Fraunhofer IAF enhances functionality of GaN power ICs with integrated sensors

Monolithic integration of power components with sensors and control circuit saves space, reduces assembly and improves reliability.

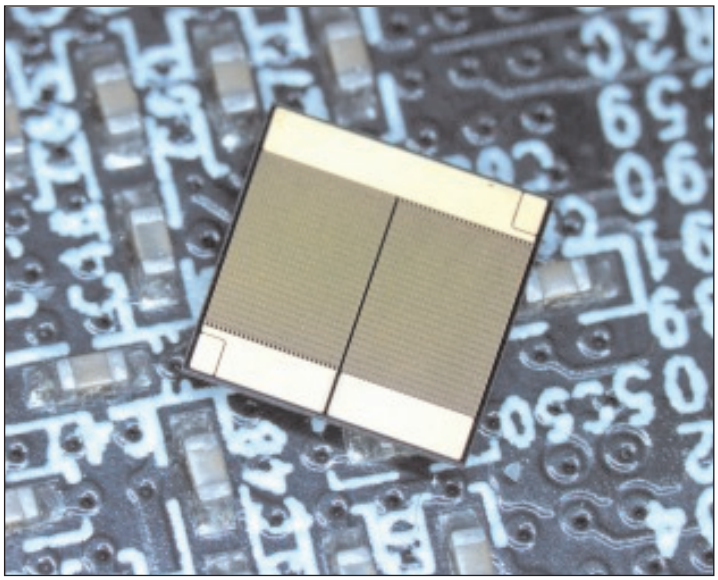
Fraunhofer Institute for Applied Solid State Physics (IAF) of Freiburg, Germany says that it has significantly enhanced the functionality of gallium nitride (GaN) power ICs for voltage converters by integrating current and temperature sensors onto a GaN-based chip, along with power transistors, free-wheeling diodes and gate drivers. The development could pave the way for more compact and efficient on-board chargers in electric vehicles.

For vehicles with electric drive to become a lasting presence in society, there needs to be greater flexibility in charging options, says Fraunhofer IAF. To make use of charging stations using alternating current, wall charging stations or conventional plug sockets where possible, users are dependent on on-board chargers. As this charging technology is carried in the vehicle, it must be as small and lightweight as possible, and also cost-efficient. It therefore requires extremely compact yet efficient power electronics systems such as voltage converters.

Several components on a single chip

Fraunhofer IAF has been conducting research on monolithic integration in power electronics for several years. This requires several components such as power components, the control circuit and sensors to be combined on a single chip. The concept makes use of gallium nitride. In 2014, Fraunhofer IAF integrated intrinsic freewheeling diodes and gate drivers on a 600V-class power transistor. In 2017, a monolithic GaN half-bridge was then operated at 400V for the first time.

The latest research results combine current and temperature sensors and 600V-class power transistors with intrinsic freewheeling diodes and gate drivers in a GaN power IC for the first time. As part of the project GaNIAL ('Integrated and efficient power electronics based on gallium nitride'), the researchers have provided functional verification of full functionality in a GaN power IC, achieving what is reckoned to be a breakthrough in the integration density of power electronics systems. "By additionally integrating sensors on the GaN chip, we have succeeded in significantly enhancing the functionality of our GaN technology for power electronics," says GaNIAL's project manager Dr Patrick Waltereit, deputy head of the Power Electronics business unit at Fraunhofer IAF.



The GaNIAL project is funded by Germany's Federal Ministry of Education and Research (BMBF). Since 2016, this collaboration between Fraunhofer IAF and the BMW Group, Robert Bosch GmbH, Finepower GmbH and the University of Stuttgart has been working to develop powerful, compact GaN-based components for electromobility.

Integrated sensors for direct control

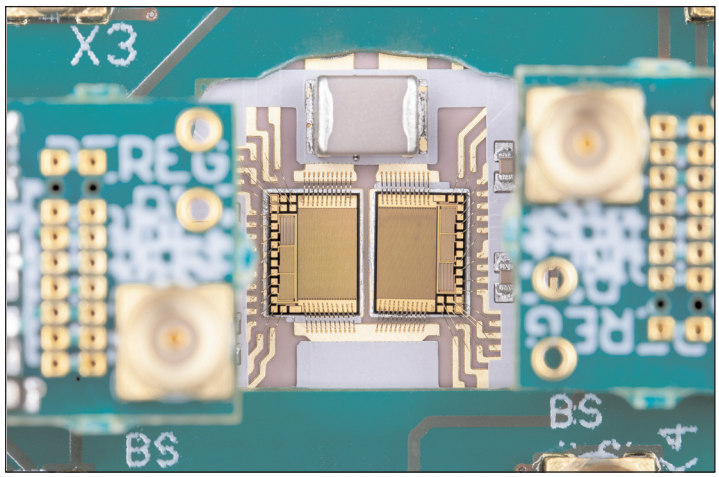
Compared with conventional voltage converters, the new circuit simultaneously not only enables higher switching frequencies and a higher power density but also provides for fast and accurate condition monitoring within the chip itself. "Although the increased switching frequency of GaN-based power electronics allows for increasingly compact designs, this results in a greater requirement for their monitoring and control," says Stefan Mönch, a researcher in the Power Electronics business unit. "This means that having sensors integrated within the same chip is a considerable advantage."

Previously, current and temperature sensors were implemented externally to the GaN chip. The integrated current sensor now enables feedback-free measurement of the transistor current for closed-loop control and short-circuit protection, and saves space compared to the customary external current sensors. The integrated temperature sensor enables direct measurement of the temperature of the power transistor, mapping this thermally critical point considerably faster and more accurately than previous external sensors, as the distance and resulting temperature difference between the sensor and the point of measurement is eliminated by the monolithic integration.

"The monolithic integration of the GaN power electronics with sensors and control circuit saves space on the chip surface, reduces the outlay on assembly and improves reliability," says Mönch, who designed the integrated circuit for the GaN chip. "For applications that require lots of very small, efficient systems to be installed in limited space, such as in electromobility, this is crucial," he adds. Measuring just 4mm x 3mm, the GaN chip is the basis for the further development of more compact on-board chargers.

Exploiting GaN's unique characteristic

For the monolithic integration, the research team utilized the gallium nitride deposited on a silicon substrate. The unique characteristic of GaN-on-Si power electronics is the lateral nature of the material: the current flows parallel to the surface of the chip, so all connections are located on the top of the chip and connected via conductor paths. This lateral structure of the GaN components allows for the monolithic integration of several components, such as transistors, drivers, diodes and sensors, on a single chip.



GaN power ICs with integrated transistors, gate drivers, diodes and current and temperature sensors for condition monitoring.

"Gallium nitride has a further crucial market advantage compared to other wide-bandgap semiconductors, such as silicon carbide: GaN can be deposited on cost-efficient, large-area silicon substrates, making it suitable for industrial applications," says Mönch.

Presentation at PCIM Europe

Project partner Finepower GmbH displayed the new GaN power module at PCIM (Power Conversion Intelligent Motion) Europe 2019 in Nuremberg, Germany (7–9 May). Researchers from Fraunhofer IAF are unveiling their latest research results and developments in power electronics at the accompanying conference. ■

www.mesago.de/en/PCIM/main.htm
www.iaf.fraunhofer.de/en/researchers/electronic-circuits/power-electronics/Ganial.html