Intelligent Stopping

Tough requirements are no problem for SKF's Electronic Parking Brake system for heavy agricultural machines

SKF's Electronic Parking Brake system is an extremely convenient solution for parking brakes and emergency brakes in tractors. Its intelligent functions support drivers in all situations and on completely different types of ground. SKF chose dSPACE solutions for the decisive phases of its software development.

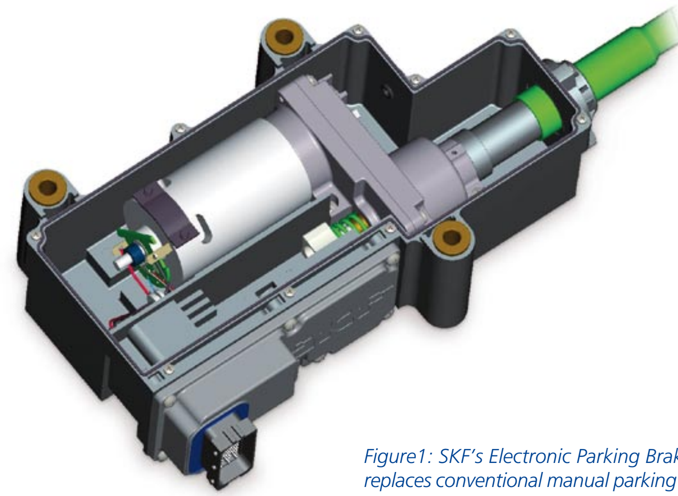


Figure1: SKF's Electronic Parking Brake replaces conventional manual parking brakes.

Electronic Parking Brakes in Agriculture

The Electronic Parking Brake (EPB) is based on a geared electric motor in a watertight enclosure with an integrated control unit. As an actuator, it tightens and releases the Bowden cable connected to the brake system. The system is designed to replace conventional manual parking brakes (Figure 1).

Intelligent Functions for Maximum Convenience

The EPB's intelligent functions make the driver's work much easier.

- Automatic Apply switches the parking brake on when the driver removes the key and leaves the vehicle.
- Hill Holder and Drive Away make driving more convenient, even on hilly terrain.
- Automatic wear compensation eliminates the necessity of regular maintenance checks.

The new technology is suitable for numerous vehicle platforms with intelligent transmissions (CVT/IVT, full powershift). The software is adaptable, so the unit can be used in numerous vehicle types and under different operating conditions. Using intelligent solutions has a direct positive impact on the productivity, operating costs and safety of utility vehicles like tractors.

Software Development and Architecture

Software development follows the phases of the V-cycle with support by dSPACE solutions for software design, implementation and software tests (Figure 2).

> "After successfully completing the electronic parking brake development project with the dSPACE tools, we are now using the same approach in all our mechatronics development projects."

Fortunato Pepe, Product Development Manager at SKF

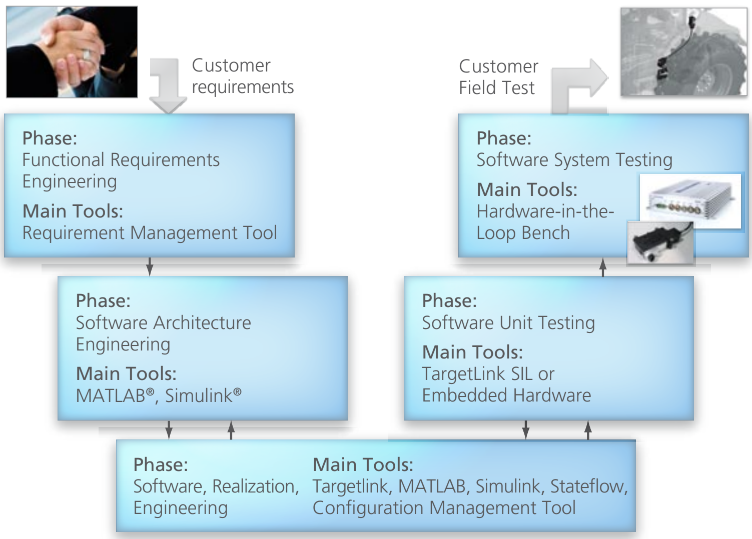


Figure 2: The main phases of software development and associated tools.

The software is divided into three main abstraction levels with clear interfaces. This reduces complexity and avoids having to handle implementation details on every level. It also makes the data and functions more robust against software errors, and lowers the cost of integration into different vehicle architectures.

The low-level software controls the brake's hardware functions such as electric motor control, low-level I/O and low-level CAN bus management, and is independent of the vehicle in which the parking brake is integrated.

The vehicle interface software collects the data from the low-level software and passes the input signals to the application software with the correct scaling and format. It is highly dependent on the vehicle network architecture.

The application software consists of controls for the parking brake. Its great advantage is that it can be adapted to implement any intelligent functions that customers require, like Auto Apply on removal of the ignition key. The parking brake can therefore be used in different vehicles without any hardware changes (mechanics and electronics).

Better Development with TargetLink®

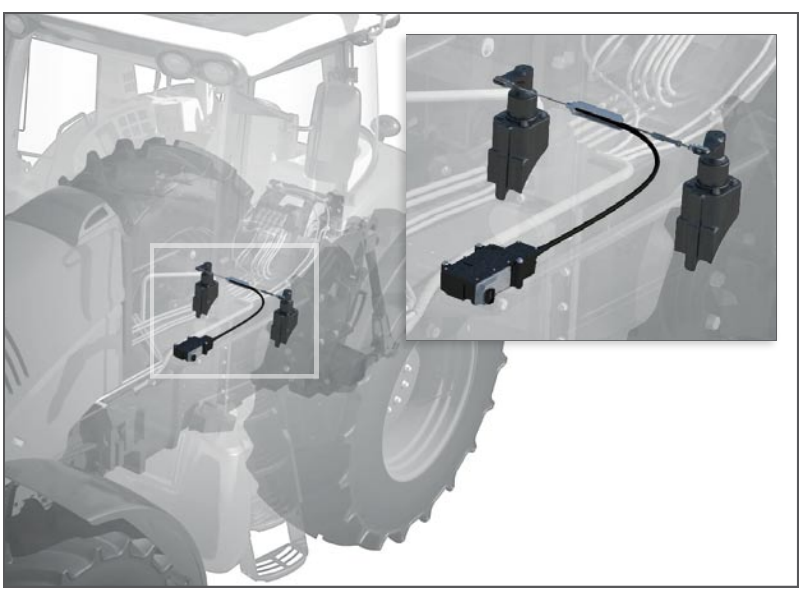
When developing the application level, SKF benefited from using dSPACE TargetLink.

- The application software was modeled in Simulink® and Stateflow®, and TargetLink generated production code straight from the diagrams and charts.
- SKF designed clear interfaces between the model-based software and the lower software levels, so the application software integrated seamlessly into the parking brake's software architecture.
- TargetLink ensured that the software modules were extremely reusable.
- SKF used variable scaling options to achieve the highest possible resolution for precise control and improved diagnostics with fixed-point variables.
- TargetLink automatically generated the ASAP2 database, enabling SKF to perform measurement and calibration tasks on the actual vehicle.
- The resulting data flow facilitated detailed software analysis, such as software fault tree analysis.

Testing Approach

For the system software test phase, SKF needed a programmable test bench with reproducible test

The EPB with bowden cable installed in a tractor.



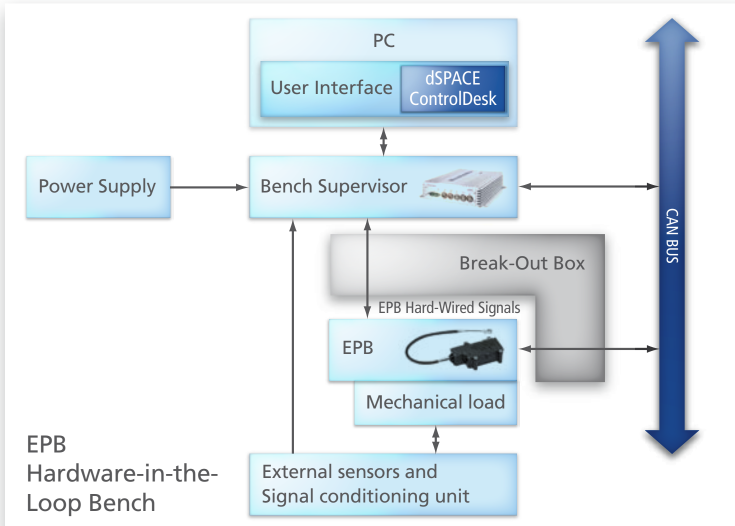


Figure 3: Block diagram of the HIL test bench for the parking brake.

sequences. They had to record test results (pass/fail, inputs, outputs) and measure the system's response times, and extremely long test sequences had to be executed. SKF designed a hardware-in-the-loop (HIL) test bench (Figure 3) in which the parking brake is connected to a mechanical load consisting of springs that simulate the properties of the vehicle's braking system. A MicroAutoBox acts as the main test bench control. It simulates all the vehicle's hard-wired and CAN-based interfaces to the parking brake. The MicroAutoBox has a break-out box to support tests that use fault generation. The external sensors can be used separately to measure the force and position effected by the parking brake. A signal conditioning unit conditions the signals and passes them to the main test bench control for the test sequences.

Model-Based Testing

Modular test software was created to ensure that the HIL test bench was flexible and adaptable to all customer requirements. The test sequences were modeled in Simulink and Stateflow with the aid of dSPACE RTI libraries. With model-based design, complex and intensive test sequences can be created. The pass/fail criteria are also integrated into the test sequences. The test engineer runs each test sequence from ControlDesk®, which also displays the pass/fail results. This considerably boosts the productivity of the test execution phase. ControlDesk also saves the test sequence results and manages test data configurations, so the test report phase is much simpler. ■

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Conclusion

The EPB supports intelligent features such as Auto Apply, Hill Holder and Drive Away for various tractor types. It is easy and flexible to install and enhances the driver's safety and comfort. With TargetLink, MicroAutoBox and ControlDesk, SKF was able to implement and validate the EPB according to the highest quality standards.