SiC MOSFET Intelligent Power Module Platform for E-Mobility Applications

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OUTLINE

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- SiC Intelligent Power Module (IPM) Platform
- 3-Phase 1200V/450A SiC MOSFET IPM
- Integrated SiC Gate Driver
- Modelling for design support
- Conclusions
- Leader in High Temperature Semiconductors for Demanding Markets
- Solutions for efficient power conversion and compact motor drives
10 YEARS OF INNOVATION IN SiC GATE DRIVERS & POWER MODULES

1st SiC Gate Driver ICs
- High Temperature Gate Driver Chipset

225°C discrete SiC MOSFET
- 10A/1200V SiC MOSFET in TO-257

225°C SiC MOSFET Module
- Dual 30A/1200V SiC MOSFET

2nd Gen SiC Gate Driver ICs
- 2nd Generation Gate Driver Chipset

1st SiC MOSFET IPM
- 3-Phase 1200V/200A SiC IPM for Aerospace

125°C SiC Gate Driver Board
- For 62mm & XM3 SiC MOSFET Power Modules

SiC MOSFET IPM For E-Mobility
- 3-Phase 1200V/450A SiC IPM for E-Mobility

SiC Gate Drivers
Reliable SiC Power Packaging
SiC Intelligent Power Modules (IPM)

Timeline:
- 2011: 1st SiC Gate Driver ICs
- 2013: 225°C discrete SiC MOSFET
- 2015: 225°C SiC MOSFET Module
- 2015: 2nd Gen SiC Gate Driver ICs
- 2016: 1st SiC MOSFET IPM
- 2019: 125°C SiC Gate Driver Board
- 2020: SiC MOSFET IPM For E-Mobility

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3-PHASE 1200V SiC MOSFET INTELLIGENT POWER MODULE PLATFORM

- Highly Integrated SiC Power Module **platform** with SiC-Optimized Gate Driver
- Drastically shortening the design cycle of SiC-based inverters or active rectifiers
- Drain-Source breakdown voltage: 1200V
- Low On-Resistance: 2.2mΩ to 4.4mΩ
- Max Continuous Current: 300A to 600A
- Low Switching Energies
- Extended Operating Temperature
- Liquid cooling thanks to Lightweight AlSiC Pin Fin baseplate
SiC INTELLIGENT POWER MODULES
ROADMAP

2020

SiC MOSFET IPM
- Optimized for E-Mobility
- 450A/1200V
- 3.25mΩ Ron
- Pin Fin AlSiC Baseplate

SiC MOSFET IPM
- Optimized for E-Mobility
- 300A & 550A/1200V
- 4.4mΩ & 2.2mΩ Ron
- Pin Fin AlSiC Baseplate

SiC MOSFET IPM
- HPD compatible package
- 300A to 600A/1200V
- 2.2mΩ to 4.4mΩ Ron
- Pin Fin AlSiC Baseplate

Released
In development

2021

2022-2024
CXT-PLA3SA12450: 3-Phase 1200V/450A SiC MOSFET Intelligent Power Module

- Drain-Source breakdown voltage: 1200V
- Low On-Resistance: typ 3.25mΩ
- Max Continuous Current:
  - 450A typ. @ Tf=25°C
  - 330A typ. @ Tf=90°C
- Low Switching Energies, @ 600V/300A:
  - Eon: 7.8 mJ
  - Eoff: 8 mJ
- Max Switching Frequency: 25kHz
- High Isolation Grade: >3.6KVrms
- Junction-to-Fluid Thermal Resistance: 0.15°C/W
- Baseplate dimensions: 152mm*100mm
CXT-PLA3SA12450: 3-PHASE 1200V/450A SiC MOSFET INTELLIGENT POWER MODULE

- Thermally Robust
  - Max Junction Temperature of Power Transistors: 175°C
  - Lightweight Pin Fin AlSiC baseplate for water-cooling
  - Junction-to-Fluid Thermal resistance: 0.15°C/W at 10l/min at Flow Rate; 50% ethylene glycol, 50% water, 75°C inflow temperature
  - Junction-to-case Thermal resistance: 0.13°C/W
  - Temperature robust Gate Driver with Max Ambient Temperature up to 125°C
CXT-PLA3SA12450:

**TURN-OFF WAVEFORMS AT 600V/400A**

- Drain-Source voltage
  - 4-points sensing through power module control pins
- $\frac{dV}{dt}=15.4$KV/µs
- $\frac{dI}{dt}=10$A/ns
- $V_{overshoot}=220$V
- $L_{loop}=220$V/10A/ns=22nH
  - $\rightarrow \approx 11.5$nH for power module stray inductance [Ref 1]
  - $\rightarrow \approx 10.5$nH for DC bus capacitor ESL
CXT-PLA3SA12450: Voltage Overshoot versus Phase Current

The IPM can support 850V DC bus voltages with sufficient margin.

Note: Drain-Source voltage 4-points sensing through power module control pins.
INTEGRATED GATE DRIVER
CXT-PLA3SA12450: 3-Phase 1200V/450A SiC MOSFET Intelligent Power Module

- SiC-Optimized Gate Driver
  - High peak current (>10A) for fast switching
  - Robust against high dV/dt (> 50KV/µs)
  - High temperature (Tamb>125°C) for high power density
  - Accurate gate driver voltages (+/-5%)
  - Protection functions
    - UVLO (primary and secondary sides)
    - Desaturation Detection & Soft Shutdown
    - Active Miller Clamp
    - PWM glitch filter
    - PWM anti-overlap protection
CXT-PLA3SA12450 GATE DRIVER

OUTPUT CURRENT CAPABILITY

- Average Gate Current $I_{G\text{-}AVG}=30\text{mA}$ at 25KHz & with actual gate charge
  - Onboard DC-DC Converter can supply up to $95\text{mA}$ per channel without temperature derating
- Max Peak Gate Current $I_{G\text{-peak}}=3.8\text{A}$ with actual gate resistors
  - The gate driver can deliver up to $10\text{A}$ at $125^\circ\text{C}$

→ the gate driver keeps headroom for higher current ratings or switching frequencies!
CXT-PLA3SA12450 Gate Driver has been designed to be robust to high \( \frac{dV}{dt} \): the power transformer has been optimized for low parasitic capacitance in order to minimize common mode currents.

- The total parasitic capacitance between high-side and primary side, including power transformer and isolators, is < 10 pF.
- CXT-PLA3SA12450 Gate Driver is guaranteed to \( \frac{dV}{dt} > 50 \text{KV/µs} \).

→ High \( \frac{dV}{dt} \) enables fast switching & low losses!
CXT-PLA3SA12450 GATE DRIVER

PROTECTIONS

- **Anti-overlap:**
  - avoid simultaneous turn-on of both high-side and low-side to prevent short circuit of the power half bridge

- **Glitch filter:**
  - suppress glitches on incoming PWM signals which might be due to common mode current

- **Undervoltage Lockout (UVLO):**
  - monitors primary & secondary voltages and reports a fault when below a programmed voltage

- **Protection against any short-circuit at secondary:**
  - isolated DC-DC converter cycle-by-cycle current limitation protect the gate driver against any short-circuit (eg gate-source short-circuit)
CXT-PLA3SA12450 GATE DRIVER

PROTECTIONS

- **Active Miller Clamping (AMC):**
  - implements a bypassing of the negative gate resistor after turn-off to protect power MOSFET against parasitic turn-on

- **Desaturation detection:**
  - at turn On, check after a programmed blanking time, that the power MOSFET drain-source voltage is below a programmed threshold

- **Soft Shut-down:**
  - in case of fault, slow turn-off (speed programmable) of the power transistor to minimize overshoots due to high $dI/dt$
3D MODELLING
CXT-PLA3SA12450 3D STEP FILE

- IPM concept allows to directly start mechanical design without uncertainties regarding the integration of the gate driver
- IPM 3D model [Ref 2] accelerates Inverter design
3D MODELLING
CXT-PLA3SA12450 REFERENCE COOLER

- Reference Liquid Cooler 3D Step file [Ref 3] and 3D printing file [Ref 4] are available for download as explained in a detailed application note [Ref 5]
- For a rapid evaluation, this cooler can be 3D printed in polymer material (e.g. PA12) [Ref 4]
- O-Ring reference also available
This model [Ref 6] supports:
- Transistor-level modelling of SiC MOSFETs
- Behavioral modelling of the gate driver
- Modelling of parasitic inductances
- Modelling of $dV/dt$, $dI/dt$ and voltage overshoots
- Modelling of SiC MOSFETs On resistance variation with temperature
- Transient thermal modelling with thermal RC network between $T_{\text{Fluid}}$ and $T_J$
CONCLUSIONS

▪ A 1200V SiC MOSFET Intelligent Power Module platform has been developed for high power density applications
▪ The first product out of this platform supports motor drive at 600VDC, 450Arms and 10KHz
▪ The robust integrated gate driver solves the challenges of driving SiC MOSFETs
▪ It also enables immediate evaluation and testing of the 3-Phase SiC Power Module
▪ Mechanical, Electrical & Thermal modelling accelerates the design of SiC-based power inverters for E-Mobility
REFERENCES

9. "Intelligent Power Modules Accelerate Transition to SiC-Based Electric Motion", in E-Mobility Technology International Magazine, Winter 2020, p128.(Download the full article in PDF).
THANKS FOR YOUR ATTENTION

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