EC-1

Notes on Operation at High Temperatures

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Outline

The range of operating temperature for the EC-1 is Tj = -40 to 125ºC. That is, operation of the devices within this range is guaranteed. However, the quality and reliability of semiconductor devices are greatly influenced by the environment of use. In other words, products with the same quality may be less reliable in harsh environments, and more reliable when the usage environment is less harsh. Even when used within the maximum ratings, if a device is used under extremely stringent conditions equivalent to lifetime tests, wear-out-like failures may result.

This document gives notes on the operating environment when a product of the EC-1 is used in high-temperature (Tj = 110 to 125ºC) applications.

Target Devices

EC-1

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1. Relationship between Actual Usage Environment and Reliability for the EC-1

1.1 Concept of Microcontroller Reliability

When using an EC-1 microcontroller, follow the advice given below to ensure the reliability of the device.

The reliability of semiconductor devices is represented by the failure rate curve (called the “bathtub curve”). The curve can be divided into the three following regions: (1) infant mortality, failures which occur within a relatively short time after a device starts to be used, (2) normal-life failures, random failures which occur over longer periods of time, and (3) wear-out failures (service life), which occur with the passage of time reaching the essential end-of-life for the device. For details on the bathtub curve, refer to the Semiconductor Reliability Handbook (R51ZZ0001EJ0100).

Of these failures, wear-out failures are strongly dependent on the temperature environment in which the semiconductor device is used. Derating is an important measure to consider in reducing the average time until wear-out failure of an EC-1.

1.2 Derating

Derating is defined under JIS Z 8115 as the systematic reduction of load for the sake of improved reliability.

The quality and reliability of semiconductor devices are greatly influenced by the environment of use. In other words, products with the same quality may be less reliable in harsh environments, and more reliable when the usage environment is less harsh. Even when used within the maximum ratings, if a device is used under extremely stringent conditions equivalent to lifetime tests, wear-out-like failures may result. Hence the concept of derating is extremely important.

Derating is applied to product groups, such as discrete devices and power ICs, that require adjustment of the operating conditions, such as ambient temperature, junction temperature, voltage, current, and power, which are mutually related. This is because in addition to having wide usage condition ranges these products have the property that even if they are operated within the corresponding usage range (e.g. voltage), concern for the junction temperature will be required due to the relationships between characteristics such as the power generated, ambient temperature, and heat sink used.

For details on the derating, refer to section 5.2.3, Derating, in the Semiconductor Reliability Handbook (R51ZZ0001EJ0100).

This application note describes temperature profiles assumed for typical high-temperature (110 to 125ºC) applications and gives examples of derating to suit products of the EC-1.

2. Thermal Design

In general, the junction temperature of a semiconductor device affects its lifetime, and high enough temperatures may lead to its destruction. Therefore, the junction temperature (Tj) should be specified for any LSI with large power consumption, so that thermal design can be applied such that it operates below the maximum allowable temperature.

If the temperature of the environment where a device is used approaches or exceeds the maximum allowable temperature specified for the junction temperature (Tj), estimate the junction temperature of the device by as accurate a method as is possible. The point of calculating Tj for the device in actual usage is to check it is operating below the maximum operating temperature given in the electrical characteristics. If the estimated result exceeds the maximum, reconsider the parts layout, board configuration, and power consumption.

The junction temperature cannot be measured directly, so it must be estimated from power consumption and thermal characteristics parameters. There are several methods of estimation, and the accuracy varies with the method. This application note describes an example of thermal design.

2.1 Example of Thermal Design

2.1.1 Calculation from the Temperature at the Top-Center of the Package (Tt)

Measure the temperature at the center of the top of the package (Tt) in the usage environment, and use the following formula to estimate the junction temperature (Tj).

Tj = Tt + Tβ

Tj: Junction temperature

Tt: Temperature at the center of the top of the package

Tβ: Temperature correction value (Table 2.1)

Table 2.1 Temperature Correction Value (Tβ)

Printed Circuit Board	Tβ (ºC)
4-layer (see EIA/JEDEC STANDART 51-7)	13
6-layer (This is the above 4-layer board plus two extra layers. In addition, 36 via holes run from the top surface to the back surface and connected only to the second layer are added.)	12

Even if sufficient margin is determined in the initial investigation, make sure that Tj is within the range listed in Table 3.1 by measuring Tt. If Tj exceeds the value listed in Table 3.1, reconsider the parts layout, board configuration, and power consumption.

(1) Points for caution in measuring Tt

- Measurement by a thermocouple

In using a thermocouple to measure the temperature accurately, take care in selecting the thermocouple used and mounting it on the objective of measurement. Notes and recommendations are as follows.

- Use a thermocouple with wire having as narrow a diameter as is possible to obtain good thermal conduction (recommendation: 150 um or less).

- We recommend a thermocouple of the K-type. Thermocouples of the T-type have larger heat dissipation, raising the possibility of measuring a falsely low temperature.
- Heat-resistant resin tape or a heat-resistant resin for affixing the thermocouple is recommended.
- The thermocouple should be firmly affixed to the objective of measurement ("floating" will lead to errors in measurement).

- Measuring point

Measure Tt at the center of the top of the package after confirming that the temperature has reached the steady state.

- Measurement by thermography (thermal camera)

In order to measure the temperature accurately, set the emissivity of the objective of measurement by thermography. Though the emissivity of a board’s surface is approximately 0.8 to 0.9, the value is generally smaller for metal surfaces. (Measurements from a metal surface will be lower than the actual temperature if measurement is with a setting in the 0.8 to 0.9 range.) If the emissivity is unknown, spray the surface with black spray and set the emissivity of the black spray to obtain an accurate measurement of the temperature.

Also, note that anything between the thermal camera and the objective of measurement (even a transparent acrylic plate) will lead to incorrect results of measurement. (With a transparent acrylic plate, the camera will measure the temperature of the plate.)

Temperature measurement with thermography is sometimes difficult because of how the objective of measurement is placed. However, because knowledge of the temperature distribution is useful, we recommend using a thermocouple.

3. Examples of Derating in Typical High-Temperature Applications

Table 3.1 lists expected temperature profiles and the corresponding recommended temperature profiles for derating of EC-1 products in typical high-temperature applications.

The target packages are BGA-196, and the package codes are PLBG0196GA-B. For the specific target products, refer to the EC-1 User's Manual: Hardware. Derating is assumed to be for 10 years.

Choose an example close to your usage conditions. If there is no suitable example in the list, please contact a Renesas sales representative.

Table 3.1 Typical High-Temperature (110 to 125ºC) Applications

Example	Application	Assumed Temperature Profiles	Recommended Temperature Profiles for Derating			
			Case 1		Case 2	
1	Industrial motors, power tools, power conditioners (running around-the-clock: example 1)	Continuous use Tj max = 110°C	-40°C*1 ≤ Tj ≤ 110°C	100%	-	
2	Industrial motors (running around-the-clock: example 2)	Continuous use at higher temperature Tj max = 115°C	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 115°C	34% 66%	-40°C*1 ≤ Tj ≤ 105°C 105°C ≤ Tj ≤ 115°C	50% 50%
3	Industrial motors (running around-the-clock: example 3)	Continuous use at higher temperature Tj max = 120°C	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 120°C	50% 50%	-40°C*1 ≤ Tj ≤ 105°C 105°C ≤ Tj ≤ 120°C	67% 33%
4	Industrial motors (running around-the-clock: example 4)	Continuous use at higher temperature Tj max = 120°C	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 110°C 110°C ≤ Tj ≤ 120°C	5% 90% 5%	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 110°C 110°C ≤ Tj ≤ 120°C	10% 80% 10%
5	Industrial motors (running around-the-clock: example 5)	Continuous use at higher temperature Tj max = 120°C	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 115°C 115°C ≤ Tj ≤ 120°C	35% 60% 5%	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 115°C 115°C ≤ Tj ≤ 120°C	37% 53% 10%
6	Industrial motors (running around-the-clock: example 6)	Continuous use at higher temperature Tj max = 120°C	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 110°C 110°C ≤ Tj ≤ 120°C	15% 70% 15%	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 115°C 110°C ≤ Tj ≤ 120°C	39% 46% 15%
7	Industrial motors (running around-the-clock: example 7)	Continuous use at higher temperature Tj max = 125°C	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 125°C	60% 40%	-40°C*1 ≤ Tj ≤ 105°C 105°C ≤ Tj ≤ 125°C	75% 25%
8	Industrial motors (running around-the-clock: example 8)	Continuous use at higher temperature Tj max = 125°C	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 110°C 110°C ≤ Tj ≤ 125°C	8% 87% 5%	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 110°C 110°C ≤ Tj ≤ 125°C	15% 75% 10%
9	Industrial motors (running around-the-clock: example 9)	Continuous use at higher temperature Tj max = 125°C	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 115°C 115°C ≤ Tj ≤ 125°C	37% 58% 5%	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 115°C 115°C ≤ Tj ≤ 125°C	40% 50% 10%
10	Industrial motors (running around-the-clock: example 10)	Continuous use at higher temperature Tj max = 125°C	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 110°C 110°C ≤ Tj ≤ 125°C	23% 62% 15%	-40°C*1 ≤ Tj ≤ 100°C 100°C ≤ Tj ≤ 115°C 115°C ≤ Tj ≤ 125°C	44% 41% 15%

Note 1. The ambient temperature (Ta) should be no less than -40ºC in a low-temperature environment.

4. Reference Document

- Semiconductor Reliability Handbook Rev1.00 (R51ZZ0001EJ0100) 2012.9

Website and Support

Renesas Electronics website

http://www.renesas.com/

Inquiries

http://www.renesas.com/inquiry

Revision History	Application Note: Notes on Operation at High Temperatures

Rev.	Date	Description	
		Page	Summary
1.00	Aug. 09, 2016	—	First Edition issued

General Precautions in the Handling of MPU/MCU Products

The following usage notes are applicable to all MPU/MCU products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Handling of Unused Pins

   Handle unused pins in accordance with the directions given under Handling of Unused Pins in the manual.

   — The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible. Unused pins should be handled as described under Handling of Unused Pins in the manual.

2. Processing at Power-on

   The state of the product is undefined at the moment when power is supplied.

   — The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the moment when power is supplied.
   In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the moment when power is supplied until the reset process is completed.
   In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the moment when power is supplied until the power reaches the level at which resetting has been specified.

3. Prohibition of Access to Reserved Addresses

   Access to reserved addresses is prohibited.

   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

4. Clock Signals

   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has stabilized.

   — When the clock signal is generated with an external resonator (or from an external oscillator) during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Moreover, when switching to a clock signal produced with an external resonator (or by an external oscillator) while program execution is in progress, wait until the target clock signal is stable.

5. Differences between Products

   Before changing from one product to another, i.e. to a product with a different part number, confirm that the change will not lead to problems.

   — The characteristics of an MPU or MCU in the same group but having a different part number may differ in terms of the internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

SALES OFFICES Renesas Electronics Corporation http://www.renesas.com

Refer to "http://www.renesas.com/" for the latest and detailed information.

Renesas Electronics America Inc.
2801 Scott Boulevard Santa Clara, CA 95050-2549, U.S.A.
Tel: +1-408-588-6000, Fax: +1-408-588-6130

Renesas Electronics Canada Limited
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K
Tel: +44-1628-585-100, Fax: +44-1628-585-900

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
Room 1709, Quantum Plaza, No.27 ZhiChunLu Haidian District, Beijing 100191, P.R.China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, P. R. China 200333
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852 2886-9022

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886 2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics India Pvt. Ltd.
No.777C, 100 Feet Road, HAL II Stage, Indiranagar, Bangalore, India
Tel: +91-80-67208700, Fax: +91-80-67208777

Renesas Electronics Korea Co., Ltd.
12F., 234 Teheran-ro, Gangnam-Gu, Seoul, 135-080, Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5141

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