

# Platform for Traction-Inverter Development Eases the Road to Future Mobility

*The momentum towards electrified mobility is gathering as governments commit to ending sales of petrol and diesel cars around the 2030 timeframe. The automotive industry, including manufacturers of trucks and buses as well as passenger or specialty vehicles, needs to solve e-powertrain design challenges quickly. However, the technology is unfamiliar and significant engineering resources and time are needed to create a properly developed solution.*

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Silicon carbide (SiC) is the power-semiconductor technology of choice, bringing several advantages to electric drive systems. Its superior switching performance translates into greater efficiency that ultimately extends driving range. In addition, SiC's high breakdown voltage in relation to transistor size and high-temperature capability enable greater power density and enhance reliability.

However, there are differences, when designing with SiC, compared to ordinary silicon MOSFETs or IGBTs. The gate driver design is more complicated, calling for high peak-current capability with careful control of the applied voltage for fast transitions and efficient switching. Safe operation through high voltage transient (dV/dt) and overshoot during high-speed switching is also essential, to make the most of SiC's potential for improved energy efficiency. Another important constraint is that SiC's lower switching losses enable a higher inverter operating frequency, which, in turn, increases the demand on the controller hardware and software to maintain real-time control.

Building an intelligent power module for electric drive is no trivial task. Fortunately, suitable standard modules are becoming available, that can abstract solution developers from basic power-electronic hardware design challenges.

However, finding a suitable module, meeting suitable size, power, and supply voltage requirement is only one part of the puzzle. As delivered, it is not a ready to use solution. Significant additional engineering is needed including developing the software to control the system, as well as working out and implementing adequate cooling.

An integrated solution that covers all of these aspects can be particularly valuable to system developers under pressure to meet tight time to market window as demand for EVs and other E-Mobility applications is set to begin rising quickly in the years approaching 2030 and beyond.

## Accelerating Inverter Bring-Up

Cissoid's SiC inverter platform (figure 1) alleviates these challenges by bringing together the key elements needed in a drive system, thereby avoiding critical engineering and integration challenges. The platform comprises an intelligent power module (IPM), a controller board and customisable software, a liquid cooler reference design, and a specially designed high-density DC-link capacitor [1].

At the heart of this platform is a family of 3-phase, 1200V IPMs (figure 2) that contain gate drivers fully developed and optimised for SiC application [2].



Figure 2: The power module and gate driver at the centre of Cissoid's IPM platform.

Designed using Cissoid's long experience in power design for transportation, aerospace, and industrial environments, the modules deliver an advanced level of integration and high reliability. The portfolio comprises modules with maximum continuous current capability from 340A to 550A. Containing a SiC MOSFET array with low turn-on/turn-off losses of about 7-9mJ at 300A/600V, they also have low on resistance in the range 2.53mΩ to 4.2mΩ.

The optimised gate driver delivers a high peak current, greater than 10A, to ensure fast switching. The gate-driving voltages are tightly controlled, within +/- 5%, and all necessary protections are built-in. These include under-voltage lockout (UVLO) on the primary and secondary sides, desaturation detection and soft shutdown, and negative drive with active Miller clamp (AMC) to prevent parasitic turn-on that can damage the MOSFETs. There is also a PWM glitch filter and PWM anti-overlap protection. The gate driver also features high temperature operation ( $T_{\text{ambient}}$  up to 125°C) and a pow-



Figure 1: Cissoid's SiC Inverter platform.

er transformer designed for low parasitic capacitance to minimise common-mode current interference.

In addition to ensuring high integration that helps maximise reliability and power density, this turnkey IPM saves up to two years in SiC inverter development. The conduction and switching losses of the power module are known from the beginning and fully characterised. In addition, the optimised gate driver helps minimise the number of iterations to perfect the module performance and thermal management.

**Secret's in the Software**

Cissoid and Silicon Mobility have partnered in designing the control board to manage the IPM, aiming at accelerating SiC-based e-motor drive development. The board is based on the Silicon Mobility OLEA® T222 Field-Programmable Control Unit (FPCU), which provides real-time processing, control and functional safety optimised for automotive control applications. All needed hardware and interfaces are provided, including CAN, LIN, and SPI. The signals from motor position (resolver, encoder, or magnetic-based), current and temperature sensors are also properly managed by the control hardware and software. Mechanical and electrical integration between the control board and IPMs is completed, which removes another hurdle from the developer's path.

Up to this point, the IPM platform relieves developers of specialist power electronics and hardware design challenges and delivers the advantage of a state-of-the-art compute engine which eliminates processing bottlenecks that often hamper real-time performance of conventional controllers [3]. In addition, the chip is already ISO 26262 ASIL-D functional-safety design ready certified

But more is needed. The platform is integrated with Silicon Mobility's OLEA APP INVERTER control software, and developers can use OLEA COMPOSER design tools to quickly develop and optimise the motor-control software. APP INVERTER (figure 3) has advanced control algorithms for highly energy-efficient systems, suitable for a wide variety of motor types, with support for various control and regulation strategies including flux weakening and field-oriented control (FOC), dynamic space-vector pulse-width modulation (SVPWM) or discontinued pulse-width modulation (DPWM), and sensor or sensorless rotor-position detection. OLEA COMPOSER and OLEA APP INVERTER are ISO 26262 certified for system design up to ASIL-D.

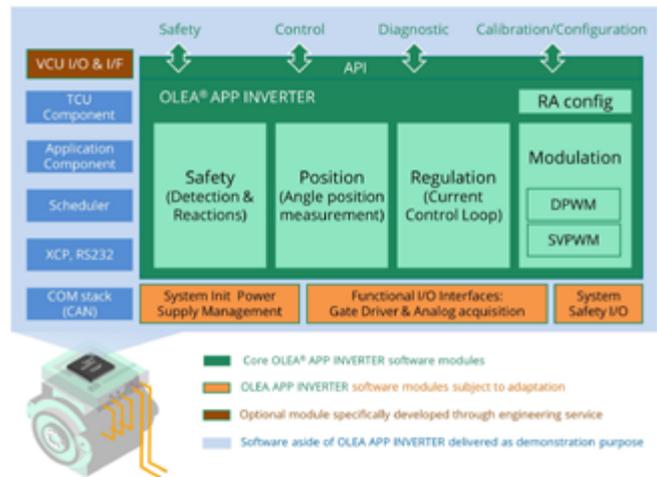
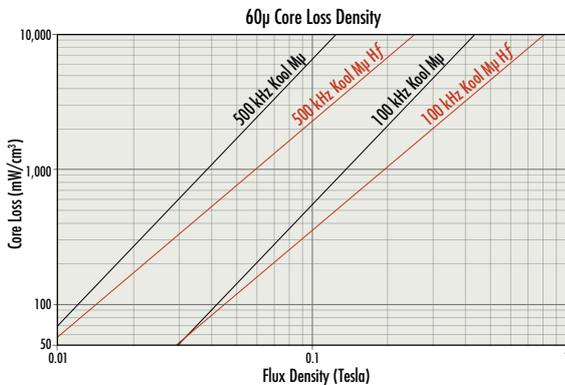


Figure 3: Motor-control software is tightly integrated with the IPM platform.

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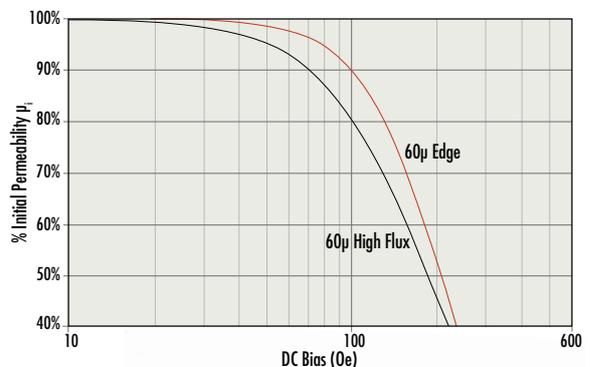
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### DC-Link Capacitor

The performance of some aspects of the drive system, such as the DC-link capacitor, often passes under the radar. However, this is an aspect that rewards investment in proper engineering to stabilise the inverter input and provide noise attenuation within a compact footprint and low bill of materials cost.

Cissoïd has collaborated with NAC Semi and Advanced Conversion Inc. to create a DC-link capacitor that brings important advantages to automotive electric drives [4]. The resulting integrated capacitor/busbar solution has very low inductance that gives full freedom to take advantage of the fast-switching capability of the SiC MOSFETs. The capacitor topology is optimal for high power density thanks to low series resistance and high amperes per microfarad, that ensures the capacitor to be sized depending on the power inverter control needs rather on its current rating.

Depending on the module power and voltage, a variety of DC-link capacitors is available from NAC Semi, all based on the same design, with operating voltage from 500V to 900V and capacitance from 135 $\mu$ F to 500 $\mu$ F. Figure 4 shows the capacitor installed in the rear of the module behind the inverter and gate driver assembly.

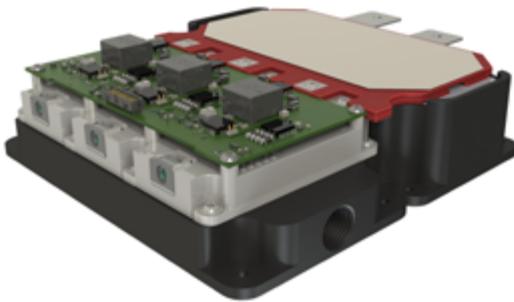


Figure 4: The IPM, comprising inverter, gate driver, and DC-link capacitor.

### Keeping Cool

Finally, a reference design and 3D-printed cooler (figure 5) provide a thermally calculated solution for cooling and rapid evaluation of power the module [5]. The reference cooler features a fluid channel, sealing O-rings, and provision for attaching a thermocouple and pressure sensor. Threaded inserts allow the IPM to be bolted directly in place and 19mm hose nozzles are fitted for coolant input and output.

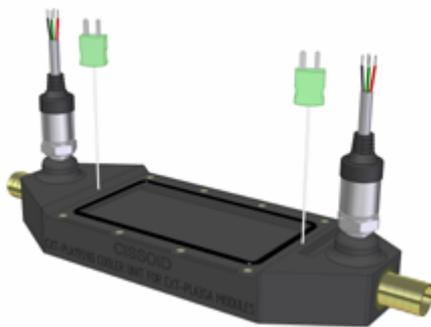


Figure 5: The 3D-printed reference cooler is optimally sized and comes ready to attach the power module and coolant supply.

### Proving Performance

LTSpice models for the IPM are available [6] and allow modelling of key performance parameters including transistor-level and gate-driver modelling, parasitic inductances, temperature dependence, transient thermal modelling, and switching characteristics including  $dV/dt$ ,  $dI/dt$  and voltage overshoot (figure 6).

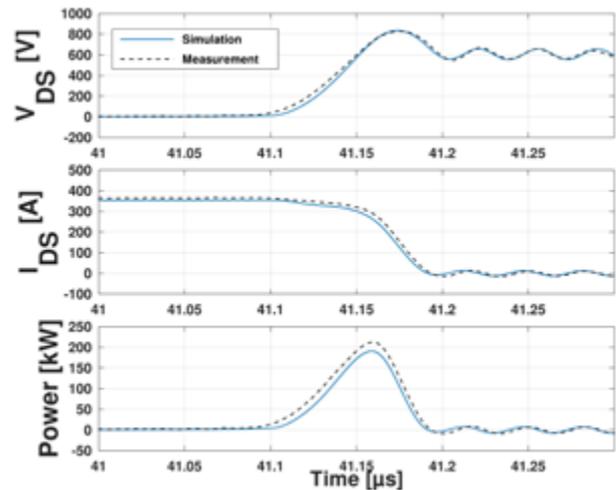


Figure 6. LTSpice models facilitate assessment of key parameters including switching: Turn-off waveforms of the CXT-PLA3SB12450AA ( $V_{bus}=600V$ ,  $I_{phase}=328A$ ,  $L_{load}=63\mu H$ )

### Conclusion

Bringing up a robust and reliable, high-performing electric drive system demands diverse specialist engineering skills and can take two years or more to complete satisfactorily and ensure optimum hardware and software performance.

An IPM platform that combines solutions to the numerous hardware and software challenges reduces the time typically needed to create efficient and compact SiC-based inverters, with fault protection and ready to meet functional-safety standards, to just a few months.

### References

- [1] SiC Inverter Platform: <https://www.cissoïd.com/sic-power-modules/#SiC-Inverter-Platform>
- [2] Pierre Delatte, "A 3-Phase 1200V/450A SiC MOSFET Intelligent Power Module for E-Mobility" in Bodo's Power Systems Magazine, May 2020
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- [4] Application Note - "DC-Link Capacitors for CISSOID SiC Intelligent Power Modules": <https://www.cissoïd.com/download/private-documents/dc-link-capacitors-for-cissoïd-s-sic-intelligent-power-modules/>
- [5] Application note - "Mounting & Cooling recommendations for 3-phase SiC MOSFET Intelligent Power Modules CXT-PLA3SA Series": <https://www.cissoïd.com/download/private-documents/cxt-pla3sa-intelligent-power-module-mounting-and-cooling-recommendations-application-note/>
- [6] Application Note - "LTSpice Model Library for 3-Phase 1200V/340A-550A SiC MOSFET Intelligent Power Modules Platform": <https://www.cissoïd.com/download/private-documents/cissoïd-sic-intelligent-power-module-ltspice-models/>