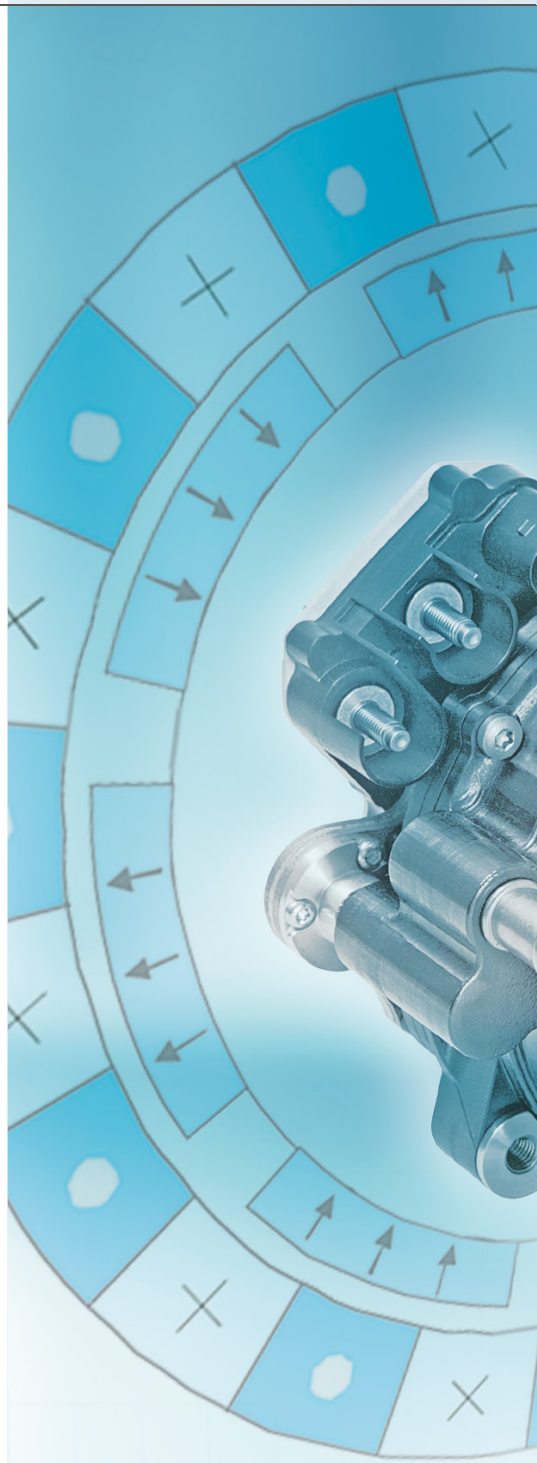


Continental's new belt-driven starter generator uses not only the 48 V vehicle electrical system but also an asynchronous machine as the electric motor and generator – a novelty. dSPACE's flexible HIL test systems spur the development of the mild hybrid ECU.

The ancient Greek word 'synchronos' means 'together with time'. In the field of electric motors and generators, the term 'synchronous machine' is therefore often used to refer to a permanent magnet synchronous machine (PMSM) or a separately excited synchronous machine (SSM) with sliding contacts, where the rotor revolves around the stator with exactly the same speed as the stator's rotating fields, in other words: synchronously.
Asynchronous machines (induction machines) are different. In generators, the rotor runs faster than the stator rotating field; in electric motors, it runs more slowly. While the power density of asynchronous machines is not as high as that of a PMSM, asynchronous machines are more affordable because they do not use an expensive permanent magnet. In addition, an asynchronous machine does not require a direct connection to the rotor and therefore works without sliding contacts. This simple setup makes them very robust. For this very reason, the industrial sector has been using asynchronous machines for decades, and the technology prevails even in the tough environment of combustion engines, making the system more reliable.

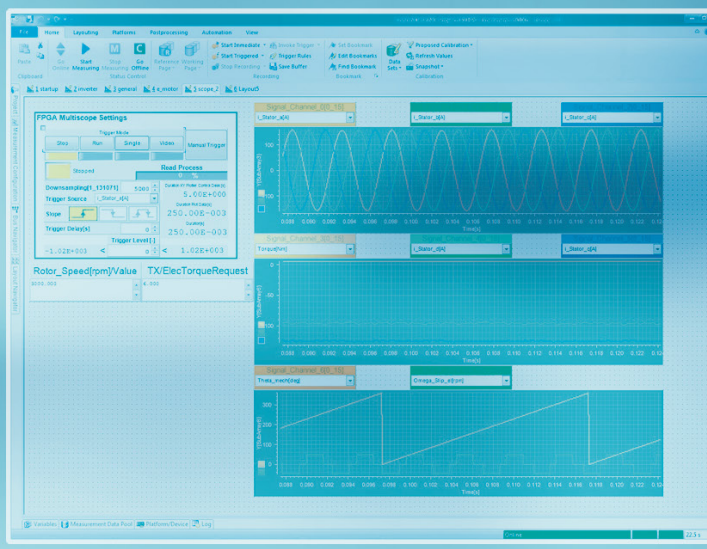
Continental is the first automotive supplier to use an induction motor in a 48 V belt-driven starter generator (BSG) in order to produce a high number of units at low costs while also offering new ways for reducing $CO_2$ emissions in an affordable mild hybrid.

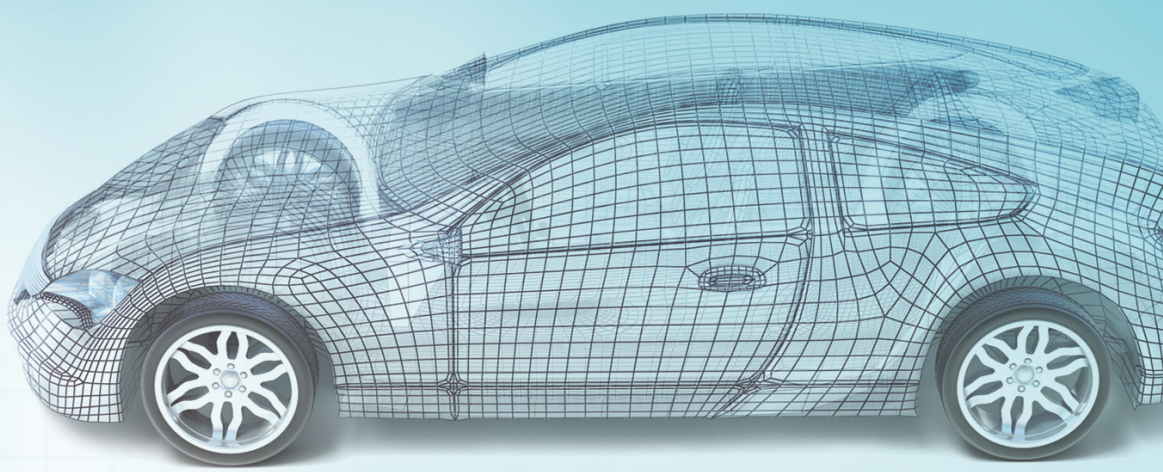
### Proven Test Platforms

The 48 V vehicle electrical system consists not only of the electric motor with the drive belt and an integrated inverter, but also includes a lithium-ion battery and a 12 V DC/DC converter with the associated control software. The developers focus on designing, implementing, and validating these controls, and also on the software for functional safety. Building on its long-standing experience in developing high-voltage power electronics, Continental uses only tried and tested concepts, platforms and tools for the 48 V BSG. This considerably shortens development time, increases robustness, and reduces development costs. This is where the high flexibility and realism of the dSPACE hardware-in-the-loop (HIL) test systems come into play. Continental has already worked with these systems for many years to validate control functions in the development phase. >>

# Synchronously Asynchronous

New ways for cost-effective mild hybrids



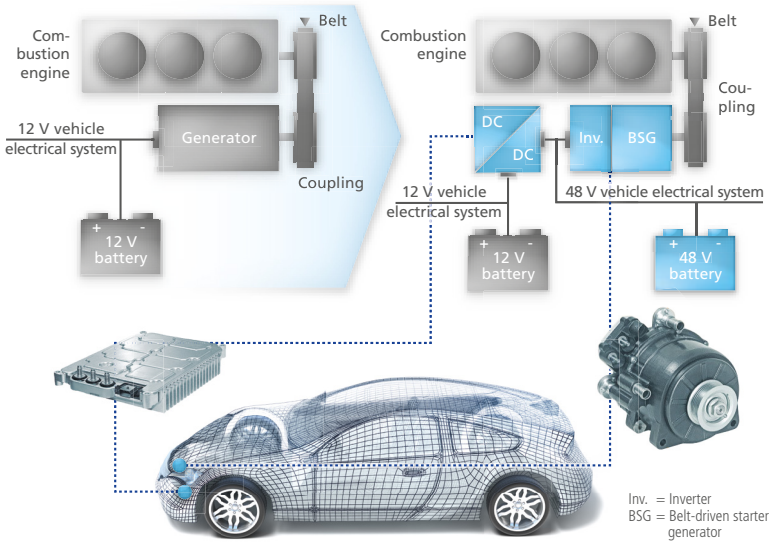



*Figure 1: For the mild hybrid components (light blue) in the 48V Eco Drive, Continental included an additional 48 V vehicle electrical system in addition to the conventional 12 V system.*

The systems link the pure, PC-based simulation with the much more expensive and time-consuming test rigs that include real electric motors. The developers can use the measured motor parameters and the control algorithms that were developed from MATLAB® models during simulation to further optimize the electric motors.

## Early Optimization and Tests

The new functions can be tested and analyzed on the inverter hardware at a very early stage. For this, the HIL simulator emulates the electric motor. This approach lets developers detect potential errors in the interplay of the hardware and functions early on, eliminate them, and begin to optimize the two components even before the control software is integrated into the 48 V BSG and taken to the test bench. Test automation on a HIL simulator also provides a quick and comprehensive way to cover a broad range of tests and validate the software against customer requirements at an early stage. The requirements and tests are specified in IBM® Rational® DOORS®. Continental performs, analyzes, and summarizes the resulting automated regression tests on the HIL simulator by means of automated test coverage metrics before shipping the software to the customer.

## No Red Tape for the Long-Standing Partner

For the 48 V BSG, Continental used dSPACE's highly dynamic DS5203 FPGA Board with the Xilinx® System Generator (XSG) library. This library contains quasi-continuous models for the inverter, the mechanics, and the electric motor. In order to correctly simulate the electric motor for the development of the 48 V BSG, an asynchronous machine first had to be integrated into the XSG Electric Components Library. Although the library was planned for a future dSPACE Release at the time, dSPACE granted Continental access to a beta version of the latest XSG library. This made it possible to gain joint practical experience with the new models, which have since been published in a regular Release.

## Exact Simulation of the Induction Machine

Within a few days, the first FPGA-based asynchronous machine that can interact with the inverter ECU was commissioned at the HIL laboratory at Continental Regensburg in collaboration with dSPACE. To make the simulation results as realistic as possible, not only current- and temperature-dependent effects were considered, but also frequency-dependent effects. The required FPGA model extensions were also implemented fast and easily with the dSPACE XSG Utils Library, which is also FPGA-based. By using this new model approach, Continental was able to consider many relevant effects and use the 2-D look-up tables that were recorded at the test rig for the HIL simulator as they were. This made the simulation of the real behavior of the machine as exact as possible.

> "Because of our very positive experience during the development of the 48 V belt-driven starter generator, the first follow-up projects at Continental also use FPGA- and machine-model-based HIL simulation."
>
> *Anja Poppe, Continental*

## High Flexibility and Simulation Quality

The high flexibility of the dSPACE modeling interface also makes it possible to simulate recorded look-up tables on the FPGA without creating a new FPGA version. The look-up tables can be created in MATLAB®/Simulink® or adjusted during run time in dSPACE ControlDesk® Next Generation. This ensures flexibility for future applications, such as validating a new motor variant. By integrating the multiscope instrument of the XSG Utils Library in ControlDesk, Continental is able to visualize FPGA-internal variables (such as currents, voltages, inductivity, or magnetic saturation) at the FPGA's rate. Continental can therefore optimize control strategies and continuously improve control quality. dSPACE immediately provided optimizations for the asynchronous machines and solutions for problems that Continental discovered during the test phase, spurring the development of the 48 V BSG.

## On the Path to Production Quality

Due to the positive experience during the development of the 48 V BSG, the first follow-up projects at Continental already use the tried and tested HIL simulation based on the FPGA and the machine model. The starter generator decreases the fuel consumption of a compact car by up to 20%, partly due to energy recuperation. But the ancient Greek definition holds true not only for recuperation, i.e., in the generator mode of the asynchronous machine. Because just like the rotor that moves faster than the stator rotation field, the entire 48 V belt-driven starter generator will be ahead of its time when the series production starts in 2016. ■

*Anja Poppe, Josef Laumer, Continental*


*Figure 2: One of the HIL test rigs at Continental in Regensburg.*


*Figure 3: Multiscope instrumentation in ControlDesk Next Generation.*

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