



# Simulation of a Tire Pressure Control System

## Time savings and new options by ECU tests on the model

Increased traction, minimized fuel consumption and avoidance of site damage: These are good reasons to always drive off-road utility vehicles with tire pressure adjusted for specific conditions. Developers at Daimler AG used a new type of test system for realistic tests of the next generation tire pressure control system for off-road Unimog vehicles. The test system simulates all sensors and actuators of an ECU's environment and enables comprehensive HiL tests, including simulation of fault situations in the environment's hardware and wiring.

By Mario Wirmel and Katja Hahmann

The business site at Wörth am Rhein is home to one of the largest commercial truck manufacturers in Europe. Besides producing the well-known Mercedes-Benz Atego, Axor and Actros trucks, Daimler AG also develops and manufactures special purpose vehicles such as the Unimog, Econic and Zetros.

The Unimog U3000/4000/5000 product line achieves extreme off-road mobility with portal axles, coil springs, manually selectable all-wheel drive and thrust-tube technology; its performance capabilities include a maximum fording depth of 1.20 m (figure 1). Low-emitting diesel engines with power outputs ranging from 110 kW

(150 PS) to 160 kW (218 PS) are used for the drives. One of the special features Mercedes-Benz offers in its program is the tire control option – an electro-pneumatic system for inflating and deflating the tires that lets the driver modify tire pressure right from the cab.

While high tire pressure ensures low rolling resistance and fuel consumption on pavement, other properties are preferred in off-road driving. When driving on a soft surface like sand or a wet field reducing the tire pressure also reduces tire contact pressure, so that no appreciable site damage occurs (figure 2). When it comes to available traction, there is a direct relationship between soil composition and the tire pressure used. By reducing tire pressure off-road you can easily double available traction. This could be a crucial factor in determining a task's success or failure. In addition, low tire pressure can contribute to better self-cleaning of the tires,

because of the tire's greater deformation.

### ■ Model-based development of the tire pressure control system

The electronic concept that was successfully applied to the Unimog series is currently undergoing advanced development to meet performance and operating convenience requirements. Advanced development of the next generation tire pressure control system involves a model-based development application on a new high-performance hardware platform. For the driver this means increased operating convenience: In Automatic mode the operator simply selects the terrain type, and the system automatically ensures correct pressure in all tires via a four channel pneumatic system.

### ■ PC-based MiL tests

In developing the new tire pressure control system, first a model of the new pneumatic system (plant model), including the tires, was created and verified based on measured data and design documents. This was followed by initial implementations of the application model. Daimler hired the company ITK Engineering to create the Matlab/Simulink models. The models realistically simulate the dynamic behavior of the real system. Pressure sensors continually acquire the pressure of individual tires, which are always interconnected with the pneumatic system via a central air channel in the portal axles.

Another sensor serves as a reference for the system and automatically verifies the sensors that have fixed assignments. Also included in the model are momentary pressures, compressor power and channel cross-sectional areas. The relationships, including effective time constants when increasing and reducing tire pressure, are compu-

ted precisely in the model. As a result, PC-based Model-in-the-Loop tests (MiL tests) are already possible in this development phase.

### ■ Simulink models in SiL tests

The model-based approach is also taken in subsequent development phases. By integrating the models in the



■ Figure 1. All-terrain mobility is the primary feature of the Unimog.

CANoe simulation and test tool from Vector, model behavior is tested in conjunction with bus communication. Using the CANoe blockset for Matlab/Simulink, the model interfaces are connected directly to bus signals, system variables or environment variables. The Simulink Real-Time Workshop generates a Windows DLL that is loaded in the CANoe simulation environment. The CANoe Interaction Layer handles sending of messages according to the send behavior stored in the database. Finally, the test sequences are created and automatically executed with the CANoe Test Feature Set.

This is followed by initial tests in the vehicle. Previously, these tests were not possible until the availability of prototype ECUs or rapid prototyping platforms. When CANoe is used with the integrated application model, this enables in-vehicle testing of the operation and display concept without requiring a special hardware setup. CANoe is responsible for CAN communication with the vehicle. A sensor/actuator module, in this case the current level ECU, makes I/O functionality available in the vehicle over

CAN. Test sequences that have already been created can be re-used for this purpose. The first Software-in-the-Loop tests (SiL tests) are executed early in a phase in which requirements have not all been fully described yet.

### ■ The path to the component HiL test bench

Since the developers would not always have access to a test vehicle, Daimler decided to procure a component test bench based on the VT System test hardware from Vector. The system is tailored to the needs of the automotive industry. It is a modularly configurable and powerful test system for uses ranging from a small bench-top setup to a large HiL system in the laboratory. In the VT System, the focus is on simulating the sensors and actuators connected to the ECUs as well as simulating potential error situations such as short circuits, overvoltages and undervoltages. The system is set up modularly with various VT modules for load simulation, measurement and stimulation. Another important factor in the decision to use this hardware was that it would be optimally integrated in the CANoe software system already in use at Daimler for many years. In particular, direct integration of these modules in CANoe would make it easy to perform later extensions or modifications to the system for new projects. The test system is connected to the test computer via its Ethernet port, utilizing the real-time capable Ethernet protocol EtherCAT. CANoe permits access to all parameters of the VT System and is the tool for test automation (figure 3).

For HiL tests on the real ECU, the plant model is integrated in CANoe. Another advantage of using models is



■ Figure 2. Tire pressure control while driving is possible, e.g. to avoid site damage.

revealed here: Any desired initial states may be produced essentially „at the press of a button“. In the plant model, this relates in particular to the pressure in the tires and in the pressurized reservoir. That is because in tests on real vehicles it may take 20 minutes until four flat tires are filled back to their specified operating pressure when a vehicle air compressor is used. The laboratory test system, on the other

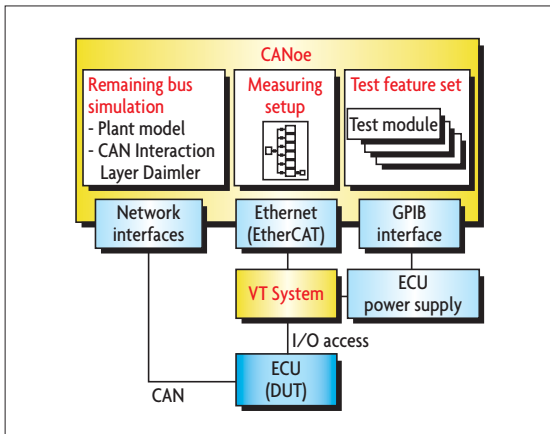


Figure 3. Layout of the component HiL test bench.

hand, is capable of doing this immediately. It addresses parameters of the model directly and represents values such as pressure curves graphically.

### VT System as HiL test bench component

The plant model is integrated in the CANoe Simulation via the CANoe Blockset – the real ECU is being tested here. All ECU inputs and outputs are connected to the relevant bus signals or hardware channels of the VT System. Communication between the CANoe Simulation and the Simulink models occurs directly via a signal interface or via CANoe environment and system variables. As a standard feature, the ECUs check their inputs and outputs to verify that the relevant components are actually connected and that sensor data or termination resistors are plausible. Therefore, for meaningful tests, either the original sensors and actuators are necessary, or else the ECU’s environment must be simulated as realistically as possible. However, because reasonable test automation with original components involves enormous cost and effort, e.g. when controls are operated by robo-

tics, simulation of the environment is generally preferable. The VT System is now responsible for simulating the environment hardware. The VT2004 stimulation modules apply the relevant voltage values to ECU inputs to which the tire pressure sensors are connected in the real vehicle. The switches for inflating and deflating the tires can be simulated as well. On the other hand, the VT1004 load and measurement modules are used to simulate valves by electronic loads or measure the values at the ECU outputs. CANoe also handles the network simulation and test automation. This component HiL test bench (figure 4) for testing an individual ECU is re-used later for tests in the real vehicle as well.

The focus of the new test system is to simulate error situations caused by incorrect wiring, defective sensors or actuators. These components do not supply any values, supply incorrect values or they may have internal resistances and current consumptions that deviate from the specification. In the case of pressure sensors, for example, voltages outside of the measurement range are generated, electronic loads simulate the valves and current consumptions deviating from normal values can be parameterized. The ECU’s reactions to such unpredictable events are of interest to Unimog experts in their efforts to further develop the system, as is information on whether the ECU generates correct entries in error memory.



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Figure 4. Modular setup of the VT System as a component HiL system.

### Availability of test vehicles is not critical anymore

In testing the tire pressure system at Daimler, it no longer makes any difference whether a real or simulated ECU is tested. Developers also enjoy independence from the availability of real test vehicles. As a result, the test system can be used universally – from the design phase to functional tests. This is what is required if test results for the ECU are to be directly comparable.

Motivated by the success of the VT System in the tire pressure control system, developers in Wörth are already planning their next projects. They include advanced development of the hydrostatic traction drive, in which the system is extended by 16-channel digital modules and the power supply module.

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