IGBT

Renesas automotive IGBT technology improvement

About this document

This document will discuss the trends in technology for Renesas's IGBT AE series.

Target Device

IGBT: AE5

Contents

1. Introduction

1.1 Overview

Renesas IGBT and FRD have been widely adopted for chips using advanced wafer technology. It has been widely used in power module of HEV/EV development in power train applications. Renesas has developed the Insulated Gate Bipolar Transistor (IGBT) AE series, optimized for automotive applications. This series utilizes a unique trench gate configuration and advanced process technology to achieve superior performance, including low saturation voltage, without sacrificing robustness and minimizing switching loss.

In addition, Renesas offers a lineup of automotive power diodes, including Fast Recovery Diodes (FRD). These diodes offer low forward voltage and exhibit fast, soft recovery characteristics, achieved through Renesas's cutting-edge ultra-thin wafer technology and precise lifetime control.

These products deliver high-performance, high-quality bare die solutions for customers designing power modules.

1.2 IGBT coverage in HEV/EV System

The AE series of IGBTs is specifically designed for HEV/EV systems, with a voltage range spanning from 650V to 1200V, as illustrated in the IGBT Coverage figure.

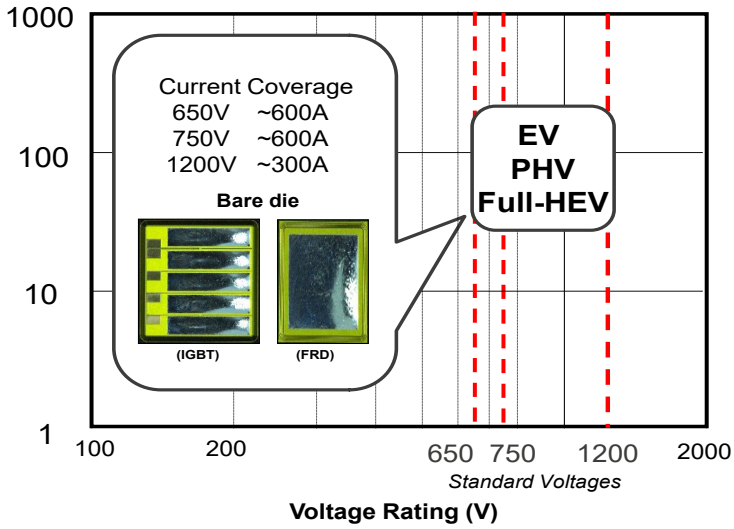

Figure 1-1 IGBT Coverage

The AE series has significantly advanced over time, with each iteration offering notable improvements. From AE3 to AE5, the series has achieved a 20% reduction in switching losses and a 10% reduction in conduction losses.

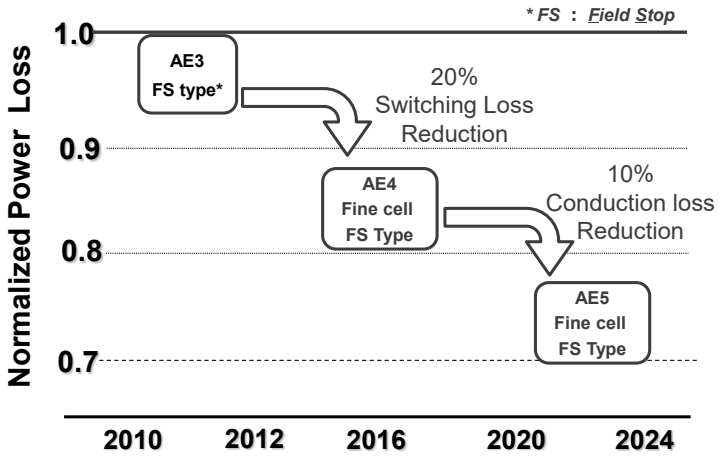

Figure 1-2 AE series IGBT Development Trend

2. Process Overview

2.1 Cell structure and advantages

In the AE5 design, the emitter trench design further enhances performance by reducing parasitic capacitance between the gate and other regions of the IGBT. Lower capacitance enables the gate to switch on and off more quickly, allowing for faster switching speeds, which is crucial in high-speed applications where quick transitions are necessary.

Additionally, the emitter trench improves the robustness of the IGBT by helping charge carriers (like electrons) escape more effectively, reducing the risk of overheating and stress on the device. This smoother flow of charge keeps the device cooler and more reliable, making it stronger and better equipped to handle high levels of stress without breaking down.

All the above give Renesas IGBT an advantage to be top-class low loss performance and provide bare chips that achieve in high quality.

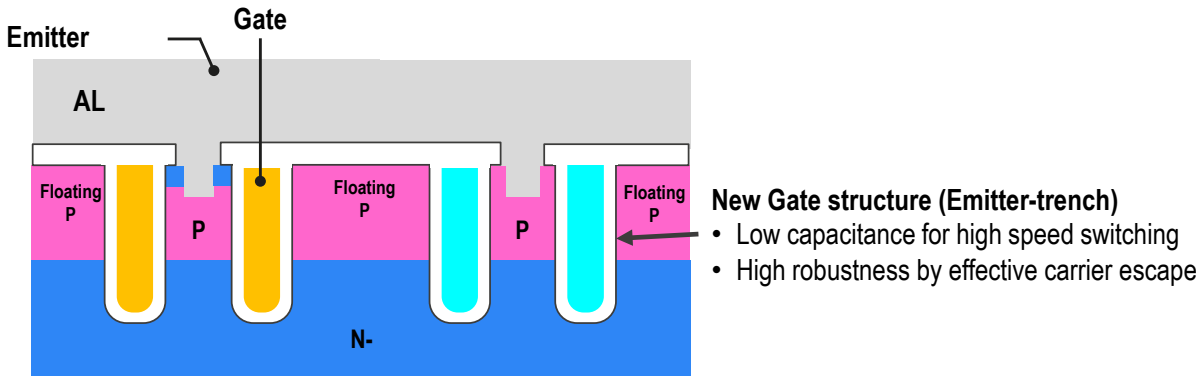

Figure 2-1 New Gate Structure (Emitter-Trench)

2.2 Renesas IGBT: AE5

Renesas AE series IGBT is optimized for automotive applications, using a unique trench gate technology to achieve low saturation voltage while maintaining robustness and reducing switching losses. The latest series of IGBT products (AE5) has offered high-performance bare die products for power module designers. It improves electrical characteristics by reducing both conduction and switching losses by 10% and provides a 50% better V_{GE}(th) distribution compared to the older model.

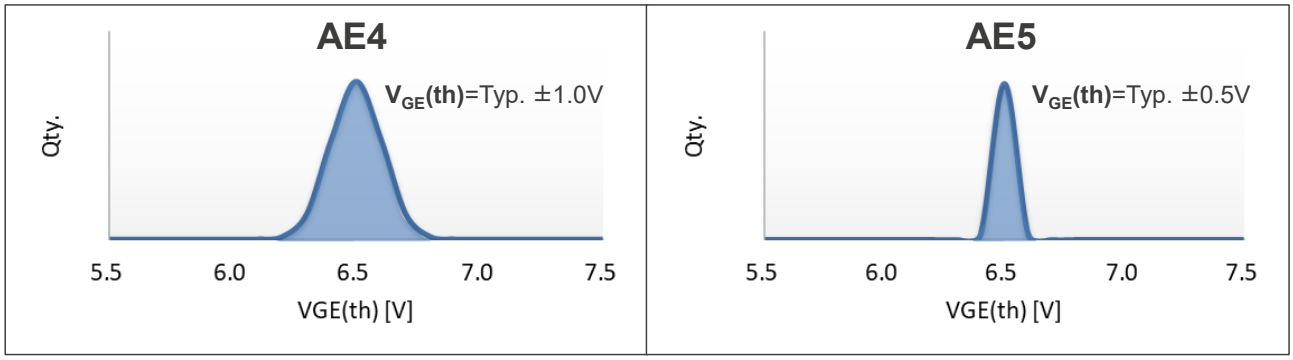

Figure 2-2 V_{GE}(th) Distribution Comparison

Renesas offers a lineup of anti-ring products in the AE series with featuring built-in gate resistor (rg), as shown in the figure below. This series includes several excellent features:

- AEC Q101(HTRB, HTGB) qualified
- 750V Trench & Field-Stop AE5 Technology
- Lower Collector-Emitter Saturation Voltage, V_{CE}(sat) of 1.35V typ.
- Low switching loss
- Narrow V_{GE}(th) distribution
- Well-designed Short-circuit withstand time (TSC)

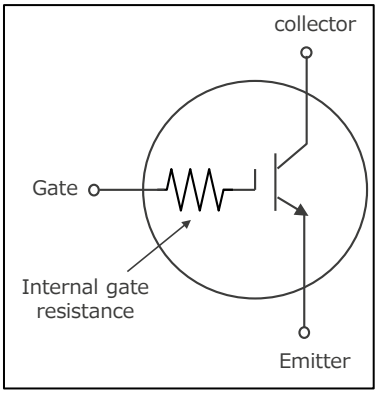

Figure 2-3 The AE5 IGBT with built-in gate resistor

3. Result Improvement for AE4 vs AE5

Renesas has enhanced the manufacturing process and developed the new AE5, incorporating advancements from AE4. The following section will explain and present the data highlighting the improvements between AE4 and AE5.

3.1 V_{CE}(sat) Reduction

By utilizing cell shrinkage, the AE5 achieves a lower V_{CE}(sat) at 350A/cm², showing a 9% reduction at 25°C (Left) and a 15% reduction at 175°C (Right) compared to the AE4 in measured results.

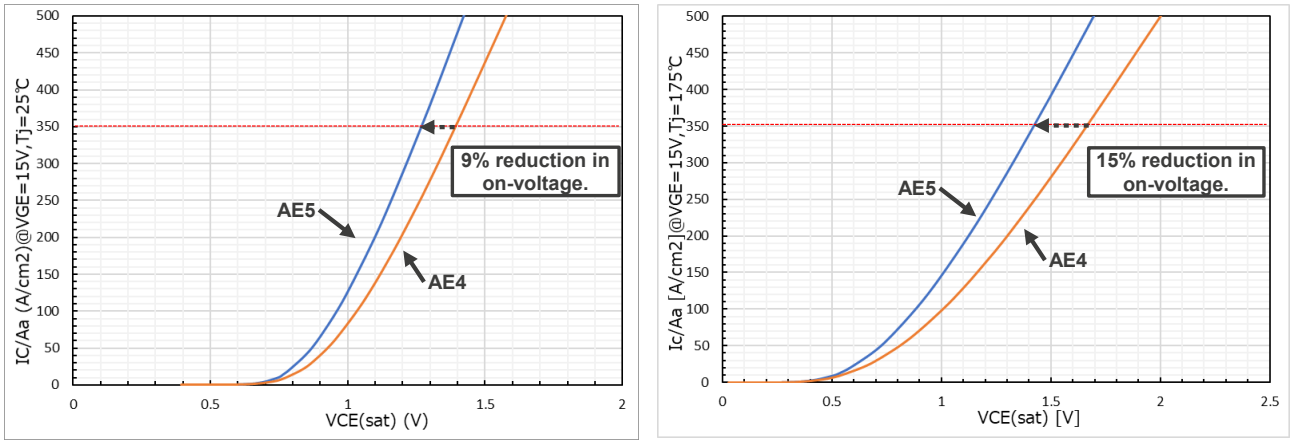

Figure 3-1 V_{CE}(sat) reduction on different temperature level

3.2 V_{GE}(off) Impact on Performance

The performance of V_{GE}(off) directly affects conduction and switching losses, with a narrower V_{GE}(off) width leading to reduced overall losses. Below are the measurement results for V_{CE}(sat), Eoff, and Eon, showing how they are influenced by V_{GE}(off) and comparing the changes between AE4 and AE5.

The graph plots show the measurement result with different temperature level 25°C (Left) and 175°C (Right).

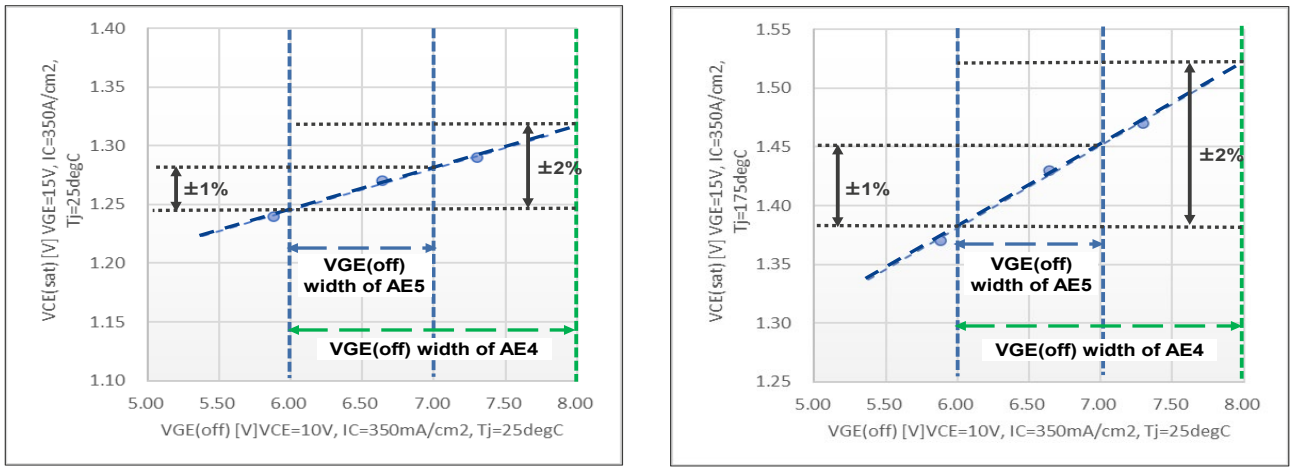

Figure 3-2 V_{GE}(off) vs VCE(sat)

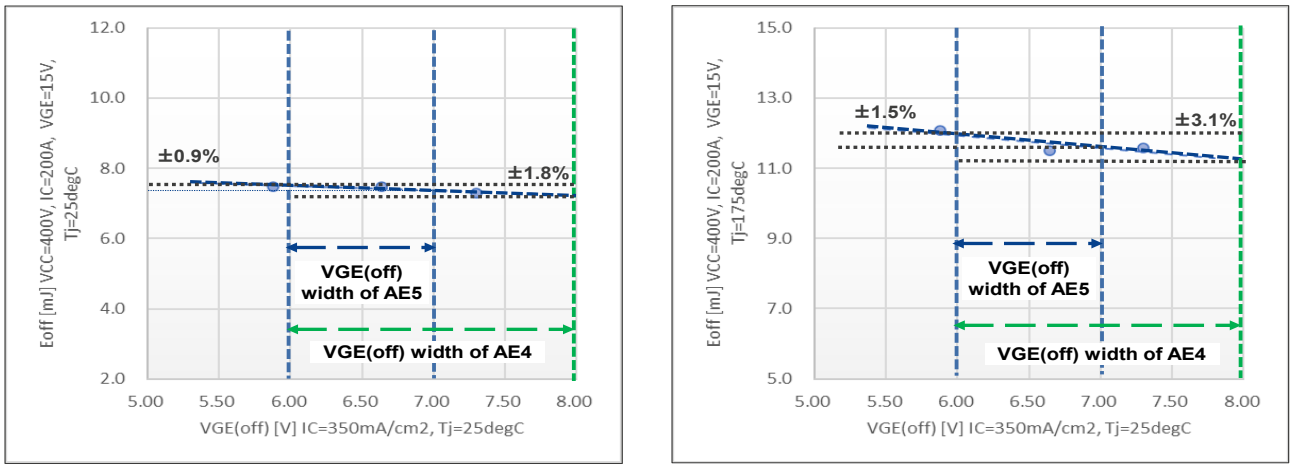

Figure 3-3 V_{GE}(off) vs TSC at 25°C

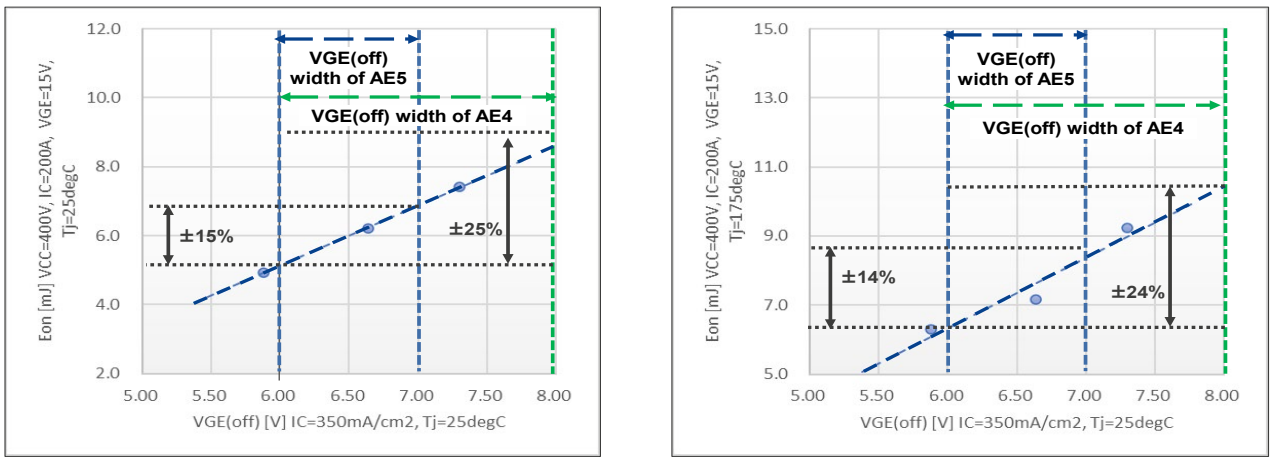

Figure 3-4 V_{GE}(off) vs TSC at 175°C

3.3 Short-circuit withstand time (TSC)

Reducing the V_{GE}(off) width helps decrease the TSC and enhances the device's response speed. By narrowing the V_{GE}(off) voltage range, the device's performance becomes more consistent, allowing it to detect anomalies and respond more quickly in short-circuit situations. This improvement not only shortens the TSC, protecting the device from severe damage, but also ensures more stable performance under varying conditions. Therefore, narrowing the V_{GE}(off) width is an effective method to enhance the device's safety and reliability.

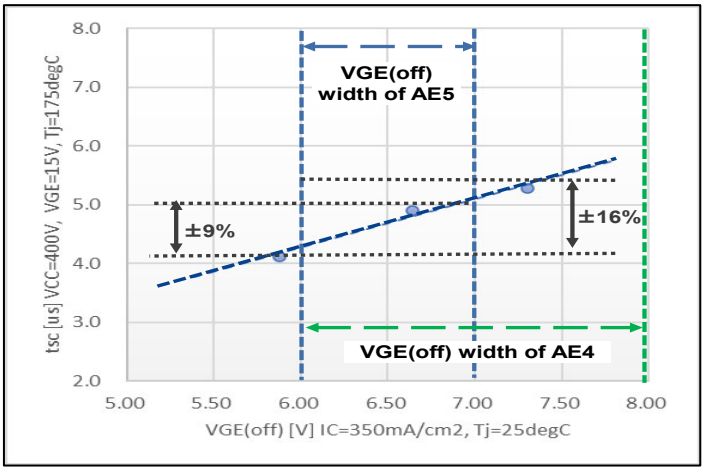

Figure 3-5 V_{GE}(off) vs TSC at 175°C

3.4 Short-circuit Test for AE5

Renesas has used the AE5 IGBT to perform the short-circuit test. The condition and result are shown as below:

VCC=400V, VGE=15V, Rg_on=5.6ohm, Rg_off=47ohm, Tj=175degC, Ls≒30nH, Built-in Rg=4ohm

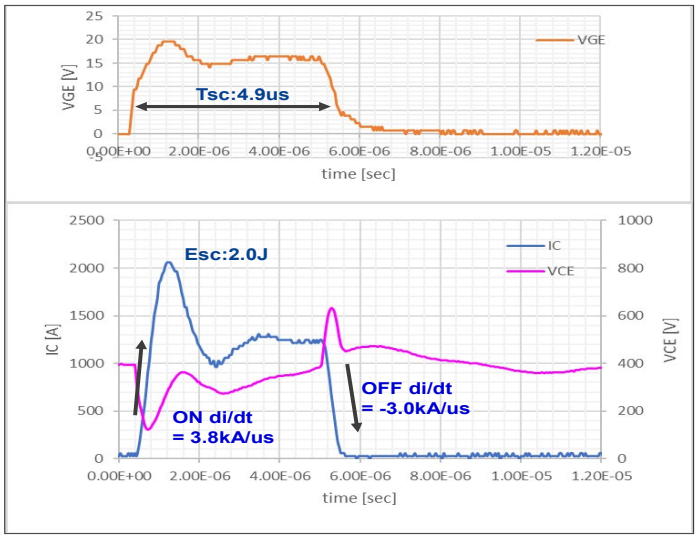

Figure 3-6 Short-circuit test waveform

3.5 Ringing Behavior Comparison

The comparison of the waveform during the recovery operation of three types of IGBT + FRD products with VCC = 475V and IF = 50A

The waveform shows a comparison of three products regarding surge and ringing during the recovery operation. The AE 5 product demonstrates better performance with no ringing compared to the other two products.

Table 3-5 Ringing Judgment

IF \ VCC	AE5	Competitor's A	Competitor's B
50A @ 475V	√	×	×

Note: ✓= No Ringing (Passed), × = Ringing (Failed)

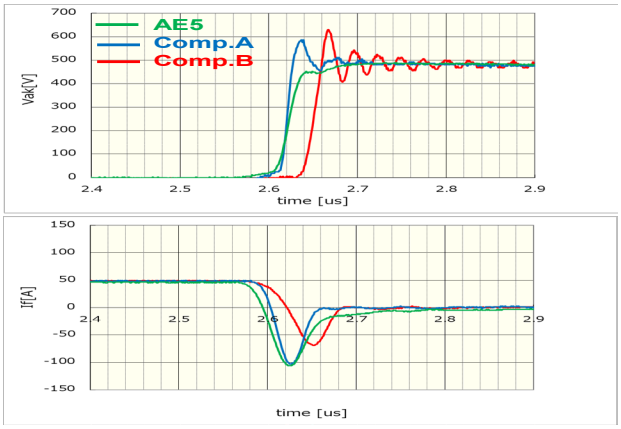

Figure 3-7 FRD waveform comparison during recovery operation

4. Conclusion

In conclusion, this application note highlights and explains the improvements made in the AE series IGBT with the introduction of the AE5. Based on the data measurements and comparisons, it is evident that the AE5 outperforms the older AE4 model and other similar competitors' products.

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	10.10.2024.	-	First edition

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall be responsible for determining what licenses are required from any third parties, and obtaining such licenses for the lawful import, export, manufacture, sales, utilization, distribution or other disposal of any products incorporating Renesas Electronics products, if required.
5. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
6. Renesas Electronics products are classified according to the following two quality grades: “Standard” and “High Quality”. The intended applications for each Renesas Electronics product depends on the product’s quality grade, as indicated below.
   "Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.
   "High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.

   Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user’s manual or other Renesas Electronics document.
7. No semiconductor product is absolutely secure. Notwithstanding any security measures or features that may be implemented in Renesas Electronics hardware or software products, Renesas Electronics shall have absolutely no liability arising out of any vulnerability or security breach, including but not limited to any unauthorized access to or use of a Renesas Electronics product or a system that uses a Renesas Electronics product. RENESAS ELECTRONICS DOES NOT WARRANT OR GUARANTEE THAT RENESAS ELECTRONICS PRODUCTS, OR ANY SYSTEMS CREATED USING RENESAS ELECTRONICS PRODUCTS WILL BE INVULNERABLE OR FREE FROM CORRUPTION, ATTACK, VIRUSES, INTERFERENCE, HACKING, DATA LOSS OR THEFT, OR OTHER SECURITY INTRUSION (“Vulnerability Issues”). RENESAS ELECTRONICS DISCLAIMS ANY AND ALL RESPONSIBILITY OR LIABILITY ARISING FROM OR RELATED TO ANY VULNERABILITY ISSUES. FURTHERMORE, TO THE EXTENT PERMITTED BY APPLICABLE LAW, RENESAS ELECTRONICS DISCLAIMS ANY AND ALL WARRANTIES, EXPRESS OR IMPLIED, WITH RESPECT TO THIS DOCUMENT AND ANY RELATED OR ACCOMPANYING SOFTWARE OR HARDWARE, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE.
8. When using Renesas Electronics products, refer to the latest product information (data sheets, user’s manuals, application notes, “General Notes for Handling and Using Semiconductor Devices” in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
9. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
11. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
12. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
13. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
14. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note1) “Renesas Electronics” as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.

(Note2) “Renesas Electronics product(s)” means any product developed or manufactured by or for Renesas Electronics.

(Rev.5.0-1 October 2020)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.

Contact information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:
www.renesas.com/contact/.