Motivation for C-based Modeling and Simulation of Automotive Systems

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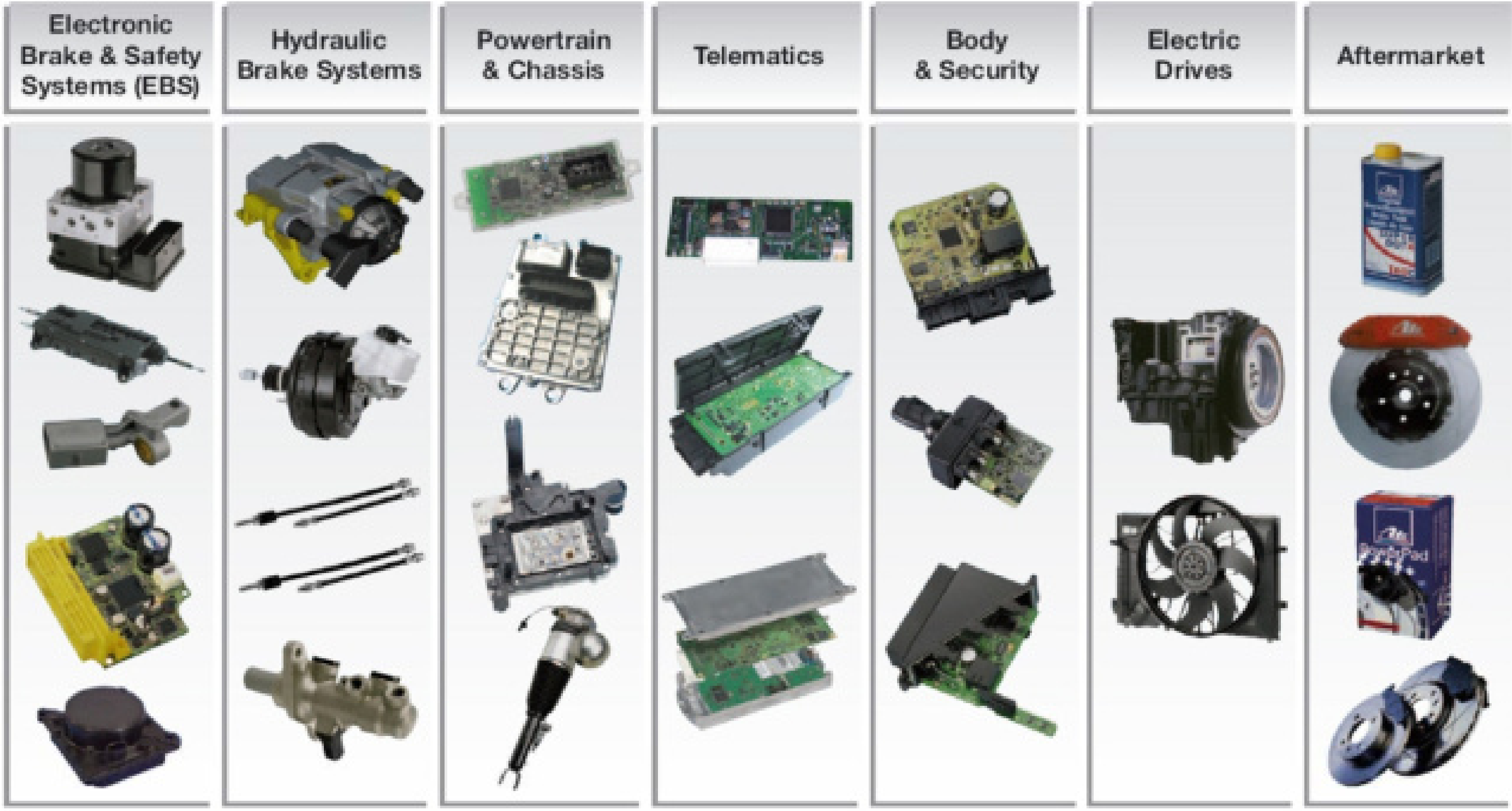
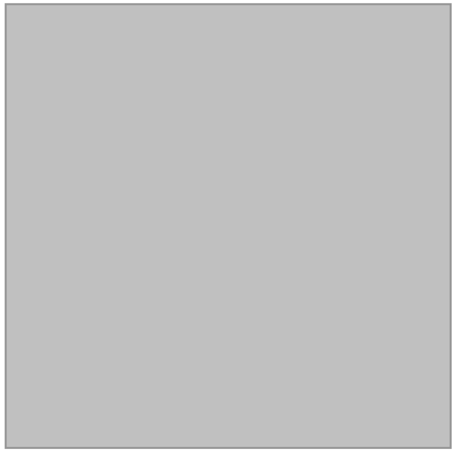


Business Unit Electronic Brake and Safety Systems (EBS)

ABS: Anti-lock Brake System; TCS: Traction Control System; ESC: Electronic Stability Control

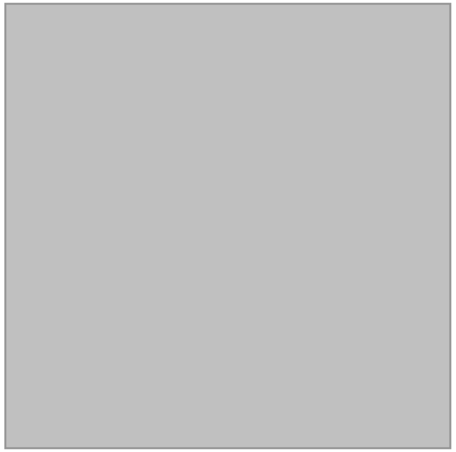
Continental Teves IC Development Competence



MCU for ESP systems (series since mid 2003)
0.18um CMOS, 2MB Flash

- Continental Teves has experience since 1990 in full-custom microcontroller design
  - Three generations with more than 30 Flash/ROM derivates
  - ~ 15 million MCU’s / year
- CT Microcontrollers are „cutting edge“ custom solutions optimized for
  - Failsafe for EBS (Dual-Core)
  - Cost
- The thorough HW-/SW-concept assures highest quality in series production

Continental Teves IC Development Competence



Analog/Mixed Signal power control unit for ESP systems
(series since 2003), 0.35um BiCMOS

- Continental Teves has experience since 1986 in full-custom mixed signal IC design
  - Long-term development partnership with leading IC manufacturers
  - ~ 15 million mixed signal ICs / year
- CT mixed signal devices are automotive industry leader in integration density
  - Single chip for all mixed signal functions
  - Cost and board space optimized
  - Low number of PCB circuit nodes keeps failure probability low
  - Failsafe system concept with redundant safety features (FMON, Watchdog and other hardware based safety functions)

System Simulation

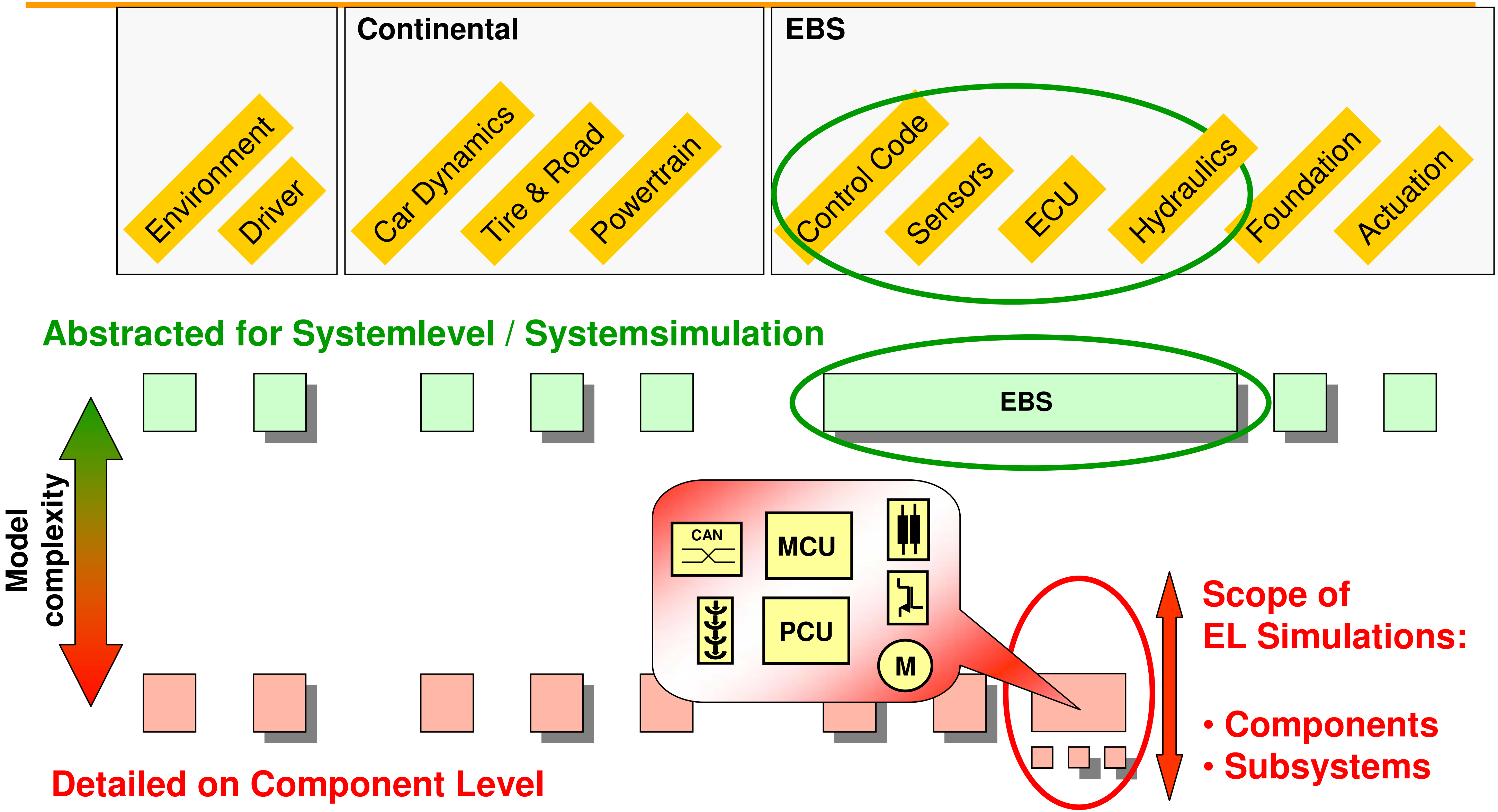
Benefits

- Parallelizing development of hardware and software
- Reducing number of iterations during hardware development

  ⇒ reduced time to market
- Evaluation of hardware components to be developed in complex hardware/software environment
- Reducing cost for testing equipment

- Enhanced verification capabilities
- Verification of software components
- Verification of complex analog/mixed signal systems
- Verification of complex hardware/software systems

Modeling Levels / Matrix



System Simulation

Some Typical Use Cases

- Development and validation of hardware dependent SW (low-level drivers)
- Development and validation of Basis-SW
- Development of silicon test cases prior to silicon availability
- Cross correlation to silicon during silicon evaluation
- Application SW performance analysis
- Validation of HW/SW-interface in SW-release process
- Definition of requirements for new microcontroller architectures
- System-level mixed mode simulations of e.g.
  - ABS/ESP maneuver with series code on chipset
  - Valve control subsystems
- Application SW development / validation
- Custom IC development / validation

Modeling Issues

- Effort to create and maintain models
- Simulation speed
- Integration into different simulation environments
- Finding appropriate abstraction levels for each model
- Consistency check for models modeling one component at different abstraction level
- Finding appropriate simulator /simulation technology

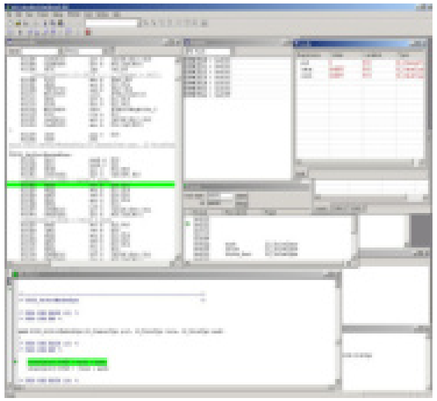
Requirements: Model Accuracy

- Main use cases

System Simulation

Hardware development

Software development



Requirements: Model Accuracy

Required degree of accuracy depends on use case!

Some application examples:

Hardware dependent low-level software

- Functional model of analog sufficient

Development/validation of Application software :

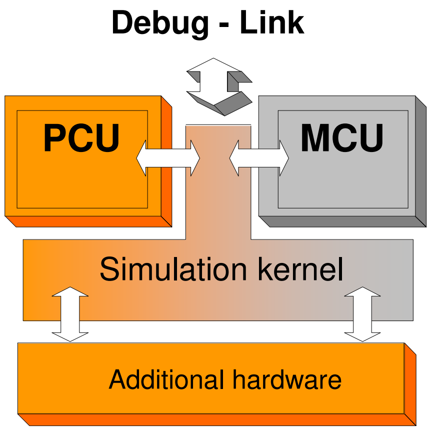
- No information about structure of analog components required
- Accurate models of behavior required, e.g., where software uses hardware mechanisms to measure analog values like voltage , current, phase, …

Hardware development:

- Partially detailed modeling of structure and behavior
- Pin-accurate
- Timing-accurate

Fields of application of models

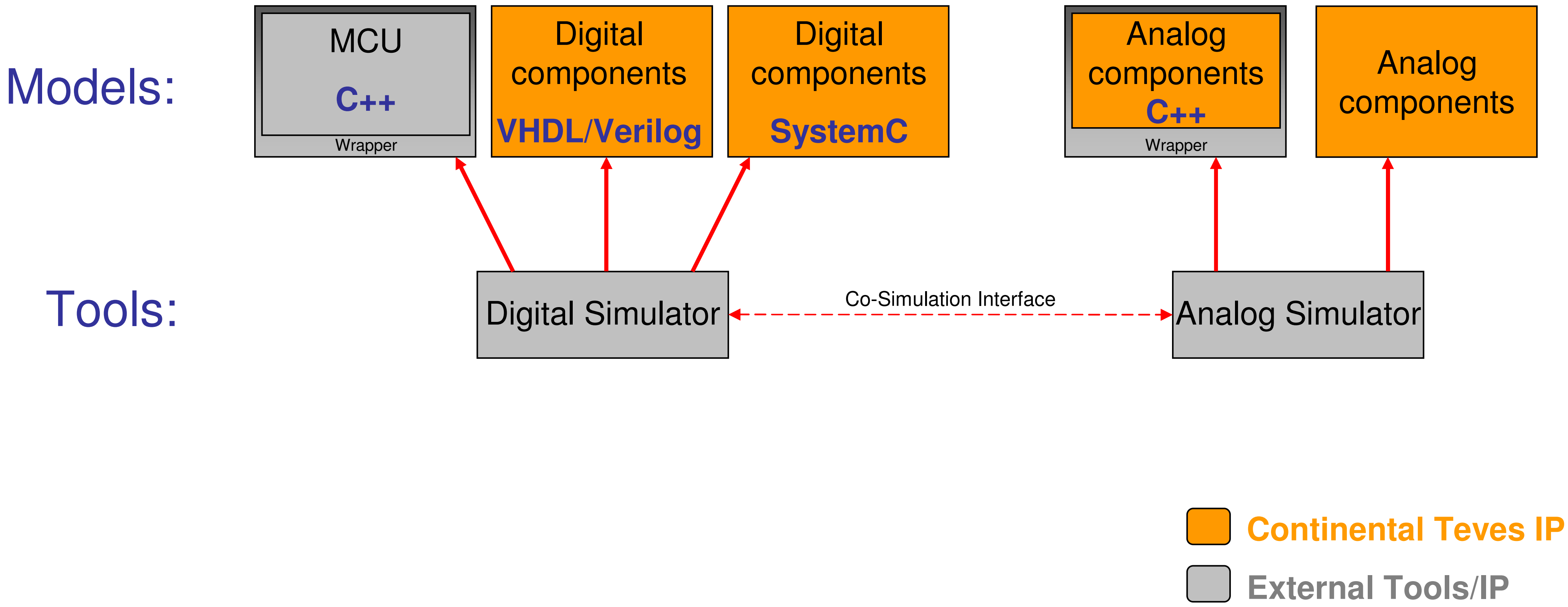
- Different Simulations environments depending on use case
- Models have to fit into various simulation environments
- Simulation environments consist of:
  - In-house models
  - 3rd party models



- Interfaces, linking mechanisms for coupling of models required

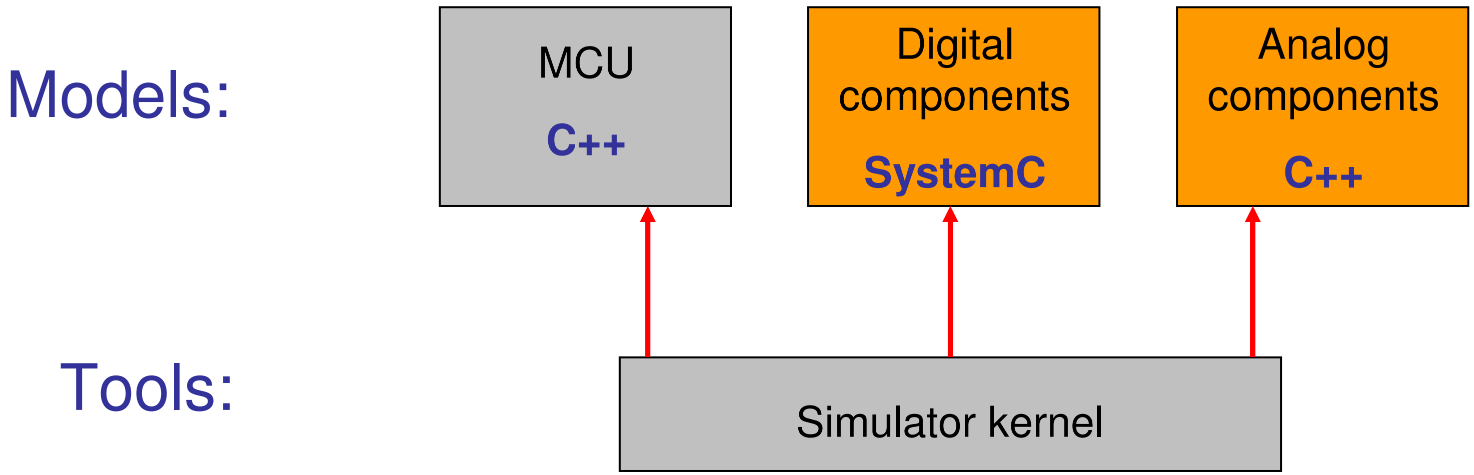
Exemplary Simulation Environment

- Simulator being used for Hardware Development



Another Exemplary Simulation Environment

- Simulator being used for development/validation of low-level (hardware dependent) - software



C++ - based Modeling

Benefits

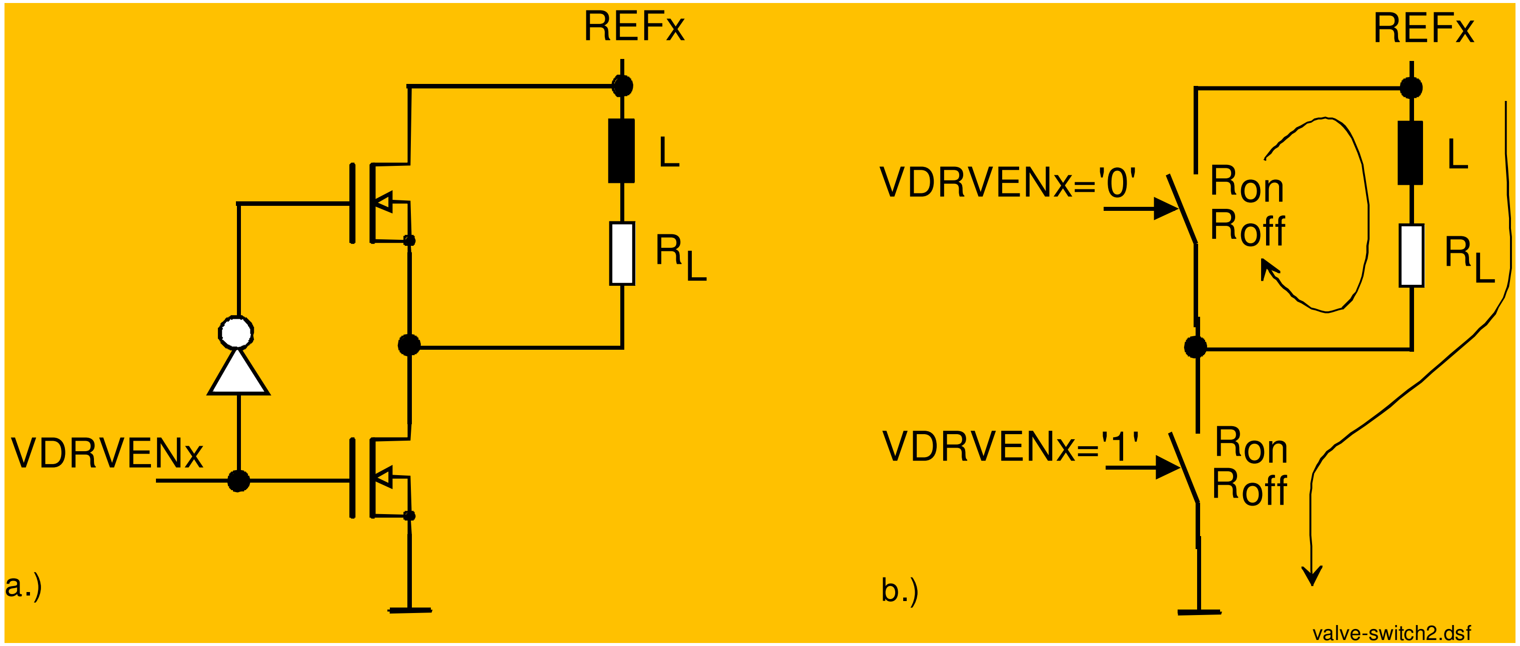
- Easy integration of in-house models into various simulation environments
- Enables modeling on various levels of abstraction
- **Enables modeling of analog modules at higher abstraction levels**
- Easy coupling of analog and digital components
- Enables building up one unique model database for various use cases
- Easy integration of in-house C++ test beds/tools for generating stimuli, performing online analysis, modeling remote stations for communication system tests, …
- Easy portable to other platforms

AVSL (Advanced Vehicle Simulator Link)

- Continental Teves in-house Simulation Technology
- C++ based
- Designed for building simulation slaves
- Offers time driven and event driven module invocation mechanisms
- Used for digital and analog components
- Used successfully in system simulation for many years

Application Example: PWM Valve Driver

- Valve driving stage: low-side and recirculation driver (principle)



Application Example: PWM Valve Driver

Motivation for using C++

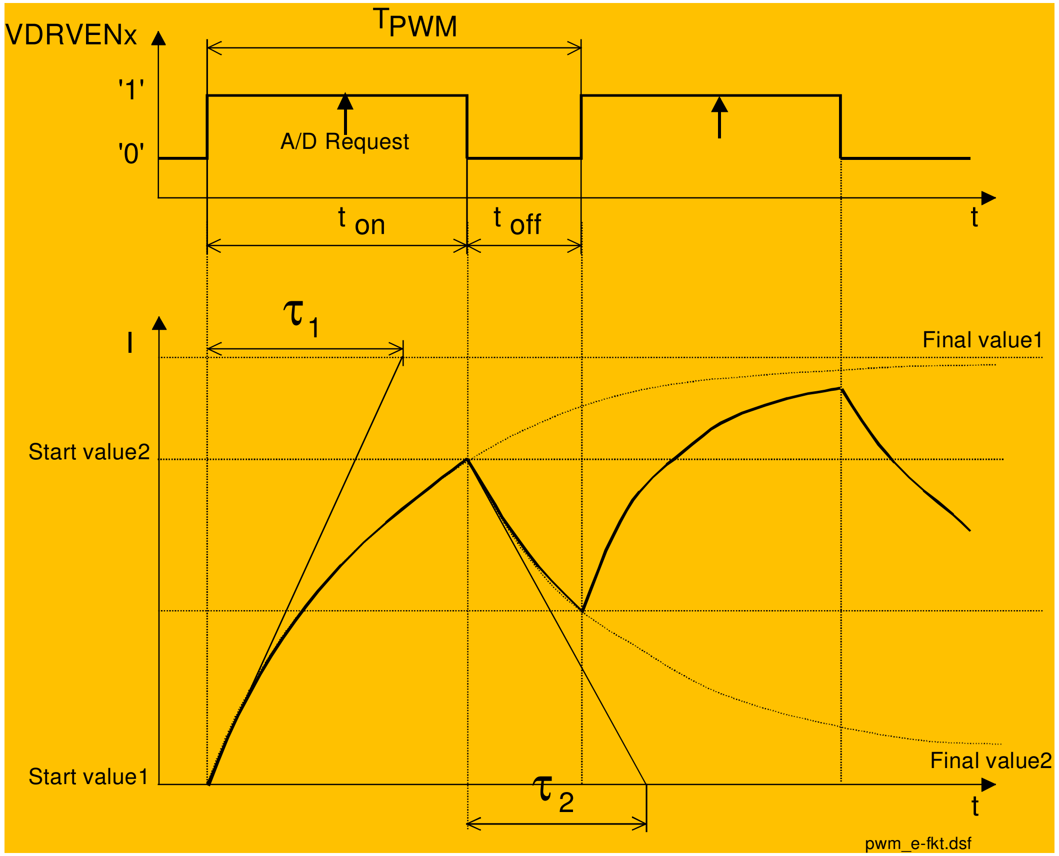
- Numerical integration very slow (Spice, Saber, ...)
- Power electronics: only one path switching (pull-up, pull-down)

Approach:

- Taken from switch-level simulation of digital circuits (pull-up, pull-down of nodes)
- Abstract model written in C++: charging & discharging described by exponential functions

Application Example: PWM Valve Driver

- Current curve progression within a coil using PWM



Application Example: PWM Valve Driver

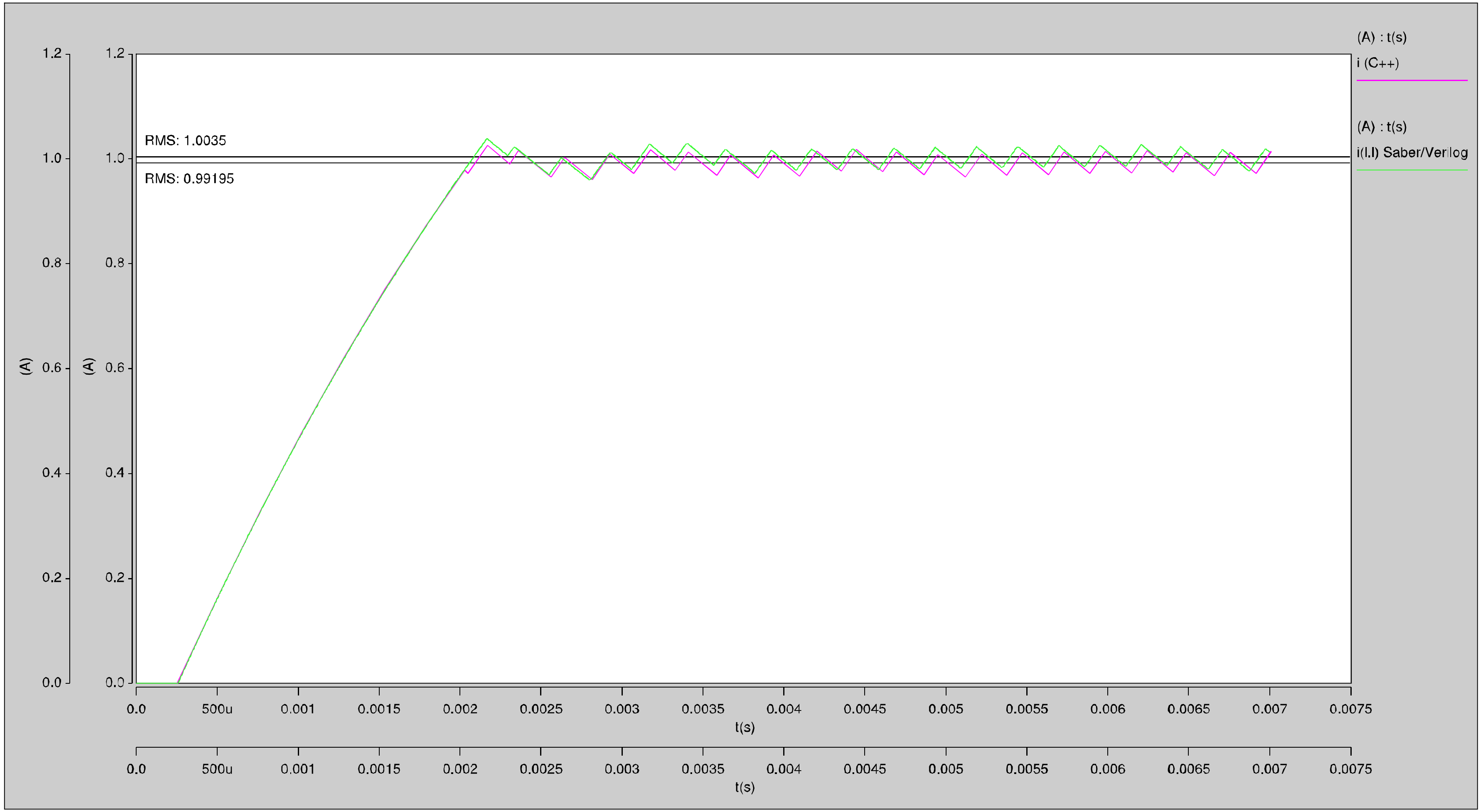
Modeling and Simulation Strategy

- Determination of the actual resistances (R_{on}, R_{off})
- Calculation of the dominant path (minimum resistance, driving voltage)
- Summing of R, L, C of a dominant path $\rightarrow$ Parameters
- Choice of proper equation
- Calculation of voltages and currents

Application Example: PWM Valve Driver

PWM valve drivers are embedded into PWM valve control module (mixed analog/digital)

- Simulation of switching operation with a simplified ***C++ Model*** and with ***Saber/Verilog***



Application Example: PWM Valve Driver

Simulation runtime

Simulation technology	C++	Saber/ Verilog
Run time	approx. 5 sec	approx. 5 min

Migration to Industry Standard

Industry standard vs. in-house technology :

- Reusability at supplier for other in - house purpose / other customers
- Exchangeability of models (sub modules) between suppliers
- Tool support (e.g. code generators, analysis tools, etc.)
- Cost for maintenance

Digital Domain

- Moving to SystemC for new projects
- Model suppliers deliver SystemC models

Analog Domain

- Migration planned from AVSL to SystemC-AMS, once
  - SystemC-AMS is standardized
  - Tool support is available

Requirements for the Future

SystemC - AMS Language

- Modeling analog systems on structural level as well as on abstract behavioral level
- Modeling of parameter uncertainties (e.g. temperature drifts)

Simulation Technology

- Speeding up simulation
- Automatic generation of fast behavioral models from complex structural models

