2022

PROJECT NEWSLETTER

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INTEGRATION
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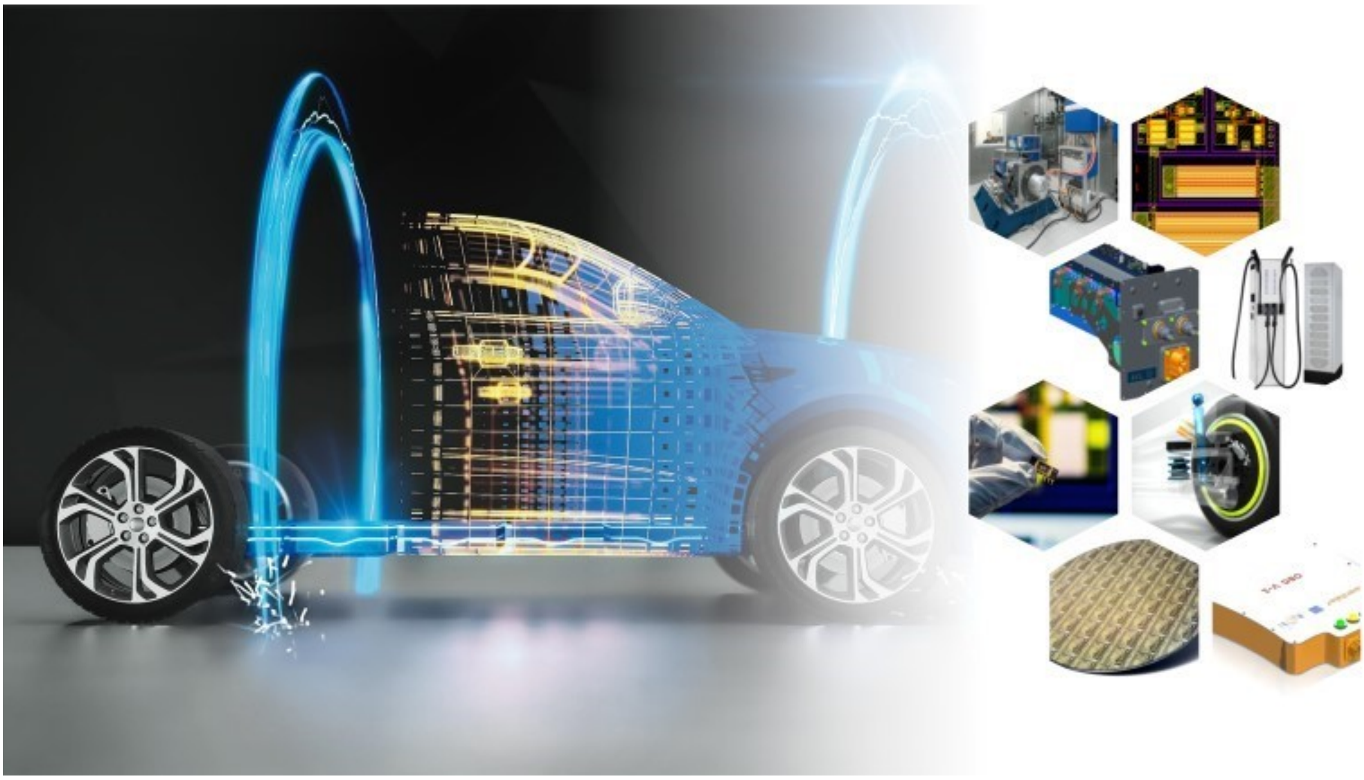
RELIABILITY



ENVIRONMENTAL IMPACT GREEN DEAL

At the end of 2019, the European Commission presented "The European Green Deal", with the aim of transforming the European Union into a modern, resource-efficient and competitive economy. The most important objectives thereby are the reduction to zero net greenhouse gases emissions by 2050 and to ensure economic growth decoupled from resource use. The HiEFFICIENT project – a Research and Innovation Action funded by the ECSEL Joint Undertaking – directly addresses these objectives targeted in the "The European Green Deal", having a focus on sustainable mobility and resource efficiency. By making use of highly reliable and integrated wide-bandgap (WBG) technologies in electronic power circuits and systems of electrified vehicles, testing systems, and charging infrastructures, HiEFFICIENT will directly support the development towards a more resource-efficient and decarbonized transportation system.

USE OF HIGHLY RELIABLE AND INTEGRATED WIDE-BANDGAP TECHNOLOGY

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

THIS PROJECT IS DRIVEN BY 6 industrial use cases (UCs). They include, amongst others, modular inverters with different voltage levels (such as 48V and 400V), flexible on- and multi-use off-board chargers for different voltage levels, multi-purpose DC/DC converters and test systems for power electronics' lifetime testing. These UCs are led by OEMs and other industrial partners, who define requirements and specifications for the envisioned systems.

In HiEFFICIENT, 33 partners from 9 European countries are cooperating in this 3-year project with a total budget of 42 M€. The consortium of this project is an outstanding combination of well-known European industrial companies and research institutes, being located along the whole value chain, starting from semiconductors industry and ending up with OEMs.

Figure 1: Project consortium

KICK-OFF MEETING

The project officially started on May 1st, 2021 and it was kicked-off on May 10th. Due to the COVID-19 pandemic the meeting had to be held virtually.

SCOPE & OBJECTIVES

The project aims to demonstrate the advantages of integrating wide-bandgap power electronics on component (e.g., System-on-Chip, System-in-Package), sub-system (e.g., embedding power electronics components in printed circuit boards) and system level (e.g., traction inverter with / without on-board charger). This will help to increase efficiency and extend the lifetime of power electronics by adding (also virtual) sensors.

- O1: Integration and volume reduction of up to 40%
- O2: Increase efficiency beyond 98% and reduce losses of up to 50%
- O3: Lifetime improvement of up to 20%
- O4: Intelligent power modules

Figure 2: Project objectives

- Key Facts -

Partners: 33

Countries: 9

Budget: 42 M€

JU Funding: 12 M€

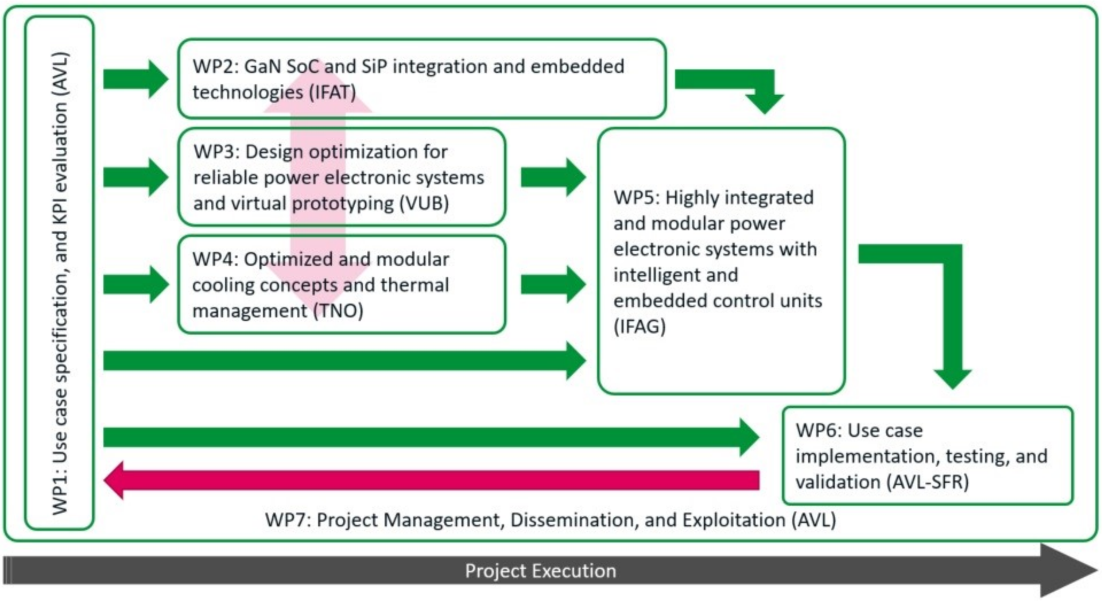
Project Start: May 1st, 2021

Duration: 36 months

Coordinator: AVL List GmbH

www.HiEFFICIENT.eu

PROJECT EXECUTION



FROM SEMICONDUCTOR TO INTEGRATED SYSTEMS

HiEFFICIENT's main focus is on the reliability and integration of WBG technologies in electronic power circuits and systems of electrified vehicles, test systems, and charging infrastructures.

Therefore, the project structure consists of work packages and use cases, which are organized as a matrix. All WPs deliver input to all use cases. Additionally, reliability and prognostic health management is added as a transversal topic across all borders.

First, requirements are derived in WP1 based on the use cases and are directly fed into the technical work packages. WP2, WP3 and WP4 will be executed in parallel which build the basis for the integration of modular power electronic systems.

There will be a close collaboration and exchange between the work packages to fulfill all requirements and to guarantee a smooth subsystem integration within WP5. The demonstration and validation of the concepts and approaches will take place in WP6 and will be evaluated against the requirements set in WP1, to close the loop.

Six use cases are set up to demonstrate the potential of the proposed technologies in various application domains of the automotive industry.

INDUSTRIAL USE CASES

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.

UC1

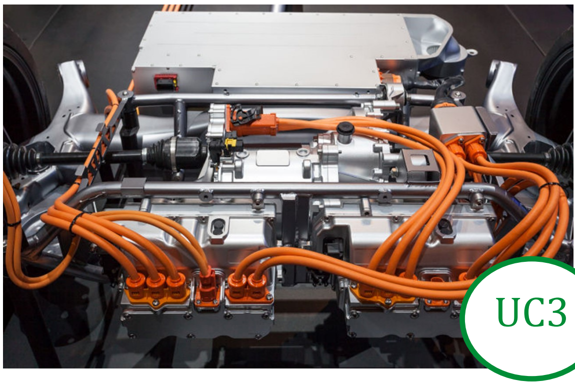
Highly integrated e-Powertrain

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

UC2

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.



UC3

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.

UC4

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.

UC5

GaN automotive DC/DC Converter

Development of DC/DC converter for a solar electric vehicle. Efficiency is of utmost importance to maximize driving ranges.

UC6

FIRST GAN SIP AND SOC DEVICES OUT OF EUROPE

Highest current of 40 A for an integrated 100 V version of a GaN-switch with the smallest footprint. First SoC half-bridge for 650 V on a fully isolating substrate on one single piece of semiconductor.

KEY RESLUT 1

GaN IC Technology for 100 V Applications

Today the GaN (Gallium Nitride) market is dominated by discrete off-the-shelf components. However, to unlock the full potential for fast switching GaN technology in high power applications, monolithic integration is crucial. For instance, integration reduces the parasitics between the driver and the power devices or between the two power devices and a half-bridge (HB) at the switching node etc. It helps to reduce ringing and switching losses, which in-turn makes a smooth highly efficient circuit. Furthermore, GaN ICs (Integrated Circuit) provide a faster, smaller, lighter, and more cost-effective solution compared to other silicon alternatives.

IMEC'S LOW-VOLATAGE GAN-IC TECHNOLOGIES

In imec's low-voltage GAN-IC technologies, two switches in series can be integrated on a single die without having back-gating effects by processing on SOI (silicon-on-insulator) wafers, where the buried oxide (BOX) combined with the deep trench isolation (DTI) effectively isolate high-side and low-side switches.

IN THIS PROJECT GaN ICs are developed that contain a half-bridge switch with integrated driver and the entire circuit is monolithically integrated in all GaN technology. Due to the absence of a complimentary device in GaN technology, analogue circuits are made by using RTL (Resistor-Transistor Logic) based design. A half-bridge switch is an essential part of any synchronous power converter. For the Use Cases in this project, HB switches are symmetrical in size. Power transistor sizes are derived based on the application's current requirements by considering the targeted efficiency. The driver in both cases mainly consists of a totem stage, bootstrap circuit, and a pre-driver. In the pre-driver, multiple stages of inverters are used to increase the gain and delay matching.

The driver is designed for 1 MHz switching frequency. The bond pads are designed for flip-chip packaging and a small value of a bootstrap capacitor is integrated on chip. Both sides of the driver have two non-inverting level shifters. These level shifters take the low voltage signal as input from the micro-controller and convert it to the higher voltage that is required as the input to the pre-driver. The block diagram shows the different blocks of the integrated driver.

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The picture of the demonstrator circuit represents a typical fabricated GAN-IC of a half-bridge with integrated driver.

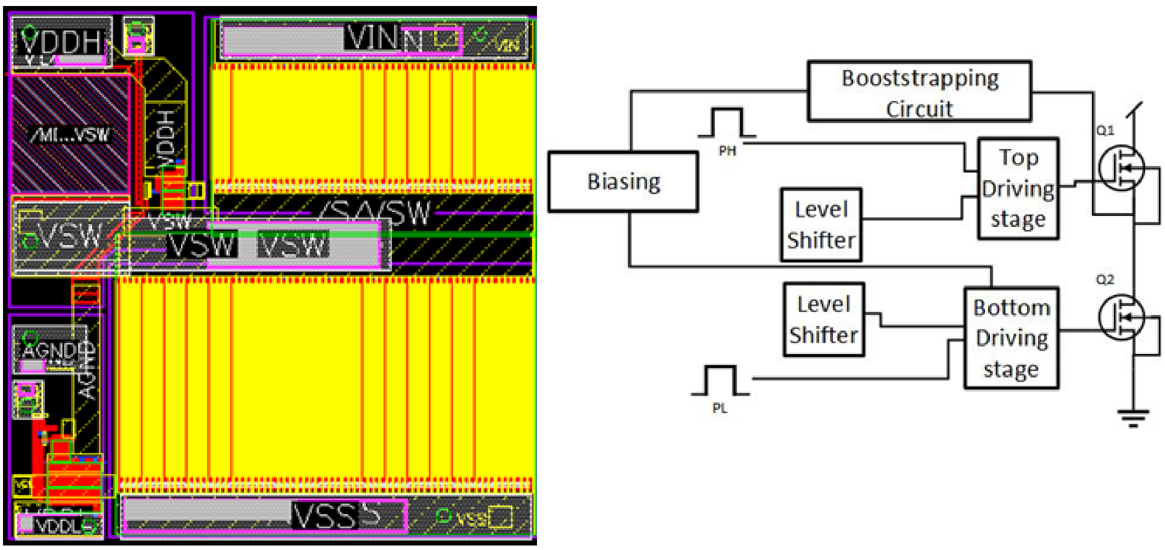

Figure 3: Inverter interface and data stream for internal (iPHM) and external (ePHM) prognostic and health management system

Make Reliability and PHM functions visible at the top system level and to the end user

Hybrid and electric vehicles have been developed rapidly in the last years. The increment of the number of electric vehicles in the market results in tight technical requirements for key powertrain components such as the traction inverter. The main requirements that must be fulfilled involve power density, efficiency, heat dissipation, and ease-of-integration. The development objectives are generally focused on the improvement of the efficiency, the reduction of the dimensions, and the optimization of the thermal behaviour to reach the largest power density possible. A second big challenge is related to powertrain reliability.

Use case 2a of the project HiEFFICIENT is an appropriate example to show the activities related to prognostic health management and how it can be made visible to the end user.

The scope of this use case is the development of an integrated smart modular electric drive system for multi-motors battery electric vehicle (BEV) and plug-in hybrid EV (PHEV) up to 400 V battery voltage. The system will be able to detect device failures and fail operational control algorithms will be implemented. Different system options will be evaluated with the aim to balance overall system reliability and subsystems level of integration. On a glance, the inverter interface and data streaming are depicted in the figure below. Data from various levels of integration of the inverter will be collected to drive data-based prediction methodologies.

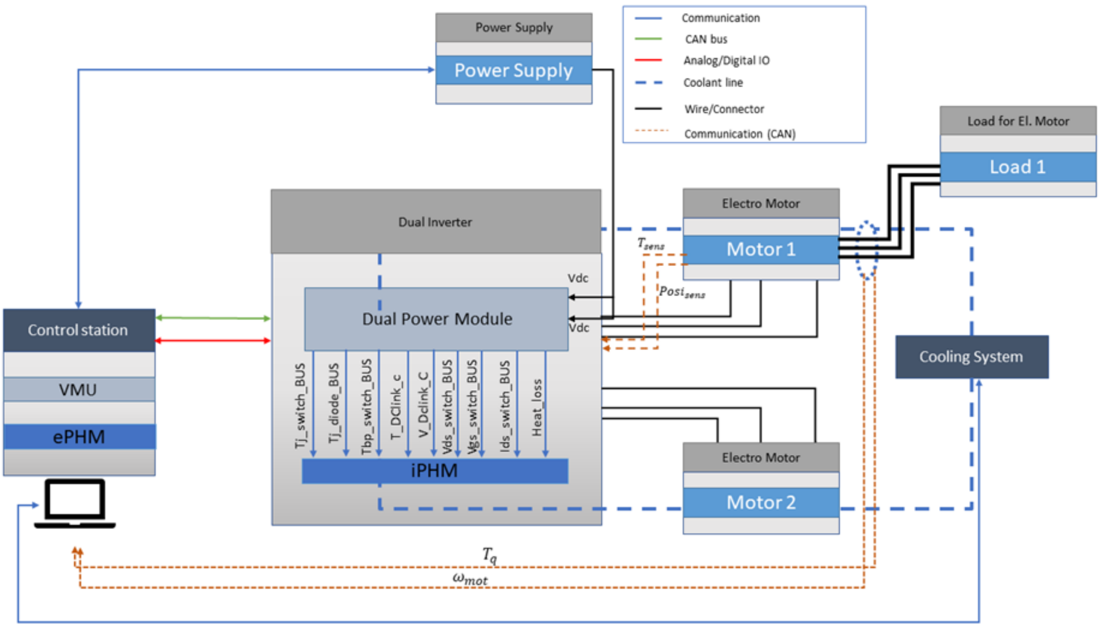

Figure 4: Inverter interface and data stream for internal (iPHM) and external (ePHM) prognostic health management system

TECHNICAL APPROACH

Parallel to the development of a smart modular electric drive system, prognostic health management and functional safety (FuSa) analysis will be conducted with the goal to identify possible faults on the inverter over its lifetime using step 1) Hazard Analysis and Risk Assessment (HARA) and step 2) Failure Modes and Effects Analysis (FMEA). The first step in the concept phase is the item definition where the needed information about the item and environment is collected. To identify potential hazards and operability problems in a system the Hazard and Operability Analysis (HAZOP) will be used as an input for the HARA. During the HARA we identify and classify hazardous events on the item level and determine the ASIL classification and derive Safety Goals. In step 2, the FMEA for each system level is conducted. To identify risks and potential failure modes of the inverter a bottom-up approach is considered, starting from component level up to the system level of the multidrive e-powertrain. For each level a FMEA will be conducted to identify most critical risks. These potential risks will then be used as baseline for prognostic health management. The workflow will be devised in accordance with ISO 26262 in the context of a target vehicle application.

In addition, physical models based on complex finite elements models representing dedicated failure modes are evaluated and implemented with time-efficient surrogate modelling approaches. At the end a combined approach consisting of purely data based methods as wells as of a methods taking into account the physics of degradation are captured. In case of internal failure the design will then ensure that (inverter level) inverters fail in a safe manner, and in case of external failures (vehicle-powertrain level) inverters cooperate to shut down the system safely. The end user will be prompted for action to be done.

- Authors -

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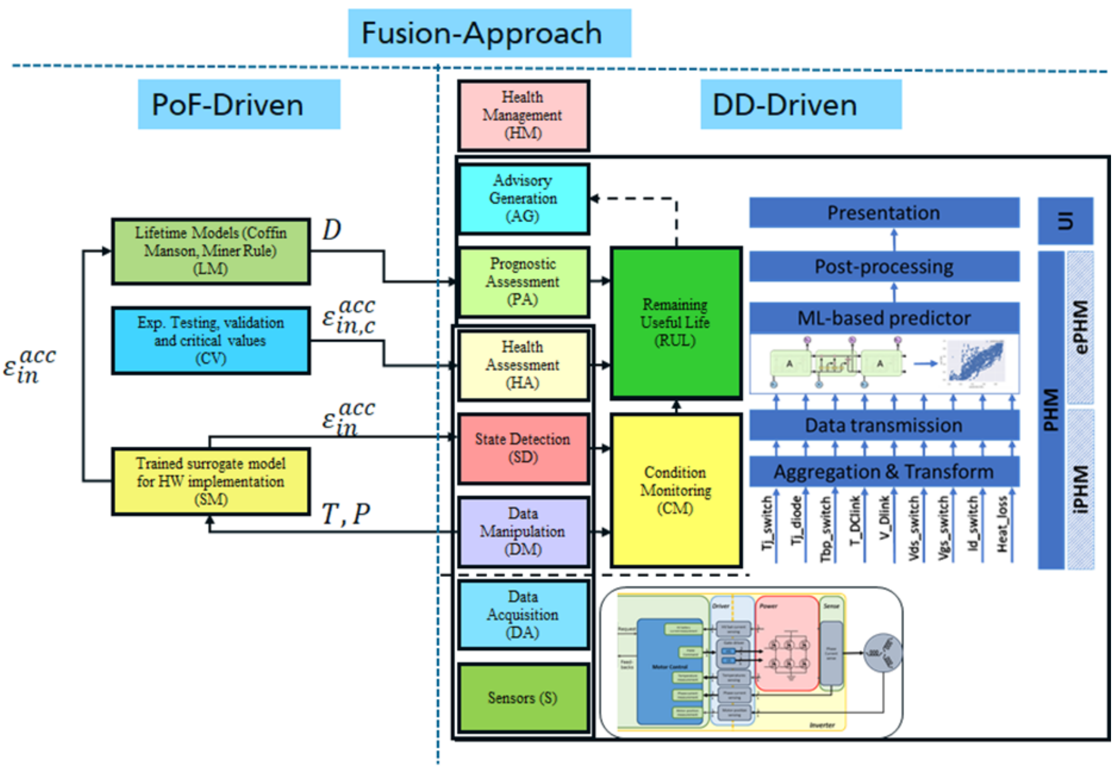

Figure 5: Combined physics of failure and data driven approach for prognostic health management

A PARTNER INTRODUCTION

- Gianluca Botto, CEO -

Master's degree in Electronic Engineering, Ph.D. in Mechatronics, both at Polytechnic of Turin, where he was a researcher for 8 years in mechatronics applications for automotive. His main skills are related to electronics for automotive, digital platforms and real time embedded firmware. Since 2012 he is a partner in FLAG-MS.

FLAG-MS stands for Flexible and Green Mechatronic Solutions and is an *innovative SME* based in *Italy*, specialized in *system electrification*, especially in the *automotive*, *agricultural*, and *special vehicles* sectors.

THE COMPANY IS SENSIBLE to the theme of decarbonization and sustainability that is why it proposes innovative solutions in the field of vehicles and systems electrification to support such a central topic of our future. Besides of the complete **powertrain design**, **prototype assembly** and **system integration**, the R&D department works mainly in the development of innovative solutions for the key components such as **battery pack**, **battery management system (BMS)**, **e-motor drive** for applications of different natures, from **proof of concept**, **vehicle prototypes**, **one-off car** up to **production applications**. The activity process characterizing every new component development starts from the customer requirement analysis, pass through the application field **regulatory standards study**, the first proof of concept, the design and production of different stages of samples.

FLAG-MS FOCUS PRODUCTS

Power inverter and **battery pack**, including a **proprietary BMS**, are two of the key components of an electric powertrain for which FLAG-MS has full development capabilities. The focus is on introducing of highly innovative contents aimed at increasing **energy & power density,** optimizing the **cooling system,** and implementing the concept of **reusability and repairability**. To fulfill the growing demands of reliability and functional safety, the **prognostic health management** of powertrain components is a central theme in our developments. In 2019 FLAG-MS started the development of eMotor Drives's new generation, based on SiC devices, suitable for brushless motors in 800 Vdc applications. The first versions used in real applications (700 Vdc) are a 4x15 kW and a single 100 kW inverters. A 380 kW inverter for **hypercar applications** is under development (available in Q1 2023).

Figure 6: Quadruple (left) and single (right) eMotor Drives

CONTRIBUTION TO THE PROJECT

As a partner of HiEFFICIENT, FLAG-MS is working on the development of an **integrated bidirectional On-Board Charger** (OBC) and **DC/DC converter** for (PH)EV powered by batteries up to 450 V. Requirements of electric and hybrid vehicles are mainly related to obtaining as longest range as possible, maintaining high-performance and this brings constraints in terms of efficiency and weight of the vehicle itself. The use of hybrid solutions such as **SiC and GaN** and the level of integration will target both efficiency and density requirements of future vehicles. The project work starts at component-level, working with the power device supplier partners, and is followed by multi-objective design optimization and virtual prototyping approaches. The high integration level requested brings challenges in thermal management, which will be addressed by the development of high-performance cooling system. The bi-directional on-board charger, **suited for 1/3 phase and world-wide grid compatibility** will be conceived to guarantee a power density higher than current market standards of power handling with an **expected power density greater than 1.5kW/l** and a **power wide range of 3.6kW to 22kW**. It will be equipped with **vehicle to grid (V2G) functionality** compliant with new smart grid technologies requirements.

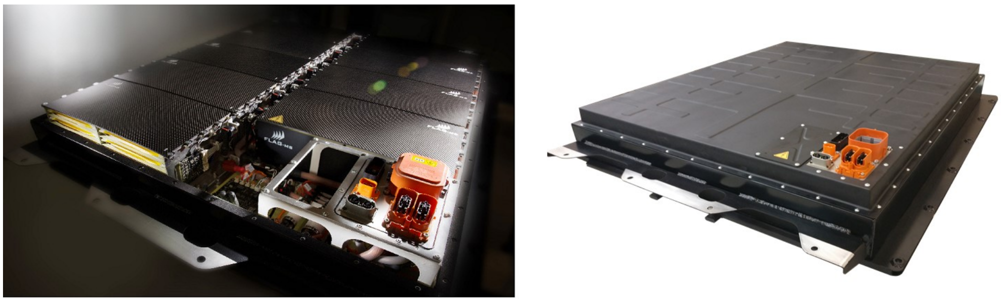

Figure 7: BEV Battery Pack

BENEFITS FROM THE PROJECT

By taking part in the HiEFFICIENT project, FLAG-MS **acquires know-how** on additional key components of an electric powertrain among the product's portfolio of which it can manage a **complete development**. The know-how gained in the development of OBC and DC/DC will represent an **added point of attraction** for the customers who ask FLAG-MS to develop their own components. Thanks to HiEFFICIENT the company can work on the latest generation of SiC and GaN devices, provided by the suppliers of power devices in the project partnership, which are not yet available on the market. The last benefit is related to the development of a **business network** with European companies operating in the field of electrification, which eventually will lead to **partnerships** or to an increase of **business with European companies**.

- FLAG-MS -

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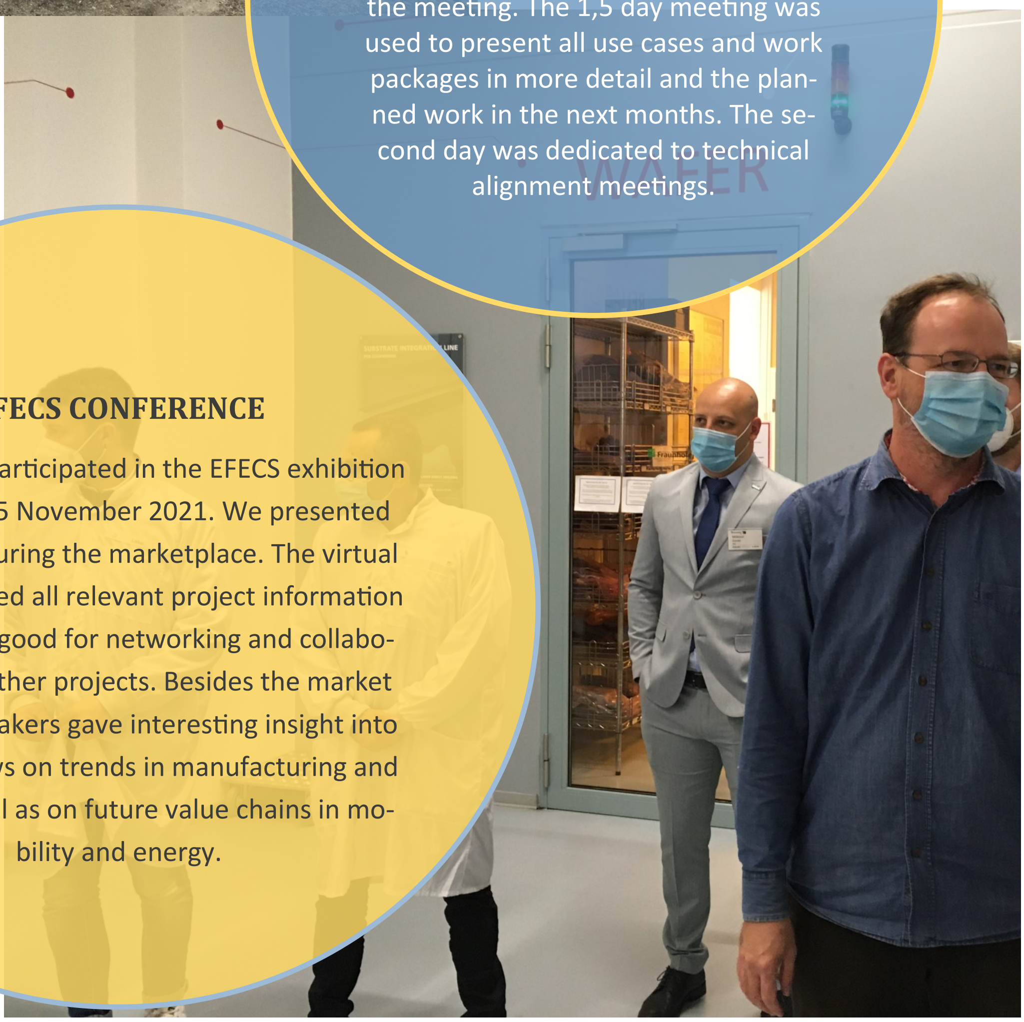
PROJECT EVENTS

KICK-OFF MEETING

First of May 2021, the HiEFFICIENT project – a Research and Innovation Action funded by the ECSEL Joint Undertaking – was launched under the lead of AVL List GmbH. In this three-year project 33 partners from nine European countries are collaborating with a total budget of 41 million Euros. The project was successfully kicked-off on May 10th. Due to the COVID-19 pandemic the meeting had to be held virtually.

1st GENERAL ASSEMBLY

The 1st General Assembly Meeting took place from September 28th-29th in Berlin. A big thank you to the project partner Fraunhofer IZM, who hosted the meeting. The 1,5 day meeting was used to present all use cases and work packages in more detail and the planned work in the next months. The second day was dedicated to technical alignment meetings.



EFECS CONFERENCE

HiEFFICIENT participated in the EFECS exhibition from 23 to 25 November 2021. We presented our project during the marketplace. The virtual booth displayed all relevant project information and this was good for networking and collaborating with other projects. Besides the market place the speakers gave interesting insight into strategic views on trends in manufacturing and design as well as on future value chains in mobility and energy.

2nd GENERAL ASSEMBLY

The 2nd General Assembly meeting took place in Helmond at the Automotive Campus hosted by the Dutch partners Heliox, LY, TU/e and TNO. This time the focus of the meeting was on direct exchange and collaboration in the use cases.

EVENTS AT A GLANCE

For more information, visit the project's website. Here you can find all information about the project.

CONTACT & NEWS

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Upcoming Events

- May 3rd to 5th, 2022: ECS Brokerage and KDT Kick-off, Brussels, Belgium
- May 30th, 2022: ISS Europe, Brussels, Belgium
- June 20th to 22nd, 2022: 1st Annual Project Review Meeting, Brussels, Belgium
- August 24th to 26th, 2022: IWIPP - International Workshop on Integrated Power Packaging, Aalborg, Denmark
- September 8th to 9th, 2022: EPE-ECCE Europe Conference on Power Electronics and Applikation, Hannover, Germany
- September 11th to 16th, 2022: ICSCRM Conference, Davos, Switzerland
- October 2022: 3rd Project General Assembly Meeting, Ljubljana, Slovenia
- October 23rd to 26th, 2022: ASDAM Conference, Smolenice Castle, Slovakia
- November 24th to 25th, 2022: EFECS, Amsterdam, The Netherlands

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