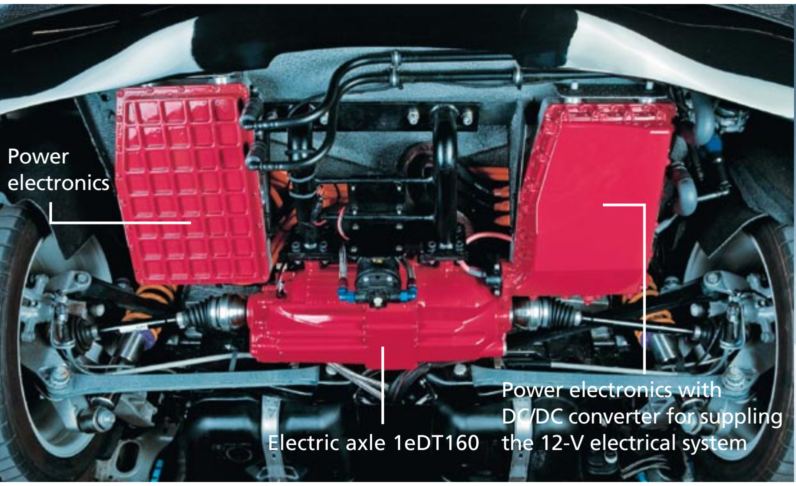
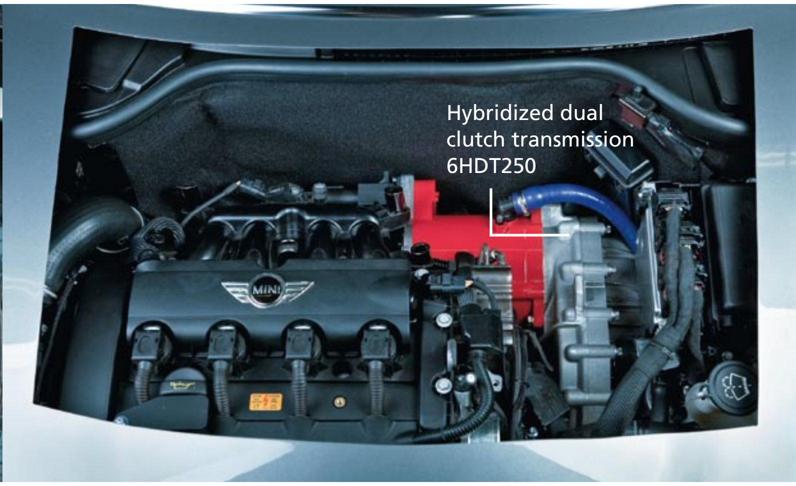
Five in One

Different hybrid variants in one vehicle

Left: Underside view of the demo vehicle with the power electronics from BOSCH that control the electric machines, the electric axle 1eDT160 and the hybridized 6HDT250 dual clutch transmission. The right-hand FC supplies the vehicle's 12-V electrical system via an integrated DC/DC converter. For the axle, BOSCH supplied the motor, and GETRAG the single-gear transmission with an electromagnetic decoupling mechanism and a mechanical oil pump.
Right: View of the engine compartment with 6HDT250 PowerShift® transmission.





Hybrid drives and electric vehicles are hot topics in the automobile industry right now. But what few people know is that the first electric vehicles actually hit the roads in the early 20th century. In fact, until electric starters were invented, electric vehicles were used as widely as gasoline engine vehicles, especially in North America. Now with crude oil becoming scarcer and more expensive, and public awareness of environmental issues rising, the interest in alternative forms of propulsion is growing again.

In a joint hybrid project with BOSCH, GETRAG constructed a demo vehicle based on a Mini Clubman that represents different hybrid variants (torque split and axle split) and makes them "driveable". This allows different approaches to be compared directly. BOSCH was the cooperation partner that supplied the electric machines, the power electronics and the motor electronic control unit (ECU). GETRAG contributed the modified 6-speed PowerShift® dual clutch transmission (DCT), which is going into production as the nonhybrid version in spring 2010. With purely electromotive actuation of the clutch and gears, it is an ideal basis for hybridization.

Design of the Demo Vehicle

In the demo vehicle, both the electric machine flanged to the transmission and the rear-axle electric machine can be coupled and decoupled by an electromagnetic clutch according to the operating state. This avoids unfavorable operating points in the electric machine, such as the field weakening required at high motor speeds, and also reduces drag torques when the auxiliary hybrid functions are deactivated. The reason behind combining the two hybrid approaches in one vehicle is that their different driving behaviors can then be compared at the push of a button.

The demo vehicle can represent the following drivetrain configurations:

- Purely conventional drivetrain
- Purely conventional drivetrain with start/stop functionality
- Hybrid drivetrain with GETRAG PowerShift® transmission and electric rear axle
- Hybrid drivetrain with GETRAG torque split hybrid transmission
- Hybrid drivetrain with GETRAG torque split hybrid transmission and electric rear axle

Interactions and Dependencies

The task of designing a hybrid drive with a large number of interactions and dependencies can be mastered

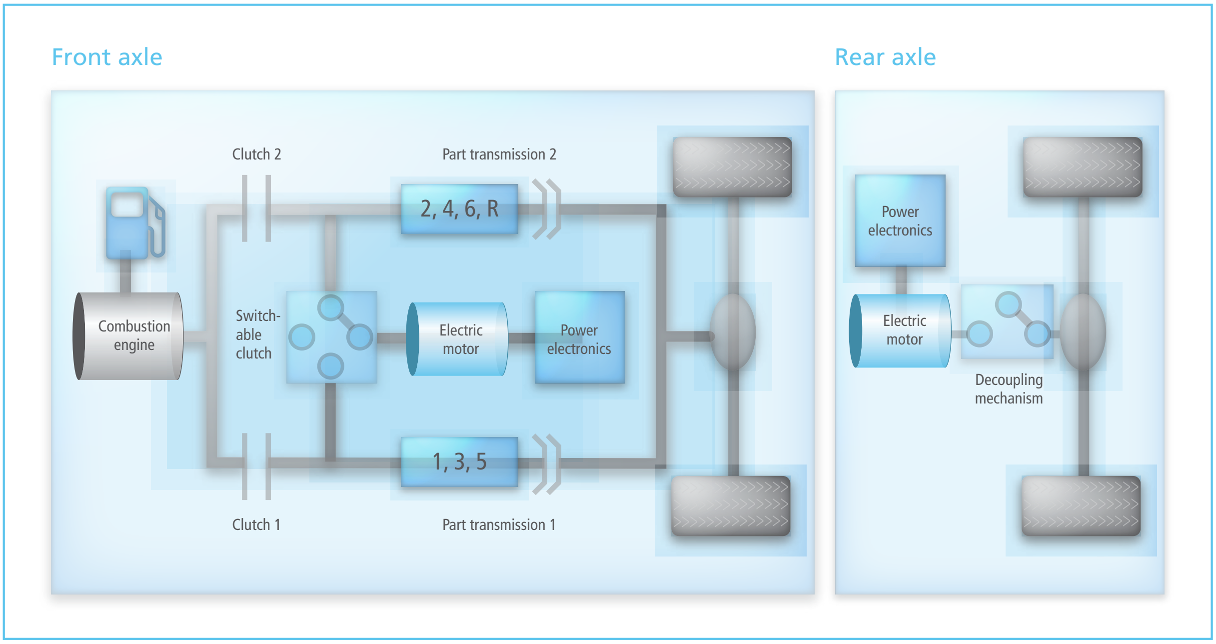
Application panel: Optimum access for the application with six CAN connectors, connection to the dSPACE system, main contactor control in electronic form.

by model-based development methods. For example, the battery and the electric machine interact with each other directly, and have to be adjusted to one another for optimum performance. The size of the electric machine, in turn, determines the extent to which the combustion engine can be downsized while preserving or even increasing the level of comfort and driving performance. Last but not least, the individual components and their current states decide how they can be used in driving operation.
The higher-level operating strategy developed by BOSCH receives data on the components' operating conditions and decides where to use each component at any given point in time. Optimal component design and the best possible component utilization during operation then determine how much fuel economy the hybrid drive can deliver. To investigate different operating strategies, the hybrid manager is implemented on a modified engine ECU from BOSCH, and the transmission software is implemented on a dSPACE system. Hybridizing the drivetrain necessitates intensive adaptations in the transmission software, such as modifications to the torque interventions and switching sequences.

Transmission Control Design

By using the dSPACE system, GETRAG has the flexibility and computing power it needs to implement the extended functionalities that control

> "The dSPACE system delivered the flexibility we needed to develop the control for the hybrid system."
>
> *Tibor Niedermayer, GETRAG*



The demo vehicle of the GETRAG-BOSCH hybrid project has a production motor, and its front axle is equipped with a dual-clutch, 6HDT250-type transmission with an additional electric motor. This modification allows the vehicle to run as a hybrid, with the electric motor supporting the combustion engine. Because the combustion engine and the electric motor are both coupled via the DCT, both types of drive can be used in a gear that is optimal for a specific speed, in other words, with the maximum possible efficiency. A separate electric drive unit is mounted on the rear axle, so the rear wheels can be used to drive the vehicle either as a hybrid or as a purely electric vehicle.

Left: Dipl.-Ing. Tibor Niedermayer
is a development engineer for electrical hardware at GETRAG with responsibility for the vehicle's electrical functionalities.

Middle: Dipl.-Ing. (FH) Ingo Matusche
is a development engineer responsible for the software of the axle-split hybrid at GETRAG.

Right: Dipl.-Ing. (BA) Thomas Hoffmeister
is a development engineer responsible for the software of the torque-split hybrid at GETRAG.

the transmission together with the added electric machines. The production transmission ECU was replaced by a specially built, extended version so that all the additional functionality could be served and all the measurement variables integrated simultaneously and without additional hardware in dSPACE CalDesk.
The hardware system is subdivided into a highly integrated power stage mounted on the transmission, four brushless DC motors for dual clutch and gear actuation, a magnetic decoupling mechanism and ten output stages for controlling pumps, fans and additional consumers in the vehicle. In the trunk, a signal adaptations board with a field-programmable gate array (FPGA) conditions the captured signals for further processing by the dSPACE system and implements an emergency shutdown concept.
The currents of each electric actuator are captured, as well as the currents of the pumps and fans. Temperature capture goes one step further, acquiring not only the cooling agent and oil temperatures in the hybrid sections, but also the temperature of each single power stage in the transmission control. A total of 16 currents, 16 temperatures and 14 position sensors are captured. This ensures that a high-resolution, synchronized representation of a driving situation can be obtained at any point in time. High-resolution capture is performed for nine speed sensors in all, including wheel speeds, so that the current torque distribution can be determined. Four CAN interfaces support communication with the drivetrain components, the hybrid master and the high-voltage battery. Altogether, 150 lines connect the output and signal boards, and 170 lines lead to the dSPACE system.

Going Live in the Vehicle

Taking the idea of "everything in one system" one step further, an operating panel was developed so that the driver can switch and view the current driving state. This operating panel is controled by the dSPACE system.
One important development goal was to integrate all the additional functionality in such a way that the vehicle interior remains unchanged, apart from the extra controls and the additional technology in the trunk. This demonstrates the vehicle's suitability for everyday use and the know-how of the GETRAG-BOSCH hybrid partners.

Great Potential Savings

Simulations have already shown that in the New European Drive Cycle (NEDC), fuel consumption is reduced by approx. 6% (micro hybrid), 18% (axle-split hybrid) and 24% (torque-split hybrid) in comparison with consumption in the unhybridized 6DCT250 PowerShift® transmission. These figures are for an operating strategy that is oriented towards comfort and vehicle dynamics. With a consumption-oriented strategy, the fuel economies achieved by torque split and axle split are even greater. Hybridization provides electric power in addition to the conventional drivetrain, and this improves driving performance. The time taken to accelerate from zero to 100 km/h is shortened from 7.8 s with conventional automatic transmission to 7.5 s with the GETRAG PowerShift® transmission, 7.1 s with the hybridized PowerShift® transmission, and 6.7 s with the combination of PowerShift® transmission and electric axle. ■

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Conclusion

- Demo vehicle built with integrated hybrid variants: torque-split and axle-split hybrid
- dSPACE system replaces transmission ECU
- Different hybrid variants tested and compared
- Up to 24% fuel economy and up to 1 s faster acceleration to 100 km/h
- Current status: The hybrid drivetrain's customer-value driving functions are being put into operation