**Introduction**

New power devices using wide bandgap semiconductors such as Silicon Carbide (SiC), and Gallium Nitride (GaN), are becoming quite attractive in the field of power electronics. They provide excellent properties such as higher withstand voltage and lower on-resistances, when compared with Si-IGBTs. They also enable high-temperature operation (at temperatures over 200 °C), which is difficult for Si power semiconductor devices. We developed a power module with SiC devices, and have already developed a mounting technology for low inductance power modules [1], reliability for high temperature operation[2], and a mounting technology enabling the mounting of snubber circuits into the power module[3]. Moreover, we have demonstrated a 3 phase inverter and a resonant DC-DC converter which can achieve high power density and high efficiency [4]. SiC power devices can realize switching at higher speeds, compared to the conventional Si-IGBTs. In other words, they show high $dv/dt$ and $di/dt$ during the switching operation. On the other hand, the power-module circuit contains large amounts of parasitic capacitances and stray inductances. Therefore, the leakage current ($C\cdot dv/dt$) at the insulator part and the voltage drop ($L\cdot di/dt$) at the conductor cannot be ignored.

In this paper, a simple analytical model is proposed in which the parasitic capacitances and stray inductances are integrated inside the power module. The circuit parameters are obtained mainly from measured data of a 2-in-1 SiC power module that we actually fabricated. And some parameters such as $C_{gs}$, $C_{ds}$ and $C_{dg}$ were derived from the datasheet of the SiC device we used.

**SiC-power module and switching waveforms**

The power module for the experiment is shown in Fig.1. This module is composed of a half-bridge and a built-in snubber circuit. The SiC-MOSFET was fabricated by Cree Inc. (CPM-1200-0025B was used). Al bonding is used to connect the surface of the device, and its back is connected using Au-Ge solder. The low stray inductance is realized through a multiceramic substrate.
An actual switching waveform of this module at \( I_D = 100 \text{ A} \) is shown in Fig.2. The turn-on waveform shows that the \( V_{ds} \) waveform has inflection points at A, B, and C.

**Analysis Model**

An analysis model is described in Fig.3. The MOSFET in the upper side is connected to the ideal diode, and the MOSFET in the lower side is replaced by a current source \( I_Q \), which is controlled by a voltage in parallel and connected to a capacitor. The parasitic capacitances and stray inductances are calculated based on the values obtained using an “ANSYS Q3D Extractor.”

An analytical result of the switching is shown in Fig.4. Each waveform corresponds to the symbol in Fig.3. The \( V_{q2} \) in Fig.4 is the same point as the \( V_{ds} \) in Fig.2, and the inflection points from A to C in Fig.2 are reproduced. The voltage waveforms in Fig.2 and Fig.4 correspond well. Accordingly, using our method, the main current \( i_Q \) in Fig. 3, which cannot be measured experimentally is able to predict with a certain precision that is secured by voltage \( v_{q2} \) waveforms. The difference between \( i_Q \) and \( i_{q2} \) in Fig.4 is due to the charging and discharging of \( C_{q2} \).

![Equivalent circuit](image)

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**Reference**


