

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

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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.

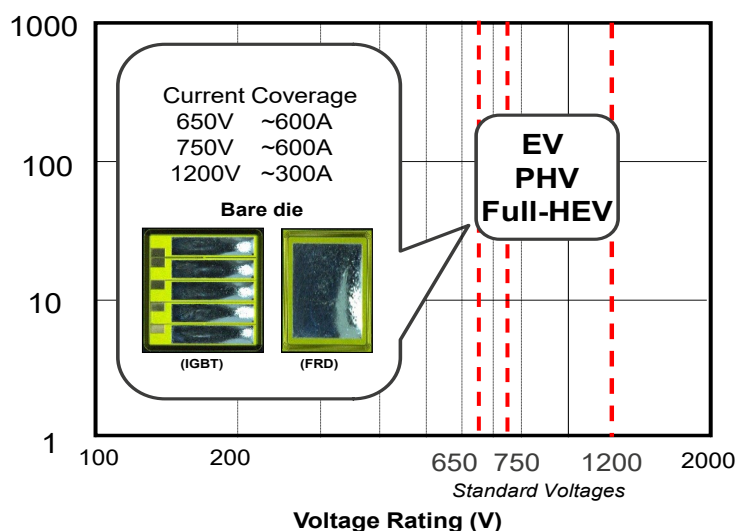


Figure 1-1 IGBT Coverage

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.

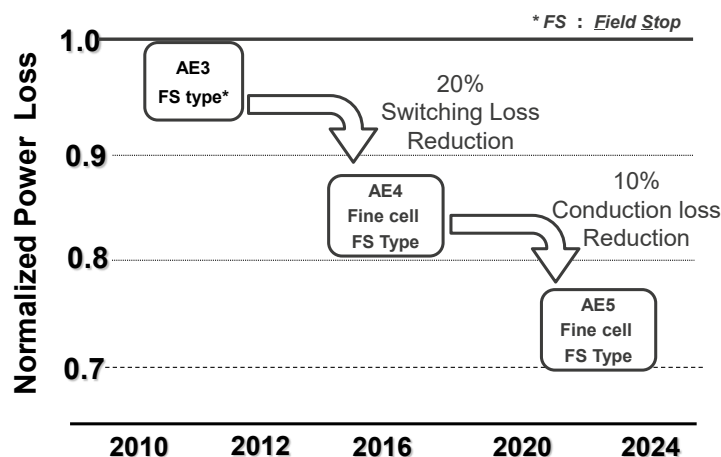


Figure 1-2 AE series IGBT Development Trend

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.

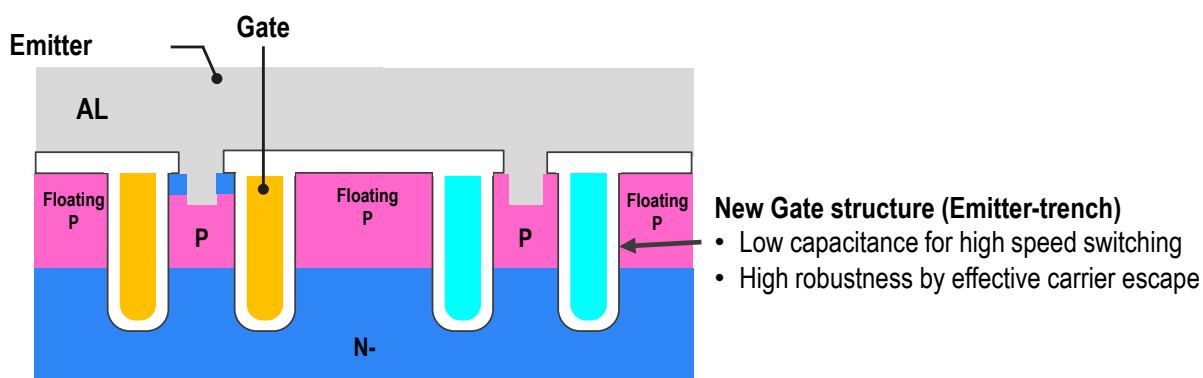


Figure 2-1 New Gate Structure (Emitter-Trench)

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.

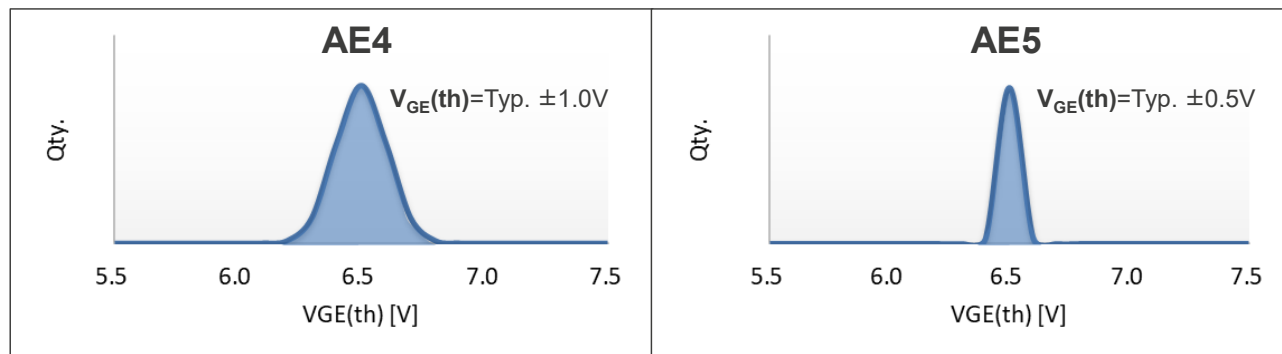


Figure 2-2 $V_{GE(th)}$ Distribution Comparison

Renesas offers a lineup of anti-ring products in the AE series with featuring built-in gate resistor (r_g), 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)

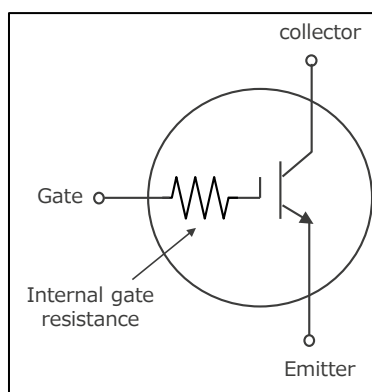


Figure 2-3 The AE5 IGBT with built-in gate resistor

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.

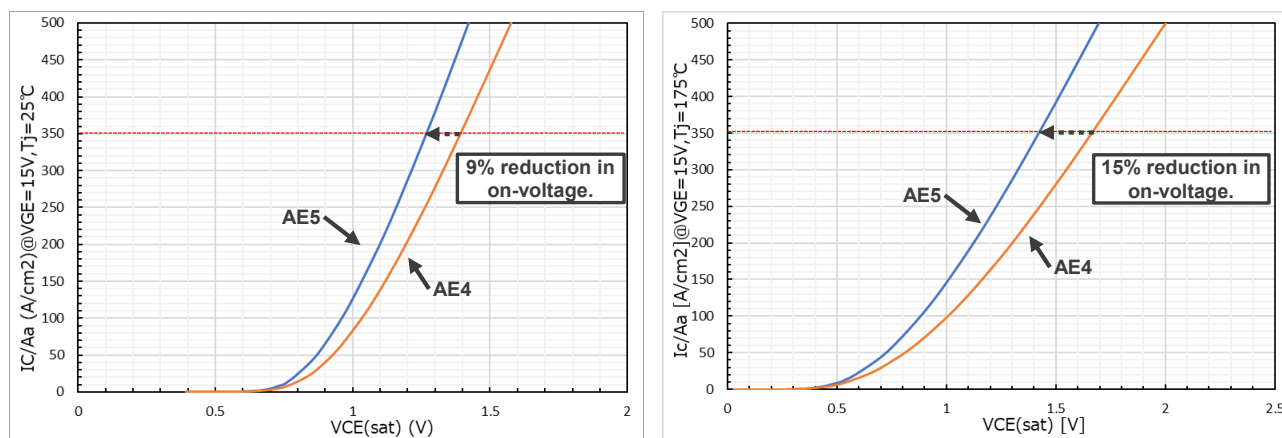


Figure 3-1 $V_{CE(sat)}$ reduction on different temperature level

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 $V_{CE(sat)}$, E_{off} , and E_{on} , 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).

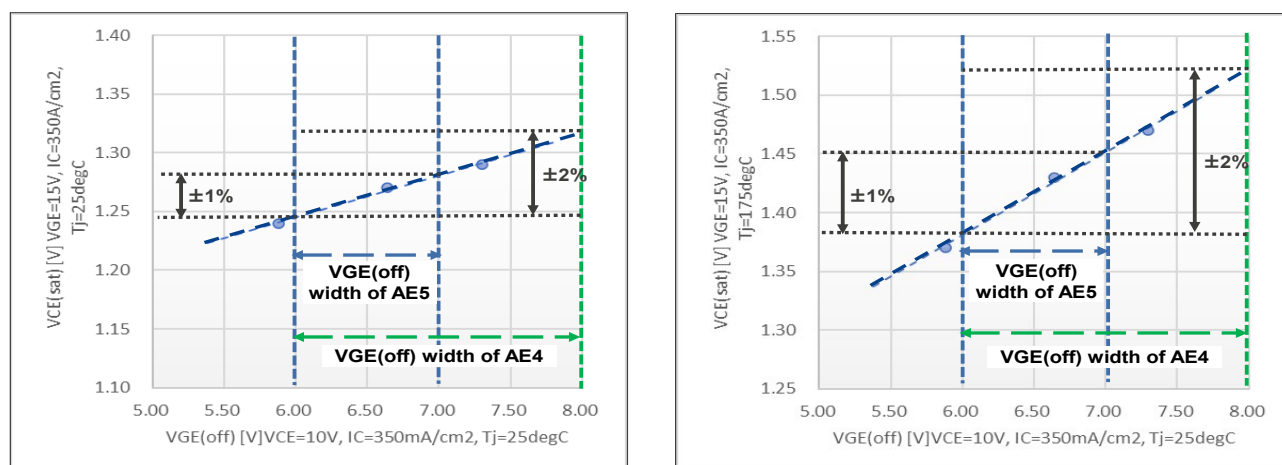
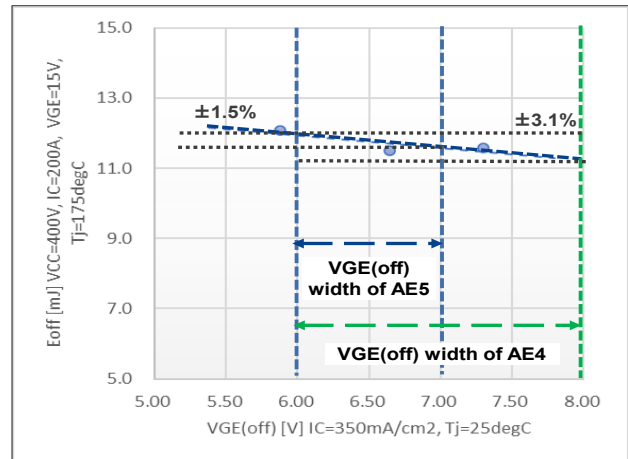
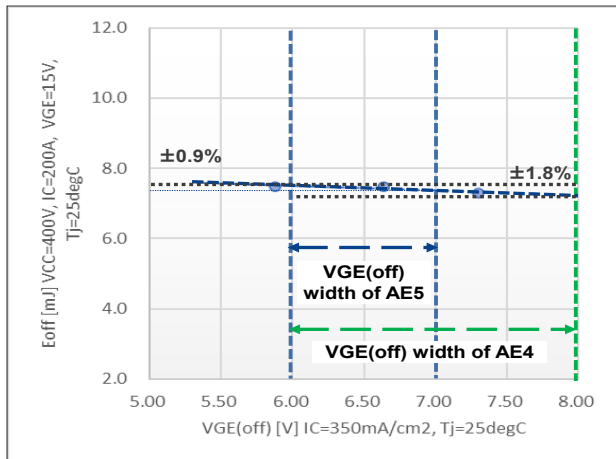
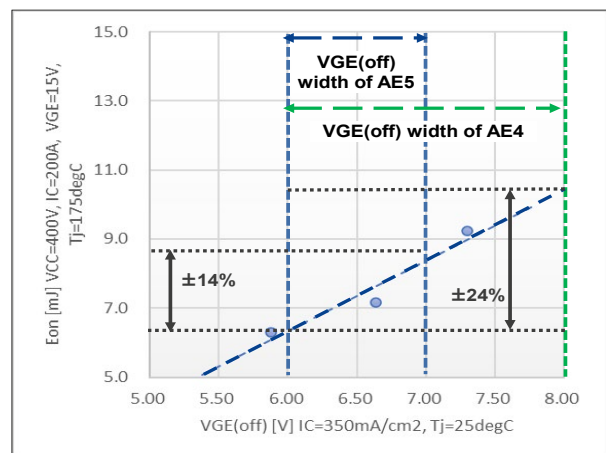
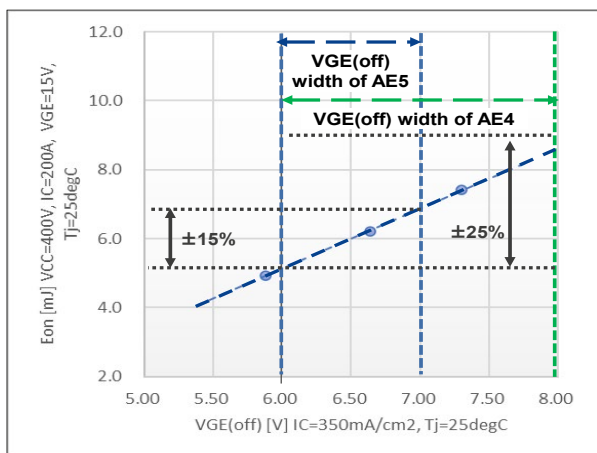


Figure 3-2 $V_{GE(off)}$ vs $V_{CE(sat)}$

Figure 3-3 $V_{GE(off)}$ vs TSC at 25°CFigure 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.

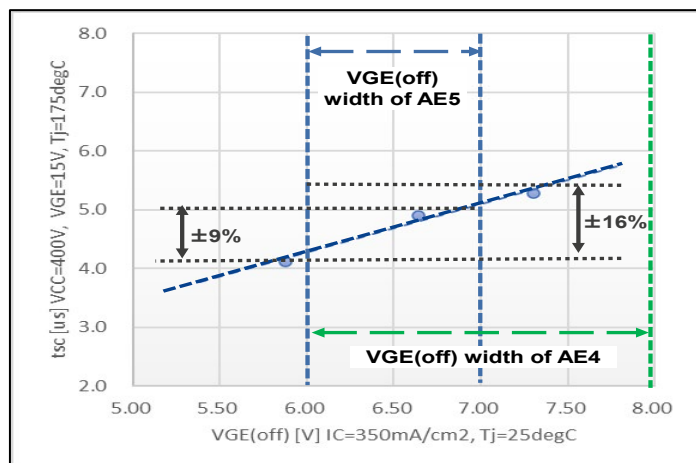


Figure 3-5 $V_{GE(off)}$ vs TSC at 175°C

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

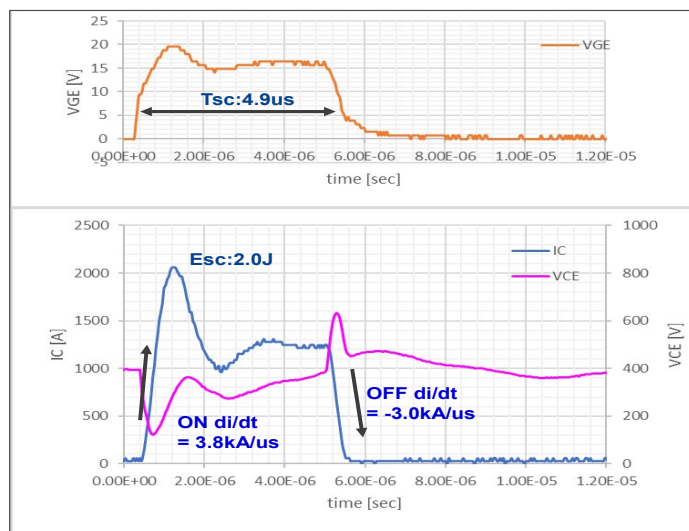


Figure 3-6 Short-circuit test waveform

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)

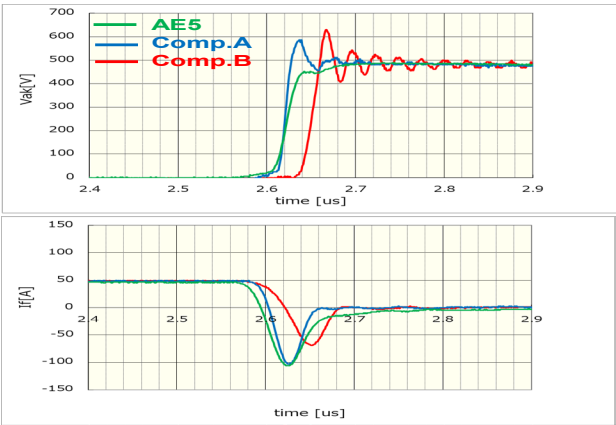


Figure 3-7 FRD waveform comparison during recovery operation

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

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