

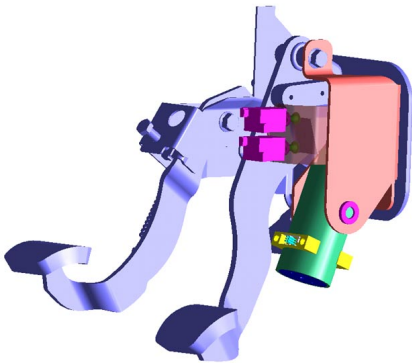
Advanced Electro-Mechanical Braking System  
**Delphi's Brake-by-Wire Concept**

"The entire brake-by-wire project was substantially a journey into the technical unknown. The amount learned was enormous and all the projects goals were met. TTTech's role was essential and the project would not have been successful without their technology and direct personal support of the developments required."

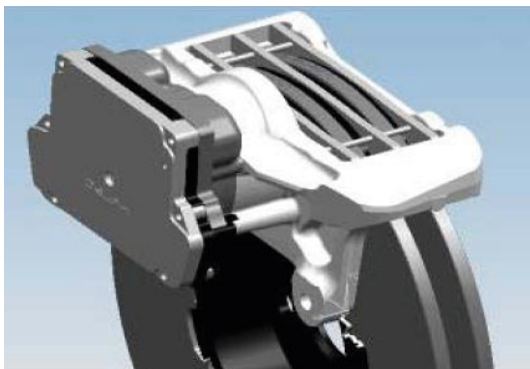
Nick Jones, Chief Engineer Dynamics & Propulsion at Delphi



The automotive industry is replacing more and more hydraulic systems by electronic systems. This not only reduces the weight of vehicles, but also has the potential for a large number of new features. One of these applications is the brake-by-wire technology for the braking system. Delphi started working on an advanced electro-mechanical braking (EMB) system with the aim of replacing the conventional hydraulic braking system by electrically driven actuators. Based on a fault-tolerant architecture, the brake-by-wire system would have no more mechanical link between pedals and brakes.



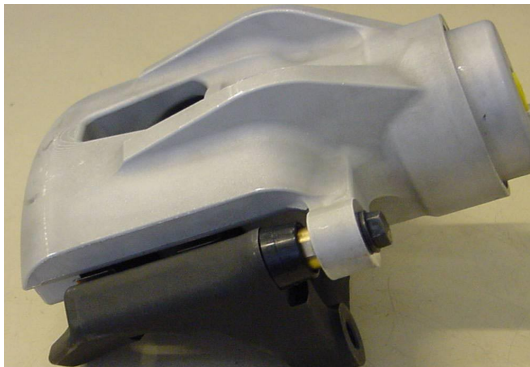
The overall goal of the Delphi project was the design of a new electro-mechanical braking based on time-triggered communication. As the brake-by-wire system had to work without any hydraulic brake components, it would have a faster brake response behavior to maximize braking performance. The project was focused on the design, evaluation, implementation and testing of a cross-company brake-by-wire application. The activities led to the development of a prototype based on a current series car model.



Delphi's brake-by-wire system featured a pedal module, a dependable power system, a central supervisory control system, four intelligent braking actuators, and interfaces to other on-board vehicle systems. Each EMB caliper comprised an electric motor, a gear reduction stage, a ball screw and all associated control electronics integrated into a package. A central processor provided supervisory control and a pedal feel emulator driver feedback. Main benefits included the near elimination of the residual torque between brake pads and disks, a more accurate response to driver commands and an easier integration with vehicle dynamic control systems.

“The limited bandwidth of today’s most frequently used bus systems ask for time-triggered solutions. Instead of being driven by events, the time-triggered communication is based on the progression of time. Major OEMs and Tier-1 suppliers have been working on by-wire applications with the time-triggered technology.”

Marc Lang, Director Sales at TTTech Automotive



An applicable E/E architecture for the by-wire application was designed after the decision for a time-triggered communication protocol as backbone was taken. Based on an active star coupler, the four electronic actuators with integrated ECUs were connected with the brake pedal. As system safety was one of the key requirements, a number of application fault models were assumed. TTTech’s time-triggered solutions assisted in designing the entire system, from cluster design and scheduling to implementation and testing.



During the project Delphi was responsible for the planning and definition of the project and for providing all the needed hardware components of the braking system, the higher level application software and the actuator control software. TTTech supplied the communication and development software components for the whole system. The wide range of its products covered automatic scheduling tools, node design tools, embedded software and tools for integration, manipulation and validation.



With the design of an electro-mechanical braking system Delphi and TTTech demonstrated that economical and technical advantages could be achieved by replacing conventional hydraulic braking system with electrically driven actuators. The use of innovative technologies such as a safety-critical fault-tolerant architecture based on a time-triggered communication protocol and reliable smart actuators resulted in the design, implementation and test of a fully functional by-wire system.

### **About TTech Computertechnik AG**

TTTech Computertechnik AG is the leading supplier of solutions in the field of time-triggered computer systems. The company's products improve the reliability of data communication systems in transportation and automation industries. The solutions are based on TTP and TTEthernet. FlexRay offerings are provided by TTTech's subsidiary, TTTech Automotive.

Further information is available at  
**[www.tttech.com](http://www.tttech.com)**

### **About Delphi**

Delphi is a leading global supplier of mobile electronics and transportation systems, including powertrain, safety, steering, thermal, and controls & security systems, electrical/electronic architecture, and in-car entertainment technologies. Engineered to meet and exceed the rigorous standards of the automotive industry, Delphi technology is also found in computing, communications, consumer electronics, energy and medical applications.

Further information is available at  
**[www.delphi.com](http://www.delphi.com)**

# **TTTech**

---

TTTech Computertechnik AG  
Schoenbrunner Strasse 7, A-1040 Vienna, Austria  
Tel.: +43 1 585 34 34-0, Fax: +43 1 585 34 34-90  
E-mail: [office@tttech.com](mailto:office@tttech.com)