Features

Technical advantages

- Increased reliability of electrical drive systems: Real-time failure prediction models for motor (bearing failure) and inverter (semiconductor failure)
- GaN in inverters: Increased energy efficiency and current carrying capacity at higher switching frequencies, smaller passives
- Benefits for drives: Improved motor power quality and reduced motor losses, especially in the partial load range
- Embedded AI: Run AI models locally on the PWM controller (no cloud service required)

Customer benefits

- Innovation of a GaN-based inverter to increase the efficiency of electric motors
- Embedded intelligence in the power module (data analysis with machine learning algorithms) to enable intelligent maintenance
- Increased ROI and system cost savings (passive components) for power modules through fast switching vertical GaN power semiconductors

Power module prototype

care

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Fraunhofer

Highly efficient motor control with integrated intelligence

POWERcare

PowerCare

Three Fraunhofer Institutes, Fraunhofer ISIT, Fraunhofer IMS and Fraunhofer IISB, are working on integrated intelligence: Independence from fossil fuels and the switch to renewable energy sources require extensive electrification of production and mobility. This increases the demand for compact, energy-efficient and reliable power electronics. In PowerCare, novel vertical GaN power semiconductors and real-time fault models are developed and applied to an engine drive. PowerCare takes a new approach to the monitoring concept by using a miniaturized motor controller with integrated AI-based failure prediction. **Possible applications** are:

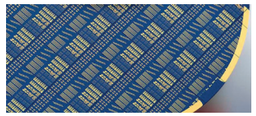
- Efficient and fail-safe industrial drives such as conveyor drives and pumps
- Electric mobility from cars to drones and electric aircrafts
- Point-of-Load converters for data centers
- Safe cobots and mobile medical robots with extended battery life

POWER

vGaN device and inverter development

Technical specifications on our vGaN development:

- Normally-off trench MOSFET based on 8” GaN-on-QST substrates
- Transistor and inverter manufacturing and development at Fraunhofer
- Continuously expanding device design, modeling (TCAD, behavioral models) and characterization capabilities
- Expected specifications: 48V, >40A (>600V / 100A in parallel development)
- Sample ETA mid 2025



GaN wafer with process qualification structures

SEM image of partially processed MOSFETs

Motor controller with embedded AI

Open-source AI software framework AIfES®

- AI models optimized for memory-limited devices are ported to the motor controller
- Local execution of hybrid AI models for condition monitoring of motor and transistors within the inverter

Artificial Intelligence for Embedded Systems

AI-based failure detection models

- Implemented on a domain-specific RISC-V control SoC
- Combined with high efficiency GaN power transistors to form a motor driver

AI-based RISC-V processors

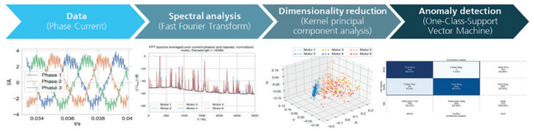
Motor and inverter condition monitoring

Motor condition monitoring evaluates the state of the electric drive by analyzing the three stator currents. Two approaches are used for analysis:

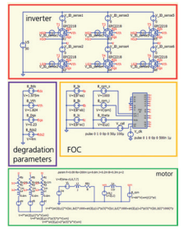
- Machine Learning pipeline with FFT
- Deep Learning pipeline with explanation

Condition monitoring of the inverter is performed as:

- Under development based on commercial GaN HEMTs
- Extended compact device models and system-level simulation in QSPICE
- Based on phase currents only



Machine Learning pipeline for motor failure model



SPICE schematic of system components

Intelligent motor control

Novel GaN semiconductors for high efficiency

Embedded AI failure prediction for converter and motor

Timeline