

Press Release

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500 kilowatts per liter

A novel inverter redefines the limits of power density

Inverters are the heart of modern electric drives. They control the energy that flows from batteries to motors, giving them massive influence over efficiency and performance. Fraunhofer IZM has achieved an evolutionary leap for this most crucial technology: An innovative inverter that handles 500 kilowatts of power in a unit just one liter in volume. With its extremely low inductance promising 99 percent efficiency, it is time to fasten the seatbelts.

Powerful electric motors usually work with three-phase AC power, including those built into electric vehicles. But their batteries provide power in the form of direct current. Turning this into three-phase current needs an inverter as a core part of the drive train. And since the space under the hood comes at a premium for electric vehicles, a simple rule applies: The smaller, the better - but without compromising on performance.

The Power Electronic Systems group at Fraunhofer IZM has again pushed the envelope with its innovations in the field: Working on behalf of Mitsubishi Heavy Industries (MHI), Wiljan Vermeer and his colleagues at Fraunhofer IZM came up with a cost-efficient inverter design that could deliver a full 0.5 megawatts of power (around 680 bhp) with an efficiency of 99 percent, yet only occupies a volume of one liter. How did they manage to do that?

Twelve SiC semiconductors per embedded power module

Four tricks were needed to get to the inverter that could do the job: They start with a two-level half-bridge power module, with one working per phase. An RC snubber decouples them from the DC-link capacitor to reduce unwanted oscillations and increase the switching speed. Each module includes twelve silicon carbide switches, MOSFETs chosen by the project partner and client MHI and embedded right onto the PCB to save space. The end result is highly compact modules with an extremely small electromagnetic footprint. Their effective inductance is just one nanohenry - low enough to not limit the switching speed and allow switching at the MOSFETs' limit, with 63 volts per nanosecond. Faster switching means lower losses, which in turn reduces the need for cooling. Enter the second trick.

Extruded aluminum cooler

A flat, extruded aluminum cooler is placed underneath the three modules. Its low form factor not only saves space. It also creates a short thermal path from the semiconductors to the

coolant. More than forty thin, slightly corrugated channels give the coolant lots of surface area to exchange heat. Aluminum offers the advantage of low material costs and highly cost-effective production via the extrusion process: The entire heat sink is produced in a single step, a design that saves both space and money.

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Laser-welded smart design

The third trick needs laser welding: "The contacts of the busbars were formed just so that we could laser-weld them directly onto the circuit board. That means we could get rid of screws that would not only eat up valuable space but increase inductance as well", Wiljan Vermeer explains. Additionally, the vertical integration of the two input busbars means that they can be placed near enough to each other for their fields to almost cancel each other out, again minimizing inductance.

NanoLam™ Capacitors – with copper contacts for better heat management

The fourth and final trick works with the choice and arrangement of the DC-link capacitors that buffer the power running through the modules. Working with the company PolyCharge, their NanoLam capacitors were specifically configured for the purpose, and arranged side by side with the busbars, so that the DC link reaches a total inductance of only two nanohenries despite a capacity of 300 microfarads.

The capacitors' nano-technology achieves very high power density, albeit at a cost of higher thermal losses - putting more strain on the cooling system. "We picked copper contacts for their better dissipation of the heat", Vermeer explains. "Our system was designed so that the electrical connections balance the poorer heat distribution, spreading the heat equally both horizontally and vertically. The capacitors can stand a maximum temperature of 150 degrees centigrade, but we limited them to 130 degrees in the interest of reliability."

This is still a very high number in conventional terms. The excess heat is channeled directly to the aluminum cooler that also handles the waste heat of the power modules. The capacitor unit was therefore placed below the cooler and integrated right into the casing to again reduce the size of the overall system.

With its combination of innovative power electronics, capacitors, and cooling systems, the inverter takes 800-volt drive technology to a new level. With 500 kilowatts - a full 0.5 megawatt - of performance in a one-liter-scale package, it outperforms common alternatives five-fold and even beats the current top systems by a factor of 2.5. Its 99 percent efficiency is another new benchmark - while the costs to produce the innovative system stay moderate.

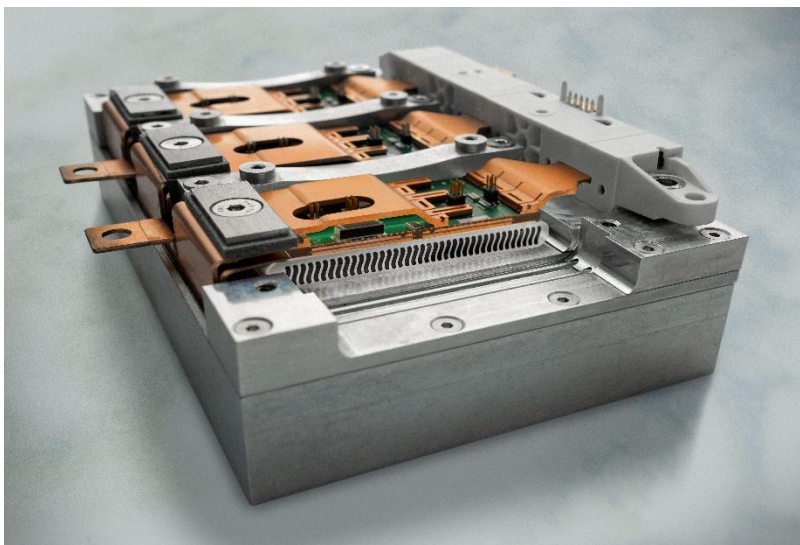
Wiljan Vermeer will unveil the novel inverter to the public at the Fraunhofer IZM exhibit (hall 6, booth 260) at Nuremberg's PCIM Europe (9 to 11 June 2026). The researchers will be on site to explain the innovative technology behind the inverter - and offer a peek at the future of e-mobility.

For more information about the exhibition, visit: https://www.izm.fraunhofer.de/de/news_events/events/pcim.html

(Text: Christoph Hein)

Technical specifications

3-phase drive inverter; Power density: 500 kVA per liter; 500 A_{RMS} per phase at 800 V DC voltage; Switching speed: 65 V/ns; Effective inductance: approx. 1 nH; Peak efficiency: >99%



Highly integrated inverter with a power density of 500 kW/l, optimized for maximum power density. © Fraunhofer IZM/Volker Mai | print-quality image: www.izm.fraunhofer.de/pics

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The **Fraunhofer Institute for Reliability and Microintegration IZM** is one of the world's premier research institutions for electronics packaging. With its dedication to developing miniaturized, high-reliability electronics in cutting-edge lab facilities, the institute works to maintain the competitive edge of Germany and Europe.

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