SiC Solution for Industrial Auxiliary Power Supply

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ROHM’s Power Devices

ROHM’s power item lineup covers wafers/bare dies, discrete packages, module, ICs and Intelligent Power Modules.

Today we focus on an auxiliary supply solution around discrete SiC MOSFETs and driving/control IC.
ROHM’s power devices

50+ years experience in Si Transistors/Diodes, 15+ years in WBG Semiconductors.

<table>
<thead>
<tr>
<th>Material</th>
<th>Si</th>
<th>SiC</th>
<th>GaN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device</td>
<td>SJ MOSFET</td>
<td>Hybrid MOSFET</td>
<td>FRD</td>
</tr>
<tr>
<td>Breakdown Voltage</td>
<td>500V~800V</td>
<td>600V*</td>
<td>300V 600V 1200V*</td>
</tr>
</tbody>
</table>

*in development

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Myths of SiC MOSFET technology

Expensive

Device cost may be higher, but overall system cost equal or lower
Application advantages vs. Si components

Lower Resistance
- Smaller Passive Components
- Smaller Size / Higher Efficiency
- Smaller Size
- Higher Efficiency
- Down sizing

Higher Frequency Operation
- Smaller Passive Components
- Simpler Cooling System
- Smaller Size
- Higher Efficiency
- Down sizing

Higher Temp Operation
- Smaller Passive Components
- Simpler Cooling System
- Smaller Size
- Higher Efficiency
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Application advantages vs. Si components

- Lower Resistance
- Higher Frequency Operation
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Device cost may be higher, but **overall system cost equal or lower**

Not reliable

Extensive reliability testing done, comparable to Si-based devices
Reliability aspects of SiC Trench MOSFETs

Reliability tests for ROHM Trench MOSFETs

<table>
<thead>
<tr>
<th>Test</th>
<th>IEC Standard</th>
<th>Conditions</th>
<th>Si</th>
<th>SiC</th>
<th>Comments SiC</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Temperature Reverse Bias</td>
<td>60747</td>
<td>1000 h @ 95% $V_{ds,max}$, $T_{amb} = 125..145°C$</td>
<td>✔️</td>
<td>✔️</td>
<td>@ 100% $V_{ds,max}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_{amb} = T_{j,max} = 175°C$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Temperature Gate Bias</td>
<td>60747</td>
<td>1000 h @ ±$V_{GS,max}$</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
</tr>
<tr>
<td>High Humidity High Temperature Reverse Bias</td>
<td>60068-67</td>
<td>1000 h @ $V_{ds,max}=80V$, $85% RH$, $T_{amb}=85°C$</td>
<td>✔️</td>
<td>✔️</td>
<td>$V_{ds,max}=100V$</td>
</tr>
<tr>
<td>High Temperature Storage</td>
<td>60068-2-1</td>
<td>1000 h @ $T_{STG,min}$</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
</tr>
<tr>
<td>Low Temperature Storage</td>
<td>60068-2-1</td>
<td>1000 h @ $T_{STG,min}$</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
</tr>
<tr>
<td>Thermal Cycle</td>
<td>60068-2-14</td>
<td>100 cycles $T_{STG,max} - T_{STG,min}$</td>
<td>✔️</td>
<td>✔️</td>
<td></td>
</tr>
</tbody>
</table>

SiC 3 Gen. MOSFETs undergo reliability tests similar to those for Si MOSFETs and IGBTs ➔ Automotive qualification soon to be finished
Myths of SiC MOSFET technology

Expensive

Device cost may be higher, but overall system cost equal or lower

SOLVED

Not reliable

Extensive reliability testing done, comparable to Si-based devices

SOLVED

Complex

Use of SiC MOSFETs can simplify circuit design

Todays focus:

Simple solution for aux supply
Auxiliary power supplies for industrial applications

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

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

INPUT

OUTPUT

Main converter

Auxiliary power supply

24V
12V
5V

LV subsystems (i.e. control units, sensors, human interfaces, gate drivers)
Typical circuit for industrial auxiliary supply

Flyback converter with 3-phase input

AC mains 3ph
$V_{ac,in} = 210...690V$

$V_{dc,in} \approx 300...1000V$

Reflected voltage from secondary side

$V_{refl} \approx 100V$

$V_{surge} \approx 200V$

(turn-off overshoot)

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

$V_{dc,in} + V_{refl} + V_{surge} = 1300V$

Device rated voltage: $\geq 1500V$
Typical Si-based solutions

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

1500V Si MOSFET
e.g. 1500V, 6Ω

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

Series connection of 800V Si MOSFETs

- Higher complexity in design and assembly
- Isolated gate driver & power supply for high side
- Larger space for the heat sink

Two-switch flyback topology
## Why use a SiC-MOSFET in this application?

<table>
<thead>
<tr>
<th>Property</th>
<th>unit</th>
<th>SCT2H12NZ</th>
<th>Si-MOSFET-A</th>
<th>Si-MOSFET-B</th>
<th>Si-MOSFET-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>V(BR)DSS</td>
<td>V</td>
<td>min 1700</td>
<td>min 1500</td>
<td>min 1500</td>
<td>min 1500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>typ</td>
<td>typ</td>
<td>typ</td>
<td>typ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>max</td>
<td>max</td>
<td>max</td>
<td>max</td>
</tr>
<tr>
<td>Id @ 25°C</td>
<td>A</td>
<td>3,7</td>
<td>2</td>
<td>2,5</td>
<td>6</td>
</tr>
<tr>
<td>Rds(on)@25°C</td>
<td>Ω</td>
<td>1,15</td>
<td>9</td>
<td>6</td>
<td>2,2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,5</td>
<td>12</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Idss@25°C</td>
<td>µA</td>
<td>0,1</td>
<td>500</td>
<td>10</td>
<td>1000</td>
</tr>
<tr>
<td>Ciss</td>
<td>pF</td>
<td>184</td>
<td>990</td>
<td>993</td>
<td>2025</td>
</tr>
<tr>
<td>Rg</td>
<td>Ω</td>
<td>64</td>
<td>4</td>
<td>114</td>
<td></td>
</tr>
<tr>
<td>Qg</td>
<td>nC</td>
<td>14</td>
<td></td>
<td>29,3</td>
<td></td>
</tr>
<tr>
<td>Rth(j-c)</td>
<td>K/W</td>
<td>3,32</td>
<td>4,32</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

- SiC MOSFET has lower $R_{DS(on)}$
- Also, Qg and capacitance are much reduced
- High gate resistance of SiC device demands a low-impedance gate drive
Why use a SiC-MOSFET in this application?

- The underlying advantage is the significantly reduced $R_{DS(on)} \cdot A$ value of SiC MOSFETs vs Si-MOS.
ROHM SiC-MOSFETs for Auxiliary Power Supplies

### Lineup 1700V SiC MOSFET devices:

<table>
<thead>
<tr>
<th>Part No.</th>
<th>$V_{DS}[V]$</th>
<th>$R_{DS_{on,typ}}[m\Omega]$ @Vgs=18V</th>
<th>$I_D[A]$ @Tc=25°C</th>
<th>$I_D[A]$ @Tc=100°C</th>
<th>$T_{j\max}[{^\circ C}]$</th>
<th>Package</th>
<th>Die Part No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCT2H12NZ</td>
<td>1700</td>
<td>1150</td>
<td>3,7</td>
<td>2,6</td>
<td>175</td>
<td>TO-3PFM</td>
<td>-</td>
</tr>
<tr>
<td>SCT2H12NY</td>
<td>1700</td>
<td>1150</td>
<td>4,0</td>
<td>2,9</td>
<td>175</td>
<td>TO-268-2L</td>
<td>-</td>
</tr>
<tr>
<td>SCT2750NY</td>
<td>1700</td>
<td>750</td>
<td>5,9</td>
<td>4,0</td>
<td>175</td>
<td>TO-268-2L</td>
<td>-</td>
</tr>
<tr>
<td>S2409</td>
<td>1700</td>
<td>100</td>
<td>34</td>
<td>-</td>
<td>175</td>
<td>bare die</td>
<td>S2409</td>
</tr>
</tbody>
</table>

*NEW*
SiC MOSFET in auxiliary power supplies

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

- Single switch
- Isolated package
- Control IC BD768xFJ
- Heat sink not mandatory if <40W

Input: 300-900 Vdc
Output: 12 Vdc
Power: 40 W (no heat sink)
Sw. freq.: 90…120 kHz
Efficiency: 85% (300 Vdc), 83% (700 Vdc)
BD768xFJ-LB’s features

**Feature**
- Optimum System for driving SiC MOSFET
- Quasi – Resonant DC/DC convertor
- Low VCC current (19μA@VCC=18.5V)
- Burst function at light load
- Max Frequency Controlled (120kHz)
- VCC Over Voltage Protection
- VCC Under Voltage Locked Out
- Brown IN/OUT Function
- DC/DC Soft Start
- DC/DC Cycle by Cycle current limiter
- 250nsec Leading-Edge Blanking
- ZT Trigger mask function
- ZT Over Voltage Protection
- Over Load Protection (128ms Timer) • MASK Function

**Specification**
- Operating VCC Range: 15.0V ~ 27.5V
- DCDC Max Frequency: 120kHz
- Operating current: 800 μA
- Operating Temperature: -40deg. to +105deg.

**PIN place / Package**

<table>
<thead>
<tr>
<th>NO.</th>
<th>Pin</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ZT</td>
<td>Zero Current Detect pin</td>
</tr>
<tr>
<td>2</td>
<td>FB</td>
<td>Feedback pin</td>
</tr>
<tr>
<td>3</td>
<td>CS</td>
<td>Current Sense pin</td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
<td>GND pin</td>
</tr>
<tr>
<td>5</td>
<td>OUT</td>
<td>MOSFET drive pin</td>
</tr>
<tr>
<td>6</td>
<td>MASK</td>
<td>External TR drive</td>
</tr>
<tr>
<td>7</td>
<td>VCC</td>
<td>Power Supply pin</td>
</tr>
<tr>
<td>8</td>
<td>BO</td>
<td>Brown IN/OUT monitor pin</td>
</tr>
</tbody>
</table>

**Application**
- Factory Automation, Adaptor, Smart Meter

**Line up**

<table>
<thead>
<tr>
<th></th>
<th>FBOLP</th>
<th>VCCOVP</th>
</tr>
</thead>
<tbody>
<tr>
<td>BD7682FJ</td>
<td>AutoRestart</td>
<td>Latch</td>
</tr>
<tr>
<td>BD7683FJ</td>
<td>Latch</td>
<td>Latch</td>
</tr>
<tr>
<td>BD7684FJ</td>
<td>AutoRestart</td>
<td>AutoRestart</td>
</tr>
<tr>
<td>BD7685FJ</td>
<td>Latch</td>
<td>AutoRestart</td>
</tr>
</tbody>
</table>
SiC MOSFET in auxiliary power supplies

Control IC for SiC based solution: BD768xFJ

- Implements quasi-resonant switching to minimise dynamic losses and achieve low noise
- Suitable drive voltage for SiC MOSFET

Reduced effective switching voltage leads to lower turn-on loss
SiC MOSFET in auxiliary power supplies

Waveforms of flyback switch for different operating conditions:

- Quasi-resonant operation is maintained across the output power range
- As the delay time decreases the effective switching frequency increases with increased load
SiC MOSFET in auxiliary power supplies

Operation at 40W without heat sink ➔
(with heat sink ca. 100W possible)

\[ V_{out} = 12 \ V_{DC} \]
Next step: Integration of SiC MOSFET and controller

Target Specification

- Operating VCC Range: 15.0V ~ 29.5V
- Operating DRAIN Range: ~ 1700V
- Drain Current (Continuous): 4A
- Drain Current (Pulsed): 10A
- Drain-Source on resistance: ca. 1.6 Ohm
- Power Range (Without Heat-Sink): ca. 30W
- Power Range (With Heat-Sink): ca. 100W

Application

Factory Automation, Adaptor, Smart Meter

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<tr>
<th>NO.</th>
<th>Pin</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DRAIN</td>
<td>DRAIN pin</td>
</tr>
<tr>
<td>2</td>
<td>SOURCE</td>
<td>Current Sense pin</td>
</tr>
<tr>
<td>3</td>
<td>FB</td>
<td>Feedback pin</td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
<td>GND pin</td>
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<tr>
<td>5</td>
<td>ZT</td>
<td>Zero Current Detect pin</td>
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<td>6</td>
<td>BO</td>
<td>Brown IN/OUT monitor pin</td>
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<tr>
<td>7</td>
<td>VCC</td>
<td>Power Supply pin</td>
</tr>
</tbody>
</table>
Next step: Integration of SiC MOSFET and controller

Additional features (tbc)

- VCC Over Voltage Protection
- VCC Under Voltage Lock Out
- Soft Start
- Cycle by Cycle current limiting
- Burst function
- Over-load protection
- Brown-out
- Gate voltage clamping

- etc.
Conclusions

• Auxilliary supply solution using BD768xFJ with 1700V SiC MOSFET is a good alternative to auxilliary supply circuits that today use series connection of Si MOSFETs or complex topologies to achieve the desired blocking voltage level.

• Taking advantage of SiC device benefits cost advantages can be realised on the system level.

• The next development step for SiC based auxilliary supply solutions is integration of the control IC and power switch in one package.