2024

PROJECT NEWSLETTER

HiEFFICIENT

Inside this issue

INTEGRATION

Volume reduction by means of integration on all levels

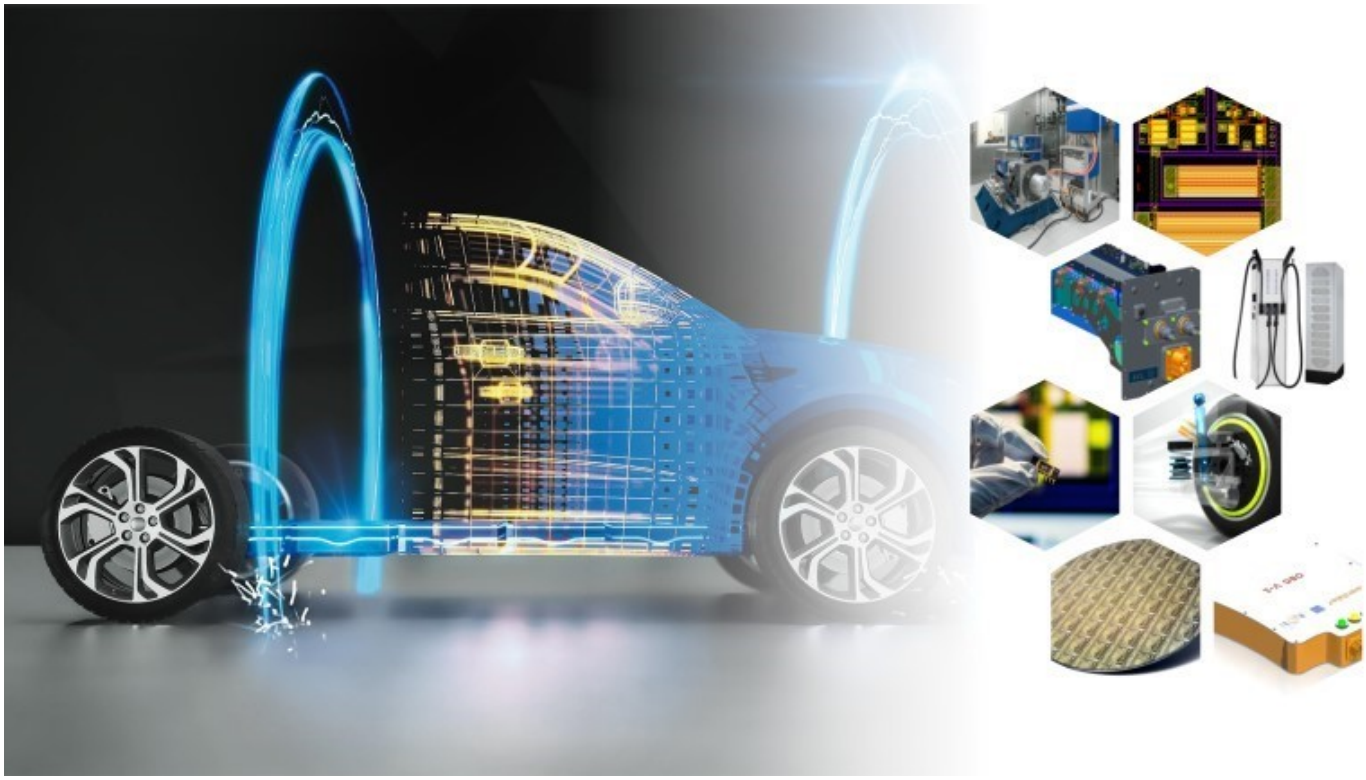
EFFICIENCY

Compact & highly efficient electric drivetrains

RELIABILITY

Make reliability and Prognostic Health Management visible

DECARBONIZED
ENVIRONMENTALLY FRIENDLY
SUSTAINABLE TRANSPORT



MINIMIZING IMPACTS ON THE ENVIRONMENT

With HiEFFICIENT, the partners will enable the transition to a decarbonized and thus more sustainable and environmentally friendly transport, by enabling the European automotive industry to develop highly efficient and durable power electronics for electrified vehicles. By deploying highly reliable and integrated wide-bandgap (WBG) technologies in electronic power circuits and systems of electrified vehicles, testing systems, and charging infrastructures. HiEFFICIENT directly supports the development towards a more resource-efficient and decarbonized transportation system by addressing the entire value chain, from semiconductor industry to system integrators and automotive manufactures.

This edition reflects on the achievements on technological innovations in the different application domains.

READ MORE AND STAY TUNED!

ADVANCED GaN TECHNOLOGY AND NEW MARKET OPPORTUNITIES FOR WBG TECHNOLOGIES

HiEFFICIENT aims for a resource-efficient and decarbonized transportation system, supported by the use of highly reliable and integrated wide-bandgap technologies in electronic power circuits and systems of electrified vehicles and charging infrastructures.

BETTER TOGETHER is the motto in research projects. Diverse and complex tasks, numerous benefits: in the HiEFFICIENT project, you can experience the world of research from its most exciting side.

USE CASES VERSUS OBJECTIVES

The Use Cases (UC) reflect the main challenges in vehicle electrification and e-mobility. All Use Cases contribute to achieving the defined objectives. The partners have a clear view on the four overall objectives. These objectives are key for the successful electrification of the automotive sector based on WBG power electronics, especially with advanced GaN technologies.

INNOVATIVE RESULTS

In addition, important contributions to the design optimization and prognostic health management are expected to have a significant impact on cost reduction and reliability improvement. The expected advances in cooling solutions may enable higher power density and better performance.

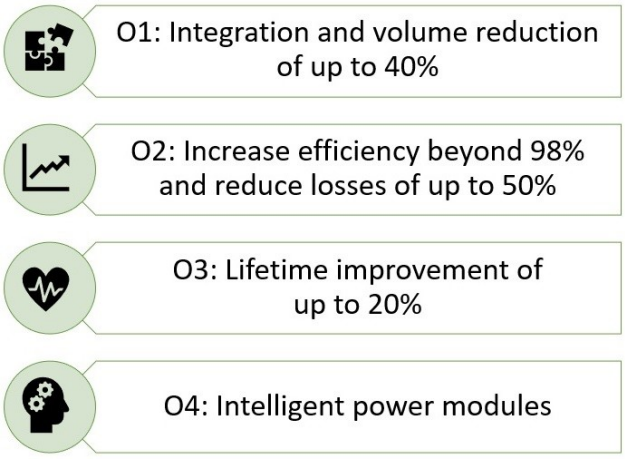


Figure 1: Project objectives

PROJECT CONSORTIUM

The consortium of this project is an excellent combination of well-known European industrial companies and research institutes located along the entire value chain, from semiconductors industry to OEMs. 31 partners are working well together in this 3.5-year project with a total budget of 42 million euros to achieve the set goals.

During the project the partners Lightyear and Powerdale went bankrupt and were terminated from the project. Nevertheless, the tasks could be taken over within the consortium to fulfill the set targets.

Figure 2: Project consortium

- Key Facts -

Partners: 31

Countries: 9

Budget: 42 M€

JU Funding: 12 M€

Project Start: May 1st, 2021

Duration: 42 months

Coordinator: AVL List GmbH

www.HiEFFICIENT.eu

THREE YEARS
36 PROJECT MONTHS
A FLASH OF MOMENTS

36 months HiEFFICIENT, a perfect moment for a brief reflection on the project from a management point of view. Project folders were combed through, many events and conferences were listed, we found a colorful bouquet of 36 months of project history - happy to be a part of it!

LOOKING BACK

M1

Kick-off meeting, online due to COVID19 pandemic

M6

1st General Assembly Meeting, Berlin

M9

Detailed specifications of Use Cases ready

M12

Preliminary design of all Use Cases ready

2nd General Assembly Meeting, Helmond

1st Annual Review Meeting, Brussels

M18

100 V GaN SiP half-bridge samples delivered to Use Cases

Cooling concept for all Use Cases and first cooling models available

3rd Annual Review meeting, Ljubljana

M24

WBG reliability methods and tests available

Simulation models established, new reliability and characterization tests defined and executed

4th General Assembly Meeting, Turin

2nd Annual Review Meeting, Leoben

M30

Use Case validation tests defined

5th General Assembly Meeting, Aachen

M34

Optimized sensor, power-module and system design

Cooling concepts and design for all Use Cases available

M36

Thermal condition monitoring systems and active thermal management available

Digital twin for Prognostic Health Management (PHM) in all Use Cases available

6th General Assembly Meeting, Leuven

CREATING LASTING AND SUSTAINABLE VALUES FOR THE FUTURE

It's a great feeling to have created something lasting and sustainable in the end. HiEFFICIENT - efficiency, functionality, reliability & cost reduction!

CREATING LASTING VALUES is very important in this project. Since project start, the HiEFFICIENT team achieved great results together. With all the work done, it can be expected that the innovations in the project will create new market opportunities for WBG technologies in the automotive sector, and that these innovations will strengthen the competitiveness and growth of European companies. The HiEFFICIENT project is more important than ever - it increases functionality, energy efficiency and system reliability and hence reduces costs at the same time. This is the way forward!

HiEFFICIENT IS CONSEQUENTLY FOCUSED ON THE FOLLOWING AMBITION TOPICS

1 Increase in efficiency and power density by integration

- GaN technology reduced design complexity enabling high-density and high-frequency applications thanks to the development of developed 9x6 mm^2 half -bridge module offers a plug-and-play half-bridge solution achieving a superior switching performance even inside a low cost system Printed Curcuit Board (PCB) design.
- First GaN SoC half-bridge for 650 V on a fully isolating substrate on one single piece of semiconductor.
- First integrated GaN devices out of Europe validated in Use Cases.

2 Reliability and prognostic health management for power electronics hardware

- End of Life (EoL) reliability assessment.
- Design for Reliability (DfR).
- Physics of Failure (PoF) and data-driven Prognostic Health Management (PHM).

3 High packaging and compactness up to the module level

- Integration by embedding the chip in a laminate process: high performance laminate material; multi-layer interconnects for routing and heat dissipation; metallization thickness depending on the current density in operation; metal routing design rules for the avoidance of discharging and cross talk of power and signal lines.
- Advanced thermal management by using simulation aided design of layout and embedding concept (e.g., proper deployment of thermal vias).

4 Advanced cooling concepts and integration up to system level

- Microfluidic flow boiling cooling.
- Advancements in indirect and direct cooling solutions using advanced surface enhancing structures.

LOOKING AHEAD

Benefiting from the best?
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Use Case 1: Electrification Test Systems

Development of highly compact and reliable test and emulation systems for electric components in e-vehicles using latest SiC and GaN technology.

Use Case 1 focus is on Electrification Test Systems and related technologies. Therefore, several demonstrators are developed to benchmark latest technologies and their application in the field of electric vehicle testing. UC1a aims at developing modular power electronic (PE) components with SiC and GaN power semiconductors in converter applications. Figure 3 shows the first fully functional prototype of a power converter with six 1200 V SiC half bridge modules, using PCB embedding for the power switches. The second modular PE component evaluates 650 V GaN switches in an amplifier application, whereby high heat losses due to fast switching need to be handled. Therefore an innovative cooling approach based on micro-fluidic cooling has been developed, which is currently under final assembly.

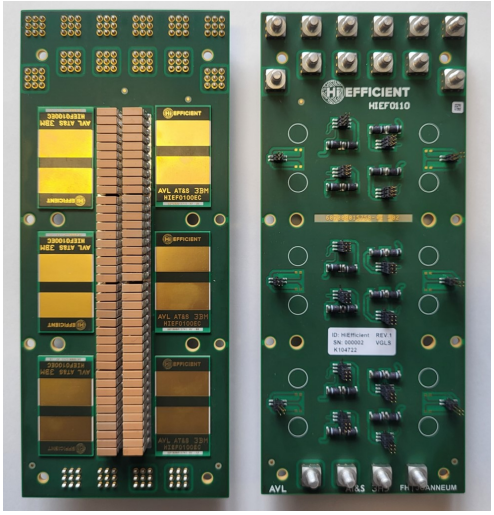

Figure 3: First 1200 V SiC Prototype using PCB embedding

Highlights & Achievements

- *First 1200 V SiC embedded prototype available*
- *650 V GaN amplifier with microfluidic cooler and cooling circuit developed*
- *Two different approaches for active thermal management of power electronics developed and evaluated in lab*
- *Testing concept for PE lifetime testing elaborated*

In UC1b, the focus was laid on active thermal management of PE converters, to optimize the power as well as extending the lifetime due to safe control operation. Therefore, two different approaches were followed. One approach is making use of analytical simulations, machine learning (ML) and reduced order models which have been developed and have been verified by means of experiments. The second one is using active gate driver management to reduce thermal cycling and hence enable a more temperature stable operation.

Last but not least, UC1c develops a test system to predict the lifetime of power electronics components. Therefore a Hardware in the Loop testbed (HIL) with an attached simulation environment is developed to enable an accelerated testing of newly developed EV components, like inverters.

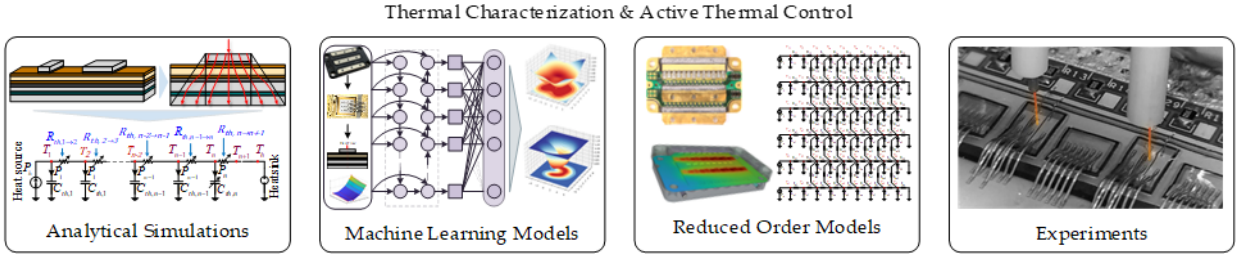

Figure 4: Advanced Thermal Control

Use Case 2: Highly integrated e-Powertrain

Development of two traction inverters, having a focus on fail safe multi-drive powertrain application and on highly integrated powertrain inverter, using power electronics embedding technologies.

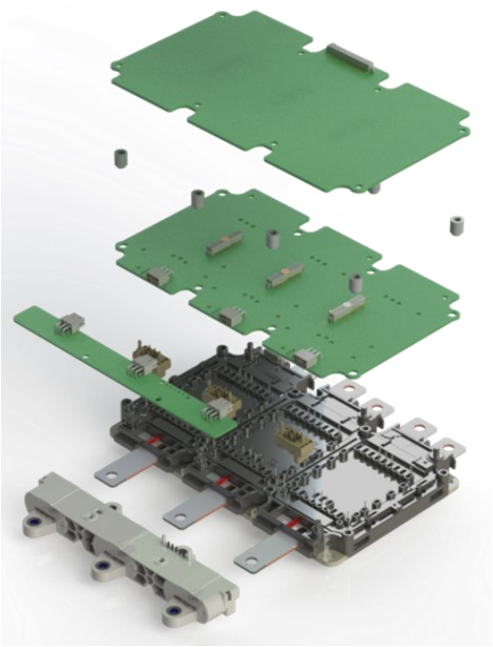

Figure 5: UC2a Power section structure

In Use Case 2a, the analysis of the previously collected requirements was conducted with the aim of function partitioning. This process led to the definition of a flexible power stage section, conceived as a system of boards, each addressing a specific subset of features. At the bottom layer of this stack (see Figure 5), the Hybrid Pack Drive SiC power module provides sturdy busbars on both AC and DC sides. Additionally, it integrates a heatsink featuring pin-fin technology to optimize heat exchange with the coolant liquid. At the top layer, the Gate driver board hosts the interface circuitry between the logic low voltage section and the power high voltage one. Furthermore, it provides monitoring and sensing functions. This power section serves as the fundamental building block of the demonstrator that will be prototyped and validated.

In Use Case 2b, the first iteration of the embedded GaN half bridge module has been designed. It is intended to be a plug-and-play module compatible in terms of power connections with the Hybrid Pack Drive module. It is sintered on top of the aluminum heatsink (see Figure 6).

Highlights & Achievements

*In **Use Case 2a**, requirements analysis led to the **function partitioning** to define a **flexible** system of boards. The conceived power section serves as **basic building block** for the demonstrator. The compact and integrated design enables a noticeable power density of **90 kVA/l** including the **EMC** high voltage filtering stages. The unit provides direct (e.g., Rds_on) and indirect (e.g., estimated junction temperature) measurements to **monitor its own state of health**.*

*In **Use Case 2b**, the first iteration of the embedded **GaN half bridge module**, compatible with the Hybrid Pack Drive module, **targets 80 A rms phase current**. Samples are produced, undergoing reliability assessment. More that **5750 thermal shock cycles** have been completed successfully. The second iteration, featuring an integrated **GaN half bridge SoC**, is in progress.*

Featuring two GaN dices for each high-side and low-side switch, it targets an rms phase current of 80 A. Samples have been produced, and the reliability assessment is ongoing, showing encouraging results. The second iteration process is underway, featuring the integrated GaN half bridge SoC.

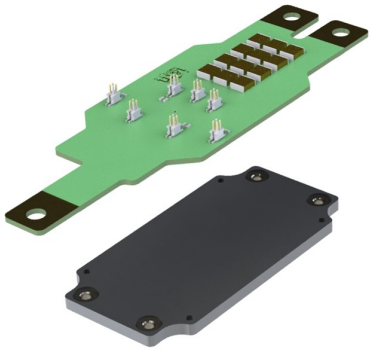

Figure 6: UC2b Half Bridge module structure

Use Case 3: High Power 48V DC/AC Inverter

Investigation of the benefits of a highly compact 48 V inverter for use in long haul duty vehicles. Focus is on the package density and improved reliability.

It is aimed to create a compact and innovative inverter by combining the switching frequency and high electron mobility advantages of GaN over Si, as well as the flexible system integration and improved thermal performance of embedded die technology. UC3 partners use their expertise in their fields to translate these design objectives into an industrial product.

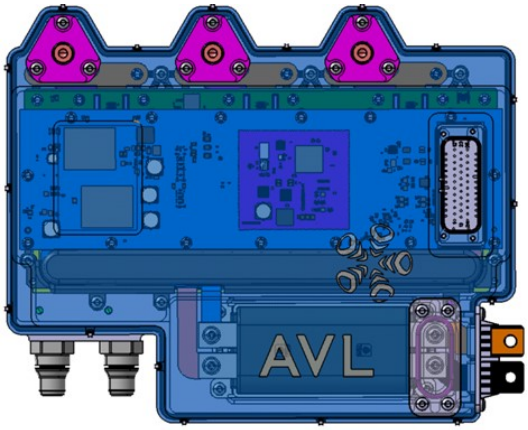

Figure 7: 48 V Inverter Design

Highlights & Achievements

- *Production of embedded 48 V - GaN half-bridge modules*
- *Compact and modular inverter design*
- *Thermal performance analysis with digital twin concept*
- *Control board and gate driver board design*
- *Innovative second iteration of gate driver board design with embedded GaN Mosfets*
- *1000 A peak switching current based on initial double pulse measurement results*

Electronic card production of the inverter has been completed. The next steps of the development process will be the mechanical build-up of the inverter and the verification tests of the design.

The half-bridge GaN modules, which are designed as stand alone in the current design, can be embedded into the gate driver board layers with the second iteration of the design. The mechanical implementation of this innovative design is currently being analyzed by the experts.

Use Case 4: Multi-use DC Charger

Development of bidirectional, flexible multi-output off-board charger, which aims to accommodate different charging needs for different e-mobility devices.

The basis of this flexible charger are high power modules which can be easily put in series as well as parallel to get a higher power rating and still have the flexibility to change the output power and output voltage. For the module itself a two stage converter is used: The first converter stage allows for sinusoidal input current and a stabilized DC-output voltage, the second stage takes care of the isolation and the right output voltage.

Prototypes of these converters are currently being built and are ready for testing. In order to increase lifetime, volume and efficiency, it was not possible to use standard converters, but more complex ones (Three level AFEE, extended DAB). These more complex converters also required more complicated control algorithms. For both converter stages, a microcontroller of STMicroelectronics the STM32G474 is used to implement their specific control algorithm. The advantage of this microcontroller is the availability of a high resolution timer (Hrtim) with 12 output channels.

In addition to these new power modules, TUDO, TNO and TU/e have also contributed to this Use Case: TUDO has succeeded in implementing an improved 3-level gate driver in order to achieve improved switching behavior. TNO and TU/e have worked together to incorporate additional functionality in the charger. By adding a variable AC current to the DC charging current, various information could be extracted from the battery. Finally, TU/e also worked on a single-stage converter to charge 48 V vehicles.

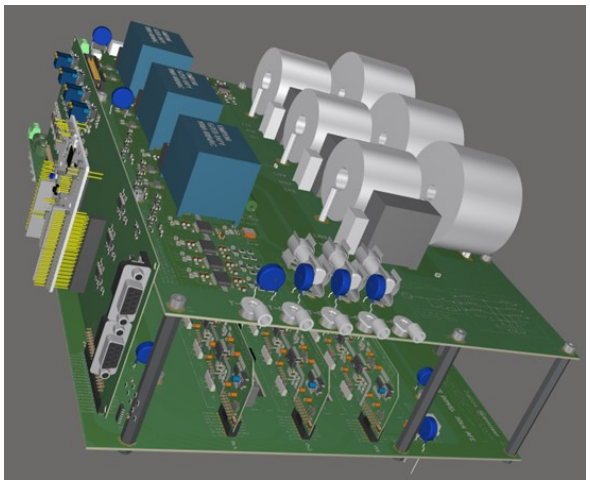

Figure 8: 3D view of the first stage converter

Highlights & Achievements

- *Prototypes are ready to be tested*
- *Basics of the control-loop tested via simulation*
- *New 3-level gate driver by TUDO*
- *Single state converter to charge 48 V vehicles*

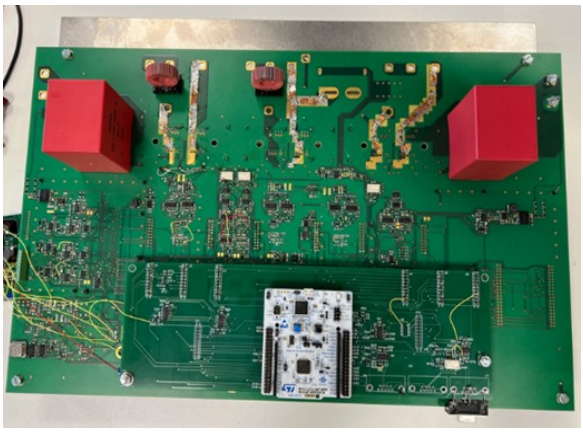

Figure 9: First prototype of the second stage converter

Use Case 5: On-board Chargers

Demonstration of different power electronic converters for on-board chargers, featuring more compact system, high efficiency, high power density and integration with other automotive subsystems.

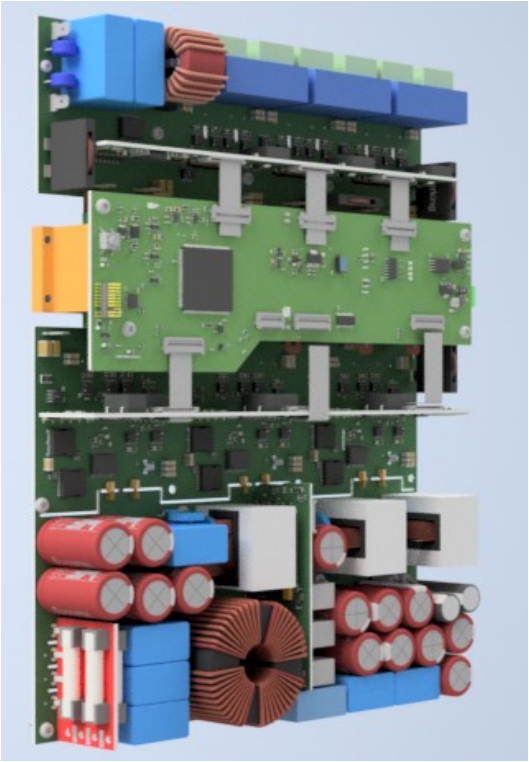

Figure 10: 3D view of UC5a OBC hardware design

Highlights & Achievements

UC5a, with integration of 650 V GaN half-bridge (HB) SOCs, boasts V2G and G2V functions within a modular design, aiming to achieve optimized power density while following a reliability oriented design phase. Key impact indicators of this Use Case are:

- *Prognostic and Health Management (PHM)*
- *Intelligent thermal management*
- *97% peak efficiency*
- *Specific power ≥ 1.5 kW/kg and power density ≥ 2 kW/L*

UC5a aims to advance the implementation of a 650 V GaN-based bi-directional on-board charger, focusing on system integration, safety, durability, and performance optimization.

Recently, System-On-Chip (SOC) package dimensions and gate driver architectures have been miniaturized and integrated. In addition, layer stack-up and thermal characteristics of the package have been finalized, and the final prototype design for the On-Board-Charger (OBC) is nearing completion, after having gone through an iterative multi-physics design optimization procedure.

CAD models of the prototype have been completed and electronic board production has been started. The next steps in the development process will involve the mechanical assembly of the converter and the integration of the cooling system. Subsequently, verification tests will be conducted to validate the design based on GaN HB system in packages (SiPs).

Finally, performance of the converter over a real-life charging profile will be evaluated in the laboratory of VUB.

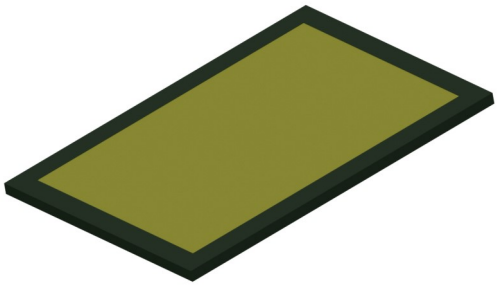

Figure 11: PCB embedded 650 V GaN HB—SiP

Use Case 6: GaN Automotive DC/DC Converter

Development of DC/DC converter for photovoltaic (PV) applications.

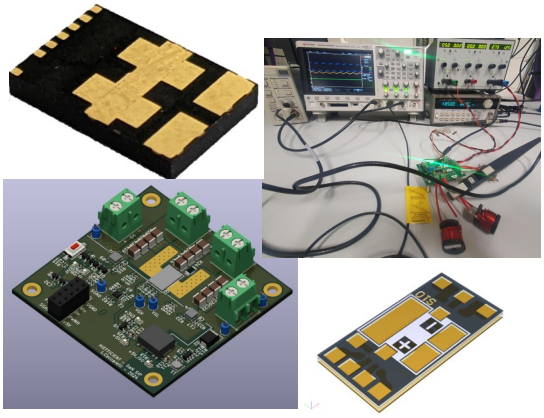

Figure 12: Preliminary DC-DC GaN converter prototype design

The progress of UC6 has been severely impacted by the exit of the UC leading partner Lightyear from the HiEFFICIENT consortium. The efforts of the consortium are now focused on developing a low-power, modular DC/DC converter suitable for PV applications as these relate to the automotive sector.

From a scientific perspective, UC6 retains the focus on the comparison of the newly developed GaN devices by IFAT (100 V SiP) and IMEC (100 V SoC) as these were specified at the initial phase of the project and have been provided by the relevant partners.

The objective is to evaluate their reliability in testing (TUC) and compare them with respect to design, development, and performance of the DC/DC converter. Testing of the converter, evaluating its efficiency and overall performance will also be included.

The already concluded activities are:

- Semiconductor **requirement specification**
- **Development** of 100 V GaN SoC and 100 V GaN SiP power module

The ongoing activities are:

- **Reliability** studies for the developed GaN devices
- **Functionality** of GaN devices in a DC-DC PV converter: Design finished, waiting for manufacturing and assembly; Planar coupled inductor design ongoing
- DC-DC GaN converter testing and **performance evaluation**

Highlights & Achievements

- *Development of SiP and SoC GaN 100 V devices for integration in the design and implementation of a PV DC-DC converter - Infineon 100 V Integrated Power Stage (SiP) & IMEC 100 V GaN SoC.*
- *Selection of DC-DC converter topology and main design choices - small power stage with PCB-embedded coupled planar inductor.*
- *Reliability investigation on new devices in the existing converter design-test specification under discussion.*

KEY RESULT 5

A highly integrated electric powertrain solution including traction inverters, DC/DC converters and On-Board-Charger optimized at system level in terms of volume and overall efficiency. A modular approach based on high flexible and scalable components enabling a reliable E/E architecture able to monitor its own health.

Efficient Integration: Streamlining Electric Powertrains for Enhanced Performance and Reliability (Authors: C. Romano/i&m, G. Lampič/Elaphe)

As the automotive industry undergoes a paradigm shift towards electrification, the optimization of electric powertrains becomes paramount. The integration of traction inverters, DC/DC converters, and On-board Chargers plays a pivotal role in shaping the efficiency and performance of electric vehicles. The development of a highly integrated electric powertrain solutions represents a significant milestone in the advancement of electric vehicle technology. By optimizing efficiency and volume at the system level, while adopting a modular approach for scalability and reliability, this integrated powertrain promises to deliver enhanced performance, reduced environmental impact, and improved user experience. As electric vehicles continue to gain momentum in the automotive market, investments in holistic integration and advanced health management systems will be essential to accelerate the transition towards sustainable transportation.

Integration for Efficiency and Volume Optimization: The integration of key powertrain components - traction inverters, DC/DC converters, and OBCs - offers several advantages in terms of efficiency and volume optimization. By consolidating functionalities and sharing common components, redundant hardware and interconnections are minimized, reducing both weight and space requirements. Furthermore, optimized thermal management and electromagnetic compatibility (EMC) strategies are implemented to enhance overall system efficiency and reliability.

Modular Architecture for Scalability and Reliability: A modular architecture is adopted to facilitate scalability and ensure system reliability. By employing standardized interfaces and communication protocols, individual components can be easily swapped or upgraded, accommodating diverse vehicle platforms and future technological advancements. Additionally, the integration of advanced sensors and monitoring systems enables real-time assessment of component health and performance. By analyzing data metrics such as temperature, voltage, and current, potential failures or degradation can be detected early, allowing for proactive maintenance interventions. Furthermore, machine learning algorithms and predictive analytics are utilized to anticipate future system behavior and optimize operational parameters accordingly.

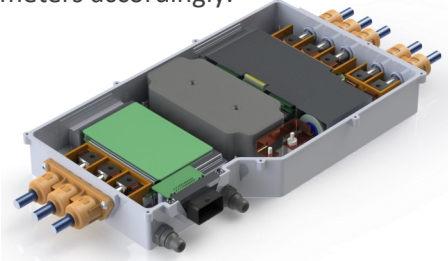

Figure 13: UC2a Dual Inverter

HiEFFICIENT deals with all these challenges that affect system integration at various levels. In modern BEV the onboard energy management system plays a crucial role. UC5 demonstrates that a seamless integration of a bidirectional OBC and DC/DC converter system is possible, leveraging SiC and GaN technologies for efficiency. The unit achieves a power density exceeding market standards, spanning from 3.6 kW to 22 kW, while incorporating Vehicle-to-Grid functionality for grid compatibility and enhancing vehicle performance. In terms of powertrain architecture, UC2a compares a standard central motor architecture to an in-wheel motor (IWM) layout. The lower diagram in Figure 14 describes this approach: two motors are directly coupled with the wheels, removing any mechanical link between the active wheels. According to several OEMs, there are many advantages to report using this kind of approach in term of frame layout flexibility, saving in terms of volume and weight and, last but not least, drivability. In-wheel motor (IWM) technology heralds a transformative era in torque vectoring control: unlike traditional systems, IWMs deliver instantaneous, unencumbered control, enhancing vehicle agility and responsiveness.

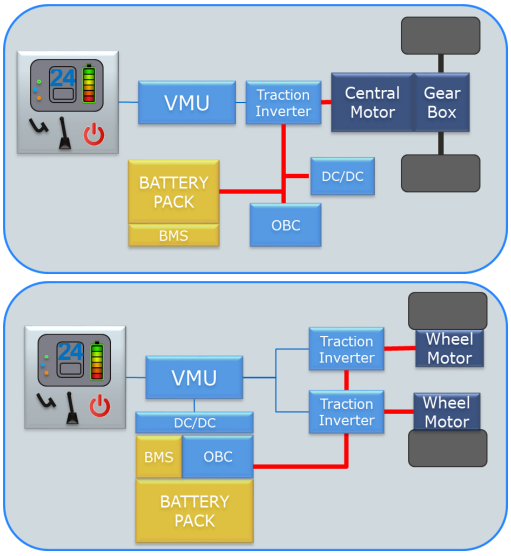

Figure 14: Block diagrams of distributed architecture with central motor (upper), and centralized architecture with multi-motor (lower)

This facilitates dynamic adjustments to traction, stability, and handling in real-time, optimizing vehicle dynamics during cornering, acceleration, and braking. With streamlined inertia and mechanical simplicity, IWMs afford finer control over torque distribution, pivotal for advanced torque vectoring in next-generation electric vehicles, bolstering both performance and safety. The Vehicle Management Unit (VMU) spreads torque over the available wheel motors and thus each wheel needs its own traction inverter. Therefore, in-wheel or near-wheel motor-based e-axle requires always a couple of traction inverters and a management unit. These considerations are the rationale, which stay behind the idea to focus on a Dual Inverter architecture.

The aim is to provide a single platform integrating two independent three-phase inverters and an edge-technology Vehicle Management Unit. There are at least three aspects to be reported as key improvements. The first is related to safety: since the generation of motor commands and the acquisition of motor feedbacks of the two wheels are performed by the same computational unit, the system may react immediately, preventing risks, in case of any kind of failures of one of the two motors. Furthermore, the integration of the Vehicle Management Unit ensures a safe and low latency channel for toque request and thus more accurate torque vectoring strategies are possible. Last, this approach allows some costs saving, for instance the items are sharing the same mechanical housing.

In HiEFFICIENT, the combination of Elaphe IWMs with I&M Dual Inverter platform delivers significant results concerning high bandwidth control of the electric powertrain systems. In conventional setups, mechanical components like driveshafts and transmission limit frequency response to approximately 10 Hz, suitable for human drivers. However, for computer-driven systems or functionalities exceeding basic traction or braking torque, higher frequencies and bandwidth present promising opportunities. Direct drive motors circumvent these mechanical constraints, allowing for response rates exceeding an order of magnitude faster. These advancements are validated in testing scenarios, showcasing their efficacy as direct drive machines.

A PARTNER INTRODUCTION

elaphe

- Gorazd Lampic, CEO -

Focuses on innovation and research in the field of direct-drive electric motors for electric vehicles as co-founder of Elaphe since 2006.

Elaphe Propulsion Technologies is a European in-wheel system provider, offering extensive support on designing customized in-wheel motor-based traction drive solutions, platform architecture and controls.

ELAPHE IS A SLOVENIAN company with its headquarters in Ljubljana. The enthusiastic team of Elaphe engineers is highly motivated to commercialize in-wheel electric motor technology, which will significantly reduce cost of vehicle platforms, increase their functionality and safety, and directly save millions of tons of raw materials, millions of GWh of energy and billions of tons of CO2 per year.

Elaphe has won several national and international awards for its innovative and robust powertrain technologies. Currently in its 6th generation of technology development, Elaphe has provided all top automakers with automotive grade, validated solutions for future platform planning. In addition, Elaphe is the first globally recognized company to deliver in-wheel technology for homologated and validated production cars on the market.

PARTNER's FOCUS PRODUCTS

Elaphe focuses on highly-scalable and compact direct-drive high-torque powertrain solutions, which can be integrated into regular vehicle wheels using standard brake, bearing and suspension systems - thus saving hundreds of litres of space and removing chassis design constraints. In parallel, Elaphe also has full test vehicle electrification capabilities.

As part of extensive infrastructure development, Elaphe has built up significant testing equipment, focusing on performance, durability, and endurance testing of powertrains with control of multiple environmental and cooling system variables for high torque and high power drives.

Figure 15: Elaphe in-wheel motor

CONTRIBUTION TO THE PROJECT

Elaphe Propulsion Technologies Ltd. is a fast-growing SME focused on in-wheel high-torque motors and powertrains: its role in the project is researching possible introduction of advanced inverters, using wide-bandgap semiconductors, enabling high switching frequencies. This is especially useful for compact high-pole-pair electric machine control, such as in-wheel motors. One of the key tasks is related to the development of motor control algorithms and software, especially focused on inverters operating at high switching frequencies.

Elaphe's key motivation is to improve efficiency on the powertrain level by smart control algorithms, based on well characterized inverter and motor efficiency at different switching frequencies.

Figure 16: General Assembly Meeting M18 at Elaphe's premises

BENEFITS FROM THE PROJECT

The project is in line with Elaphe's mission to revolutionize electric mobility by significantly improving powertrain architecture with regard to packaging, weight, energy consumption and user experience.

Elaphe is responsible for the inverter software development to control multiphase motors in UC2a. Elaphe will also provide Propulsion Control Unit for communication and coordination of torque operation between powertrain and energy source.

- Elaphe Propulsion Technologies Ltd. -

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1000 Ljubljana, Slovenia
https://in-wheel.com/

A PARTNER INTRODUCTION

- Pietro Perlo -

- Marco Biasiotto -

P. Perlo, co-founder of I-FEVS, has many years of experience in Research and Development, Automotive development, Project Management, Research and Development and Management with focus on Urban Fully Electric Vehicle Development. M. Biasiotto is the Head of Mechanical Department at I-FEVS.

I-FEVS - Interactive Fully Electrical Vehicles - is an innovative SME in Italy and is specialized in integrating high efficiency flexible solar panels in the I-FEVS Passengers, VANs, Pick Ups, I-bikes and Air Vehicles.

I-FEVS IS AN ITALIAN COMPANY situated in Turin and was founded in 2011. The founders set themselves the ambitious goal of growing a company that would follow the spirit of the Florentine Renaissance workshops: creativity and technical-scientific knowledge at the service of new forms of sustainable mobility.

Thanks to the support of the European Community, I-FEVS was able to hire a group of technicians and engineers unique for their dedication to work and their expertise. With them it was possible to generate demonstrators of great industrial potential, protected by a portfolio of over 140 patents and trademarks.

The international reputation in the world of research and development has grown steadily, collaborating with many European research centers and major industrial partners in the Automotive industry.

IFEV's FOCUS PRODUCTS

I-FEVS has followed the evolution of PV technologies year over year and updates have always been integrated in all its demo vehicles. Currently high efficiency flexible solar panels are integrated in the I-FEVS Passengers, VANs, Pick Ups, I-bikes and Air Vehicles. I-FEVS uses proprietary solutions to couple the partitioned solar panels with the battery pack.

Figure 17: I-Bike

CONTRIBUTION TO THE PROJECT

I-FEVS is contributing to the project by developing a 4WD vehicle with 48 V motorization, in which an OBC and a solar panel are integrated.

BIDIRECTIONAL DC CHARGER: The external charger developed is equipped with a connector based on the Combined Charging System type 2 (CCS2). On the vehicle side, I-FEVS provided a dedicated socket which is placed aside on frontal fender. A customized circuit board was implemented to connect the charging station with the vehicle. The E/E architecture of the vehicle developed by I-FEVS is based on CAN-bus protocol communication that requires a dedicated connector.

The battery-packs are interfaced with the charging system via CAN-bus protocol referred to the related regulation of CAN2.0B and J1939.

I-FEVS performed specific tests to validate the functionality of the external DC charger for both vehicle types (100 V and 48 V voltage supply). The charging system is designed to recharge both, the 48 V and the 100 V battery of the I-FEVS vehicles including the 4WD drive with motors provided by Valeo.

SiC MOSFETs have been chosen as converter power semiconductor devices, in order to maximize the charger efficiency, throughout the whole operating range.

Figure 18: Vehicle Demonstrator for UC5b

BENEFITS FROM THE PROJECT

The most important result for I-FEVS is the commercialization of the use of the technology in HiEFFICIENT for urban electric vehicles, which are among the safest on the market.

Our aim is to produce vehicles for urban mobility that are top class in terms of safety, energy consumption, robustness and total cost of ownership.

The good cooperations with partners from the automotive and semiconductor industries will foster this approach.

For the worldwide expansion of the microfactory concept I-FEVS has specific agreements with world's largest major provider of automotive body in white

- I-FEVS -
Strada Carignano 50
10040 La Loggia, Italy
https://www.ifevs.com

A PARTNER INTRODUCTION

Ideas&Motion

- Claudio Romano -

Claudio Romano received his MSc in Electronic Engineering at the Politecnico of Torino (Turin, Italy) in 2007. He joined Ideas & Motion S.r.l in 2015 and he is still working there as head of system design. He leads several advanced research projects mainly in the field of power electronics.

Ideas & Motion's main focus is on technical excellence and innovation in the development of high-efficiency power inverters for the electric mobility sector, with very clear goals: innovation transfer into products, access to the best-in-class technologies and strong commitment to sustainability.

Ideas & Motion started operations in 2013. The company originates from the intuition of a group of engineers who has succeeded in combining technical excellence and innovation with the development of worldwide successful automotive systems. The headquarter is located in Cherasco (northern Italy) and a second design center mainly devoted to SW development was established in Turin since 2017.

Figure 19: I&M headquarter

Partner's FOCUS PRODUCTS

Ideas & Motion business grows along two lines: providing engineering services, both on HW and SW domains, in the automotive industry and being a supplier of smart control systems in niche applications with low volumes and high technological contents. The company benefits from its long and in-depth experience of leading edge technologies in the automotive electronic systems, which makes Ideas & Motion able to support and facilitate customers in the development of efficient and tailor made systems. Furthermore, a strong commitment to research and development programs enables the company to develop innovative and high performance solutions to be offered as standard products, in particular in the domains of e-mobility traction controllers and telemetry modules. A modular design approach always leads the internal development process, enabling the company to reduce the time to market for customized solutions, based on standard and consolidated products.

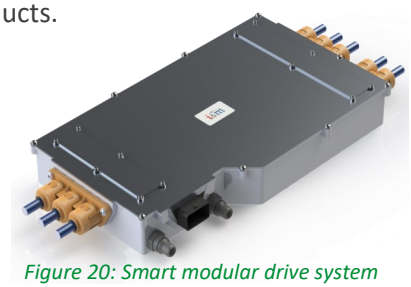

Figure 20: Smart modular drive system

CONTRIBUTION TO THE PROJECT

Electric vehicle technology has seen rapid development in recent years. The shift towards electrification in passenger cars is evident as OEMs are heavily investing in new electric vehicle models, leading to an increase in sales number. This growth poses technical challenges for crucial powertrain components, such as traction inverters. The primary goals of the HiEFFICIENT project are to meet these challenges by focusing on power density, efficiency, reliability, and ease of integration. Ideas & Motion is leading HiEFFICIENT UC2. It consists of two sub-Use Cases addressing different objectives. UC2a aims at developing an integrated smart modular electric drive system for multi-motors or multiphase motor battery electric vehicle (Figure 19). The system is designed to operate up to 400 V battery voltage. The development of a highly integrated system contributes in lowering the cost of electric powertrain and gives many technical advantages. Conversely, UC2b seeks to leverage various promising technologies by proposing the development of a novel power stage based on GaN System-on-Chip (SoC) devices directly integrated into the power stage PCB (Figure 21). The new development approach of integrating SoCs with GaN half-bridge on Poly-AlN is the novel miniaturization step for power system level integration in cars. The benefits of embedding several SoCs in order to realize a full working power system inside of a multilayer PCB are novel cooling concepts, improved electrical performance and lifetime, which will be demonstrated first time according automotive requirements in a highly integrated e-powertrain.

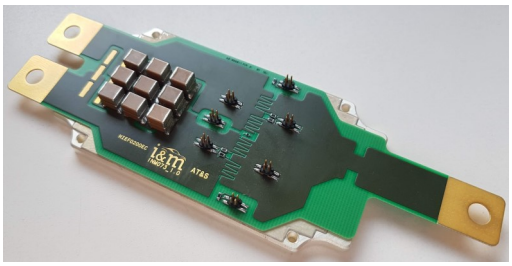

Figure 21: Half bridge module with GaN dice embedded into the PCB

BENEFITS FROM THE PROJECT

Joining the HiEFFICIENT project empowers Ideas & Motion with a competitive advantage in the electric vehicle industry. It enhances the company's reputation as a leader in innovative powertrain technology, attracting clients and partners. Successfully implementing the project can drive business growth through increased demand and market expansion opportunities. Collaboration within HiEFFICIENT fosters strategic partnerships, facilitating knowledge sharing and resource pooling. Additionally, investing in sustainability-oriented projects like HiEFFICIENT reinforces Ideas & Motion's commitment to environmental responsibility, appealing to environmentally conscious stakeholders. Overall, leading HiEFFICIENT positions Ideas & Motion for long-term success in the evolving electric vehicle market.

- Ideas & Motion S.r.l. -
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12062, Chearasco (CN), Italy
https://www.ideasandmotion.com/

4th GENERAL ASSEMBLY

Impressive presentations were given at this two-day meeting in Turin in May 2023. The partners engaged in lively discussions during the breaks. The meeting was rounded off by an extraordinary social event with a guided tour of the city, coffee, chocolate and ice cream tasting and typical dishes from Piemont!

PROJECT EVENTS

2nd ANNUAL REVIEW

AT&S hosted this meeting in Leoben in June 2023. The reviewers were impressed by the results achieved on technical side. The meeting was rounded off with a tour of the company, where we were warmly welcomed by the CTO, and a visit to the Gösseum to learn more about traditional Austrian beer culture.

EPE'23 ECCE CONFERENCE

Together with the iREL4.0 project, a special session was held on the reliability of WGB semiconductors and related applications. Additionally, HiEFFICIENT was part of the conference keynote "Power Electronics in Electric Vehicles: It's not just about cost", by Kunal Goray from AVL SFR.

ESBS AUSTRIA CONFERENCE

HiEFFICIENT was presented at the ESBS-Austria conference "Chips JU as integral part of European Chips Act" in October 2023. C. Abart and M. Scharrer gave an insight into the project with a focus on highly reliable and integrated WBG technologies in electronic power circuits and systems of electrified vehicles.

5th GENERAL ASSEMBLY

RWTH Aachen hosted this GA meeting in November 2023 in Aachen. In this 1,5 day meeting, the coordinator gave a status overview, followed by UC and WP summaries. A special lessons learned session was held to point out weaknesses and improvements. Also, we were given a tour of all the labs at the university. It was impressive to see the work being done there!

6th GENERAL ASSEMBLY

The 6th General Assembly took place in Leuven, Belgium, at the imec premises! We were quite a large group of participants and we enjoyed the atmosphere during the meeting where we discussed the next steps to successfully complete this project. A big thank you to imec for organizing the meeting and for the insight into their fabs!

RELATED EVENTS

- March 12th to 14th, 2024: CIPS—International Conference on Integrated Power Electronics Systems, Düsseldorf, Germany
- April 15th to 18th, 2024:Transport Research Arena (TRA), Dublin, Ireland
- May 19th to 23rd, 2024: WOCSDICE EXMATEC 2024 conference, Heraklion, Greece
- June 11th to 13th, 2024: PCIM Europe, Nuremberg, Germany
- June 18th to 21st, 2024: EPoSS Annual Forum 2024, Cork, Ireland
- June 27th to 28th, 2024: ECPE Workshop on Condition & Health Monitoring, Bilbao, Spain
- October 2024: HiFFICIENT Webinar series, online (in planning)
- October 9th to 10th, 2024: ECPE workshop „Materials Innovations for Advanced Power Packaging - Substrate, Interconnection and Encapsulation“, Frankfurt, Germany
- October 19th to 23rd, 2024: IEEE ASDAM conference, Smolenice, Slovakia
- November 26th to 28th, 2024: 7th HiEFFICIENT General Assembly Meeting & Final Review Meeting, Graz, Austria

PUBLIC DELIVERABLES

Public deliverables are available for download from the project website in the section NEWS→Public Deliverables

List of currently available public deliverables (click for download):

- D1.1 Specification of Use Cases
- D1.3 Report on EOL Reliability Targets and PHM Measures
- D1.4 Initial Project metrics
- D2.1 Feasibility study for integration technologies at high volume/low cost
- D3.1 Report on Performance of Components Models and Dynamic Behaviors
- D4.1 Assessment of cooling concepts for HiEFFICIENT Use Cases
- D7.1 Press Release
- D7.4 Initial Dissemination Plan
- D7.5 Newsletter M12
- D7.7 Newsletter M24
- D7.10 Newsletter M36

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