Control of a Power-Split Hybrid-Electric SUV

- Hybrid electric SUV developed at Ohio State University
- Government, industry, and university partnership
- Supervisory control implemented on MicroAutoBox

Ohio State University students designed and built a power-split hybrid-electric vehicle (HEV) for the Challenge-X vehicle development competition. They re-engineered a mid-sized sport utility vehicle (SUV), provided by General Motors Corporation®. The Ohio State team used dSPACE's MicroAutoBox as the primary vehicle control unit to perform fundamental hybrid powertrain operations. dSPACE Inc. also is one of the Silver Sponsors for this event.

Hybrid electric vehicles (HEVs) reduce dependency on nonrenewable fuels and significantly eliminate pollutant emissions, while maintaining similar consumer acceptability, safety and utility features as their non-hybrid counterparts. No wonder they are growing in popularity. The Challenge-X competition is a government- and industry-sponsored event that motivates engineering students to find innovative solutions to improve fuel economy and reduce emissions for mid-sized SUVs, which are popular in the North American market.

The Ohio State Hybrid-Electric SUV

As part of this competition, Ohio State University (OSU) engineering students developed an HEV that is powered by a combination of a turbocharged diesel engine, a high-voltage, belted starter-alternator (BSA) and an AC induction type traction electric machine. In this configuration, the rear and front drive systems are coupled through-the-road.

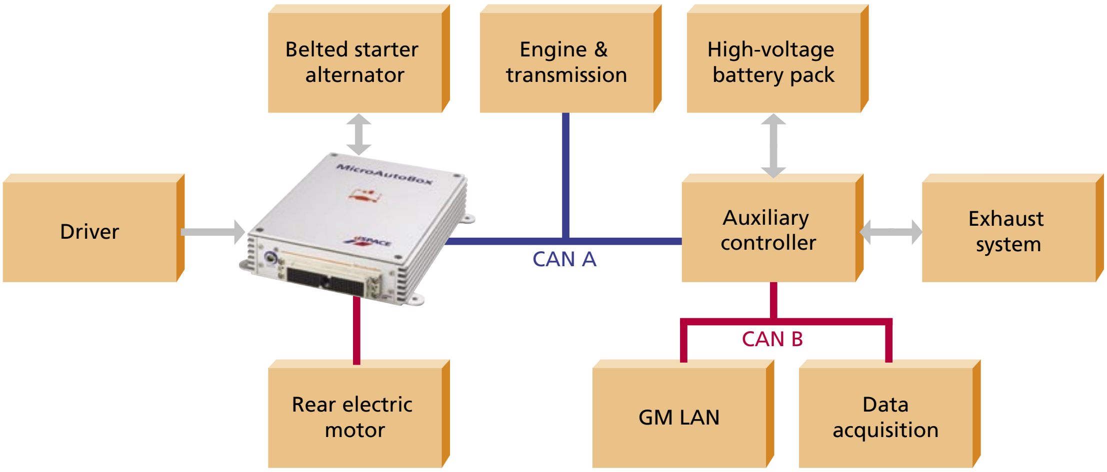
▲ *Ohio State Challenge-X hybrid-electric vehicle competing in a dynamic handling event.*

The selected vehicle architecture and control strategy enabled the use of the following features:

- **Energy optimization via adaptive control:** The control strategy utilizes a weighted combination of actuator torques to fulfill the driver's power request under normal driving conditions. This power split is based on the estimated efficiencies of all hybrid drivetrain components. Using statistical techniques, the control strategy also adapts itself to driving conditions to achieve further improvements in fuel savings.

- **Electric launch:** Due to the high torque capacity of electric machines at low speeds, our control strategy launches the vehicle using the rear electric drive. This provides a smooth and quiet vehicle launch, since the engine is off during this period. The electric-only operation also helps to achieve additional fuel savings by eliminating engine idling while also operating the vehicle in zero-emissions mode.

- **Start-stop:** We have the ability to start and stop the engine within less than 0.3 seconds using the BSA system. This feature enhances consumer acceptability of our vehicle and helps us to utilize the electric-only operation in a variety of driving conditions.



▲ *The MicroAutoBox interfaces with the powertrain control modules via dual CAN buses and several I/Os.*

- **Regenerative braking:** During deceleration, part of the vehicle's lost kinetic energy is recuperated by utilizing electrical braking via the rear electric machine. The braking power generates electrical current which is stored in the high-voltage battery pack.

- **Electric traction control:** Our vehicle has the ability to drive rear and front axles individually, which enables us to do electric traction control. The traction control system appropriately changes the power split between the front and rear axles when an adverse driving or weather condition is detected.

- **Driveline torque smoothing:** The presence of various hybrid operating modes requires a careful blending between the modes during transients. This prevents the high-frequency dynamics from being excited and helps to maintain a high level of driving comfort. We designed a hybrid transition controller for the vehicle to avoid such issues.

Control Implementation Using the MicroAutoBox

Prior to the actual implementation, we tested the performance of its control strategy using custom-designed vehicle simulation tools developed in the MATLAB®/Simulink® environment. After initial testing, the control strategy was implemented on the MicroAutoBox system via dSPACE's Real-Time Interface and the RTI CAN Blockset. MicroAutoBox is the primary vehicle control unit to perform fundamental hybrid powertrain operations such as energy optimization, battery charge control, engine start-stop, drivability control, electric traction control, and regenerative braking. In the student-designed vehicle, the MicroAutoBox communicates with several control modules through dual CAN buses. The versatile I/O interface simplified the integration of several analog and digital I/Os into the controller for the added hybrid components. The fast numerical processor featured by the MicroAutoBox made it possible to implement computationally burdensome algorithms onboard the vehicle.

> *"ControlDesk greatly reduced our controller development time."*
> ***Kerem Koprubasi, Ohio State University***

The OSU engineering team greatly benefited from the real-time calibration capability of the MicroAutoBox system. A supervisory control algorithm contains numerous parameters that need to be tuned to achieve high performance. dSPACE's ControlDesk software allowed us to modify these parameters and monitor I/O signals in real time. This feature greatly reduced our controller development time.

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dSPACE Inc. congratulates the Ohio State University team on its fine results during the Challenge X event.
For the individual scores in the different categories, please see www.challengex.org/competition/2006_competition_results.html