Embedded Success dSPACE

Integration of EtherCAT in Advanced Test Systems – Solutions and Challenges

Dr. Frank Schütte, Andreas Tenge, Dr. László Juhász
dSPACE GmbH, Paderborn

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Introduction

Actual developments in the mobile machinery and tractor industry are similar to the ones in the automotive area:

- The relevance of electronics and software is continuously increasing.
- Most innovation is based on the new developments or enhancements of electric and electronic systems, like:
  - New engine and transmission technologies (e.g.: hydrostatic drives with closed-loop control)
  - Advanced Driver Assistance Systems (ADAS)
  - Safety systems
  - Networking and Information Technology
  - Replacement of hydraulic system and mechanical drives with electrical ones

To cope with this trend:

- Parallel development and testing of the mechatronic and ECUs is required.
- Automated ECU tests are necessary.

The mentioned challenges are solved in the automotive industry by means of

Hardware-in-the-Loop-Simulation (HIL)

What is Hardware-in-the-Loop-Simulation?

*"**Hardware-in-the-Loop-Simulation** is a (test-)method in the product development cycle in which one or several real control components interact with real-time simulated components (dynamic models) instead of real ones."*

- Real component ("Hardware"):

  Devices, machines, test benches, mechatronic systems,

  often also: ECUs, control systems, electronic

- Simulated components ("Models"):

  Dynamic systems (real-time simulated models)

Hardware-in-the-Loop-Simulation vs. Traditional Testing

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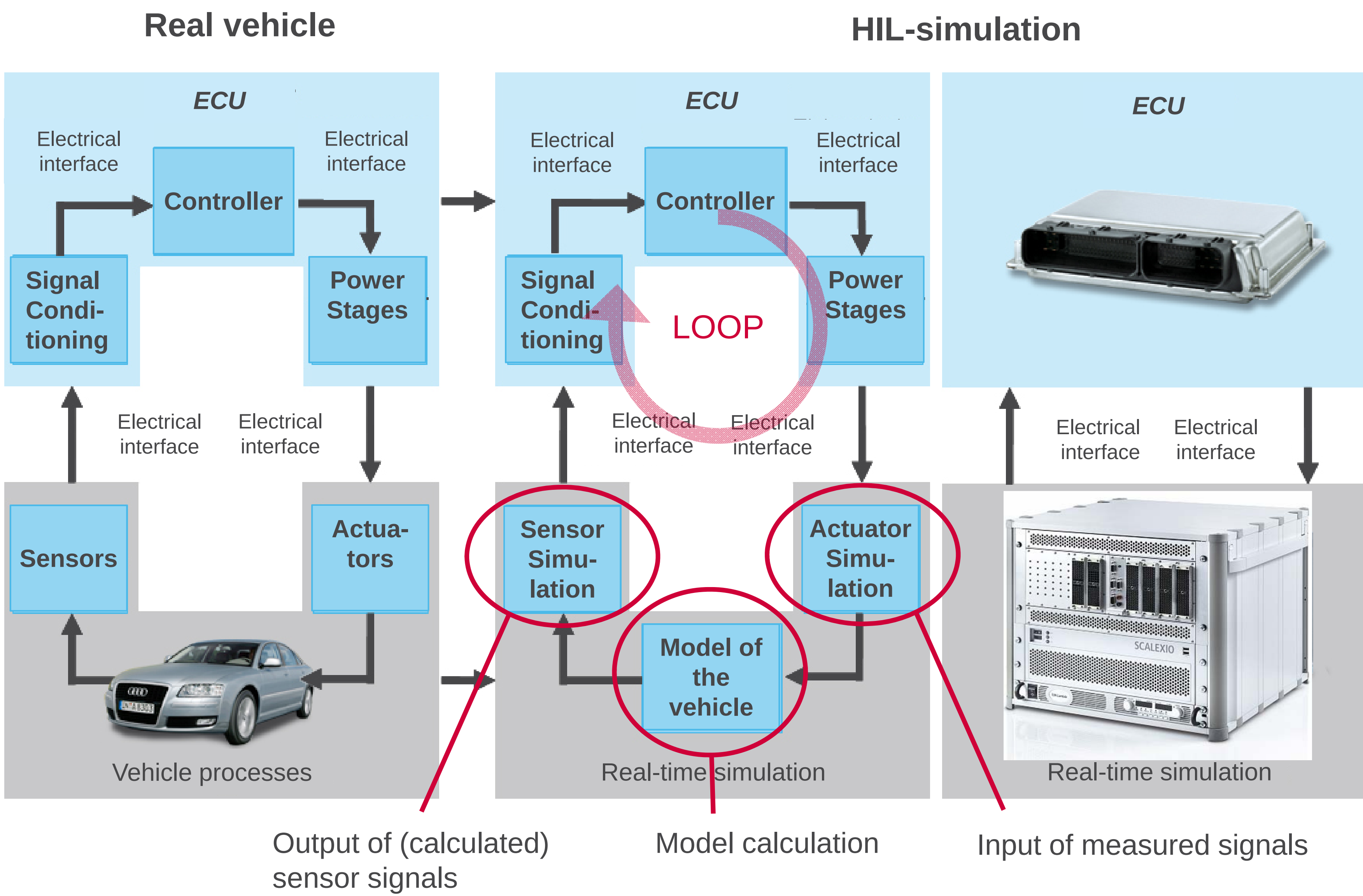
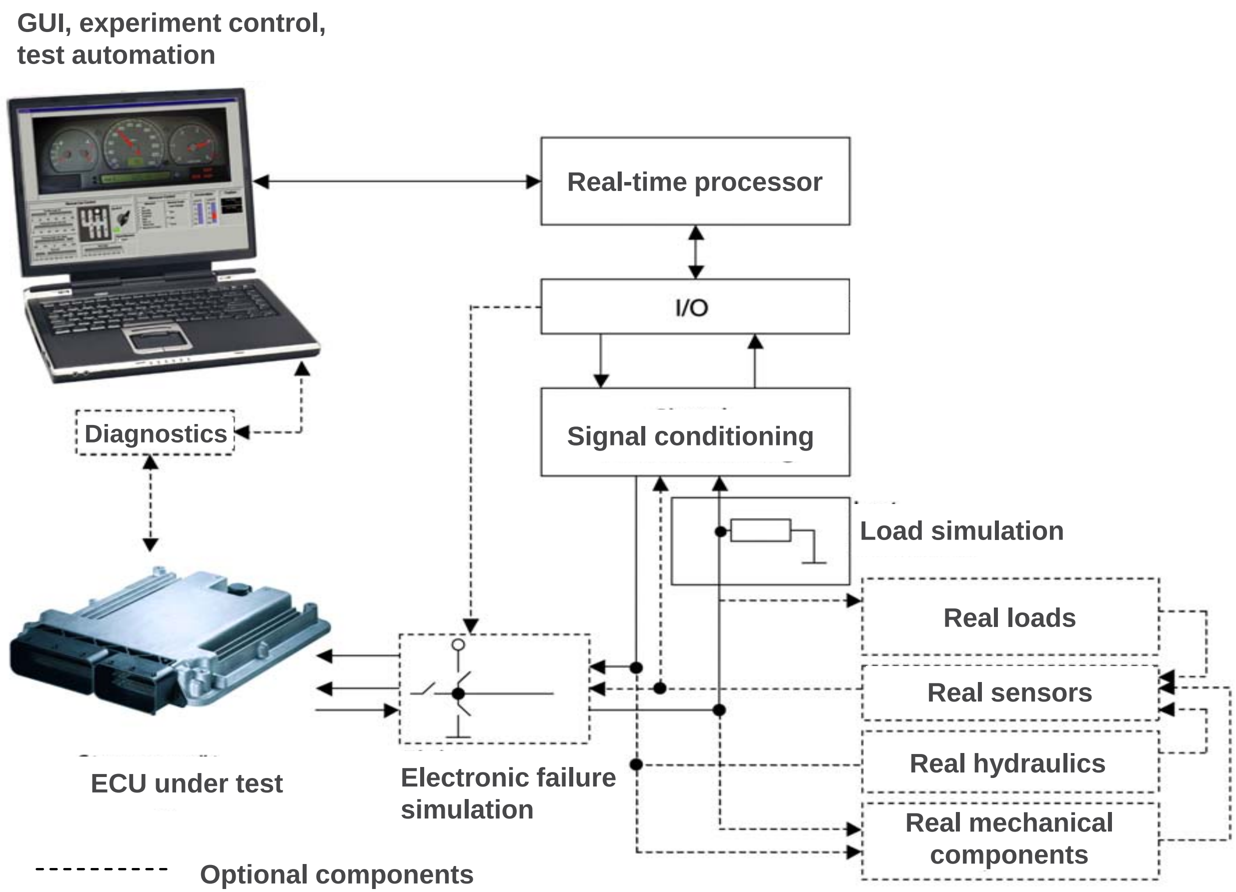


HIL Systems: Hardware-Components

Hardware-Components for HIL simulation

- User-PC
- Real-time processor
- I/O-boards and signal conditioning
- Bus systems
- Electric loads and load simulation
- Electric failure simulation
- Power supply for battery simulation
- Real components



HIL Systems: Software-Components

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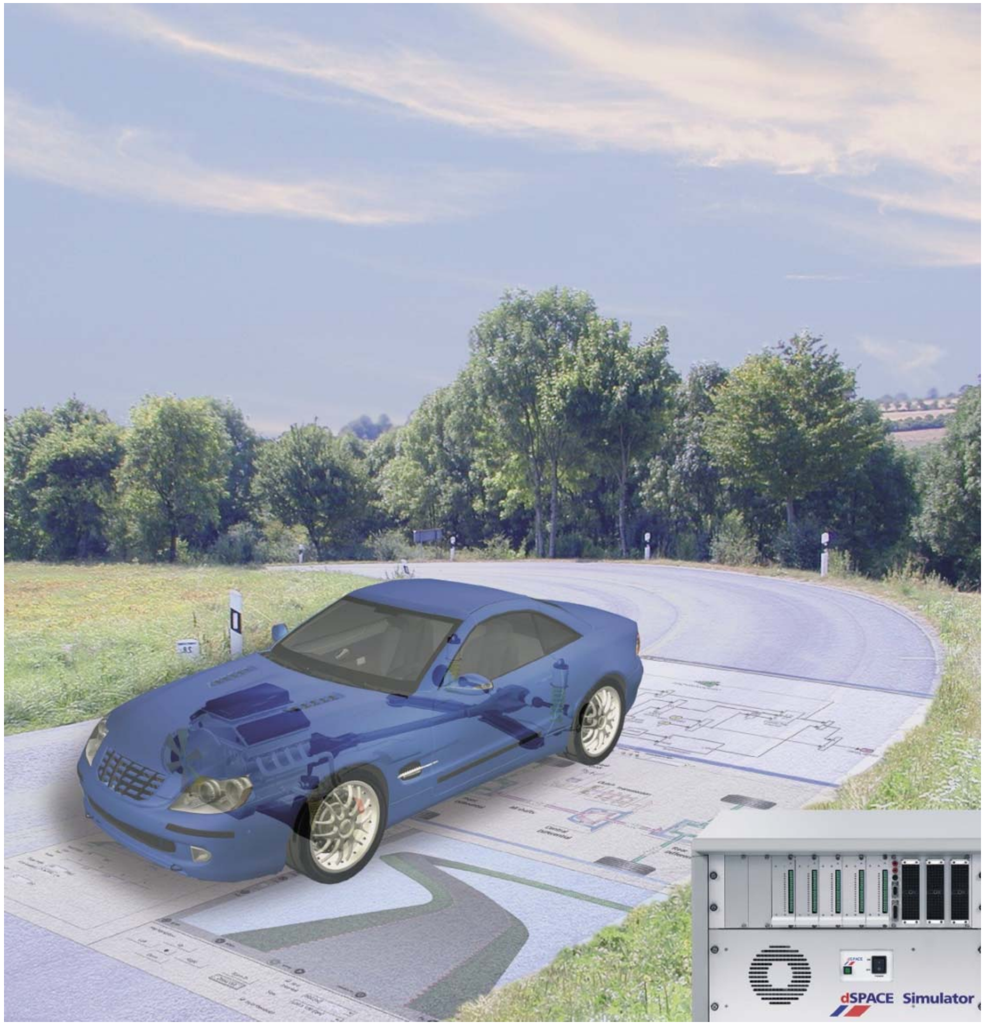
Software-Components for HIL Simulation

- User-Software:
  - Simple I/O (Digital, PWM, A/D, D/A) implementation and configuration
  - **Bus/Network-system** implementation and configuration
  - Experiment software
  - Real-time animation
  - Test automation
- Real-time software
- Dynamic models
  - Combustion engine models
  - Environmental models
  - Electric components and electrical system



Different HIL Test Scenarios

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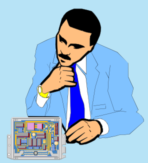
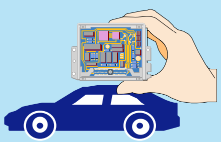
ECU Function Tests

Testing a Single ECU

Software Integration Tests

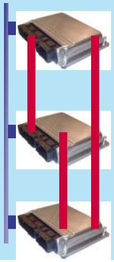


Acceptance and Release Tests



Testing an ECU Network

Testing Distributed Functions



Testing Networked Systems

ECU Function Tests

- Control strategy
- Diagnostics procedure
- Development ECUs

Testing a Single ECU

- Entire operating range
- Critical operating states
- Diagnostic functions
- Measurements from test drives
- Restbus simulation

Testing an ECU Network

- “Interaction”
- Bus behavior
- Network management
- Power consumption
- Integration test

Testing of ECU-Networks

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Test of an ECU-network

- Test of all ECUs in an ECU network ("virtual vehicle")
- ECUs are communicating through different bus systems

Methods

- Check mechanisms (Message counters, checksums, toggle and parity bits)
- Generating messages independently of, or depending on the simulated environment
- Error emulation/injection
  - Temporary replacement of model-related messages/signals by synthetic signals
  - Manipulation of signals on logical and/or electrical level
  - Manipulation of signal timing
  - Switching individual message(s) or complete transmission on/off

HIL system for testing an ECU-network

Integration Test System

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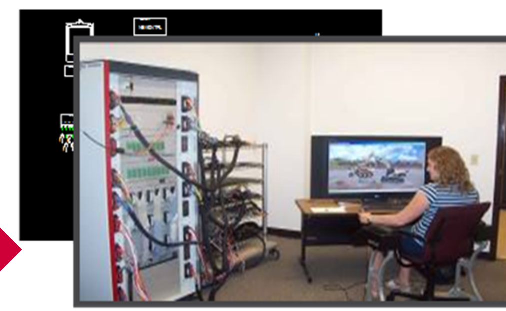
Testing Considerations

- Network Performance and Bus Analysis
  - Communication implemented correctly by suppliers?
  - Do ECUs make sensor signals available to other ECUs fast enough?
  - Do gateways between the sub-networks work correctly?
  - Correct ECU behavior under high bus loads or in cases of bus error?
  - Does network management work correctly?
- Power Measurement Capability
- Test user-interface components
- Manual overrides and debugging capabilities
- Comprehensive Automated Testing

Machine Test Bed

$10x/hr.

Weekly Iterations



Model based Virtual Lab

$1x/hr.

Hourly Iterations

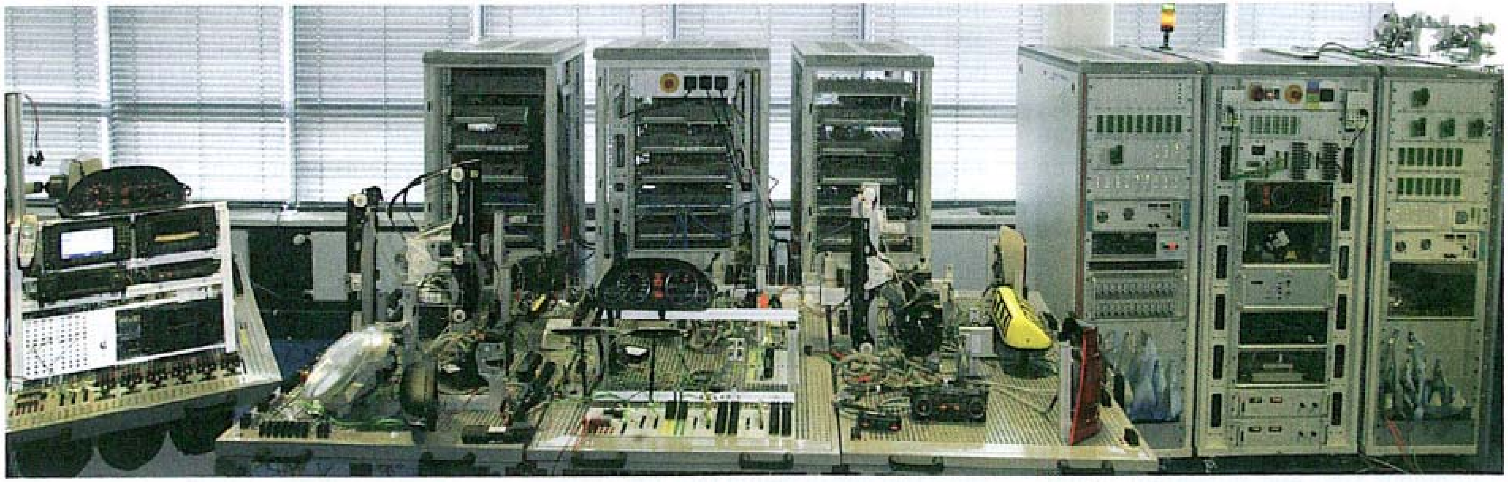
Integration Testing

SAE Off-Highway Engineering Magazine – March 2009

System Integration is the Key

- Need to Reduce Fuel Consumption to meet Tier4 EPA Regulations
- Mandates the need to have multiple ECUs working together
- New Challenges – System Integration Testing
- Dynamic Testing of Interaction of Transmissions, Engines, and other devices

"The CAN bus network is the key for connecting the pieces," Rick Hall, CNH Construction Equipment.



ECU Testing for Diesel Engine Variants

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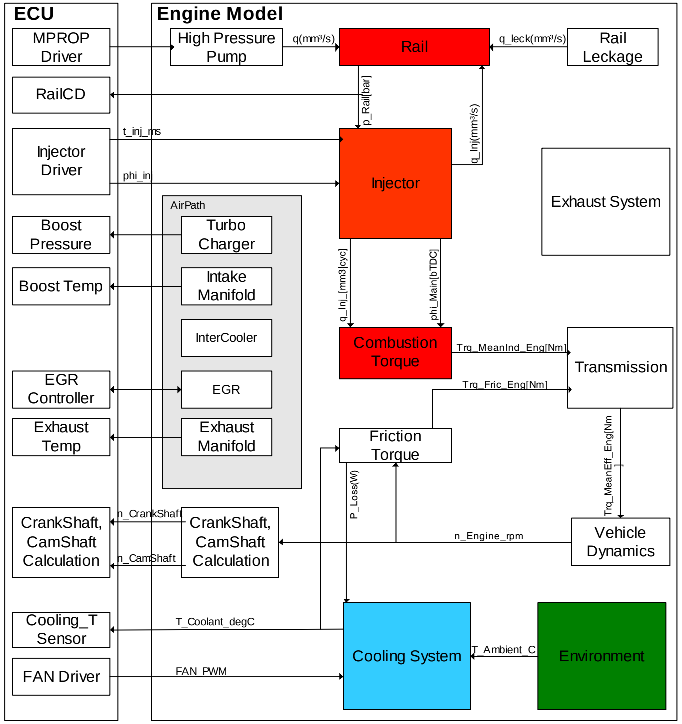
- Deutz release tests for diesel engine ECUs
- HIL test system based on dSPACE Simulator and ASM Diesel Engine Simulation Package
- Fast variant handling (50) by dynamic models
- Automated testing via AutomationDesk



DEUTZ®

„With its flexible, fast configuration, the ASM Diesel Engine Model enables us to cover all our engine variants with a single model, and to switch back and forth between the variants very fast.”
(Mark Zimmermann, Deutz)

Goals and Advantages of the HIL-Simulation

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Achievements through the HIL-simulation

- Increased productivity (higher coverage of potential test cases)
- Coping with increased complexity
- Reduction of development cost (less test benches and prototype vehicles)

Advantages of HIL-tests

- HIL-Tests can be reproduced and automated
- Certain tests are with a real-system not possible or too dangerous
- HIL-tests give the possibility to reproduce a certain error condition (diagnostic tests, emergency run programs, fallback programs)

Important Off-Road Customers

Bobcat
CNH
CLAAS
JCB
DEUTZ
CAT
LIEBHERR
JOHN DEERE
VALTRA

dSPACE and EtherCAT

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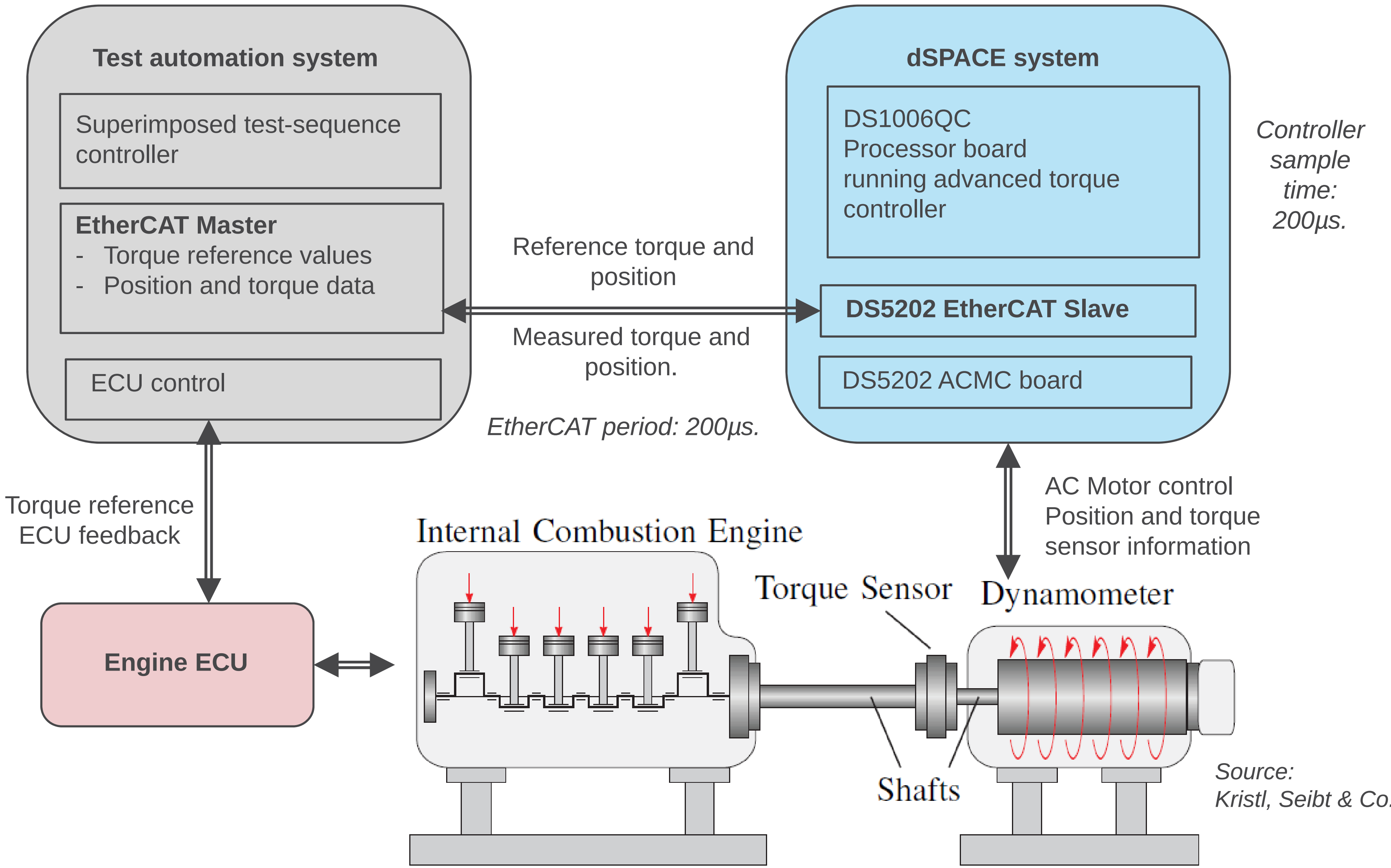
- Usage of **Beckhoff** FB1111-0140 as slave modules
  - 8 KB DPMEM for communication
  - 8 configurable Sync Managers
    → allows different cycle times

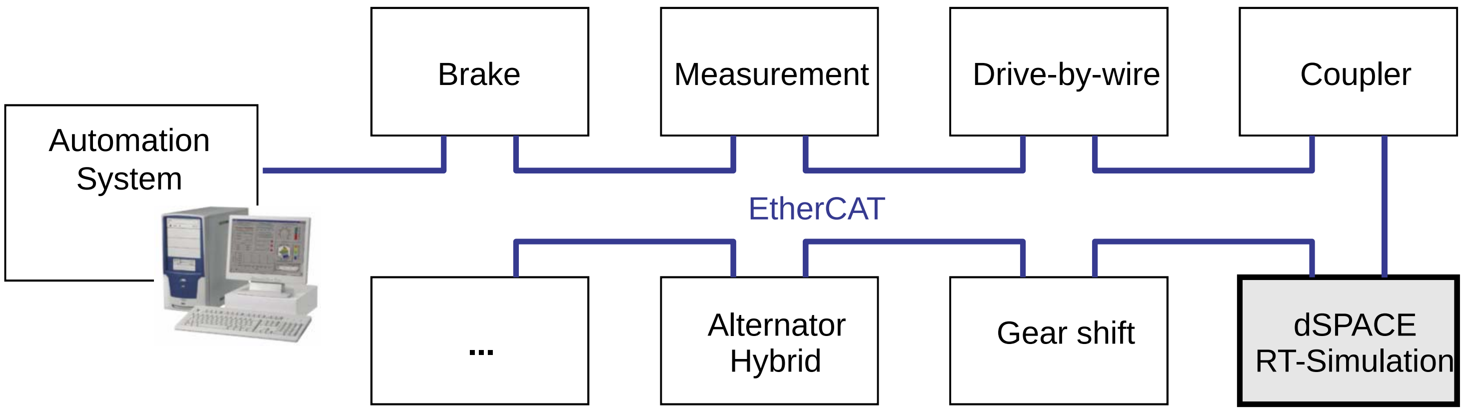
EtherCAT®

- New Simulator Generation SCALEXIO
  - Usage of **Hilscher** CifX/NetX PCI(x) SW-reconfigurable modules
  - Master and Slave

EtherCAT Test-Bench Integration (1)



EtherCAT Test-Bench Integration (2)



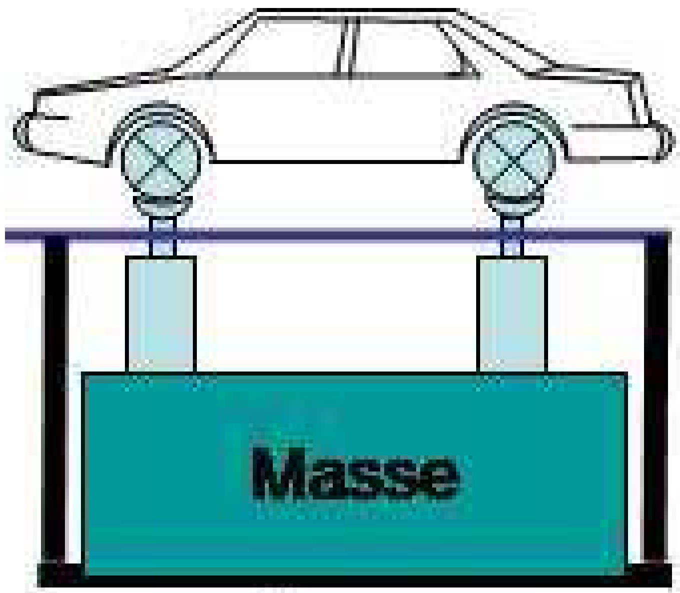
Engine Test Bench

- Usage of KPA EtherCAT Master included in Automation System
- dSPACE simulator connected as slave to EtherCAT network
- Usage of different tasks for sending and receiving
  - 200µs, 1ms and 10ms cycle

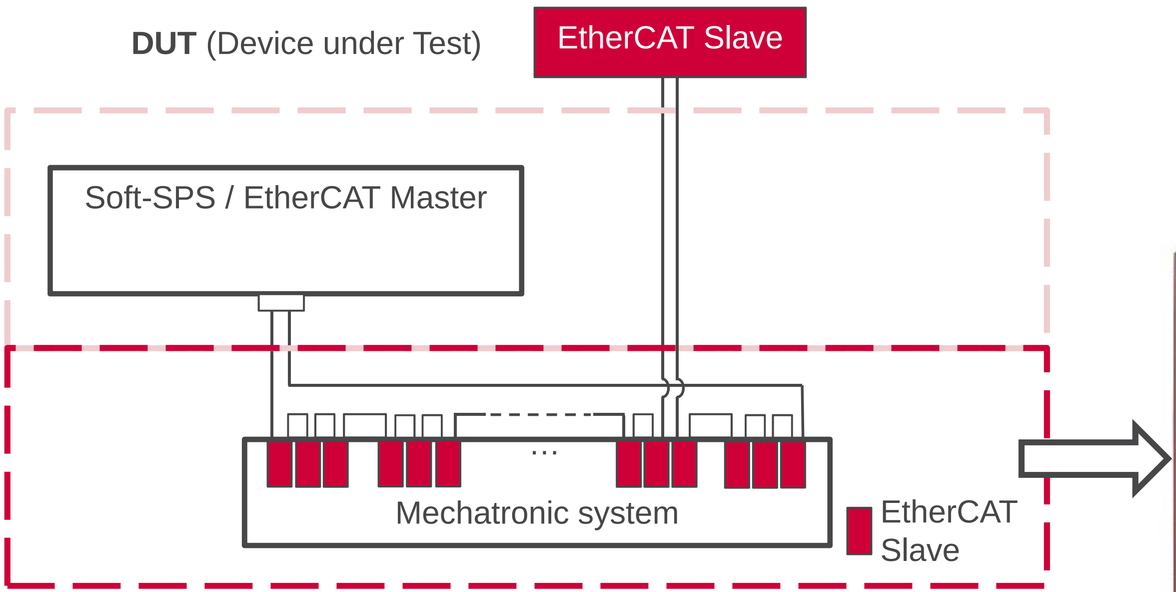
EtherCAT Test-Bench Integration (3)

Vehicle Dynamics Test Bench

- Excitement of street profiles to the car by means of hydraulic shakers
- Local measurement acquisition
- One processor board (and I/O) per axis
- Exchange of analog sensors and data transmission by EtherCAT
- dSPACE simulator connected as slave to the EtherCAT network
- One EtherCAT slave per axis
- Usage of TwinCAT as master
- Small cycles (200 µs) and many signals

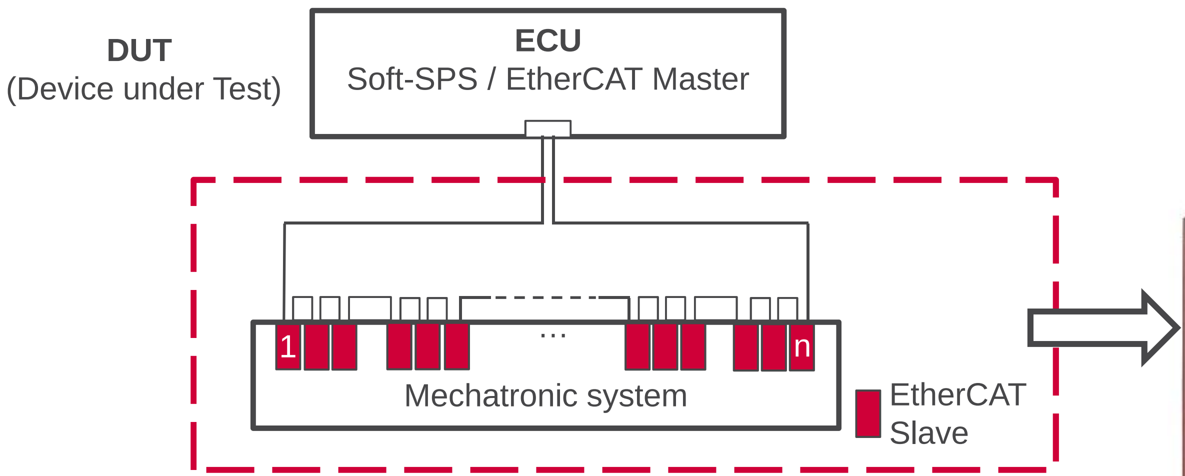


Use Case: Testing ECU with EtherCAT Slave



- Test of EtherCAT slave by means of restbus simulation
  - Simulation of not existing slaves by few flexible slaves
  - Master implementation has to be adjusted (application layer and process data remain the same)
  - Restbus simulation for several slaves also possible

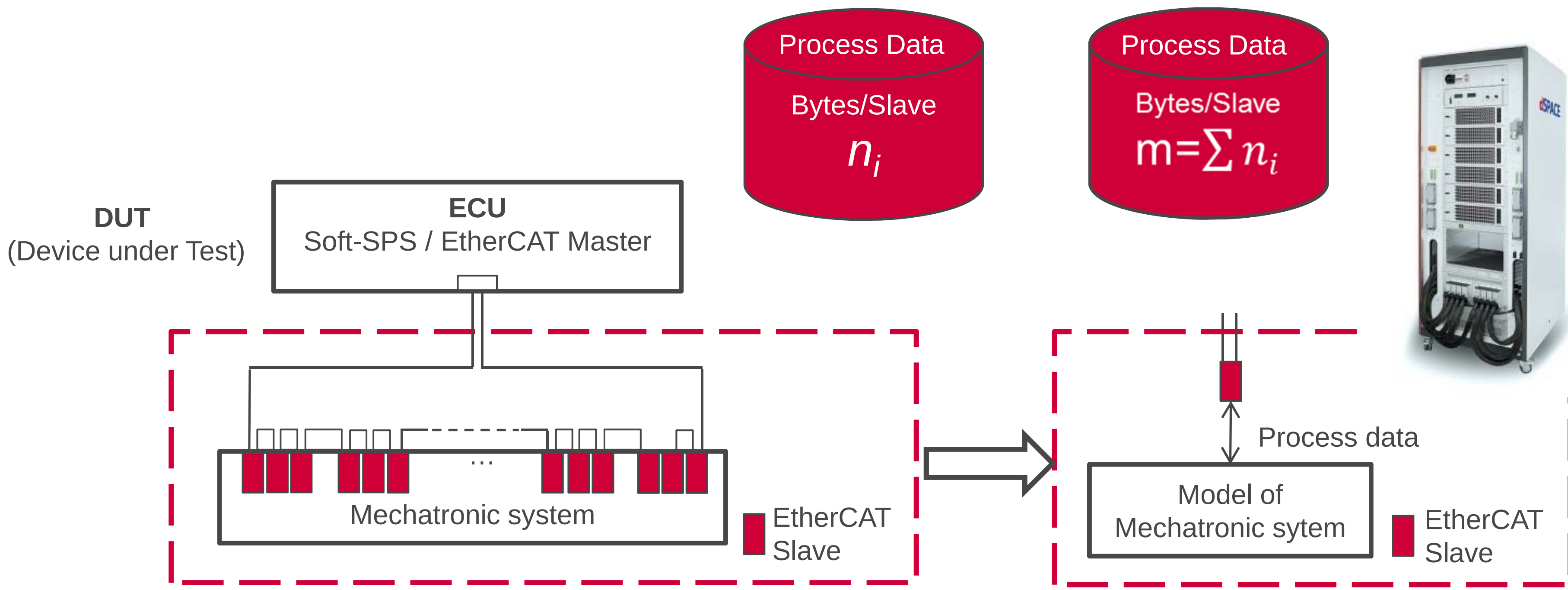
Use Case: Testing ECU with EtherCAT Master



- Test of Soft-SPS / EtherCAT master by means of restbus simulation
  - Includes simulation of the mechatronic system (Simulink model) **and complete bus topology**
  - Each slave of the real machine (about 300) has to be replaced by a slave in the simulator
  - **There is no appropriate technological solution today!**
    ➔ Would require kind of high flexible “Multi-Slave”

Use Case: Testing ECU with EtherCAT Master

- Alternative: Simulation of complete process data by means of few flexible slaves



Consequences

- **Master implementation has to be adjusted** (application layer and process data remain the same) ➔ changes of DUT!
- No real network topology → differing roundtrip times and latencies
- No hardware layer specific tests possible (e.g. breakdown of a specific slave)

Summary

Summary

- The relevance of electronics and software in mobile machinery is continuously increasing. Most innovation is based on the new developments or enhancements of electric and electronic systems.
- Hardware-in-the-Loop testing is the key technology, which is able to cope with the increased test requirements.
- Use cases for EtherCAT in advanced test systems
  - ✓ Test bench integration
  - ✓ Restbus simulation for EtherCAT slave(s)
  - ✗ Restbus simulation for EtherCAT master
  - ✓ Restbus simulation for EtherCAT master without real topology

➢ **Particularly, the requirement for genuine emulation of a large number of EtherCAT slaves with one physical unit is one of not yet solved challenges.**