IGBT, FRD

How do smaller Co-Pack Diodes help improve IGBT Performance in UPS/PV Inverters?

Introduction

Renesas G8H series IGBT+FRD co-pack discrete products are suitable for high frequency UPS/PV inverter applications. The product concept is to have a smaller current rating of co-packed FRD to achieve the best performance, especially at light to medium load operation and good cost.

Target Device

IGBT & FRD

Contents

1. Discrete IGBT products

A wide range of IGBT products are utilized in the power electronics market. Especially in the industrial power converter market, there are a lot of discrete packaged products implemented. Almost all discrete IGBT products have a co-pack diode in the same package for reverse current conduction.

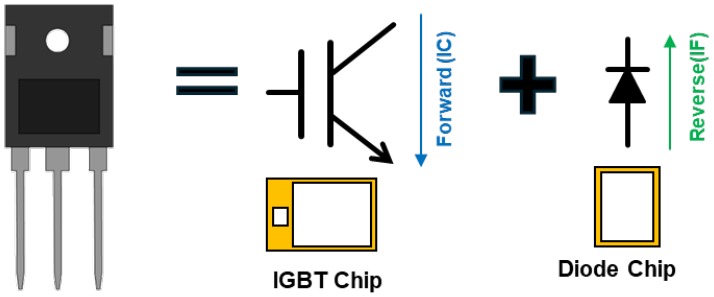

Figure 1 IGBT Diode co-pack device

The diode is mandatory for IGBT in inverter applications which require reverse current conduction to power devices. IGBT characteristics are very important for the efficiency of inverter circuit, but the co-pack diode is also important for the performance and the overall device cost. In this article, the Renesas G8H generation IGBT/FRD concept is explained in relation to its target applications, including UPS and PV inverters.

2. What is the current rating of Discrete devices

Power devices have absolute maximum ratings for voltage, current, and temperature. Renesas has a dedicated application note for each parameter definition. Design engineers refer to “Collector current IC” and “Diode forward current IF” individual ratings to find the correct device for their application. However, in practice, comparing the maximum current in the application with IC and IF is not meaningful. Those current ratings are DC current ratings defined by the formula below. Actual current in inverter applications is not DC current

$$Ic = \frac{(Tjmax - Tc)}{R_{th(j-c)} \times V_{CE(sat)}}$$

Equation 1: DC current rating definition.

IGBT and Diode can support higher current than the IC & IF ratings as long as the junction temperature does not exceed the junction temperature rating (Tj max) and peak current does not exceed IC (peak) or IF(peak).

3. UPS and PV inverter operating conditions

The UPS and Photovoltaics (PV) market is growing at a rapid pace. Those applications contribute to carbon dioxide emission reduction. Both applications have inverter circuits, requiring high voltage switch solutions, such as discrete IGBTs.

In inverter circuits, IGBT (and diode) work with the PWM gate control. Their conduction duty is dependent on the Power Factor (PF). In Figure 2, the blue area shows IGBT conduction duty, the green area shows diode duty. As depicted in Figure 2, They are the same duty under PF=0 condition and IGBT conduction area is bigger than diode in cases where PF>0.

In the inverter of UPS and PV applications case, PF is nearly +1.0, and never goes to the PF<0 condition. This means that the diode's forward voltage, which contributes to conduction loss, has minimal impact on the performance of UPS and PV systems. On the other hand, switching loss and diode recovery loss are independent of the power factor (PF) and are instead influenced by the switching frequency.

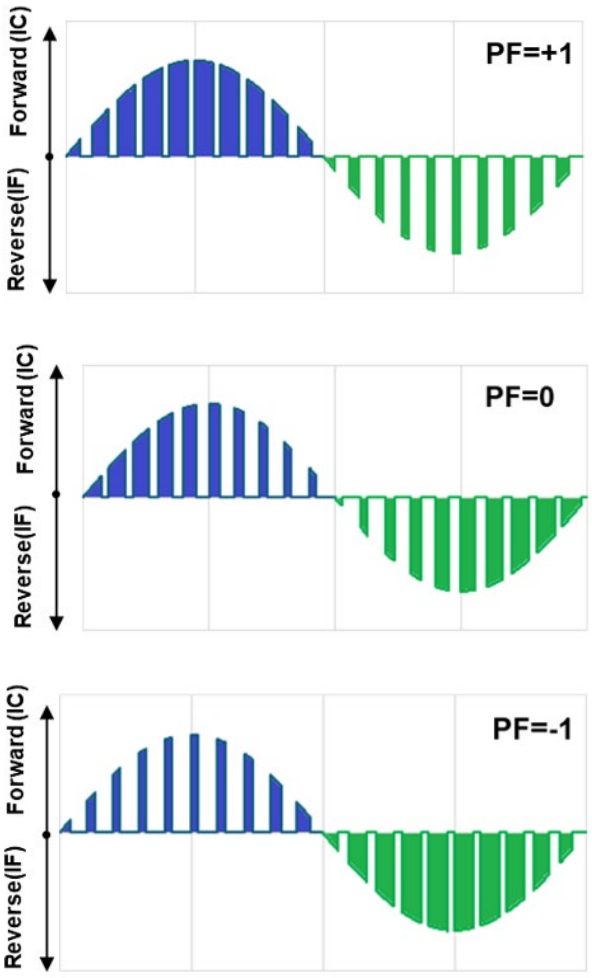

Figure 2 PF dependency of IGBT and Diode conduction duty.

4. Power loss in FRD

Conduction loss by VF and Recovery loss by Qrr are the power loss factors in diode characteristics. They are in a trade-off relationship such that if we design the diode to focus on low recovery loss, that affects Forward voltage and vice versa. In addition, both power losses depend on chip size. Generally speaking, a bigger chip has lower VF and higher Qrr. Chip size directly relates to IF rating.

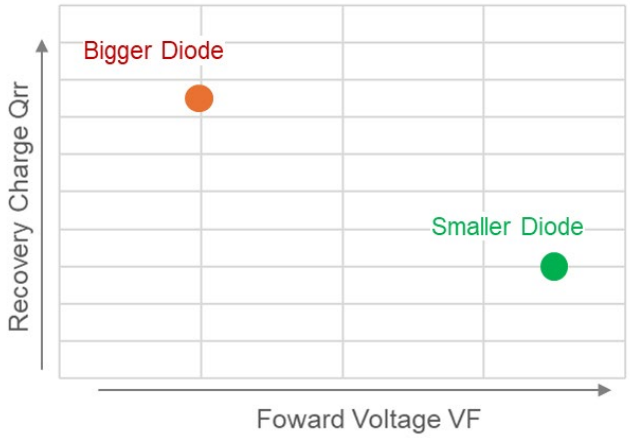

Figure 3 Chip size dependency of Diode characteristics.

Another important point is that Qrr also impacts the IGBT turn-on loss. The basic half bridge configuration is shown in Figure 4. The high side diode is in conduction state before the turn-on of the low side IGBT. Then, recovery current appears in the turn-on current waveform and affects turn-on loss.

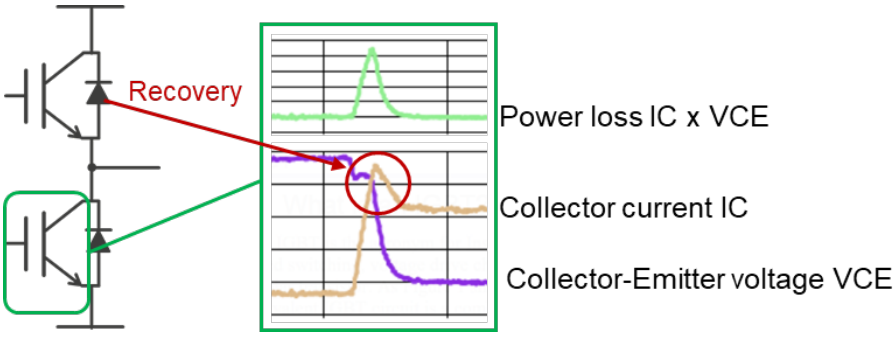

Figure 4 Turn-on waveform, recovery affects turn-on loss

This indicates that for UPS and PV inverters, a smaller co-pack diode rating compared to the IGBT might be more suitable, as the diode's conduction duty is lower than that of the IGBT. Additionally, a smaller diode can help reduce both recovery loss and IGBT turn-on loss.

5. G8H concept

Renesas conducted an investigation to determine the optimal diode size for UPS and PV applications. Renesas simulated the total power loss of the IGBT and diode based on an evaluation of switching characteristics. The device consists of a 650V 50A class IGBT. Two different co-pack diode sizes, 30A (smaller) and 50A (larger), were evaluated in combination with the IGBT with the same voltage class. Those current classes refer to the IC and IF rating. As you can see in Figure 5, IGBT + Smaller diode configuration shows smaller Power loss thanks to low recovery loss and low Turn-ON loss. Even though diode conduction loss is higher, smaller diode can contribute 2.5% improvement in efficiency. Another important point is that we can save diode chip cost by 20% with a smaller chip. This achieves a good cost and performance balanced solution.

Note, a smaller chip has a smaller IF rating, and higher thermal re¬sistance, but power loss of the diode is sufficiently small due to low duty (Figure 2) and Tj of the diode that it does not exceed its Tj maximum rating.

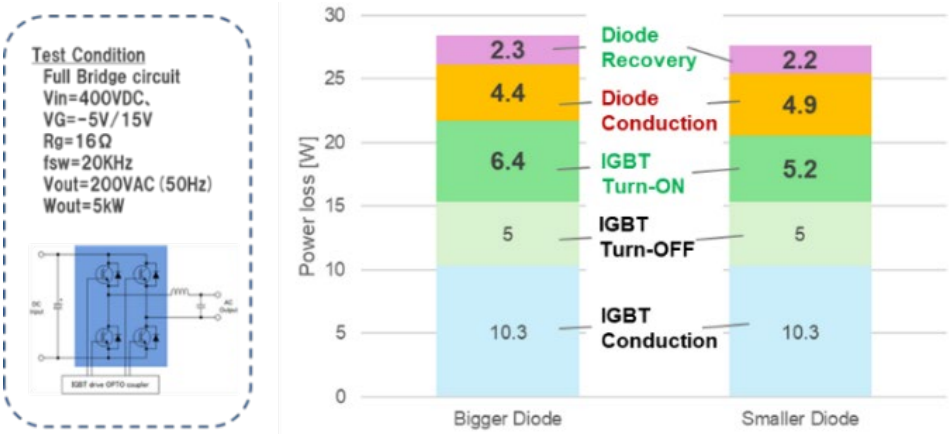

Figure 5 Total power loss simulation conditions and results

This is one of the Renesas G8H series key concepts. Based on this result and application requirements, Renesas has optimized its IGBT product lineups as shown in Table 1, where the co-pack diode has smaller current rating than the IGBT for better performance in UPS and PV applications.

Table 1 Renesas G8H series lineups

Part Number	VCES[V]	IC [A]	IF[A]
RBN25H125S1FPQ-A0	1250	25	15
RBN40H125S1FPQ-A0	1250	40	25
RBN75H125S1FP4-A0	1250	75	50
RBN40H65T1FPQ-A0	650	40	30
RBN50H65T1FPQ-A0	650	50	50
RBN75H65T1FPQ-A0	650	75	50

6. Summary

The inverter circuit in UPS and PV are operated under high PF conditions. In high PF operation, diode conduction duty is low, so a smaller diode should be better for circuit efficiency. Renesas confirmed by power loss simulation. A smaller diode contributes to total performance as well as cost improvement. Furthermore, a smaller diode has higher thermal resistance, but power loss is low enough in high PF operation that we can keep lower junction temperature than the Tj max rating. So a smaller IF rating diode can work with a higher IC rating IGBT.

Renesas G8H series is focused on UPS and PV applications. The lineup includes smaller diodes to improve cost and efficiency. Renesas next generation IGBT discrete series is currently under development. Renesas has plans for a larger lineup to support additional applications, such as UPS, PV, EV charging system, motor drive and more, while keying in on further performance improvement.

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	12.02.2024	-	First edition

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