PRESS RELEASE

Inverters with constant full load capability enable an increase in the performance of electric drives

Overheating components significantly limit the performance of drivetrains in electric vehicles. Inverters in particular are subject to a high thermal load, which is why they have to be actively cooled. In the Dauerpower project, Fraunhofer IZM is working with project partners from the automotive industry to develop an electric inverter that can work at a lower operating temperature thanks to optimized cooling management, resulting in a lower power loss. In addition to longer full-load utilization, the required semiconductor area can also be reduced as a result, which can further decrease the costs of the electric mobility transition.

Efficient powertrains for electric vehicles are of great importance in driving forward the phase-out of fossil fuels, but the performance of these powertrains strongly depends on the thermal properties of the installed components. In addition to the battery and motor, the thermal performance of the inverter is particularly important for the highest possible efficiency: It converts the direct current from the battery in the alternating current required by electric motors and supplies the entire drive unit with energy.

In cooperation with Porsche and Bosch, Fraunhofer IZM is now developing a compact three-phase drive inverter with a high continuous output of 720 kilowatts or 979 horsepower and a rated current of 900 amperes. Eugen Erhardt, head of the project at Fraunhofer IZM, assesses the performance of the new system: "Compared to existing silicon-based inverters, our approach achieves an increase in performance of between 20% and 30%." The researchers achieved this increase in power density through the thermal optimization of advanced materials and optimized embedding processes in production. Erhardt's group had already dealt with these in the SICefficient predecessor project.

Transistors made of heat-resistant silicon carbide

To prevent the passive components of an inverter, such as capacitors and copper elements, from being damaged by heat build-up, conventional systems throttle their maximum output in continuous operation. This process is also known as "derating": Chips made of silicon carbide allow a smaller cooling surface while maintaining the same performance, which means that semiconductor material can be saved compared to silicon chips, as more optimum cooling is provided.

The system developed by Fraunhofer IZM uses modern silicon carbide transistors, which are more efficient and more temperature-resistant than pure silicon. Two of

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these silicon carbide transistors are applied directly to a ceramic substrate at Fraunhofer IZM using an innovative prepackaging process. These prepackages can then be flexibly embedded in conventional PCBs. Thanks to the thin design and a reduction in the materials required, less mechanical stress and more uniform deformation behavior occurs in case of heat exposure. In addition, the segmented ceramic substrates make optimum use of the limited space available to best meet the specific requirements of the automotive industry.

Copper cooling elements from the 3D printer
In addition to the optimized materials, the researchers also looked at how to cool the individual components more efficiently. The better the cooling effect, the less expensive semiconductor material is required, as the chips can be arranged even more compactly. The researchers' aim is to achieve a high level of thermal integration of the various semiconductor elements, as well as passive components such as capacitors and copper conductors. For this purpose, the temperature-critical components are connected directly to the cooling system via silver sintered connections and thermally integrated in the best possible way: Thanks to a parallel arrangement, the cooling liquid reaches all heat sinks and connected semiconductor elements simultaneously, and the thermal energy is dissipated evenly. Copper is also being used for the first time in a 3D printing process to manufacture the cooling elements, allowing the excellent thermal conductivity of copper to be combined with the full flexibility of 3D printing, instead of only being able to access aluminum heat sinks as before. Compared to CNC milling processes, 3D printing allows a great deal of freedom with regard to the design of the cooling channel and, in turn, optimum utilization of the limited installation space.

High modularity of the prototype
In addition to advances in materials and production processes, the scientists were also able to achieve greater modularity of the individual elements for the prototype. While the concept envisaged in the previous project was still based on a solution in which all components were permanently connected to each other, the elements of the inverter can now be replaced and repaired more easily as sub-modules. As a result, electric vehicles can be produced even more resource-efficiently and can also be operated longer. Especially in a resource-critical industry such as the automotive industry, low material costs are an important factor in being able to manage the energy transition cost-effectively.
Following a simulation phase, the prototype is currently under construction and will ultimately undergo an extensive testing process at Porsche AG in order to one day find its way into series production. The Dauerpower project was successfully launched in 2021 and received funding of EUR 1.2 million from the German Federal Ministry of Economics under the reference number 19I21023C. In addition to Fraunhofer IZM, other project partners include Porsche AG and Robert Bosch GmbH.

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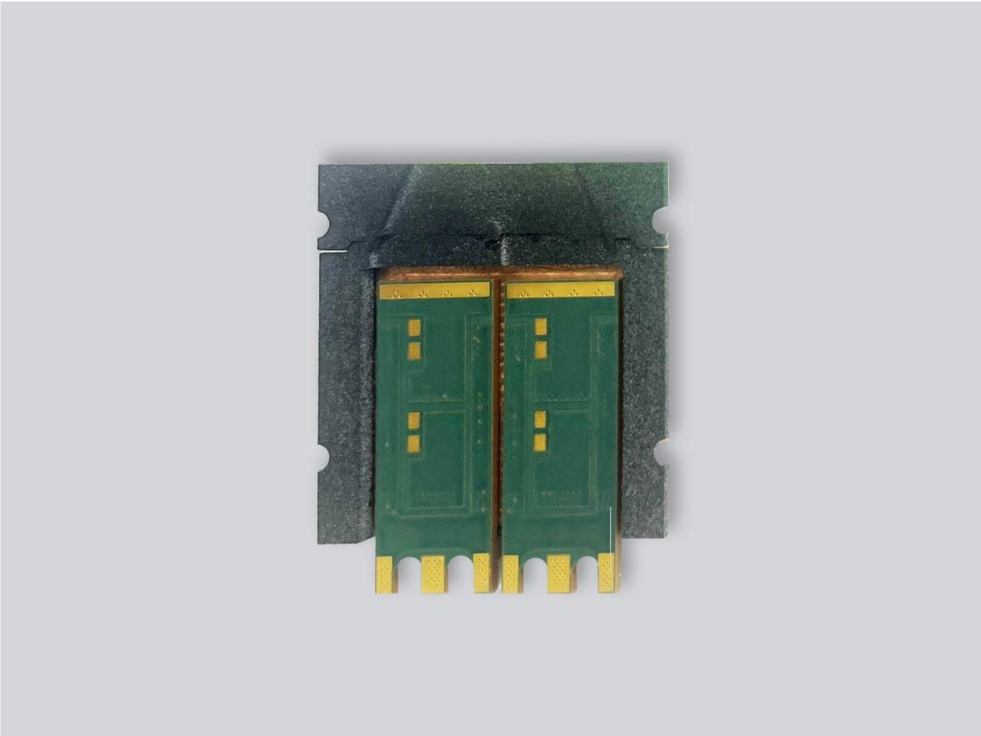

Model of the inverter prototype. © Fraunhofer IZM l Graphic in print quality: www.izm.fraunhofer.de/en/news_events/pics.html

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