

IGBT

How to tune Renesas IGBT performance

Introduction

This document will discuss how to tune the performance for Renesas's IGBT AE5 series.

Target Device

IGBT: AE5

Contents

1. IGBT Improvements overview.....	2
2. Adjustment of drive gate voltage.....	2
3. Confirmation of robustness by increasing gate voltage.....	4
4. Further Improvement for turn-off loss by adjusting turn-off gate resistance.....	5
5. Summary for the improvements.....	6
6. Conclusion.....	6
7. References Application Note	6
Revision History	7

1. IGBT Improvements overview

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.

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

This document provides how to maximize IGBT performance of the Renesas AE5 series.

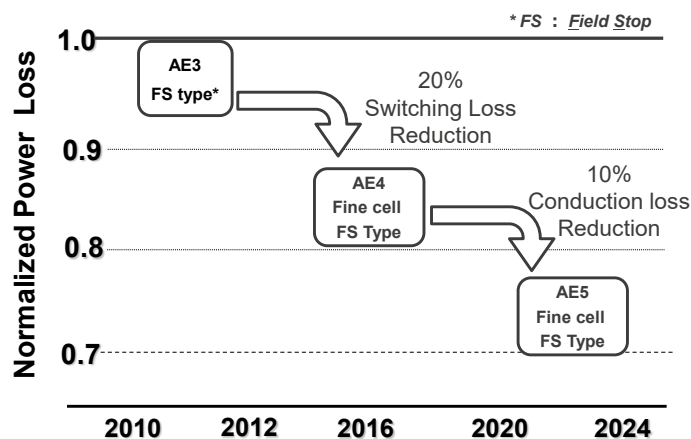


Figure 1-1 AE series IGBT Development Trend

2. Adjustment of drive gate voltage

In the AE5 design, IGBT is optimized for automotive applications, using a unique trench gate technology to achieve low saturation voltage while maintaining robustness and reducing switching losses. In normal usage, the recommended gate voltage is 15 V.

However, the performance of on-voltage $V_{ce(sat)}$ and turn-on loss (E_{on}) can be further improved by increasing the gate drive voltage. The following table shows the improvement by VGE 15V to 18V for the Renesas AE5 series IGBT & FRD combination, RBN300N75A5JWS & RBC300A75F3JWS (750V-300A).

Table 2-1 Reduced Loss by Changing VGE

VGE	VCE(sat) @150degC	Eon @150degC	Eoff @150degC
15V	1.57V	17.0 mJ	32.6 mJ
18V	1.49V	8.4 mJ	32.4 mJ
Improvement	-5%	-50%	+/-0%

Target Device: RBN300N75A5JWS (IGBT) & RBC300A75F3JWS (FRD)

SW conditions: VCC=400V, IC=450A (2 parallel devices), VGE=15V or 18V, Rg_on/off=4.8/15 Ohm, Tj=150degC

Increasing the gate drive voltage from 15V to 18V reduces the on-voltage $V_{ce(sat)}$ from 1.57V to 1.49V, a 5% reduction, and the turn-on loss (E_{on}) from 17.0mJ to 8.4mJ, a 50% reduction. There is no effect on turn-off loss (E_{off}) by changing gate drive voltage.

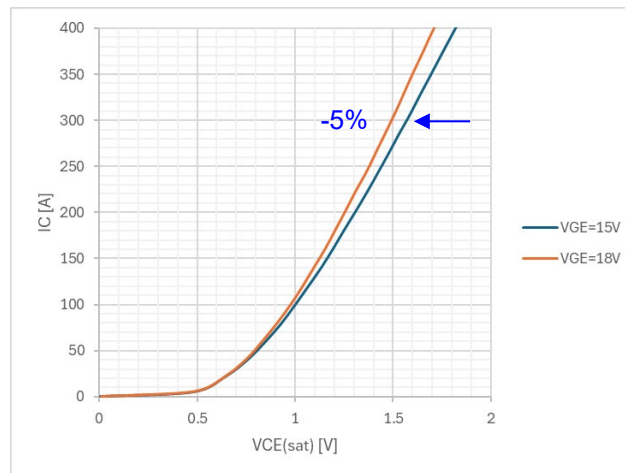
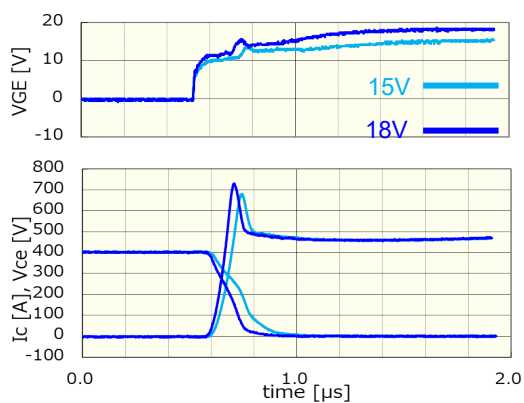
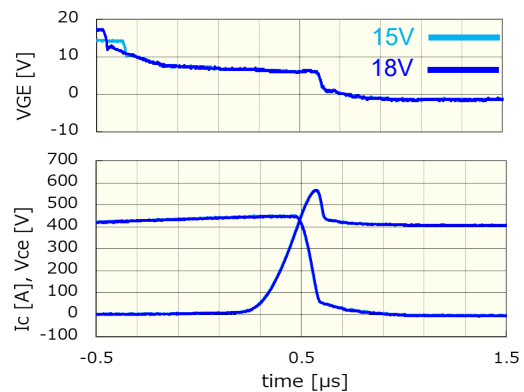


Figure 2-1 $V_{CE(sat)}$ Comparison



Turn on waveform comparison



Turn off waveform comparison

Figure 2-2 Turn on/off Waveform

3. Confirmation of robustness by increasing gate voltage

This section describes the robustness when the gate drive voltage is increased. In general, as the drive gate voltage of IGBTs is increased, the short-circuit withstand capability deteriorates due to the increased energy input.

The Renesas AE5 series IGBTs feature high robustness under high gate-voltage drive conditions. The following figure shows the evaluation results of the short-circuit withstand capability between other company's product and the Renesas AE5 IGBT.

In the other company's product, the destruction of the device has occurred due to insufficient dynamic breakdown capability under the drive condition of $V_{GE}=17V$.

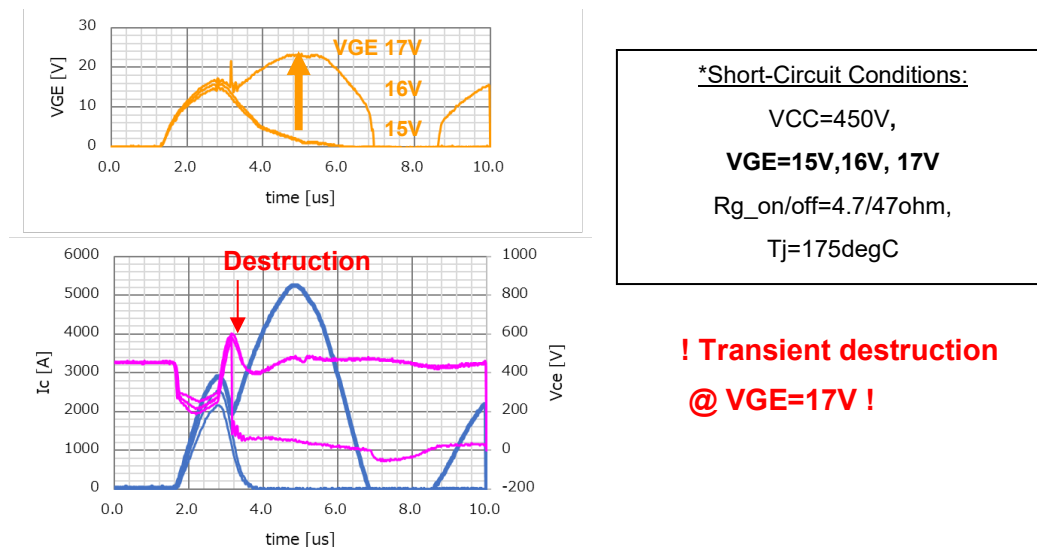


Figure 3-1 Other companies IGBT Short-Circuit Waveform Results

In contrast, the Renesas AE5 series is designed to safely turn on/off without damage up to $V_{GE} = 20V$, even if the high di/dt condition such as 5kA/ μ sec.

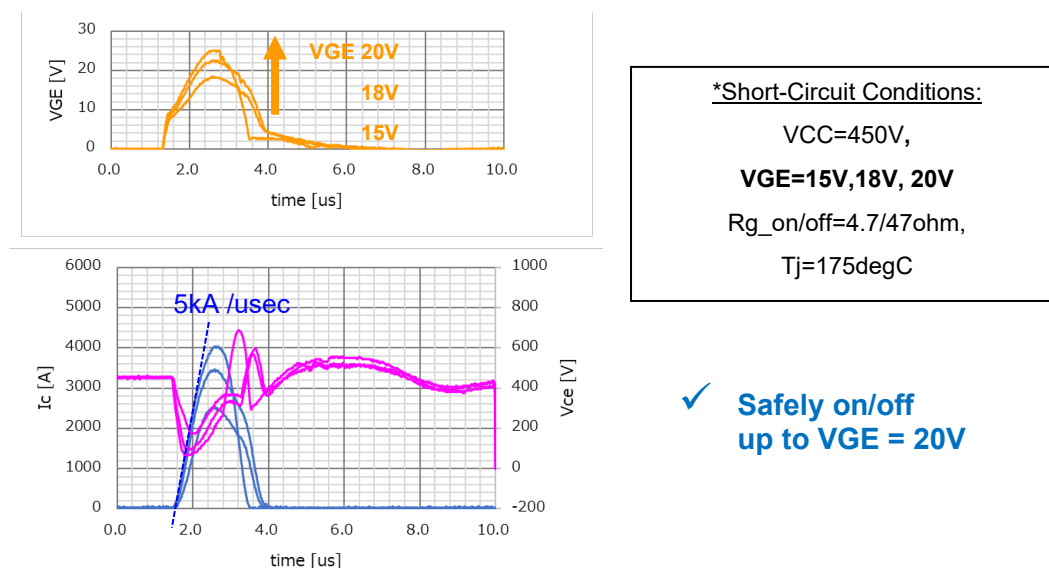


Figure 3-2 Renesas AE5 Short-Circuit Waveform Results

4. Further Improvement for turn-off loss by adjusting turn-off gate resistance

In the Renesas IGBT AE5 series, it can be reduced the gate resistance while maintaining the surge voltage generated during turn-off within the breakdown voltage level.

By reducing the off-side gate resistance from 15Ω to 7.5Ω, the turn-off loss (E_{off}) can be reduced from 32.6mJ to 27.1mJ while maintaining the surge voltage below the breakdown voltage level with a certain margin.

Table 4-1 Reduced Loss by Changing VGE

Gate Resistance (VGE-OFF)	E _{on} @150degC	E _{off} @150degC	Surge Voltage (turn off)
Rg _{off} =15ohm	17.0 mJ	32.6 mJ	568 V
Rg _{off} =7.5ohm	17.0 mJ	27.1 mJ	596 V
Improvement	+/- 0 %	-17%	+5%

Target Device: RBN300N75A5JWS (IGBT) & RBC300A75F3JWS (FRD)

SW conditions: VCC=400V, IC=450A (2 parallel devices), VGE=15V, Rg_{on/off}=4.8 Ohm / (15 or 7.5) Ohm, T_j=150degC

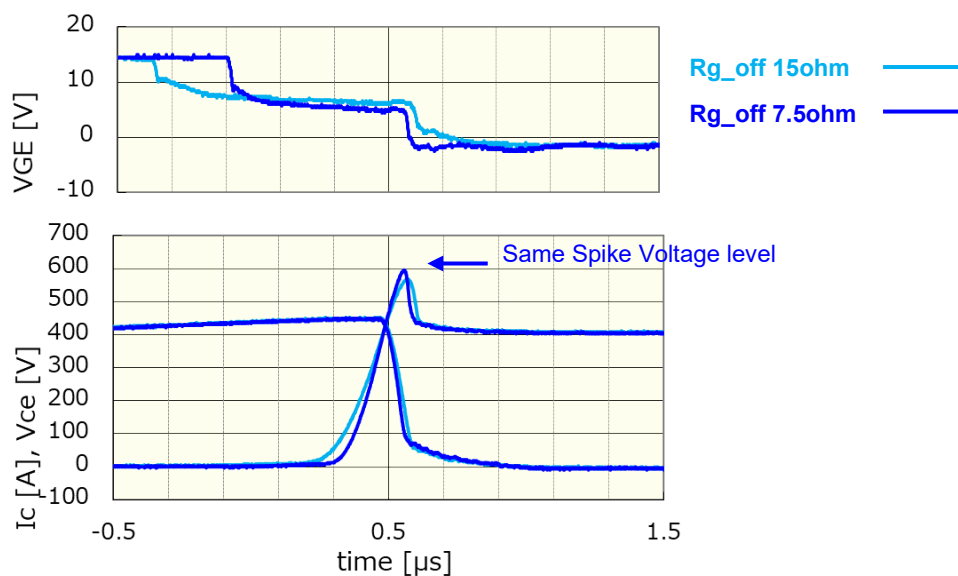


Figure 4-1 Turn off waveform comparison

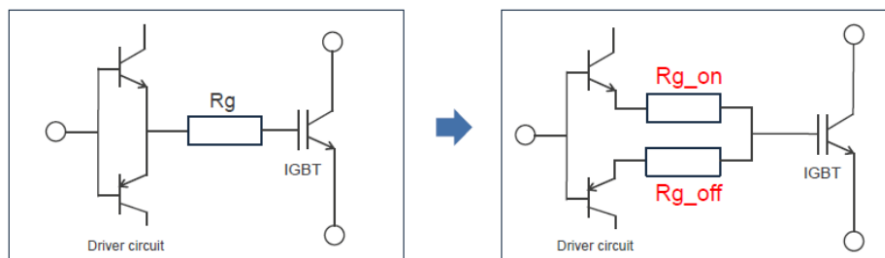


Figure 4-2 Gate Resistance Adjustment

5. Summary for the improvements

The Renesas IGBT AE5 series have high robust characteristics. By increasing its gate drive voltage from 15V to 18V, the IGBT's on-voltage $V_{ce(sat)}$ and turn-on loss E_{on} can be improved. Also, by reducing the Off-side gate resistance, the surge voltage can be kept below the breakdown voltage, and the turn-off loss (E_{off}) can be reduced.

The total power loss reduction summarizes the following table.

Table 5-1 Reduced Loss by Changing VGE & Rg_off

Setting of VGE (V)	Setting of Rg_off	Vce(sat)	Esw (= Eon + Eoff) @150degC
15 V	15 Ohm	1.57 V (+/- 0%)	49.6 mJ (+/- 0%)
15 V	7.5 Ohm	1.57 V (+/- 0%)	44.1mJ (- 11.1%)
18 V	15 Ohm	1.49 V (- 5%)	40.8 mJ (- 17.7%)
18 V	7.5 Ohm	1.49 V (- 5%)	35.5 mJ (- 28.4%)

Target Device: RBN300N75A5JWS (IGBT) & RBC300A75F3JWS (FRD)

SW conditions: VCC=400V, IC=450A (2 parallel devices), VGE=15V or 18V, Rg_on/off=4.8 Ohm / (15 or 7.5) Ohm, Tj=150degC

It is shown that by optimizing VGE and Rg_off, the on-voltage and the switching Loss could be reduced by 5% and 28.4%, respectively, compared to normal settings.

6. Conclusion

In conclusion, this application note highlights and explains the fine tuning for improvements in the IGBT AE5 series. Based on data measurements and comparisons, Renesas AE5 IGBTs are highly robust, highly durable, and can be used in a wide range of setting methods.

7. References Application Note

- [1] [IGBT Application Note](#): Renesas.com
- [2] [IGBT Usage Notes on Gate Drive](#): Renesas.com
- [3] [Renesas automotive IGBT technology improvement](#): Renesas.com

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	10.30.2024.	-	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/.