IGBT

Renesas IGBT SPICE model

About this document

This document will describe the IGBT SPICE model provided by Renesas

Target Device

IGBT

Contents

1. Introduction

In recent years, heat and noise caused by power devices have become an issue in the development of applications that incorporate power devices, and simulation is becoming more important to shorten development time. SPICE, a circuit simulator, can perform various calculations such as power loss calculation of power devices, prediction of gate drive performance, circuit avalanche energy, switching time, and transient junction temperature rise.

Since there is no standard SPICE model for power devices, power device manufacturers develop their own models and provide them to users. This paper describes the features of Renesas SPICE model for IGBTs.

2. IGBT SPICE MODEL

2.1 Supported Simulators

There are many types of commercial circuit simulators. Renesas provides SPICE models for the following simulators (Table 2-1), which are mainstream in the field of power electronics.

Table 2-1 Supported Simulators

Name	Vendor
PSPICE	Cadence
LTspice	Analog Devices
Simetrix	SIMetrix Technologies Ltd

2.2 Grades of SPICE model

As mentioned in the Introduction, SPICE models for power devices must be developed independently by the manufacturer. To obtain high simulation accuracy, SPICE models need to be complex, but this in turn reduces simulation speed and worsens calculation convergence. Therefore, two types of SPICE models are offered: a simple SPICE model (G1 model) that emphasizes calculation speed and a high-precision SPICE model (G2 model) that emphasizes accuracy (Table 2-2)

Table 2-2 Grades of SPICE model

Grade	Encryption	Features
G1	Non-encryption	emphasizes calculation speed and convergence
G2	Encryption	emphasizes calculation accuracy

2.3 Encryption

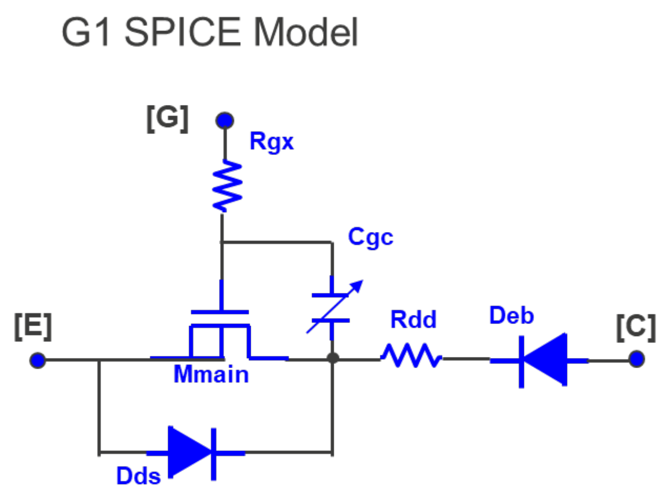
SPICE models contain confidential information such as modeling techniques to accurately represent device characteristics and device structures. Therefore, G2 models, which are high-precision SPICE models, are encrypted and published. Encrypted models can only be used on the target simulator and cannot be edited at all, which is not convenient for users. Therefore, for user convenience, the G1 model, which is a simple SPICE model, is published without encryption.

2.4 Topology

The G1 model is a model consisting of a minimum number of elements to represent the basic operation of IGBTs in order to prioritize calculation speed.

The G2 model consists of a large number of elements to analyze switching characteristics with high accuracy.

Among the parasitic components of the package, resistance and capacitance components are included in the SPICE model, but inductance components are not.



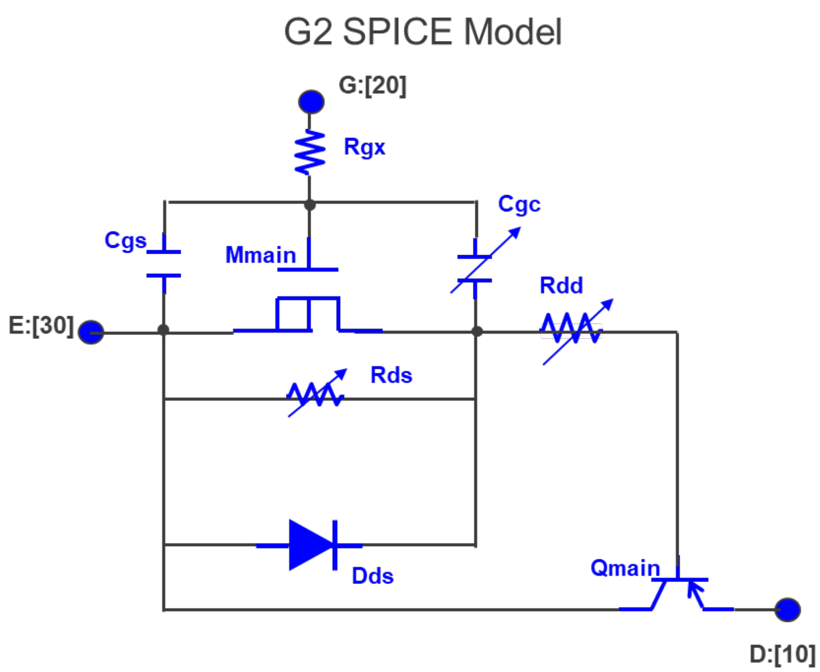


Figure 2-1 Topology of IGBT SPICE models

3. Accuracy Comparison

3.1 DC & Temperature

The accuracy comparison of the G1 and G2 SPICE models using Renesas 8th generation IGBTs (1800V class) as the subject of actual measurements are shown in Figure 3-1. The G1 model shows the overall trend, but as VGS increases, the transition from linear to saturation deviates from the actual measurement, and this trend increases as temperature increases. On the other hand, the G2 model agrees well with the actual measurement under all conditions because BSIM3 is used for the MOS model and the bias dependence of the drift resistance is modeled

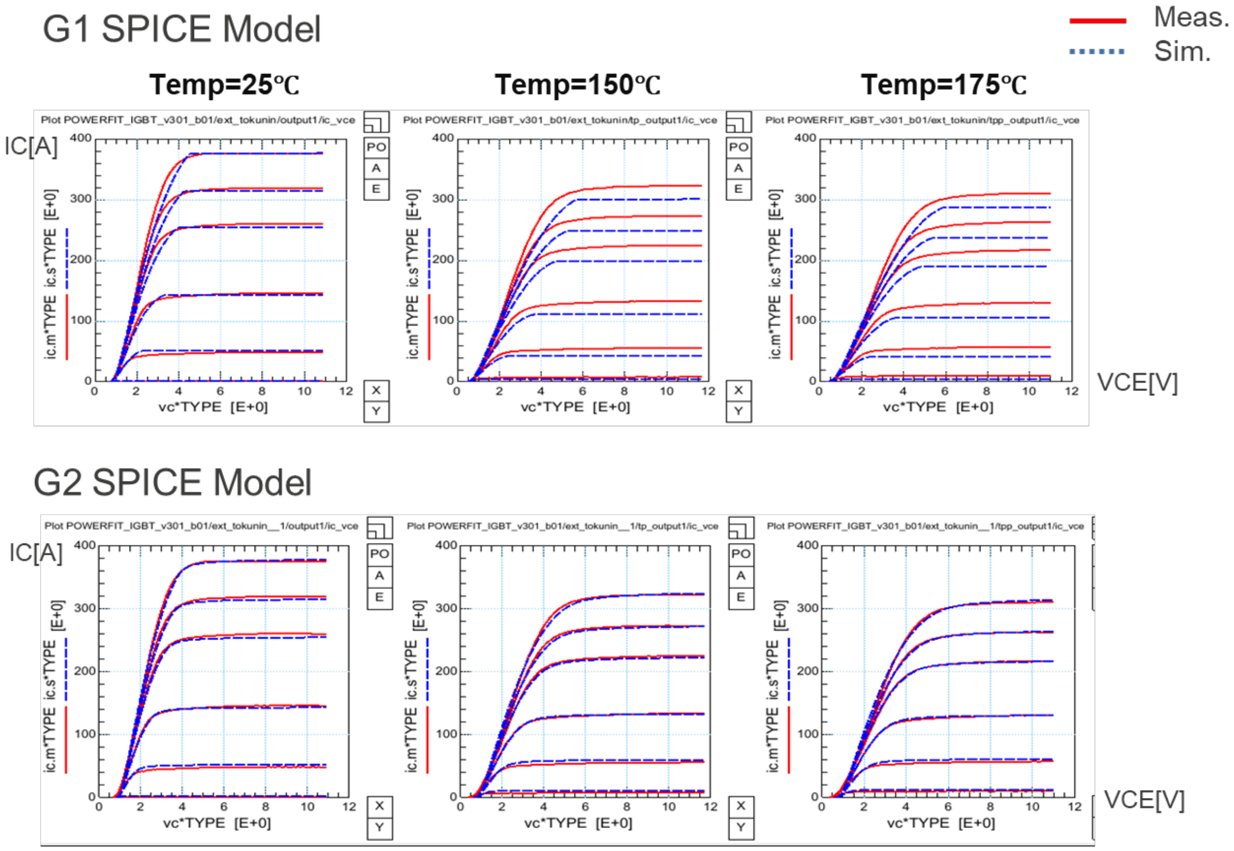


Figure 3-1 Comparison of modeling accuracy of DC characteristics (G1 vs. G2 model)

3.2 Capacitance

It is known that the general PN junction capacitance decreases with sqrt(V) with respect to voltage. Cres and Coes of classical IGBTs show bias dependence according to this theory. However, as IGBTs continue to change their device structure and achieve improved device performance, the device structure becomes more complex with each successive generation. As a result, the capacitance shows a very complicated bias dependence. The solid lines in the figure show the VDS dependence of Cres, Cies, and Coes. The G1 model shows a decrease in capacitance with increasing VDS, but not a change in trend. The G2 model, on the other hand, shows a change in the bias-dependent trend of capacitance with a boundary of about 0.5 V.

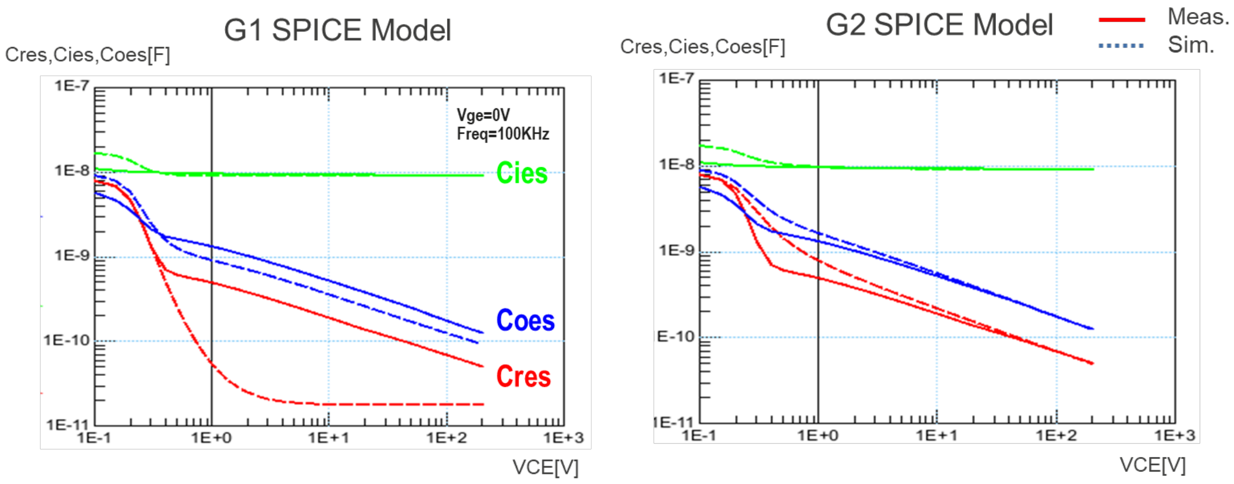


Figure 3-2 Comparison of modeling accuracy of CV characteristics (G1 vs. G2 model)

3.3 Switching

IGBTs are mainly used in inverter circuits for motor drives, so accuracy under inductive load is important. In addition, it is necessary to select the optimum external gate resistance value for each application, and it is important to ensure high simulation accuracy even when the gate resistance value fluctuates.

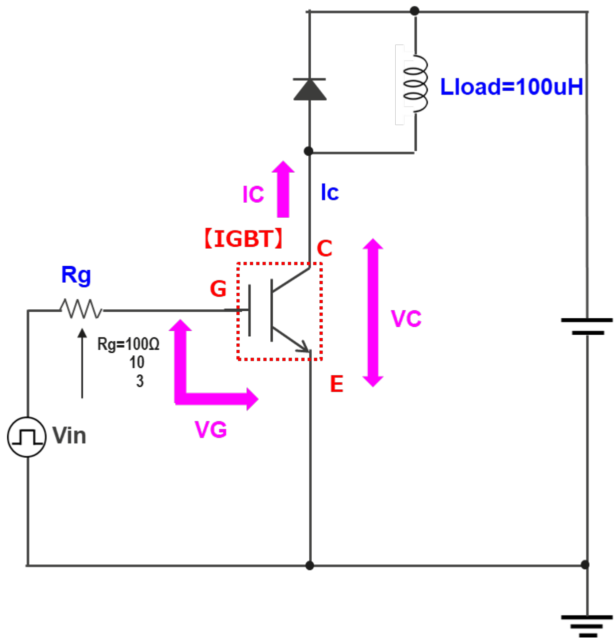


Figure 3-3 Switching Test bench

Figure 3-4 and Figure 3-5 show the switching characteristics (Turn-Off and Turn-On) when the external RG is changed (RG=3, 10, 100Ω), red is the actual measurement and blue is the simulation. The G1 model shows a tendency for switching to slow down as RG increases, but the slopes do not match at all, resulting in a large error in loss. On the other hand, the G2 model shows the bias dependence of capacitance and the introduction of a special model to match switching, and thus shows with high accuracy the tendency for switching characteristics to vary with gate resistance, including losses.

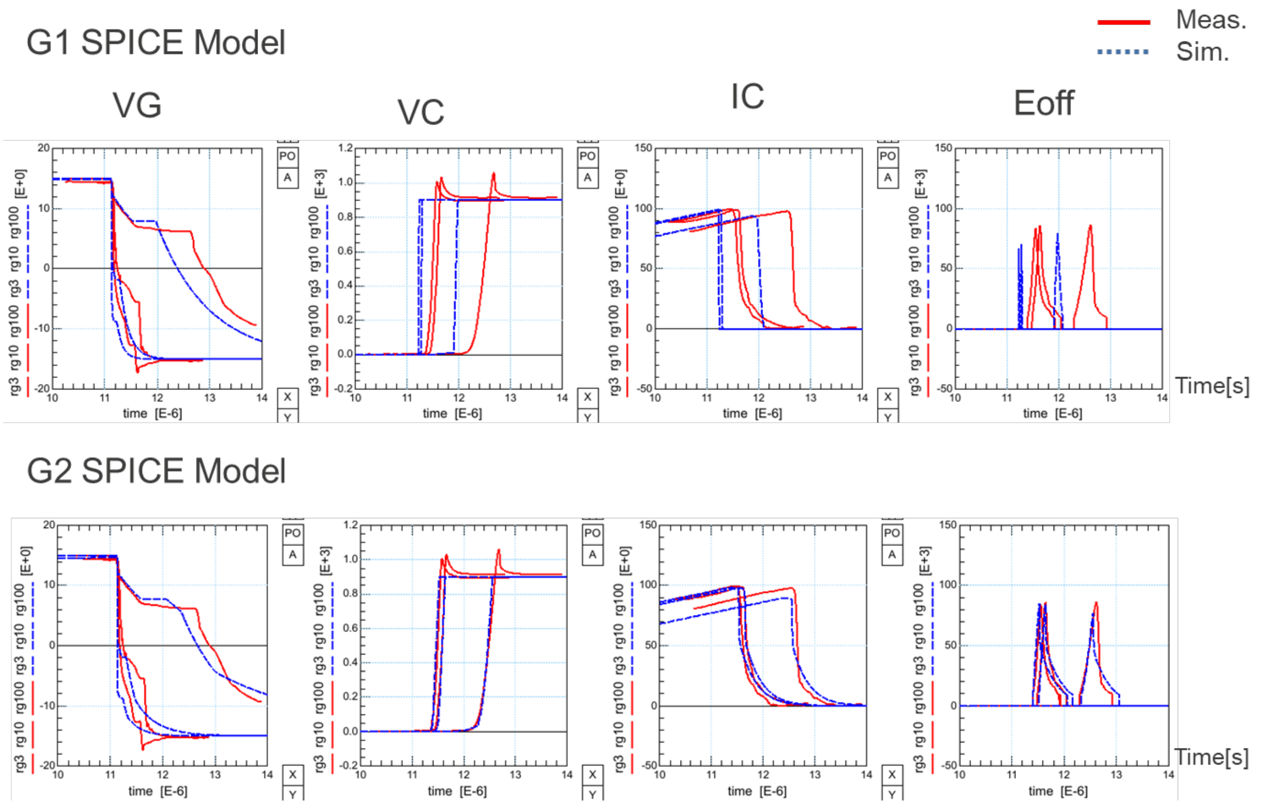


Figure 3-4 Comparison of modeling accuracy of Turn-off characteristics (G1 vs. G2 model)

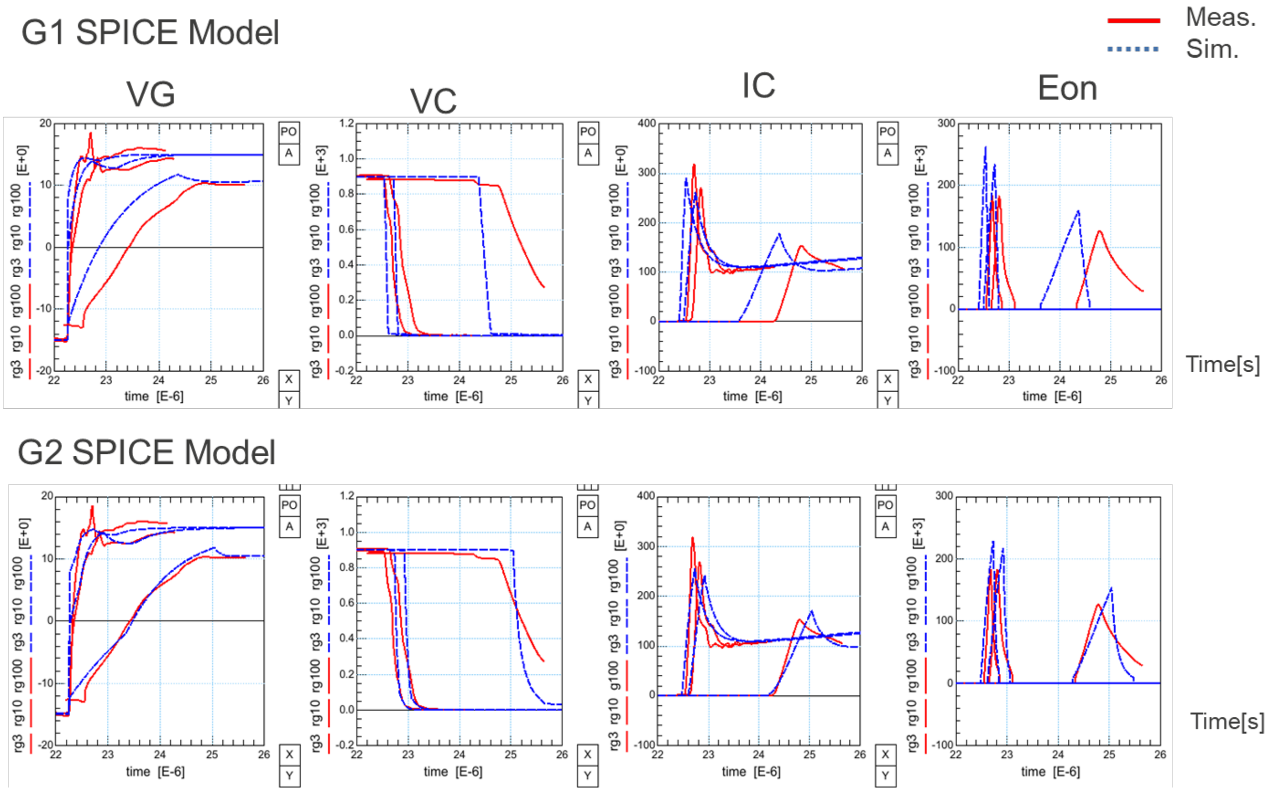


Figure 3-5 Comparison of modeling accuracy of Turn-on characteristics (G1 vs. G2 model)

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Sep.11.2024	-	First edition

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