

PRESS RELEASE

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600 kilowatts? This inverter knows how to keep its cool!

Power inverters are the beating heart in the drive train of modern electric cars. They turn the electrical energy from the batteries into something that engines can actually use. Fraunhofer IZM has now redefined what this key component is possible of doing: Using the newest developments in power electronics, the „Dauerpower“ inverter was born that can handle enormous amounts of power with low inductance and in a tiny body - with peak efficiency measured at 98.7%. Let's roll!

Modern electric cars need advanced inverters to bring the power from the battery and onto the road. These inverters act like small on-board transformer stations and turn the DC current coming from the battery into the three-phase AC current that the engines need to get the wheels rolling. The higher the power in the drive train, the greater the current flow, and the more likely it is that the system is giving off a lot of heat. A novel inverter created by Fraunhofer IZM in cooperation with Porsche and Bosch is set to minimize this effect: The Dauerpower inverter.

Its German name says it all: The system promises power for the long haul, with approx. 600 kW or 815 horsepower of constant output even of long periods of time. This is not only 1.5 times the power handled by today's Diesel-powered heavy trucks. It will set a new benchmark for high-end electric sports cars. The Dauerpower inverter can even handle 720 kW or 979 horsepower for short bursts. To cope with these enormous amounts of power, the Dauerpower module relies on cutting-edge semiconductor technology that uses silicon carbide transistors and an innovative cooling system.

PCB embedding for high efficiency and low inductance

The exceptional performance of the Dauerpower inverter is made possible by the choice of silicon carbide (SiC) transistors. The lower inductance of 1.1 nanohenrys achieved with the modules is a great plus, putting it at the top of the class among modules with a similar conductivity. Dominik Seidenstücker, one of the lead scientists behind the innovation, explains: „Compared to conventional silicon transistors, silicon carbide means that we get much greater temperature resistance, lower semiconductor capacities, and lower on-state resistance for the same area of semiconductors. The potential is to massively reduce switching and conduction losses.“

Keeping this system as compact as it needed to be meant using DC link capacitors with the PolyCharge NanoLam technology, which offers more than twice the output density compared to traditional polypropylene capacitors. The efficiency of the system was increased even more by means of a sophisticated process for embedding the semiconductor modules. Dominik Seidenstücker: „Semiconductor embedding allows us to

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place the supply and return conductors far closer to each other and reduce leak inductance. The module's lower leak inductance allows faster switching transition. This, in turn, means even lower losses in the semiconductors." The technology is also ready for economical mass production processes. The cutting-edge SiC design keeps the temperature in check on all of the twelve semiconductor modules built into the system. And when the Dauerpower inverter is asked to feed a maximum of power into the drive system, its sophisticated cooling system comes into play.

3D printing for an advanced coolant system

For the power electronics to stay reliable even under full load, the designers came up with a cooling system essentially based on two elements: First, they developed a 3D-printed cooling element. „We picked copper as our material, because it has better thermal conductivity than aluminum and lets the heat dissipate better,“ Seidenstücker explains. The element was made bespoke to match the thermal requirements of the modules and ensures even heat dissipation. The critical components are mounted right onto the cooling system by silver sintering, which again ensures their optimum thermal integration.

The heat is conducted away by a water cooling system, which forms the second half of the entire cooling concept. This system was 3D printed in aluminum and guides the water through a parallel cooling infrastructure, designed to spread out the pressure in the system optimally. The system runs with 10 l of coolant per minute but loses only 150 millibars of pressure – a resounding proof of the cooling technology's high efficiency. Even after 15 minutes of operation, the heat difference between the casing and the coolant is less than 20 kelvin, and the greatest increase in temperature measured at the cooled outputs was a mere 41 kelvin. With cooling technology this advanced, the inverter remains in the optimum operating temperature even when under heavy load. One could say that the Dauerpower inverter knows how to keep its cool.

Maximal output density

The individual modules of the Dauerpower inverter are perfectly orchestrated with each other, with a unique software made for the project by Fraunhofer IZM acting as the conductor. The smart design of the module has turned the system into a small-size, big-punch behemoth when it comes to power density: With 200 kVA per liter, the inverter handles outputs two to four times above the numbers achieved in current electric vehicles. It even leaves the top-flight models trailing behind with its output a third higher than that achieved in today's premium segment. Tomorrow's high-performance electric vehicles can expect to use far smaller inverters, but still bring far greater power on the road. The Dauerpower design also promises great modularity. The individual components are easy to maintain or replace, saving resources and prolonging the working lives of the cars.

The combination of cutting-edge semiconductor technology, sophisticated cooling, and exceptional performance means that the inverter heralds a new generation of electric

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drive systems. The project is advancing electric mobility and has already raised the bar in terms of performance, efficiency, and sustainability.

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The project was supported with funding from the Federal Ministry for Economic Affairs and Climate Action and managed in cooperation with Porsche AG and Robert Bosch GmbH.

Specifications

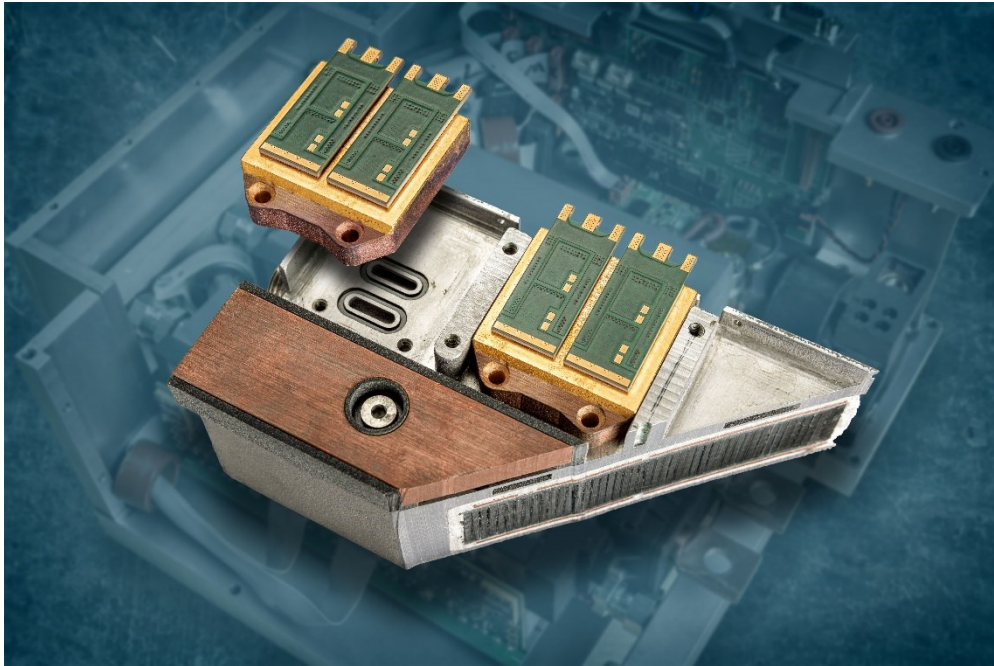
3-phase drive inverter
48 SiC semiconductors
Power core volume: approx. 3l
800 or 1200 V base
Constant output: approx 600 kW (835 V x 720 A_{RMS})
Peak output: 720 kW (800 V x 900 A_{RMS})
Output density: 200 kVA per l
Peak efficiency: 98.7 %

From 6 to 8 May, Fraunhofer IZM will be showcasing the Dauerpower inverter at its booth at PICM Europe (hall 5, booth 300). Meet our team to learn more about the innovative technology and get a closer look at the groundbreaking drive inverter with its embedded power modules and novel DC link capacitor. For more information about our booth:

https://www.izm.fraunhofer.de/en/news_events/events/pcim.html

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Section of one of the 600kW inverter's three phase-modules© Fraunhofer IZM / Volker Mai | Print-quality images: <http://www.izm.fraunhofer.de/pics>

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Highly integrated microelectronics are omnipresent and yet often evade the eye. With 4 central technology clusters, **Fraunhofer IZM** covers a wide range of areas in quantum, as well as medical, communications and high-frequency technology. With our world-leading expertise, we offer our customers cost-effective development and reliability assessment of electronic packaging technologies, as well as custom-tailored system integration technologies at wafer, chip and board level. For over 30 years and at 3 locations, we have been supporting start-ups as well as medium-sized and large international companies (with knowledge transfer) and researching key technologies for intelligent electronic systems of the future.

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