

The European Research Project BRAKE

Delphi used TargetLink for a new brake-by-wire system

Four companies cooperating in the EU research project BRAKE

Working brake-by-wire prototype car is the result



With the goal of developing a safe brake-by-wire system based on distributed control, four companies – the electronic systems manufacturer Delphi, and automobile, microprocessor, and operating system manufacturers – got together in the European Union research project BRAKE and produced a working prototype car which has already been presented in public. This car has a braking system whose hydraulics have been completely replaced by electromechanical components. Throughout the project, Delphi made extensive use of the TargetLink code generator.

The BRAKE Project

For a number of reasons, automotive companies are trying to replace in-vehicle mechanical subsystems by purely electronic control elements. This will not only reduce the weight of vehicles, but also has potential for a large number of new features which mechanical

systems are unable to provide. A further advantage is that the electronic systems can communicate with each other and exchange information that is relevant to safety. The BRAKE project builds on this global control approach and aims at developing an advanced distributed brake-by-wire system in close cooperation

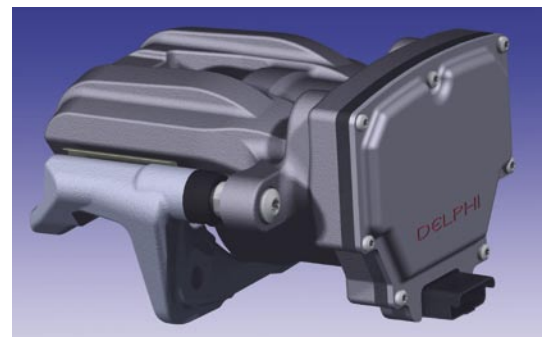
between car manufacturers, electronic control unit (ECU) suppliers, electronic device vendors, and tool suppliers. The main objectives defined for the BRAKE project were to create a distributed fail-safe system using a time-triggered communication protocol, to expand an existing OSEK-based operating system to

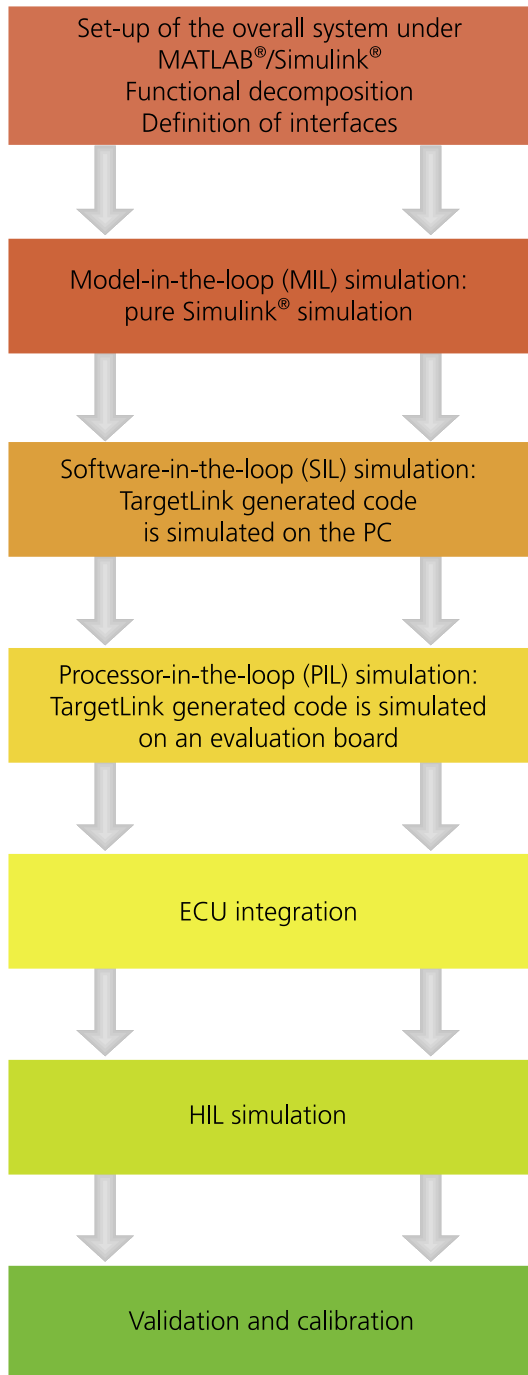
match time-triggered features, and to define an open interface between all subsystems.

Task Distribution and Accomplishments

Each of the four companies in the BRAKE project had its own tasks, which interlinked with those of the other companies. The overall system – consisting of the vehicle model, brake actuators, sensors, communications, electronic control units, control strategy, I/O, and operating system – was put together in one single MATLAB®/Simulink® model. At first, Delphi was given the object code for the vehicle level control in Simulink by the car manufacturer. The embedded real-time systems capable processors on which the control algorithms were implemented, and the necessary time-triggered communication protocol, were supplied by the manufacturer of the microprocessor, while the operating systems manufacturer provided an

► Electromechanical brakes are part of the new brake-by-wire system developed in the European Union research project BRAKE. The result of this project, a working brake-by-wire prototype car, was already presented in public and test-driven on the car manufacturer's test circuit.





▲ Steps of the model-based design process in the EU research project BRAKE.

operating system in accordance with the OSEK standard and tuned to match the time-triggered implementation of the application software. Delphi developed the remaining parts of the software using TargetLink for automatic code

generation. We also performed software integration and finally built the prototype ECUs. At Delphi and at the other three companies, we consider the experience gained with the model-based development process, which allowed us to work so efficiently in parallel, to be a major outcome of this project. And all four companies have benefited by extending our know-how on brake-by-wire systems and on development tools for distributed systems.

The Model-Based Development Process

The development process during the project can be characterized by the steps shown in the figure on the left. As the complete system was in a single Simulink model, the simulation of the overall brake-by-wire system was relatively simple to do. Both Delphi and the car manufacturer provided parts of the overall system model. Delphi contributed the actuator and sensor models, the basic braking algorithm, sensor processing, network communication, and the operating system. The various parts of the model were linked using the Simulink library concept.

Keys to a Successful Project

One advantage of the approach used was that the model-based process allowed exactly the same tests to be run in all the testing steps: model-in-the-loop simulation (MIL), software-in-the-loop (SIL), processor-in-the-loop (PIL), and hardware-in-the-loop (HIL). With TargetLink, the Simulink behavior could be translated into efficient code precisely, quickly and consistently in accordance with the Delphi software process for safety-critical systems. The TargetLink Optimization Module (TOM) for the processor in use was especially helpful, as it ensured optimal implementation. All in all, we at Delphi and the car manufacturer were able to implement 100 % of the control strategies with TargetLink. We believe that the keys to future success are an open architecture for vehicle control software with industry-wide interface standards, model-based development and automatic code generation.

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