SiC MOSFET Intelligent Power Module Platform for E-Mobility Applications

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OUTLINE

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- Introduction
- SiC Intelligent Power Module (IPM) Platform
- 3-Phase 1200V/450A SiC MOSFET IPM
- Integrated SiC Gate Driver
- Modelling for design support
- Conclusions

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- 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

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1st SiC Gate Driver ICs — High Temperature Gate Driver Chipset — **2011**

225°C discrete SiC MOSFET — 10A/1200V SiC MOSFET in TO-257 — **2013**

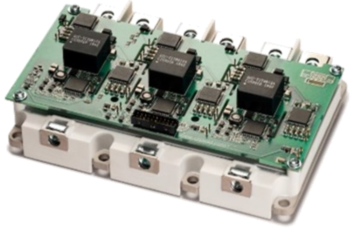
225°C SiC MOSFET Module — Dual 30A/1200V SiC MOSFET — **2015**

2nd Gen SiC Gate Driver ICs — 2nd Generation Gate Driver Chipset — **2015**

1st SiC MOSFET IPM — 3-Phase 1200V/200A SiC IPM for Aerospace — **2016**

125°C SiC Gate Driver Board — For 62mm & XM3 SiC MOSFET Power Modules — **2019**

SiC MOSFET IPM For E-Mobility — 3-Phase 1200V/450A SiC IPM for E-Mobility — **2020**



SiC Gate Drivers

Reliable SiC Power Packaging

SiC Intelligent Power Modules (IPM)

3-Phase 1200V SiC MOSFET Intelligent Power Module Platform

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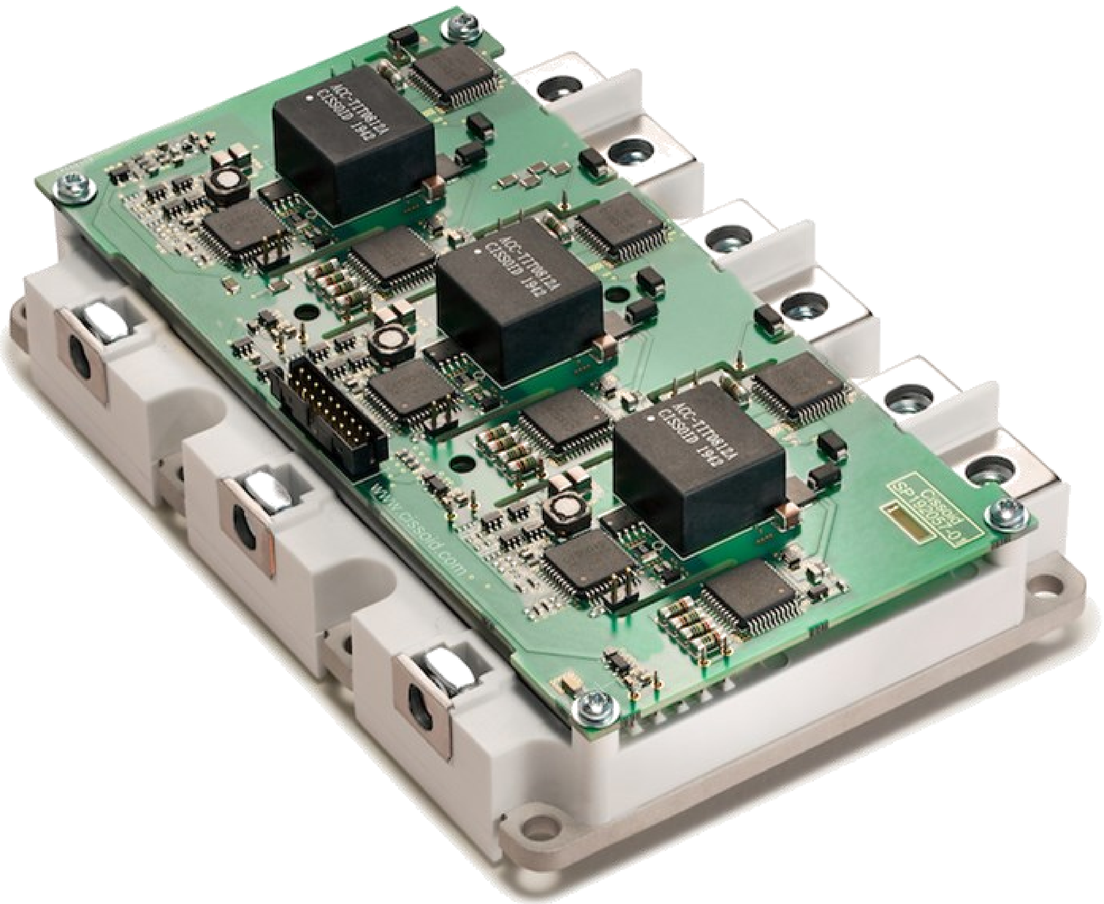
- Highly Integrated SiC Power Module **platform** with SiC-Optimized Gate Driver
- Drastically shortening the design cycle of SiC-based inverters or active rectifiers
- Drain-Source breakdown voltage: 1200V
- Low On-Resistance: 2.2mΩ to 4.4mΩ
- Max Continuous Current: 300A to 600A
- Low Switching Energies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



SiC Intelligent Power Modules Roadmap

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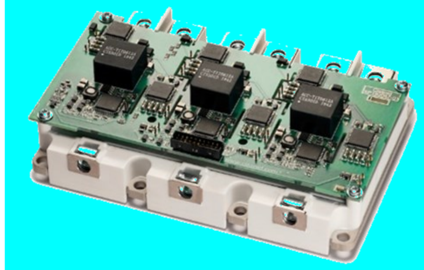
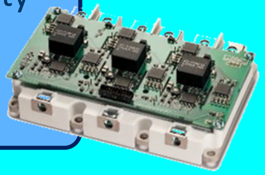
2020 | 2021 | 2022-2024

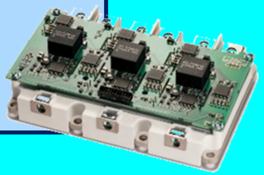
SiC Intelligent Power Modules



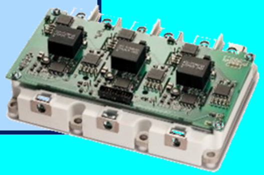
SiC MOSFET IPM
- Optimized for E-Mobility
- 450A/1200V
- 3.25mΩ Ron
- Pin Fin AlSiC Baseplate



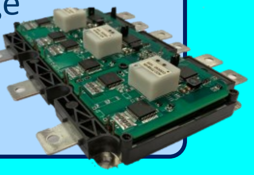
SiC MOSFET IPM
- Optimized for E-Mobility
- 300A & 550A/1200V
- 4.4mΩ & 2.2mΩ Ron
- Pin Fin AlSiC Baseplate



SiC JFET IPM
- Optimized for E-Mobility
- 600A/1200V
- 1.8mΩ 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

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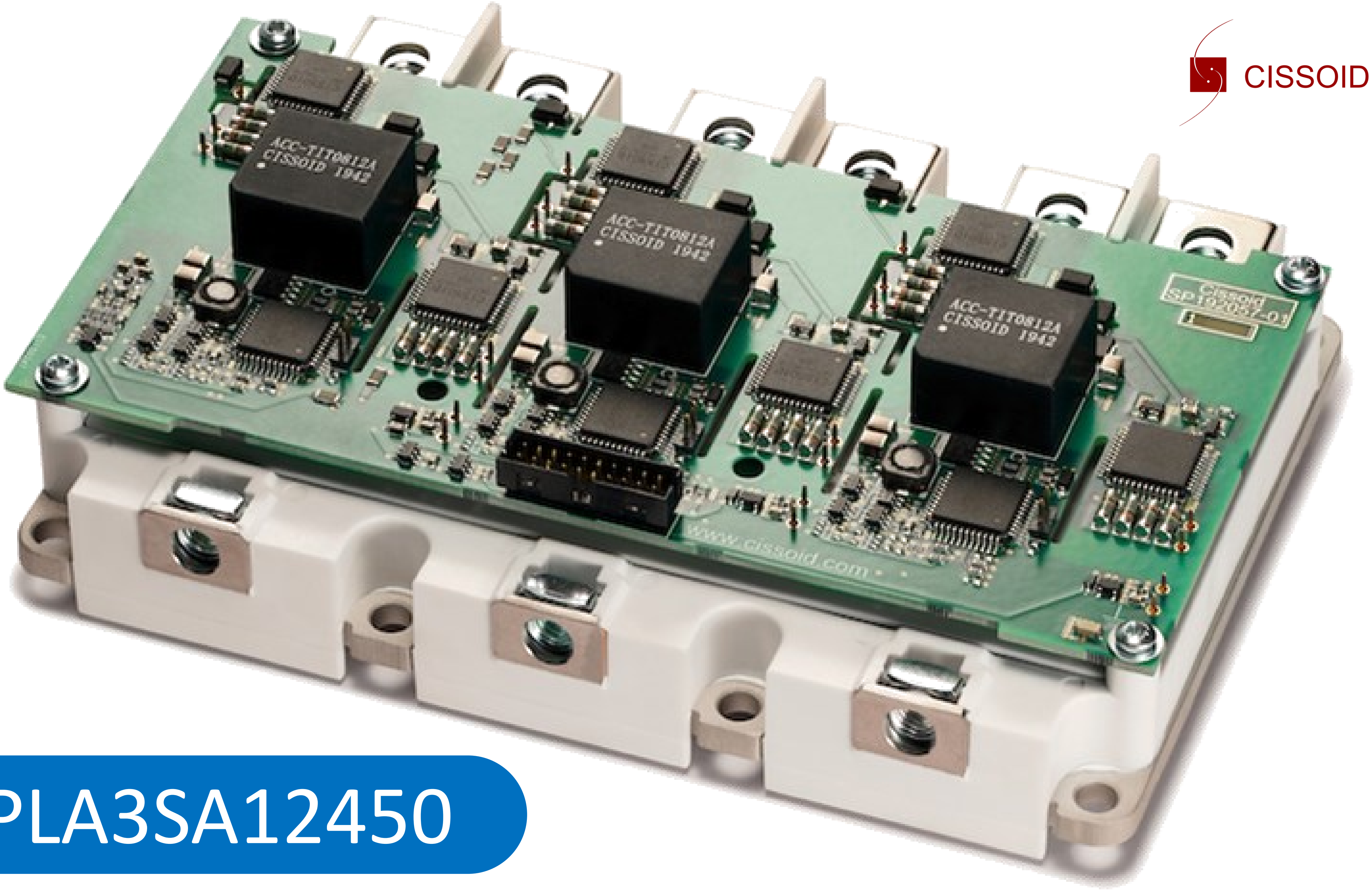

CXT-PLA3SA12450

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

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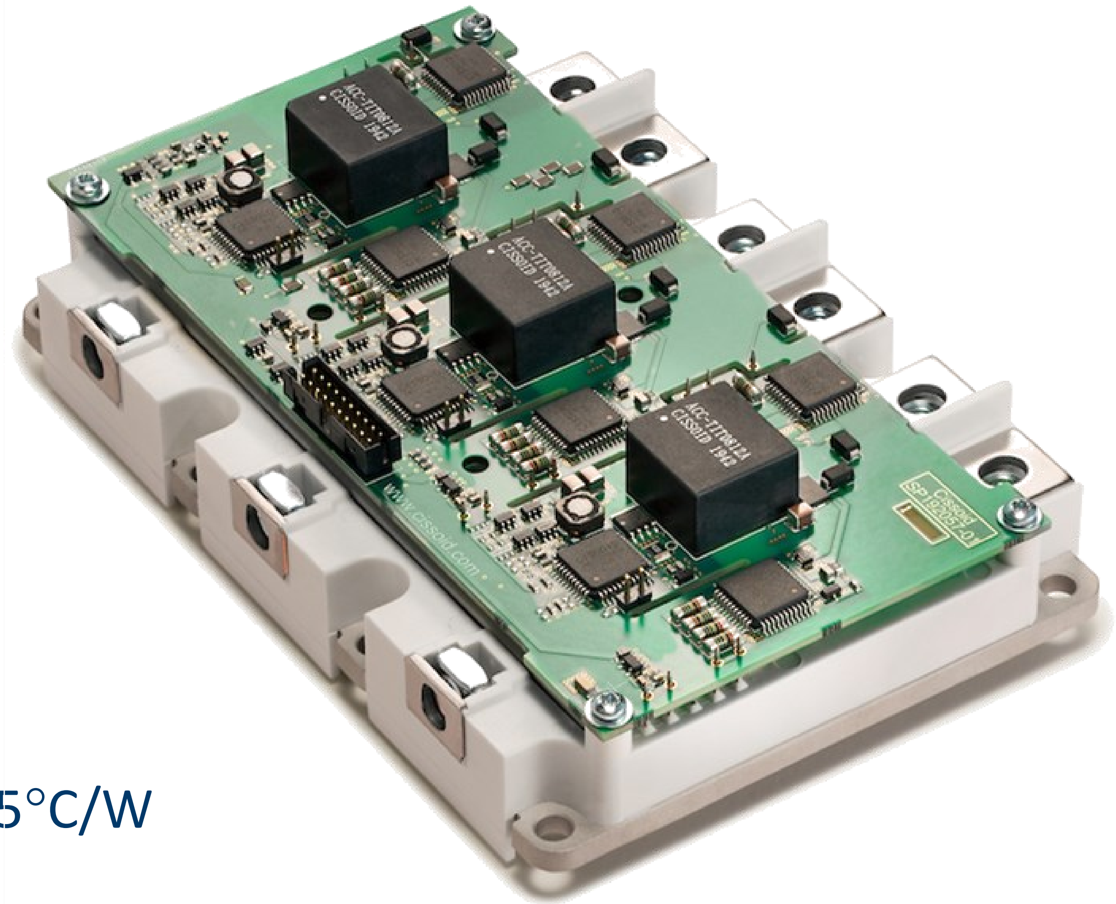
- Drain-Source breakdown voltage: 1200V
- Low On-Resistance: typ 3.25mΩ
- Max Continuous Current:
  - 450A typ. @ Tf=25°C
  - 330A typ. @ Tf=90°C
- Low Switching Energies, @ 600V/300A:
  - Eon: 7.8 mJ
  - Eoff: 8 mJ
- Max Switching Frequency: 25kHz
- High Isolation Grade: >3.6KVrms
- Junction-to-Fluid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



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

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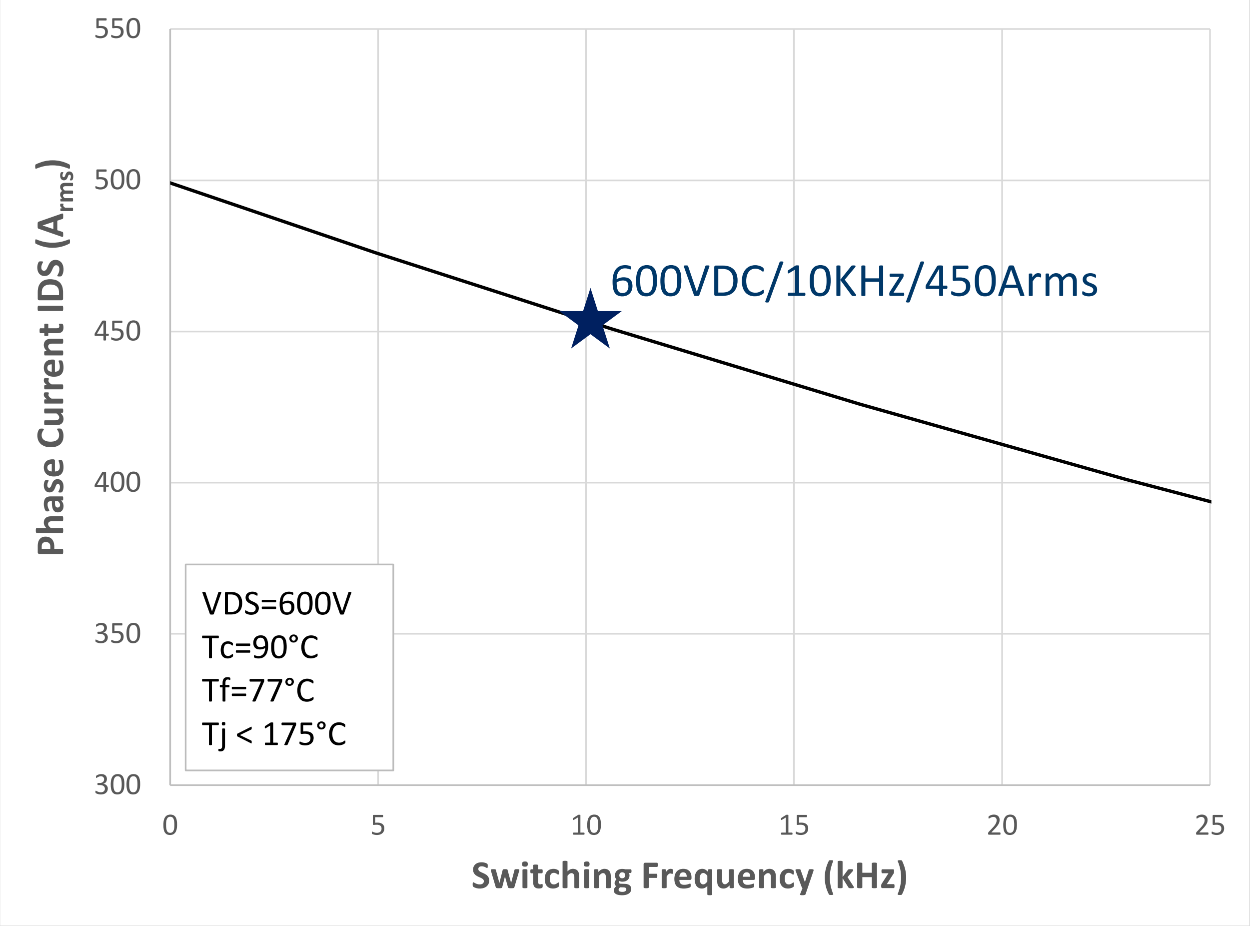
- Thermally Robust
  - Max Junction Temperature of Power Transistors: 175°C
  - Lightweight Pin Fin AlSiC baseplate for water-cooling
  - Junction-to-Fluid Thermal resistance: 0.15°C/W at 10l/min at Flow Rate; 50% ethylene glycol, 50% water, 75°C inflow temperature
  - Junction-to-case Thermal resistance: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



CXT-PLA3SA12450:
TURN-OFF WAVEFORMS AT 600V/400A

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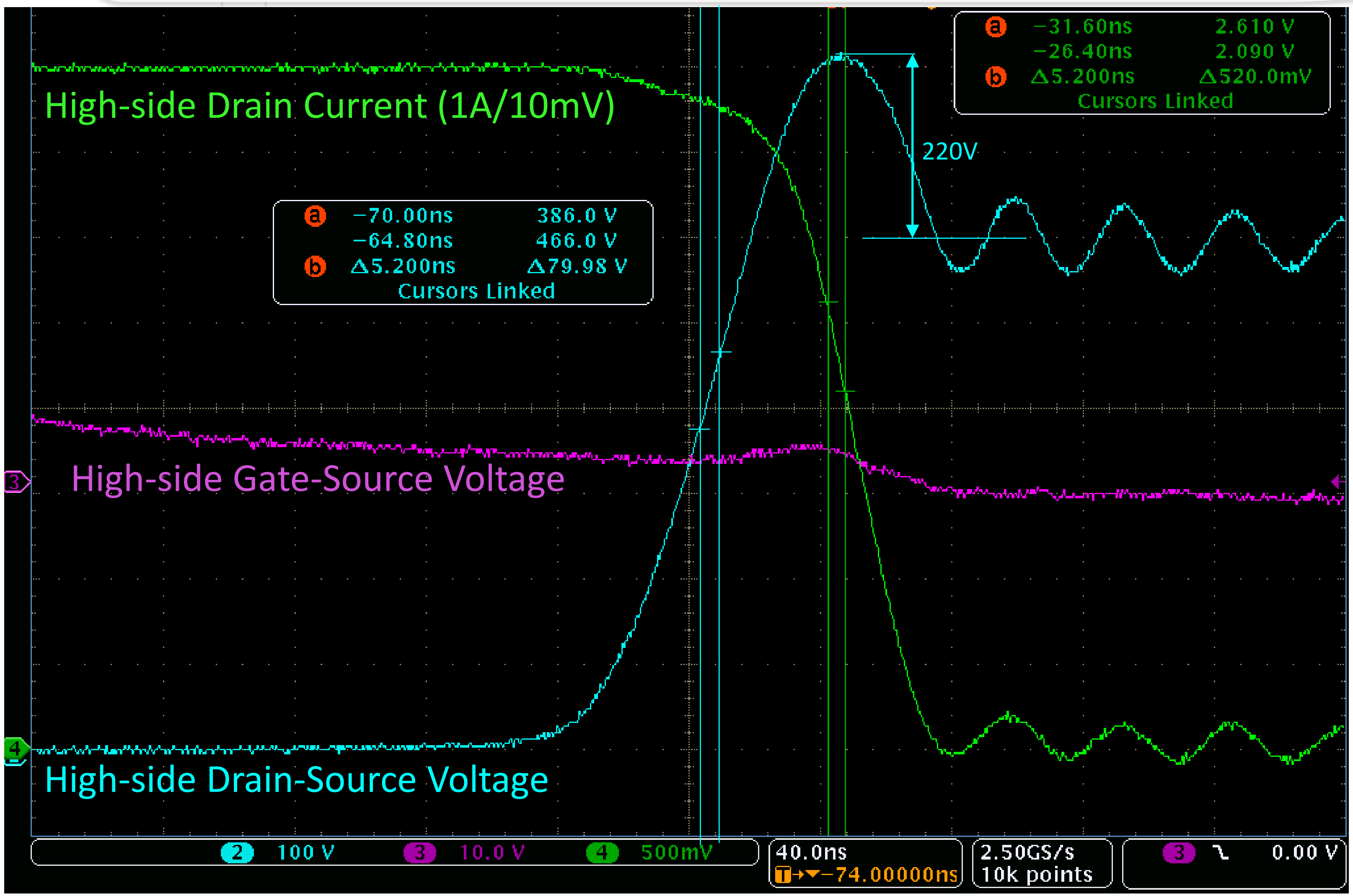
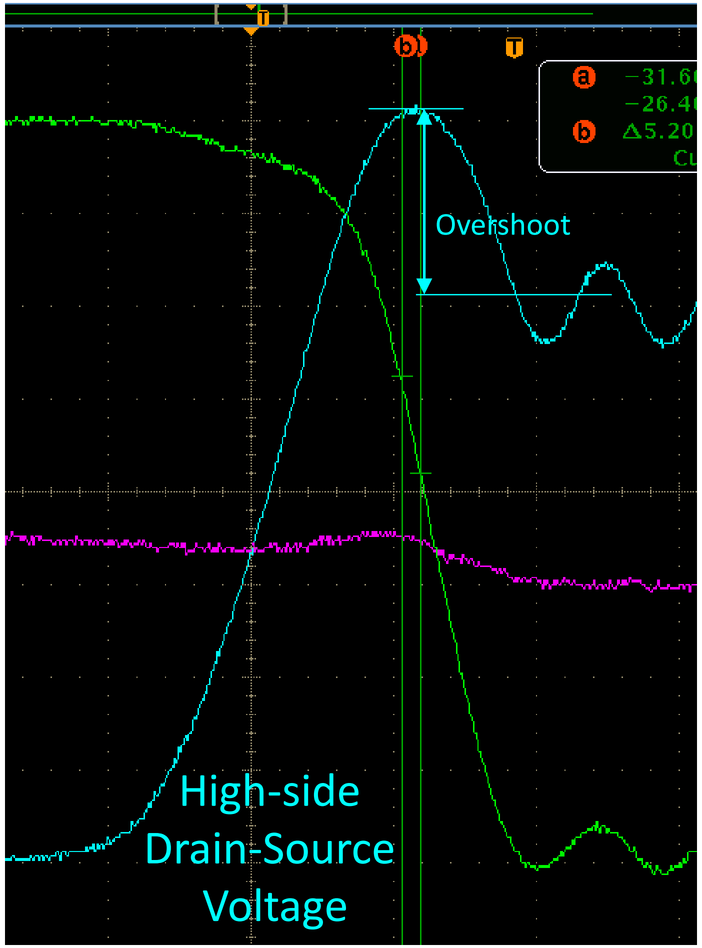
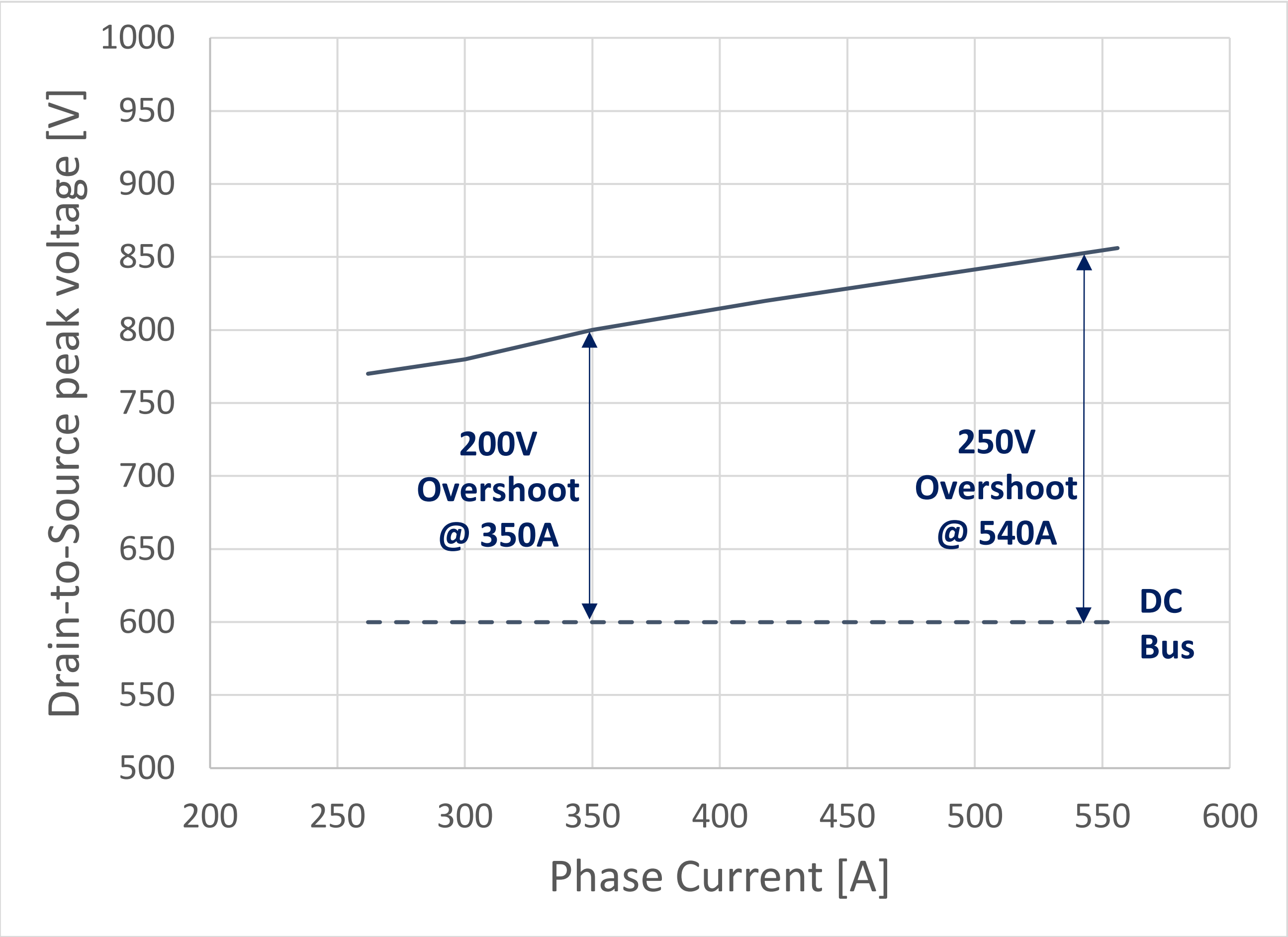


- Drain-Source voltage 4-points sensing through power module control pins
- dV/dt=15.4KV/µs
- dI/dt=10A/ns
- $V_{overshoot}$=220V
- L_{loop}=220V/10A/ns=22nH

→≅ 11.5nH for power module stray inductance [Ref 1]
→≅ 10.5nH for DC bus capacitor ESL

CXT-PLA3SA12450: Voltage Overshoot versus Phase Current





Note:
Drain-Source voltage 4-points sensing through power module control pins

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

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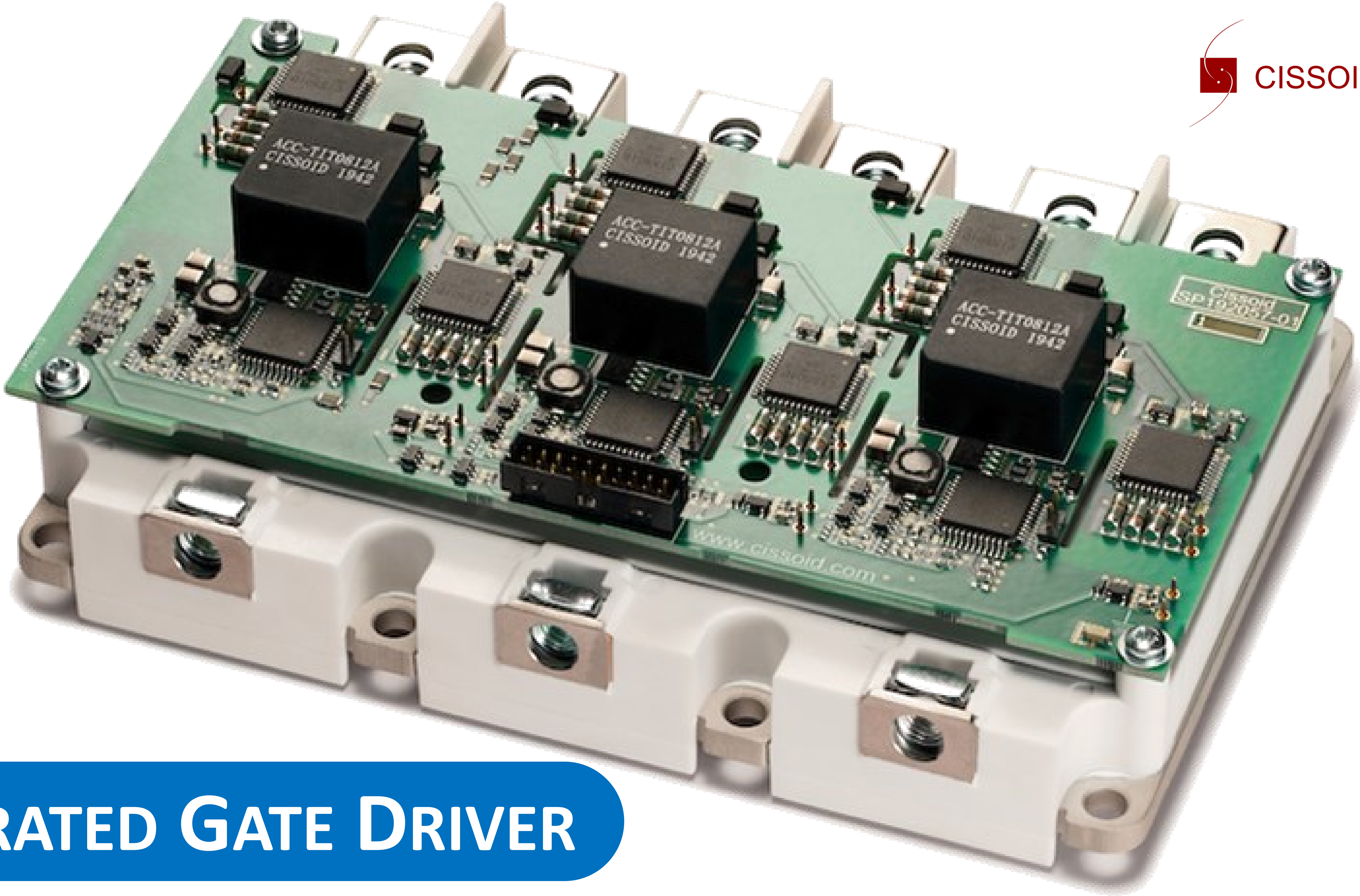

Integrated Gate Driver

CXT-PLA3SA12450: 3-PHASE 1200V/450A SiC MOSFET INTELLIGENT POWER MODULE

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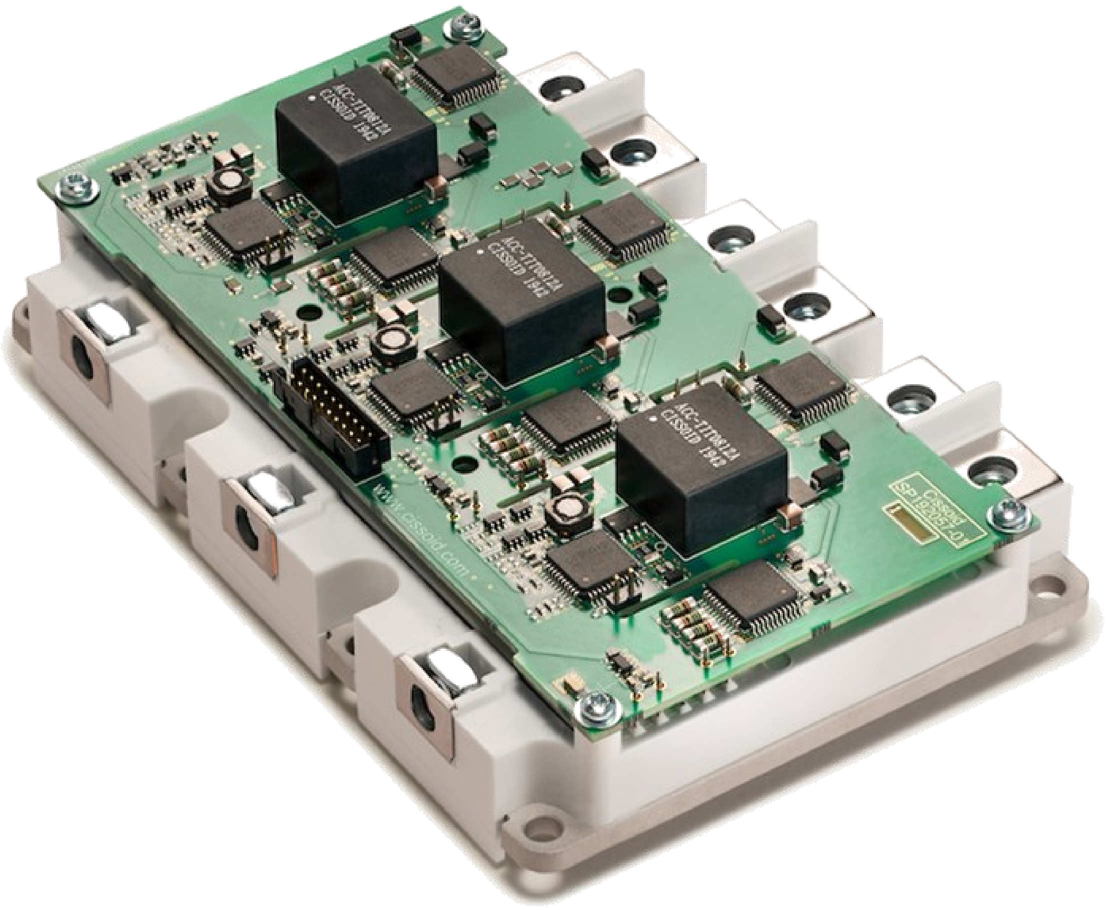
- SiC-Optimized Gate Driver
  - High peak current (>10A) for fast switching
  - Robust against high dV/dt (> 50KV/µs)
  - High temperature (Tamb>125°C) for high power density
  - Accurate gate driver voltages (+/-5%)
  - Protection functions
    - UVLO (primary and secondary sides)
    - Desaturation 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_AVG}**=30mA** at 25KHz & with actual gate charge
  - Onboard DC-DC Converter can supply up to **95mA** per channel without temperature derating
- Max Peak Gate Current I_{G_peak}**=3.8A** with actual gate resistors
  - The gate driver can deliver up to **10A** at 125°C

→ **the gate driver keeps headroom for higher current ratings or switching frequencies!**

CXT-PLA3SA12450 GATE DRIVER
COMMON-MODE IMMUNITY

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- CXT-PLA3SA12450 Gate Driver has been designed to be robust to **high 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 **< 10pF**
- CXT-PLA3SA12450 Gate Driver is guaranteed to **dV/dt > 50KV/µs**

→ **<u>High dV/dt enables fast switching & low losses!</u>**

CXT-PLA3SA12450 GATE DRIVER

PROTECTIONS

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- **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

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- **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

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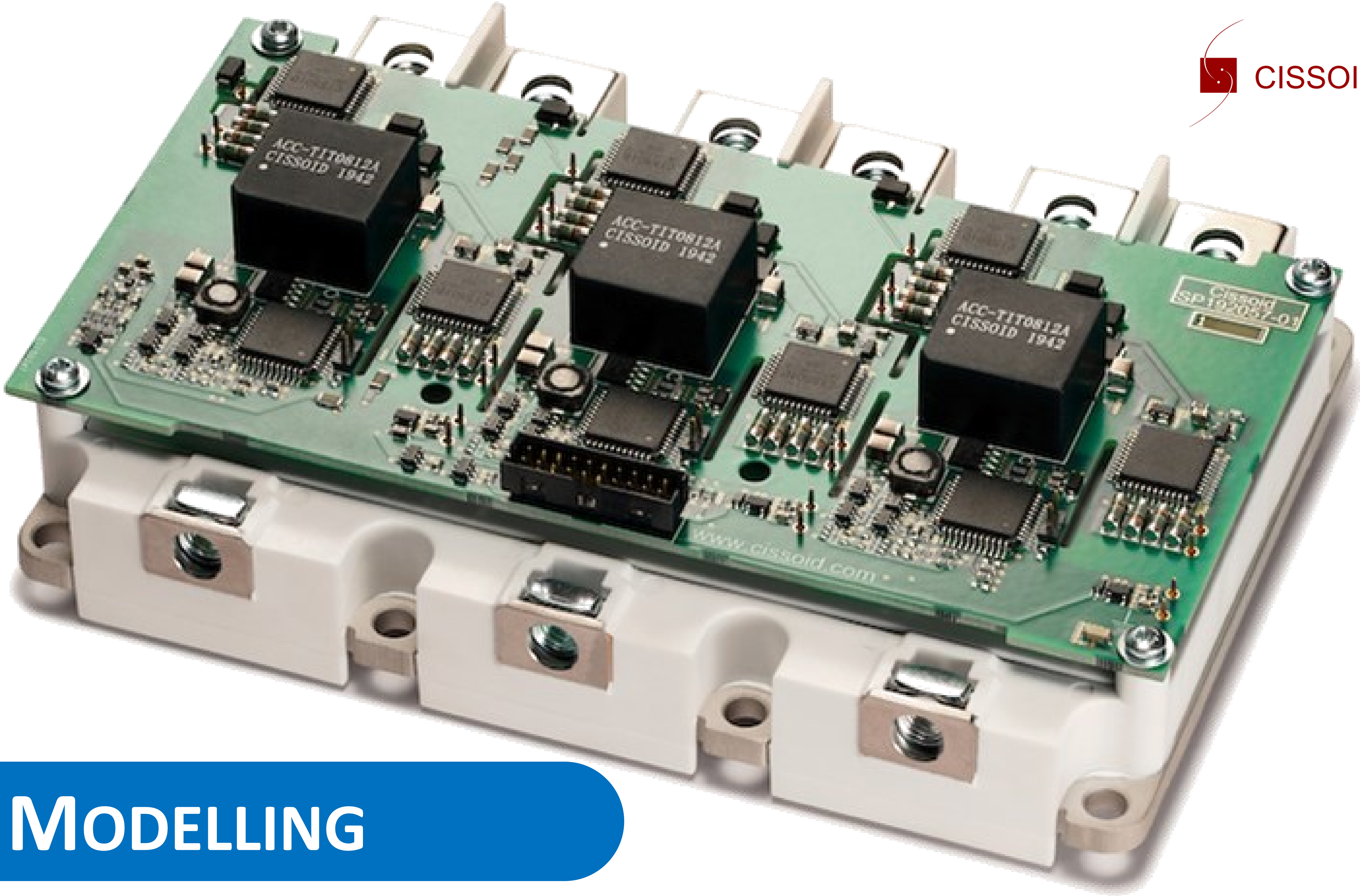

MODELLING

3D MODELLING
CXT-PLA3SA12450 3D STEP FILE

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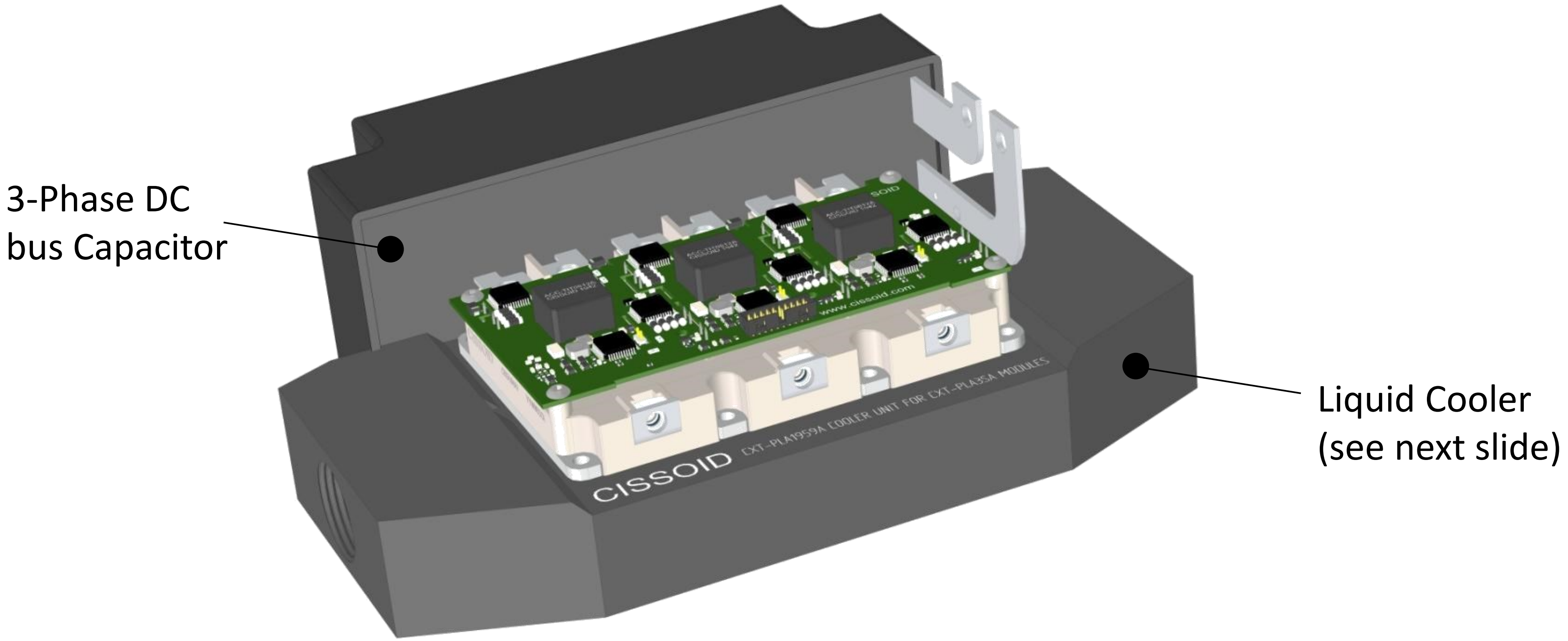
- IPM concept allows to directly start mechanical design without uncertainties regarding the integration of the gate driver
- IPM 3D model [Ref 2] accelerates Inverter design



3D MODELLING

CXT-PLA3SA12450 Reference Cooler

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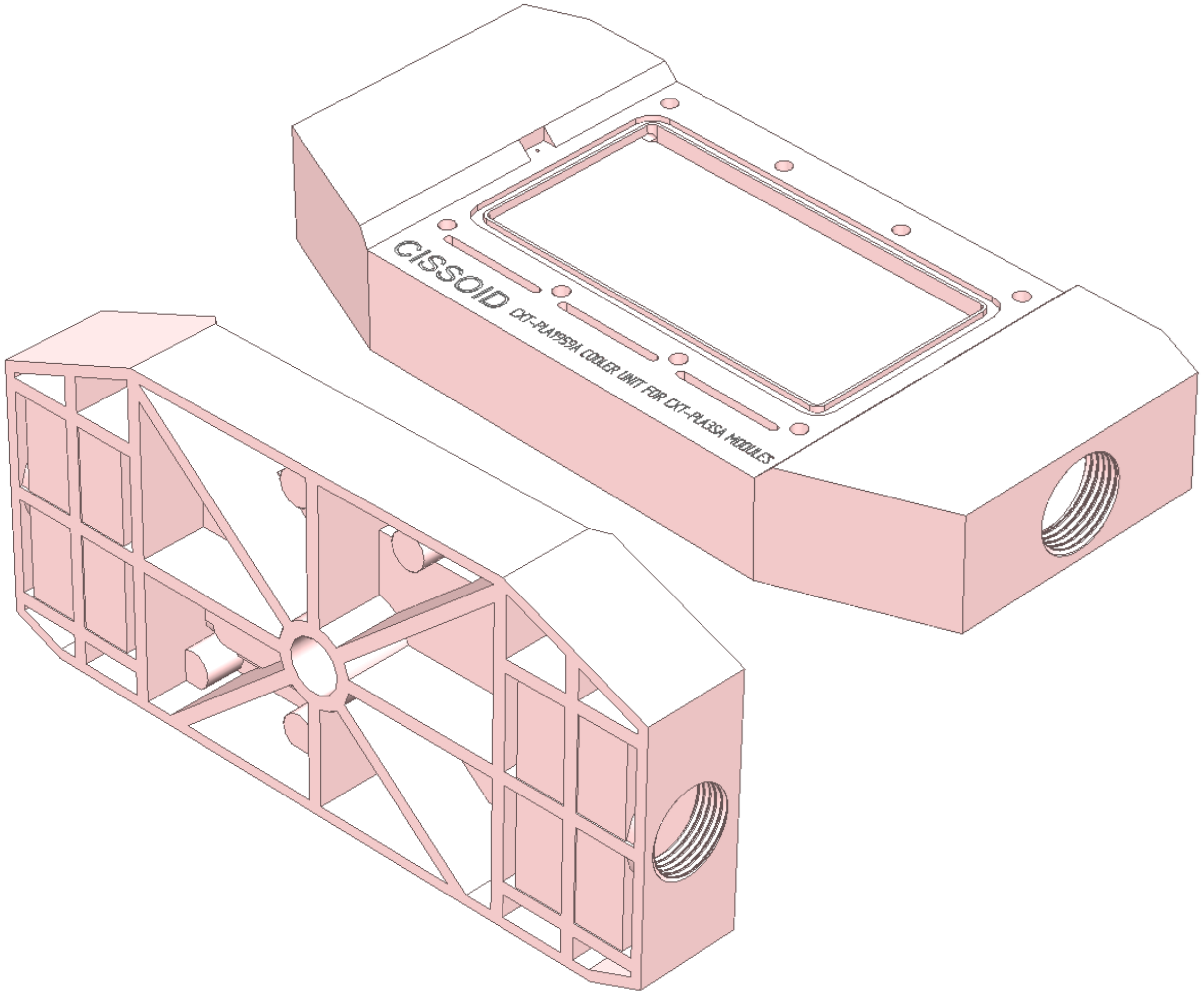
- Reference Liquid Cooler 3D Step file [Ref 3] and 3D printing file [Ref 4] are available for download as explained in a detailed application note [Ref 5]
- For a rapid evaluation, this cooler can be 3D printed in polymer material (e.g. PA12) [Ref 4]
- O-Ring reference also available



ELECTRICAL & THERMAL MODELLING
CXT-PLA3SA12450 LTSPICE MODEL

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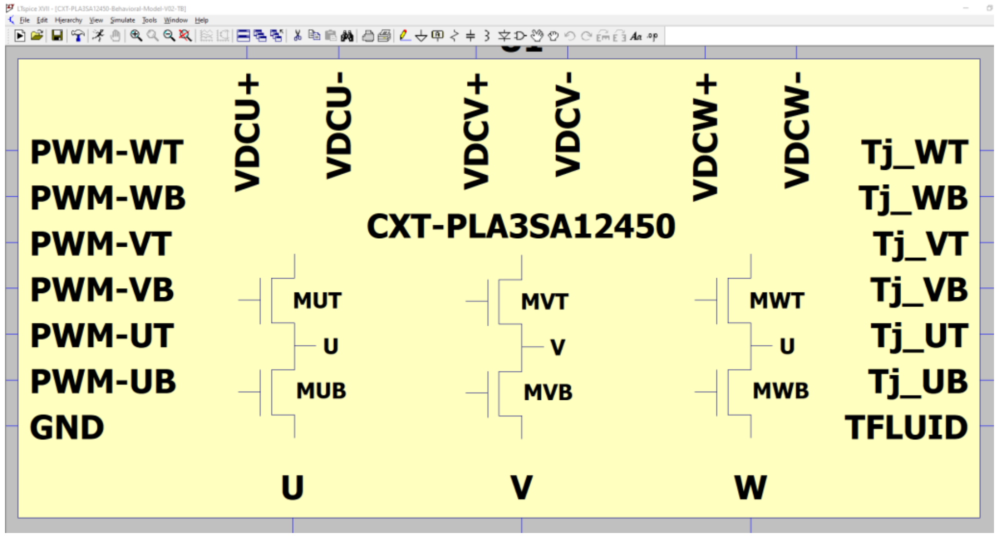
- This model [Ref 6] supports
  - Transistor-level modelling of SiC MOSFETs
  - Behavioral modelling of the gate driver
  - Modelling of parasitic inductances
  - Modelling of dV/dt, dI/dt and voltage overshoots
  - Modelling of SiC MOSFETs On resistance variation with temperature
  - Transient thermal modelling with thermal RC network between T_{Fluid} and T_J



CONCLUSIONS

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- 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

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1. **CXT-PLA3SA12450 datasheet:** http://www.cissoid.com/files/files/products/planet/CXT-PLA3SA12450.pdf
2. **CXT-PLA3SA12450 3D step model**: https://www.cissoid.com/download/private-documents/cxt-pla3sa12450-intelligent-power-module-3d-step-file/
3. **CXT-PLA3SA Reference Cooler 3D step model:** https://www.cissoid.com/download/private-documents/cxt-pla3sa-intelligent-power-module-reference-cooler-3d-step-file/
4. **CXT-PLA3SA Reference cooler 3D printing file:** https://www.cissoid.com/download/private-documents/cxt-pla3sa-intelligent-power-module-reference-cooler-3d-printing-file/
5. **Mounting & Cooling recommendations for 3-phase SiC MOSFET Intelligent Power Modules CXT-PLA3SA Series, Application Note**: https://www.cissoid.com/download/private-documents/cxt-pla3sa-intelligent-power-module-mounting-&-cooling-recommendations-application-note/
6. **CXT-PLA3SA12450 LTspice Model:** https://www.cissoid.com/download/private-documents/cxt-pla3sa12450-intelligent-power-module-LTSpice-model/
7. **"A 3-Phase 1200V/450A SiC MOSFET Intelligent Power Module for E-Mobility"** in Bodo's Power Systems Magazine, May 2020 (Download the full article in PDF, English).
8. **"三相 1200V/450A SiC MOSFET 电动汽车智能 功率模块"**, in Bodo's Power Systems China Magazine, June 2020 (Download the full article in PDF, Chinese).
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).
10. **"Modulo di Potenza Intelligente per la Mobilità Elettrica"**, Elettrica Oggi Power, Oct. 2020 (Download the full article in PDF).

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THANKS FOR YOUR ATTENTION

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