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

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.

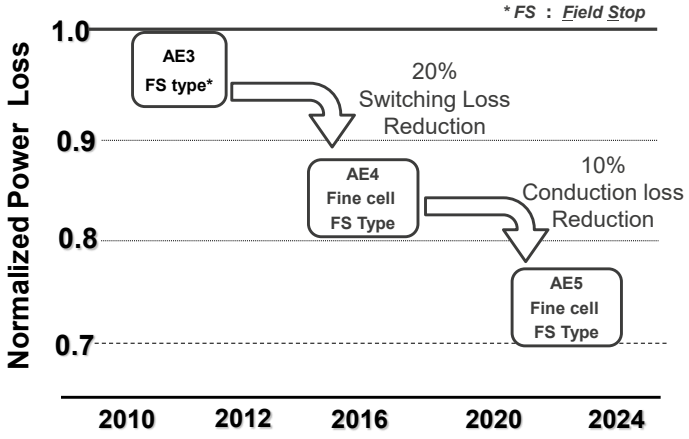


Figure 1-1 AE series IGBT Development Trend

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 Vce(sat) and turn-on loss (Eon) 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 Vce(sat) from 1.57V to 1.49V, a 5% reduction, and the turn-on loss (Eon) from 17.0mJ to 8.4mJ, a 50% reduction. There is no effect on turn-off loss (Eoff) by changing gate drive voltage.

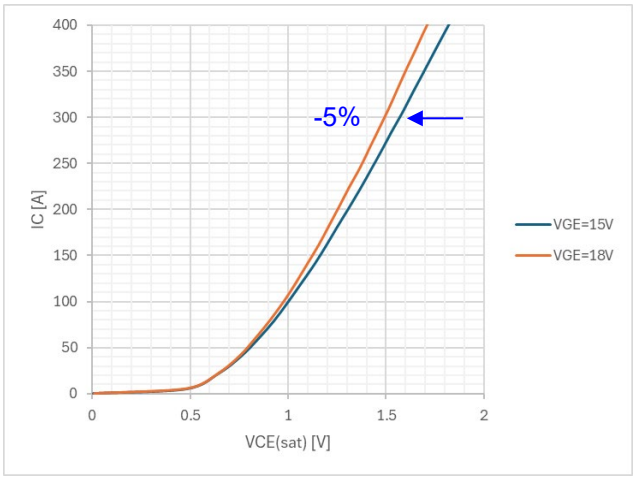


Figure 2-1 VCE(sat) Comparison

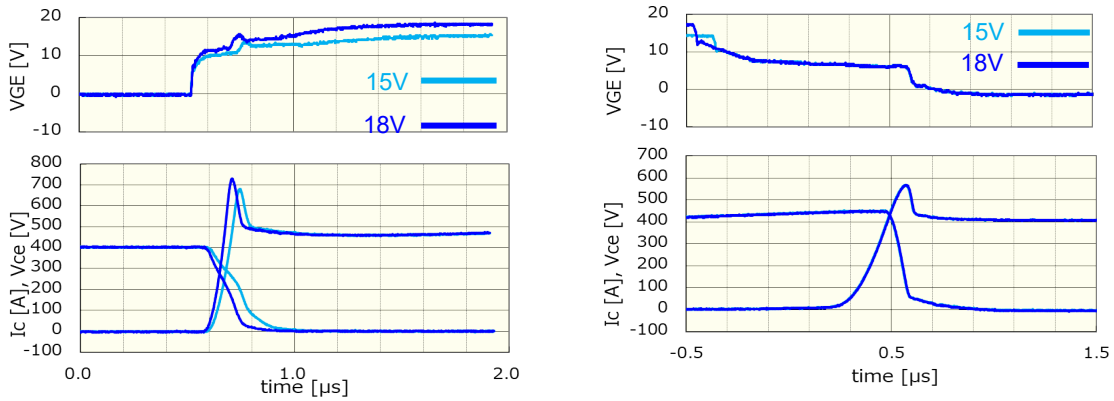


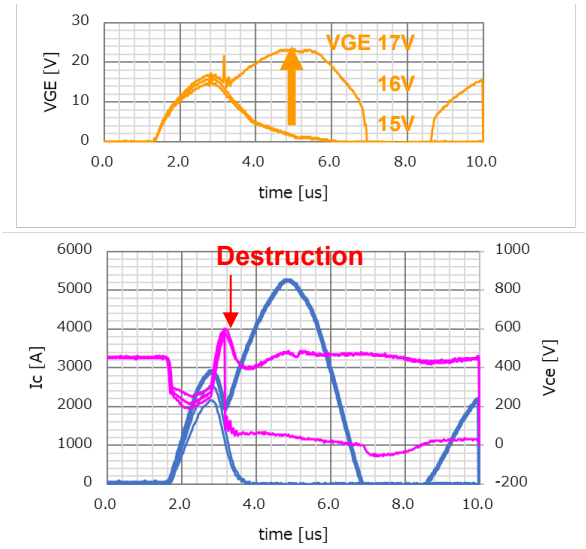
Figure 2-2 Turn on/off Waveform

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 VGE=17V.

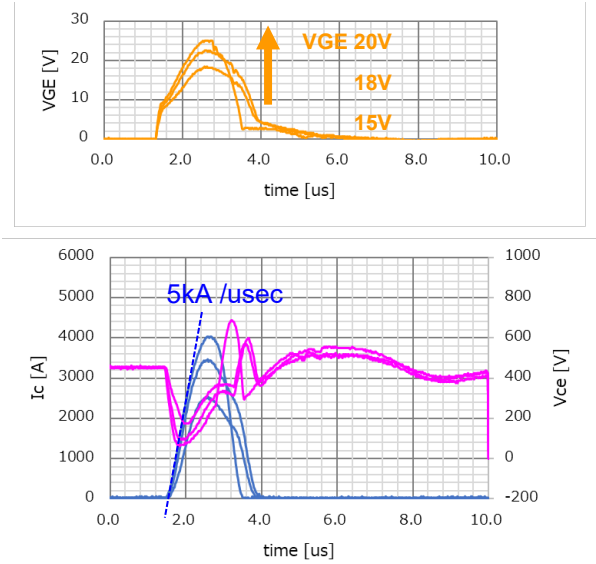


*Short-Circuit Conditions:
VCC=450V,
VGE=15V,16V, 17V
Rg_on/off=4.7/47ohm,
Tj=175degC

! Transient destruction @ VGE=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 VGE = 20V, even if the high di/dt condition such as 5kA/µsec.



*Short-Circuit Conditions:
VCC=450V,
VGE=15V,18V, 20V
Rg_on/off=4.7/47ohm,
Tj=175degC

✓ **Safely on/off up to VGE = 20V**

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 (Eoff) 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)	Eon @150degC	Eoff @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, Tj=150degC

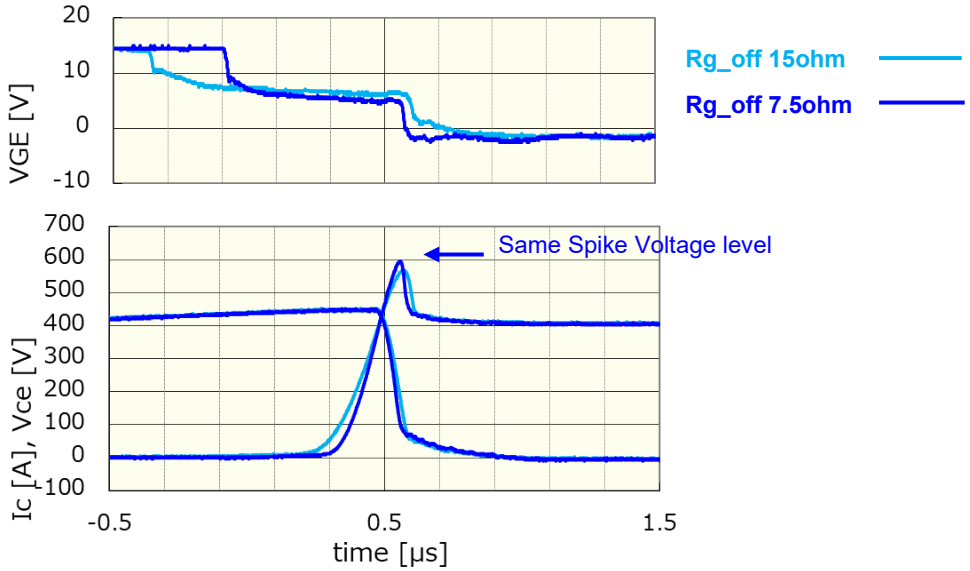


Figure 4-1 Turn off waveform comparison

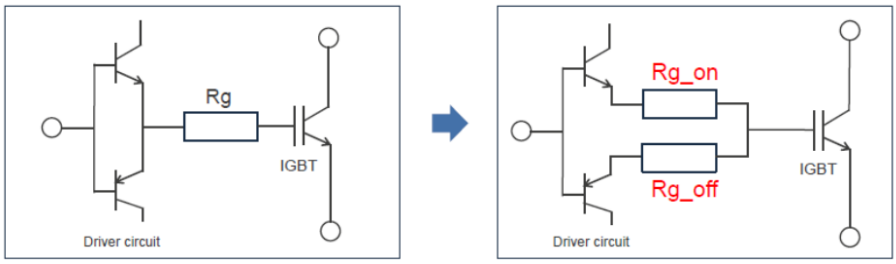


Figure 4-2 Gate Resistance Adjustment

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 Vce(sat) and turn-on loss Eon 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 (Eoff) 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

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