SiC Solutions for Industrial and Automotive Applications

03. December 2019
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Field Application Engineer
Agenda

1. Package line-up extension & advantage of driving sense packages

2. Comparison of 40mΩ 1200V SiC MOSFETs in TO-247 / TO-247-4L / TO-263-7L
   • Switching waveforms
   • Switching losses
   • Further switching characteristics

3. Application example: Totem Pole and Power supply

4. Summary
ROHM SiC device development

- 19 years of experience
- Fully integrated production system

- Started SiC R&D
- Acquired SiCrystal SiC substrate
- SiC SBD / MOS mass production
- Full SiC Module mass production
- World’s first Trench SiC MOS mass production
- 6 inch SiC SBD mass production

• 19 years of experience
• Fully integrated production system

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Integrated In-House Manufacturing System

Substrate

Device

Package

Fully Integrated Production

- **2009**: SiCrystal M&A
- **2011**: 4inch MP
- **2014**: 6inch MP

- **SiC-SBD**
  - Since 2010
- **SiC-DMOS**
  - Since 2010

- **Power module**
  - Since 2012

- **Nuremberg, Germany**
- **Fukuoka, JPN**
- **Kyoto, JPN**
- **Thailand**
- **KOREA**
Advantage of packages with driving sense

Reduced switching speed because $L_S$ is common to gate-drive and power loop:

Benefits:
- $L_S$ is no longer common to gate-drive-loop and main current path.
- Overall package inductance is much lower (TO-263-7L)
- Increased creepage (TO-247-4L)
Double pulse test set-up

TO-263-7L (DUT below board)

TO-247-4L (DUT below board)

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<th>Ch</th>
<th>Signal</th>
<th>Probe</th>
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<tr>
<td>1</td>
<td>$V_{DS,LS}$</td>
<td>PHVS 662-6 1000:1, 400 MHz</td>
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<tr>
<td>2</td>
<td>$V_{GS,LS}$</td>
<td>HVFO0103 – 40x tip (+CM filter)</td>
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<tr>
<td>3</td>
<td>$I_{S,LS}$</td>
<td>100mΩ coaxial shunt</td>
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<tr>
<td>4</td>
<td>$V_{DS,HS}$</td>
<td>TT-SI 9110, 1000:1</td>
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Switching loss of 40mΩ 1200V SiC MOSFETs (Gen 3)

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Switching loss of 40mΩ 1200V SiC MOSFETs (Gen 3)

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# Package line-up extension

## 650V

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*AEC-Q101 qualified, exact P/N for SMD devices tbd

- ✓ In mass production
- ✔ Under development
- ✓ In mass production (new)

Schedule and development plan are subject to change without notice.
Application example: Totem Pole

Implementation

- ROHM 1 Ch Gate-Driven ICs
- 60mΩ 650V SiC MOSFETs
- Si SJ MOSFETs
- 60mΩ 650V SiC MOSFETs

Control Circuit

- EMI Filter
- RHOM Half-Bridge Gate-Driven
- Si SJ MOSFETs

Grid Emulator

- Sinus-filer
- DUT
- Power Analyser
- AC
- DC
- Fan
- Height: ca. 55mm
- Inductor
- EMI Filter
- Control Circuit

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Application example: Totem Pole

Features:
- A compromise between compactness and accessibility
- Control: Based on the TI C2000 control card
- Current measurement: Hall sensor IC

THT Variante

SMD Variante

SiC MOSFETs

Si SJ MOSFETs

Inductor

Fan

Height: ca. 55mm

DC out

ca. 185 mm

EIM filter

ca. 153 mm

AC in

ca. 185 mm
Test results

- **Maximal Efficiency:** 98.5%

- **Maximal Power:**
  - 3.6 kW (THT)
  - 2.4 kW (SMD)

- Both present comparable electric Performance

- SMD variant needs better cooling to reach 3.6kW

Conditions: $V_{OUT} = 400V$, $f_{SW} = 100$ kHz, $T_{amb} = 25^\circ C$,

*Power supply consumption has not bee considered for the calculation*
Thermal results

SMD Variante
\( (V_{\text{IN}} = 230V, V_{\text{OUT}} = 400V, P_{\text{OUT}} = 2.4 \text{ kW}) \)

→ SiC MOSFETs reach ca. 99°C
→ Cooling needs to be improved to reach \( P_{\text{OUT}} = 3.6 \text{ kW} \)

THT Variante
\( (V_{\text{IN}} = 230V, V_{\text{OUT}} = 400V, P_{\text{OUT}} = 3.6 \text{ kW}) \)

→ SiC MOSFETs reach ca. 97°C
→ Max. \( P_{\text{OUT}} \) of 3.6 kW reached
Auxiliary power supplies for industrial applications

System
(PV inverter, DC/DC converter, battery charger, etc.)

- Auxiliary supply is separated from the main power path
- High voltage input
- Low voltage output
- Isolated

Today’s focus application

Today’s focus application
Typical circuit for industrial auxiliary supply

Flyback converter with 3-phase input

AC mains 3ph
\( V_{ac,in} = 210 \ldots 690 \text{V} \)

\( V_{dc,in} \approx 300 \ldots 1000 \text{V} \)

Reflected voltage from secondary side

\( V_{refl} \approx 100 \text{V} \)

\( V_{surge} \approx 200 \text{V} \)

(turn-off overshoot)

What is the max. voltage the MOSFET has to withstand?

\( V_{dc,in} + V_{refl} + V_{surge} = 1300 \text{V} \)

Device rated voltage: \( \geq 1500 \text{V} \)
Typical Si-based solutions

- High gate charge $Q_g$ (high gate driving losses)
- High leakage current, especially at high temp.
- High conduction losses

**1500V Si MOSFET**

- e.g. 1500V, 6Ω

**Series connection of 800V Si MOSFETs**

- Gate driving circuit more complex
- Static voltage balancing network
- Larger space for the heat sink

**Two-switch flyback topology**

- Only overvoltage can be reduced, HV switches still needed
- Isolated gate driver & power supply for high side
- Larger space for the heat sink
Auxiliary power supply solution

SiC-based solution with 1700V MOSFET and single-switch flyback topology

- Single switch
- Isolated package
- Control IC BD7682FJ

Input: 300-900 Vdc
Output: 24 Vdc
Power: 100 W
Sw. Freq.: 90…120 kHz
Efficiency: 92% (300 Vdc), 90% (700 Vdc)

BD768xFJ evaluation board available

BD7682FJ_EVK_302
Auxiliary power supply solution

Efficiency

Output voltage stability

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AC/DC converter with built-in 1700 V SiC MOSFET

**Eval. board BM2SCQ123T-EVK-001**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
<th>Conditions</th>
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<td>600</td>
<td>900</td>
<td>V</td>
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<tr>
<td>Output Voltage</td>
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<td>26.4</td>
<td>V</td>
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<td>Maximum Output Power</td>
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<td>I_{OUT} = 2 A</td>
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</table>

**Package**

TO220-6M

W (Typ) x D (Typ) x H (Max)  
10.0 mm x 4.5 mm x 25.6 mm

**BM2SCQ123T**

Includes the 1700 V 4 A SiC MOSFET inside the package

- Quasi Resonant Operation
- TO220-6M Package
Summary

- Driving sense in both SMD and THT devices offer a substantial benefit for switching performance of fast SiC MOSFETs.

- Experimental results shows that Totem Pole PFC based on 60mΩ 650V SiC MOSFETs achieve an efficiency of 98.5%

- A 3.6kW Totem Pole PFC, with appropriate thermal design, can be use for OBCs applications, but also for industrial application.

- Combination of BD762xFJ and 1700V SiC MOSFET

  → **Simple** and **high performance** auxiliary supply solution