Braking at its Best

- **Tunable pedal characteristic**
- **Environmental benefit of eliminating brake fluid**
- **Easy integration of electronic parking brake**

The technological concept of "x-by-wire" means replacing essential mechanical components by electrical ones. It was originally used for aircraft only, but now the automotive industry is showing increased interest. As in aeronautics, this method has enormous potential for implementing new design concepts. For example, it will be possible to design the interior of a car with completely different mechanical connections between the steering wheel or the pedals and the engine compartment. Innovative user interfaces will also be possible – for example, a joystick instead of a steering wheel. At TRW Automotive, we are currently designing a new brake-by-wire system, using dSPACE tools to speed up the development.

Brake-by-Wire Basics

The "x" in x-by-wire is a wildcard for automotive systems like gearshifting, steering, braking or damping. In this article we will describe the development of brake-by-wire systems. Brake-by-wire means no more mechanical connections between the braking actuators on each wheel and the brake pedal. The required braking force is calculated from the driver's input at the brake pedal unit and applied individually to the wheel actuators.

In the first generation of brake-by-wire systems (electro-hydraulic brake, EHB), all the control functions are implemented in one main electronic control unit (ECU) only. A hydraulic backup mode is still installed for safety reasons to ensure braking in the case of an ECU outage or electrical failure.

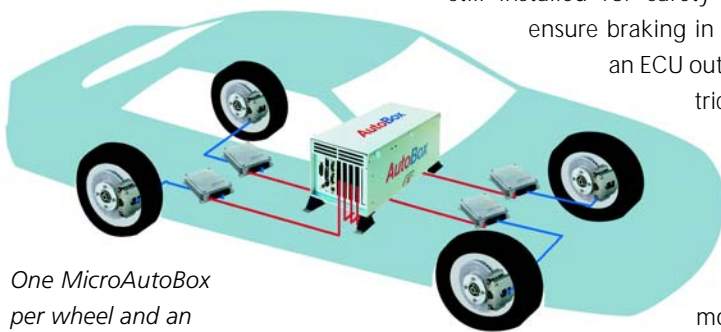In the next generation, the hydraulic backup mode will no longer be necessary, because there will be an autonomous braking system with its own ECU on every wheel. So there will be at least four independent ECUs, which means a multi-redundant system – a method well-known from aircraft construction. This electro-mechanical brake (EMB) is still under development by TRW and has some time to go before mass production.

One MicroAutoBox per wheel and an AutoBox as the main electronic control unit.

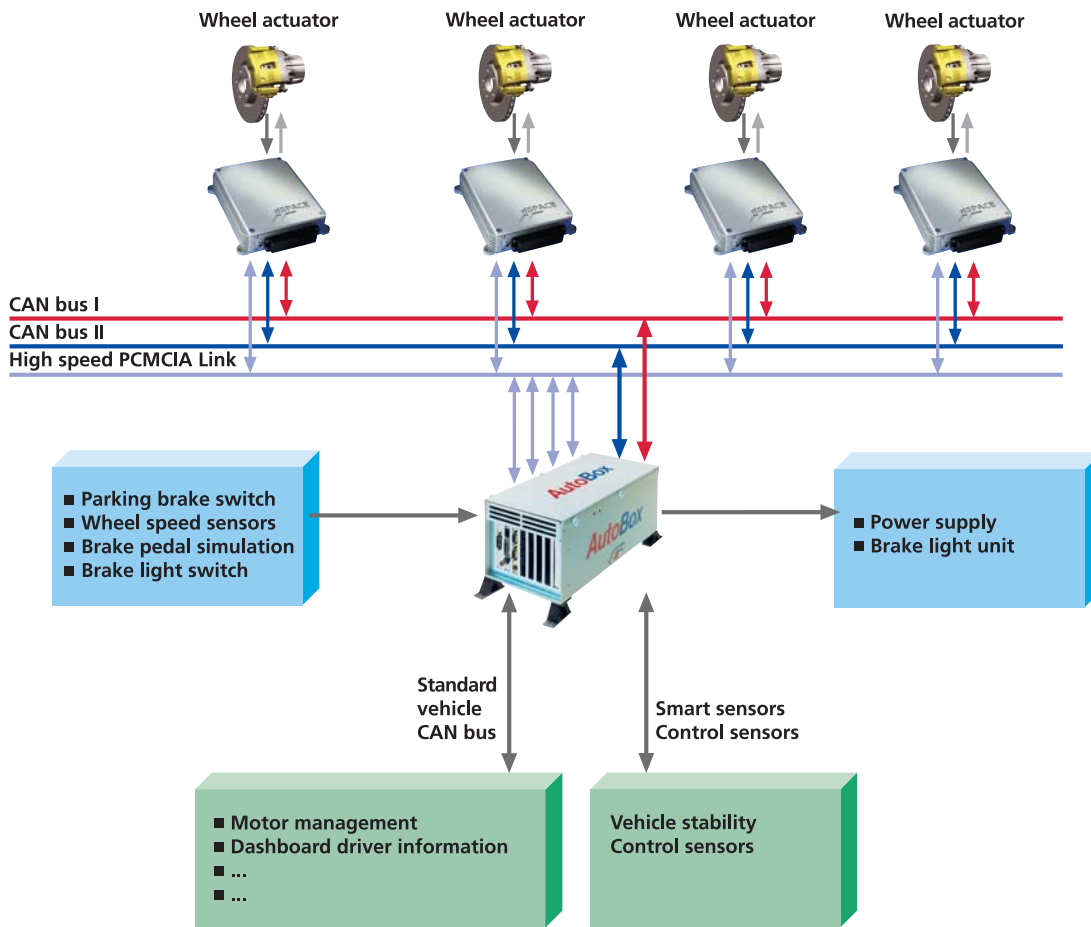### Benefits of Second-Generation Brake-by-Wire (EMB)

The second generation (EMB) will have advantages at all stages for both manufacturer and consumer – from production to a lifetime of service. The properties and behavior of the brake will be easy to adapt by changing software parameters and electrical magnitudes instead of adjusting mechanical components. So it will be far easier to integrate new features, for instance ABS (anti-lock braking system), VSC (vehicle stability control), BA (brake assist), EPB (electronic parking brake), GCC (global chassis control) or IVCS (integrated vehicle control systems), and the next generation of ACC (adaptive cruise control) features. Diagnostic features are an additional benefit.

For drivers, optimum control of the braking behavior of each individual wheel means a higher braking performance. The feel of the brake pedal is also significantly improved and easily adjusted to different needs. And because the need for brake fluid is eliminated, the environment benefits too.

Each wheel actuator of TRW's EMB consists of a brushless DC motor, a gear and a spindle arrangement, which are housed in a conventional Colette-type caliper. The brake force control is provided with the highest possible system safety by a fault-tolerant system architecture and redundant fail-safe power management (42-V technology). For the prototype concept development, we are using one MicroAutoBox per wheel as an electronic control unit (wheel ECU) and an AutoBox as the main electronic control unit (main ECU).

Wheel actuator   Wheel actuator   Wheel actuator   Wheel actuator

CAN bus I
CAN bus II
High speed PCMCIA Link

■ **Parking brake switch**
■ **Wheel speed sensors**
■ **Brake pedal simulation**
■ **Brake light switch**

AutoBox

■ **Power supply**
■ **Brake light unit**

Standard
vehicle
CAN bus

Smart sensors
Control sensors

■ **Motor management**
■ **Dashboard driver information**
■ **...**
■ **...**

Vehicle stability
Control sensors

The set-up in detail of the second-generation brake-by-wire system (EMB) at TRW.

Results

The dSPACE architecture makes it easy to observe all the system components, using standardized software under real-time conditions on a central system PC. Since function development is carried out exclusively by MATLAB®/Simulink®/Stateflow® and the dSPACE hardware platform, code generation can be automated. This considerably speeds up function development.

The integration of simulation blocks (simulation of the remaining function components and the actuator/sensor units) in the Simulink/Stateflow models makes start-up easy to perform. As a result, most of the everyday start-up problems can be detected early on, and putting the vehicle into operation is astonishingly uncomplicated and speedy. Because only a reduced number of test vehicles is needed, a huge cost reduction is possible and we can concentrate on our main task, control design. The develop-

ment work is well accepted by our customers, since they are familiar with the electrical assemblies and software tools used.

The Future

To put brake-by-wire technology on the road, it is clear that a new hardware platform needs to be developed. The platform will have a time-triggered architecture (TTA) with TTP/C, FlexRay or TTCAN, and will integrate the signal conditioning and performance output stages. Because of our good experience with dSPACE tools, TRW is looking forward to using TargetLink in this next step. This will make it very easy to reuse existing functions and minimize the overall development time.

Reference: TRW Automotive, Koblenz, Germany
New Product Europe Team

◢ **Wheel-specific braking**

◢ **Enhanced system functions**

◢ **Functionality dependent on software only**