HIL Test Bench for BMW's Active Steering

- Test bench solution for testing active steering systems for the BMW Group
- Optimizing and validating functions for networked chassis control systems
- dSPACE technology for test bench and test automation

For the BMW Group, IABG has developed a complex test bench, used to optimize functions and validate concepts for active steering systems. Failure simulation and test automation were implemented by means of dSPACE technology. The hardware-in-the-loop (HIL) system test bench has proved itself an efficient tool, from the concept phase to production development, and right through to product support during start of production. Essential aspects of function validation and fail-safe testing are no longer covered by test drives, but put on the test bench instead – with additional benefits such as enhanced reproducibility, efficiency and economy.

A Big Step Towards Steer-by-Wire

The BMW Group's active steering systems in the new 5 series are a milestone along the road to x-by-wire vehicles. Active steering combines enhanced comfort with increased agility and greater safety. The active steering systems perform stabilization and steering functions, giving motorists immediate benefits.

System Test Bench and HIL Test Bench in One

Our test bench allows optimization of steering system components and validation of networked system functions in all essential partner ECUs.

▲ *The HIL test bench has proved to be an effective tool for testing active steering.*

For example, as a system test bench, it performs the following tasks:

- Capturing steering properties such as transmission characteristics and elasticity
- Optimizing component properties such as the actuating response of the drive unit
- Calibrating the electrically controlled power-steering pump

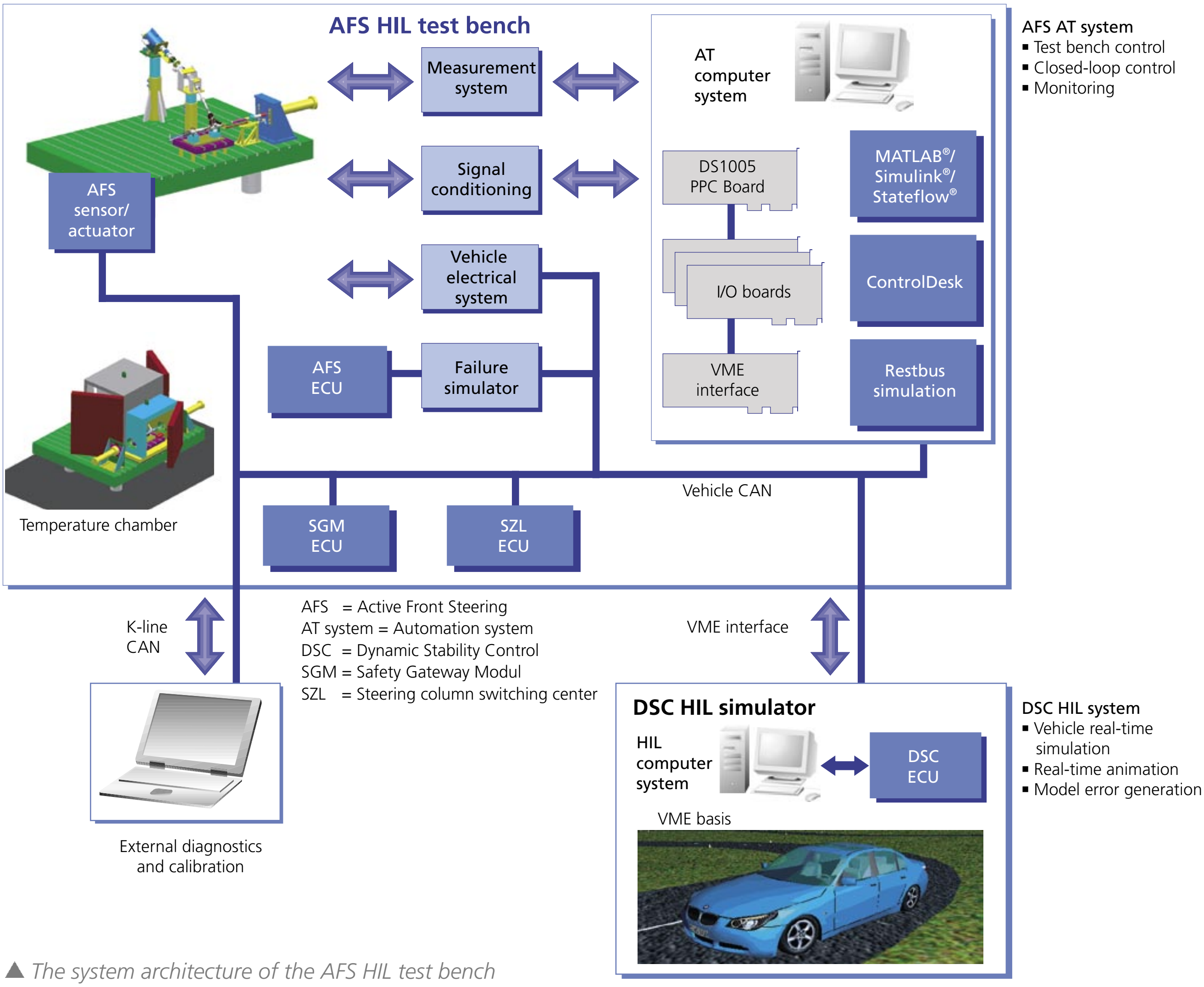
In its capacity as an HIL test bench, it performs extra tasks:

- Simulating the dynamic behavior of a virtual vehicle in real time
- Controlling the dynamic restbus simulation and the test bench actuators

For this type of simulation, an HIL simulator that has an embedded dynamic stability control (DSC) ECU is connected. The HIL simulator simulates the vehicle's dynamic behavior in real time. The computed physical vehicle variables are used for realistic control of dynamic restbus simulation and the test bench actuators.

All this means that developers can use the test bench for the following tasks:

- Analyzing active steering intervention for vehicle stability in critical vehicle dynamics situations
- Systematically testing all driving maneuvers and failure scenarios
- Mapping steering system properties and their effects on vehicle behavior
- Realistic testing, including extreme thermal conditions



▲ *The system architecture of the AFS HIL test bench has a DS1005-based automation system and a DSC HIL simulator as its central components.*

Test Bench Design and System Architecture

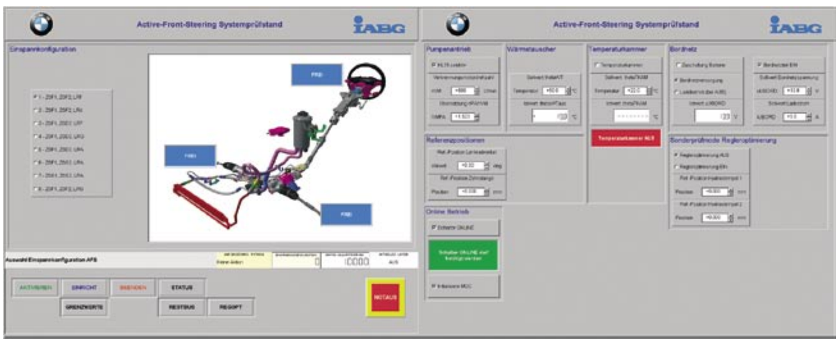
The flexible mechanics of the test bench allow a great variety of steering systems, from a MINI to a Rolls-Royce, to be mounted, in varying configurations. To simulate temperature conditions ranging from -40 °C to 150 °C in the engine compartment, there is a thermally insulated chamber mounted over the steering system. The steering system is linked to three load actuators, and the rack forces can be fed in either on one side or on both sides by a servohydraulically controlled hydropulse cylinder via coupling or drag links. Mechanical, electrical and hydraulic steering system variables are captured by high-precision sensors at more than 40 measurement points and transmitted to the automation system via private CAN connections at a maximum update rate of 1,200 Hz. The core of the automation system is a DS1005 PPC Board from dSPACE, networked with several dSPACE I/O boards. Signal conditioning boards (for example, for level adjustment, galvanic separation and relay control) form the link to the actuators and peripheral components.

The HIL simulator and the automation system communication in real time via a dSPACE VME interface at a rate of 4.6 MB/s. The automation software is based on MATLAB®/Simulink®/Stateflow® and ControlDesk, and on dSPACE's test automation software. The implemented offline functions include:

- Automatic evaluation and generation of test reports
- Accessing and calibrating ECU variables (for example, to the ASAM-MCD standard), and connection to the diagnostic channel (for example, K-Line or Softing)
- Evaluation scripts for representing measurement data graphically

These are some of the functions that have to be executed on the AT real-time system at a 1-ms clock rate:

- Sequence control for the superordinate coordination level
- Control of the hydropulse cylinder, steering machine and pump drive
- Controlling and monitoring the peripheral units
- Data capture
- Safety and monitoring functions
- Dynamic restbus simulation and communication with the HIL simulator via VME interface



▲ *The interactive user interface for controlling the test bench.*

Test Automation and Fault Scenarios

The test automation system on the test bench executes various test runs under batch control, performs the individual operating steps of the test bench in a coordinated manner, and aborts test execution if a fault occurs. The test report and test execution documentation are generated automatically according to the user's specifications.

One of the test automation system's main applications is simulating fault scenarios. For example, various driving maneuvers are studied to determine whether the redundancy monitoring system detects signal deviations or sensor faults, enters them correctly in the fault memory, and triggers the necessary follow-up processes. Faults in the wiring harness are implemented by a "fault insertion box". The DS1005 PPC Board controls the fault insertion box via a serial interface.

Superposition Steering

With superposition steering, the ratio of steering wheel angle to wheel angle is not fixed. A planetary gear in the suspension linkage is driven via a worm gear, allowing an additional steering angle to be superimposed. This makes it possible to implement speed-dependent steering transmission, with direct steering at low speeds and indirect steering at high speeds.

In addition to wiring harness faults, the test bench can also reproduce signal faults, CAN bus faults, and errors in the model.

Automation Solution Based on dSPACE Hardware and Software

The dSPACE solution has a number of advantages over conventional automation solutions:

- Model-supported development of automation functions and HIL simulation
- Significant reduction of project time
- Modular, transparent program structure for automation functions via block-oriented representation under MATLAB/Simulink/Stateflow
- Efficient implementation
- Extensive support for the CAN, KWP2000, and ASAM communication interfaces
- Simulation mode for implementing new test bench functions

New HIL Test Benches: Networked Vehicle Mimics

Chassis electronic systems are fast becoming a decisive factor in the competition for automobile customers. ECUs are rapidly growing in number, and so is the diversity of vehicle variants. The volume of networking is expanding, and functions are increasingly being distributed across ECUs. The result is such complexity that only extremely sophisticated test bench functionality can cope with the testing required. To implement this functionality efficiently, and within narrow cost constraints, a powerful development environment was essential. We are currently putting another, very complex HIL test bench into operation, this time for integrated chassis control systems. All the actuators and sensors of the participating chassis control systems, including the vehicle wiring harness, are integrated into this test bench. Issues that were once investigated painstakingly in expensive experimental vehicles can now be solved in the lab.

Dr. Ahmed Abou-El-Ela,
Mechatronic Systems and Vehicle Simulation, IABG
Manfred Wachinger, Martin Krenn,
Development Steering Systems, BMW Group
Germany