

Automotive Simulation Models (ASM)

ASM Electric Components

- Vehicle Electrical System Simulation
- Electric Drive Simulation
- Hybrid Drive Simulation

The vehicle graphics used in this brochure are by courtesy of Maserati.

Content

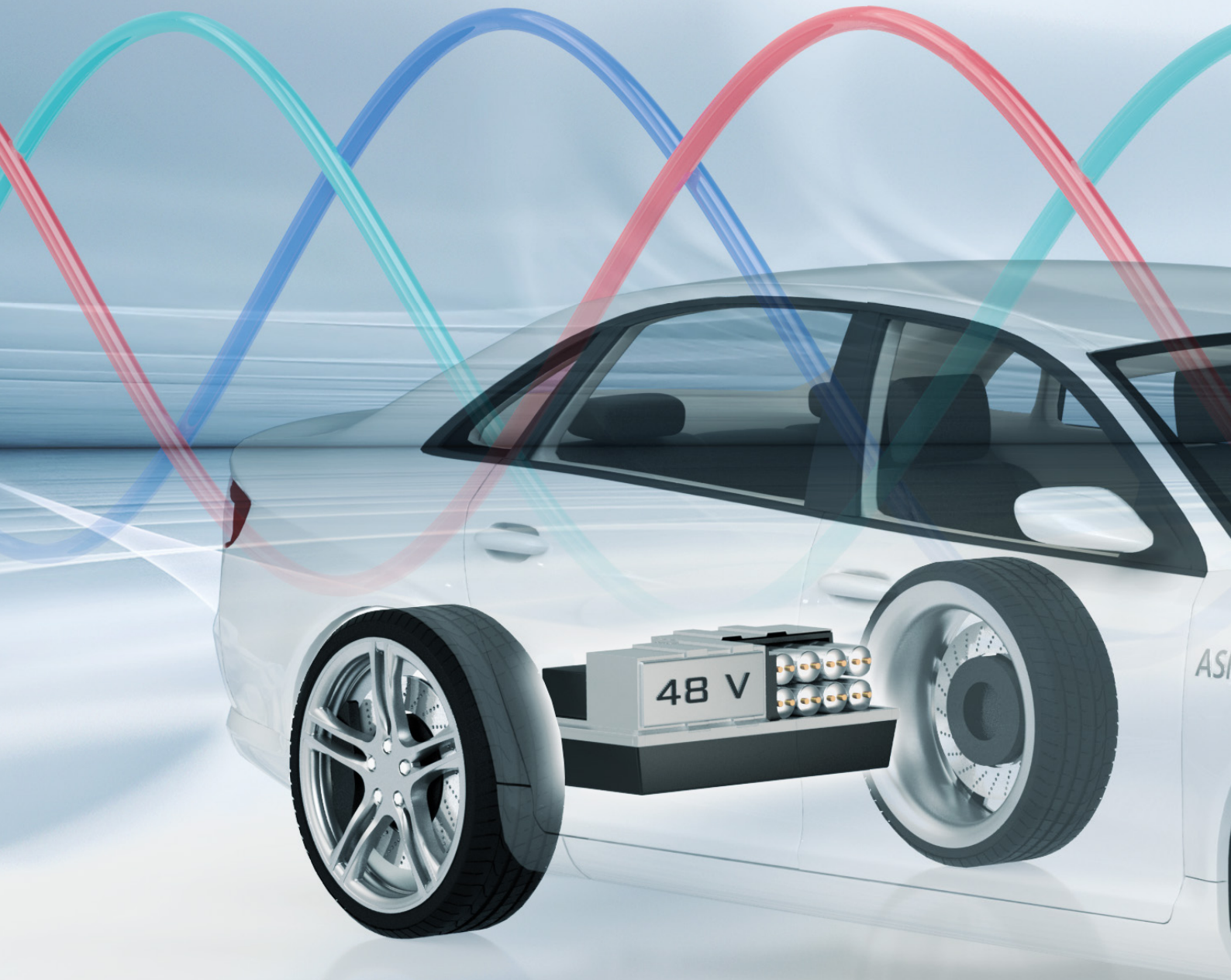
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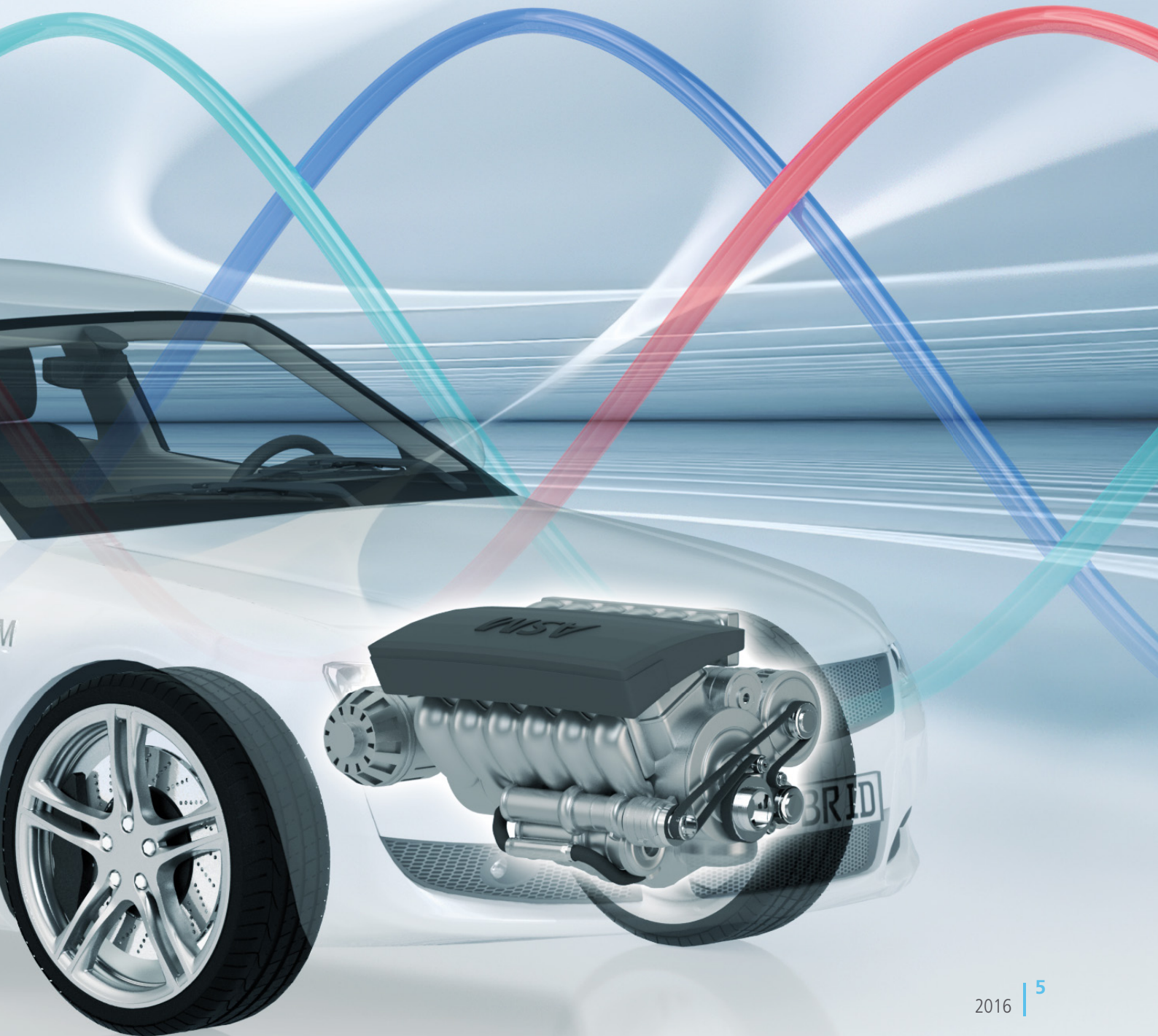
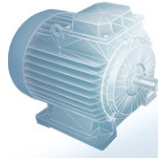
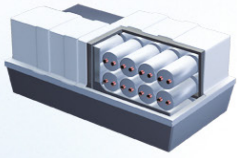
Virtual Electrics

Efficient Controller Development

Whether you are working on e-mobility, renewable energy, electrification or going hybrid. There is one common question: How can you test new control software long before your vehicles and devices are even ready? Do it virtually. And how can you validate electronic control units (ECUs) before production release? Again, virtual testing on a simulator is the indus-

try-proven method. With configurable, off-shelf simulation models you are well equipped for tests in all development phases. Power up the virtual electric components and work with high voltages – completely hazard-free and at your desk. The advantages are clear: Quick and convenient testing and many savings compared to test beds or prototypes.



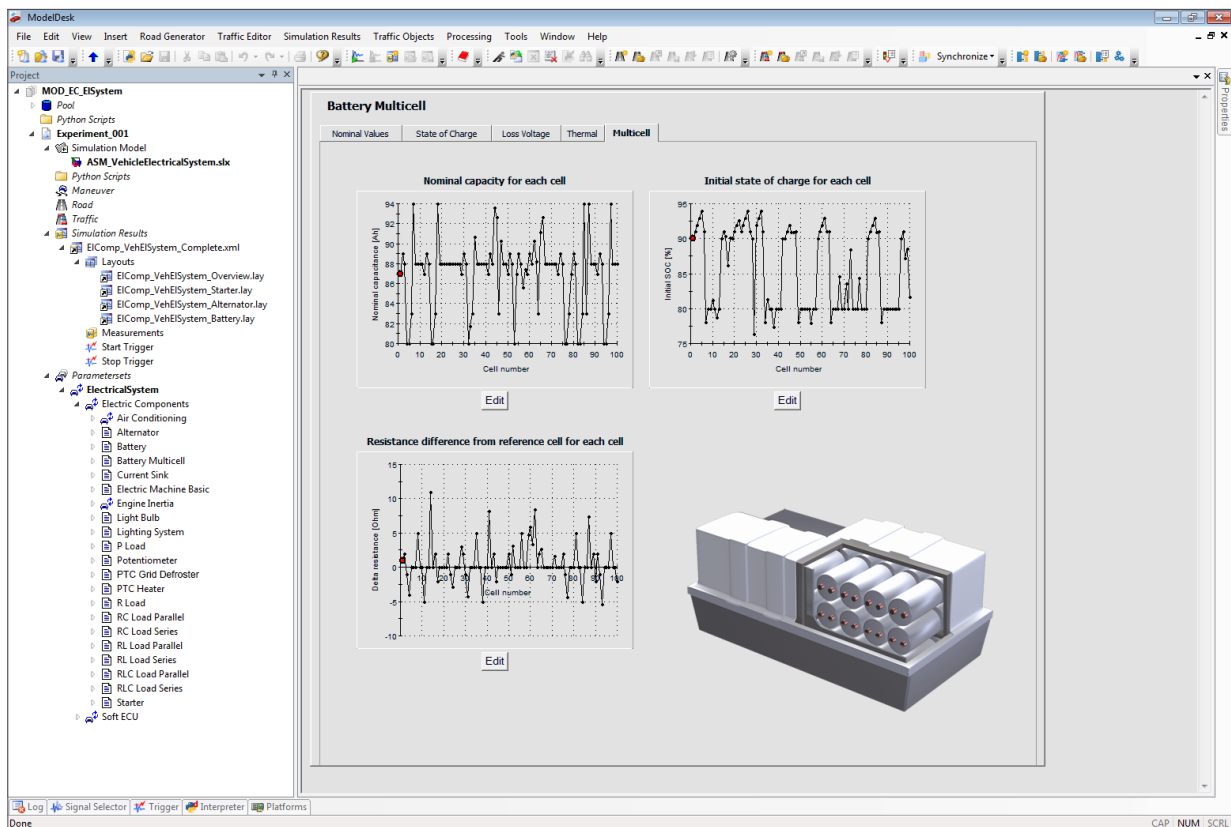


The Simulation Workbench

Automotive Simulation Models

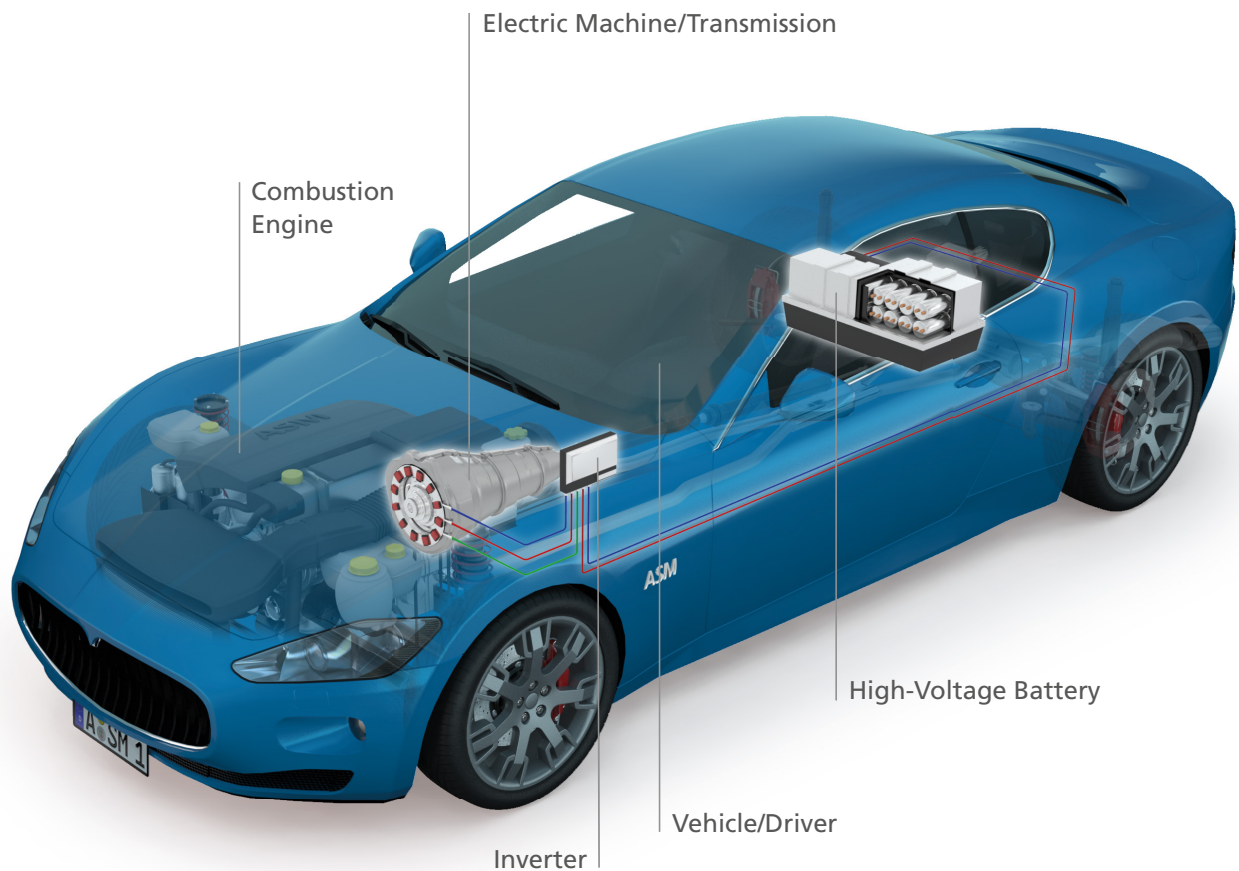
Automotive Simulation Models (ASM) by dSPACE are industry-proven virtual vehicle software. The ASM Electric Components simulation models give you realistic electric motor, battery, and load behavior simulations in real time. The models are the ideal choice for function design and controller testing in model-based development processes.

Jump-start developments with easy-to-use validated tools: a comfortable user interface for all aspects of your tasks and high-performance simulation models that perform under the hood, ensuring precise simulation results.



Comfortable User Interface

ModelDesk is the intuitive user interface for defining and initiating tests. Specify the motor, the battery and various components with easy-to-use graphical methods. Benefit from efficient workflows and seamless data management.



High-Performance Models

ASM are open, validated Simulink models that major OEMs and suppliers rely on to develop controllers for all kinds of electrical applications. They support the whole development process from function design to ECU testing.

Virtual Vehicle

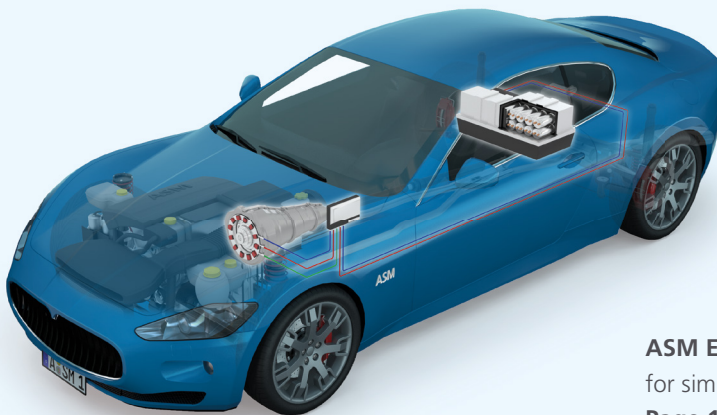
ASM consist of models for the engine, battery, suspension, traffic and many other components. You can easily combine them to build a whole virtual vehicle. ASM supports application areas such as combustion engines, vehicle dynamics, electric components, and traffic, including the traffic environment.

Overview

Electric Simulation Software

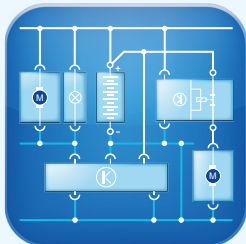
ASM Electric Components supports a broad variety of application tasks for simulations of vehicle electrics and electric drives. To provide what is needed for these areas, it consists of specialized simulation models and tools.

Basic Software



ASM Electric Components is the base package for simulating vehicle electrics and electric drives.
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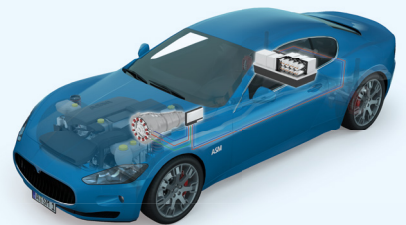
Sublibraries and Extension Software



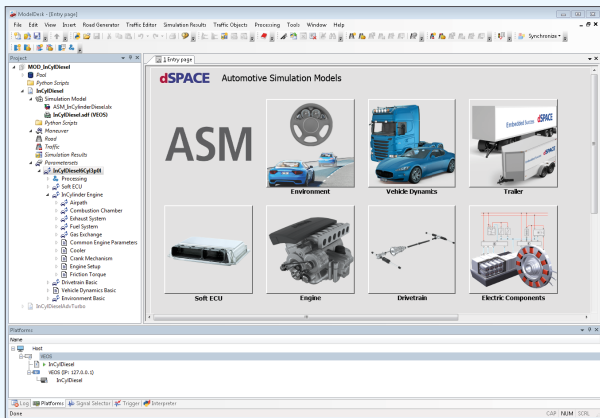
Vehicle Electrical System Components is a sublibrary that includes batteries, the starter, the alternator and loads to simulate a vehicle's electrical system.
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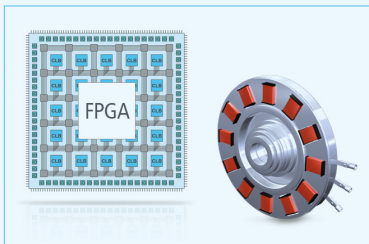
Closed Loop Electric Components is a sublibrary that includes electric drives and power electronics to simulate them closed loop with an ECU.
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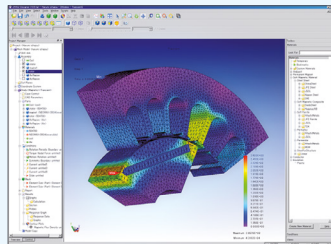
Hybrid Vehicle is a demo model with a Hybrid Manager Soft-ECU to develop and test hybrid powertrain management systems.
Page 30



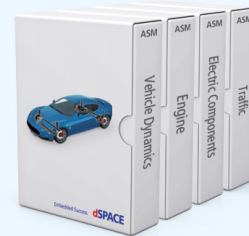
ModelDesk is the graphical user interface to manage simulations, parameterizations and parameter sets.
Page 13



XSG Electric Components are FPGA-based simulation models of electric components that require the highest dynamics and precision.
Page 32



Parameter import is available for JMAG Designer, the graphical development tool for the electromechanical design of electric motors.
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ASM packages from different domains can be used to extend the detailed electrical system and motor simulations for simulation tasks that are more comprehensive.

Philosophy

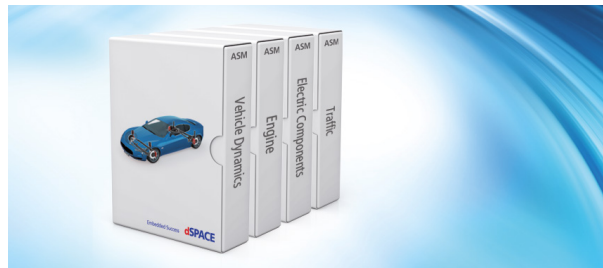
Supports Model-Based Design

- 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 included
- 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



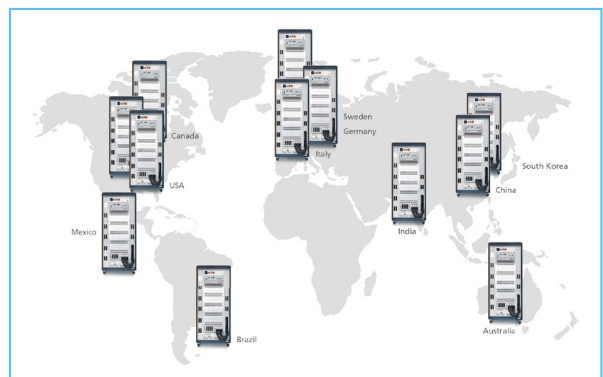
Complete ASM Product Portfolio

- 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 customer-specific model engineering

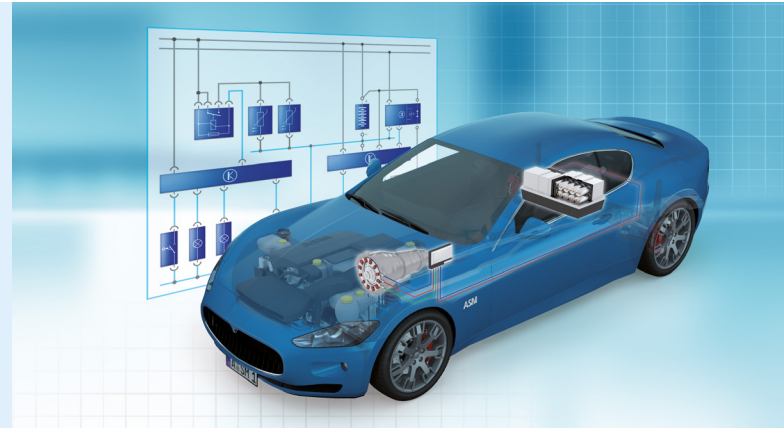


ASM Electric Components

Simulation of Real-Time Electric Components

Highlights

- Open MATLAB®/Simulink® model
- Ready-to-use components with automotive features
- Simulation of a complete vehicle electrical system
- Simulation of electric drive components and power electronics in a closed loop with ECU
- Demo models for simulating a hybrid vehicle
- Prepared for testing battery management controllers



Application Areas

ASM Electric Components is a library of models for the real-time simulation of a vehicle's electrical system. The possible applications vary from electric drives and inverters for closed-loop simulation with an electric drive controller to complete vehicle electrical systems including a battery, starter, and alternator. It is typically used to simulate realistic battery behavior during starter activation, to simulate electric drives that are integrated into a hybrid electric vehicle (HEV) powertrain, etc. ASM Electric Components can be combined with other ASM products such as the engine models and the vehicle dynamics models to simulate a complete virtual vehicle.

Key Benefits

ASM Electric Components is open down to the Simulink block level. This provides enormous advantages when models need to be combined or integrated with custom models. You can use the models either to simulate a complete vehicle electrical system or for controller development. Or combine both cases when developing electric vehicles in order to simulate the power consumption of the whole vehicle to evaluate the driving range. The characteristics of each modeled component can easily be modified by graphical means. To support different performance demands there are models for two types of simulation platforms: processor and FPGA.

Components and Characteristics

ASM Electric Components consists of components for vehicle electrical system simulation, as well as components for closed-loop simulation, and is optimized for hardware-in-the-loop (HIL)-based simulations in real time. The vehicle electrical system components can be used directly to create the electric circuits of an automotive system, since they are already equipped with all the necessary automotive features. The closed-loop components are ideal for HIL simulation of electric devices like drives or inverters in a closed control loop.

Offline and Online Simulation

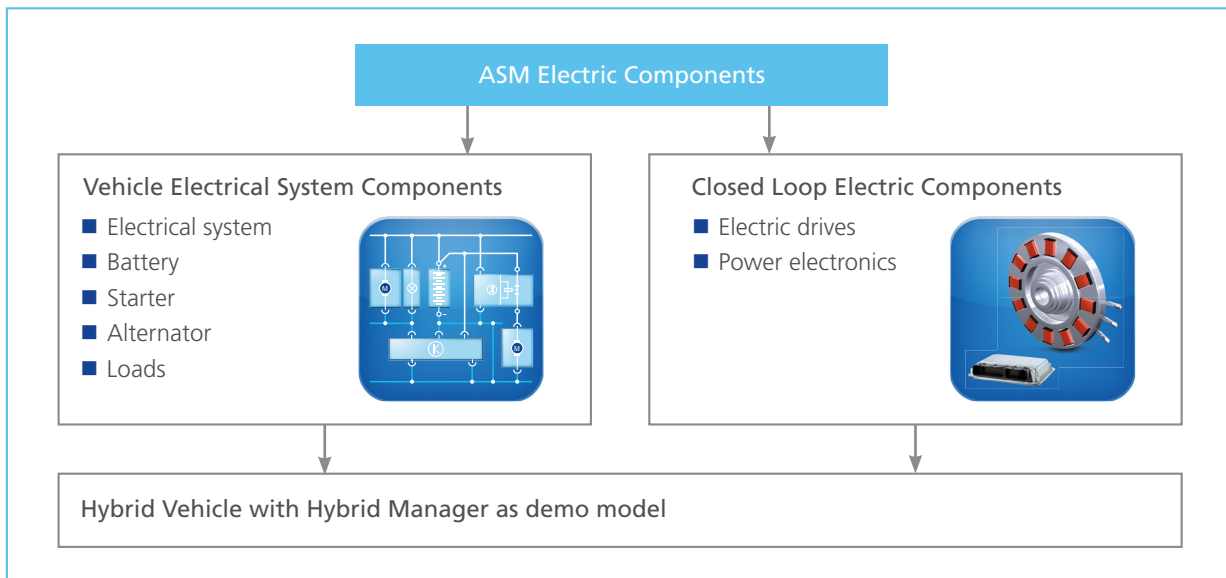
The ASM Electric Components model can be used together with real controllers in a hardware-in-the-loop environment (real-time or online mode), or to simulate electric components in combination with software controller algorithms (PC or offline mode). The model supports code generation via MathWorks' Real-Time Workshop® and dSPACE's RTI for online simulation on a dSPACE real-time system.

Component Categories

Application-specific Sublibraries

ASM Electric Components is divided into two main sections: a sublibrary with model components to simulate a vehicle electrical system, and a sublibrary with models for closed-loop applications of electric components. The vehicle electrical systems sublibrary can be used to simulate the electric circuits of an automotive system with components such as

batteries, machines, and loads. The closed-loop sublibrary provides models for testing a real machine controller with an HIL system. Both sublibraries can be combined to simulate an electric vehicle along with its electrical system, for instance.



ModelDesk

The Graphical User Interface

The ModelDesk Concept

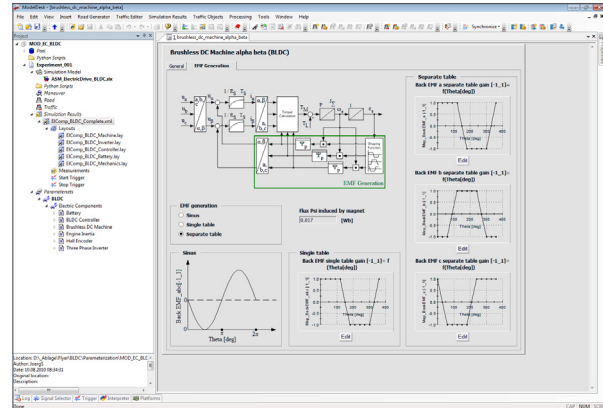
ModelDesk is a graphical user interface for simulation, intuitive model parameterization, and parameter set management. It also provides project handling and can download parameter sets to offline and online simulations. It supports tool automation via a COM interface. ModelDesk can be used seamlessly 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
- Tool automation
- Custom model parameterization

Benefits

- Seamless simulation process from MIL to HIL
- Intuitive, graphically supported parameterization
- Parameterization during online and offline simulations (dSPACE SCALEXIO®/dSPACE Simulator and dSPACE VEOS®/Simulink®, respectively)
- Managing parameter sets and entire projects

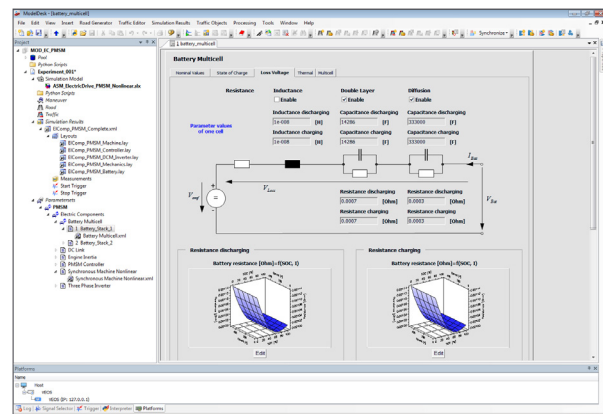


Parameterization of Electric Components

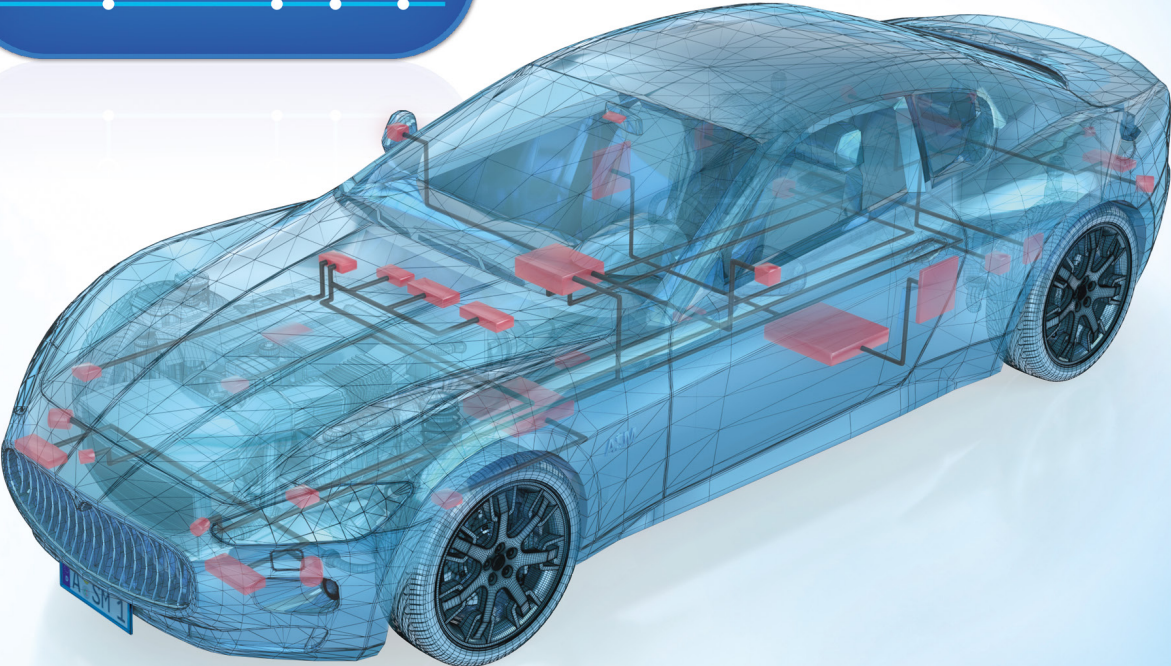
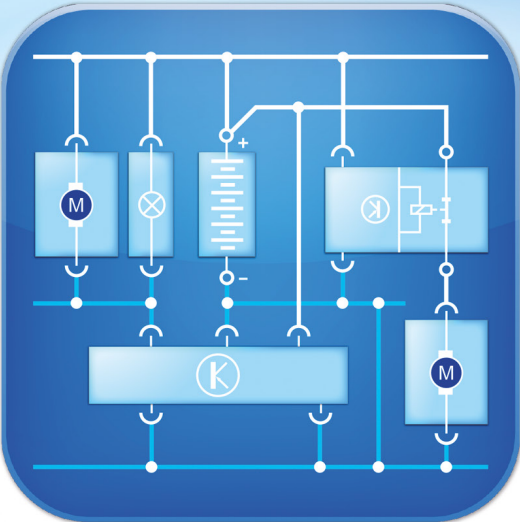
All the modeled electric components are displayed graphically in ModelDesk for convenient parameterization. Parameters can be applied directly to the equivalent circuit diagrams of each model. Table editors are available to define the characteristic curves of features like a BLDC motor's back EMF generation. Each and every cell in the multicell battery model can be parameterized. Parameters such as nominal capacity, initial state of charge (SOC), and resistance can be applied to every cell.

Features

- Graphical parameterization of all electric components
- Parameters applied directly to equivalent circuit diagrams
- Table editors for characteristic curves



Vehicle Electrical System



Vehicle Electrical System Components

Vehicle Electrical System Modeling

The Vehicle Electrical System sublibrary includes models such as the battery, machines, and loads required for simulating the electric circuits of an vehicle electrical system. The simulation model features battery voltage calculation according to the charge and discharge current of different electri-

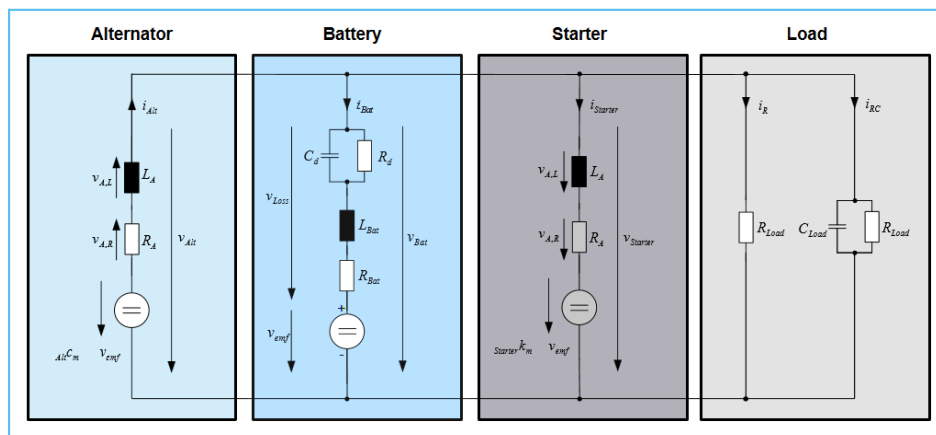
cal loads, the starter, and the alternator. To take mechanical effects between the combustion engine and coupled electric components into account, the torque load of the engine crankshaft generated by an electric machine is simulated.

Simulation Features

The components of the Vehicle Electrical System sublibrary realistically represent the behavior of standard automotive components, so they are ready to use in automotive applications. To create a basic electrical system, all that needs to be done is connect the battery, starter, alternator, and loads. To guarantee HIL operation in real time, the simulation automatically adapts to real-time boundary conditions.

Features at a Glance

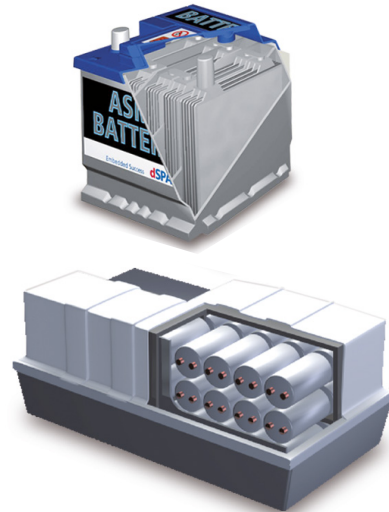
- Ready-to-use automotive electric components (battery, machines, loads)
- Vehicle power voltage (battery voltage) calculated and used as an option to control the HIL system's power supply
- Load torque and inertia of engine crankshaft calculated (e.g., from starter and alternator)
- Automatic adaptation of simulation (dynamic or static) to real-time boundary conditions
- Compatible with Closed-Loop Electric Components



A basic electrical system can consist of an alternator, battery, starter and load. Additional load models can be connected to extend the electrical system.

Battery Model

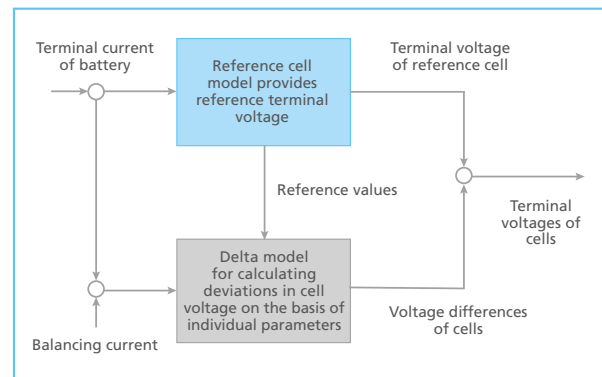
The battery model supports the simulation of lead acid (Pb), nickel cadmium (NiCd), nickel metal hydride (NiMH), and lithium ion (Li-ion) batteries. It is scalable from starter batteries up to high-voltage batteries with a high number of cells. The model consists of submodels that calculate the terminal voltage, the state of charge, and the battery temperature. The battery voltage drop is calculated on the basis of static effects like internal resistance and the dynamic effects like inductivity, diffusion and double-layer capacity behavior. The heat generation and dissipation takes account of effects like heat from the main reaction, ohmic losses, and heat flux due to thermal radiation. The state of charge is calculated from the battery current, temperature, and leakage current.



Standard automotive system batteries and also high-voltage batteries for electric powertrains are supported.

High-Voltage Multicell Battery Simulation

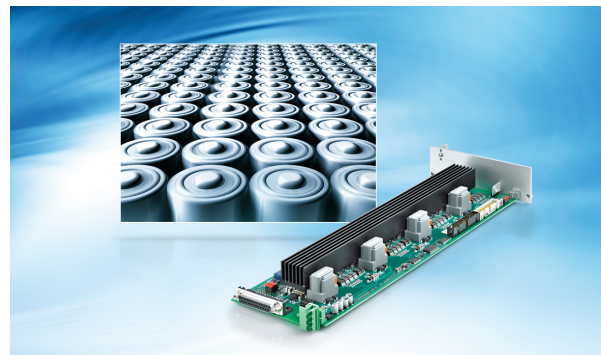
To simulate high-voltage batteries consisting of a series of multiple battery cells, the approach used in ASM is to connect single cells of identical design to create a series string of cells. This consists of a reference cell model that describes the basic behavior of the cell type used, and a delta model that computes the deviation of each individual cell's voltage from the reference voltage. The capacity, initial charge state, and deviation from the reference value of the internal resistance can be specified for each cell. It is perfectly suited for developing and testing battery management systems (BMS).



The ASM cell model consists of a reference cell model and a delta model that computes the deviation of each individual cell's voltage from the reference voltage.

Components and Characteristics

- Real-time-capable simulation of multiple battery cells
- Supports Pb, NiCd, NiMH, and Li-ion batteries
- Terminal voltage calculation
- State of charge calculation
- Temperature calculation
- Multiple batteries can be connected in parallel
- Complexity of the model is independent of the number of cells
- Individual physical effects such as internal resistance, diffusion and double-layer capacity
- Supports charge, discharge, and leakage currents
- Online and offline simulation
- Supports dSPACE's cell voltage emulation hardware



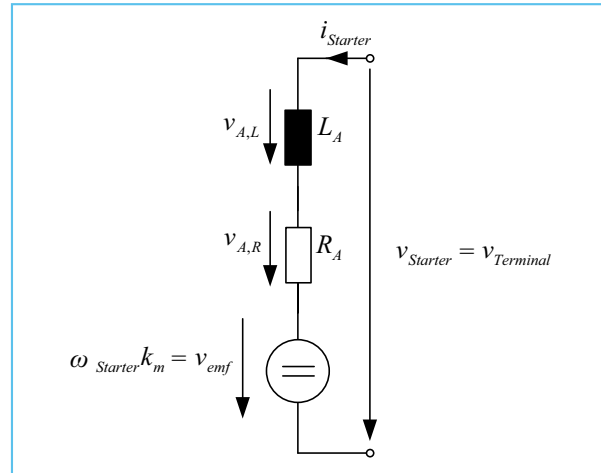
Development and test of BMS controllers with the battery model and the cell voltage emulation hardware (EV1077).

Starter Model

The starter is modeled as a direct current (DC) machine with a constant magnetic flux and is equipped with an overrunning clutch. The starter and engine crankshaft are therefore connected via a transmission. The model consists of an armature circuit in which a voltage is induced by a constant magnetic field. With the inner resistance and the inductivity of the armature circuit, the model calculates the starter current and the torque on the basis of the terminal voltage.

Components and Characteristics

- DC machine with constant magnetic flux
- Overrunning clutch
- Transmission between starter and engine crankshaft
- Starter voltage and current
- Starter torque



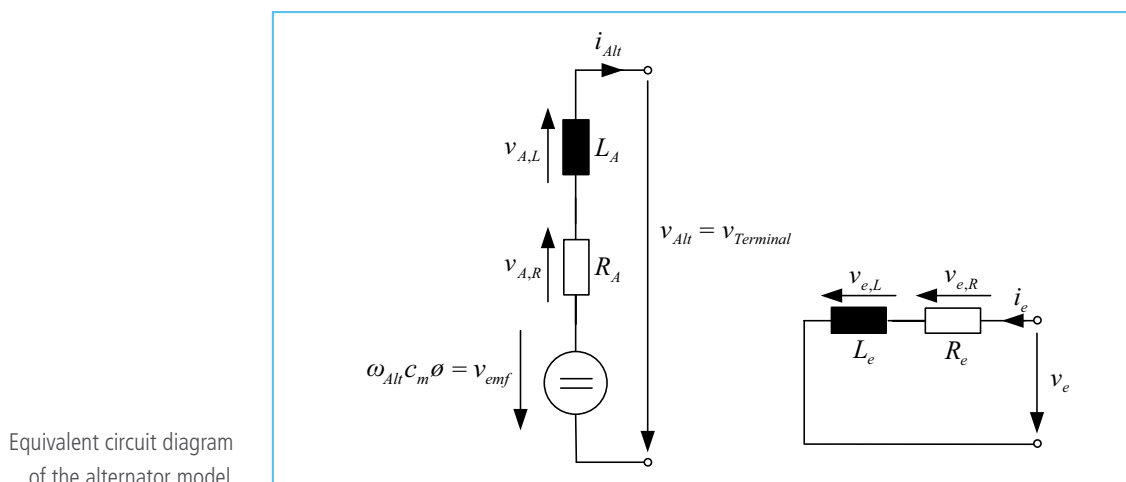
Equivalent circuit diagram of the starter model.

Alternator Model

The alternator is modeled as a DC machine with a variable magnetic flux and is actuated by the combustion engine via a mechanical connection. The alternator and engine crankshaft are therefore connected via a transmission. The model includes an exciter and an armature circuit. The exciter circuit generates a magnetic flux which induces a voltage in the armature circuit. With the inner resistance and the inductivity of the armature circuit, the model calculates the terminal voltage and the alternator current. An exciter voltage controller is used to control the alternator voltage, also known as the output current.

Components and Characteristics

- DC machine with a variable magnetic flux
- Transmission between alternator and engine crankshaft
- Exciter voltage controller
- Alternator voltage and current
- Alternator torque



Equivalent circuit diagram of the alternator model.

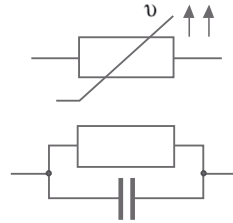
Load Models

ASM Electric Components comes with automotive loads like the positive temperature coefficient (PTC) heater, grid defroster and lighting system, and basic loads such as resistors, capacitors, and inductors. The physical values like resistance, capacity and inductivity can be parameterized. It is also possible to combine these types individually.

Examples of electric loads: PTC heater, RC load

Components and Characteristics

- Automotive loads like the PTC heater, grid defroster and lighting system
- Basic loads like resistors, capacitors and inductors
- Individual combinations of the basic loads
- Further loads like current sink and P load

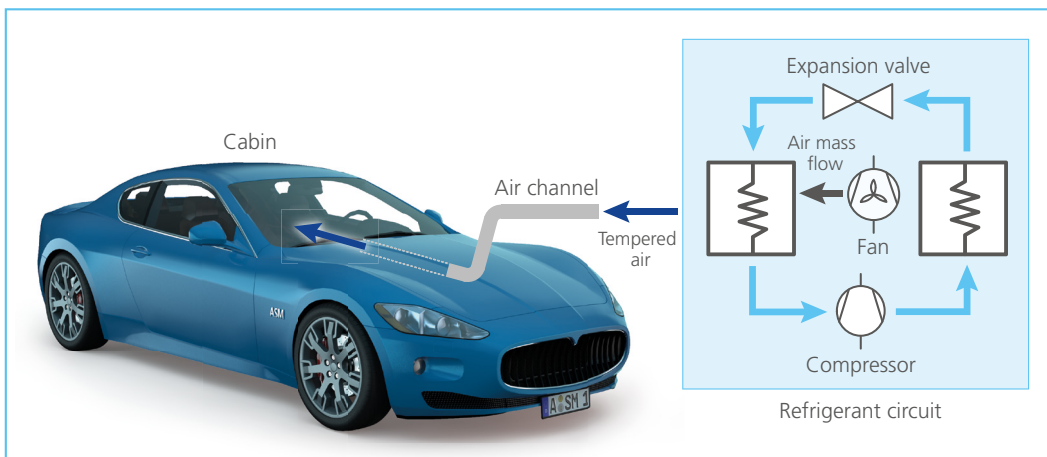


Air Conditioning Model

ASM Electric Components supports the simulation of a complete air conditioning system with a compressor and fan that are driven by an electric motor. The model for the thermal simulation of the vehicle interior is used to determine the temperature in the vehicle cabin. This value depends on the ambient temperature, the manipulation via the air conditioning system, the fan, and the vehicle's material parameters. A soft ECU is used to control the vehicle's cabin temperature.

Components and Characteristics

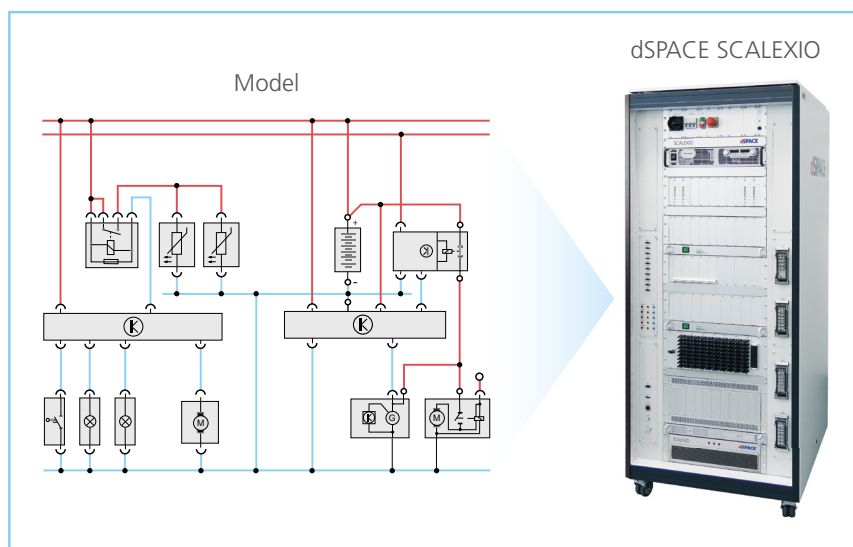
- Compressor (PMSM)
- Fan (DC machine)
- Refrigerant circuit
- Air channel
- Cabin
- Air conditioning controller



Use Cases

The following use cases are a representative selection of applications for the automotive simulation components.

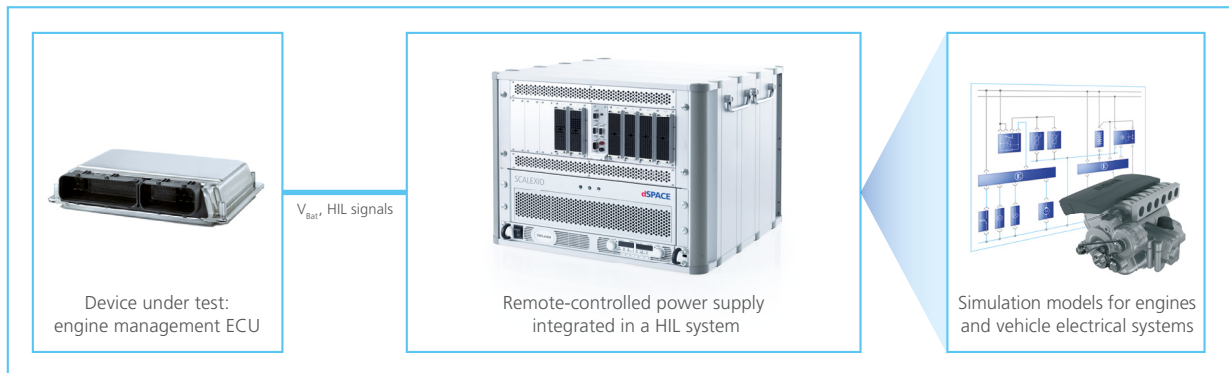
- Controlling the power supply of a HIL simulator on the basis of battery simulation to emulate the automotive system's voltage
- Investigating ECU reactions according to voltage drop during start-up
- Voltage and ECU behavior analysis when faults occur (e.g., alternator not working)
- Electrical behavior examinations with a new or an old battery (parameterization)
- Overall current consumption investigations of all electric loads during operation (e.g., lights, fans, air conditioning)
- Combined simulation of electrical and mechanical systems within the vehicle, using DC machines



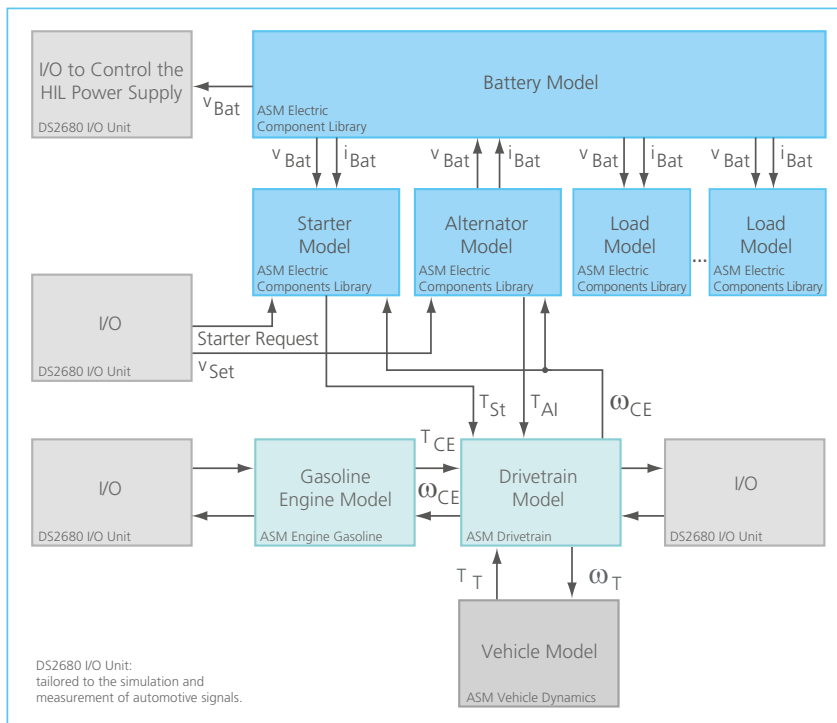
Application Example: Vehicle Electrical System

To investigate ECU behavior during fluctuations of the battery voltage, ASM Electric Components can simulate the behavior of the vehicle electrical system by using a remote-controlled power supply of the HIL system to emulate the real terminal voltage. This simulation is performed in addition to the initial application, namely combustion engine management. The setup in this application example shows powertrain models and vehicle models extended by a basic

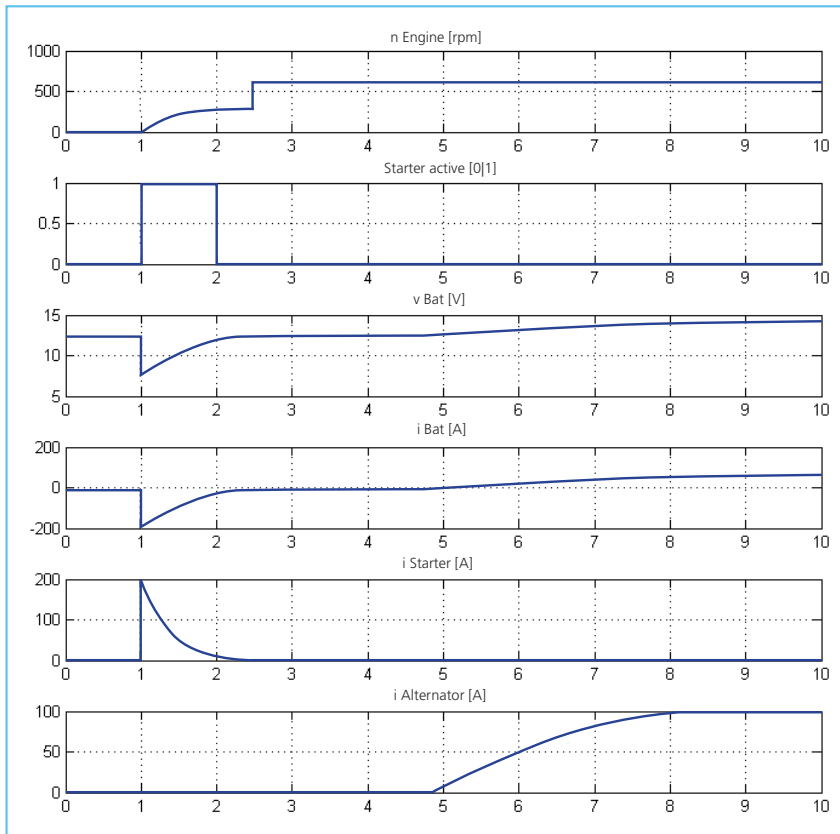
electrical system. A mechanical connection is simulated between the starter, alternator and drivetrain models. The starter produces a torque; the alternator is a mechanical load. The simulation results show the behavior of the main mechanical and electrical values during starter activation and the startup phase of the combustion engine. The V_{Bat} signal of the battery model controls the power supply.



The vehicle electrical system is simulated to control the power supply of the HIL system and thus emulate the voltage for the ECU.

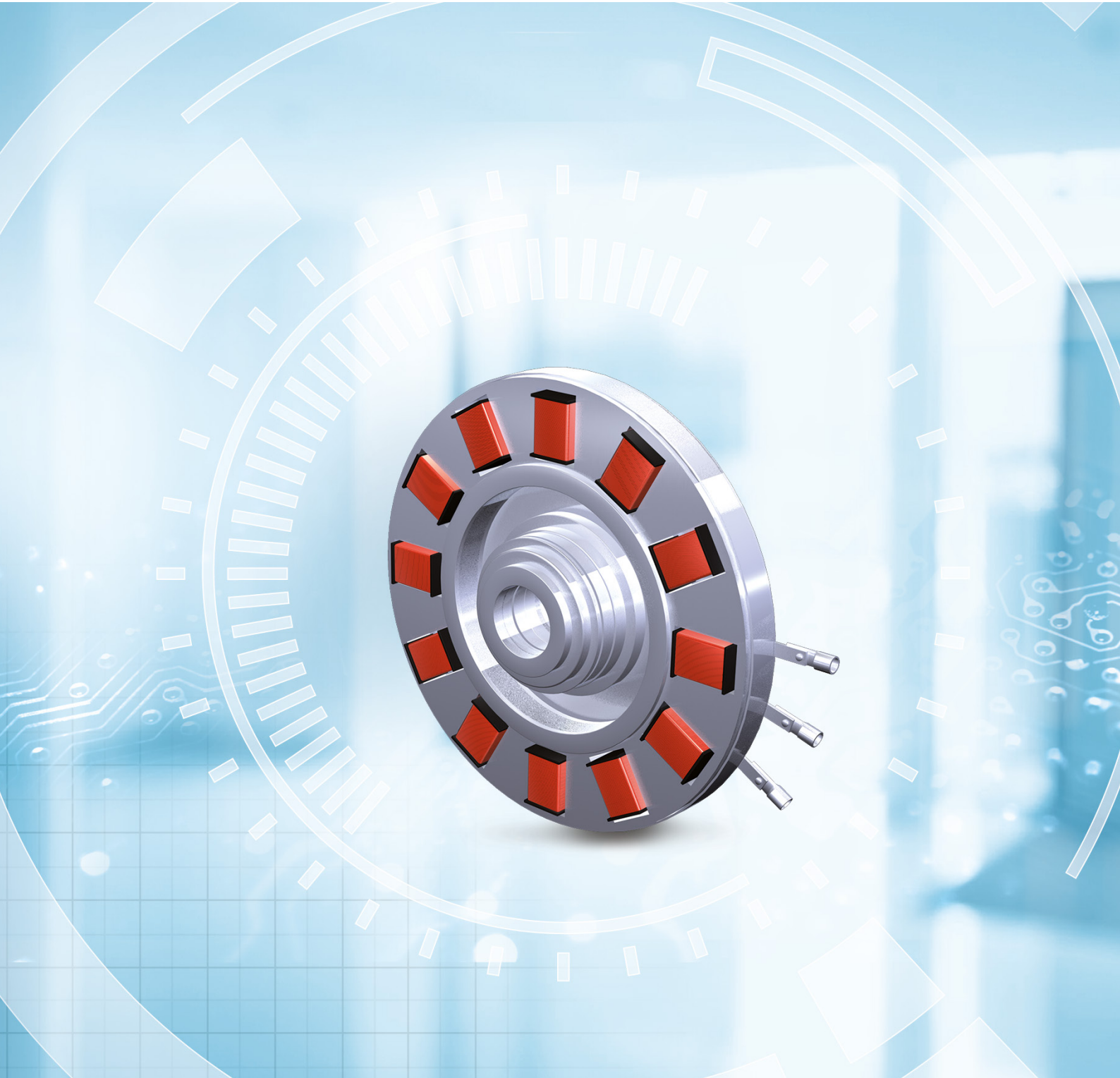


Example of a vehicle electrical system combined with powertrain models and vehicle models.



Simulation results of electrical effects during starter activation.

Closed-Loop Simulation



Closed-Loop Electric Components

Closed-Loop Simulation Components

The Closed-Loop Electric Components sublibrary includes components such as electric machines, controllers, and power electronics. These components represent the controlled system for closed-loops tests of machine controllers in a HIL system. The models support real-time simulation in fast timer tasks or hardware interrupt tasks like those necessary for PWM-synchronous model calculation with extremely short sample times such as 50 μ s.



Features at a Glance

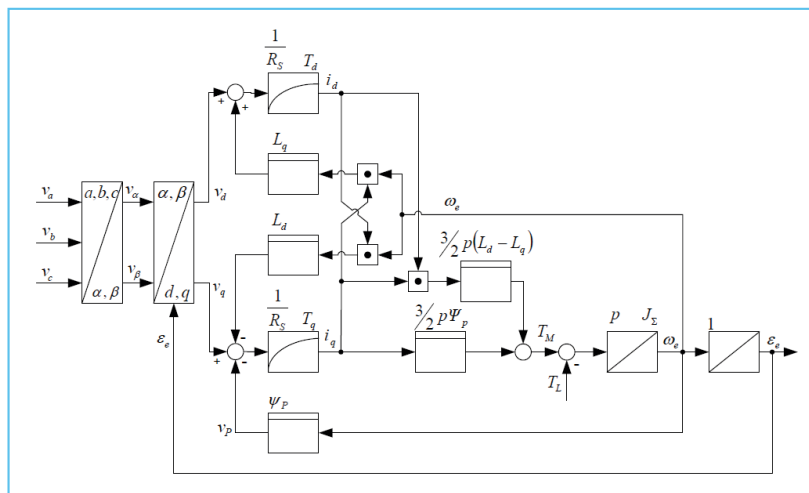
- Simulating electric drive components and power electronics in a closed loop with an ECU
- Testing real machine controllers in a HIL system
- Used in conjunction with three-phase PWM measurement I/O
- Variable sample times for PWM-synchronous model calculation
- Different internal discrete integration methods (forward and backward Euler, Tustin's and mixed methods)
- Compatible with vehicle electrical system models

Permanent Magnet Synchronous Motor (PMSM) Model

The PMSM model is based on a stator and a magnetic field with a configurable number of magnetic poles. The generated back EMF in the stator windings is sinusoidal, so the machine is modeled in d-q coordinates (also known as rotor reference frame). The parameter integration method selects between backward Euler, Tustin and mixed integration algorithms.

Components and Characteristics

- d-q coordinates
- Variable sample times for PWM-synchronous model calculation
- Backward Euler, Tustin and mixed integration algorithms
- Linear or nonlinear characteristics can be selected
- Configurable for delta-star connections



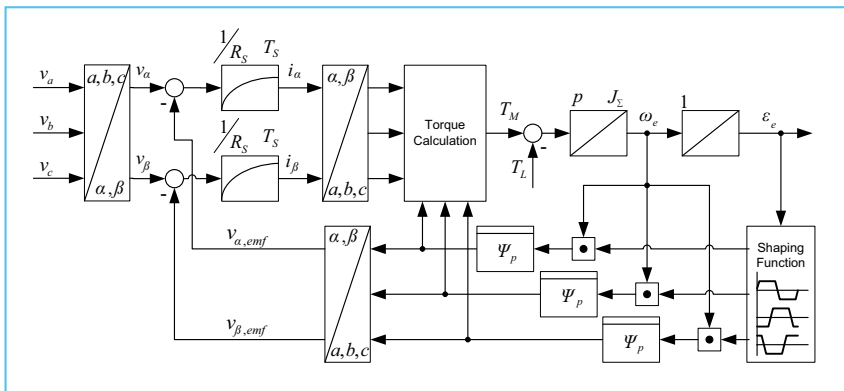
Block diagram of the Permanent Magnet Synchronous Motor Model.

Brushless Direct Current (BLDC) Motor Model

The BLDC motor consists of modeled stator windings and a magnetic field. The generated back EMF can be sinusoidal, trapezoidal or user-defined. Modeling is done in alpha-beta coordinates, also known as a stator-fixed reference frame, or abc-fixed to a machine stator reference frame.

Components and Characteristics

- Variable, user-defined shaping of back EMF
- Alpha-beta coordinates
- Variable sample times for PWM-synchronous model calculation
- Backward Euler, Tustin and mixed integration algorithms



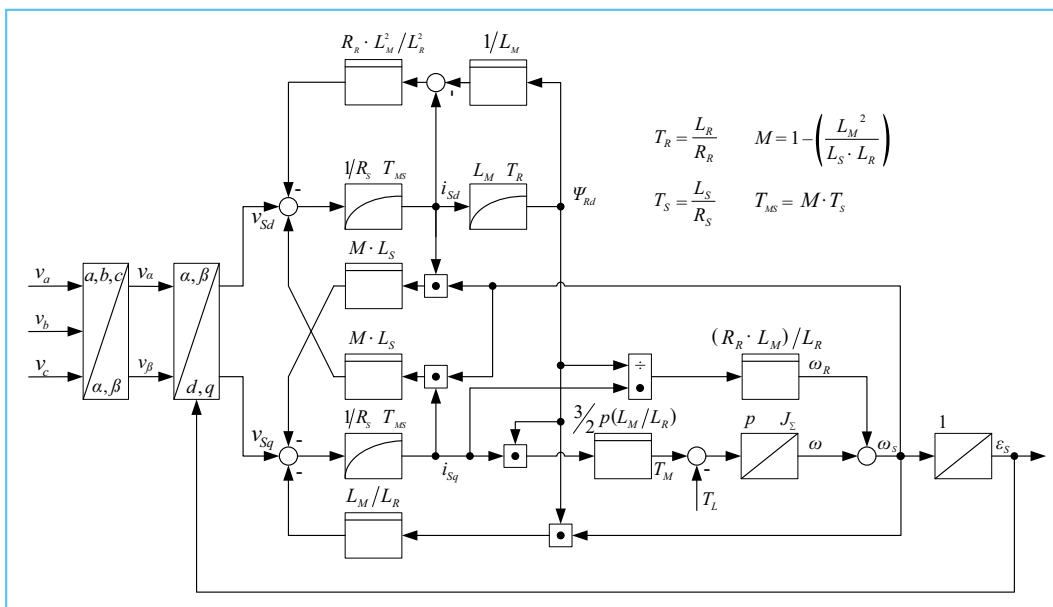
Block diagram of the BLDC motor model.

Squirrel Cage Induction Motor (SCIM) Model

The squirrel cage induction motor is modeled using d-q coordinates. The parameter integration method selects between the backward Euler, Tustin, and mixed integration algorithm.

Components and Characteristics

- d-q coordinates
- Variable sample times for PWM-synchronous model calculation
- Backward Euler, Tustin and mixed integration algorithms
- Configurable for delta-star connections



Block diagram of the Squirrel Cage Induction Motor Model.

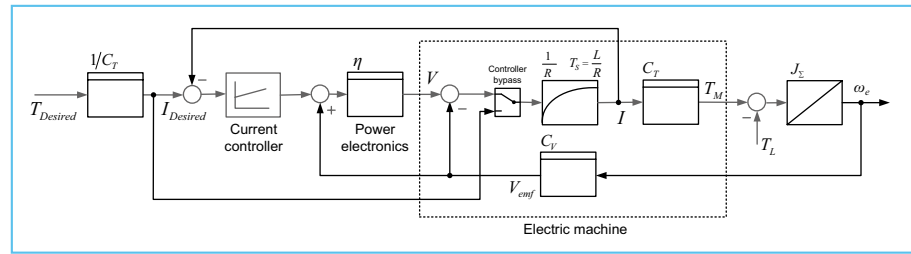
Electric Machine Basic Model

The Electric Machine Basic is the perfect solution whenever a regular electric machine is required. It simulates the basic function of an electric machine (e.g., PMSM or SCIM) with current controller and power electronics.

Components and Characteristics

- Based on first-order transfer function
- Desired torque as input
- Current controller
- To use an external controller the controller bypass functionality of the model can be used

Block diagram of the basic electric machine (e.g., PMSM or SCIM) with current controller and power electronics.



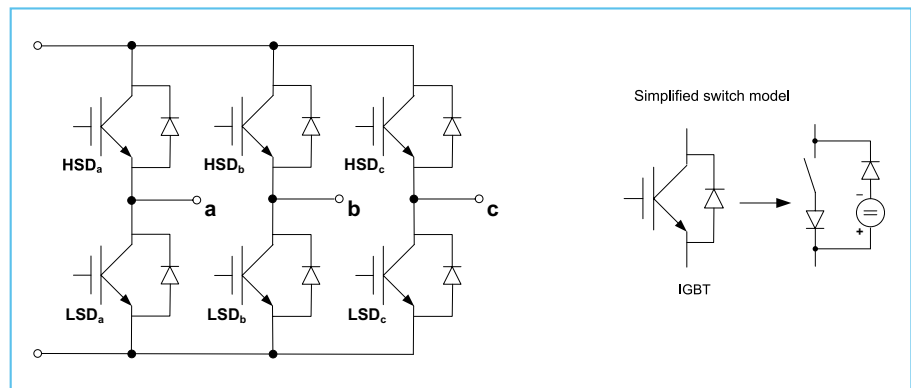
Three-Phase Discontinuous Mode Inverter Model

The inverter model calculates a three-phase AC voltage on the basis of the duty cycle of the PWM signal at its input. The model represents a three-phase power converter that consists of six power switches and its body diodes connected in a bridge configuration.

Components and Characteristics

- Three-phase power converter
- Natural switching effects like freewheeling diode
- Changeable energy flow, like passive energy recovery into the battery
- Simulation of dynamic failures (e.g., missing driver signals)
- Defined output behavior if gates are not triggered
- Also usable as a passive rectifier

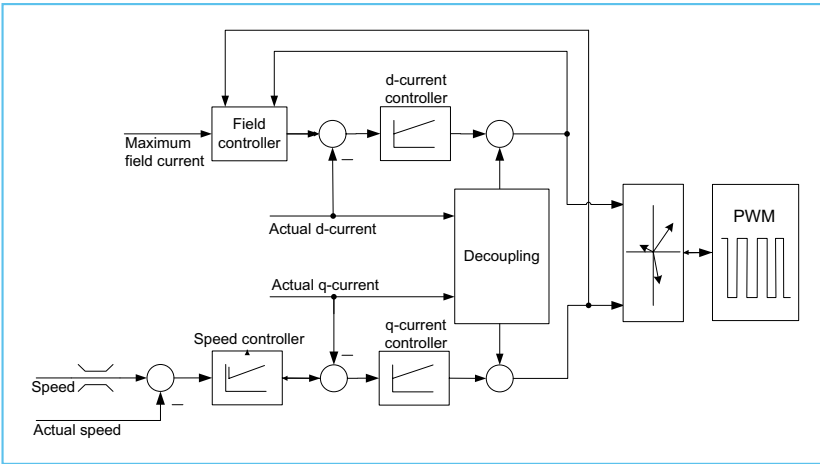
Circuit diagram of a three-phase converter.



Controller Models

Certain controller types are available for closed-loop control of the electric drives. A controller is a control-loop feedback mechanism widely used in electric drive control systems. It attempts to correct the error between a measured variable and a desired set point by calculating and then outputting a corrective action. The supported controllers are:

- PMSM controller
- BLDC controller
- SCIM controller
- Basic types, like PI controller



Block diagram of a PMSM controller.

Use Cases

The following use cases are a representative selection of applications for using the Closed-Loop Electric Components sublibrary in closed-loop HIL simulation of electric drives with an ECU.

Examples in the Automotive Industry

Chassis Actuators

- Electrical steering system (e.g., EPS)
- Electrical brake system
- Adaptive suspension

Powertrain Actuators

- Electric vehicle
- Mild/full-hybrid systems
- Starter-generator systems
- Gearbox actuator

Body Actuators

- Electric climate compressor

Examples in Other Fields

- Electric landing gears
- Flap actuators
- Industrial inverters
- Mining equipment
- Pod drives for ships
- Robotics
- Wind turbines



Application Example: Closed-Loop Simulation of a Hybrid Drive

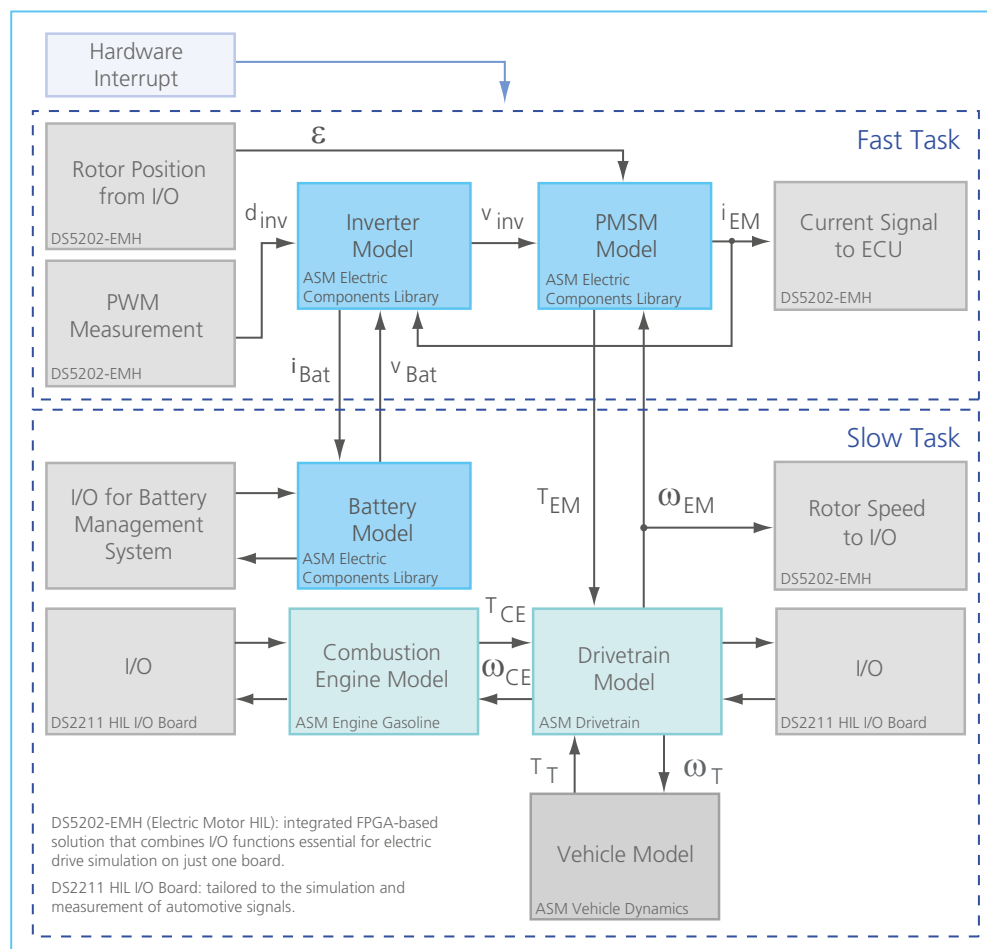
The ASM Electric Components models can be used in combination with powertrain models to create a hybrid powertrain for HIL or offline simulation. The combustion engine and the electric motor both deliver torque to the drivetrain model. Because of their different performance levels, the two drives operate in separate control loops.

Overview of the Controlled System Model

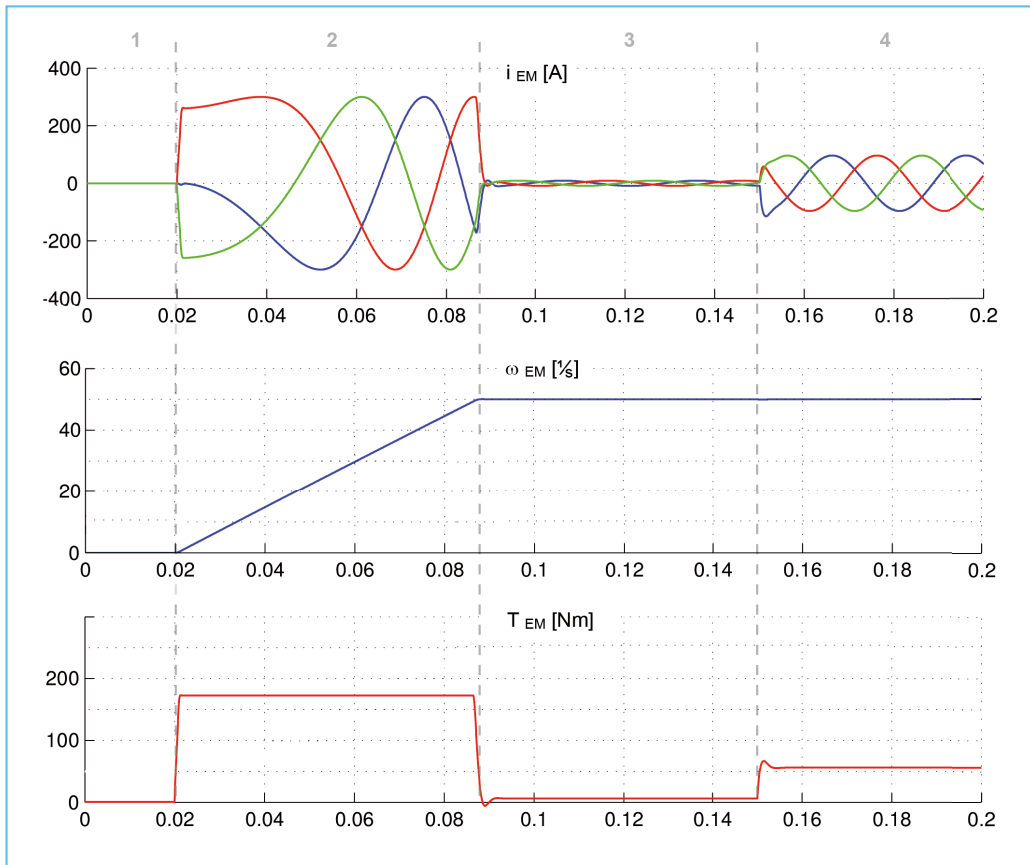
PWM signals of the electric machine controller are measured with a DS5202-EMH board, for instance, and then fed into the inverter model, which generates a three-phase output

signal v_{inv} for the electric machine model (PMSM). The machine current i_{EM} is fed back to the controller. These models are grouped in a task that runs at high sampling rates and can be triggered by a PWM-synchronization interrupt. The PMSM model delivers torque to the drivetrain model, which adds to the torque from the coupled combustion engine.

The combustion engine model, the drivetrain model, and further vehicle models are grouped in a task running at lower sampling rates.



Example of a HIL setup for a hybrid electric vehicle. An inverter model and a PMSM model run in a closed loop at a fast sampling rate. The electric machine model has a simulated mechanical connection to a virtual vehicle via the drivetrain model. The high-voltage battery model is part of the virtual vehicle. The virtual vehicle performs at a slower sample rate.



Simulation results of the modeled hybrid vehicle: Power-up of the PMSM model

1st Phase: Standstill

2nd Phase: Acceleration at maximum torque to desired speed of 50 1/s

3rd Phase: Motor running under no load at 50 1/s (only friction torque effective)

4th Phase: Load torque of 50 Nm applied

Hybrid Vehicle

Demo models of parallel hybrid drive with Hybrid Manager

The Hybrid Vehicle demo models are part of ASM Electric Components and provide a fast lane to hybrid drive simulations. By using the models in combination with the ASM Engine and ASM Vehicle Dynamics models they feature the following configurations:

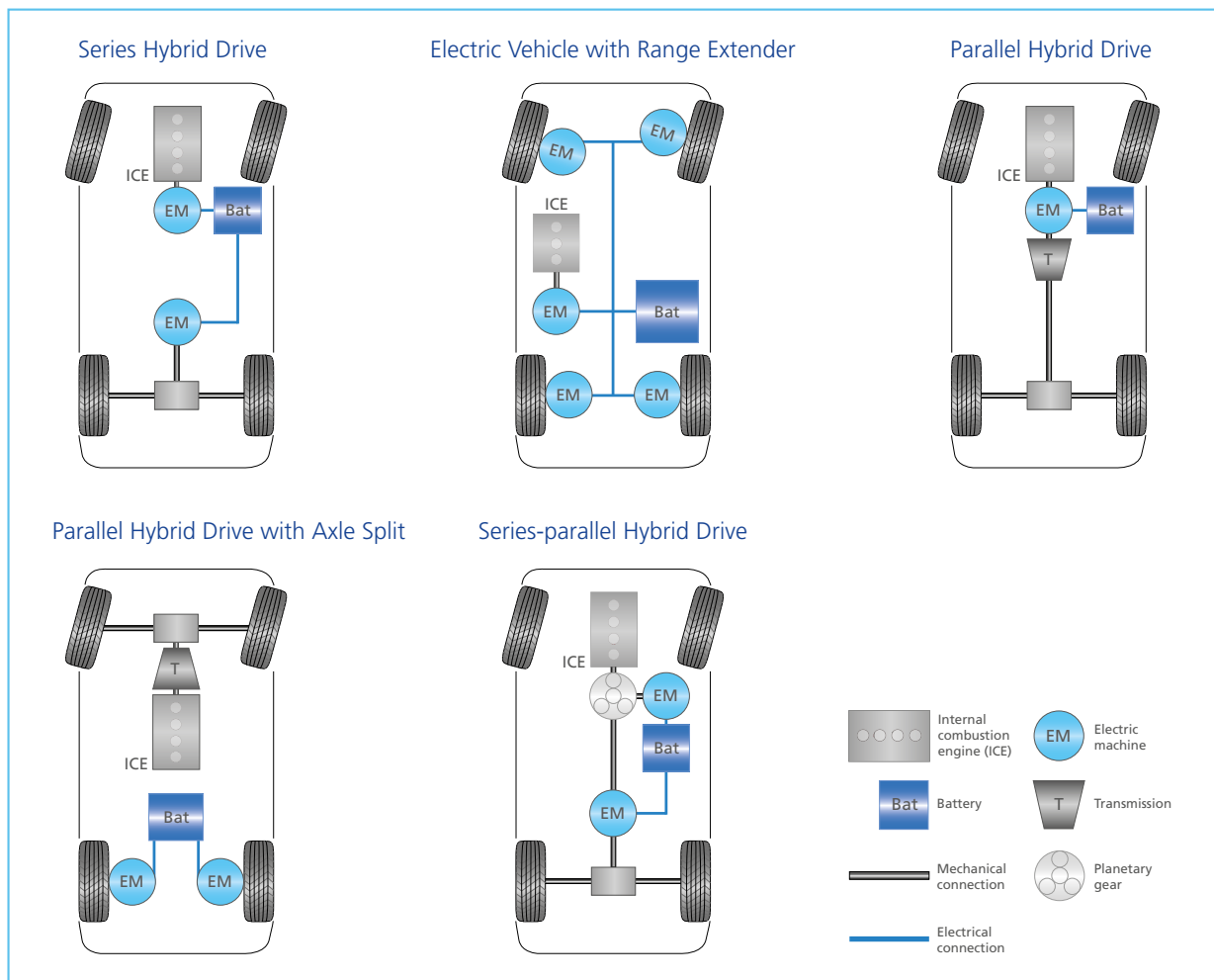
- ASM Vehicle Dynamics Hybrid with rigid drivetrain
- ASM Engine Gasoline Hybrid

The demo models include the Hybrid Manager Soft-ECU which means that a fully configured and complete parallel hybrid drive is available for real-time simulation.

Topologies of Electric Vehicles

ASM supports various hybrid topologies. The ASM Electric Components includes all necessary electric components and can be extended by the ASM Engine or ASM Vehicle Dynamics models to simulate the complete hybrid vehicle topology

like parallel and series hybrid drives or a pure electric vehicle with a range extender. An easy and comfortable integration of custom models like a one-mode or power-split transmission allows the simulation of the series-parallel hybrid.



Representative selection of hybrid topologies supported by ASM.

Hybrid Manager

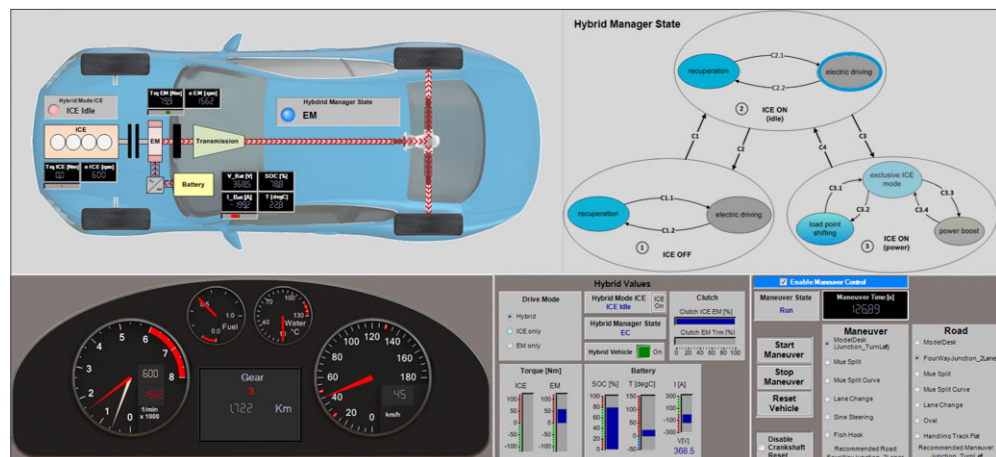
The main task of the Hybrid Manager Soft-ECU is to coordinate other ECUs according to driver requests, on the basis of the driving situation, and system conditions like the battery's state of charge (SOC) and temperature or the combustion engine's cooling temperature. For example, it will choose the hybrid mode to allocate the desired torque across the electric machine (EM) and the internal combustion engine (ICE):

- Load point shifting
- Exclusive ICE mode
- Boosting
- Electric driving
- Recuperation

It also takes care of the vehicle deceleration via recuperation and conventional brake control. Moreover, it manages the starting and stopping of the ICE and controls the two clutches.

Components and Characteristics

- Handle driver requests by coordinating other ECUs
- Choose hybrid mode to allocate desired torque across the EM and ICE
- Decelerate vehicle by recuperation and conventional brake control
- Manage the ICE starter, including starting and stopping
- Controlling the two clutches



ControlDesk layout for hybrid vehicle.

Use Cases

- Developing and testing hybrid powertrain management systems
- ECU tests for engine ECUs in combination with electric motor controllers
- Fuel consumption investigations
- Developing and testing regenerative braking systems
- Developing environment-based driving strategies for fuel efficiency enhancements

XSG Electric Components

Plant models for FPGA-based simulations

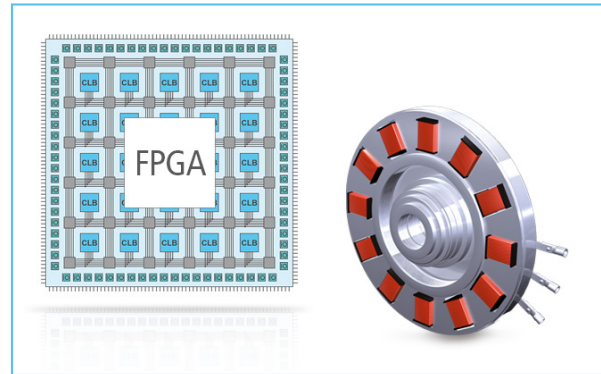
Application Examples

Electric motor control applications that demand very high precision and correspondingly high sample rates are simulated best on field-programmable gate arrays (FPGA). To support identical workflows for controller development and testing, the XSG Electric Components Models (closed-loop simulation components) are implemented as Xilinx® System Generator (XSG)¹⁾ models that run on a dSPACE DS5203 (PHS Systems) or DS2655 (for SCALEXIO) FPGA board. Closed-loop simulations of electric devices and their controls are supported at very high sample rates in real time.

Direct FPGA I/O Access

In addition to the plant models, the XSG Electric Component Library is supplemented by enhanced I/O functions from the included XSG Utils Library on the DS5203/DS2655 FPGA boards, e.g., for timing analysis and capturing digital input sources.

The XSG Electric Components Library and the DS5203/DS2655 FPGA boards can be used together for E-motor simulation on both the signal and the power level.



Components and Characteristics²⁾:

- Permanent magnet synchronous motor (PMSM)
- Brushless DC motor (BLDC)
- Advanced inverter model supporting DCM (discontinuous conduction mode)
- Squirrel cage induction motor
- Resolver, sine, TTL, and Hall encoder
- XSG Electric Library contains XSG Utils Libraries offering further functionality
- Configurable for delta-star connections of three-phase motor models

Example of a Simple Electric Drive Application

The FPGA carries:

- The motor model
- The model for the three-phase inverter

The processor carries:

- The mechanics model
- Parameterization for the FPGA models

Benefits

- High precision and stability
- Very high oversampling rate corresponding to the PWM switching frequency
- No PWM synchronization necessary
- Current ripple (PWM effects) can be simulated
- Better precision in simulating higher fundamental frequencies
- Open models – can be modified or partly replaced by users
- Run-time license available

Highly Nonlinear Electric Motor Models

- Inductance and flux depending on stator current
- Spatial harmonics

- Continuous integrated parameterization workflow from FEA tool JMAG®-RT to FPGA model
- Available on request

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.

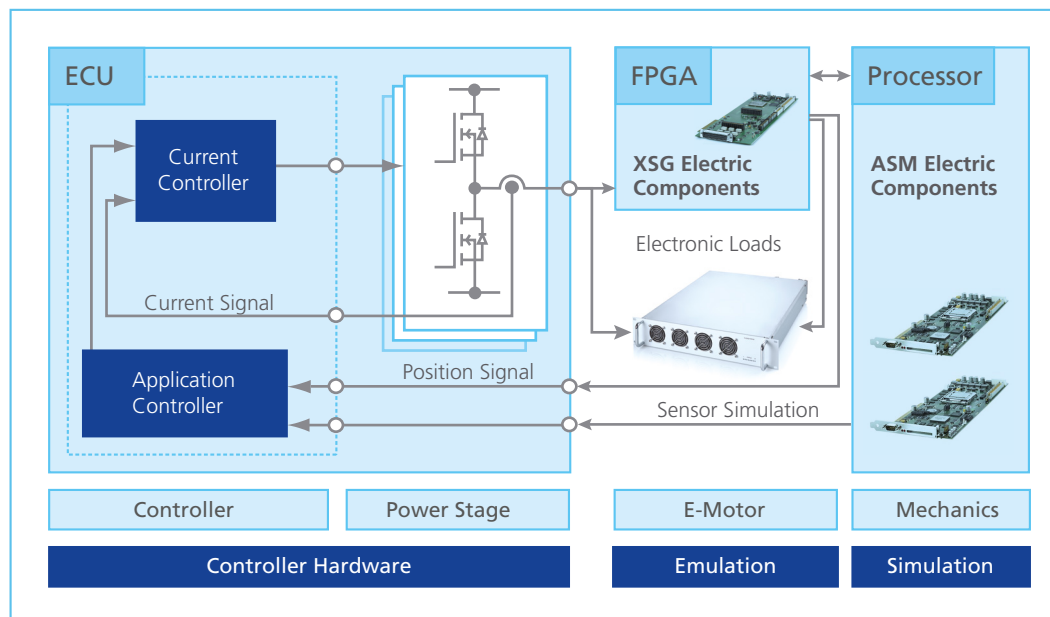
²⁾ In rapid control prototyping projects you can use the XSG Utils Library to implement ready-to-use function blocks in FPGA models.

Application Example: Electric Motor Emulation

Simulation at Power Level

Simulations at power level require that the highly dynamic behavior of electric motors and loads is represented exactly in real time. To achieve a highly precise emulation, special simulation models and platforms with low latency are required. The XSG Electric Components offer the necessary performance by running on a FPGA (field-programmable gate array) simulation platform.

This allows a very high sampling of the ECU signals (voltages), a fast calculation of the plant models, and the associated setpoint for the load emulation. It results in significantly improved simulation quality in terms of stability and accuracy when compared to processor-based simulation, primarily because FPGA-based simulations can be performed with very low latencies.



Parameter Import for Electric Machines

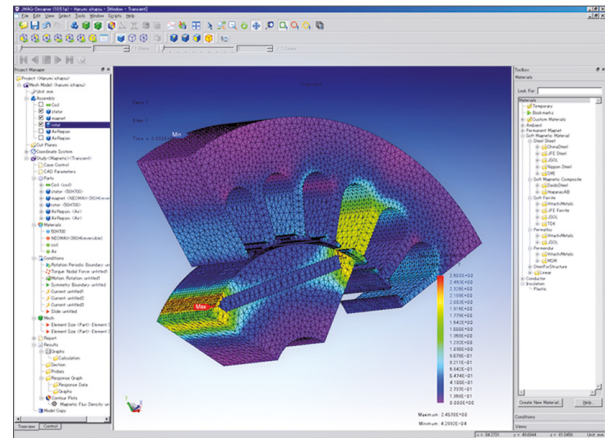
JMAG-RT Parameterization Support for ASM

Application

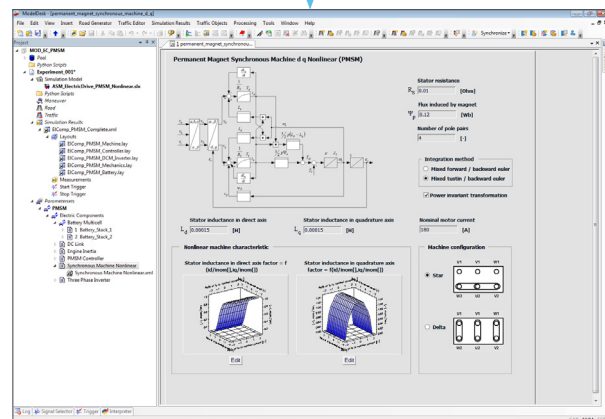
JMAG is a graphical development tool for electromechanical design that can be used to define the key characteristics of electric motors. JMAG-RT supports both the ASM Electric Components model and the XSG Electric Components FPGA-based models. With its export feature, the detailed characteristics of an electric motor can be exported and transferred in ASM parameter files to parameterize the ASM electric motor models.

Features

- Graphical definition of motor characteristics
- Import of motor characteristics into ASM
- Easy and precise parameterization of the ASM electric motor models
- Parameterization and calculation of FPGA-based spatial harmonic motor models



JMAG Designer



ModelDesk

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

Type	Order Number
ASM Electric Components	<ul style="list-style-type: none"> ASM_L_EC
XSG Electric Components	<ul style="list-style-type: none"> XSG_EC_LIB

Relevant Software and Hardware

Software for Online Simulation		
Required	Integrated development environment	<ul style="list-style-type: none"> MATLAB®/Simulink® from MathWorks Real-Time Workshop®
	Operating system	<ul style="list-style-type: none"> www.dspace.com/go/os_compatibility
	dSPACE implementation software	<ul style="list-style-type: none"> Real-Time Interface (RTI)
	dSPACE experiment software	<ul style="list-style-type: none"> ControlDesk®
Optional	Other simulation models from dSPACE	<ul style="list-style-type: none"> ASM packages

Software for Offline Simulation		
Required	Integrated development environment	<ul style="list-style-type: none"> MATLAB®/Simulink® from MathWorks Accelerator mode is recommended
	Operating system	<ul style="list-style-type: none"> www.dspace.com/go/os_compatibility
Optional	Other simulation models from dSPACE	<ul style="list-style-type: none"> ASM packages

Hardware		
Required	Minimum system	<ul style="list-style-type: none"> Pentium® 4 processor, 1.4 GHz or higher Memory = 2 GB RAM¹⁾
	Recommended system	<ul style="list-style-type: none"> Intel® Core™ i5 Processor, 3 GHz or higher Memory ≥ 4 GB RAM
	SCALEXIO®, MicroLabBox, or dSPACE Simulator, equipped with...	<ul style="list-style-type: none"> DS1005, DS1006, DS1007

¹⁾ Offline simulations only.

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