

## PROJECT IMPACT

19009

GaNext project is the development of an intelligent Gallium Nitride (GaN) power module where the drive, control, and protection circuits are integrated or co-packaged with the power device.

**GaNext**

July 2023

**GaN transistors are wide-bandgap compound semiconductor devices that revolutionize power electronic systems. They offer lower resistance, faster switching times, and reduced losses compared to silicon devices. GaN enables higher operation frequencies, leading to smaller passive components and more compact power electronic systems. In GaNext, 13 partners collaborated and developed a GaN-based Intelligent Power Module (IPM) integrating drive, control, and protection circuits.**

### Background, objectives of the project and challenges

GaN is arguably the most promising material to replace silicon in power electronics applications in the 650V market sector. This sector is worth multi-billion with applications ranging from power supplies, power factor correction, AC-DC converters, and wireless charging to inverters in electric vehicles. Power systems based on GaN are lighter, more compact, significantly more efficient and potentially cheaper than those based on silicon. But the high switching speed and low gate voltage of state-of-the-art GaN devices make them challenging to use.

The aim of project 'GaNext' was to remove the barriers to the adoption of GaN and fully demonstrate the higher efficiency and compactness of GaN-based systems in a range of power systems. The heart of the project was the development of an intelligent GaN power module where the drive, the voltage control, and the protection circuits are integrated or co-packaged with the power device.

The new suggested integrated power module addresses some key problems with current GaN-based circuits. Currently, GaN has certain advantages, but its switching speed needs to be slowed down to prevent high-frequency oscillations. This means that users do not fully benefit from GaN's capabilities. However, by integrating some passive components into the module, GaNext has reduced these oscillations and also decreased electromagnetic interference. Another issue is that the gate voltage distortions can cause unreliable switching of the transistors. But with the tailored design of the GaNext gate driver and its close integration with auxiliary devices on the GaN – Integrated Circuit (IC), these distortions have been minimized and the reliability of switching has been improved. To fully unlock the potential of GaN, a high-speed control IC has also been added with advanced safety features and heat extraction has been implemented. Furthermore, current and temperature sensors have been directly integrated onto the GaN-IC. This allows to significantly expand the safe operating area of the system. Additionally, a dedicated

package for the power module has been developed, encompassing the GaN power transistor, control circuitry, and drive circuitry. This module has been successfully demonstrated, providing a competitive advantage in power systems such as Electric Vehicles' (EV) chargers, lighting, drives, and photovoltaic (PV) inverters, all of which feature optimized magnetic components. By addressing these various aspects, GaNext IPM has become a central component in the next generation of GaN power systems.

### Technological achievements

The project aimed to address two main challenges related to GaN adoption and achieved specific outcomes. The key achievements include:

#### Goal 1: Remove barriers to adoption for GaN

The project successfully built a co-packaged intelligent GaN power module (see Figure 1), which integrated GaN technology into a compact and efficient power module design. This achievement aimed to overcome challenges such as limited knowledge, high costs, and complex integration associated with GaN adoption.

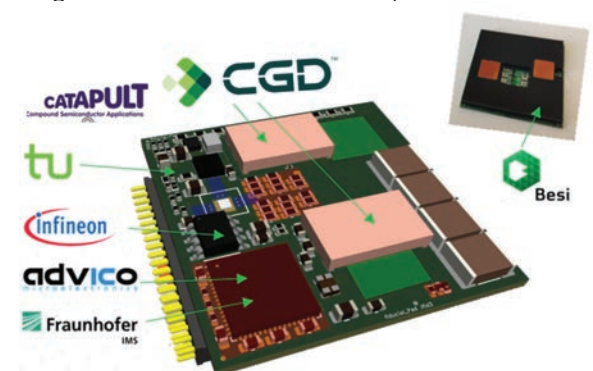
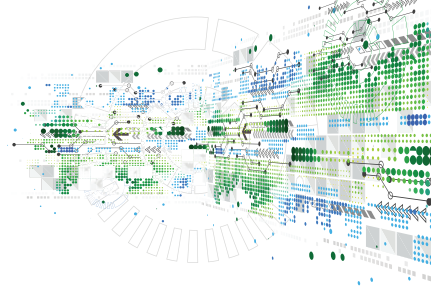


Figure 1: GaNext GaN IPM Development. CGD developed the GaN chip, Infineon developed Gate Driver, Advico and Fraunhofer IMS developed the Si Controller, TU Dortmund conducted the design of PCB power electronics, Besi developed the encapsulation for the IPM and CSAC conducted application testing.



## Goal 2: Demonstrate higher efficiency and compactness of GaN-based systems

The project successfully demonstrated the higher efficiency and compactness of GaN-based systems in a range of power systems (Figure 2). This achievement validated the potential benefits of GaN technology, including improved energy efficiency and reduced size of power electronics.

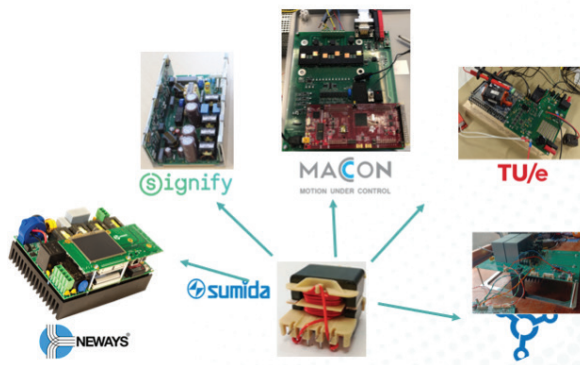


Figure 2: SUMIDA developed the magnetics to support the different application partners to integrate GaN IPM, Neways developed PV Inverter, Signify developed the Horticulture driver, MACCON developed a motor drive demonstrator, TU/e developed High-Frequency Modulation Strategies and Lyra developed the prototype on-board charger.

GaNNext made breakthroughs in four main areas.

1. GaN-on-Si power Integrated Circuit (IC) (650V, up to 70A) with integrated sensing and driving elements.
2. Si and GaN low-voltage logic, control, and level-shift Silicon-on-Insulator (SOI) gate drive circuitry.
3. Manufacturing of a dedicated package for the power module that included the GaN power transistor and the control and drive circuitry.
4. Demonstrated competitive advantage of the power module in power systems such as EV charger, lighting, drives and PV inverter; featuring optimised magnetic components.

### Key Achievement by Project Partners

Cambridge GaN Devices (CGD) 55mR chip has been qualified as per JEDEC standards (Figure 3, left). The Cu and back metallization of GaN devices developed in GaNext (Figure 3, right) has enabled CGD to serve markets that need GaN devices integration in the Intelligent Power Module (IPM).

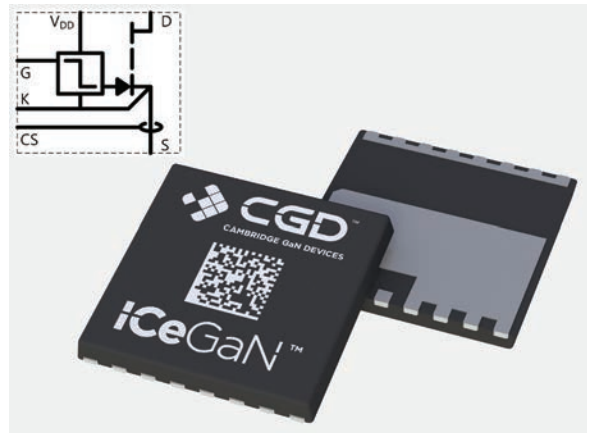


Figure 3: Cambridge GaN Devices 55mR chip product qualified (left). (CGD©)

Infineon developed an Optimized Gate Driver Testchip with enhanced SOI technology, featuring 50% less propagation delay (45ns vs. 90ns), 2X driving capability, 19% design shrink, increased breakdown voltage (700V), superior Electro-static Discharge (ESD) performance (above 2kV), and lower costs for module assembly (IPM)

Fraunhofer IMS and Advico developed a High Resolution Digital Pulse Width Modulation (PWM) Controller (Figure 4) with integrated power management, feedback channels, a programmable 32-Bit RISC-V safety core, and an AI hardware accelerator interface. It also offers functional safety functions, external hardware interfaces, and a selectable digital communication interface.

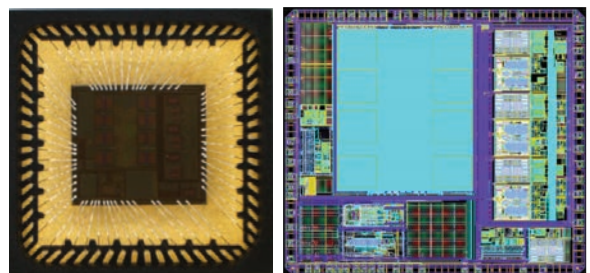
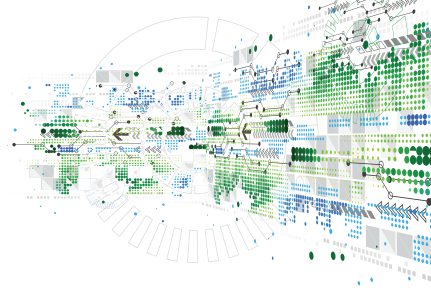


Figure 4: Si Integrated Circuit by Fraunhofer IMS and Advico (FIMs© and Advico©)

In the GaNext project, TU Dortmund (TUDo) developed alpha and beta versions of circuit boards. The alpha versions have 4 layers and filled vias, while the beta versions have 6 layers, filled buried vias, and include a microcontroller. The iFF circuit's efficiency was demonstrated with alternative boards, resulting in a 50% reduction in switching losses. The comparison showed slight improvement with parallel connected gate drivers.





Besi demonstrated encapsulation of a IPM containing GaN technology with novel high thermal conductive epoxy molding compounds (Figure 5).

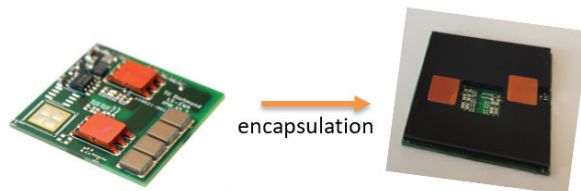


Figure 5: GaN-based power module, suitable for operation at 650 V. Packaged with high thermal conductive material and exposed copper heat spreader for increased thermal performance. The module has two exposed board areas to enable flexible application and re-use. © Besi

The CSAC's involvement in the project supported the gaining of deeper knowledge about boot-strapped gate drivers, designing a thermal resistance test rig, developing a dynamic thermal impedance characterization system, creating a GaN double-pulse test rig with a GUI, and designing a resonant test PCB (Figure 6) for high power functional tests.

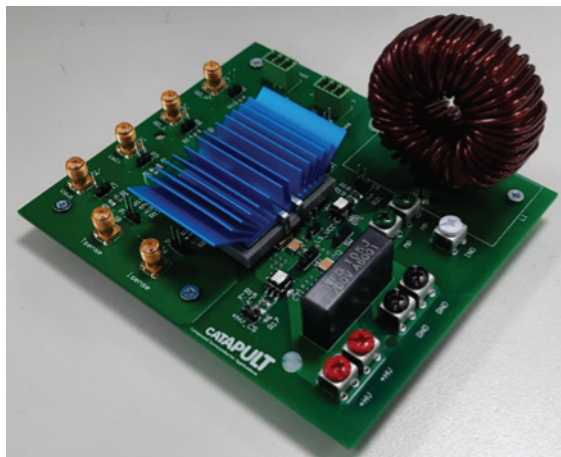


Figure 6: Resonant test PCB for high power functional tests up to 400VDC, 10A RMS and 1MHz switching. ©CSAC

SUMIDA developed custom magnetic components for a wide range of applications, including automotive and industrial. They worked closely with partners to develop advanced and optimized components that meet power application needs. An example is their magnetic development with Neways for PV inverter (Figure 7).



Buck & Heric Choke  
4kW @ 350 kHz



Common Mode  
Chokes  
High Z @ MHz Range

Figure 7: EMI chokes for High Frequency Applications for PV Inverter. ©SUMIDA

Lyra designed and developed a prototype of GaN based Dual Active Bridge (Figure 8) with High speed PWM control software, operating at 5kW, ~400V, and with a Soft switching algorithm.



Figure 8: GaN-based EV Charger by Lyra. ©Lyra

Signify developed a Buck Converter with GaN-based Horticulture (Figure 9). It reduces driver size by 30% and enables the use of 600V GaN technology with 400Vac mains. The output stage switches at 1-2 MHz using GaN technology, resulting in smaller magnetic components. It incorporates advanced digital control, new PCB techniques to reduce noise and EMI, and a semi-flex PCB design for higher volume utilization.



Figure 9: The technology to reduce the size of the output stage by increasing the switching frequency has been transferred from Signify research to Signify product development to be implemented in commercial products within one year from now. ©Signify

MACCON has developed drives that expand the voltage range of their 40kHz inverter portfolio by a factor of 5 (Figure 10). They achieved this by introducing a GaN Half-Bridge module that utilizes discrete components. Additionally, they have designed a Universal Mainboard that supports the IPM and the MACCON Module.

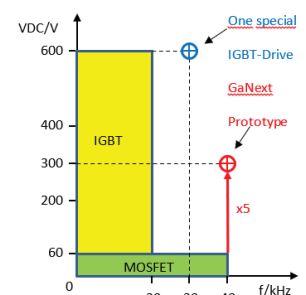
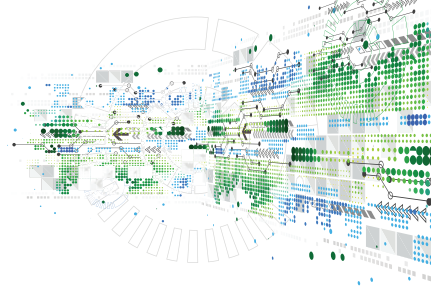
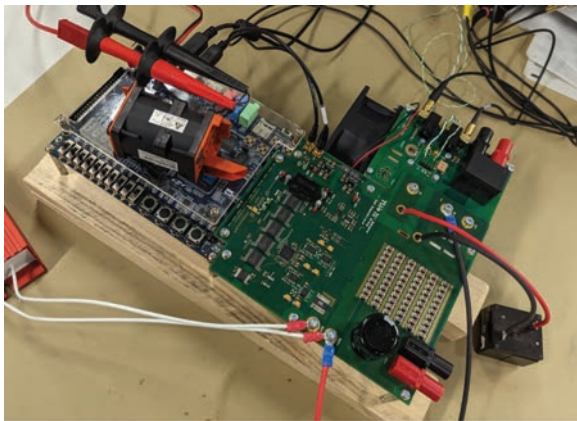


Figure 10: MACCON's GaNext Demonstrator for Motor Drives Applications (left) that extends voltage range of 40kHz inverter portfolio by factor of 5 (right). ©MACCON

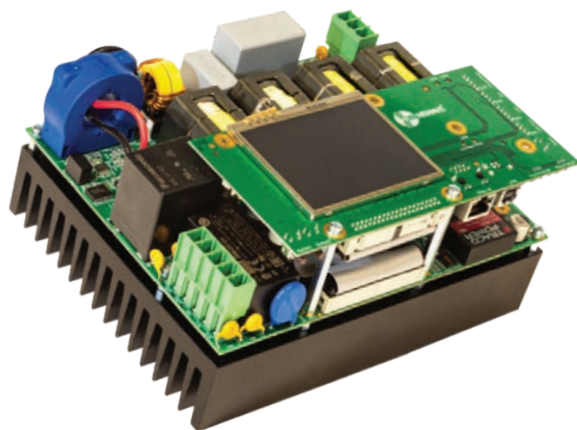


The Eindhoven University of Technology (TU/e) has developed strategies to increase the switching frequency of power converters using GaN technology (into the megahertz range). This enables smaller, cheaper, more efficient converters. They employed new modulation strategies and real-time state observers for variable frequency operation with zero-voltage switching. A 3kW demonstrator (Figure 11) was created to test and verify the performance of these techniques, including cooling concepts.



● Figure 11: 3kW Prototype developed by TU/e. ©TU/e

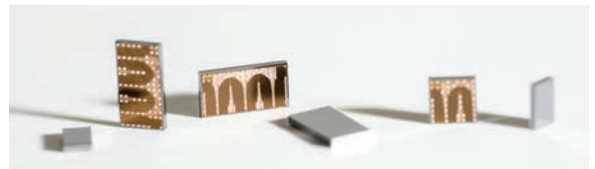
Neways has developed a 3kW PV inverter technology demonstrator (Figure 12) with a high efficiency (up to +/- 99.2% for the boost stage) in a small form factor (312W per litre). It can beneficially be used to reduce the total cost of ownership on the application level, increase the efficiency of applications, and downsizing existing applications



● Figure 12: Discrete GaN inverter designed and Prototyped with efficiency greater than 98% and power density of 312W/l. ©Neways

## Market Potential

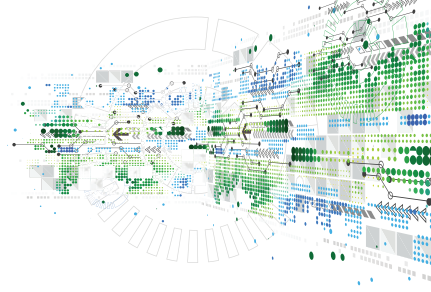
Besi gained valuable insights through GaNext, facilitating the design of advanced GaN-based IPM packages with exceptional thermal performance for the GaN power market. CGD utilized GaNext to establish a comprehensive supply chain, enabling compatibility with advanced packaging technologies and positioning themselves in the bare-die business. Infineon holds the second position in the gate driver IC market, leveraging optimized SOI technology to strengthen its presence in established applications and penetrate new markets. Their gate driver ICs, enhanced with optimized SOI technology, drive the adoption of Wide Band Gap (WBG) GaN and SiC semiconductors, expanding their share in the IPM market. Neways, an EMS supplier, is well-positioned to benefit from the demand for power electronics in the e-mobility and automotive sectors. The growing e-mobility charging market offers an opportunity for Neways to differentiate with GaN IPMs. Signify dominates the Horticulture market, delivering innovative lighting solutions. These companies are poised to capitalize on industry trends, technological advancements, and market growth, ensuring their competitive advantage and driving success in their respective markets.



● Figure 13: GaN Chip Copper (Cu) metallization enabling CGD to setup for Bare Die business. ©CGD

## Societal & Economic Impact

The GaNext project has significant societal and economic impacts. It has closed the technology gap in GaN module manufacturing, enabling the faster and simpler design of high-performance power electronics. This disruptive approach has given European companies a competitive edge, increasing their market penetration and strengthening the European electronics market. GaNext fostered collaboration among companies and supported the creation of an integrated European GaN chain. The project aligned with clean growth missions, reducing of carbon emissions, and improving energy efficiency. It supported inverterization of home appliances, increasing energy savings. GaNext's advancements in power electronic modules for drive train electrification lead to higher efficiency, lower costs, and increased reliability. It also contributed to the development of sustainable horticulture, enhancing lighting systems for energy-efficient cultivation. The publicly available GaNext open source components, including the AIRISC RISC-V processor, have garnered



## KEY APPLICATION AREAS



Energy



Transport and Smart Mobility



ECS Process Technology,  
Equipment, Materials &  
Manufacturing

## ESSENTIAL CAPABILITIES



Systems and Components  
Architecture, Design  
& Integration



Connectivity & Interoperability



Safety, security and reliability



Computing & Storage



ECS Process Technology,  
Equipment, Materials &  
Manufacturing

## PARTNERS

advlCo microelectronics GmbH  
Besi Netherlands B.V.  
Cambridge GaN Devices Ltd  
CSA Catapult  
Eindhoven University of Technology  
Fraunhofer IMS  
Infineon Technologies AG  
Lyra Electronics Ltd  
MACCON Elektroniksysteme GmbH  
Neways Technologies B.V.  
Signify B.V.  
SUMIDA Components & Modules GmbH  
TU Dortmund

## COUNTRIES INVOLVED



Germany



The Netherlands



United Kingdom

## PROJECT LEADER

Muntasir Hashim, Martin Arnold,  
Cerdin Lee and Chang Shu  
*Cambridge GaN Devices Ltd*

## PROJECT WEBSITE

[ganext-project.com](http://ganext-project.com)

## KEY PROJECT DATES

01 Feb 2020 - 30 Apr 2023

significant interest among academic users. These components have already found applications in radiation-resistant DC/DC controllers for the CERN ATLAS experiment and have been utilized in research focused on developing efficient AI hardware. GaNext's development of higher-efficiency power converters with a compact footprint is a notable achievement. These converters offer cost-effective solutions and potential affordability compared to existing options. They contribute to energy savings, reduced environmental impact, and the adoption of renewable energy sources.

Overall, GaNext pushed for innovation, competitiveness, clean growth, and sustainability across industries. GaNext's intelligent GaN-power module demonstrator facilitated solutions for reducing carbon emissions and improving energy efficiency. They support sustainability goals and enhance the quality of life for future generations.

## Patents, Standardisation, Publications

GaNext dissemination efforts have included:

- Acquisition of 7 valuable granted patents (with more in the publication stage)
- Release of 7 informative press releases
- Participation in 13 conferences (such as PCIM, APEC, Electronica etc.)
- Publication of 4 research papers in prestigious journals (with more in progress)

- Coverage in 5 renowned magazines
- Completion of 5 theses (4x Bachelors & 1x Masters)
- Garnering over 18,000 website views along with a strong presence on LinkedIn

These endeavors collectively showcase the project's commitment to widespread knowledge sharing and impactful contributions to the field.

## Future Developments

Besi and Neways will participate in "R-Podid". Besi will further investigate the influence of encapsulation on GaN-based power module reliability. CGD's collaboration with CSAC has impacted product development, including the dv/dt immunity improvement circuit and thermal characterization in the UK-funded project "P3EP." Infineon leverages project results to enhance gate driver IC derivatives and expand the Level Shifter and IPM portfolios. Memorandum of Understanding signed between Neways-CGD on further enhancement of future collaboration. Signify develops GaN-based Horticulture drivers and conducts research in projects like PowerizeD and All2GaN. TUDo focuses on iFF circuit development and reliability testing, comparing multiple setups. TU/e will develop a power electronics building block using ALL2GaN techniques, studying WBG device reliability. FHG secured internal funding to advance the TRL of the AIRISC-POWER processor to TRL5, following successful outcomes in GaNext. To aid the development process, an advisory board led by Siemens and X-Fab has been established by FHG.