Safe Legends

Developing and testing control systems for high-performance tasks in the ultimate super sports cars

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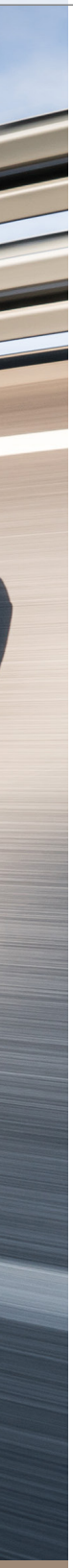
The performance range of Bugatti vehicles is defined by their integrated, safe electronic systems. A simulator from dSPACE ensures that the systems function extremely reliably.



Bugatti owes its very distinctive character to a family of artists and engineers, and since its beginnings the company has striven to achieve the extraordinary, the very best, the superlative. Each and every element in the new Bugatti Chiron is reminiscent of the marque's history and yet full of innovative technology. The result: creations of enduring value and automotive masterpieces.
At the heart of the Chiron is its quad-turbocharged 8 liter W16 engine. This exceptional masterpiece delivers almost unbelievable power of 1,500 hp and 1,600 Nm torque at a virtually linear performance of between 2,000 and 6,000 rpm. Four high-powered turbochargers running in a configuration with two-stage control define this champion of performance.

The Challenge: The Utmost in Reliability

Making this performance available to the driver reliably and safely under any conditions whatsoever requires numerous electrical systems and highly complex electronic controls. Efficient validation of the electronic control units is a core activity in vehicle development. In particular, tests have to be performed in extreme performance ranges to ensure that the vehicle is completely under control at all times. For optimum efficiency, developers need the ability to test new electronic control units and software versions even when the tested component, or indeed the entire vehicle, is not (or not yet) available.

Solution Approach: Efficient Vehicle Simulation

At Bugatti, hardware-in-the-loop (HIL) simulation is a well-established procedure for ECU testing. With regard to the new Chiron vehicle model, it was imperative to build an optimized testing solution that would reach new performance dimensions and that could also easily be extended for future vehicles. Put more concretely, a detailed simulation of the entire powertrain, including vehicle dynamics, was required in order to connect the engine, transmission, and vehicle dynamics ECUs to the simulator and test them.

Evaluating a Simulation Platform

After evaluating various commercial simulation models and simulators, Bugatti decided to go for a tailor-made simulation solution from dSPACE. The solution consists of a HIL simulator and detailed simulation models that represent the vehicle, including all its components. The mathematical models in the Automotive Simulation Models (ASM) tool suite are used to do this. The developers precisely virtualized the vehicle and the powertrain with the following models:

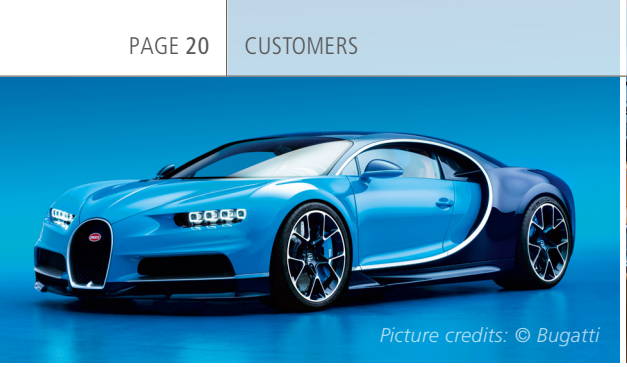
- W16 engine: ASM Gasoline Engine
- 7-stroke dual clutch transmission (DCT): ASM Drivetrain
- Chassis and vehicle dynamics: ASM Vehicle Dynamics

Designing and Parameterizing the Simulator and Models

The planning and design of the simulator, and the creation of the I/O model that would become the interface between the real ECUs and the virtualized vehicle, were based on data on the electrics/electronics system and the ECUs and also on the specifications for the engine and transmission. A model structure was then derived from the design, and requirements for parameterization were defined. The precision of the parameters is a measure of simulation quality; they can be acquired from design data, for example, and also by means of measurements. By making test bench measurements, the team was able to produce finely resolved characteristic maps for parameterization. The parameterization was then validated by means of the soft ECUs from the ASM library. A further validation step, which included the I/O model and the real ECU, followed. This provided the foundation for putting the overall simulator into operation, which included comparing the simulation results with the measured reference values. Experts from Bugatti and dSPACE worked together closely. >>

"Before we ventured to put the vehicle through speed ranges of over 450 km/h, we made comprehensive investigations and tests with the dSPACE Simulator. This meant we were able to find any issues at an early stage."

Dr. Alexander Riedel, Bugatti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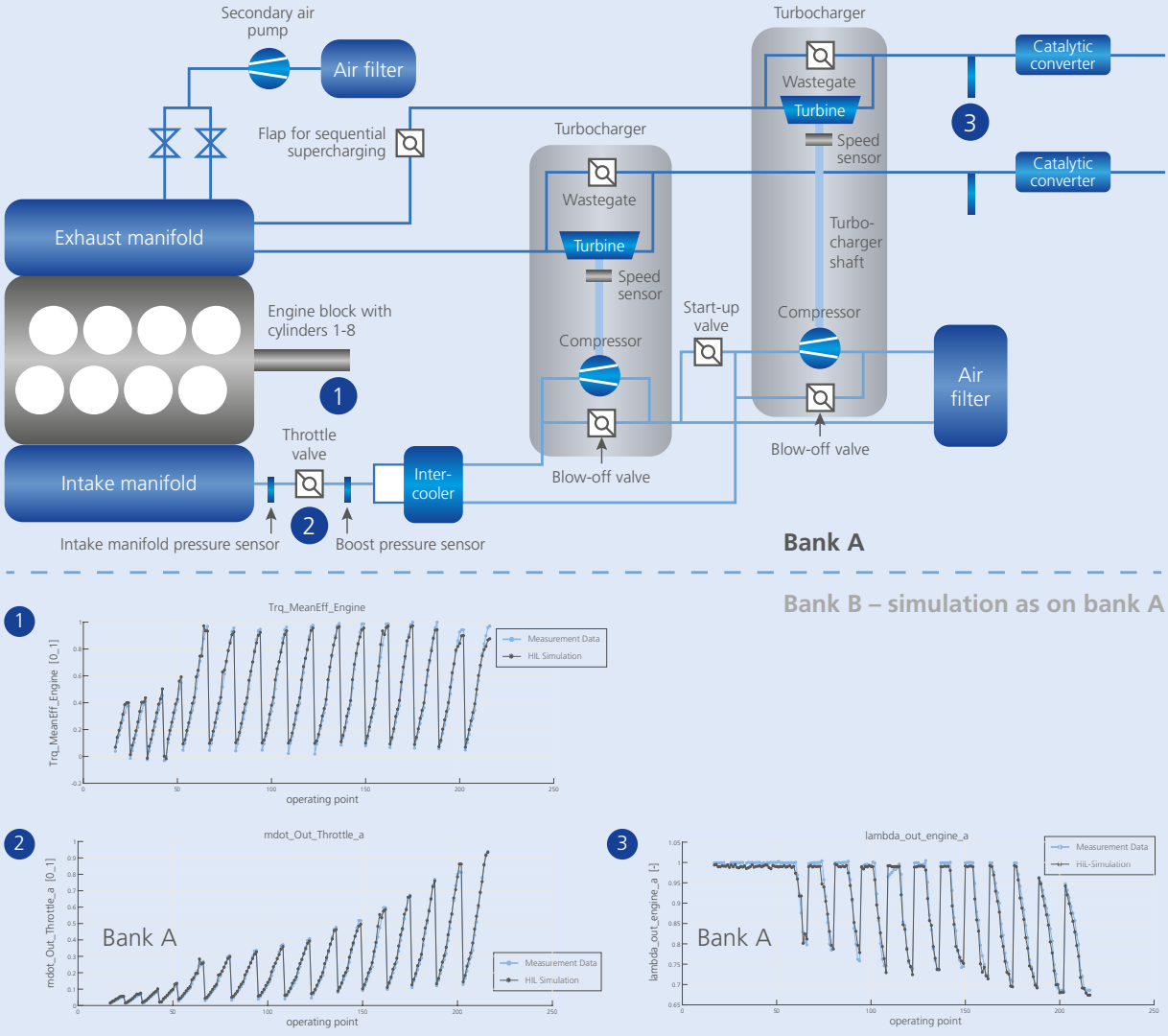
Development and Test Tasks on the Simulator

The Bugatti team uses the HIL simulator for a variety of test tasks. Among these are classic release tests for new software versions. The procedure is to first test an ECU with the new software on the HIL simulator and not to transfer the software to the actual production vehicle until the test has been passed. For example, to validate engine and transmission software, onboard diagnostic (OBD) tests are performed with the simulator in specific speed and load ranges. These are manufacturer-independent, standardized tests that are performed continuously while the vehicle is running. They check whether the response to errors is correct and the appropriate responses are produced, and whether the correct error output is made to the ECU's error memory.

While the vehicles then undergo tests



A diagram of a bank of the modeled W16 engine together with the measured and simulated signals. The signals are superimposed to show the high level of simulation accuracy.

Picture credits: © Bugatti

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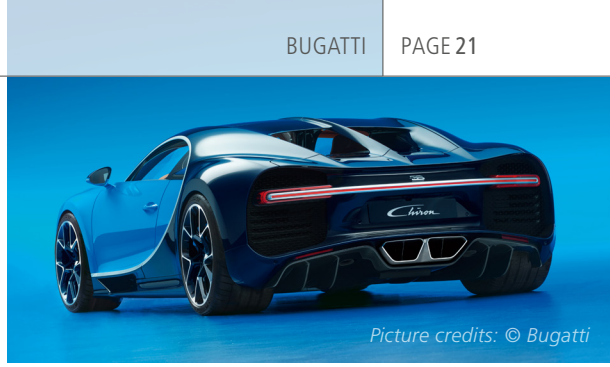


Picture credits: © Bugatti

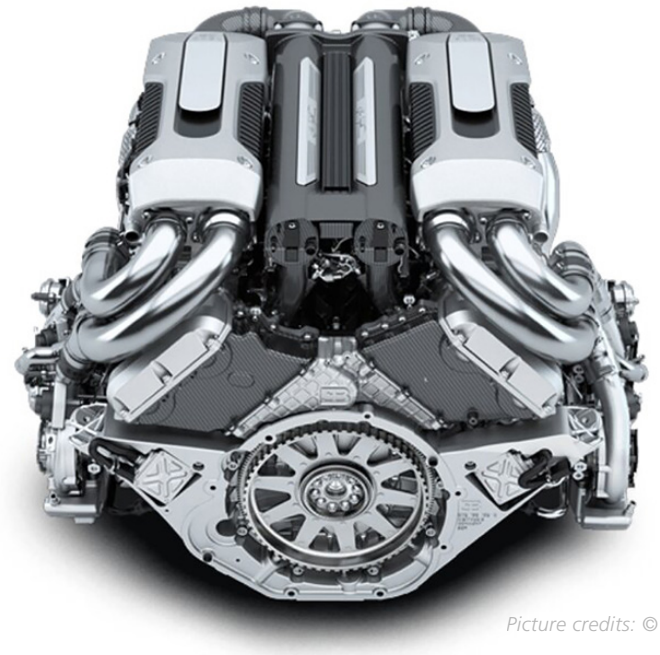
all around the world, the HIL simulator has further test tasks to perform: It is used to replicate errors that were found during test drives. It does this by making a virtual drive along the same route, for example, the Ehra-Lessien test track, which is located near Wolfsburg, Germany. Function tests are also run, and this is where the simulator really shows its special strengths. For example, responses that affect driving behavior can even be tested at speeds of over 400 km/h, risk-free. Other important function tests are in the domain of control strategies for overtemperatures, ignition failures, etc. The simulator can also offer support for development tasks. The diverse electronics systems – such as the ones that control rear spoiler adjustment, active aerodynamics, and level control – can be tested in early phases and optimized while they interact.

Quality Enhancement by Test Automation

To ensure that tests can be performed at any time, even 24 hours a day and 7 days a week, the dSPACE test authoring and automation tool AutomationDesk is used. AutomationDesk has libraries with a selection of predefined test steps, for example, for access to the simulation model, a failure insertion unit (FIU), or the application and diagnostics software. This lets developers automate test execution in order to increase test coverage and enhance the quality of the ECU software, while at the same time saving time and costs.

Evaluating the Test Solution

Because of its reproducible simulations, the dSPACE Simulator played a major role in preparing for the world speed record of the Bugatti Chiron Super Sport 300+. It let the developers investigate the vehicle's behavior at extreme performance ranges in detail and then use the findings to shape the development process, all at an early stage. The relevant components from the domains powertrain, chassis, and body are mapped in real time using the simulation models in ASM. These include the W engine with both banks, including the turbocharger and variable valve timing mechanism, plus the dual clutch transmission (DCT), the Haldex clutch for four-wheel drive, right through to active shock absorbers, differential lock, and adaptive rear spoiler. The position changes for the shift collars, the torque synchronization between all the shafts during gear changes, gear preselection, and position control for transmissions and transmission adaptation can be tested together with the ASM DCT model. The range of tests also includes tests for diagnostic functions and a compre- >>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The heart of a Bugatti: The legendary W engine with 16 cylinders.

"The good working relationship we had with our dSPACE counterparts was a major factor in the project's success. We appreciate the dedication that they showed and their flexibility in our project work."

Dr. Alexander Riedel, Bugatti

The experiment software ControlDesk sends Bugatti's simulated vehicles on virtual test drives.

hensive results analysis. Moreover, the simulator can be extended flexibly. For example, an ionic current measurement was quickly integrated, helped along by close contact between the responsible developers at dSPACE and Bugatti.

Conclusion

A manufacturer with short production runs like Bugatti cannot simply cover its investments for tools by producing large quantities. Even so, there are two good reasons why using a HIL system is well worth the outlay:

- Bugatti can ensure that its vehicles are up to its quality standards – even in the numerous extreme ranges that vehicles in this performance class can reach.
- Moving some of the development tasks to the HIL simulator to supplement other activities makes complete sense. It helps developers achieve greater efficiency. For example, it reduces the number of tests needed on the actual vehicle and on the test vehicle. ■

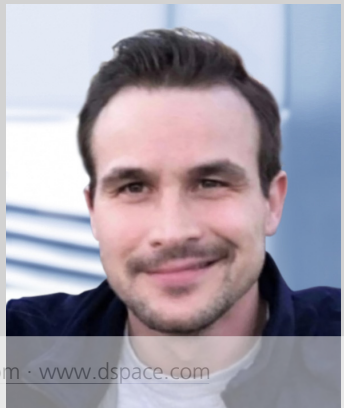
Dr. Alexander Riedel, Bugatti

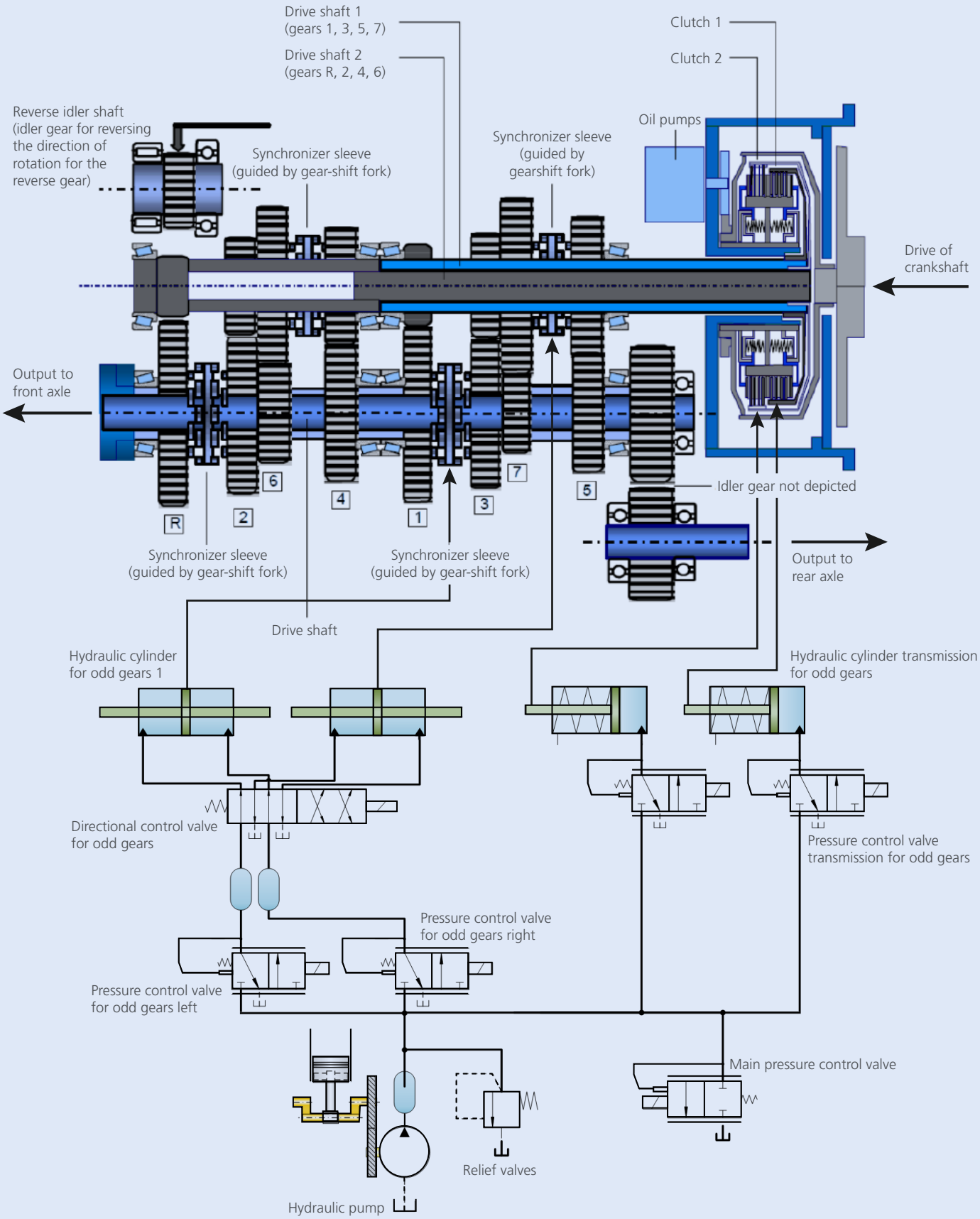
"We use the ASM simulation models to map all the relevant components of the powertrain."

Dr. Alexander Riedel, Bugatti

A Bugatti vehicle on the virtual test track, visualized with MotionDesk, the 3-D online animation software from dSPACE

Dr. Alexander Riedel
Dr. Alexander Riedel, Engine Application BG-EA/2, Bugatti





Extract from the detailed model of the dual clutch transmission. The hydraulic control shown here is an extract from the ASM demo model, which was adapted to Bugatti's hydraulics.