

Automotive Simulation Models (ASM)

Tool suite for simulating the engine, vehicle dynamics, electrical system, and traffic environment

Highlights

- Open MATLAB®/Simulink® models
- For ECU testing and function development
- Intuitive graphical parameterization with road and scenario creation in ModelDesk



Application Areas

The Automotive Simulation Models (ASM) are a tool suite of open Simulink models for the real-time simulation of passenger cars and trucks as well as their components. They are used as plant models for the development and testing of engine controls, vehicle dynamics controls, on-board power electronics and driver assistance systems.

The ASMs are typically used on a dSPACE SCALEXIO for hardware-in-the-loop (HIL) testing of electronic control units (ECUs) or during the design phase of controller algorithms for early validation by offline simulation.

Key Benefits

All the Simulink blocks in the models are visible, so it is easy to add or replace components with custom models to adapt the properties of modeled components perfectly to individual requirements. The ASMs' standardized interfaces make it easy to expand a single model such as an engine or body, or even create a whole virtual vehicle. Roads and driving scenarios can be easily and intuitively created using graphical tools with preview and clear visualization.

Modular Concept

The ASM concept consists of coordinated, combinable models of automotive components. There is a vehicle model with a trailer, plus other ASMs for gasoline, diesel and hybrid engines, exhaust systems, turbochargers, brake hydraulics, electrical systems, electric motors, environment sensors, roads and traffic. The ASMs support a whole range of simulations from individual components to complex virtual traffic scenarios.

Offline and Online Simulation

The ASMs can be used in combination with real controllers in a hardware-in-the-loop environment (HIL or online mode), or for model-in-the-loop simulations (PC or offline mode). The same model configurations and parameters can be used seamlessly throughout all the steps from function development to ECU testing.

Main Features and Benefits

Feature	Description	Benefit
Open Simulink models	<ul style="list-style-type: none"> Almost all models are open down to the Simulink block level 	<ul style="list-style-type: none"> Custom models can easily be added or used to replace model components
ModelDesk	<ul style="list-style-type: none"> Graphical user interface with parameter and simulation management 	<ul style="list-style-type: none"> Easy, intuitive parameterization and seamless simulation handling
Online simulation	<ul style="list-style-type: none"> Real-time simulation on real-time hardware 	<ul style="list-style-type: none"> Hardware-in-the-loop simulations with ECUs
Offline simulation	<ul style="list-style-type: none"> Simulations as early as the design phase 	<ul style="list-style-type: none"> Controller validation in early development stages
ASMSignalBus	<ul style="list-style-type: none"> Simulation signals are part of a structured Simulink signal bus 	<ul style="list-style-type: none"> Standardized and fast access to model variables
Online tunable parameters	<ul style="list-style-type: none"> Direct parameter access during real-time simulations 	<ul style="list-style-type: none"> Online parameter optimizations and behavior studies
Model interoperability	<ul style="list-style-type: none"> ASM models are easy to combine to create a virtual vehicle 	<ul style="list-style-type: none"> An entire virtual vehicle can be simulated

Order Information

Classification	Type	Order Number
Packages	ASM – Gasoline Engine Basic Simulation Package	<ul style="list-style-type: none"> Please inquire
	ASM – Gasoline Engine Simulation Package	<ul style="list-style-type: none"> Please inquire
	ASM – Diesel Engine Simulation Package	<ul style="list-style-type: none"> Please inquire
	ASM – Gasoline Engine InCylinder Simulation Package	<ul style="list-style-type: none"> Please inquire
	ASM – Diesel Engine InCylinder Simulation Package	<ul style="list-style-type: none"> Please inquire
	ASM – Vehicle Dynamics Simulation Package for VEOS	<ul style="list-style-type: none"> Please inquire
	ASM – Vehicle Dynamics Simulation Package	<ul style="list-style-type: none"> Please inquire
	ASM – Truck and Trailer Simulation Package	<ul style="list-style-type: none"> Please inquire
Libraries	ASM – Turbocharger	<ul style="list-style-type: none"> ASM_L_TC
	ASM – Drivetrain Basic	<ul style="list-style-type: none"> ASM_L_DTB
	ASM – Electric Components	<ul style="list-style-type: none"> ASM_L_EC
	XSG – Electric Component	<ul style="list-style-type: none"> XSG_EC_LIB
	ASM – Brake Hydraulics	<ul style="list-style-type: none"> ASM_L_BH
	ASM – Diesel Exhaust System	<ul style="list-style-type: none"> ASM_L_DEXH
	ASM – Traffic	<ul style="list-style-type: none"> ASM_L_TRF
	ASM – Pneumatics	<ul style="list-style-type: none"> ASM_L_PNEU
	ASM – KnC	<ul style="list-style-type: none"> ASM_L_KNC

Relevant Software and Hardware

Software		
Required	Integrated development environment	<ul style="list-style-type: none"> MATLAB/Simulink¹⁾ from MathWorks Simulink® Coder™ (formerly Real-Time Workshop®)³⁾ Simulink Accelerator²⁾
	dSPACE implementation software	<ul style="list-style-type: none"> Real-Time Interface (RTI)³⁾
	dSPACE experiment software	<ul style="list-style-type: none"> ControlDesk³⁾
	Additional software	<ul style="list-style-type: none"> Microsoft® Excel®
	Operating system	<ul style="list-style-type: none"> www.dspace.com/go/os_compatibility
Hardware		
Required	Recommended system	<ul style="list-style-type: none"> Intel® Core™ i7 Processor Memory ≥ 8 GB RAM Dual-head graphics accelerator card matching the requirements of MotionDesk⁴⁾
	SCALEXIO or dSPACE Simulator (equipped with DS1006 Processor Board or DS1007 PPC Processor Board), MicroLabBox	

¹⁾ MATLAB®/Simulink® Student Suite does not support Automotive Simulation Models (ASM).

²⁾ Offline simulations only

³⁾ Online simulations only

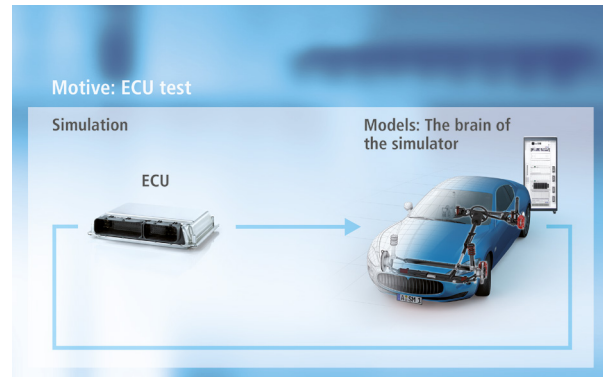
⁴⁾ Graphics accelerator required for MotionDesk which is part of the ASM Vehicle Dynamics Simulation Package. More details on graphics card requirements and compatibility at www.dspace.com/go/mdhwreque

Introduction

Why Use Simulation? Why Use Models?

In model-based design (MBD), simulation is a widely used and proven method. It is applied to test and validate control algorithms in a virtual world instead of on the real controlled device. For automotive applications this ranges from simulated individual components, such as engines, to complete virtual vehicles, up to virtual environments consisting of a vehicle and its surrounding traffic, traffic signs, and so on.

Virtualized controlled device (vehicle) and controller (ECU) in a control loop.



ASM Simulation Tool Suite

The Automotive Simulation Models (ASM) from dSPACE are a simulation tool suite covering four application areas: combustion engines, electric components, vehicle dynamics and the traffic environment. These ready-to-use simulation models exactly represent the behavior of the controlled devices. The ASM tool suite is designed to fully comply with the MBD approach. All models are implemented with MATLAB®/Simulink®.

Tool suite for simulating engines, electric components, vehicle dynamics and traffic.



Simulation Platforms

The support of multiple platforms allows for seamless simulation processes from model-in-the-loop (MIL) to software-in-the-loop (SIL) to hardware-in-the-loop (HIL). The ASM tool suite can be executed on different simulation platforms: SCALEXIO, dSPACE Simulator, VEOS, or a PC running MATLAB/Simulink. Depending on the platform, simulations can be performed either with the controller software or the controller hardware (ECU) in the control loop. In either case the simulation model stays the same.



The ASM simulation tool suite supports multiple simulation platforms.

Philosophy

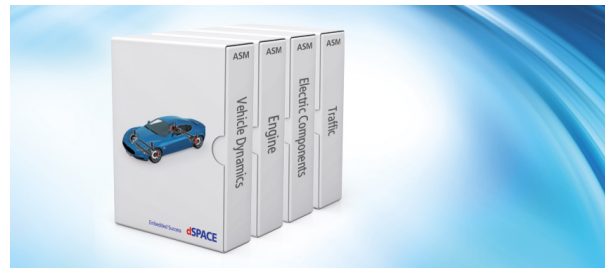
Supports Model-Based Design

- Real-time-capable Simulink models
- Provides access to internal modeling details, down to block level
- Supports all stages of controller software development (MIL, SIL, HIL)
- Soft-ECU network
- Signal interfaces for automotive applications



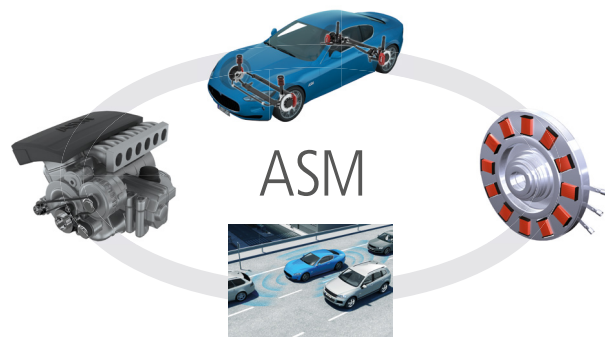
Ready-to-use Off-the-Shelf (OTS) Models

- One integrated tool chain for parameterization, validation and test automation
- Open documentation, including mathematical equations
- Supports migration, including between MATLAB releases
- Worldwide customer base and mature models



Complete ASM Product Portfolio

- Supports all automotive-relevant modeling areas
- Easily combinable models for building virtual vehicles
- Different levels of model complexity (e.g. mean value, physical) for all controller design and test use cases



Comprehensive Engineering and HIL Knowledge

- The one-stop supplier for all HIL-relevant tasks
- Customer training and worldwide support
- Combination of OTS models and custom specific model engineering

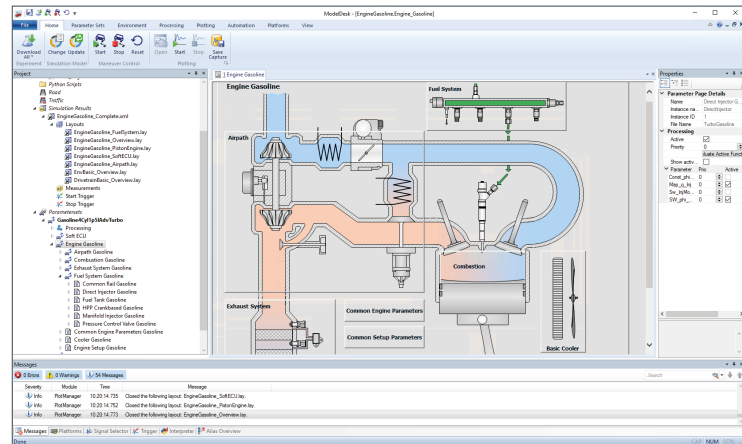


Combustion Engine Simulation

Real-time models for diesel and gasoline engine simulation

Simulation Packages and Models

- Diesel and gasoline engines
- Mean-value and InCylinder plant models
- Physical turbocharger
- Diesel aftertreatment system



Graphical parameterization of the engine model for precise simulations.

Example Use Case: Optimal Lambda Control

The Task

Test the diagnosis capabilities of a lambda-based exhaust aftertreatment control system.

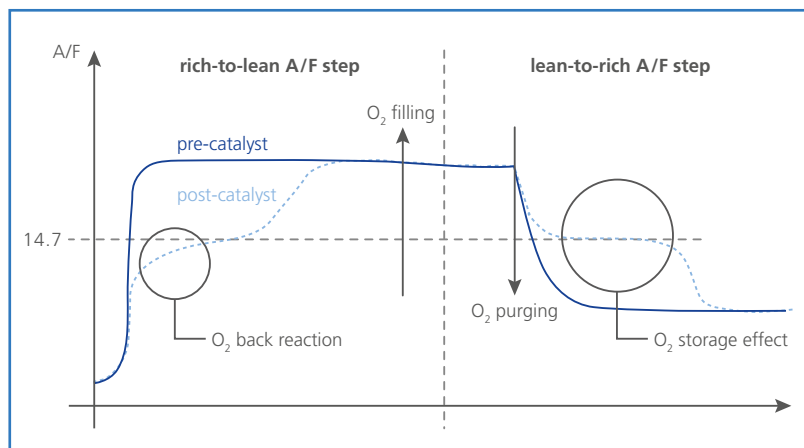
The Challenge

As part of the onboard diagnostics (OBD) system, the lambda sensor output in the engine's exhaust path underlies different diagnosis routines, which have to be validated in a HIL environment. Several chemical reactions have to be considered in a three-way-catalyst system, and the detailed simulation of all related effects drastically increases the calculation time and parameterization effort. Therefore, the dominant effects for testing OBD-relevant ECU functions must be identified, while taking into consideration the data sources available to the user to provide a real-time-capable solution that is ready for use in HIL projects.

The Solution

The three-way-catalyst simulation from

ASM considers the effects correlated to the oxygen storage capacity of the aftertreatment component as well as effects based on backward reactions within the catalyst itself. Prior knowledge on the chemical reactions and relevant effects is used to develop a phenomenological modeling approach based on oxygen storage and release rates within the catalyst to generate a lambda sensor output signal that captures effects used in the diagnosis system to identify aging aftertreatment systems, for example.



ASM Gasoline Engine Basic

Basic mean-value engine model with combustion torque modulation

Main Model Components

- Air system
- Fuel system
- Piston engine
- Turbocharger
- Drivetrain (basic)
- Vehicle dynamics (longitudinal)
- Environment (basic)
- Soft ECU

Features at a Glance

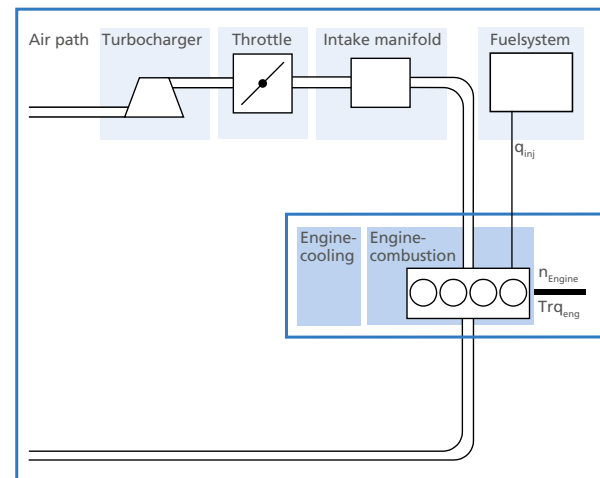
- Up to 20-cylinder gasoline applications
- Up to 4 injections per cylinder per cycle
- Intake manifold with calculation of intake manifold pressure and temperature
- Map-based turbocharger for boost pressure calculation
- Fuel injection system with fuel tank model
- Wall film evaporation taken into account
- Longitudinal driver for standard cycles (FTP75, NEDC, J10-15, ...)
- Simulation with real ECU in hardware-in-the-loop (HIL) system and simulated soft ECU in model-in-the-loop simulation
- Start/stop system support

Simulation Model Characteristics

The actual physical engine characteristics are represented by a mean-value engine model with crank-angle-based torque generation, dynamic manifold pressure, temperature calculation, and an injection model. To simulate the engine in an automotive system (car or truck), the engine model incorporates a longitudinal drivetrain model with manual and automatic transmission, a clutch, a torque converter, a starter, and a test bench mode. Models for the environment and driver complement the virtual powertrain.

More detailed information available

- www.dspace.com/asm



Schematic of the air system.

ASM Diesel/Gasoline Engine

Mean-value engine models with combustion torque modulation

Main Model Components

- Air system
- Fuel system
- Piston engine
- Aftertreatment systems
- Turbocharger
- Drivetrain (basic)
- Vehicle dynamics (longitudinal)
- Environment (basic)
- Soft ECU

Features at a Glance

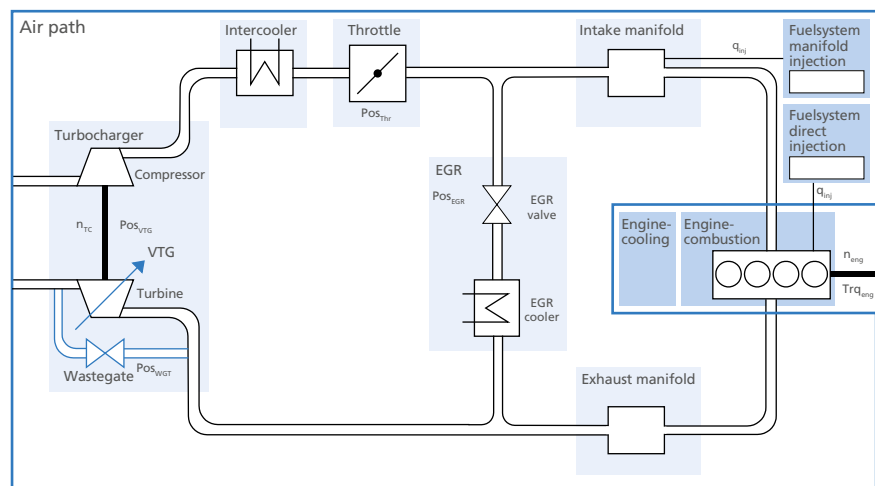
- Up to 20-cylinder diesel/gasoline applications
- Map-based turbocharger for boost pressure calculation
- Gasoline fuel injection system: direct injector and intake manifold injector
- Natural gas fuel supply systems
- Gasoline engine with homogenous and stratified combustion modes
- Gasoline engine with evaporation system support
- Gasoline exhaust system including dynamic three way catalyst simulation with respect to oxygen storage capacity
- Common rail system including rail, fuel tank as well as current or crankbased high pressure pump
- Diesel fuel injection systems: direct injector, unit injector, unit pump
- Up to 8 direct injections and 4 port injections per cylinder per cycle
- Diesel exhaust system including diesel oxidation catalyst (DOC) and diesel particulate filter (DPF)
- High-pressure and low-pressure exhaust-gas recirculation (EGR) of exhaust and unburned air with EGR cooler
- Start/stop system support
- Longitudinal driver for standard cycles (WLTC, FTP75, NEDC, J10-15, ...)

Simulation Model Characteristics

The physical engine characteristics are represented by a mean-value engine model with crank-angle-based torque modulation, dynamic manifold pressure, temperature calculation, and several fuel injection models. A soft ECU is included for scenarios where a real ECU is not available, for example, in offline simulation. To simulate the engine in an automotive system (car or truck), the engine model incorporates a longitudinal drivetrain model with manual and automatic transmission, a clutch, a torque converter, a starter, and a test bench mode. Models for the environment and driver complement the virtual powertrain.

More detailed information available

- www.dspace.com/asm



Schematic of the air system.

ASM Diesel/Gasoline Engine In-Cylinder

Real-time engine models with in-cylinder pressure and temperature simulation

Main Model Components

- Air system
- Fuel system
- Valve system
- Piston engine
- Diesel aftertreatment system
- Turbocharger
- Drivetrain (basic)
- Vehicle dynamics (longitudinal)
- Environment (basic)
- Soft ECU

Features at a Glance

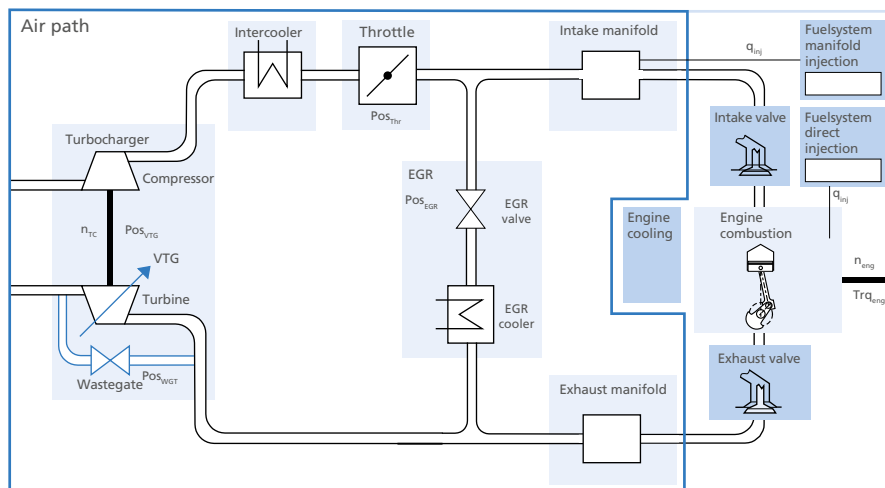
- Simulation of in-cylinder pressure and temperature in real time: for example, in response to injection or variable valve timing
- Diesel applications with up to 20 cylinders with common rail and turbocharger for real-time simulation.

- Up to 8 direct injections and 4 port injections per cylinder per cycle
- Gasoline applications with up to 20 cylinders with direct or port injection and turbocharger for real-time simulation.
- Gasoline exhaust system, including dynamic three-way catalyst simulation with respect to oxygen storage capacity
- Diesel: multiple injection patterns such as pre-, main and post-injection
- Gas exchange simulation related to the lift of the intake and exhaust valves
- Fuel injection systems: common rail injector (Diesel), direct or port injection (Gasoline)
- Exhaust-gas recirculation (EGR) of exhaust and fresh air with EGR cooler
- Start/stop system support
- Simulation of parallel intake and exhaust air paths for V-type engine

Simulation Model Characteristics

The ASM Diesel Engine In-Cylinder Simulation Package and the Gasoline Engine In-Cylinder Simulation Package are open Simulink models for developing and testing electronic control units (ECUs) with engine management based on the in-cylinder pressure. The models simulate in-cylinder pressure in real time by means of a zero-dimensional thermodynamic approach. The diesel combustion process simulation can

handle multiple injection patterns such as pre-, main and post-injection. In the combustion process, gas exchange simulation is related to the lift of the intake and exhaust valves. The gas-dynamical behavior of the air path and exhaust path is implemented as a mean value system with manifold pressure, temperature, and mass calculation. The inlet and exhaust valves are modeled as isentropic orifices. They can handle variable valve timing (VVT), variable valve lift (VVL), and the simulation of engines without a camshaft. To simulate the engine within an automotive system (car or truck), the engine model incorporates a basic longitudinal drivetrain model. Models for the environment and driver complement the virtual powertrain.



Schematic of the air system.

More detailed information available

- www.dspace.com/asm

ASM Turbocharger

Physical turbocharger model

Main Model Components

- Compressor
- Turbine
- Wastegate valve
- Shaft



Features at a Glance

- Calculates air path with the precision of a physical model
- Wastegate valve and variable turbine geometry (VTG)
- Turbocharger state calculation based on common manufacturer maps including heat loss calculation
- Alternative to map-based model with easy switching between map-based and physical approach
- Support of diesel and gasoline engine models
- Support of SAE J922 turbine model data format
- Single and double stage turbocharger
- Centrifugal compressor or positive displacement compressor (supercharger) simulation

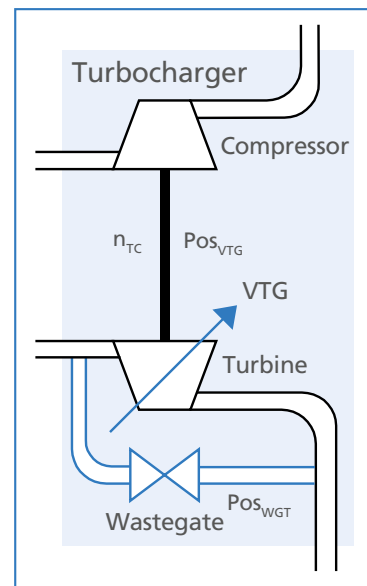
Simulation Model Characteristics

The Turbocharger Model is an extension for the diesel and gasoline engine models. It provides a more realistic model of turbocharger components and the engine air path than the map-based turbochargers models. It simulates an exhaust gas turbocharger that consists of a compressor, a turbine, and a turbocharger shaft. Turbochargers with variable turbine geometry (VTG) and wastegate can be simulated.

The turbine model calculates the mass flow, the output temperature, and the resulting power output according to wastegate or VTG position. The compressor and turbine are connected by a shaft, and the model provides the shaft speed. The compressor model calculates the boost pressure and the temperature in the compressor, using the equations for compressor power and compressor output temperature.

More detailed information available

- www.dspace.com/asm



Schematic of the turbocharger system.

ASM Diesel Exhaust System

Real-time diesel aftertreatment system

Main Model Components

- Diesel oxidation catalyst (DOC)
- Diesel particulate filter (DPF)
- Selective catalytic reduction (SCR)
- Support of all ASM engine diesel models

Diesel Particulate Filter Model

The diesel particulate filter model is designed to remove diesel particulate matter (DPM) from the exhaust gas.

Diesel Oxygen Catalyst Model

The diesel oxygen catalyst model simulates the physical effects of an oxidation process on the exhaust gas. The underlying but unmodeled chemical process can be described by using excess O_2 (oxygen) in the exhaust gas stream to oxidize CO (carbon monoxide) to CO_2 (carbon dioxide) and HC (hydrocarbons) to H_2O (water) and CO_2 .

Selective Catalytic Reduction (SCR) Model

For NO_x reduction, a model with selective catalytic reduction (SCR) is included. The model calculates the physical and chemical processes of AdBlue injection into the exhaust gas.

Diesel Aftertreatment System

The diesel aftertreatment system is a combination of models of an oxidation catalyst, a particulate filter, and a selective reduction catalyst. The system assumes an ideal gas with a steady gas constant. The different catalyst and filter models can be combined in any order. During simulation the pressure drop over the aftertreatment system is calculated as well as the temperatures and lambda of the exhaust gas before and after the system.

Components and Characteristics

- Lumped parameter model
- One-layer approach
- Filter regeneration support

Components and Characteristics

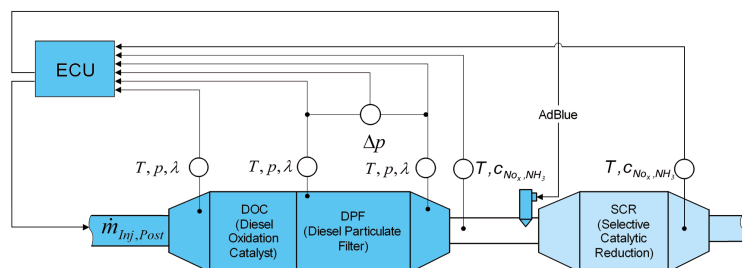
- Pressure drop over DOC/DPF
- Temperature before and after DOC/DPF
- Lambda before and after DOC/DPF
- Particulate mass in DPF
- DPF regeneration by post-injection or additional injection

Components and Characteristics

- Zero-dimensional approach
- Series connection of identical cells
- Number of cells represents the sectional discretization
- Outputs of one cell are inputs of the following cell
- Adblue dosing system with and without air supply
- Urea decomposition upstream of the SCR catalyst

More detailed information available

- www.dspace.com/asm



Schematic of the diesel exhaust system with DOC, DPF and SCR models.

ASM Drivetrain Basic

Longitudinal driving characteristics including dedicated transmission models

Application Areas

- Test of dual clutch transmission control units
- Longitudinal vehicle simulation (e.g. for testing power-train control units)

Components and Characteristics

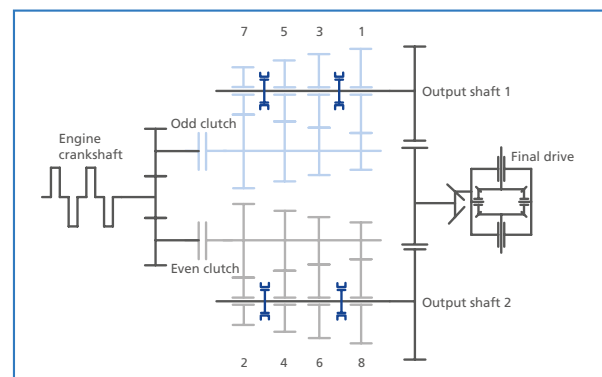
- Ready-to-use physical demo model for dual clutch transmission systems
- Soft ECU for automatic transmission including conventional systems, automated manual transmission systems as well as dual clutch transmission systems
- Map-based combustion engine simulation with fuel consumption estimation
- Empirical simulation of conventional transmission systems
- Physical simulation of mechanics and hydraulics of a

dual clutch transmission system (also applicable for automated manual transmission systems)

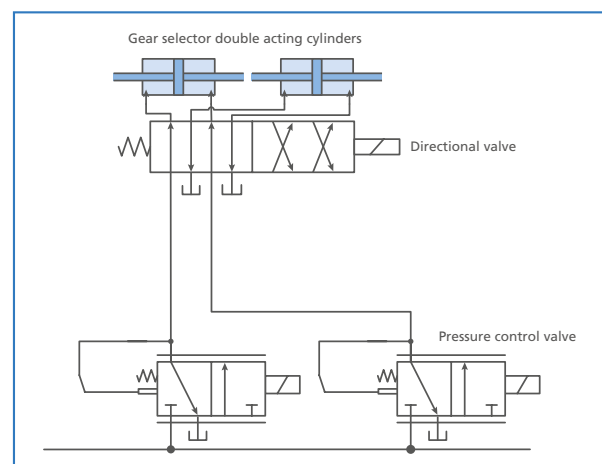
- Longitudinal vehicle dynamics
- Simulation of longitudinal driver behavior for realistic pedal actuation, including preview capability and physical driver limits
- Flexible gear actuation for various stimulus and reference signal scenarios
- Simulation of vehicle start button control systems

Dual Clutch Transmission Tests

Testing dual clutch transmission (DCT) control systems requires a sophisticated simulation of the coupled mechanical and hydraulic parts. Depending on the shaft speeds of the DCT gearbox, the control unit requests a preselection of the most probable gear by actuating hydraulic valves that create a movement of mechanically synchronized elements. As soon as the shaft speeds reach an adequate range, the next gear is engaged and the control unit smoothly moves from one output shaft to the other by actuating both clutches. In order to provide a real-time-capable model that can be applied to DCT systems of different topologies, a general approach was implemented, which allows the user to parameterize the system (e.g., gear distribution on the output shaft) or to adapt the system directly in the open Simulink model. A Soft ECU is provided with the dynamic simulation model to control the DCT system without the real controller. As soon as a real ECU is available, the actuator loops can be switched from the virtual to the real controller.



DCT example configuration.



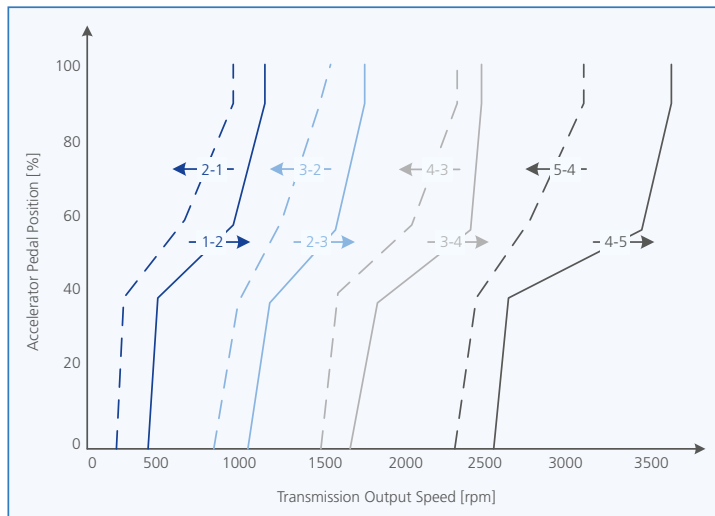
Hydraulic shift actuation system.

Longitudinal Driving Characteristics

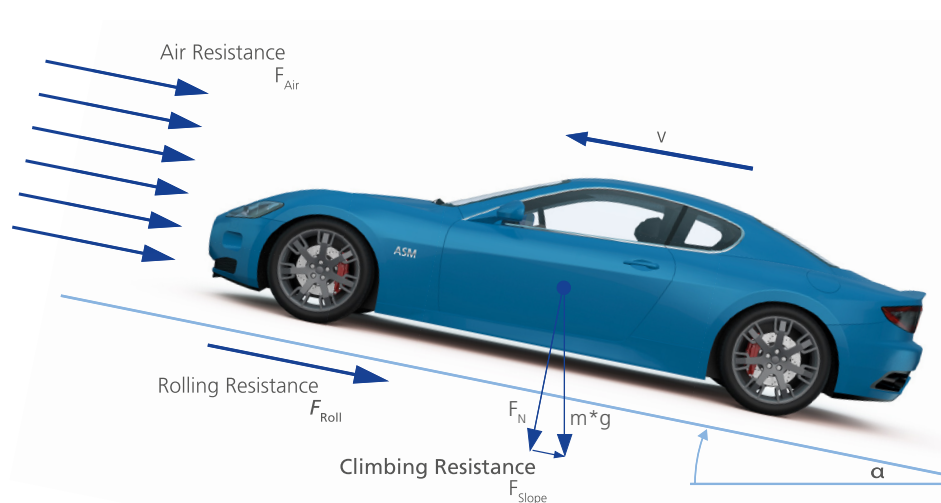
Longitudinal driving simulation methods are commonly used in testing scenarios of powertrain control units to follow a given reference velocity. The vehicle resistances, such as slope and aerodynamics as well as the driver capabilities, such as pedal actuation and gear shifting, have to be modeled.

Depending on whether the vehicle velocity is defined as a reference signal or the gears and/or pedals are given as stimulus signals, there are several use cases for the driver that have to be taken into account for simulation. Each

operation mode has to be simulated as realistically as possible to also account for efficiency analysis and test bench applications like engine- or drivetrain-in-the-loop scenarios. Preview capabilities on the required vehicle speed improve the velocity tracking performance. Furthermore, situations, such as engine startup/stall, gear skipping (e.g., truck applications), and adaptable clutch actuating behavior during gear shifting are only some examples of a highly flexible longitudinal driver implementation.



Transmission speed depending shift strategy.



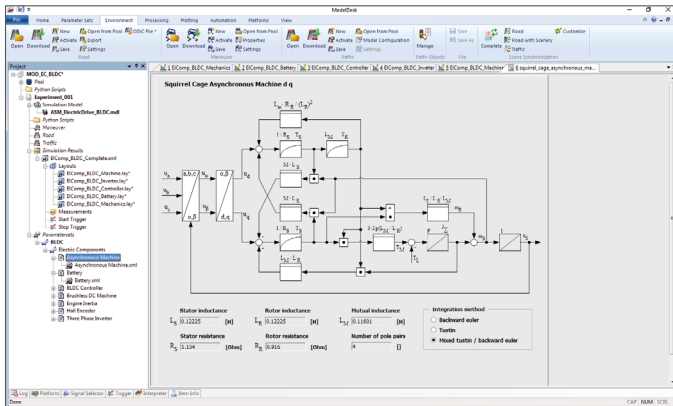
Basic vehicle dynamics model for sufficient engine simulation.

Electric Components Simulation

Real-time models for vehicle electrics and electric drive system simulation

Simulation Packages and Models

- Processor-based plant model components, including motors, power electronics and batteries
- FPGA-based plant model components, including motors, power electronics and position sensors



Parameterization of vehicle electric systems, drives, and other electric components.

Example Use Case: Testing the Charging Control Unit of an Electric Vehicle

The Task

Developing and testing the DC charging process using a vehicle charging controller.

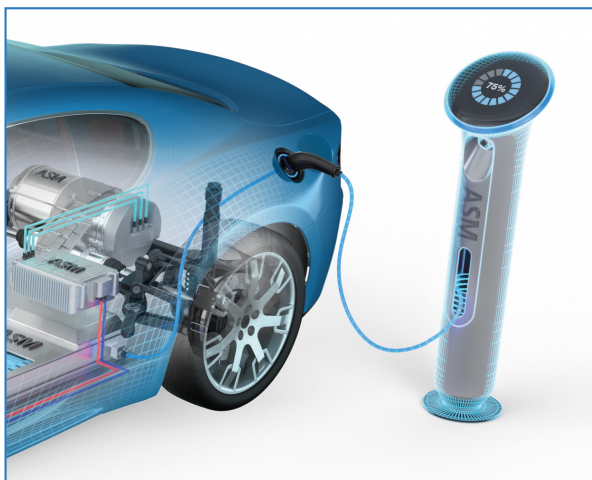
The Challenge

The charging controller monitors the high-voltage battery of the vehicle to ensure reliable charging. During the charging

process, the in-vehicle charging controller and the charging station interact. It is therefore necessary to equip the HIL systems used to validate the interaction and control algorithms with plant models of the battery and of the charging station.

The Solution

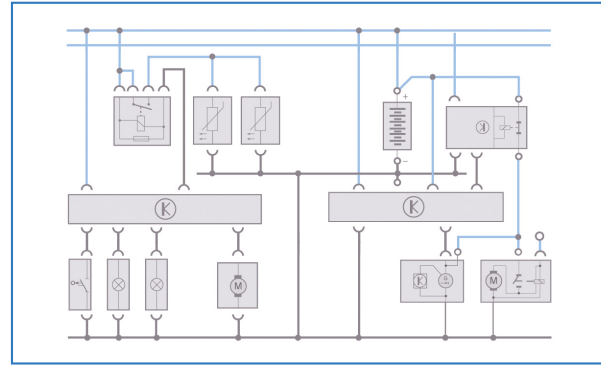
ASM provides a ready-to-use demo model for battery electric vehicles, including the real-time-capable simulation of the high-voltage battery. The demo model also includes a charging station emulation where the DC charging voltage depends on the vehicle current demand provided by the in-vehicle charging controller under test. If no real in-vehicle controller is available, ASM provides a software control unit that applies a constant current constant voltage (CCCV) charging process, which includes a pre-charge phase for low cell voltages. The models of the ready-to-use demo model are completely prepared so that all the signals required for communication with the control units are available. This enables users to test the control algorithms and the interfaces between all devices according to standards such as CHAdeMO, ISO 15118, and GB/T 20234.2.



ASM Electric Components

Automotive electrical system

ASM Electric Components consists of automotive electrical system simulation components and closed-loop simulation components. Applications can range from electric drives and inverters for closed-loop simulation with an ECU to a complete automotive electrical system, including battery, starter, alternator, and loads. The automotive electrical system simulation components can be used directly to create the electric circuits of an automotive system since they already have all the necessary automotive features. These models are also optimized for real-time HIL simulation.



Main Model Components

- Battery
- Starter
- Alternator
- Air conditioning
- Loads
- Supercapacitor

Demo Models

- Demo model for simulating a vehicle electrical system with starter, alternator, battery and different electrical loads like an electrically driven air conditioning.
- Demo models for simulating a hybrid vehicle or powertrain with ASM Vehicle Dynamics or ASM Engine simulation models.

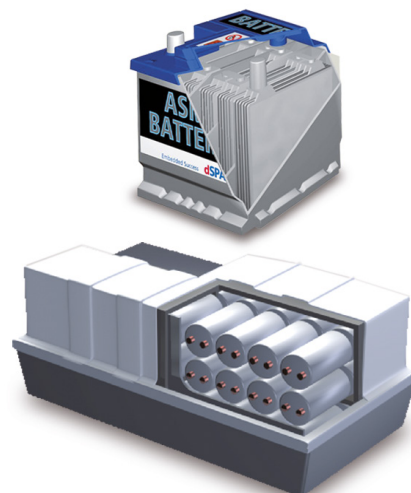
- **NEW:** Demo model for simulating a battery electric vehicle with ASM Vehicle Dynamics, including a charging station emulation and air conditioning system.

Features at a Glance

- Ready-to-use components with automotive features
- Simulation of a complete automotive electrical system
- Simulation multicell battery modules connected in series and in parallel
- Prepared for testing battery management controllers
- Temperature simulation of each individual battery pack cell and its thermal interaction with neighbor cells. Cooling plate of battery pack surfaces.

Application Example

To simulate high voltage batteries like Li-ion consisting of a series of multiple battery cells the ASM Electric Components Model features a cell simulation model. The ASM Battery Multicell Model consists of a cell voltage model, a charge state model and a thermal model. With the cell voltage model, individual physical effects such as internal resistance, inductance and double layer capacity as well as diffusion behavior can be simulated. The charge state model deals with the cell's charge and discharge currents, and also with leakage currents such as those caused by gassing effects in the charging of NiMH cells. The thermal battery model simulates the temperature for each separate cell and the thermal interaction with neighbor cells. A cooling plate can be simulated for the six battery pack surfaces. The dSPACE EV1077 Battery Cell Voltage Emulation Board is used to connect the real BMS controller.



Electric drives closed-loop

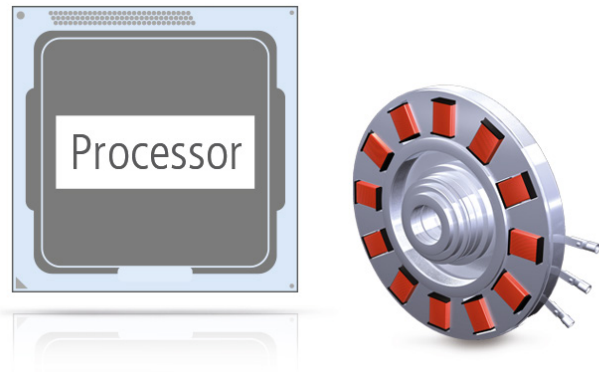
The closed-loop components are ideal for HIL simulations of electric devices such as drives or inverters in a closed control loop. The models are especially designed for pulse width modulation (PWM)-synchronous model calculations and optimized solvers for real-time simulation. ASM Electric Components can be combined with other ASM products such as the combustion engine and the vehicle dynamics models.

Main Model Components

- Permanent magnet synchronous motor (PMSM)
- Brushless DC motor (BLDC)
- Asynchronous squirrel cage induction motor
- Discontinuous conduction mode (DCM) inverter
- Three-level inverter
- Controllers
- Various auxiliary blocks
- Three-phase rectifier

Demo Models

- Demo models for brushless DC motor, induction motor and permanent magnet synchronous motor available.

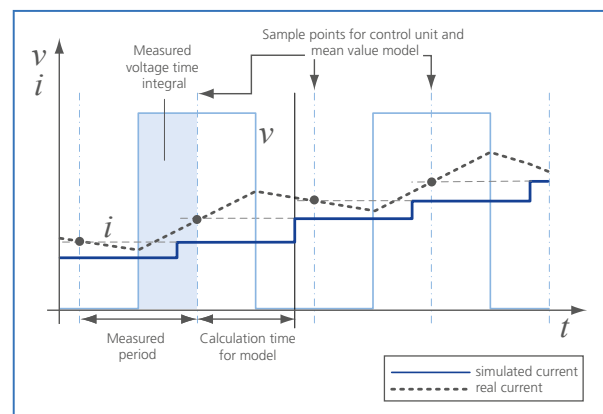


Features at a Glance

- Simulation of electric drive components and power electronics in a closed loop with an ECU
- PWM-synchronous model calculation
- PMSM machines with current-dependent differential inductances
- Three-phase rectifier with six power diodes connected in a bridge configuration.
- Delta-star connection configurable for three-phase motor models
- Advanced inverter model supporting DCM (discontinuous conduction mode)
- Open models can be modified or partly replaced by users

Application Example

For a closed-loop simulation on signal level, all power electronics devices are removed from the device under test. Power electronics models and motor models from ASM Electric Components are simulated together on the HIL system. To close the loop, the HIL system is connected to internal interfaces of the device under test such as the signals of the gate drivers and to the signals of the current transducers. This approach allows maximum scalability and full model access. For the real-time simulation of electric drive systems, dSPACE provides a FPGA-based I/O solution (SCALEXIO EMH Solution) for capturing the gate driver signals, simulating the motor current, and simulating various position sensors. This is where the power electronics and motor models are calculated on real-time processors (e.g. SCALEXIO). If faster model calculation is required, the HIL hardware can also be used for FPGA-based simulation using XSG Electric Components.



Current output signal of a processor-based mean-value motor model resulting in a stepped current simulation.

XSG Electric Components

Electric motor control applications that demand great precision and correspondingly high sample rates are simulated best on field-programmable gate arrays (FPGA). In addition to the plant models for electric drives and power electronics, the XSG Electric Components Library is supplemented by enhanced I/O functions for position sensor simulation. All components are implemented as Xilinx® System Generator (XSG)¹⁾ models that run on dSPACE FPGA boards (e.g. DS2655).

Main Model Components

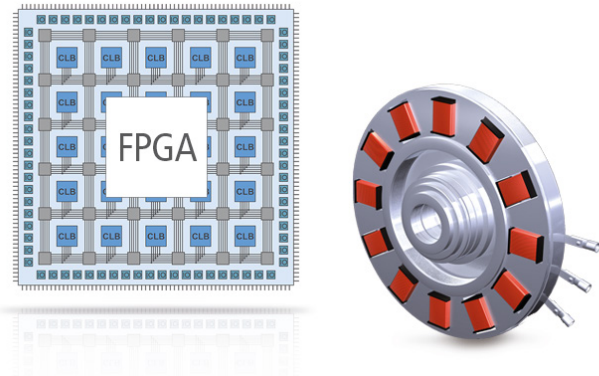
- Permanent magnet synchronous motor (PMSM)
- Brushless DC motor (BLDC)
- Asynchronous squirrel cage induction motor
- Discontinuous conduction mode (DCM) inverter
- Position sensor models
 - Resolver
 - Sine encoder
 - TTL encoder
 - Hall encoder

Demo Models

- Demo models for permanent magnet synchronous motor available.

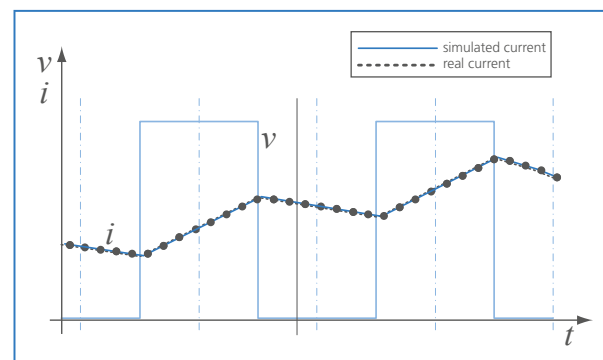
Application Example

Using FPGA-based simulation, closed-loop simulations of electric devices and their controls is supported at very high sample rates in real time. XSG Electric Components can be used for electric-motor simulation both at signal and power level. For simulations at power level, the power stage is a real component. To generate real currents and voltages high-performance electronic loads are required (DS5381). To integrate FPGA models on a dSPACE system the RTI FPGA Programming Blockset provides a Simulink library created with the Xilinx® System Generator Blockset.



Features at a Glance

- Simulation of electric motors and power electronics in a closed loop with an ECU
- Advanced inverter model supporting DCM (discontinuous conduction mode)
- Delta-star connection configurable for three-phase motor models
- High precision and stability
- No PWM synchronization necessary
- Current ripple (PWM effects) can be simulated
- Increased precision when simulating higher fundamental frequencies
- Open models can be modified or partly replaced by users
- Highly nonlinear electric motor models available on request



Current output signal of a FPGA-based motor model resulting a quasi continuous current simulation.

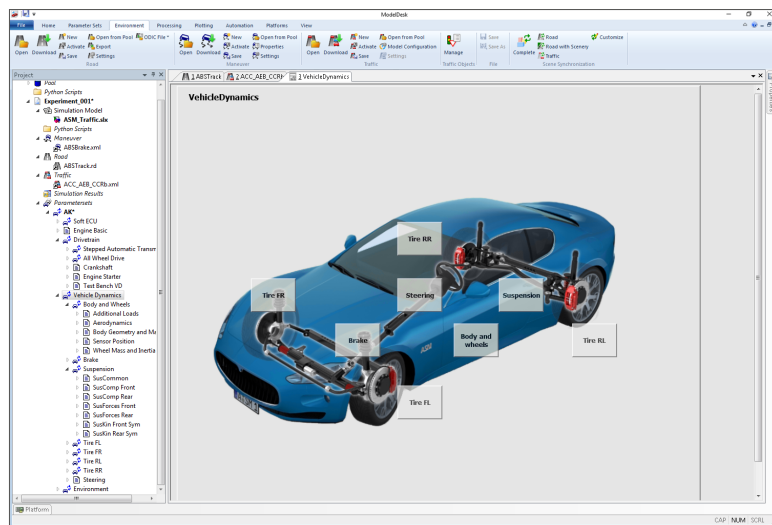
¹⁾ Please note that due to the introduction of the Vivado® software, Xilinx® will no longer support the Xilinx System Generator for DSP in combination with the ISE Design Suite after MathWorks® MATLAB® and Simulink® Release R2013b.

Vehicle Dynamics Simulation

Real-time models for ground vehicle simulation

Simulation Packages and Models

- Passenger cars
- Trucks
- Trailers
- Brake hydraulics and pneumatics



Parameterization of the vehicle dynamics model.

Example Use Case: Coupling of Driving Simulators with a Driving Dynamics Simulation

The Task

Using vehicle dynamics models to generate the realistic behavior of a mechatronic driving simulator.

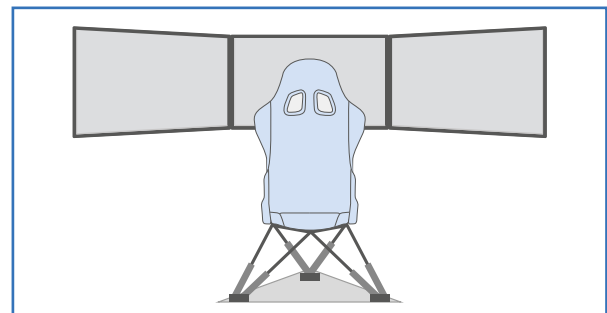
The Challenge

Driving simulators offer the possibility of subjective and objective observations of the vehicle behavior in specific driving situations. This behavior has to be simulated realistically depending on the driving situation. For this purpose, a virtual vehicle and its environment must be flexibly configured and executed in real time.

The Solution

The ASM Vehicle Dynamics model simulates the driving dynamics of a vehicle depending on the driving request. Axle drive, dimensions, and weight can be selected individually as well as important details for the design of the chassis. The simulation is performed either on freely defined

routes or on routes imported from road maps. ASM Vehicle Dynamics supports switching between different components or parameterizations during operation for quick comparisons. This way, several differently parameterized or configured axles can be successively tested, for example. The vehicle dynamics simulation is performed on a real-time platform from dSPACE and can be connected to the mechatronic driving simulator via its interfaces.



ASM Vehicle Dynamics

Vehicle multibody system plus drivetrain, roads, maneuvers, and driver

Main Model Components

- Engine (table based)
- Drivetrain
- Vehicle dynamics
- Environment
- Brake hydraulics and pneumatics
- 3DoF steering model

Application Software

- ModelDesk
- MotionDesk

Engine Model

Included table-based engine that supports ECU interventions. It can be easily replaced by a full-featured gasoline or diesel engine model.

Components and Characteristics

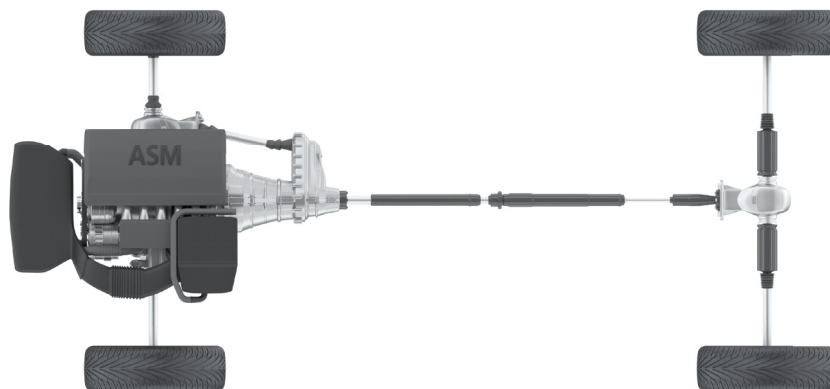
- Several strategies (injection, throttle) for reducing and increasing torque as requested by an ESP/TCS ECU
- Starter to accelerate the engine to idle speed

Drivetrain Model

The drivetrain model has manual and automatic transmission, and front-, rear-, and all-wheel-drive. The shaft drives are modeled as elastic components.

Components and Characteristics

- Clutch with elasticity (torsion spring)
- Elastic shafts included
- Front-, rear-, and all-wheel drive including differentials
- Manual and automatic transmission with torque converter
- Model stabilized by semi-implicit Euler integration method
- Drivetrain with 13 degrees of freedom (DoFs)



Overview of the drivetrain model configured with all-wheel drive. Modes for rear- and front-wheel drive are also available.

ASM Vehicle Dynamics

Vehicle Multibody System Model

The system is modeled as a nonlinear vehicle multibody system with geometrical or table-based suspension kinematics and table-based compliances. It supports the simulation of vertical, longitudinal, and lateral dynamics.

ASM Kinematics and Compliance (KnC) Testbench

ASM Kinematics and Compliance (ASM KnC) is an add-on to the ASM Vehicle Dynamics model that provides functions for designing and simulating wheel suspensions on a virtual test bench. Users can run virtual tests for numerous vehicle variants and driving scenarios to optimize vehicle suspensions and make them available for hardware-in-the-loop (HIL) applications.



Virtual kinematics and compliance (KnC) test bench.

Components and Characteristics

- Multibody system (MBS) consisting of car body and four wheels
- 13 degrees of freedom (DoF)
- Table-based kinematics and compliances for suspensions
- Suspension with nonlinear spring and damper characteristics
- Aerodynamics forces and torques included
- Brake model incl. physical brake booster model
- Additional masses (fixed on vehicle body)
- Sophisticated steering model with 3DoF, friction elements and rack and pinion based EPS support.
- Tire models: Magic Formula and TMEasy
- Data import from suspension design tools like ADAMS available on request

Item	DoF
Elastic powertrain	13
Body	6
Steering system	3
Wheels	4 ¹⁾

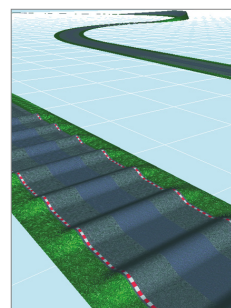
¹⁾ One independent degree of freedom per wheel for wheel vertical displacement. The wheel kinematics are included via the MBS algorithm.

Environment

The environment features models for the road, scenario and driver. Roads and scenarios are generated in ModelDesk.

Components and Characteristics

- Driver with lateral and longitudinal control
- Roads consisting of segments with slope, inclination and individual profiles
- Driving scenarios from ModelDesk or manual driving



More detailed information available

- Product Brochure: ASM Vehicle Dynamics
- www.dspace.com/asm

A road consists of segments that can be configured individually: bumps, a longitudinal and lateral inclination, etc.

ASM Truck

Truck model for tractor and trailer simulation

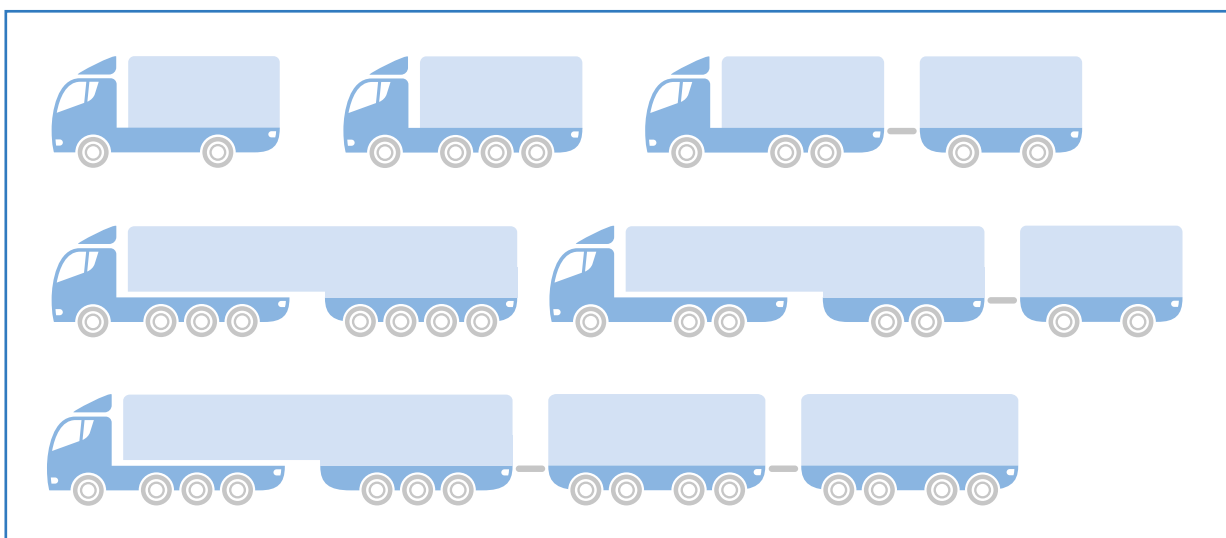
The Truck Tractor Model

ASM Truck is used together with ASM Trailer to simulate a truck (tractor with dolly) or a tractor-semitrailer combination. The models contain more than 30 degrees of freedom (DoF) in the multibody dynamics and more than 25 DoF in the powertrain depending on the configuration. The truck model features a torsional frame and truck cabin. The entire vehicle model can have an arbitrary number of axles, each of which can be steered, driven, and equipped with twin tires. Even road train, thus multiple trailers, can be simulated. It is easy to modify the configuration even during run time without manipulating the model. For example, during the simulation, axles can be activated and deactivated, and trailers can be hitched and unhitched.



Components and Characteristics

- Multibody dynamics with more than 20 DoF (depends on truck configuration)
- Powertrain with more than 25 DoF (depends on truck configuration)
- Truck body based on a torsional frame
- Tractor and trailer with an arbitrary number of axles, each of which can be steered
- Hydraulic or pneumatic brake system (ASM Brake Hydraulics, ASM Pneumatics)
- Each wheel can be equipped with a brake
- Table-based axles with 3 DoF
- Twin tires as an option on all axles
- Axles can be activated and deactivated during simulation
- Trailers can be hitched and unhitched during simulation
- Dolly extension for road train simulation
- Vehicle configurations with arbitrary numbers of axles available on request
- Truck cabin with additional DoFs
- Each axle can be driven



Examples of trailer and axle variants supported by ASM Truck and ASM Trailer.

ASM Trailer

Trailer model with hitch and four axles

The Trailer Model for Cars and Trucks

ASM Trailer is an extension to the ASM Vehicle Dynamics Simulation Package. It is based on a multibody system consisting of a trailer body, an arbitrary number of axles and an optional dolly. The model also includes suspensions, tires, brakes and aerodynamics. The connection to the towing vehicle is provided via a hitch that includes mechanical stops. The trailer and all axles can be activated or deactivated during simulation without new code generation.



Components and Characteristics

- Modular multibody system (MBS)
- Trailer body
- Arbitrary number of axles (all axles steerable)
- Dolly extension for full trailer simulation
- Multiple trailers (road train) as an option
- Tire models TMEasy and Magic Formula
- Table-based suspension
- Ball-joint hitch (including mechanical stops)
- Brakes
- Aerodynamics
- Additional loads
- Graphical parameterization in ModelDesk



The trailer can be configured as a semitrailer or it can have an optional dolly extension. It supports the simulation of road trains consisting of a truck tractor and multiple trailers.



The trailer model can be configured for different trailer types, and it can be used with various towing vehicles.



Trailer coupling/uncoupling

Axle activation/deactivation

The trailer, axles, and wheels can be modified during simulation, e.g., trailer coupled/uncoupled, axles activated/deactivated, and the wheels can have single tires or twin tires. No code generation is required.



ASM Pneumatics

Air brake and air suspension models

Application Areas

- Air brakes
- Air suspensions
- Supports ABS/EBS and suspensions (car, bus, truck, truck dolly, tractor trailer, road train)

Components and Characteristics

- Complete model including compressor, tanks, valves, and brake chambers
- Ready to use ABS/EBS and suspension configurations
- Support for mechanical/pneumatic backup functions
- Support for trailer brake systems
- Graphical user interface for parameterization
- Offline and online simulation
- Real-time capable
- Modular, library-based implementation
- Easy variable access
- Add-on library for ASM Vehicle Dynamics, ASM Truck and ASM Trailer



Pneumatics Model Concept

The pneumatics model provides ready-to-use configurations for air brake and air suspension simulations. Handling and parameterization are done via a comfortable graphical user interface.

ASM Brake Hydraulics

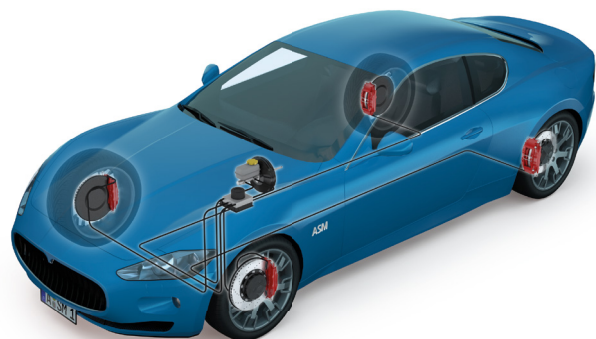
Dual-circuit brake hydraulics

Hydraulics Model for Braking Systems

The modeled ESP braking system consists of a dual-circuit hydraulics system. The model contains all the components like valves, chambers, accumulators, pumps, and braking cylinders that are necessary for simulating a standard state-of-the-art ESP braking system.

Components and Characteristics

- Linear and physical master brake cylinder model
- Valves with continuously controllable cross-sections
- Nonlinear, look-up-table based wheel brake cylinder
- Graphical parameterization in ModelDesk
- Active brake booster
- Simulation of X- and II-brake system structures



More detailed information available

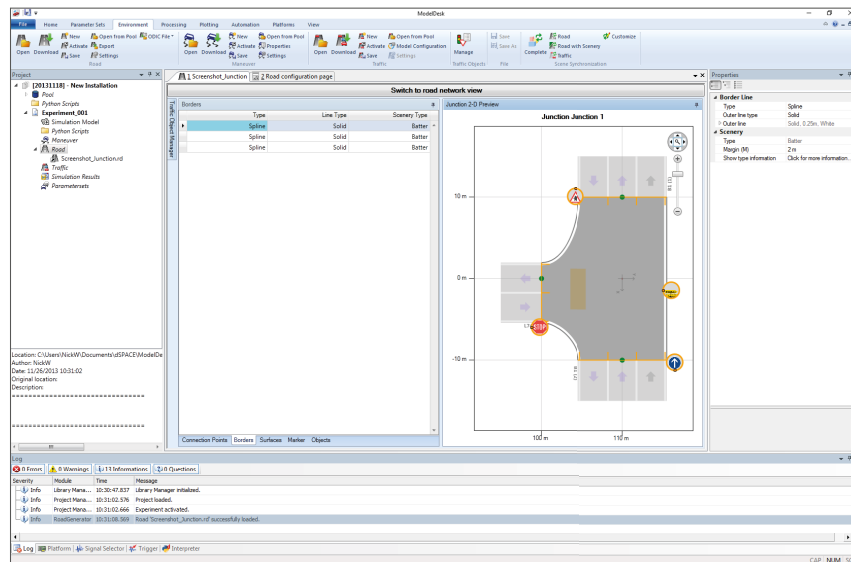
- Product Brochure: ASM Vehicle Dynamics
- www.dspace.com/asm

Traffic Simulation

Real-time models for traffic and environment simulation

Simulation Package

■ Traffic



Graphical definition of an intersection.

Example Use Case: Probabilistic Sensor Models for ADAS/AD Simulations

The Task

Algorithms of autonomous vehicles are tested by means of simulation in complex traffic scenarios to validate them at an early stage. This requires sensor models with which the simulated vehicles can detect their environment and react to it.

The Challenge

To feed the ECU software of autonomous vehicles with sensor signals in simulations, they must be processed exactly as output by a real sensor. If the sensor behavior itself does not have to be taken into account, it is sufficient to calculate classified objects and their respective motion data.

The Solution

ASM Traffic contains generic models for different sensor types, such as radar and lidar. The sensor simulation provides ideal data (ground-truth information), which can optionally be superimposed with probabilities of events (probabilistic effects). For example, superimposition is used to simu-

late a typical measurement noise of radar. The simulation returns a lists of classified objects (vehicles, pedestrians, cyclists, traffic signs etc.) as well as their coordinates and motion data (distance, relative speed, relative acceleration, relative azimuth and elevation angle). These models are suitable for SIL simulation with virtual ECUs (V-ECUs) as well as for HIL simulation in hard real-time with real ECUs.



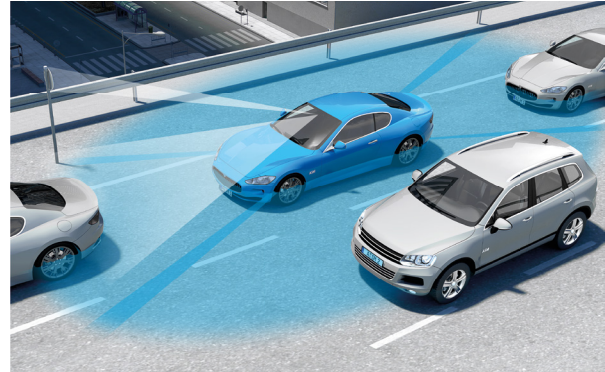
ASM Traffic

Real-time environment simulation with traffic, objects, and sensors

Features at a glance

- Simulation of complex traffic scenarios
- Road network simulation
- Static and moving objects like traffic signs and vulnerable road users
- Multiple traffic sensor types supported
- Graphical definition of roads, scenarios, and environment

(For information on defining traffic scenarios, please see the Traffic Editor which is part of ModelDesk, p. xxx)



Application Areas

ASM Traffic adds traffic and environment simulation to dSPACE's Automotive Simulation Models (ASM). It supports you in developing and testing advanced driver assistance systems (ADAS) that react to other vehicles or objects, like adaptive cruise control (ACC) and intersection assistants. The model simulates a road network, the vehicle under test, a multitude of fellow vehicles and the necessary environment. The test vehicle can be equipped with multiple sensors for object detection and recognition (ego-vehicle). ASM Traffic is typically used for hardware-in-the-loop testing of electronic control units (ECUs) or for early function validation by offline simulation during the design phase of controller algorithms.

Key Benefits

ASM Traffic is so flexible that any kind of traffic scenario can be created to ensure thorough testing of ADAS controllers. It supports the creation of complex road networks, and you can define sophisticated traffic scenarios on the roads. The simulated environment can consist of static and movable objects, like traffic signs and pedestrians. Various sensor models and user-definable sensors are available to detect these objects. To test pre-crash functionalities, you can define traffic scenarios that in real life could result in an accident, and observe system behavior under challenging conditions. Traffic scenarios can be modified and immediately simulated without having to generate code again.

Components and Characteristics

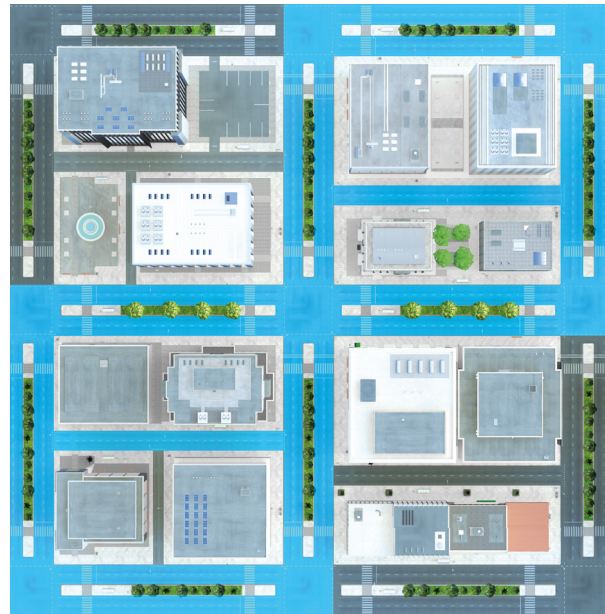
ASM Traffic consists of a graphical user interface (GUI) and a set of simulation models that perform in real time. The GUI provides several interfaces to define the necessary components like road networks, traffic signs, traffic vehicles, and sensors. Trajectories for all vehicles, objects and pedes-

trians are calculated in real time according to the defined traffic scenarios. ASM Traffic supports specific scenarios such as oncoming traffic, stop and go, and pedestrians. The Scenario Editor is the user interface for very flexible and easy traffic scenario definition.

Road Networks

Features

- Road networks with roads and intersections for vehicle dynamics and ADAS use cases
- Segment- and coordinate-based road definition
- Lanes with smooth transitions and specific line definitions
- Up to 5 lanes per lane segment
- Support for lane detection sensors
- GPS coordinate exchange with turn-by-turn navigation development tools
- Simulation of tire characteristics and road surface conditions like split- μ surfaces, bumps, potholes
- Simulation of lines according to EU regulation 351/2012 and support of free lines and barriers for construction area simulation.
- Import and Export of OpenDRIVE-format

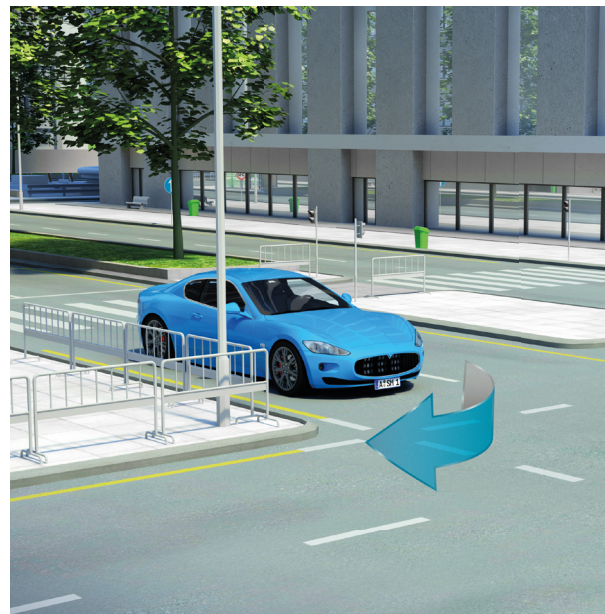


Define roads and junctions graphically.

Scenario EGO-Vehicle

Features

- Movement control of vehicle under test (ego-vehicle)
- Scenario segments defined by distance or time
- Event-based segment changes
- Lane driving and lane transition/change definitions
- Trigger events for specific scenario activities
- Open- and closed-loop scenarios
- Velocity, steering, and pedal actuation can be set by using measurement data
- User output signals programmable via time and distance
- External velocity and pedal access for man-in-the-loop use cases

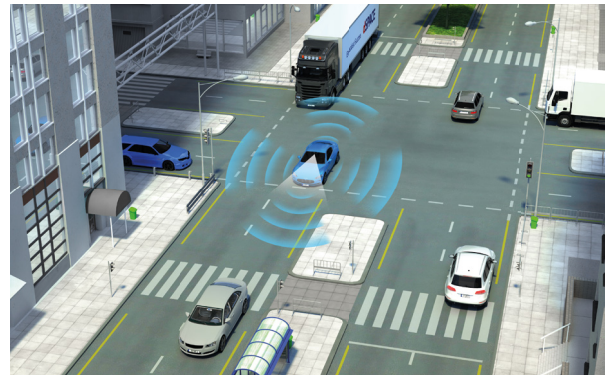


Define where and how the ego-vehicle drives on the road network.

Scenario Fellow Vehicles

Features

- Simulation of objects around ego-vehicle
- Definition of various traffic situations and complex scenarios
- Lane driving and lane change definition
- Support for intersections with oncoming and crossing traffic
- Scenarios based on distance, velocity and acceleration
- Independent and interdependent movements
- Time- and road-based trigger events
- Direct link between model and animation update
- Unlimited number of moving objects possible



Define where and how the surrounding fellow vehicles drive on the road network.

Objects and Sensors






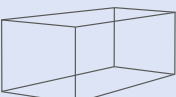
Features

- Definition of any number of traffic objects
- Road- and intersection-based positioning
- Graphical representation in MotionDesk
- Moving objects like pedestrians
- Static objects like variable traffic signs, traffic lights, parked vehicles, houses
- 2-D object sensor
- 3-D object sensor
- 3D-sensor with realistic cone scope and timing behaviour
- Line sensor
- Custom sensor
- Variable traffic sign and traffic light sensor



Define sensors on the vehicle and traffic signs, obstacles and scenery along the road.

Overview of Objects and Sensors

Sensor Type	Object	Sensor Output
Traffic Signs		Speed limit, 80
2-D		
Custom		Adult / Child
3-D		

More detailed information available:

- Product Brochure: ASM Traffic
- www.dspace.com/asm

ModelDesk

The graphical user interface

ModelDesk Concept

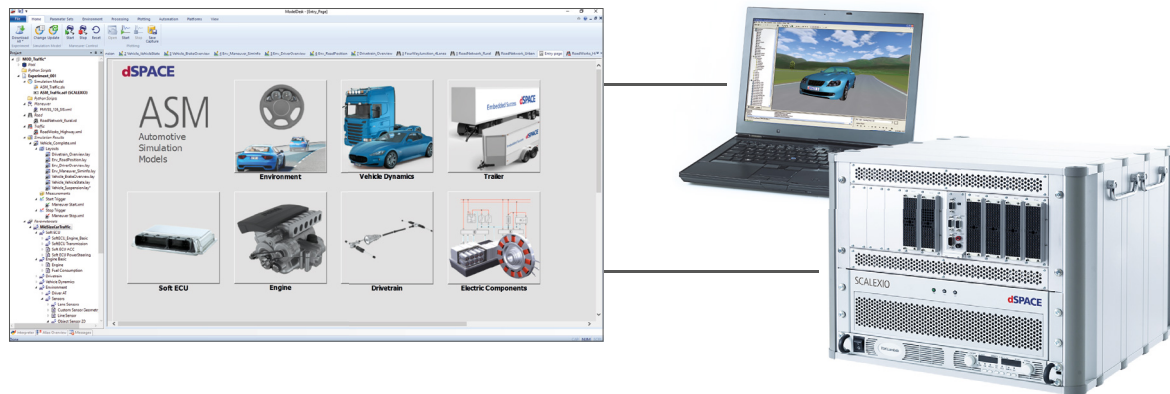
ModelDesk is a graphical user interface for simulation, intuitive model parameterization and parameter set management. It also provides project handling and allows parameter sets to be downloaded to offline and online simulations. It supports tool automation via Python scripts. ModelDesk can be used seamlessly from parameterization to offline and online simulation, and finally to parameter and result management.

Main Features

- Offline and online simulations
- Graphical user interface
- Parameter set management
- Road Generator
- **NEW:** Integrated test functionality
- Scenario Editor
- Tool automation
- Preprocessing for engine models
- Custom model parameterization

Benefits

- Seamless simulation process from MIL to HIL
- Intuitive, graphically supported parameterization
- Parameters changed online and offline
- Managing parameter sets and entire projects



ModelDesk's user interface for selecting model subsystems for configuration, parameterization, and simulation on platforms like MATLAB/Simulink, dSPACE VEOS, and dSPACE Simulator.

Graphical Parameterization

The model components and their subsystems are represented by a hierarchical graphical structure. The model components to be parameterized can be selected from the top level. Users have the vehicle model before them and can browse through its systems, guided by graphical representations of the modeled components.

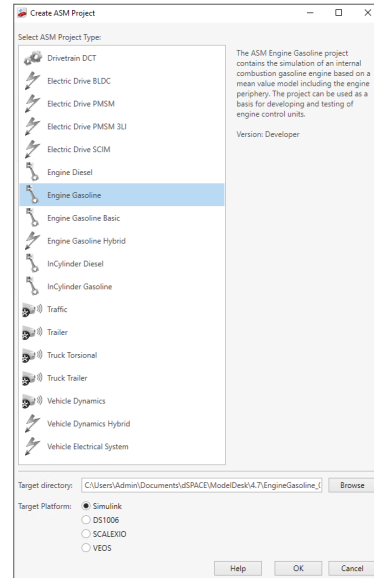
Parameter Management

ModelDesk's Project Navigator provides a means of organizing and managing large-scale model parameterization projects. Parameter files can be created and assigned to each model component (differential, tires, road, etc.), and complete vehicle parameter sets can be created and managed. Existing parameter files can be selected from a parameter pool and applied by drag & drop.

Simulation Management

ModelDesk includes powerful functions for directly executing and displaying simulations, and managing their results:

- Starting and stopping a simulation
- Maneuver control: starting and stopping predefined maneuvers and traffic scenarios.
- Plotters for visualization
- Saving, comparing and managing simulation and measurement data
- Saving simulation experiments (driving maneuvers, roads, traffic scenarios, etc.)
- Direct demo model access



Select from various demo models to jump start new projects.

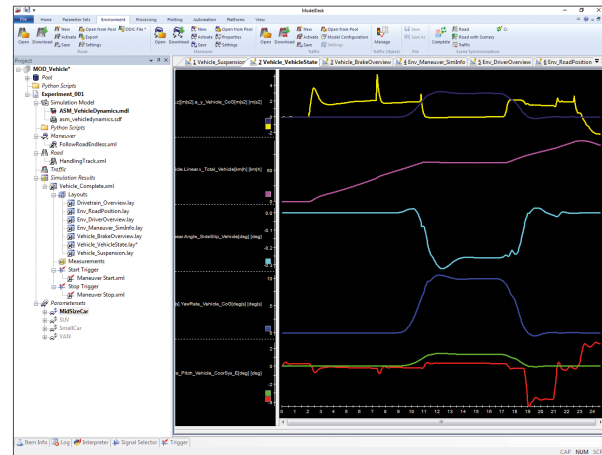
Plotter

ModelDesk features an integrated plotter which displays signals from the ASMSignalBus. The signals have the same structure as in the Simulink model. The bus can include user-defined signals. Plotter configurations can be defined and stored, and the same single configuration can be used seamlessly online (HIL simulations) and offline (Simulink simulations). A configuration includes the following data: simulation results, measurements, and parameter sets con-

sisting of vehicle parameters, roads, maneuvers, and/or traffic. A configuration collects together all the sources and conditions that the plotted results are based on.

Features

- Plots of ASM signal buses
- Plots of user-defined signals
- Plotter configurations can be saved
- The same configuration to be used online and offline
- Plot printouts
- Configuration comprises measurements, simulation and parameters



ModelDesk's plotter displaying various vehicle dynamics signals.

Visualization with MotionDesk

ModelDesk and MotionDesk work seamlessly together. In ModelDesk, users can define scene types such as country roads, tree-lined roads, and urban areas. The scenes are then automatically generated in MotionDesk with appropri-

ate objects like buildings, trees, borders, reflector posts, and street lamps. These can also be modified as required in MotionDesk's integrated Scene Editor.

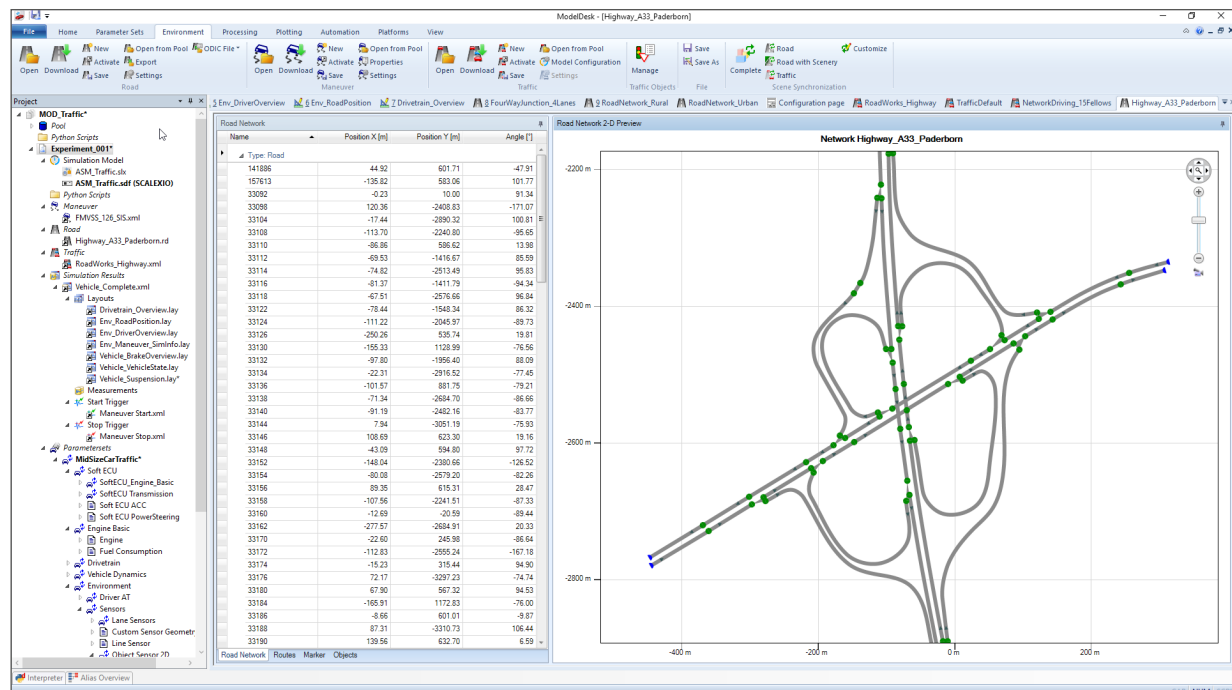
Road Networks

Road Generator

The Road Generator is the graphical user interface for defining road networks and sophisticated road features. Roads can be assembled from geometric segments or imported. Features such as lanes, intersections, height, inclination, surface condition, etc., can easily be added to a road by editing attributes that are displayed in 1-D diagrams. The whole road network is visualized in a 2-D view. The road design also interacts closely with the 3-D animation software MotionDesk to define the environment. The Road Generator gives ideal support to complex traffic scenario creation in the development and testing of advanced driver assistance systems (ADAS).

Features

- Support for vehicle dynamics and advanced driver assistance traffic scenarios
- Segment and coordinate-based road definition
- Intersections and junctions
- Lane, line and traffic sign definition
- Height, inclination, and surface condition applied via segment-independent road coordinates
- Easy definition of bumps, profiles, split- μ areas, etc.
- Dedicated 1-D and 2-D views of road features
- OpenDRIVE® format export
- Road import: map data (like OpenStreetMap, etc.), ADAS RP (Nokia HERE), and OpenDRIVE® format
- Road networks and predefined sceneries are automatically imported into MotionDesk (city center, country road, highways)
- Definition of driving routes
- Definition of lane-independent lines and shapes for concrete barriers or repeating objects
- Unlimited number of lanes
- **NEW:** Support for non-drivable lanes (e.g. bicycle lanes, emergency lanes)



The Road Generator supports the definition of intersections and complex road networks. The user interface provides a list of road segments (upper left), an overview of the whole road network (middle), and a view of lane details (right).

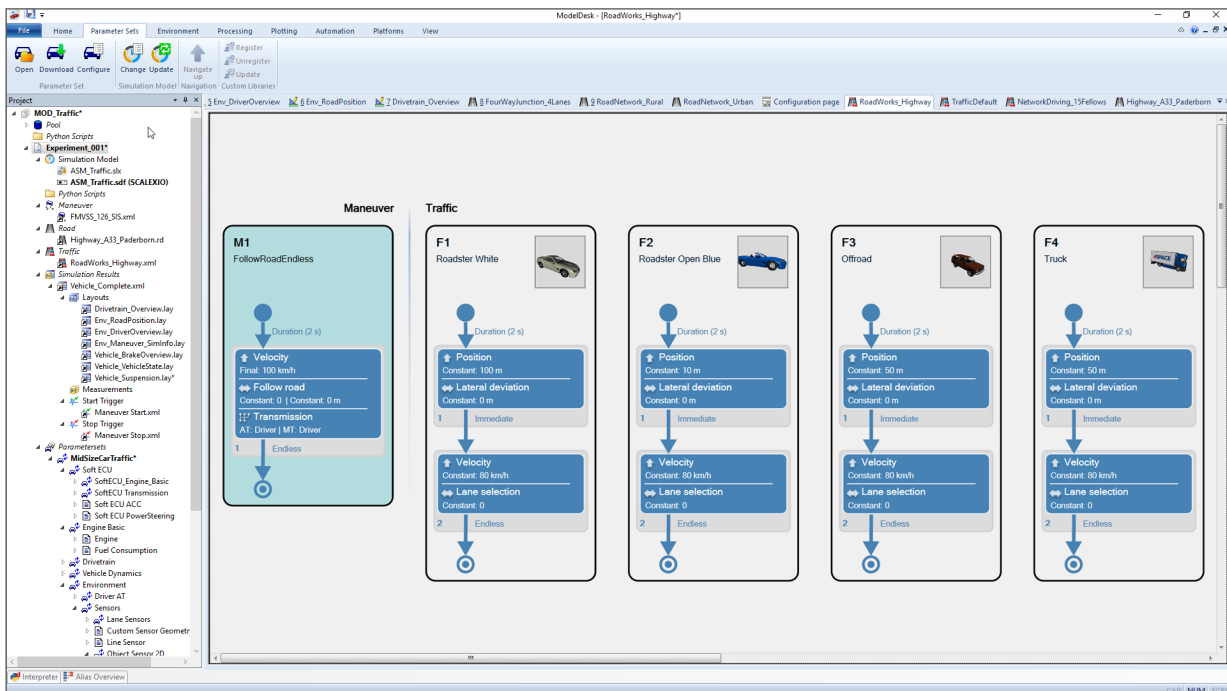
Scenarios

Scenario Editor

The Scenario Editor is used to define where and how dynamic objects, such as vehicles, pedestrians, etc. move on the road network. These types of scenarios include an EGO vehicle and optionally an unlimited number of fellow vehicles. Scenarios can be created for vehicle dynamics simulation and traffic simulation or a combination of both. Scenarios can be as simple as following a predefined road profile with route definitions or they can be complex traffic situations with a large number of vehicles, pedestrians, etc. on complex road networks. With its UML-like approach, the Scenario Editor lets you create sophisticated diagrams with good clarity. Therefore, it is the ideal tool for defining test scenarios for automated driving.

Features

- Definition of driving and traffic scenarios on road networks
- Scenario segment definition by distance or time
- Lane driving and lane change definitions
- Easy-to-use fellow vehicle activity definitions
- Definition of steering and pedal stimuli or driver-based maneuvers
- Standard maneuvers included (NCAPs, lane change, μ -split, steady-state cornering, fish hook, etc.)
- Lateral and longitudinal stimuli can be imported from measured data (MAT files).
- Programmable user output signals using time or distance
- Overview and detailed views



Example of the scenario definition page.

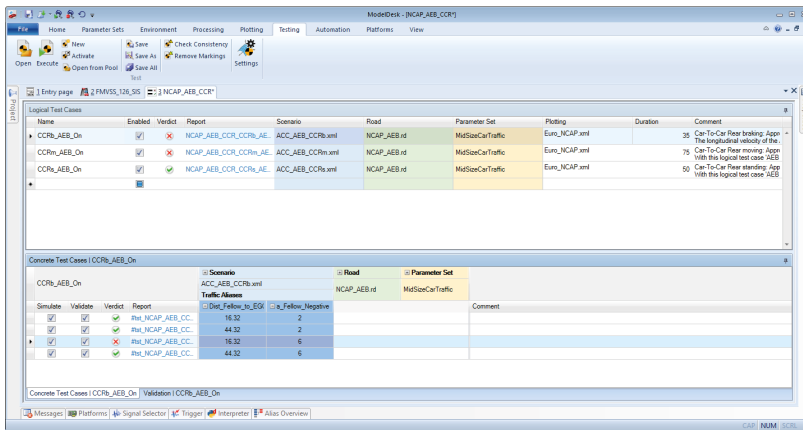
NEW: Testing

Integrated Test Automation

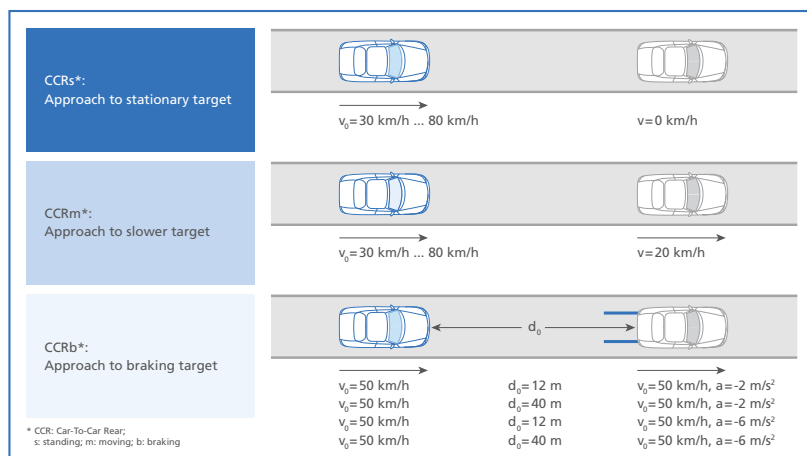
ModelDesk now provides an integrated ASM-based test functionality called Testing. It lets users define, manage and execute automated test procedures directly in ModelDesk. These procedures contain one or more simulations, which can be performed with parameter variations. This way, vehicle dynamics maneuvers, powertrain and electrical system tests as well as traffic simulations can be easily and intuitively automated and validated. In addition to the classic test automation tasks, there are other fields of application, such as direct model validation by comparing simulations and measurements or quick plausibility tests of complex scenarios for autonomous driving. Test procedures with ModelDesk and ASM can be executed throughout the entire development process on the dSPACE simulation platforms. Moreover, it is possible to integrate ASM-based tests in an overall test automation setup based on AutomationDesk and SYNECT.

Ready-to-Use Scenarios for Active Safety Tests

For a swift start, ModelDesk provides a ready-to-use test for active safety features according to Euro NCAP (European New Car Assessment Program) protocols. The test is an automated emergency braking (AEB) maneuver for moving and stationary cars (Euro NCAP AEB CCR). Using the testing function, the test is repeated with increasing velocities and varying distances and decelerations. This is done to assess an AEB system's capability to reduce the effects of an accident. Different evaluations can be conducted for each test case, such as simple signal evaluations or score calculations. Other tests, e.g., for vulnerable road users (VRUs), are available on request.



The new user interface for defining, managing, and executing automated ASM-based test runs.



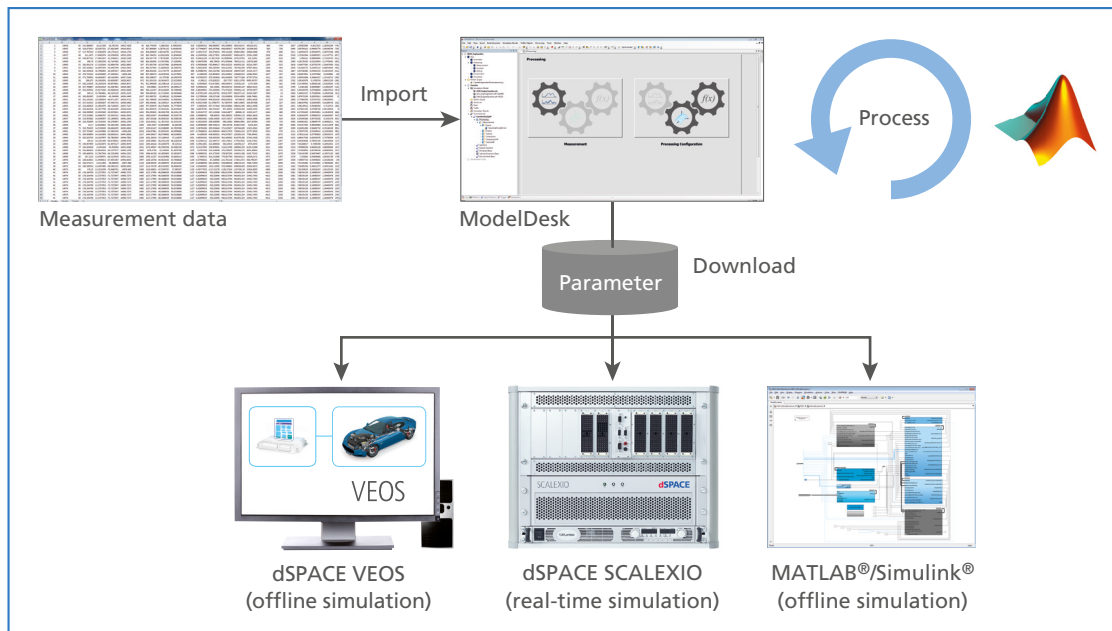
Testing control strategies for autonomous emergency braking (AEB) when obstacles like braking or stationary cars appear in front.

Processing

Parameter Processing

ModelDesk provides a fully integrated parameterization workflow. Users can include initial data, such as measurements, functions, and settings, flexibly and process it into parameters optimized for simulation models. Users can write the processing routines for parameters in the well-known

MATLAB programming environment. In addition to this customizable parameter calculation, sophisticated error handling procedures have been integrated to support the users during parameterization.



The processing feature transfers measurements, settings, and functions into parameters optimized for simulation.

Features

- Read and process measurement data
- Function administration
- Settings administration
- Execute functions with appropriate error handling
- Adapt parameter as a result of a processing function

Use Cases

- Engine parameterization based on testbench measurement
- Battery parameterization based on impedance spectroscopy
- Suspension kinematic parameterization based on kinematic and compliance testbench data

Custom Models and Demo Projects

This feature can also be used in combination with custom components to parameterize own libraries with ModelDesk. A demo projects for the ASM engine models provide pre-defined parameterization routines, to deliver a semi-automated calculation of all model parameters.

Tool Automation

Remote Control and Batch Processing for ModelDesk

To perform long-term tests or parameter studies, ModelDesk provides script-based tool automation. This gives you maximum flexibility to define custom simulation scenarios. Tool automation can be performed by means of scripting languages like Python and MATLAB M scripts.

The scripts can be executed either externally to remote-control ModelDesk or internally when ModelDesk's batch mode is used. The batch mode functionality is realized by a Python interpreter that supports Python 2.5.1.

Features

- Script-based tool automation
- Integrated Python interpreter
- Direct access to project and experiment management
- Direct alteration of all vehicle model parameters
- Direct alteration of scenario segments
- Direct alteration of road features

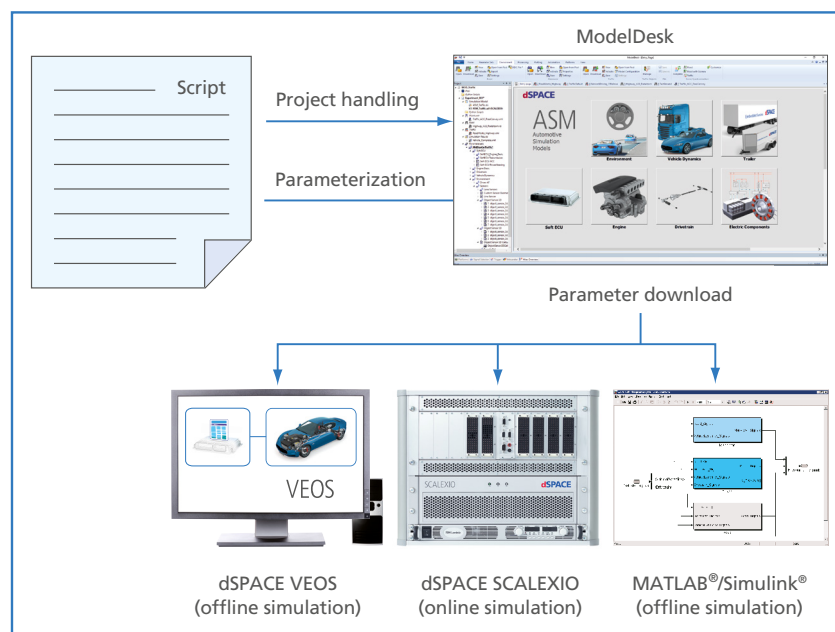
Benefits

- Direct alteration of traffic scenarios
- Simulation-based parameter studies
- Automated marginal condition analyses/detection
- Long-term behavior studies
- Sequential scenario executions

Functionality

All ModelDesk's functions for experiment management and model parameterization that are available via its GUI can now also be accessed via its COM (Component Object Model of Microsoft® Windows®) interface (except road and scenario creation). You can load existing model parameter-

ization projects and activate predefined experiments. All the vehicle parameters such as vehicle mass, suspension kinematics, engine torque, additional loads, and similarly also environment or scenario settings like road friction or vehicle velocity, can be controlled from within scripts.



The script-based tool automation for ModelDesk provides functionality for parameter set management and for direct model parameterization. The parameters of online and offline simulations can be changed during a simulation run.

Custom Model Parameterization

Graphical Parameterization of Custom Models

ModelDesk supports the graphical parameterization of model parts that were replaced by custom models or custom extensions to ASMs. This allows you to manage all the parameters of a project from a single source.

Features

- Automatic generation of new parameter pages based on custom models
- Controls provided according to parameter dimension (scalar, vector, table)
- Original ASM and customized model parts displayed as one system

Benefits

- Centralized parameter management
- Graphical parameterization without detailed modeling knowledge

Model Preparation

For use in ASM, custom model libraries have to be prepared according to ASM guidelines in order to parameterize them in ModelDesk. The guidelines mainly define how parameters are declared with masked variables and a fixed declaration structure. Libraries can have multiple masked subsystems, and each subsystem has its own parameter page for separate parameterization.

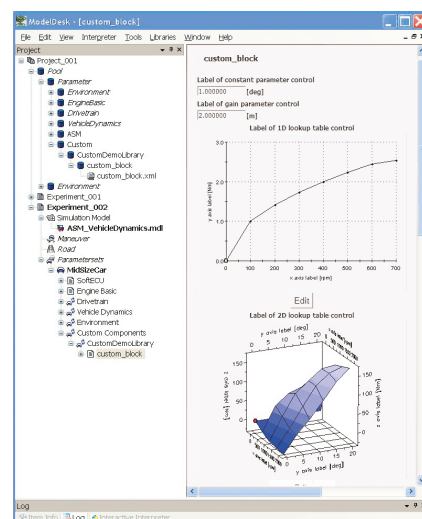
Custom Library Registration

ModelDesk's registration function lets you select new libraries to parse them and make their parameters available graphically. During registration one or more parameter pages are created automatically, depending on the number of masked subsystems. Each page lists the controls of declared parameters. Controls can be single entry fields for scalar types, multiple entry fields for vectors, or complex tables for table-based parameters.

Navigating Custom Parameters

Whenever a model containing blocks from a registered custom library is loaded into a ModelDesk experiment the related parameter pages of these blocks are provided. They can be selected in the Navigator. Each library is represented as a branch in the hierarchy with links to the subsystem pages. The new pages can be used in exactly the same manner as the standard pages.

Custom parameter page created by ModelDesk. Controls for scalar, vector or table parameters are automatically labeled with the unit and caption as defined in the custom library.



ASM Versions and License Concept

The ASM License Concept

The ASM models come with different license types: Developer License, Runtime License. This lets users apply the models in various kinds of applications, without losing any of the characteristic ASM flexibility.

- **Exchangeability** – You can use both licenses on one PC or split them to have one PC for model maintenance and one PC for simulation platform operation.
- **Mutual Parameterization** – Both license types let you parameterize all models with ModelDesk's parameterization options for simulation on a PC (offline) or on dSPACE real-time hardware (online).
- **Seamless 3-D Animation** – The vehicle dynamics models provide access to MotionDesk with all license types. The model must include the MotionDesk block-set.

The Benefits

- A simulation environment that seamlessly covers the offline and online (real-time) worlds.
- ModelDesk is the parameterization tool throughout the entire process, which means that the parameterizations can be reused.
- Cost-efficient license types for offline and online (real-time) simulation
- Simulation models parameterized and reconfigured in ModelDesk with the Runtime License. This enables real-time simulation on a dSPACE platform without an additional MATLAB license.

ASM Developer License

The Developer License is designed specifically for modifying, parameterizing and preparing the open Simulink models for simulation on a real-time platform. The license lets you generate real-time code. Moreover, the license can be used for Simulink simulation on a PC (offline).

Properties

- Modular developer models viewable down to the Simulink block level
- Modular, encapsulated operator models, designed specifically for Simulink simulation (offline)
- Easy substitution or extension of ASM models by customer-specific model parts
- Support for real-time and VEOS code generation

ASM Runtime License

The Runtime License is designed specifically for simulation on a real-time platform (online) and Simulink simulation of operator models (offline).

Properties

- Code execution on dSPACE real-time hardware (dSPACE Simulator, SCALEXIO)
- Code execution on dSPACE VEOS
- Code already generated from the models via the Developer License
- Simulink simulation of operator models, which are modular, encapsulated, and designed specifically for Simulink simulation (offline). Not included with ASM Engine InCylinder models.