Danfoss Silicon Power Introduces DCM 1000X (Full-SiC)
Next Gen Automotive Traction Inverter Power Modules

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Danfoss Silicon Power

Customized Power Modules and Stacks

Facts & numbers:

- ~500 employees
- 3,900 m² clean room, one of Europe’s largest single contiguous clean rooms
- 5,000 m² clean room manufacturing established in Utica, NY. SOP end of 2018
- SiC R&D competence center in Munich, DE
- ~30mio cars equipped with power modules from DSP
- TS16949 certified since 2006
  Automotive: <1ppm
- >30GW wind turbines installed with Danfoss Silicon Power Technology
Danfoss Silicon Power
Global Manufacturing Footprint

North-America
Utica (US)

EU
Flensburg (D)

Asia
(CN)

EU
Munich (D)

Utica (US) Manufacturing

DSP Headquarters (D)

Danfoss Drives Campus (CN)
Power Module Design for Next Generation SiC MOSFET
Making the most out of SiC

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

**Power Density**
- Tailored package size
- Customizable interfaces
- Enabling integration on system level

**Cooling Performance**
- Lowest $R_{th}$
- Low pressure drop
- Minimized temperature gradient

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

**Bonding and Joining**

**Packaging**

**Cooler Design**

**Module Design**
Bonding and Joining: DBB® improves reliability

Conventional Power Module Designs

1. Top side die bonding
2. Die – DBC bonding

Al-wires soldered

Effect of Power Cycling

Patented Danfoss Solution: DBB®

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

DBB® on Silicon Carbide

Danfoss Bond Buffer Technology
Packaging: Large moulded packages
10 years experience for automotive customers

Gen 1 - Project started 2007
Gen 1 - SOP 2010
(phased out in 2016)
Gen 2 - Project started 2008
Gen 2 - SOP 2012
(in production)
Gen 3 - Project started 2016
Gen 3 – planned SOP 2019+
Running automotive traction project

DCM™ 1000X illustration
Direct Liquid Cooling: ShowerPower® technology platform

10 years experience in advanced cooling

ShowerPower® Standard
Plastic turbulator in cooler forms channels for coolant

Gen 1 – in production since 2007

ShowerPower® Plus
Structured baseplate increases surface area

2007

ShowerPower® 3D
Coolant channels in baseplate

Gen 3 – planned SOP 2019+

2018

DCM™ 1000 illustration
Heat-sink design
cross-section view between module and heat-sink

- double gasket
- coolant outlet
- Coolant inlet
- 3-meander of SP3D® structure
  (coolant flow simulation illustrative)
Danfoss offers DCM™ 1000 technology platform for EVs
Presented in Bodo’s Power Systems® Issues through 2018
DCM™ 1000 technology platform with highest flexibility covering full range of Si-IGBT and SiC-MOSFET applications

- Blocking Voltage: 750 V + 1200 V
- Rated Current: 350 – 700 A_{rms}
- Terminals: customer specific (holes for samples)
- Semiconductors: various
- SiC ready: yes, package designed for SiC
- Stray Inductance: < 5 nH (module); ~ 8 nH (system commutation loop)
DCM™ 1000 / 1000X
Unlimited room for customization and scaling based on an existing platform

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

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

System stray inductance*

**di/dt method:**
8.2 nH

**Integral method:**
7.8 nH

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

→ **Allowing 50 A/\text{ns}**

50 V overshoot per **System-nH**

*total system commutation loop inductance measured in DSP Application Kit setup*
DCM™ 1000X - performance overview
Double-pulse switching characteristic

- No external SBD! No additional capacitors $C_{GS}$!
- Flexibility to adjust switching speed by individual gate resistors
- Fully damped chip-to-chip cross oscillations >200 MHz
- Designed to switch $2x$ nominal current at 850V up to 175°C

$\begin{align*}
I_D &= 600 \text{ A} \\
V_{DC} &= 850 \text{V} \\
E_{off} &= 23 \text{ mJ}\quad \text{preliminary} \\
E_{on} &= 30 \text{ mJ}\quad \text{preliminary} \\
R_{DS(on)25^\circ C} &= 2.5 \text{ m}\Omega \quad \text{Vgs=15V} \\
R_{DS(on)175^\circ C} &= 4 \text{ m}\Omega \quad \text{Vgs=15V} \\
V_{GS} &= -4/+15 \text{V}, \ T_j=RT, \ L_{Setup}=8\text{nH}
\end{align*}$

$V_{DC}=850\text{V}, \ I_D=1200\text{A}, \ V_{GS}=-4/+15\text{V}, \ T_j=175^\circ \text{C}, \ L_{Setup}=8\text{nH}$
DCM™ 1000X Evaluation Kit for 1200V – ready 2019

Component overview

The DCM™ 1000X evaluation kit provides a 3-phase-system.

It includes the following components:

- **3 DCM™ 1000X power modules** with ShowerPower®3D (2-Level Half-Bridge topology)
- **Gate Driver PCBA** with galvanic isolation and protection functions
- **300 µF Film capacitor**, 1000V nominal, 1200V surge
- **Aluminum cooler** and sealings
- Mounting plate and **mounting material**
Conclusion

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

- Danfoss is introducing 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 make 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**