Danfoss Silicon Power

Global Manufacturing Footprint

- **NAM**
  - Utica, NY (US)
  - Main site, all functions
  - Production
  - Global market
  - 4,000 m² cleanroom + expansion
  - 4,000 m² warehouse/ logistics
  - 9,000 m² office / admin
  - ISO/IATF 16949 certified
  - US market
  - 5,000 m² cleanroom
  - 1,000 m² warehouse/ logistics
  - 2,500 m² office / admin
  - Running production

- **CER**
  - Flensburg (D)
  - R&D
  - Wide Band Gap Design & Application Validation Center
  - 400 m² Office
  - 600 m² Laboratory
  - Germany: Flensburg
  - Running production
  - Dedicated customers/products
  - CN market
  - 2,500 m² cleanroom
  - 1,000 m² warehouse/ logistics
  - 500 m² office / admin

- **CER**
  - München (D)
  - R&D Center
  - 400 m² Office
  - 600 m² Laboratory
  - Germany: München
  - R&D Center

- **CNR**
  - Site TBD (CN)
  - Production
  - CN market
  - 2,500 m² cleanroom
  - 1,000 m² warehouse/ logistics
  - 500 m² office / admin
  - Plant Opening: 2021

- **US: Utica, NY**
  - Plant Opening: 2018
  - Production
  - US market
  - 5,000 m² cleanroom
  - 1,000 m² warehouse/ logistics
  - 2,500 m² office / admin

- **China: TBD**
  - Plant Opening: 2021
  - Production
  - CN market
  - 2,500 m² cleanroom
  - 1,000 m² warehouse/ logistics
  - 500 m² office / admin

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Danfoss Silicon Power

ENGINEERING TOMORROW
Power Module Design for Next Generation SiC MOSFET
Making the most out of SiC

**Electrical Performance**
- Decoupled gate/source routing
- Ease of switching speed controllability
- Enabling SiC multi-sourcing

**Reliability**
- High temperature operation
- Meeting automotive mission profiles
- PC capability

**Cooling Performance**
- Lowest Rth
- Low pressure drop
- Minimized temperature gradient

**Power Density**
- Tailored package size
- Customizable interfaces
- Enabling integration on system level
Danfoss Silicon Power
Serving three main industries

- Renewables
- Industry
- Automotive

#6 Worldwide
#3 In Europe
#2 in MOSFET Power Modules
DCM™ 1000 / 1000X
Unlimited room for customization and scaling based on an existing platform

- Baseplate material (Cu, Al)
- # of paralleled semiconductors (scaling option)
- Semiconductor supplier
- Electrical circuit design
- Customized die size
- Topside contact technologies
- Bonding & joining technologies
- Ceramic material
- Thickness of thermal buffer (Cu)

- Baseplate customization (cooling concept)
- Pressfit or solder pins
- Terminal plating
- Leadframe material
- Geometric dimensions

DCM™ 1000X illustrations
DCM™ 1000 – System stray inductance **below 8 nH**

Investigation of system commutation loop inductance

\[ U_i = -L \frac{di}{dt} \]

→ Allowing 50 A/\(\text{ns}\) means 50 V _overshoot_ per System-nH

**Full commutation loop inductance:**

< 8nH

(incl. Power module, DC terminals, busbar, DC capacitor)
DBB® improves reliability

Conventional Power Module Designs

1. Topside wire bonding
2. Die – DBC bonding

Effect of Power Cycling

Danfoss Solution: DBB

1. Top side die connection:
   Cu-wires
2. Die – DCB connection:
   sintered

Danfoss Bond Buffer Technology
DBB® increases power cycling capabilities

DBB enables robust Cu-Cu bonding

- 6 modules with 4 parallel IGBTs per switch.
- Test stopped after 1,000,000 cycles
- EoL criteria: \( \text{Vce increase by 5\% or } \Delta T \text{ by 20\% according LV324} \)

Test conditions:
\( \Delta T = 110\text{K}; T_m = 90\degree C; t_{on} = 1\text{sec}; t_{off} = 2.5\text{sec}; I = 800\text{A}; \) not controlled, all parameters fixed at start.
DBB® combined w/ SiC Power Chip Technology
side-by-side comparison of different bonding technologies

- 6/8 samples per test / single SiC MOSFET chip
- ΔT = 130K, T_{MIN} = 35 °C
- EoL criteria: V_{DS} +5% or ΔT +20%

Test conditions: \(t_{on}=1.5\) sec; \(t_{off}=3\) sec; \(I=80\)A
How does ShowerPower work?

Turning around corners forces the flow to rotate, well-known phenomenon in rivers ⇒ mixing action with low pressure drop
Conclusion

DCM™ 1000X enables innovative Full-SiC inverter designs up to 250kW

- Danfoss is providing the new power module platform DCM™ 1000
- Target application is the automotive drive train in 400V with currents of 350-700A RMS
- Extended variant DCM™ 1000X enables 800V SiC inverter designs for 600A RMS
- Molded packaging, direct liquid cooling and Danfoss Bond Buffer technologies are combined to get the most out of silicon or SiC
- The half-bridge design offers scaling flexibility and room for customization
- This low inductive package (<5nH) sets the benchmark for future mass-produced Full-SiC automotive power modules
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#6 Worldwide
#3 in Europe
#2 in MOSFET Power Modules
Low Inductance SiC E3XL
Scalable solution targeting mid to high current range

- E3XL type baseplate
- 2-level half-bridge configuration
- 1200V & 1700V capable
- up to 600A
- up to 2x 12 SiC Chips - customizable
- Designed to fit SiC of various semiconductor manufactures.
- Laminated DC terminal configuration to enable very low system level commutation inductance.
- Optimized DC terminal design
Switching performance

- Turn-on switching transients
- Little diode ringing

- Turn-off switching transients
- Limited over-shoot at ~12kA/µs
Short Circuit Protection Scheme

- High-side shorted using copper bar
- Well known de-sat circuit used
- \( t_0 \): turn-on of low-side gate
- \( t_1 \): 500ns de-sat blanking time
- \( t_2 \): soft turn-off initiated
  - \( \sim 100 \text{ns} \) after blanking
- \( I_{\text{PEAK}} \sim 10 \times \) nominal current
  - \( \sim 6.5 \text{kA} \) here
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Serving three main industries

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#6 Worldwide
#3 In Europe
#2 in MOSFET Power Modules
Industrial Modules
Standard Packages, SiC optimized pin-out

- Customized Power Modules
- 900V, 1200V, 1700V
- 80A to 240A, 6.25mOhm to 25mOhm
- Tailored substrates e.g. Al₂O₃, AlN, SiN
- SiC MOSFET w/ or w/o SiC-SBD
- Multiple chip suppliers
- Pin-out optimized to reduce commutation inductance (multiple/parallel DC)
- Optimized gate impedance
- 3-level T-type on request
Summary
Different packages for different applications

- Customized SiC Power Modules tailored to application and power level
- Standard packages for easy integration, SiC optimized, for lower power levels
- Special packaging for high current and high volume applications
- Danfoss Bond Buffer (DBB™) available to improve cycling capability
- Comprehensive cooling solutions
Questions ?