuit board with long I/O signals or signal lines, malfunction may result, depending on the semiconductor product.



# Chapter 3 General Usage Considerations

To protect against noise, protective measures against surges must be taken such as lowering the impedance of the signal line or inserting a noise-canceling circuit. For details of required protection, refer to the respective technical datasheets.

## 3-3-13. Electromagnetic Interference

Radio and TV reception problems have increased in recent years as a result of increased electromagnetic interference radiated from electrical and electronic equipment. To use radio waves effectively and to maintain the quality of radio communications, each country has defined limitations for the amount of electromagnetic interference which can be generated by designated devices.

The types of electromagnetic interference include noise propagated through power supply and telephone lines, and noise from direct electromagnetic waves radiated from equipment.

Different measurement methods and corrective actions are used for each type.

Difficulties in countering electromagnetic interference derive from the fact that there is no means for calculating at the design stage the strength of the electromagnetic waves produced from each component in a piece of equipment. As a result, it is after the prototype equipment has been completed that measurements are taken using dedicated instruments to determine for the first time the strength of the electromagnetic interference.

Yet it is possible during system design to incorporate measures for the prevention of electromagnetic interference, which can facilitate corrective action after design completion. One effective method, for example, is to design the product with several shielding options, and then select the optimum shielding method based on the results of the measurements subsequently taken.

## 3-3-14. Peripheral Circuits

In many cases semiconductor products are used with peripheral circuits and components. The input and output signal voltages and currents in these circuits must be designed to match the specifications of the semiconductor product, taking into consideration the factors below.

- (1) Input voltages and currents that are not appropriate with respect to the input pins may cause malfunction. Some semiconductor products contain pull-up or pull-down resistors, depending on specifications. Design your system taking into account the required voltage and current.

# Chapter 3 General Usage Considerations

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- (2) The output pins on a semiconductor product have a predetermined external circuit drive capability. If a drive capability exceeding this value is required, either insert a compensating circuit or take that fact into account when selecting components for use in external circuits.

## 3-3-15. Safety Standards

Each country and region has established safety standards which must be observed. These safety standards sometimes include requirements for quality certification systems and insulation design standards. The safety standards of the respective countries and regions must be taken fully into account to ensure compliant semiconductor-product selection and design.

## 3-3-16. Other

- (1) When designing a system, incorporate fail-safe and other measures according to system application. In addition, debug the system under actual mounting conditions.
- (2) If a plastic package semiconductor product is placed in a strong electric field, surface leakage may occur due to charge-up, resulting in malfunction. When using such a product in a strong electric field, take measures by, for example, protecting the package surface with a conductive shield.
- (3) With some memory devices and microcomputers, attention is required at power on or reset release. To ensure that your design is appropriate for a semiconductor product, refer to the respective technical datasheets.
- (4) Do not shut off the power supply while rewriting flash memory. High electric fields generated inside the package due to the power shutting off can destroy its internal elements.
- (5) Design the casing so as to ensure that no conductive material (such as a metal pin) can drop from an external source onto a terminal of a mounted semiconductor product, causing a short.

# Chapter 3 General Usage Considerations

## 3-4. Inspection, Testing and Evaluation

### 3-4-1. Grounding

<b>⚠ CAUTION</b>	
 <b>Instructions</b>	Check that there is no electrical leakage before grounding measuring equipment or a solder iron. Electrical leakage may cause electric shock or the semiconductor product you are testing or soldering to electrically break down.

### 3-4-2. Inspection Sequence

<b>⚠ CAUTION</b>	
 <b>Prohibited</b>	Do not insert devices in the wrong orientation or incorrectly. Make sure that the positive and negative terminals of power supplies are connected properly. Otherwise, the current or power consumption may exceed the absolute maximum rating, and exceeding the rating(s) may cause the semiconductor-product breakdown, damage or deterioration, and may result injury by explosion or combustion. In addition, do not use any semiconductor product that is applied the current with inserting in the wrong orientation or incorrectly even just one time.
 <b>Instructions</b>	On the evaluation, inspection or test, be sure to connect the test equipment's electrodes or probes to the pins of the semiconductor product before turning the power on. When you have finished, discharge any electrical charge remaining in the semiconductor product. Failure to do so may cause electric shock, resulting in injury.

- (1) Apply voltage to the semiconductor product after inserting it into the test jig. At this time, observe the power supply activation or shutdown standards, if existent.
- (2) After test completion, be sure that the voltage applied to the semiconductor product is off before removing the semiconductor product from the test jig. Removing the semiconductor product with the power supply on can cause semiconductor-products deterioration or breakdown.

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- (3) Make sure that no surge voltages from the measuring equipment are applied to the semiconductor product.
- (4) The chips in tape carrier packages (TCPs) are LSI chips and therefore exposed. During inspection, be careful not to crack or scratch the chip. Electrical contact may also cause chip failure. Therefore make sure that nothing comes into electrical contact with the chip.
- (5) Note that X-ray radiation can change product characteristics during X-ray inspection.

## 3-5. Mounting

There are two types of semiconductor-product packages: lead insertion and surface mount. The items that affect reliability during circuit board mounting include contamination by flux and thermal stress during the soldering process. With surface-mount packages in particular, the most significant problem is thermal stress from solder reflow, when the entire package is subjected to heat. In addition, the mounting method differs according to factors such as chip size and frame design, even for the same package type. For more details, please refer to the technical datasheet for each semiconductor product.

When a location such as a soldered area, connecting area or top surface of a product is subjected to vibration, impact or stress in actual equipment, bonding fault or device destruction may result. Therefore, be sure to keep this in mind at the time of mounting. If a product is subject to especially strong vibration, impact or stress, the package or chip may crack. Thus, at the time of mounting, carefully consider vibration, impact and stress.

# Chapter 3 General Usage Considerations

## 3-5-1. Lead Forming

<b>⚠ CAUTION</b>	
 <b>Prohibited</b>	Do not touch the lead tips of a device. Some devices have leads with sharp tips. Contact to sharp tips may result in a puncture wound.
 <b>Instructions</b>	Always wear safety glasses when cutting the leads of a device with clippers or a similar tool. Failure to do so may result in eye damage from the small shavings that fly off the cut ends.

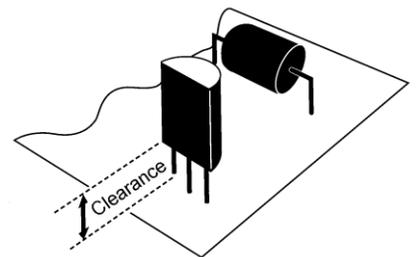
Semiconductor products sometimes undergo a process in which the leads are cut and formed before the products are installed on a printed circuit board. If abnormal stress is applied to the interior of a semiconductor product during this process, mechanical breakdown or reliability deterioration may result. This is attributable mainly to the relative stress applied between the semiconductor product itself and the lead, and can result in internal lead damage, adhesive property deterioration and sealant breakdown. Observe the following precautions during the lead-forming process.

(This does not apply to surface-mount semiconductor products.)

- (1) Lead insertion hole intervals on the printed circuit board should be designed using the same dimension standard as that for the lead interval of the semiconductor product.
- (2) If the lead insertion hole intervals on the printed circuit board do not match the lead interval of the semiconductor product, do not forcibly insert the semiconductor product.

# Chapter 3 General Usage Considerations

- (3) For the minimum dimension between a semiconductor product and printed circuit board, refer to the respective technical datasheets. When necessary, create space when forming the semiconductor product's leads. Do not use the spacers for raising semiconductor products above the surface of the printed circuit board during soldering. These spacers may continue to expand due to heat even after the solder has solidified, sometimes applying a great amount of stress to the semiconductor product.



- (4) Observe the following when forming the leads of a semiconductor product:
- (a) When bending a lead, secure the lead at the end of the bending section near the package to ensure that mechanical stress is not applied to the semiconductor product. Also, do not repeatedly bend or stretch a lead at the same location.
  - (b) Do not damage the lead during lead forming.
  - (c) Please follow the precautions defined in the respective technical datasheets.

# Chapter 3 General Usage Considerations

## 3-5-2. Soldering Temperature Profile

Perform soldering following the methods and conditions described in the respective technical datasheets for the semiconductor product used. The soldering method, temperature and time may be restricted, depending on the product. All soldering temperature profiles and conditions described in the mounting methods below are representative. The profiles and conditions vary from product to product. Therefore, mount the product after first confirming the information described in the respective technical datasheets and databooks with the customer. Reflow soldering and flow soldering must not be combined when performed. For details regarding special soldering including lead(Pb) soldering, please contact your nearest Toshiba office or distributor.

### 3-5-2-1. Using a Soldering Iron (Typical Example)

Complete soldering within 10 seconds for soldering iron temperatures of up to 260°C, or within 3 seconds for soldering iron temperatures of up to 350°C.

### 3-5-2-2. Using Infrared Reflow (Typical Example)

- (1) It is recommended the top and bottom heating method with long or medium infrared rays.
- (2) The maximum package surface temperature is 260°C. The duration where package surface temperature is 255°C or more must be no longer than 30 seconds.
- (3) Refer to Figure 3-5-1 for an example of a temperature profile.

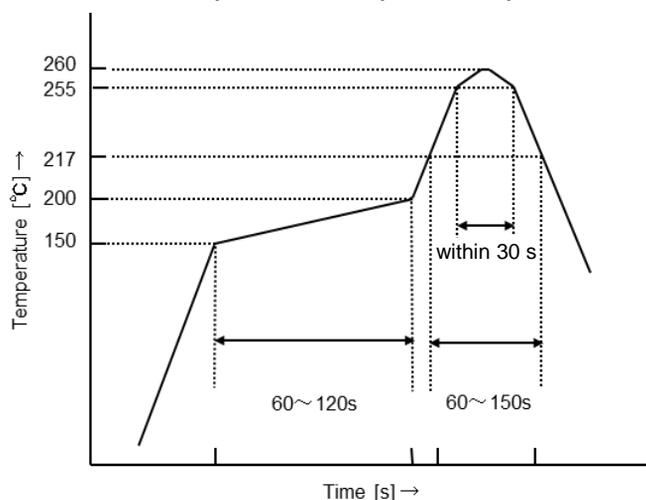


Figure 3-5-1. Example of Temperature Profile

# Chapter 3 General Usage Considerations

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This profile is based on the product's maximum heat resistance guaranteed value. Set the preheat temperature/heating temperature to the optimum temperature corresponding to the solder paste type used by the customer within the above-described profile.

## **3-5-2-3. Using Hot Air Reflow (Typical Example)**

The maximum package surface temperature is 260°C. The duration where package surface temperature is 255°C or more must be no longer than 30 seconds.

For an example of a temperature profile, refer to Figure 3-5-1 above.

## **3-5-2-4. Using Solder Flow/Dip (Typical Example)**

- (1) Apply preheating for 60 to 120 seconds at a temperature of 150°C.
- (2) Perform the solder flow at a maximum temperature of 260°C for no longer than 10 seconds.
- (3) For insertion type packages, solder the device at the stopper part or at least 1.5 mm away from the body.
- (4) For surface-mount packages, since the influence of the thermal stress on the solder flow is larger than that for insertion-type packages, it is recommended to perform soldering at a lower temperature and for a shorter time than in (2).

# Chapter 3 General Usage Considerations

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## 3-5-3. Flux Cleaning

- (1) When cleaning circuit boards to remove flux, make sure that no reactive ions such as sodium or chlorine remain. Some organic solvents react with water to generate hydrogen chloride and other corrosive gases which can result in semiconductor-product deterioration.
- (2) When washing semiconductor products with water, make sure that no reactive ions such as sodium or chlorine remain particularly.
- (3) When washing semiconductor products, do not rub markings with a brush or with your hand while the cleansing liquid is still on the product. Doing so can rub off the markings.
- (4) Dip cleaning, shower cleaning and steam cleaning processes are performed based on the chemical action of a solvent. Washing should be performed at your own discretion, utilizing information from detergent manufacturers.
- (5) Avoid use of ultrasonic cleaning with semiconductor products in hermetically sealed ceramic packages such as a leadless chip carrier (LCC), pin grid array (PGA) or charge-coupled device (CCD). Using the ultrasonic cleaning may cause the internal wires to become disconnected due to resonance. Even if a product package allows ultrasonic cleaning, keep the duration of ultrasonic cleaning in a brief time. Long hours of ultrasonic cleaning may deteriorate the adhesion between the mold resin and frame material. The basic recommended conditions are as follows:

### Recommended Ultrasonic Cleaning Conditions

Frequency : 27 to 29 kHz

Ultrasonic output : 15 W/L or less

Cleaning time : 30 seconds or less

# Chapter 3 General Usage Considerations

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Suspend the printed circuit board in the solvent bath to ensure that the circuit board and semiconductor products do not come in direct contact with the ultrasonic vibrator.

## **3-5-4. No Cleaning**

It is recommended that you clean analog or high-speed semiconductor products. If such products are not cleaned, flux may cause minute leakage between leads or migration, depending on the flux grade. Be sure therefore to check cleanliness at the time of use. If you are considering no cleaning, be sure to use a flux that does not require cleaning.

## **3-5-5. Socket Mounting**

- (1) When socket-mounting semiconductor products on a printed circuit board, use sockets that match the package.
- (2) Use sockets with contacts that have the appropriate contact pressure. If the contact pressure is insufficient, the contact may become poor when the semiconductor product is repeatedly inserted and removed. If the contact pressure is too high, the semiconductor-product leads may bend or become damaged when they are inserted into or removed from the socket.
- (3) When soldering sockets to the printed circuit board, use sockets designed to prevent flux from penetrating the contacts and to allow flux to be completely cleaned off.
- (4) Ensure that the coating agent applied to the printed circuit board for moisture-proofing does not adhere to the socket contacts.
- (5) If the leads are severely bent when inserted into or removed from a socket and you want to repair the leads and continue using the semiconductor product, repair the leads once only. Do not use products whose leads have been corrected multiple times.

# Chapter 3 General Usage Considerations

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- (6) If external vibration will be applied to a printed circuit board with semiconductor products mounted on it, use sockets with strong contact pressure so as to prevent vibration between the semiconductor products and sockets.

## 3-5-6. Chips Mounting

Semiconductor products delivered in chip form readily deteriorate or become damaged due to external factors in comparison with plastic-packaged products. Attention is therefore required during handling.

- (1) Mount semiconductor products in a properly maintained environment so that the chip will not be exposed to contaminated ambient air or other substances.
- (2) When handling chips, be careful not to expose the chips to static electricity. In particular, measures must be taken to prevent electrostatic breakdown during chip mounting. For this purpose, it is recommended that you mount all peripheral devices before you mount the chips.
- (3) Use chip mounting circuit boards (such as PCBs) that do not have any chemical residue on them (such as the chemicals used during PCB etching).
- (4) When mounting chips, use the method of assembly that is most suitable for achieving the appropriate electrical, thermal and mechanical characteristics of the semiconductor product used.

\* For chip details, refer to the relevant specification sheet.

## 3-5-7. Circuit Board Coating

When using semiconductor products for equipment that requires high reliability or used under extreme environments (where moisture, corrosive gas or dust is present), circuit boards are sometimes coated with a moisture-proof coating. Use a coating resin causing less stress.

# Chapter 3 General Usage Considerations

## 3-5-8. Heat Sinks

<b>⚠ CAUTION</b>	
 <b>Prohibited</b>	Do not touch the semiconductor product and its heat sink while the device is on or immediately after the device has been turned off. Devices and Heat sinks become hot. Contact to the heat sink may result in a burn.

- (1) When installing a heat sink to a semiconductor product, use the specified accessories. In addition, be careful not to apply excessive force to the semiconductor product during installation.
- (2) When installing a semiconductor product to a heat sink by fixing it in two or more locations, do not tighten one location to the specified torque while the rest are left not tightened. Rather, lightly tighten all locations evenly first and tighten all locations to the specified torque by rotation.
- (3) Drill screw holes in the heat sink as specified, and smooth the surface of the semiconductor-product installation area by removing burrs and protrusions or indentations.
- (4) Thinly applying silicone grease between the heat sink makes semiconductor product better to improve heat conductivity compared with no grease. If you choose to apply the silicone grease, use a non-volatile type. Volatile type silicone grease can cause cracks over time, resulting in the deterioration of the heat radiation effect.
- (5) With plastic-packaged semiconductor products, the base oil of some silicone grease compounds penetrates the package interior, significantly reducing the lifetime of the semiconductor product. We ask therefore that you use the recommended silicone grease (Manufactured by Momentive Performance Materials Japan).  
If you choose to use another product, select an equivalent one.

# Chapter 3 General Usage Considerations

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## 3-5-9. Tightening Torque

- (1) Tighten screws to a tightening torque that is within the specified values described in the respective technical datasheets for the semiconductor product used.
- (2) Be careful not to allow a pneumatic screwdriver to come in contact with products. Product damage may result.

## 3-5-10. Repeated Semiconductor-Product Mounting and Usage

Do not remount or reuse semiconductor products that have histories such as that described below. These semiconductor products may cause significant problems with regard to semiconductor-product characteristics and reliability.

- (1) Semiconductor products that have been removed from the board after soldering.
- (2) Semiconductor products that have been inserted in the wrong orientation or with reverse polarity and charged.
- (3) Semiconductor products that have undergone lead forming more than once.

## 3-6. Operating Environment

### 3-6-1. Temperature

Semiconductor products are generally more sensitive to temperature than other electromechanical parts. The various electrical characteristics of a semiconductor product are restricted by the operating temperature. It is therefore necessary to understand the temperature characteristics in advance and incorporate derating into the design. When a semiconductor product is used at a temperature outside the specified operating range, electrical characteristics will not be realized and its deterioration will occur more rapidly.

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## 3-6-2. Humidity

Plastic package semiconductor products are sometimes not completely sealed. When these products are used for an extended period of time under high humidity, moisture can seep into the semiconductor product and cause semiconductor chip deterioration or failure. Additionally, care shall be taken for using semiconductor products under conditions of dew condensation, because leads may oxidize, or ion migration may be occurred between leads.

Furthermore, when products are mounted on a regular printed circuit board, the impedance between wiring can decrease under high humidity. In systems with a high signal-source impedance, circuit board leakage or leakage between semiconductor-product leads can cause malfunction. In such a case, moisture-proof treatment to the semiconductor-product surface should be considered. On the other hand, operation under low humidity can damage a semiconductor product due to the occurrence of electrostatic discharge. As a humidity environment, we request consideration in equipment design and usage targeting 40-70% relative humidity.

## 3-6-3. Corrosive Gases

Semiconductor products may experience corroded leads or degraded characteristics when used under corrosive gases such as SO<sub>x</sub>, NO<sub>x</sub>, or H<sub>2</sub>S. Especially when corrosive gas and a high humidity environment overlap, the speed of degradation increases to a rapid pace, and a chemical reaction may cause an electrical leakage between leads. For example, sulfidizing gas may be generated from rubber products, which may lead to corrosion of device leads of semiconductor products and leakage between leads, so the use of rubber products around semiconductor products requires consideration.

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## 3-6-4. Radioactive and Cosmic Rays

Standard semiconductor products are not designed with protection against radioactive and cosmic rays. Semiconductor products must therefore be shielded if they will be used in environments that may result in exposure to radioactive or cosmic rays above the levels that exist in the natural environment.

Furthermore, depending on the product, unexpected errors, such as bit inversion in the memory cell and data inversion of the latch circuit, may occur due to external radiation or the influence of cosmic rays reaching the ground. This is called a soft error.

When designing equipment, it is necessary to design sufficient shielding or prepare a safety design according to the operating environment of the system by applying ECC, etc.

## 3-6-5. Strong Electrical and Magnetic Fields

Semiconductor products exposed to magnetic fields can undergo a polarization phenomenon in the plastic material or within the chip, which gives rise to abnormal conditions such as impedance changes or leak current increases. Malfunctions have been reported in LSIs mounted near television deflection yokes. In such cases, the LSI mounted locations must be changed or the semiconductor product must be shielded against the electrical or magnetic field. Shielding against magnetism is especially required in an alternating magnetic field due to the electromotive forces generated.

## 3-6-6. Interference from Light (such as Ultraviolet Rays, Sunlight, Fluorescent Lamps, Incandescent Lamps)

Light striking a semiconductor product generates electromotive force due to photoelectric effects, sometimes causing malfunction. Semiconductor products in which the chip is visible through the package are especially affected by such light. When designing the circuits, make sure that the semiconductor products are protected against light interference. Not just optical semiconductor products, but all types of semiconductor products are affected by light.

# Chapter 3 General Usage Considerations

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## 3-6-7. Dust and Oil

Similar to corrosive gases, dust and oil cause chemical reactions in semiconductor products, sometimes adversely affecting product characteristics. Be sure to use semiconductor products in an environment that will not result in dust or oil adhesion. Solvent and oil contained in heat release sheets similarly may result in semiconductor product quality deterioration, characteristic deterioration or disconnection. Be sure to use such products with care.

## 3-6-8. Smoke and Ignition

Semiconductor products and modularized semiconductor products are not noncombustible; they can emit smoke or ignite when excessive current or failure occurs. When this happens, poisonous gases may be produced. Be sure to develop a safe design that protects the semiconductor product from excessive current so as to ensure excessive current does not flow within the product during operation or at the time of failure.

To prevent the propagation of fire caused by a smoking or ignited Toshiba product and to ensure that Toshiba products do not emit smoke or ignite due to surrounding conditions, do not use Toshiba products in close proximity to combustible thing, heat-generating thing, igniting materials or flammable materials.

## 3-7. Disposal

Each country and region has laws and regulations for the proper disposal of semiconductor products and packing materials. Be sure to follow these laws and regulations at the time of disposal.

# Appendix

## 1. Derating Concepts and Methods

### 1-1. Concepts of Derating

Reliability greatly changes based on the level of derating, even within rated values. In particular, the usage conditions of discrete semiconductors such as power devices are left to system designers; they affect the mean time between failures (MTBF) of a system and its useful life span. Therefore, system designers must consider the reliability characteristics of semiconductor devices and check their individual derating factors. Temperature and power derating factors particularly need be modeled with environmental conditions.

Here is an example of derating. These conditions include those for worst case scenarios, including surges.

Temperature:  $T_j = 80\% T_j \text{ MAX}$  or less

\*Assuming approximately 10 years of intermittent use (about three hours per day)

$T_j = 50\% T_j \text{ MAX}$  or less

\*Assuming approximately 10 years of 24-hour use in applications that require high reliability

※  $T_j$  should be replaced by a temperature rating specified in the datasheet (e.g.,  $T_a$  or  $T_{ch}$ ) if the product is not rated with  $T_j$ .

Voltage: 80% of the maximum rating or less (Integrated circuits: within the recommended operating range)

Current: Average current 80% of the maximum rating or less (rectifying elements: 50% of the maximum rating or less)

Peak current: 80% of the maximum rating or less

Power: 50% of the permissible maximum loss or less

# Appendix

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For high reliability, a further derated design is required. Derating factors should be determined, referring to the technical datasheets of individual products and their reliability data. In addition, there are safe operation areas (SOAs) and other factors that must be observed during product design. Therefore, be sure to follow the specifications of each individual component.

It is no exaggeration to say that the reliability of an end product depends on that of its constituent components. To realize high reliability, an appropriate derating design is required, considering the reliability characteristics of semiconductor devices.

## 1-2. Methods of Derating

One well-known method for estimating the failure rate of a semiconductor device is described in the MIL standard MIL-HDBK-217. In this method, the failure rate of a semiconductor element with respect to operating conditions is found using a failure rate prediction model based on past field data. Figure 1-2-1 shows an example of a derating curve of a transistor (low frequency, bipolar) based on the MIL standard.

This prediction method, however, classifies semiconductor devices into large groups according to application without reflecting the used technical levels and process stability, which differ for each actual device. To compensate for this, semiconductor manufacturers can use a similar failure rate derating curve based on independently accumulated field data and in-house acceleration test results, although this method is not as detailed as the MIL standard method. Figure 1-2-2 shows a derating curve of a transistor that is based on acceleration tests and field performance results obtained by Toshiba.

# Appendix

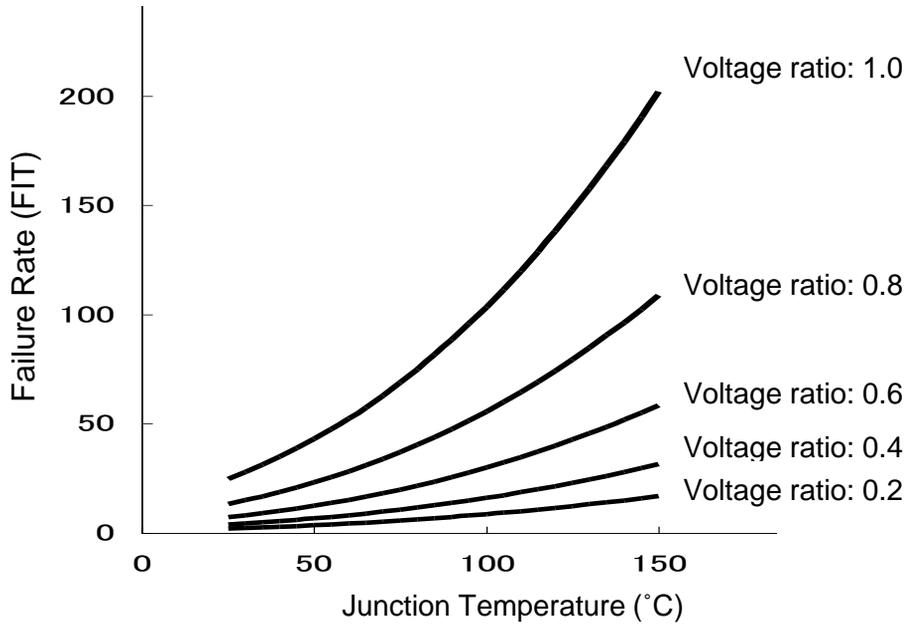


Figure 1-2-1 MIL-HDBK-217-Based Derating

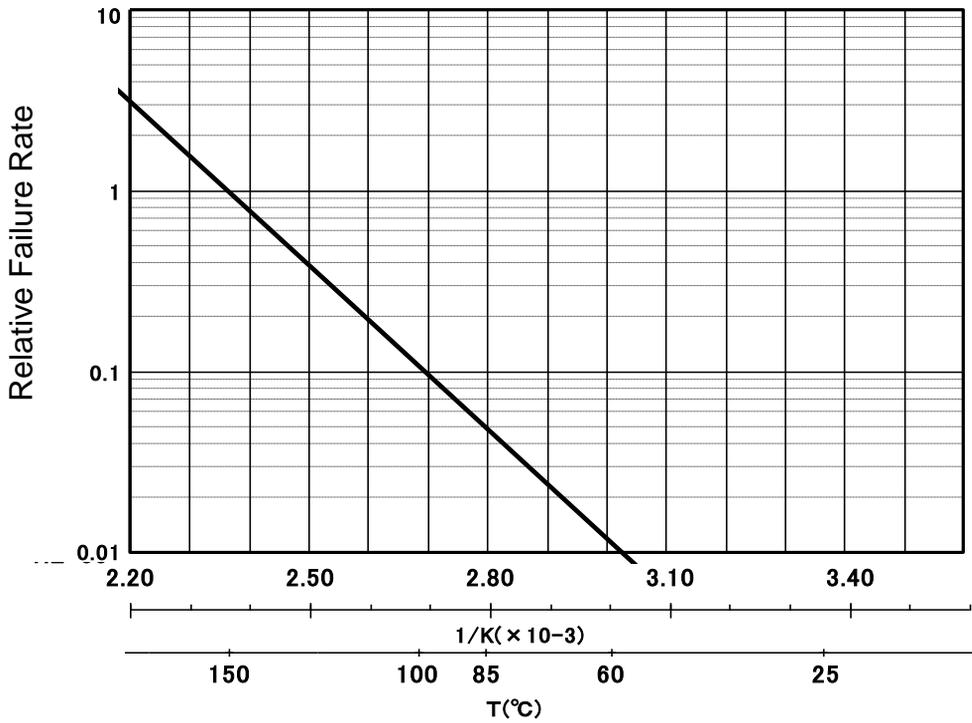


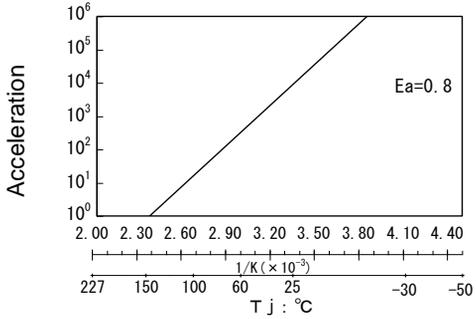
Figure 1-2-2 Transistor Derating Curve

# Appendix

It has been verified that Toshiba's semiconductor products do not enter the wear-out failure period of the bathtub curve within the reliability test time. For system design, the ratings of semiconductor products must be derated so that they will not reach the wear-out failure period (within the reliability test time) in each failure mode under the assumed actual usage conditions.

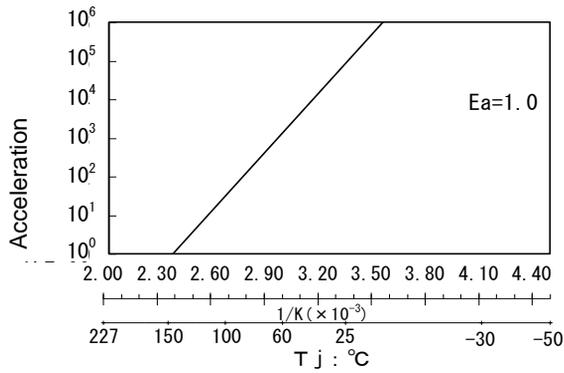
The following shows how to calculate reliability test conditions for commonly used failure modes, based on the results of Toshiba's past reliability testing.

## (1) Characteristics variations (V<sub>th</sub>, hFE, etc.)

<p>Acceleration model</p>	<p>Arrhenius model:  <math>\alpha \propto \exp(-E_a/k \cdot 1/T)</math>            E<sub>a</sub>: Activation energy (0.8 eV)            k: Boltzmann's constant            T: Absolute temperature (in Kelvin)</p> 
<p>Reliability test conditions</p>	<p>High-temperature operation test or high-temperature bias test;            e.g., T<sub>j</sub> = 150°C, 1000h</p>
<p>Assumed condition examples</p>	<p>Only the On periods are assumed.            T<sub>j</sub> = 120°C, 10h                      ... (a)            T<sub>j</sub> = 90°C, 2000h                    ... (b)            T<sub>j</sub> = 60°C, 48000h                   ... (c)</p>
<p>Conversion</p>	<p>The assumed conditions can be converted to reliability test conditions as follows (e.g., T<sub>j</sub> = 150°C):            (a): <math>\exp\{-0.8/8.617 \times 10^{-5} \cdot (1/393 - 1/423)\} \times 10h = 1.9h</math>            (b): <math>\exp\{-0.8/8.617 \times 10^{-5} \cdot (1/363 - 1/423)\} \times 2000h = 53.2h</math>            (c): <math>\exp\{-0.8/8.617 \times 10^{-5} \cdot (1/333 - 1/423)\} \times 48000h = 127.4h</math>            (a) + (b) + (c) = 182.5h</p>

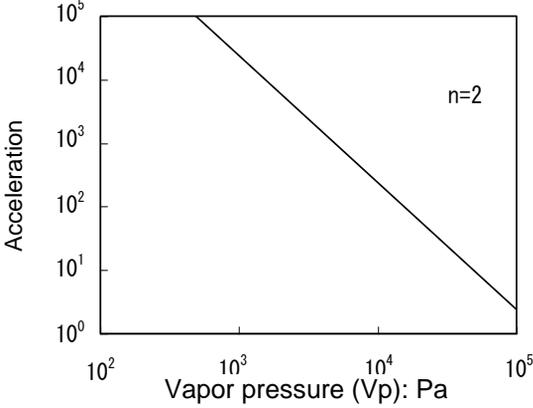
# Appendix

## (2) Metal interconnect faults (Delamination of bonding balls due to the growth of Au-Al alloy)

<p>Acceleration model</p>	<p>Arrhenius model:  <math>\alpha \propto \exp(-E_a/k \cdot 1/T)</math></p> <p>Ea: Activation energy (1.0 eV)  k: Boltzmann's constant  T: Absolute temperature (in Kelvin)</p> 
<p>Reliability test conditions</p>	<p>High-temperature storage test; e.g., Tj = 150°C, 1000h</p>
<p>Assumed condition examples</p>	<p>Both the On and Off periods are assumed.</p> <p>Tj = 120°C, 100h      ... (a)  Tj = 90°C, 7000h      ... (b)  Tj = 60°C, 80000h      ... (c)</p>
<p>Conversion</p>	<p>The assumed conditions can be converted to reliability test conditions as follows (e.g., Tj = 150°C):</p> <p>(a): <math>\exp\{-1.0/8.617 \times 10^{-5} \cdot (1/393 - 1/423)\} \times 100h = 12.3h</math>  (b): <math>\exp\{-1.0/8.617 \times 10^{-5} \cdot (1/363 - 1/423)\} \times 7000h = 75.1h</math>  (c): <math>\exp\{-1.0/8.617 \times 10^{-5} \cdot (1/333 - 1/423)\} \times 80000h = 48.2h</math>  (a) + (b) + (c) = 135.6h</p>

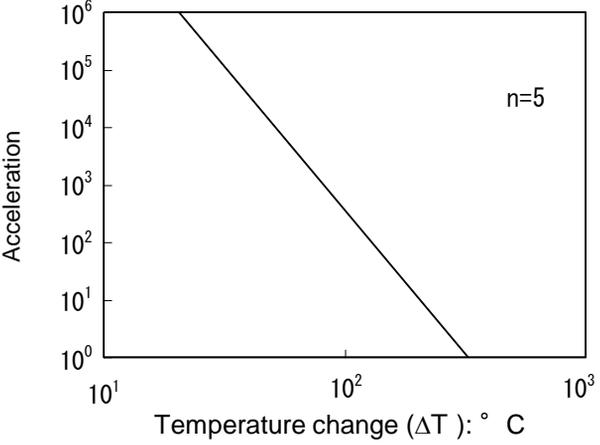
# Appendix

## (3) Metal interconnect faults (Al corrosion)

<p>Acceleration model</p>	<p>Absolute vapor pressure model:  <math>\alpha \propto Vp^{-n}</math>  Vp: Absolute vapor pressure  n: Acceleration factor  (n = 2 is used.)</p> 
<p>Reliability test conditions</p>	<p>High-temperature/high-humidity storage test or high-temperature/high-humidity bias test; e.g., Ta = 85°C, RH = 85%, 1000h</p>
<p>Assumed condition examples</p>	<p>Both the On and Off periods are assumed.  Ta = 30°C/RH = 85% (Vapor pressure: 3608.2Pa), 18000h... (a)  Ta = 20°C/RH = 70% (Vapor pressure: 1636.7Pa), 55000h... (b)  Ta = 10°C/RH = 65% (Vapor pressure: 797.8Pa), 18000h ... (c)</p> <p>*When the test equipment is on, an increase in temperature of the equipment causes the relative humidity to be decreased. It is assumed, however, that the vapor pressure remains unchanged.</p> <p>*The vapor pressure data is an excerpt from Chronological Scientific Tables compiled by the National Astronomical Observatory of Japan.</p>
<p>Conversion</p>	<p>The assumed conditions can be converted to reliability test conditions as follows (e.g., Ta = 85°C/RH = 85% (vapor pressure: 49146.2 Pa) ):</p> <p>(a): <math>(49146.2/3608.2)^{-2} \times 18000h = 97.0h</math>  (b): <math>(49146.2/1636.7)^{-2} \times 55000h = 128.6h</math>  (c): <math>(49146.2/797.8)^{-2} \times 18000h = 4.7h</math>  (a) + (b) + (c) = 230.3h</p>

# Appendix

## (4) Faults caused by repetitive thermal stress (package cracks, degradation of die bond)

<p>Acceleration model</p>	<p>Eyring model:  <math>\alpha \propto \Delta T^{-n}</math>  <math>\Delta T</math>: Temperature change  <math>n</math>: Acceleration factor          (n = 5 is used.)</p> 
<p>Reliability test conditions</p>	<p>Temperature cycling test; e.g., 100 cycles between <math>-55^{\circ}\text{C}</math> and <math>150^{\circ}\text{C}</math> (<math>T_a</math>)</p>
<p>Assumed condition examples</p>	<p><math>\Delta T = 60^{\circ}\text{C}</math>, 7950 cycles ... (a)          (Temperature change of the device itself and the ambience from <math>20^{\circ}\text{C}</math> to <math>80^{\circ}\text{C}</math> when the test chamber is switched on)  <math>\Delta T = 15^{\circ}\text{C}</math>, 2650000 cycles ... (b)          (Temperature change of the ambience from <math>80^{\circ}\text{C}</math> to <math>95^{\circ}\text{C}</math> when the test chamber is on)</p>
<p>Conversion</p>	<p>The assumed conditions can be converted to reliability test conditions as follows (e.g., <math>\Delta T = 205^{\circ}\text{C}</math>):          (a): <math>(205/60)^{-5} \times 7950</math> cycles = 17.1 cycles          (b): <math>(205/10)^{-5} \times 2650000</math> cycles = 5.6 cycles          (a) + (b) = 22.7 cycles</p>

### [Bibliography]

- 1) MIL-HDBK-217
- 2) JEITA EDR-4704, "Application guide of the accelerated life test for semiconductor devices"

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