Modeling Note

MN-PSM-1

SIGBT / EMCON-Fast DuoPacks

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Devices covered by this Modeling Note:

1200 V S-IGBT/EMCON-fast Duopacks:

- SKP02N120
- SKW07N120
- SKW15N120
- SKW25N120

600V S-IGBT/EMCON-fast DuoPacks:

- SKP02N60 = SKB02N60
- SKP04N60 = SKB04N60
- SKP06N60 = SKB06N60
- SKP10N60 = SKB10N60 = SKW10N60
- SKP15N60 = SKB15N60
- SKW15N60
- SKW20N60
- SKW30N60

Model Description:

Overview:

DuoPacks feature a fast S-IGBT in NPT-technology with soft, fast recovery anti-parallel EmCon diode. This system can be easily used in motor drive, inverter, and switch-mode power supply applications.

The base model of the DuoPack includes the base models of the NPT IGBT and the EMCON-fast diode. The PSPICE compact models of the NPT-IGBT and the EMCON-fast devices are based on the device-physics-based models described in detail in [3].

The special features of the 600V and 1200V S-IGBT/EMCON-diode combinations are the fast switching times and the low reverse charge at turn-off. The PSPICE parameters related to these features are developed from the known device geometry and doping levels.

Implementation of Temperature Influence:

The electrical characteristics of the S-IGBT and EMCON diodes are dependent on the device temperature. Of particular importance for the PSPICE implementation of the temperature-dependent equations are the bipolar device regions. The approach chosen for the implementation of the temperature dependencies is determined by the capabilities of PSPICE.
Based on the temperature dependencies of the pn-junction currents (diode and IGBT) and MOSFET currents (IGBT), the temperature-dependent excess currents are modeled by auxiliary current sources in parallel to the MOS-channel and the pn-junctions, respectively. In case of level-2 models, the device temperature is represented by a local parameter. For level-3 models, it is modeled by an auxiliary network feeding the device’s dissipated power into a thermal network.

Figure 1 shows the models that can be generally used in order to model the thermal path of semiconductor devices. The physical-correct T-type network has the advantage that it can be easily extended with additional heat-sink models [1,2].

![T-type network](image)

It should be noted that the use of the level-3 transient-temperature models requires more simulation time than the use of lower-level models.

**Typical Model Tests:**

**Static Characteristics**

The performance and quality of the compact models are tested in standard-device characterization circuits. Of particular importance is the temperature-dependent behavior of the devices.

The PSPICE schematic for the dc-simulation of an IGBT is shown in Figure 2. It can be used in order to determine the device’s transfer and output characteristics. Latter requires a shorted IGBT gate emitter. The device temperature parameter $T_J$ is local to the device and can be used as a ‘vary’ variable.

The simulation results for temperature-dependent 600V-IGBT transfer and output characteristics are shown in Figure 3. The respective diode output curves are depicted in Figure 4.
Figure 2: PSPICE schematic for determination of IGBT DC characteristics

Figure 3: Temperature-dependent 15A/600V DuoPack output characteristics (Vge = 7V/9V/15V) (simulation / measurements). Left graph: at 150°C; Right graph: at room temperature.

Figure 4: Temperature-dependent 15A/1200 EMCON-fast output characteristics (simulation / measurement)
Dynamic Characteristics

The switching behavior of the devices is mainly influenced by the intrinsic capacitances that result from the MOS cell structure, by the internal gate resistance, and the inherent pn-junctions. It is further affected by the diode charge and the commutation speed during switching. These multi-dimensional effects are tested and compared to measurements (see Figure 5).

Figure 5: Comparison 1200V-DuoPack half-bridge turn-off commutations (at 125°C; with two different external gate resistors) (simulated / measured; measured and simulated curves shifted in time)

Summary

Simulation and measurement results show an excellent agreement for the static and dynamic case. The simulation of the device’s dynamic behavior impressively demonstrates the reliability of the models when used for the simulation of application circuits.

PSPICE Settings for Power Electronic Simulations:

The standard version of PSPICE is optimized for the simulation of small-signal applications. For the simulation of power electronic devices and applications the PSPICE settings need to be modified.

Power device models utilize auxiliary circuits in order to calculate internal system parameters such as the internal free-carrier concentration. This requires a larger number of iterations for convergence. Furthermore, currents and voltages in power electronic applications are far higher than those in small-signal applications. As a consequence, it is necessary to modify the PSPICE settings for the absolute accuracy limits of currents and voltages, and for the relative error-limit. In some cases, the absolute accuracy limit for charges needs to be adjusted as well.
The PSPICE settings can be changed in the schematic-editor menu “Analysis/Setup/Options”. They can be also modified directly by changing the values in the .OPTIONS section of the “.cir” PSPICE file. The settings depend on the particular case to be simulated. However, as a rough estimate, the following numbers can be used as a first guess:

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<th>OPTION name</th>
<th>Description</th>
<th>default</th>
<th>Change to: In power electronic simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTOL</td>
<td>best accuracy of currents amp</td>
<td>1.0 pA</td>
<td>1uA</td>
</tr>
<tr>
<td>VNTOL</td>
<td>best accuracy of voltages volt</td>
<td>1.0 uV</td>
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</tr>
<tr>
<td>CHGTOL</td>
<td>best accuracy of charges coulomb</td>
<td>0.01 pC</td>
<td></td>
</tr>
<tr>
<td>ITL1</td>
<td>DC and bias point blind repeating limit</td>
<td>150.0</td>
<td>300</td>
</tr>
<tr>
<td>ITL2</td>
<td>DC and bias point educated guess repeating limit</td>
<td>20.0</td>
<td>250</td>
</tr>
<tr>
<td>ITL4</td>
<td>the limit at any repeating point in transient analysis</td>
<td>10.0</td>
<td>100 (higher when large number of stray inductances)</td>
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<tr>
<td>RELTOL</td>
<td>relative accuracy of V and I</td>
<td>0.001</td>
<td>0.005</td>
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</table>

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