IGBT・FRD

AE5 IGBT and FRD ringing behavior benchmark

About this document

This document will discuss the basics of ringing behavior and compare the ringing behavior benchmark of Renesas product AE5 IGBT and FRD with other competitors

Target Device

IGBT & FRD: AE5

Contents

1. Introduction

1.1 Overview

Ringing behavior on an IGBT (Insulated Gate Bipolar Transistor) refers to the phenomenon of unwanted oscillations or voltage spikes that occur during the switching transitions of the transistor. This occurs due to parasitic inductances (such as PCB traces, wires, etc.) and capacitances (both internal and external to the IGBT) in the circuit when switching the IGBT on or off. These parasitic elements cause the voltage to oscillate, leading to ringing.

There are several impacts when ringing behavior occurs. The oscillations can impose stress on the IGBT and surrounding components due to high-frequency voltage spikes and current oscillations. This can increase heat dissipation and potentially lead to reliability issues over time. Additionally, the high-frequency components can generate electromagnetic interference (EMI), which can affect nearby electronic devices and communications if not properly controlled.

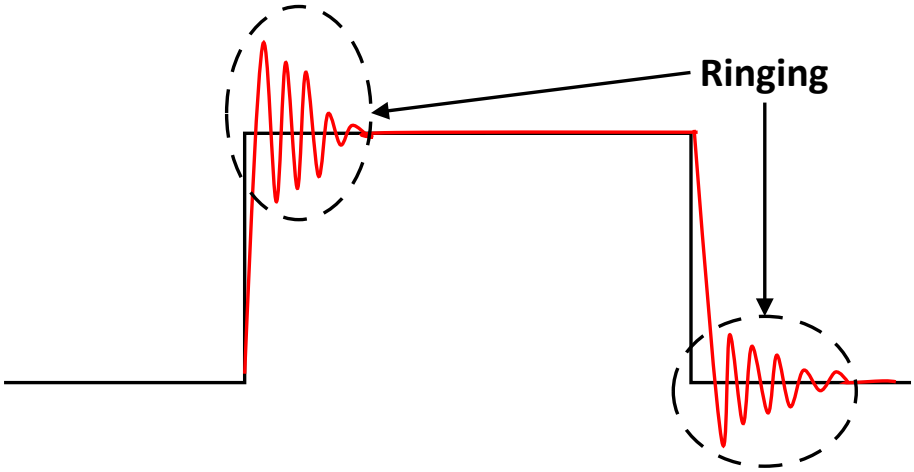

Figure 1-1 Ringing happen when switching transitions

1.2 Ringing behavior

Below is an illustration the recovery current produced by FRD recovery operation that generated a recovery surge at VGE. The Rg value need to be adjusted with consideration to the effect on loss.

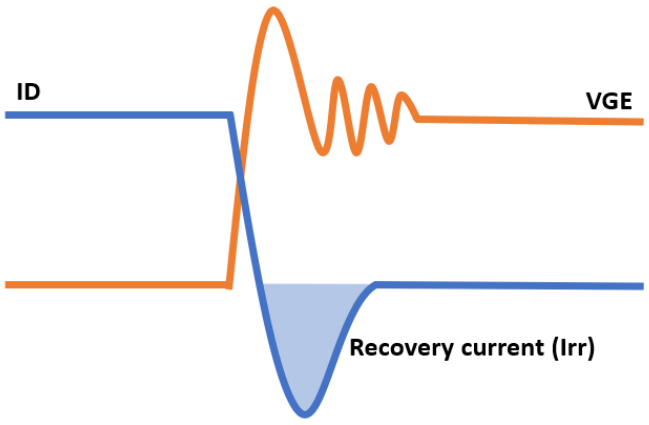

Figure 1-2 FRD waveform during the recovery operation

2. Renesas AE5 IGBT Solution

2.1 Advantage with internal gate resistance

Using an IGBT with a built-in gate resistor (rg) offers significant advantages in both cost efficiency and performance. One of the primary benefits is the elimination of the need for an external gate resistor (Rg), which reduces design complexity and lowers overall system costs.

Additionally, integrating the gate resistor directly into the IGBT helps to enhance switching performance by better controlling surge voltage and reducing ringing noise during recovery operations. This built-in feature improves the balance and stability of switching processes, leading to more reliable and efficient operation of power electronic systems.

By streamlining design and boosting operational performance, IGBTs with built-in rg provide a practical and effective solution for modern electronic applications.

2.2 Impact with Gate Resistor (Rg)

The gate resistor (Rg) plays a crucial role in managing switching speed and affecting the characteristics of the product. The table below shows how the external Rg value can impact these characteristics and highlights the need to consider its effects on the entire system.

Table 2-2 Impact of Rg on the key characteristic performance

Rg Value	Switching Time	Switching Loss	Surge Voltage	Ringing Noise
Smaller Rg	Faster	Lower	Higher	More
Large Rg	Slower	Higher	Lower	Less & stable

The resistor Rg affects the gate current (Ig) because the gate is charged or discharged during IGBT operation. If Ig is insufficient, it can directly impact the switching speed and increase losses. Therefore, to optimize IGBT switching performance, the circuit design should consider for both the chip built-in resistor rg and the internal resistor RS of the driver circuit.

$$Ig(peak) = \frac{VGE(on) - Vge(off)}{(RS + Rg + rg)min}$$

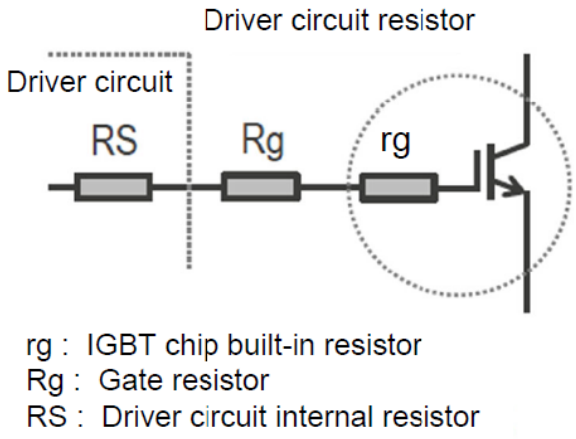

Figure 2-1 Gate Resistor

2.3 Renesas AE5 IGBT

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 of series product (AE5) has offers 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.

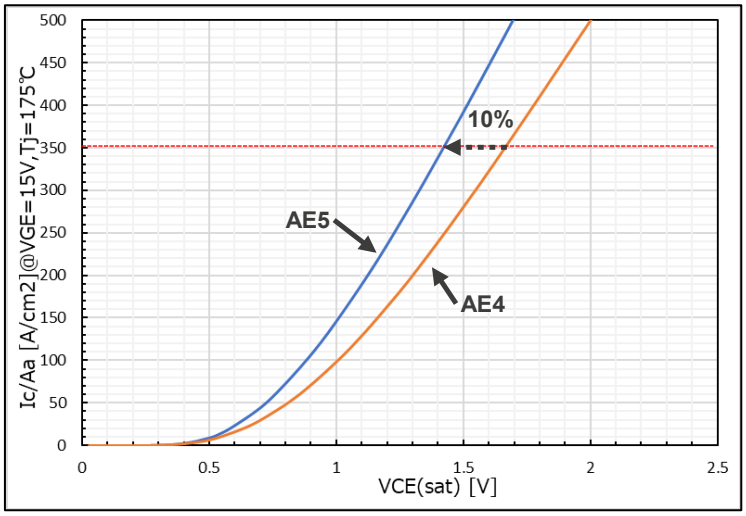

Figure 2-2 Output Characteristic

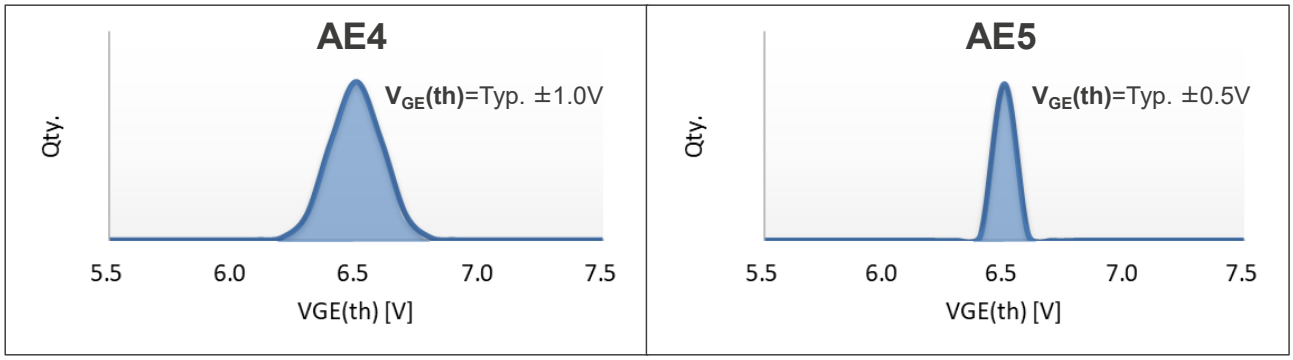

Figure 2-3 V_{GE}(th) Distribution Comparison

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:

- 750V Trench & Field-Stop AE5 Technology
- Lower Collector-Emitter Saturation Voltage, $V_{CE(sat)}$ of 1.35V typ.
- Low switching loss
- Easy paralleling by internal gate resistance (rg) and narrow $V_{GE(th)}$ distribution
- AEC Q101(HTRB, HTGB) qualified

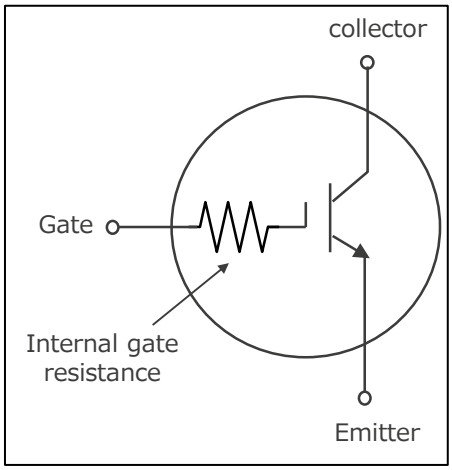

Figure 2-4 The AE5 IGBT with build-in gate resistor

3. Ringing behavior Benchmark Evaluation

In this section, Renesas has internally compare the ringing behavior performance of the Renesas AE5 IGBT with two other competitors' similar products available in the market. The measurements presented will highlight the advantages of the AE series. Below are the test conditions selected for the comparison.

Table 3 Test condition for benchmark

Test Item	Specification
VCC	400V, 475V, 530V
Forward Current (IF)	5A, 10A, 50A, 200A
Rg_on	2 Ω
Tj	25 °C

3.1 Renesas product AE5 (IGBT+ FRD)

The measurements were taken according to the table below, and it was observed that there is no ringing in the waveform. The waveform shown below was captured under the test conditions of VCC at 530V and IC at 5A. There are no surges or ringing observed under any conditions.

Table 3-1 Test result for AE5

IF \ VCC	400V	475V	530V
5A	√	√	√
10A	√	√	√
50A	√	√	√
200A	√	√	√

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

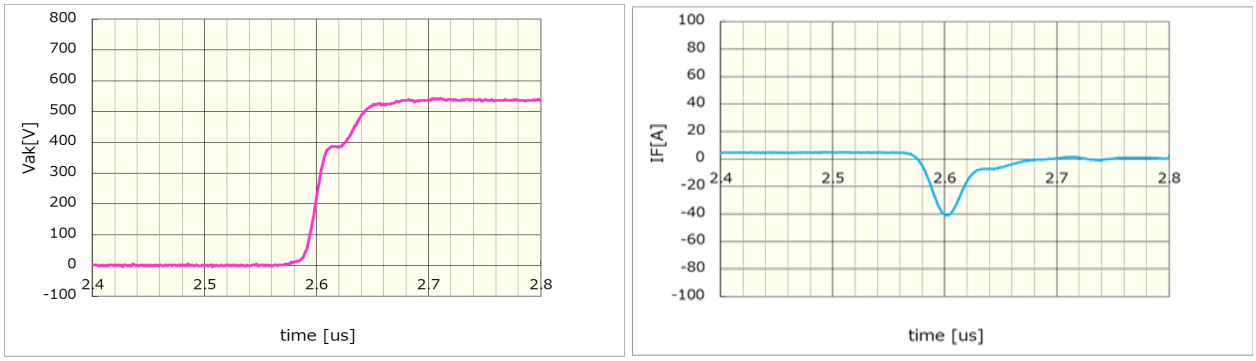

Figure 3-1 FRD waveform during recovery operation for AE5

3.2 Competitor A (IGBT + FRD)

The measurements were taken according to the table below, revealing that ringing occurred at 5A and 10A.

Table 3-2 Test result for Competitor A

IF \ VCC	400V	475V	530V
5A	×	×	×
10A	×	×	×
50A	√	√	√
200A	√	√	√

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

The waveform shown below was captured under the test conditions with VCC at 530V and IC at 5A. The surge level exceeds 200V, and ringing is occurring.

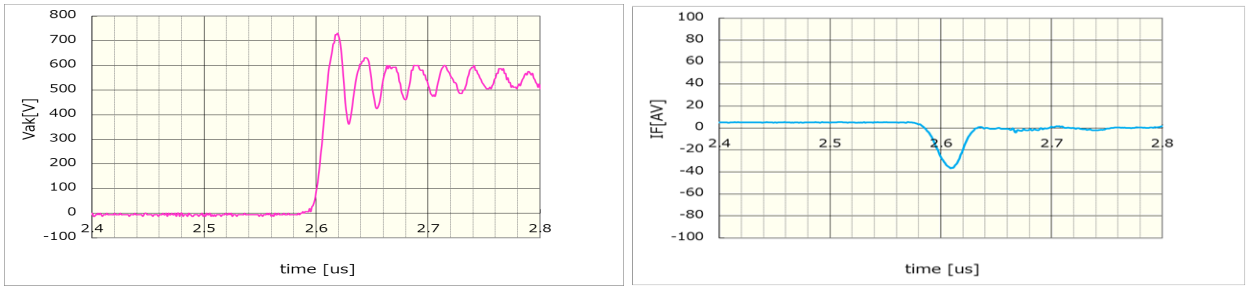

Figure 3-2 FRD waveform during recovery operation for Competitor A

3.3 Competitor B (IGBT + FRD)

The measurements were taken according to the table below, revealing that ringing occurred at 5A, 10A and 50A.

Table 3-3 Test result for Competitor B

IF \ VCC	400V	475V	530V
5A	×	×	×
10A	×	×	×
50A	×	×	×
200A	√	√	√

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

The waveform shown below was captured under the test conditions with VCC at 530V and IC at 5A. The surge level exceeds 150V, and ringing is occurring.

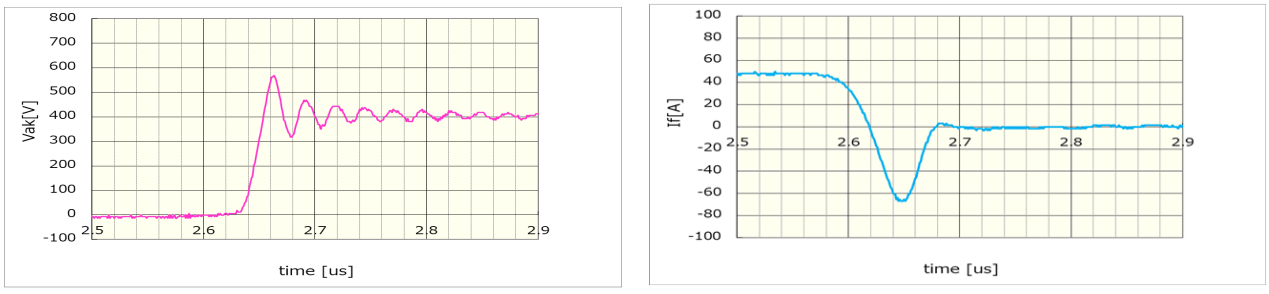

Figure 3-3 FRD waveform during recovery operation for Competitor B

3.4 Ringing behavior comparison

The comparison of the waveform during the recovery operation of three types of IGBT + FRD products under two different conditions

- Condition A: VCC = 475V and IF = 5A
- Condition B: VCC = 475V and IF = 50A

3.4.1 Condition A: VCC = 475V and IF = 5A

The waveform compares three products in terms of surge and ringing during recovery operation. Product Competitor A exhibits ringing at 5A, whereas the AE5 shows superior performance with no ringing compared to the other two products.

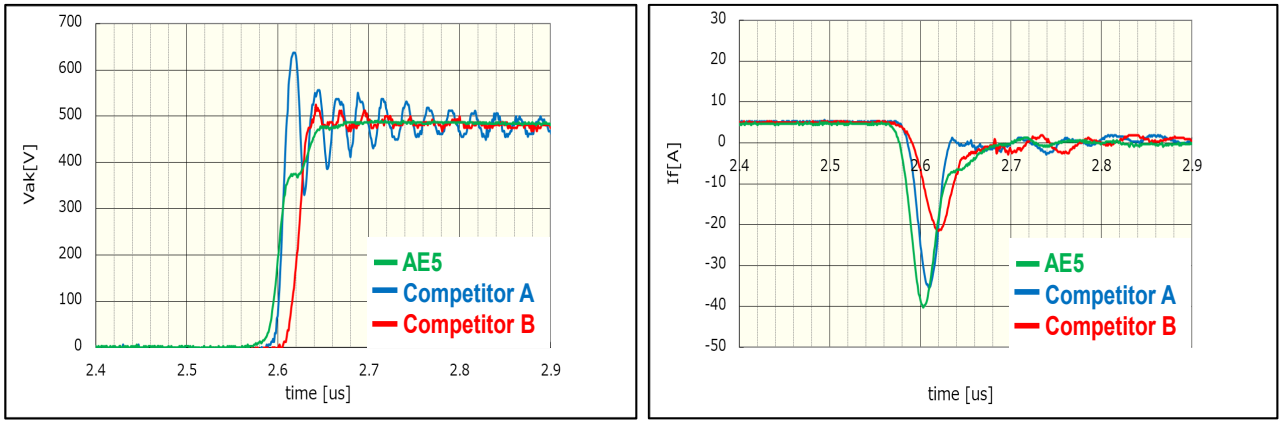

Figure 3-4 FRD waveform comparison during recovery operation

3.4.2 Condition B: VCC = 475V and IF = 50A

The waveform compares three products in terms of surge and ringing during recovery operation. Product Competitor B exhibits ringing at 50A, whereas the AE5 shows superior performance with no ringing compared to the other two products.

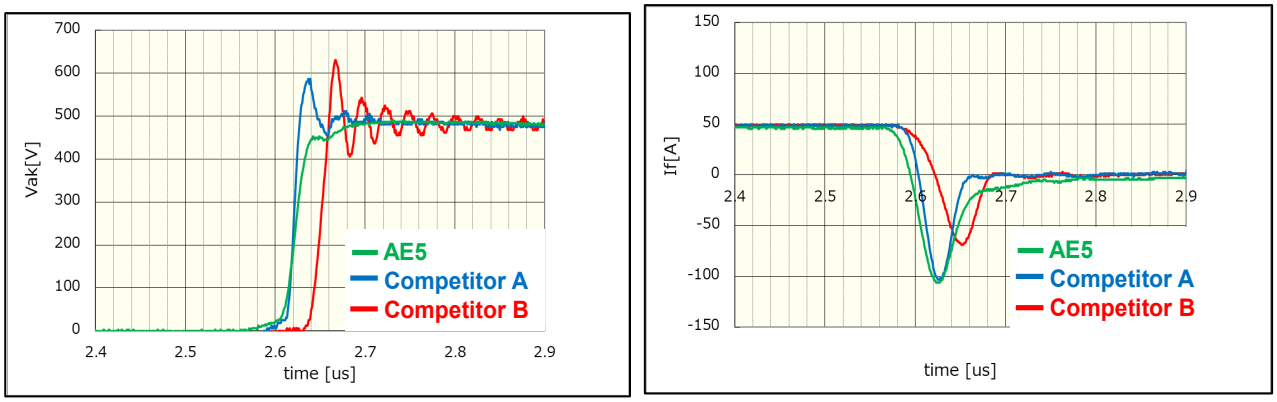

Figure 3-5 FRD waveform comparison during recovery operation

4. Conclusion

In conclusion, the ringing behavior of the IGBT affects product performance over time. Choosing a product with good ringing characteristics during surge recovery can improve durability and overall outcomes. Based on the measurements, the AE5 product demonstrates superior performance compared to the other two types.

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Aug.21.24	-	First edition

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