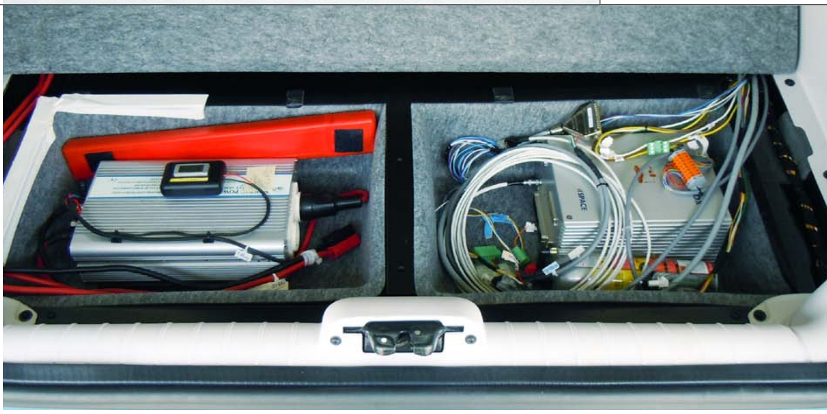
A city car for soft, CO_2-less mobility. Left: Integration of a joystick into the center console (draft prototype, under construction). Right: Installation of the MicroAutoBox in the trunk, with a 12V supply inverter.

Electric Parking

Non-intrusive, fast integration of an x-by-wire control system



A semi-automatic x-by-wire park assistance system has been designed by Continental Automotive France and integrated in the TH!NK City electrical demo car as part of the European-funded project POLLUX. With the help of the rapid control prototyping system MicroAutoBox, the steering controls were implemented quickly and reliably.

X-by-Wire Park Assistance for Electric City Cars

The park assistance concept is based on a handy joystick-driven actuator that simultaneously controls the steering, gears and traction engine during parking maneuvers semi-automatically. Successive front and rear turns are automatically programmed so that the driver does not need to actuate the pedal, gear selector and steering wheel several times during parking maneuvers. The XY position of the joystick defines a 'vector' control to program and adjust the steering directions, speeds and amplitudes of the vehicle movements with high accuracy during parking maneuvers. This is facilitated by the fast, secure and accurate controllability of the electric motor and transmission found in such electric vehicles.

Quick Function Implementation

In order to avoid intrusive modifications on the car's existing powertrain control unit (PCU), a MicroAutoBox® (first generation) was used to implement this new functionality. The comprehensive set of available I/O allows the multiple connections required by the system to connect logic, analog and CAN data signals with the pedal, gear selector, additional torque actuator on the steering wheel, PCU controller, dashboard and joystick actuator. Function design is performed with the MATLAB®/Simulink®/Stateflow® tool chain, which provides appreciable flexibility for tests and validation and a close connection with the controller in the dSPACE MicroAutoBox.

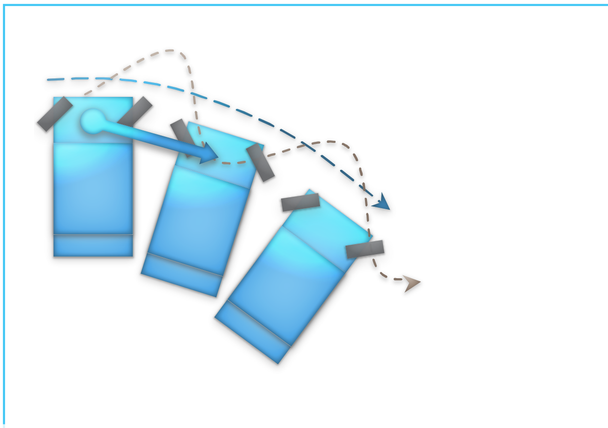
The Integration Challenge

The challenge and constraint for the initial demonstration of this x-by-wire park assistance system on an existing electric car was to integrate the complete functionality on the existing powertrain control unit (PCU) without any modifications. This PCU was already designed, when the electric vehicle Th!nk City was put on the market in the late 2000's on behalf of the Ford Group. At the time, it was not expected that the software would be modified later on. Furthermore, the steering system was not purely electric, which prevented external control of the wheels. Since then, an additional torque stepper has been integrated at the base of the steering wheel axle to allow automatic steering control. All these constraints made it evident that it was necessary to use a fast prototyping device. Continental Automotive decided to use dSPACE MicroAutoBox, one of the most useful and available devices for prototyping demo cars, for x-by-wire applications. After this project, Continental Automotive will also use MicroAutoBox for developing serial electric vehicle controllers (EVC) in our product portfolio.

Function of X-by-Wire Steering

The solution involves a (semi-)automatic maneuver control (including HW devices and SW functions) for the driver. The goal is to help the driver in low-speed maneuvers that

Figure 1: Example of a side maneuver to the right: The vehicle automatically moves in "indirect" motion mode when the position of the joystick is kept to the right.



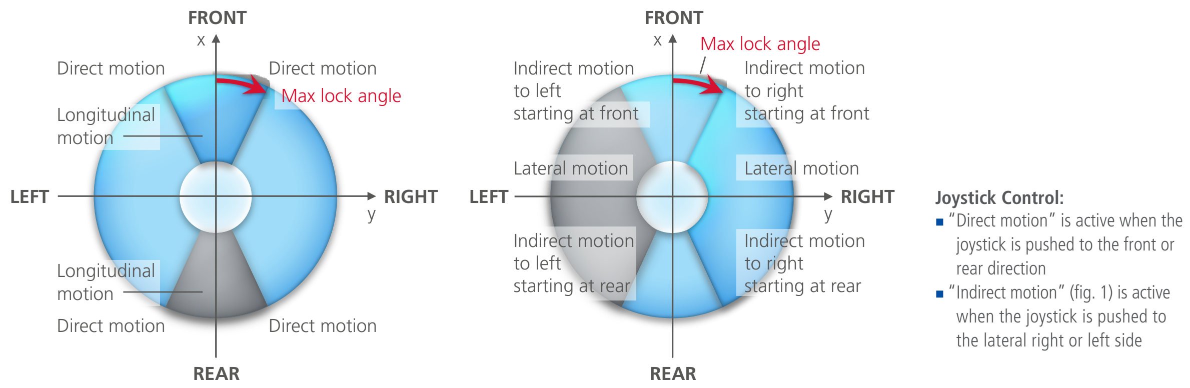
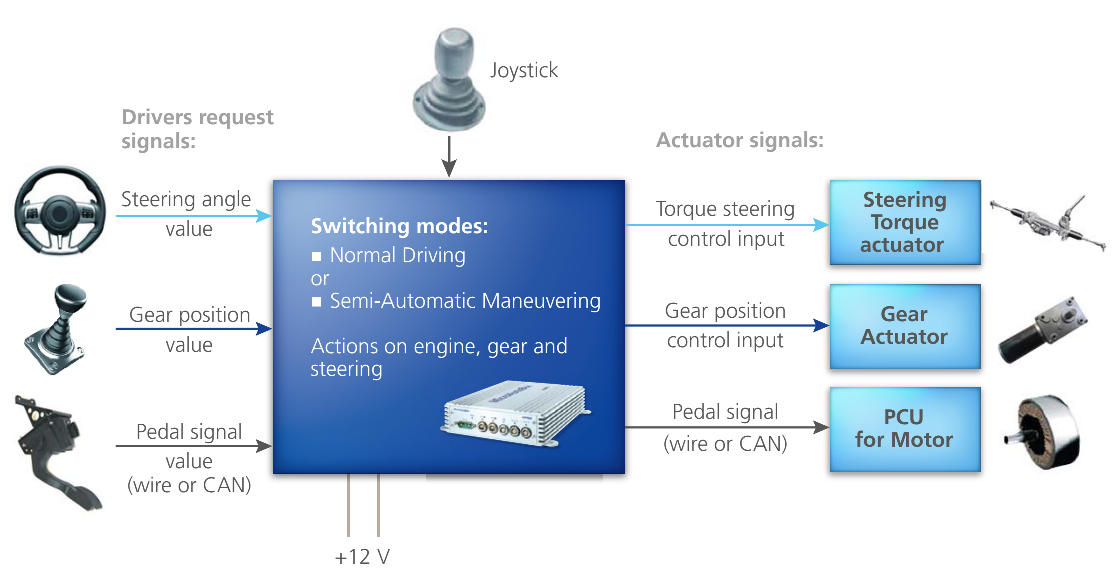


Figure 2: Operating concept of the joystick control.

> "The implementation of the electric steering controls went quickly and fluently thanks to dSPACE MicroAutoBox's versatile interfaces."
>
> *Dr. Mariano Sans, Continental Automotive*

require both traction and steering controls by avoiding the necessity to activate the accelerator and brake pedals, the gear and the steering wheel with the repeated, and annoying, 'push-&-pull' or 'front-&-rear' steps that are typical for parallel parking maneuvers. This solution is based on a joystick or a trackball (or any other equivalent 2-or 3-axis hand actuator), fixed on a central dashboard in the car. The driver uses this device intuitively to indicate the desired vector direction, which is then converted into a traction torque set-point and a steering angle set-point. In this semi-automatic mode, no action on the pedals, the gear or the steering wheel is necessary anymore. Manual gear shifting is possible by pressing the appropriate buttons on the joystick, but the preferred method is to have the gear shifts controlled automatically.
The semi-automatic movement control calculates a trajectory of the steering wheels (normally on the front axle) in order to follow this dis-

Figure 3: Connections to the vehicle controller are cut to insert the x-by-wire control system



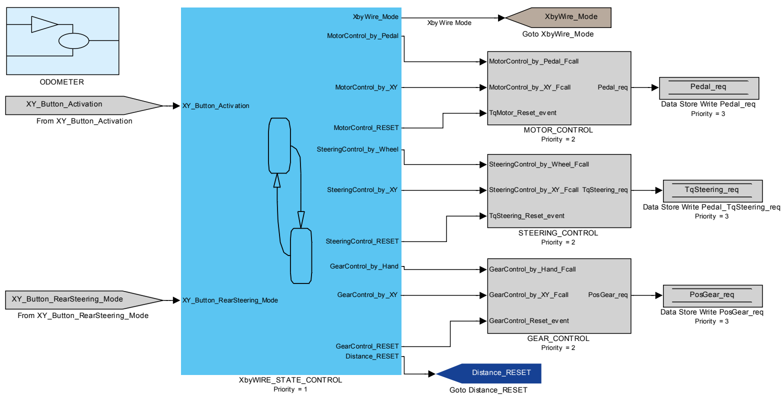


Figure 4: The main model chart, delivering control signals to the 3 actuator chains: re-calculated pedal, gear and steering signals.

placement vector with automatically programmed steering maneuvers and forward and backward movements. No external sensors are used to detect obstacles and the available distance; the driver maintains control of the vehicle's movement and can brake at any moment. In each case, the vehicle traction is stopped as soon as the joystick is released to its central (neutral) position.

System Function Architecture

The selected configuration is to plug the MicroAutoBox as an intermediate interface between the sensors (pedals, gear selector, steering position, and joystick) and the actuators (stepper and PCU). This cuts down all direct connections of the original architecture and provides re-constructed signals to the PCU, making it run as in a normal configuration.

The connection wiring harness includes all kinds of signals:

Inputs:

- analog signals from the accelerator pedal (3 redundant signals, for safety correlation)
- logical signal from the brake pedal (on/off)
- logical signals from the gearbox selector (with truth-table combination)
- digital signals from the steering motor (state, position, speed,…)
- CAN data from the vehicle system (vehicle speed, key-on, etc.)
- analog and pulse signals from the joystick (X, Y, Z, and push buttons)

Outputs:

- analog signals of the re-calculated pedal position to the PCU
- logical signals of the re-calculated gearbox selection to the PCU
- digital signals for the control of the steering motor actuator to its power drive (mainly stepper pulses)
- logical feedback information from the x-by-wire status to the PC or dashboard (with vocal messages)

The MicroAutoBox interface offers a large number of such connections for all this equipment.

Model Based Design

The functions include analytic calculations, closed-loop controls and time sequential coordination.
All of this is developed with MATLAB/Simulink/Stateflow in a user-friendly way, using all the programming capabilities of this tool, able to be autocoded on the MicroAutoBox with just light effort. ■

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Continental Automotive

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Summary

Continental Automotive integrated an innovative x-by-wire steering assistance system in the electric test vehicle TH!NK. The prototyping system MicroAutoBox was used to evaluate the control signals, control the actuators and calculate the steering functions.
It was possible to integrate MicroAutoBox nearly seamlessly into the vehicle infrastructure, so the x-by-wire steering system was implemented quickly.
The development tool chain is planned to be used to develop the serial electric vehicle controllers (EVC).

Project partners and co-authors:
ZEM Zero Emissions Mobility Company (Oslo – Norway), AKKA Technologies (Toulouse – France), SINTEF Energy Research Institute (Oslo – Norway)