To our customers,

Old Company Name in Catalogs and Other Documents

On April 1st, 2010, NEC Electronics Corporation merged with Renesas Technology Corporation, and Renesas Electronics Corporation took over all the business of both companies. Therefore, although the old company name remains in this document, it is a valid Renesas Electronics document. We appreciate your understanding.

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April 1st, 2010
Renesas Electronics Corporation

Issued by: Renesas Electronics Corporation (http://www.renesas.com)

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RENESAS

Small Signal Transistor

Precautions and Disclaimers

1. Notes on Using Transistors

1.1 Applications

The transistor products covered in this document are designed for use in general-purpose electronic equipment (personal computers, mobile phones, televisions, audio equipment, electrical household appliances, etc.), and their quality and reliability is quite sufficient for such applications.

Renesas is constantly working to improve the quality and reliability of its products. However, when considering use of these products in applications with special quality and reliability requirements, or applications where failure or malfunction could be directly life-threatening or pose a danger of injury (such as aerospace, avionics, combustion control, transportation, safety equipment, or medical equipment used for life support), the customer is urged to proceed responsibly, with safety design principles as the starting premise, and to consult beforehand with Renesas sales personnel.

1.2 Safety Precautions

When designing products employing Renesas transistors, usage conditions should be within the range guaranteed by Renesas (in particular, maximum ratings, operating power and voltage range, heat dispersion characteristics, device mounting conditions, and other conditions).

Renesas cannot be held responsible for failure or malfunction resulting from usage conditions exceeding the guaranteed range.

In addition, even if usage conditions are within the guaranteed range, the customer is urged to build in countermeasures at the system level (such as failsafe mechanisms), after considering the failure rate and failure modes that can be anticipated for semiconductor products, to ensure that the product cannot cause serious damage (such as a fatal accident or an accident leading to fire or other disaster) due to the behavior of a Renesas transistor.

1.3 Other

The transistor products covered in this document are not designed to withstand radiation.

2. Selection of Semiconductor Devices

The reliability of semiconductor devices is affected, in addition to factors on the manufacturer's side (whether Renesas or another manufacturer), by the so-called usage conditions (circuit conditions, mounting conditions, environmental conditions, etc.) selected by the customer. Consequently, this section describes considerations, such as maximum ratings, derating, and package selection, that should be borne in mind when choosing semiconductor devices, in order to attain a high degree of reliability.

2.1 Maximum Ratings

Maximum ratings for semiconductor devices are normally specified as "absolute maximum ratings." The values listed in the maximum rating tables for individual products must not be exceeded, even for a moment. For example, the following definition of absolute maximum rating is an excerpt from JIS C 7030.

Absolute Maximum Rating
Absolute maximum ratings are limit values for operating conditions and environmental conditions that apply to all transistors. They are determined based on the published specifications for the specific transistor. The limit values must not be exceeded, even under worst-case conditions. The values are decided by the transistor manufacturer and indicate that the manufacturer guarantees the device will function effectively within the range of values specified. (Excerpted from JIS C 7030)

If a maximum rating is exceeded, even temporarily, the device may immediately be damaged or destroyed. Even if it continues to function for some time, its service life will be shortened significantly. Consequently, when designing electronic circuitry incorporating semiconductor devices, it is necessary to make considerations to ensure that the maximum ratings for the device will not be exceeded due to fluctuations in external conditions during use. In addition, many maximum rating items are closely related to one another. Particular care must be taken to avoid approaching the limit of more than one related item at the same time. For example, even if the current and voltage applied to a transistor are both below the maximum ratings, the power consumption is the product of these two values, and this latter value must not exceed the transistor's maximum allowable collector dissipation. In addition, it is necessary to take into account not only the DC maximum ratings, but also, in applications subject to power pulses, the area of safe operation (ASO), load locus, peak voltage, and current.

2.1.1 Transistor Maximum Ratings

Refer to the preceding section, Symbols and Definitions Used for Semiconductor Products, with regard to maximum ratings for Renesas transistor and FET products.

2.1.2 Considerations Related to Derating

The issue of how much the maximum values should be derated is an important one when designing a system with reliability in mind. The derating items that should be considered at the system design stage differ somewhat depending on the device. They may include derating to reduce electrical stress (voltage, current, power, load, etc.), environmental conditions such as temperature and humidity, and derating to reduce mechanical stress (vibration, mechanical shock, etc.).

Table 1 lists examples of derating standards that should be considered, in the interests of reliability, when designing applications.

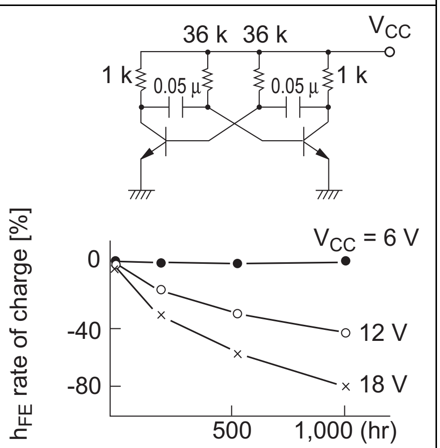
Table 1 Derating Design Standard Examples

Derating Element[Note2]		Transistor
Temperature	Junction temperature	Max. 110°C (max. Tj = 60°C)
	Device ambient temperature	— (Max. Ta = 0 to 45°C)
	Other	Power consumption, ambient temperature, heat dispersion conditions $Tj = P_D \times \theta_{ja} + Ta$
Humidity	Relative humidity	RH = 40 to 75%
	Other	In general, printed circuit boards should be coated if sudden changes in humidity may result in moisture condensation.
Voltage	Breakdown voltage	Maximum rating × 0.8 or less
	Overvoltage	Measures should be taken to prevent application of excessive voltage, including static electricity.
Current	Average current	$I_C \times 0.5$ or less
	Peak current	$i_{C(peak)} \times 0.8$ or less
Power	Average power	Maximum rating × 0.5 or less (especially power transistors)
Pulse[Note3]	ASO	Do not exceed range specified on separate data sheet.
	Surge	$i_{C(peak)}$ or less

Notes; 1. Excluding special usage conditions.
2. As far as possible, derating elements should be satisfied together.
3. Generally speaking, the peak voltage, current, power, and junction temperature should not exceed the maximum ratings in transition status, including surges, etc. The average values indicated above should be used for derating to ensure reliability.

It is advisable that these derating standards be taken into consideration at the system design stage in order to enhance reliability. If it is difficult to remain within the ranges specified in the standards, other measures should be taken, such as selecting devices with higher maximum ratings. Table 2 lists examples where derating is inappropriate.

Table 2 h_{FE} Drop when Maximum Rating Is Exceeded

No.1	Example	h_{FE} Drop when Maximum Rating Is Exceeded
	Device	Transistor
	Description	When a monostable multivibrator was used for transistor switching, a reverse high voltage was applied between the emitter and base. The voltage exceeded the maximum rating, causing low-current h_{FE} to drop, as shown in the figure. The lower figure shows the h_{FE} rate of change for the circuit shown in the upper figure, using V_{CC} as a parameter. 
	Countermeasures	(1) Prevent breakdown from occurring (lower the V_{CC} voltage). (2) Use a device with a high breakdown voltage between emitter and base. (3) Design the circuit with a sufficient margin for h_{FE}.
	Category	Maximum rating

2.2 Package Selection

Plastic-sealed semiconductor devices provide dramatically improved reliability. In recent years the range of uses for such devices has grown to include applications with comparatively demanding environments, such as automobiles (including engine control systems), instrumentation control, equipment for the IT industry, and wireless communications equipment. In fact, an examination of market data indicates that reliability on a par with hermetically sealed devices can be obtained when plastic-sealed semiconductor devices are used in equipment located indoors in favorable environmental conditions.

With the ongoing trend toward miniaturization of electronic equipment in recent years, demand has grown stronger for smaller and thinner packages for semiconductor devices. In response to this demand, device packages designed for surface mounting, in the same manner as capacitor or resistor chips, have been developed.

In comparison with pin-insertion packages, surface-mounted packages offer the following advantages.

(1) Smaller size, allowing for more compact mounting area.
(2) Thinner, allowing for lower mounting height.
(3) Higher circuit board density since no holes need to be drilled through circuit boards.
(4) Devices can be mounted on both sides of a circuit board.

A variety of types of surface-mounted packages have been developed. They differ in terms of ease of mounting, ease of use, heat resistance, etc. It is therefore necessary to have a knowledge of the features of the different package types before making a choice.

3. Notes on Circuit Board Mounting

When designing a system with reliability in mind, it is necessary of course to design the circuitry to meet the initial specifications. In addition, one should take steps such as making appropriate use of derating and building a margin into the design to account for variations in characteristics. Possible problem points that should be considered from the standpoint of reliability include wiring issues, surges from external sources, reactance loads, noise margins, reverse bias, flyback pulses, static electricity, and pulse stress.

3.1 General Precautions

In order to ensure that the system achieves the prescribed level of reliability, it is important to make sure that the usage conditions are within the parameters listed in the catalog and to take into account the effects of peripheral components. In addition, the following points should be borne in mind.

(1) Every effort should be made to keep the peripheral temperature low in order to prevent the area near the semiconductor devices from becoming too hot.
(2) The power supply voltage, input voltage, power consumption, etc., should be within the rated range, and derating should be considered.
(3) Care should be taken to prevent excess voltage due to noise from being applied or induced at the input, output, or power pins. Caution is also necessary regarding strong electromagnetic flux.
(4) Care should be taken to prevent the generation of static electricity, etc., during use.
(5) Due to the microstructure of devices that operate at high speed, a protection circuit should be provided at the input block or other measures taken to prevent the application of electrostatic pulses.
(6) Care should be taken to prevent any imbalance in the voltages applied when power is turned on and off, etc. For example, if the circuit’s ground pin is in a floating state, applying voltage to the input or power supply pins can result in excessive stress to the device.

Brief examples illustrating the main items are provided below.

3.2 Measures to Deal with Noise and Voltage Surges

Voltage surges, electrostatic, and noise are problems common to semiconductor devices in general. It is essential that measures be taken to prevent, or at least to lessen, them.

Generally speaking, when designing electronic equipment it is assumed that fluctuations in the commercial power supply will be within the range of about 10%. However, if machinery or the like that produces voltage surges is present nearby, the resulting fluctuations in the power supply voltage can cause equipment to fail or malfunction.

Such fluctuations take the form of surges superimposed on the power supply line, and natural phenomena such as lightning can also cause impulse surges. The effect of such surges can be reduced by inserting a filter of the sort shown in figure 1 on the AC line side. Even if there is no danger of power surges or electrostatic entering indirectly via the AC line, precautions such as shielding are necessary if there is a possibility of noise or voltage surges being applied directly to the parts or semiconductor devices mounted on the circuit boards. In addition, it is essential that the impedance between the shield and ground be low, as the shielding will not be effective if it is too high.

If there is a danger of direct electrostatic or surge pulses being applied in the form of noise, a protection circuit of the sort shown in figure 2 can be inserted as a special precaution. The Ri $\times$ Ci time constants should be set within a range that will not affect operation but will effectively absorb surge pulses.

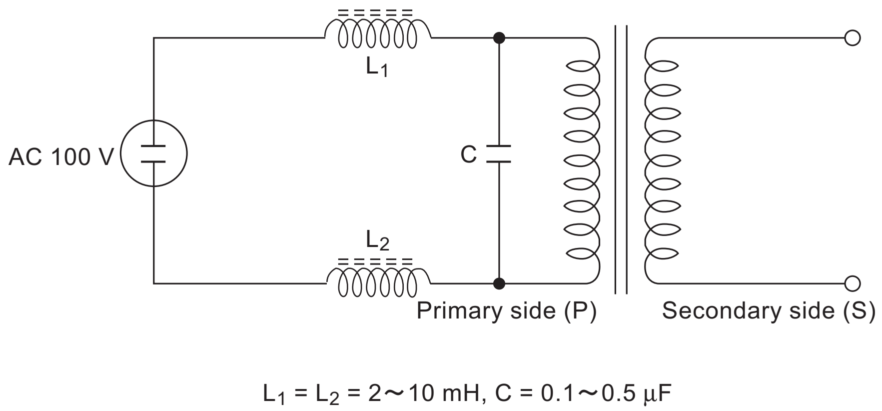


Figure 1 Example Surge Absorber Circuit

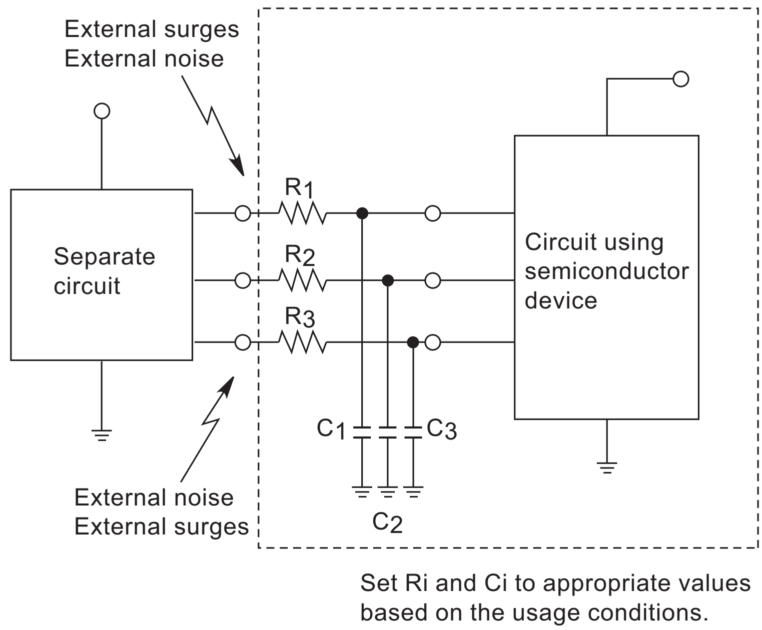


Figure 2 Example Surge Protection Circuit

Table 3 Destruction by Voltage Surges

No.2	Example	Destruction by Voltage Surges
	Device	Transistor
	Description	Shorting between the transistor's emitter and base occurred during the assembly process. The cause was the release by a high-voltage circuit of high voltage, which was induced into the transistor's pins, destroying it.
	Countermeasures	(1) To absorb voltage surges, either insert resistors connected in series, or insert a protection circuit composed of capacitors and resistors. (2) Take measures to insulate the high-voltage circuit. (3) Provide a bypass circuit for the high voltage.
	Category	Circuit implementation (surge countermeasure)

Table 4 Transistor Destruction by Strong Electromagnetic Flux

No.3	Example	Transistor Destruction by Strong Electromagnetic Flux
	Device	Transistor
	Description	Shorting occurred between the collector and emitter of a transistor used in a control circuit due to noise induced in the signal line. Noise induction occurred because the usage environment is subject to strong electromagnetic flux and the signal line is quite long. There were insufficient measures to prevent noise.
	Countermeasures	(1) Insert a capacitor between the base and the emitter. (2) Implement shielding or other preventive measures for the signal line, which is exposed to strong electromagnetic flux.
	Category	Circuit implementation (noise)

3.3 Characteristic Parameters and Reliability

Semiconductor devices have characteristic parameters determined by their specific functions and applications. These characteristic parameters define value ranges that should be conformed to. When designing systems, the importance of the various parameters often differs depending on the application, and it is impossible to lay down universal guidelines. However, it is necessary in the case of important parameters to take steps, such as adding a margin to the initial characteristics or performing derating. Ways of achieving the former include selecting devices based on a consideration of the limits of the system’s operating range, employing statistical design methods, and basing the design on reliability testing methods or failure evaluation standard values for the reliability of Renesas semiconductor devices. Regarding the latter, refer to the preceding discussion of derating. Fluctuations in parameters are unlikely to occur to any significant extent under actual usage conditions. Therefore, it is probably acceptable in most cases to base the design on initial test ratings. However, for items where there is no system margin and crucial items it is advisable to take failure evaluation standard values into consideration.

The following points should be borne in mind regarding parameters.

(1) How important is the parameter? Can it cause system failure?
(2) What margin is there in the initial value of the parameter?
(3) Are there changes over time? If so, is there enough margin present in the direction of the changes?
(4) Is there sufficient allowance for fluctuations in common with other devices?
(5) Is redundant design possible?
(6) Is it possible to introduce statistical design methods for parameters?

4. Notes on Storage, Shipping, and Measurement

Additional points requiring caution include problems that can occur during storage and shipping and problems related to handling during measurement.

General precautions related to the storage and shipping of electronic parts apply to semiconductor devices as well, but there are some additional points where special care is necessary. These are listed below together with some general items.

4.1 Storage of Semiconductor Devices

It is desirable, when storing semiconductor devices, to observe the guidelines listed below. Failure to exercise sufficient care can result in defects affecting the electrical properties, solderability, or external appearance of the devices. In some cases device failure may result.

The main precaution items are listed below.

(1) The temperature and humidity of the storage location must be within an appropriate range. A temperature range of 5 to 35°C and a relative humidity range of 20 to 75% is ideal. (Some products may have special restrictions regarding storage conditions. In such cases, the specified conditions should be adhered to.)
(2) The storage environment should be free of harmful gas and relatively dust-free.
(3) The storage containers should be resistant to electrostatic buildup.
(4) The semiconductor devices should not have additional loads stacked on top of them when in storage.
(5) If the devices are to be kept in storage for an extended period of time, they should be stored in an unprocessed state. If the devices are stored after forming of the lead wires has been performed, corrosion may form on the bent portions of the wires.
(6) Unsealed chips should be stored in a cool, dark place that is dry and relatively dust-free. The period between when the containers are opened and assembly should not exceed five days. It is desirable to store unsealed chips in a nitrogen atmosphere. They can be stored for up to 20 days in dry nitrogen with a dew point of –30°C or below, and for up to three months in an unopened state.
(7) Care should be taken to prevent sudden changes of temperature during storage that could cause moisture condensation.

4.2 Precautions During Shipping

When shipping semiconductor devices, and when shipping units or subsystems incorporating semiconductor devices, the same precautions necessary for other electronic parts are necessary. In addition, the points listed in section 4.1 should be taken into consideration, and the following items should also be borne in mind.

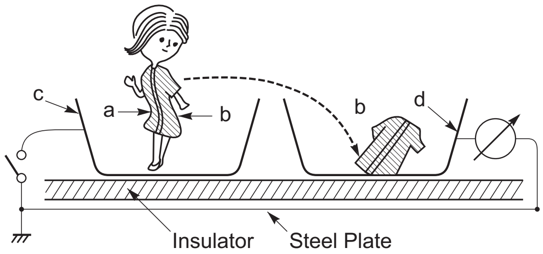
(1) The containers and jigs used for shipping must be of a type that will not carry an electrostatic charge and will not generate static electricity due to vibration during transport or the like. The use of electrically conductive containers, aluminum foil, etc., is an effective measure to prevent electrostatic buildup.

The electrostatic charge accumulating on the human body or clothing can vary substantially due to factors such as the fabric type, footwear, body characteristics, ambient temperature, and humidity. An example of how to measure the electrostatic charge voltage is described here.

Human Body Electrostatic Charge Measurement Example

	Conditions	Max. Voltage	Ambient Conditions
(1)	a 100% cotton shirt	+4,900 V	Ambient temp.: 20°C Relative humidity: 40%
	b Synthetic fiber shirt*	–13,000 V	
(2)	a Synthetic fiber shirt*	– 3,500 V	
	b 100% cotton shirt	+7,200 V	
(3)	a Bare skin	– 410 V	
	b 100% cotton shirt	+980 V	
(4)	a Bare skin	+3,200 V	
	b Synthetic fiber shirt*	–7,000 V	

a, b: Clothing
c, d: Metal tubs
(* Polyvinyl chloride synthetic fiber)



Electrostatic capacitance between steel plate and steel tub: 50 pF
Insulation resistance: $1.5 \times 10^{12}\ \Omega$

Method of Measuring Human Body Electrostatic Charge

The example proceeds as follows: Beginning naked (bare skin), the subject first puts on garment a and then garment b. The subject is grounded while performing these actions. The ground is then removed and the subject removes garment b and tosses it into tub d. The electrical potential is then measured.
In items (3) and (4) in the table, where a is bare skin, the electrostatic charge is generated by direct friction between the subject's body and a single garment.

Figure 3 Human Body Electrostatic Charge Voltage Measurement Example

(2) To prevent destruction of devices by electrostatic charges that have accumulated on people’s bodies and clothing, electrostatic buildup should be discharged from persons handling devices to a ground via a high resistance. The resistance value should be about 1 MΩ. The resistor should be inserted between the person and the ground and located close to the person. It is also necessary to take precautions to prevent electrical shock. Human body electrostatic charge measurement data is shown in figure 3 for reference.

(3) When moving items such as printed circuit boards with semiconductor devices mounted on them, it is necessary to take measures to prevent electrostatic buildup and to consider steps such as shorting the pins to equalize their electrical potential. In addition, when moving items such as printed circuit boards using conveyer belts, measures should be taken to prevent electrostatic buildup on the rubber of the belts, etc.

(4) When transporting semiconductor devices and printed circuit boards, mechanical vibrations and shocks should be minimized as far as possible.

4.3 Precautions During Measurement and Handling

When handling semiconductor devices during measurement, it is necessary to exercise sufficient caution with regard to static electricity, noise, voltage surges, etc., as described above. It is possible to prevent damage to devices by equalizing the electrical potential between the pins during shipping and storage. However, all the pins are exposed when device properties are being measured and during insertion. This increases the possibility of a person’s body, a measuring device, the workbench, a soldering iron, a conveyer belt, etc., coming into contact with individual pins. At this point the device may be destroyed if electrostatic discharge or electrical leakage from electrical equipment occurs. Sufficient care should therefore be exercised to ensure that no electrical leakage occurs from the terminals or cases of equipment such as curve tracers, synchroscopes, pulse generators, and stabilized DC power supplies.

When measuring device characteristics, particular care should be taken to prevent voltage surges from being applied to devices from testers. Possible protective measures include inserting a clamp circuit into the tester. Consideration should also be given to preventing abnormal voltage from being applied to devices due to poor contacts when the current generator is operating. In addition, care should be taken during testing to avoid incorrect pin connections, reversed connections, and shorts between pins.

Before performing operations tests on circuit boards, each board should be examined carefully to ensure there are no solder bridges or bridges composed of foreign matter. Power should not be turned on until the examination is complete.

Note that since the points requiring caution differ depending on the type of device, questions regarding any unclear points should be directed to a Renesas engineering representative.

5. Device Destruction by Static Electricity

Ultra-high-frequency, low-noise devices developed and designed for communications using the microwave band have extremely fine structures in order to meet extremely stringent performance requirements. In addition, the parasitic parameters of such devices must be minimized as far as possible due to their high operating frequencies, which range from the VHS through the SHF bands, and this makes it difficult to incorporate sufficient protection circuitry. As a result, such devices are very vulnerable to destruction by electrostatic discharges or voltage surges.

Therefore, due caution should be exercised when handling ultra-high-frequency, low-noise devices to avoid damaging them. This section lists some general precautions intended to avoid device destruction by static electricity.

(1) Electrostatic Phenomena

Electrostatic phenomena familiar to everyone include the crackling sounds made by sparks when you remove a shirt or sweater made of synthetic fabric in the wintertime and the way hair will cling to a polyvinyl sheet after you rub it. In the former case, the electrical potential of the garment is generally between 6,000 and 10,000 volts. Electrostatic phenomena have a wide variety of causes, and the amount of electrostatic buildup also varies greatly. Nevertheless, regardless of whether the charge is large or small, exposure to static electricity can destroy a semiconductor device in a worst-case scenario. It is therefore important to take appropriate measures to prevent and eliminate electrostatic buildup.

Electrostatic buildup can be divided into two main classifications: buildup that occurs when externally applied mechanical energy is converted into electrical energy (A and B), and buildup that occurs when electrical energy is applied directly (C and D).

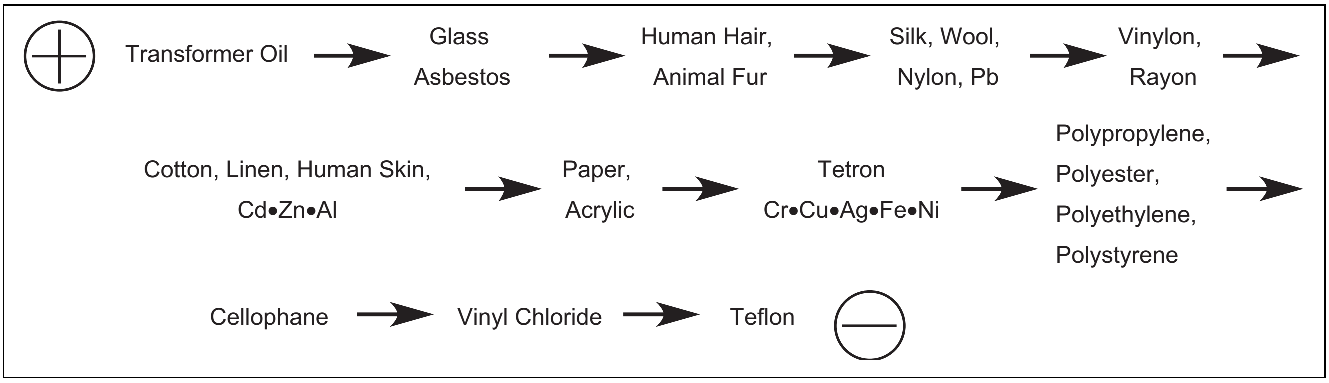
Classification	Buildup Cause	Charging Type	Notes
A	Contact and separation	Contact charging	Electron movement, ion exchange, etc.
		Separation charging	Same as above. Generally a strong charge.
		Pressure charging	Piezoelectric effect, increased contact area, etc.
		Friction charging	In addition to increased contact area, deformation, heat, etc.
		Spouting and fracture charging	Collision, friction, fracture polarization, etc.
		Fluid charging	Friction between liquids and gasses, friction between solids.
B	Deformation and transformation	Mechanical or heat-induced deformation	Piezoelectric effect, displacement of charge position, etc.
		Freezing, melting, etc.	Ion mobility differential.
C	External electric field	Induction charging	Charge shift.
		Ion adhesion	Adhesion of ions in air, injection of ions.
D	Electromagnetic radiation	Charging by irradiation	Electron emission caused by exposure to X-rays or light.
		Charging by exposure to light	

(2) Preventing Generation of Static Electricity

(a) It is truly difficult to prevent the generation of static electricity. In actual practice, anti-electrostatic measures are used to quickly minimize any charges that are generated.

(b) The generation of static electricity increases as the relative humidity drops. In particular, it becomes much more frequent when the relative humidity is lower than 40%. Therefore, it is important to humidify the work environment as appropriate at dry times of year, such as during the winter months.

(c) The amount of static electricity generated by separation or friction increases proportionally to the size of the contact area, the pressure, and the separation speed. Therefore, rapid friction and separation should be avoided. The figure below shows examples of electrostatic charge permutations. (The names of the materials are arranged by charge polarity, beginning with positive and ending with negative. Therefore, the farther apart two items are in the figure, the greater the electrostatic charge that will be produced by rubbing them together. However, the sequence it not absolute because the actual results are greatly affected by external conditions.)



(3) Anti-Electrostatic Measures

(a) Preventing Charging of Conductive Materials

- The basic principle is to dissipate charges into the earth by grounding.
- A ground resistance of 100 Ω
  (Type 3 grounding) or less is desirable.
- Even for portions of the apparatus that are not perfect conductors, it can be effective to apply an indirect ground by affixing a metal conductor (solid surface with conductivity of 1×10^{-8} S/m or more and surface resistance of 1×10^{9} Ω or less).

(b) Preventing Charging of Non-Conductive Materials

- Apply anti-static agent.
- Blend in anti-static agent.
- Modify polymer surface layer.
- Switch to a composite material incorporating an electrical conductor.
- Adjust the relative humidity. (A relative humidity of 50% or above is desirable.)

(4) Implementing Anti-Electrostatic Measures

- It is important that anti-electrostatic measures be applied to buildings, personnel, equipment, jigs, and products. Items whose efficacy has been confirmed in basic testing should be carried out comprehensively, resolutely, and in an organized manner. It is recommended that multiple measures of different types be implemented simultaneously.
- Charge potential limit target values should be established for each covered item and the necessary measures implemented to meet it. In particular, ultra-high-frequency devices with an f_T exceeding 10 GHz are very susceptible to destruction by static electricity, so surface potential charge limit target values for the pickups of taped devices during mounting should be set as low as possible. The maximum permissible value in such cases should be no more than a few dozen volts.
- It can be difficult to measure accurately the surface potential of non-conductive materials and of semiconductors. Therefore, reproducibility is very important in confirming the effectiveness of specific measures. It is recommended that, as far as possible, specific individuals be put in charge of the tasks of measuring and of recording measurement conditions and environmental data (temperature, humidity, weather, etc.) on a consistent basis.

Electrostatic phenomena constitute an issue that spans a range of scientific fields, including electrical engineering, physics, chemistry, and mechanical engineering. Measures to protect semiconductor devices from destruction by static electricity are being implemented cooperatively, by both manufacturers and customers, and in recent years the incidence of such problems has been decreasing in frequency.

Nevertheless, there is a tradeoff between increased device performance and improved protection against destruction by static electricity. It can be said that measures to prevent destruction by static electricity will always be an important issue when using ultra-high-frequency, low-noise devices. The methods to prevent and dissipate electrostatic buildup described in this document are general-purpose techniques that are actually in use today. In fact, there are still many aspects of the mechanism by which semiconductor devices are destroyed by static electricity that remain unclear to science. In order to reduce defects due to device destruction by static electricity, Renesas will continue to work to develop and implement effective and economical countermeasures, backed by the cooperation and understanding of our customers.

Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Jun.18.04	—	First edition issued

Keep safety first in your circuit designs!

1. Renesas Technology Corp. puts the maximum effort into making semiconductor products better and more reliable, but there is always the possibility that trouble may occur with them. Trouble with semiconductors may lead to personal injury, fire or property damage.
   Remember to give due consideration to safety when making your circuit designs, with appropriate measures such as (i) placement of substitutive, auxiliary circuits, (ii) use of nonflammable material or (iii) prevention against any malfunction or mishap.

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