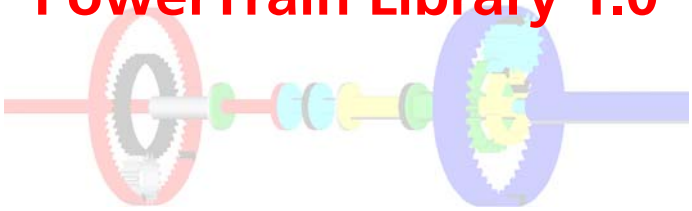
PowerTrain Library 1.0



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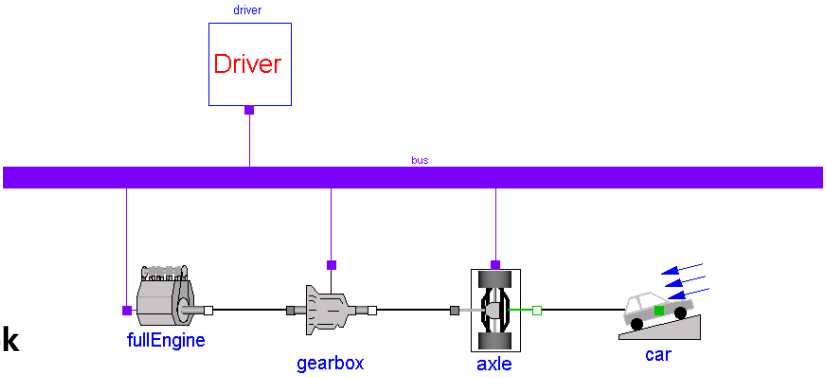
Modelica Automotive Workshop
November 19, 2002
Ford Research Laboratory
Dearborn, MI, USA

Outline

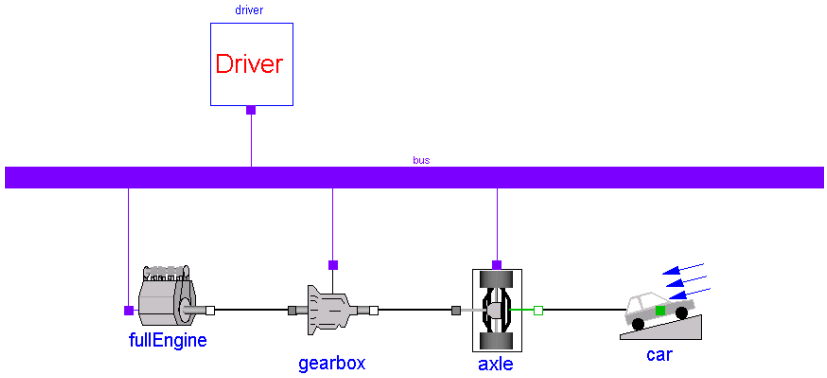
- Library overview
- Components
- Applied concepts
  - Usage
  - Implementation
- Case study
- Online demonstration
- Conclusions and outlook



The DLR PowerTrain Library

Commercial library of DLR with primarily 1D rotational mechanical components. Suitable for

- Examination of gear shift dynamics
- Hardware-in-the-loop simulation of automatic gearboxes
- Concept studies of drive lines (e.g. fuel consumption reduction)
- ...



History

1996: Project with BMW for HIL simulation of automatic gearboxes (using the Dymola language)

2000: Version 0.95 of PowerTrain library using the Modelica language (sold to BMW and other automotive companies)

2001: Start to considerably enhance the PowerTrain library

2002: Release of PowerTrain 1.0

Direct Contributors

- Ingrid Bausch-Gall, Bausch-Gall GmbH, Germany
- Mike Dempsey, Claytex Services Ltd, UK
- Martin Otter, DLR, Germany
- Clemens Schlegel, Schlegel Simulation GmbH, Germany
- Christian Schweiger, DLR, Germany

PowerTrain Library Features

45 user-callable components

Signal bus concept

Variant selection

Robust friction modeling

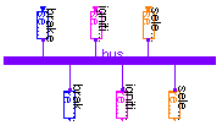
- Torque dependent losses (e.g. mesh efficiency)

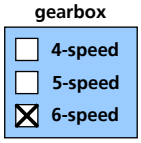
Animation of transmission components

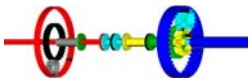
10 introductory and sophisticated examples

Universal control units

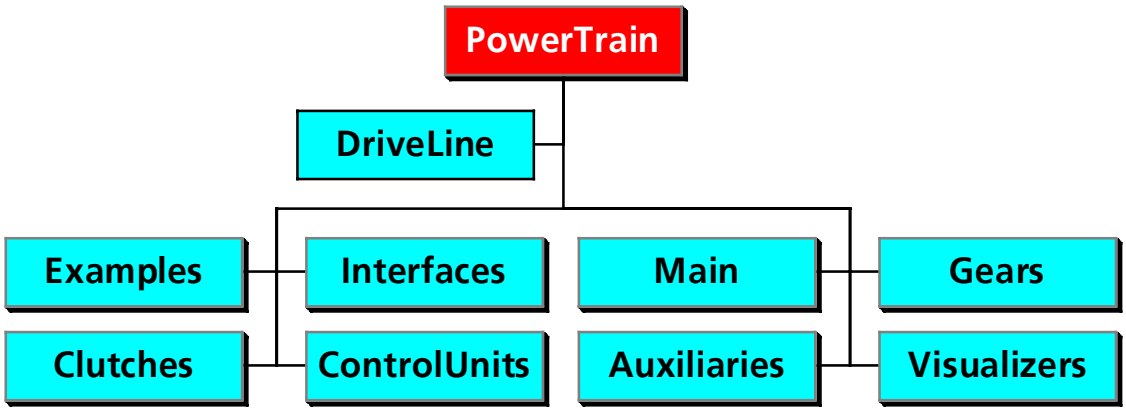
Online tutorial







Library Structure



Model DriveLine

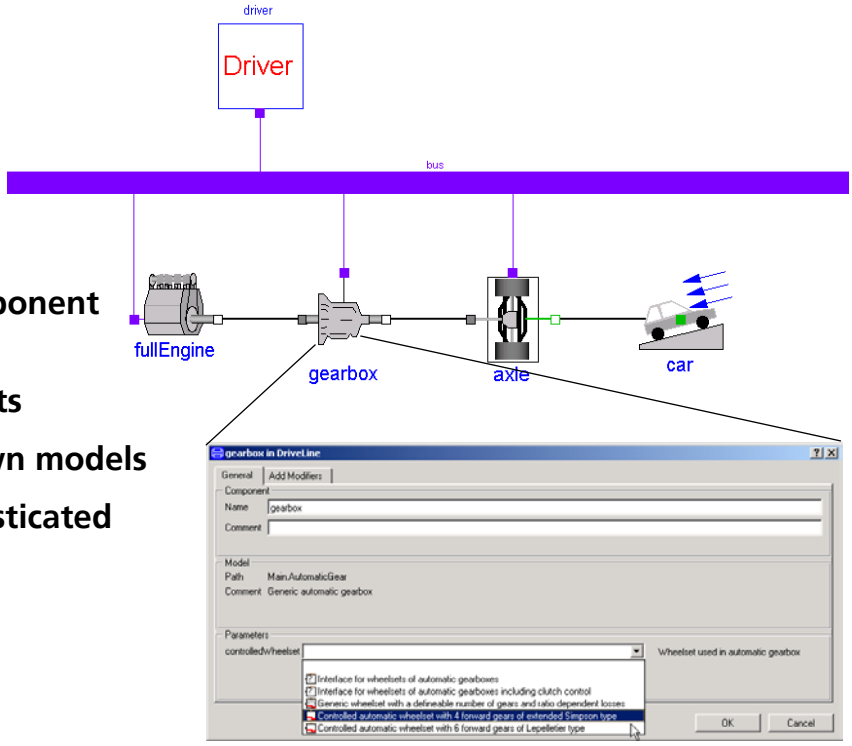
Library top-level view:
generic drive train

Different configurations selectable for every component (e.g. 3 gearbox variants)

User can add own variants

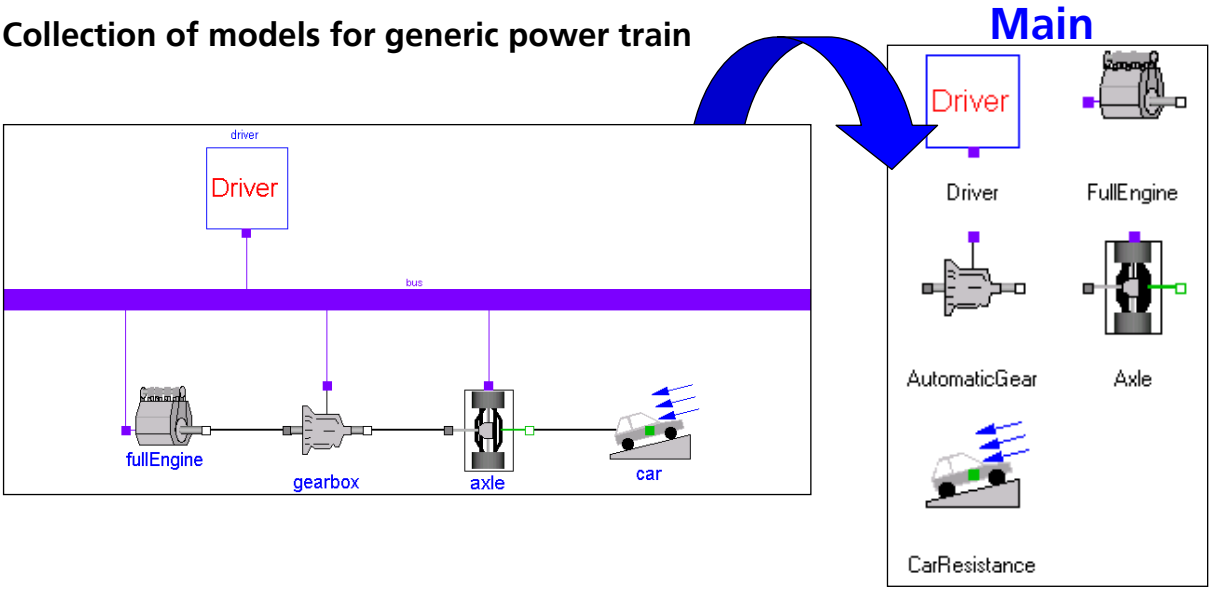
Template for building own models

Used as a basis for sophisticated demo examples



Sublibrary Main

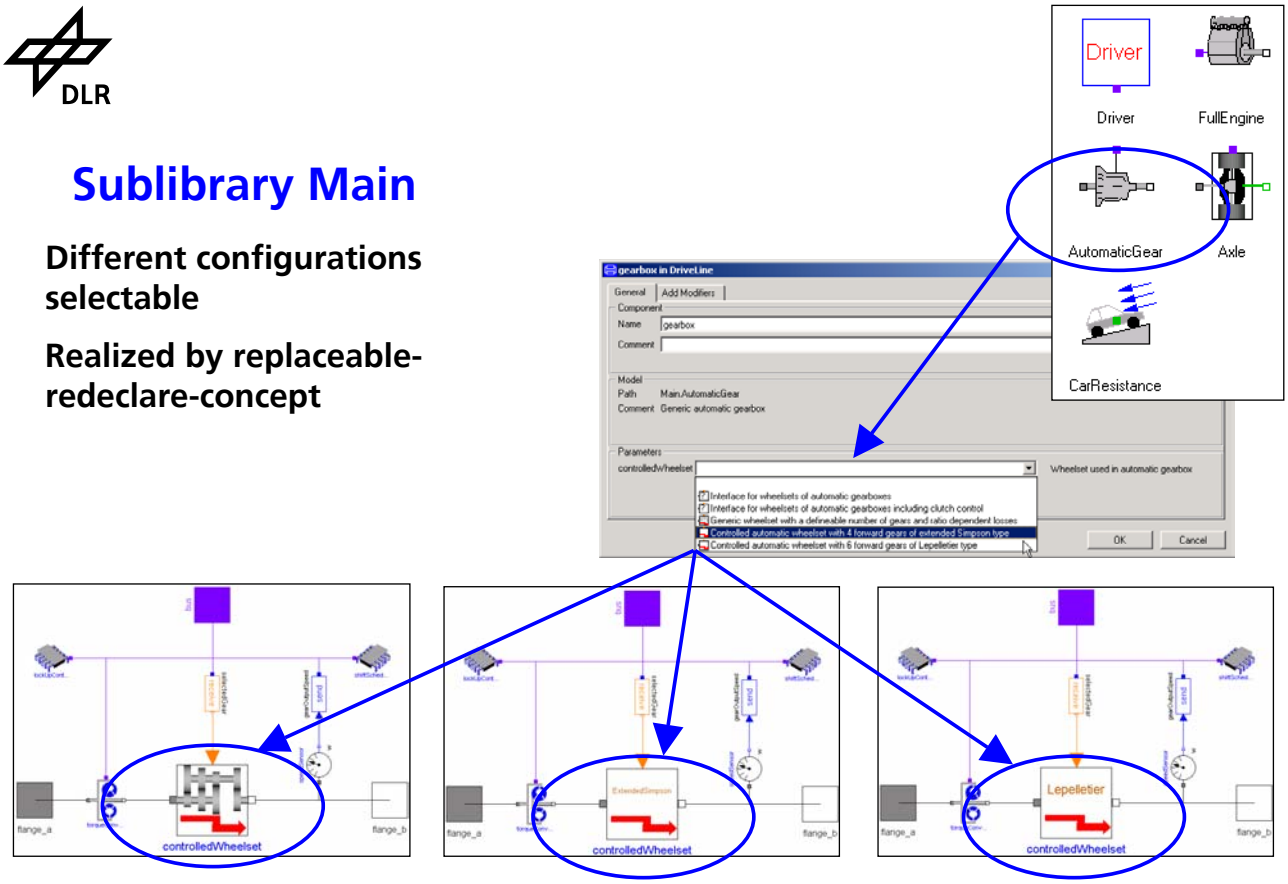
Collection of models for generic power train



Sublibrary Main

Different configurations selectable

Realized by replaceable-redeclare-concept



Sublibrary Gears

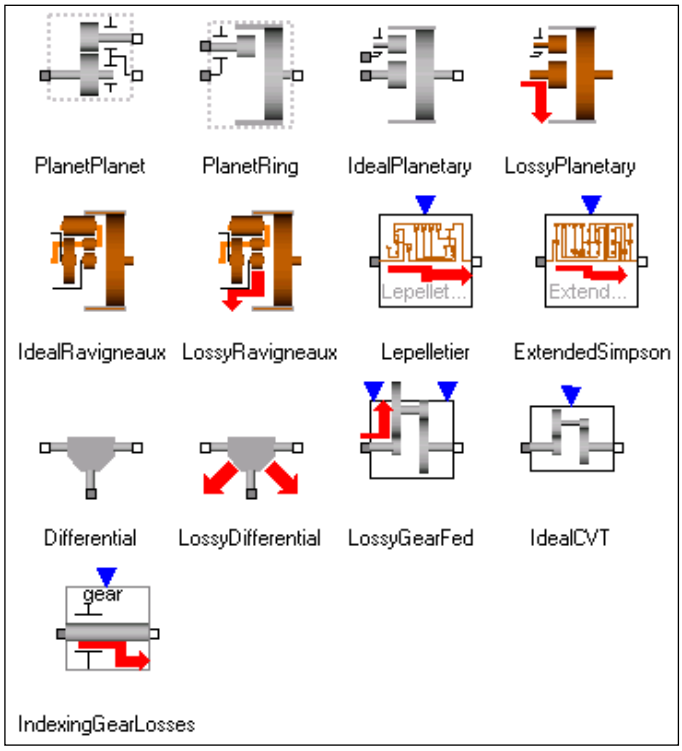
Content

- **Gear components**
- **Standard gears**
- **Complete wheelsets**

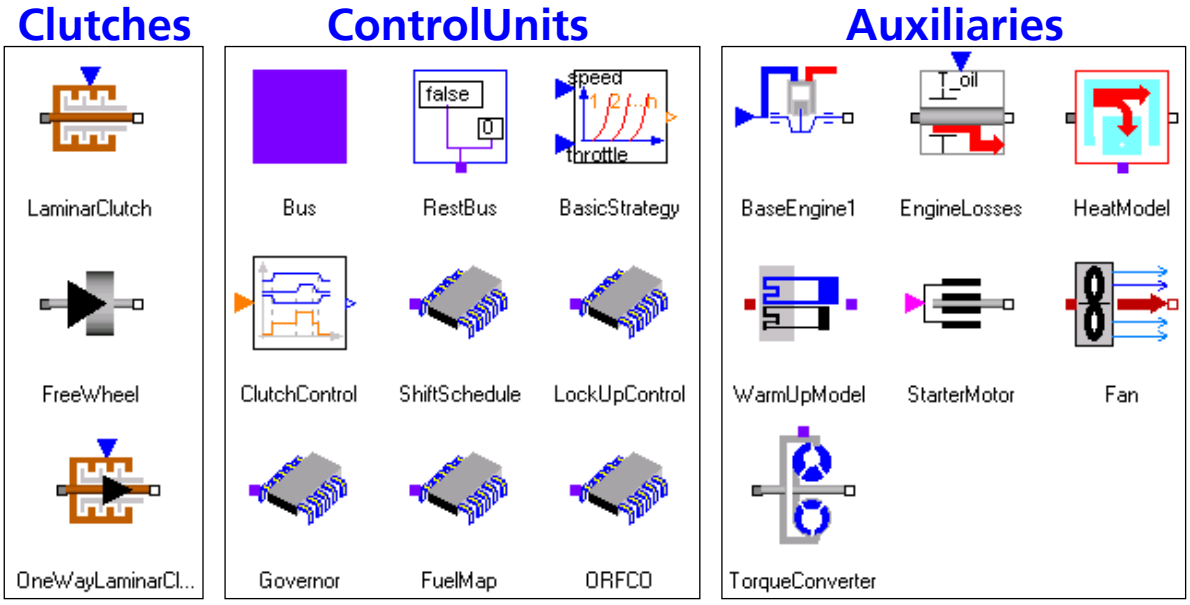
Color coding

- **Red: losses due to mesh efficiency and bearing friction**
- **Brown: built-in animation**

Gears

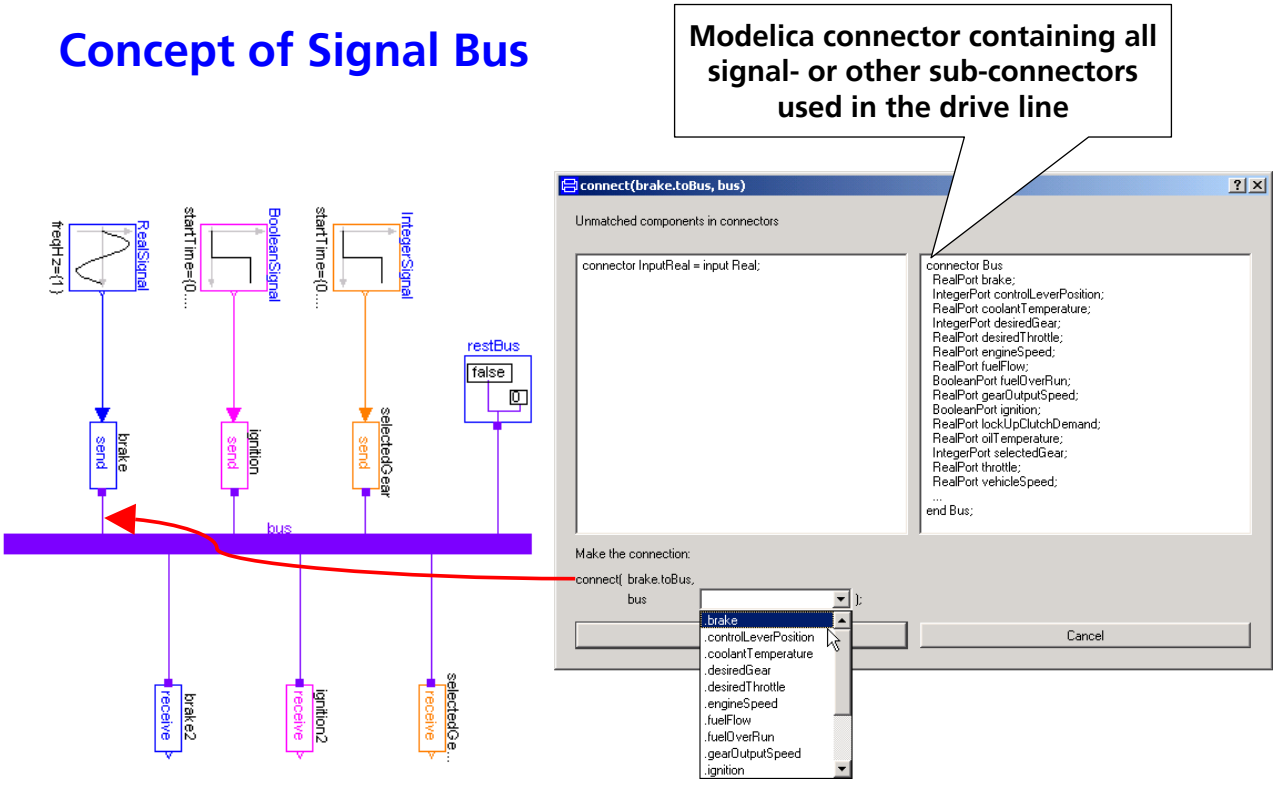


Other Sublibraries



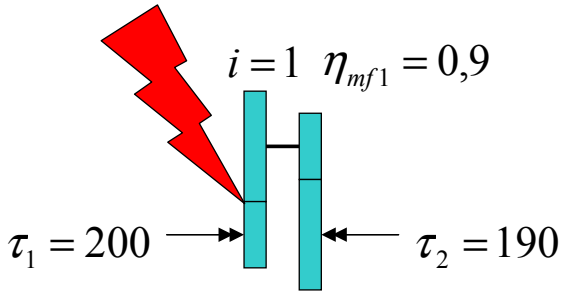
Concept of Signal Bus

Modelica connector containing all signal- or other sub-connectors used in the drive line



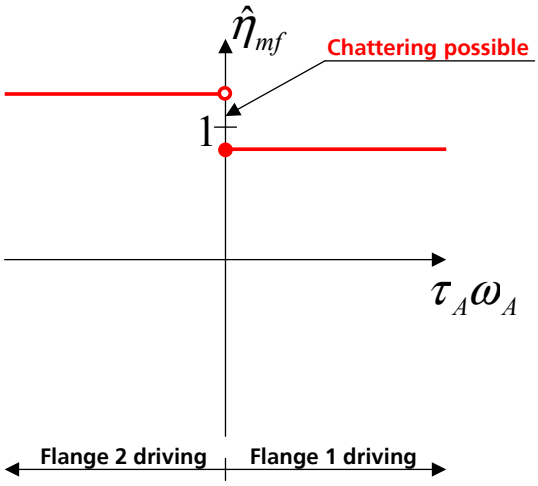
Efficiency Modeling

Locking due to mesh friction



Flange 1 driving: $\tau_1 \eta_{mf1} < \tau_2$
Flange 2 driving: $\tau_2 \eta_{mf1} < \tau_1$

Usual approach



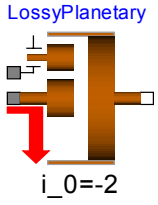
Efficiency Modeling

Efficiency is free variable while stuck mode is active

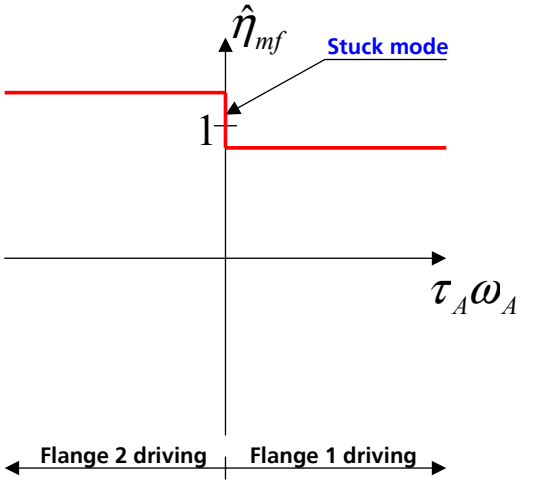
Modelica friction implementation extended for torque dependent losses

Allows robust efficiency modeling

- LossyGear
- LossyPlanetary
- LossyRavigneaux
- ...



Our approach

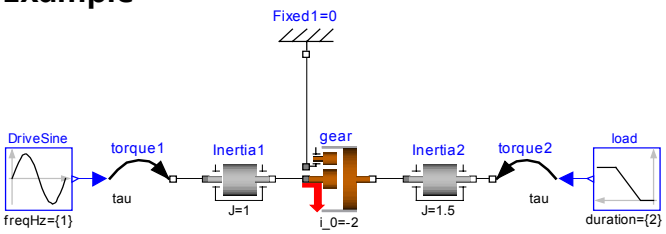


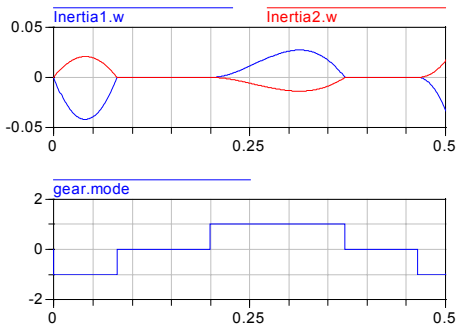
Efficiency Modeling

Takes stuck / rolling behaviour into account

Very much better than usual approach

Example





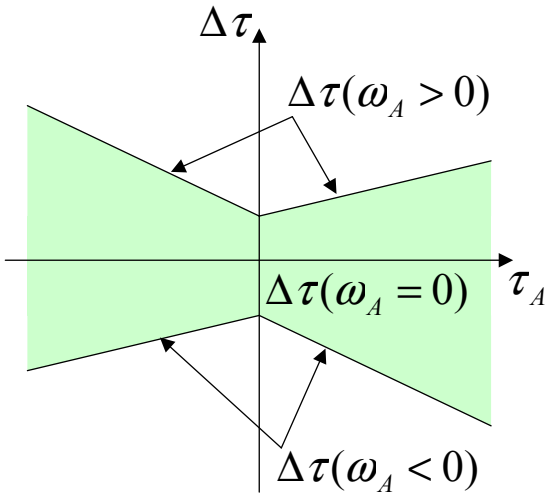
gear.mode

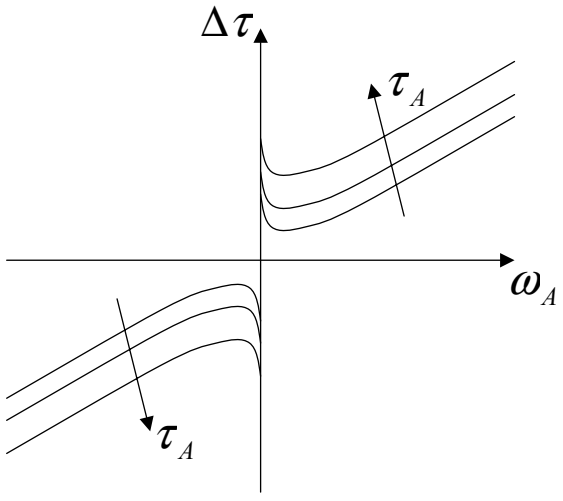
1	forward rolling
0	stuck
-1	backward rolling

Efficiency Modeling

Torque loss

$$\Delta\tau = \Delta\tau(\omega_A, \tau_A)$$

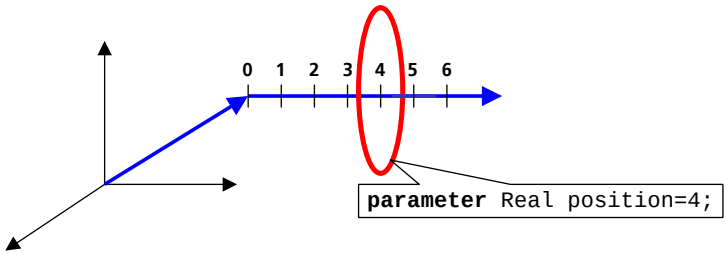


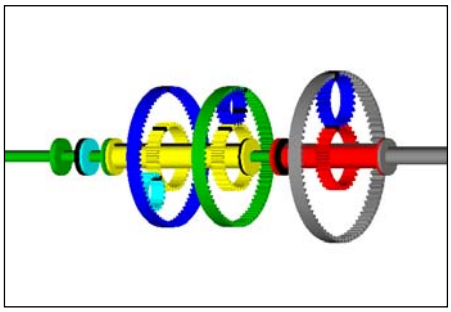


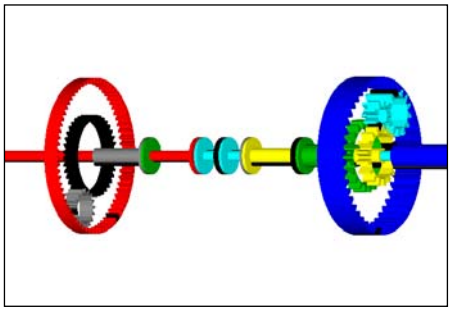
Animation

Built-in animation for gears, clutches, shafts

Easy parametrization







Possibility to turn off

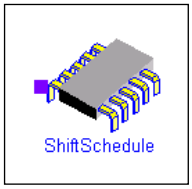
- `parameter Boolean animation=false;`
- **Animation equations removed from code (necessary for e.g. real-time simulation)**

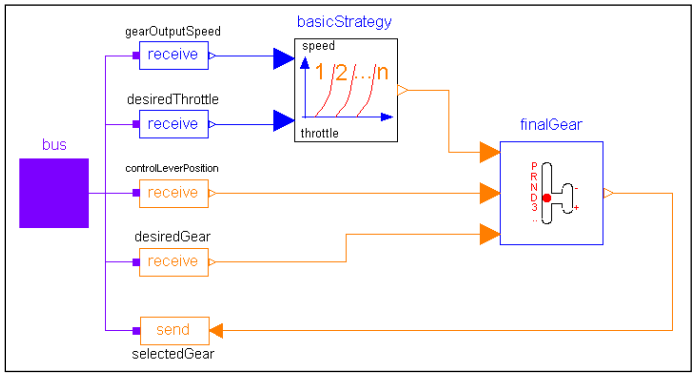
Universal Control Units

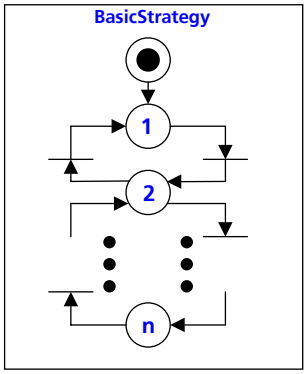
Fully parametrizable, independent from gear type or speed number

- **Transmission: shift schedule, lock-up clutch control**
- **Engine: governor, fuel map, over-run fuel cut-off control**

Example



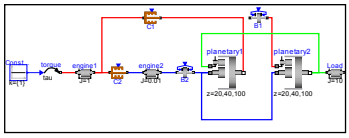


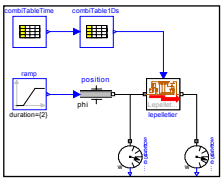


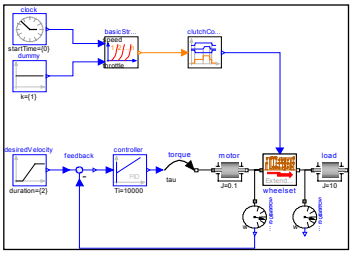
PowerTrain.Examples

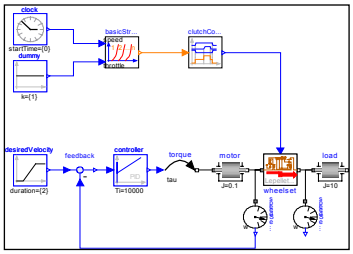
Purposes

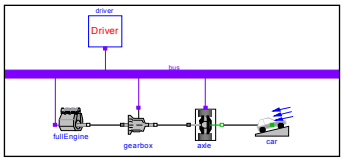
- Introduction to library
- Hints for development of own models
- Starting point for own models



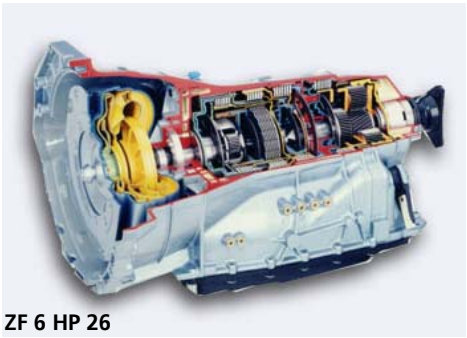






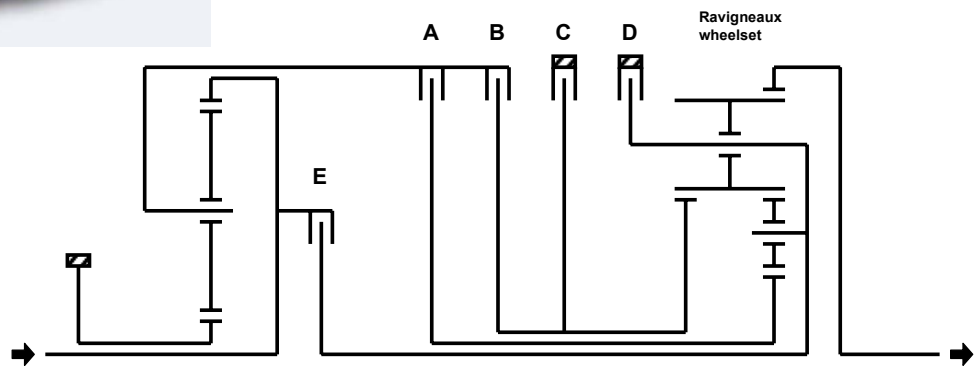


Example: 6-speed automatic gearbox

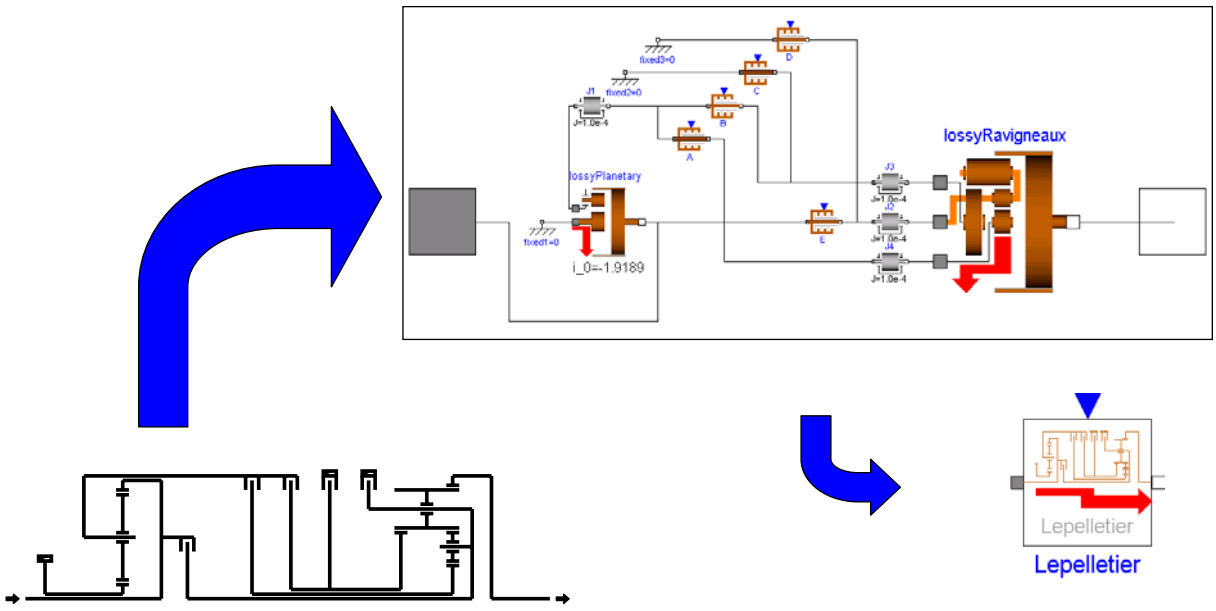


ZF 6 HP 26

Lepelletier type

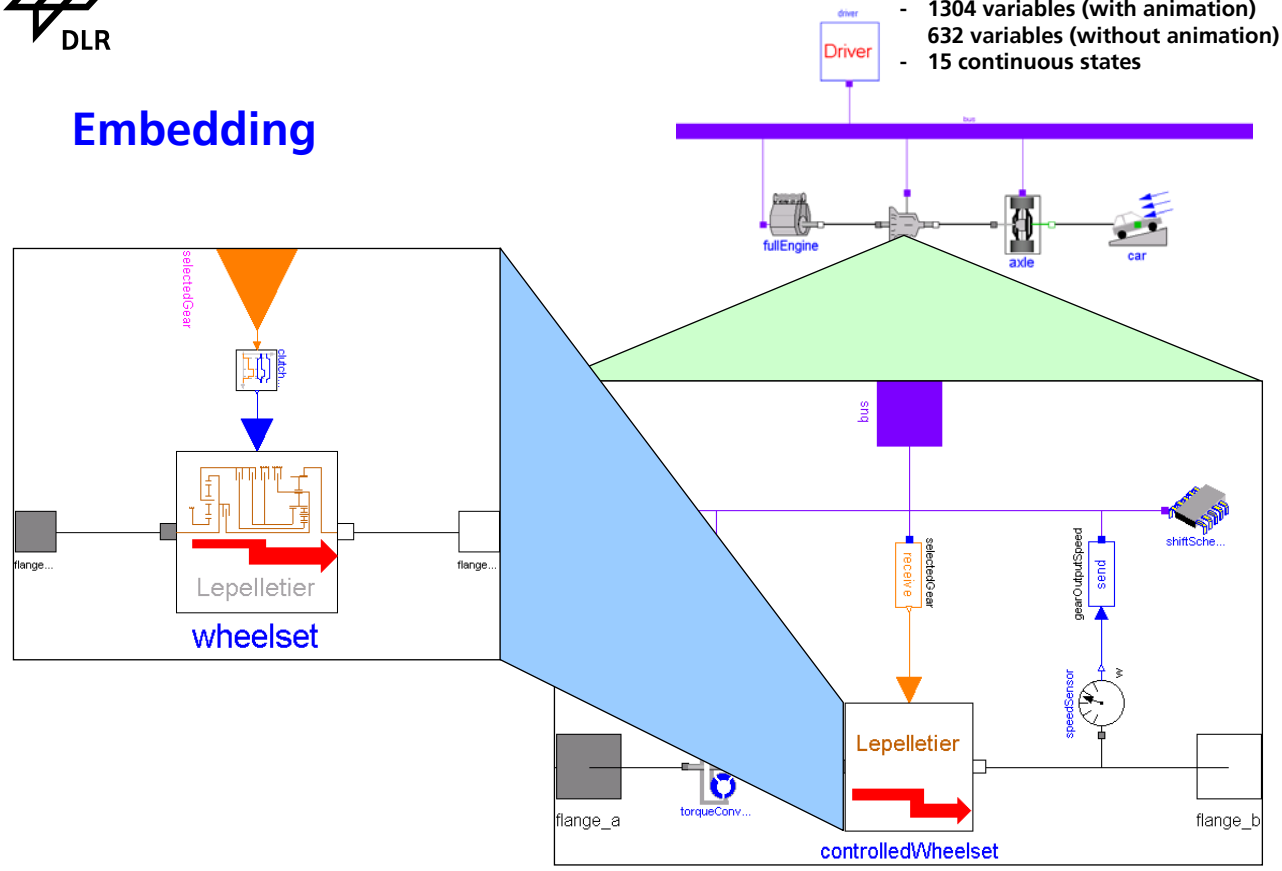


Modelica Object Diagram

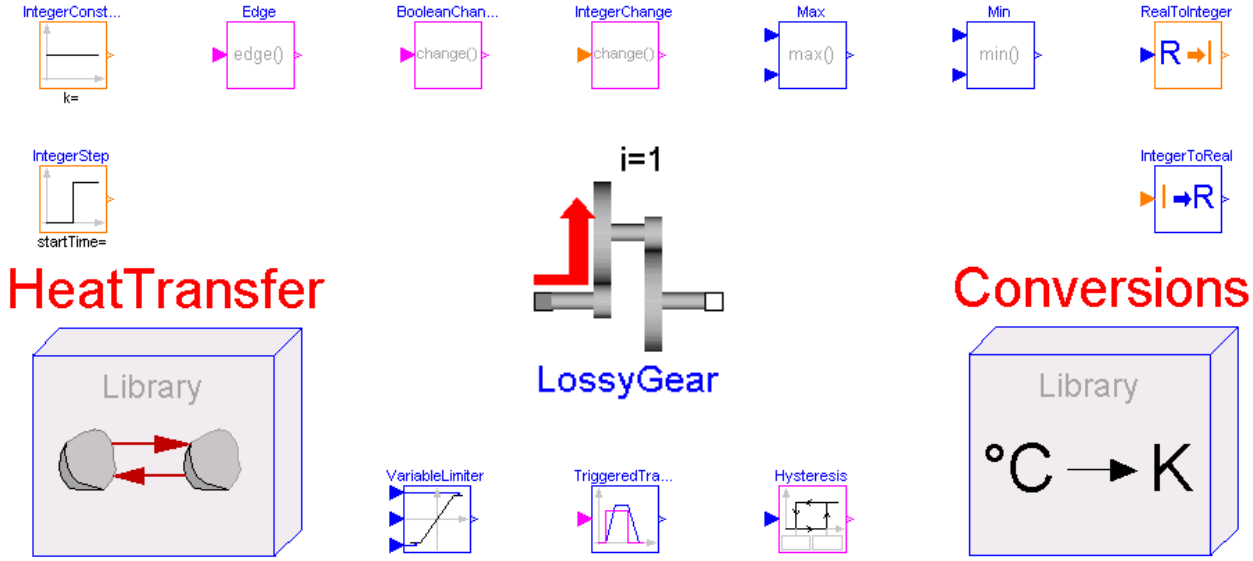


Embedding

Complexity:
- **1304 variables (with animation)**
  632 variables (without animation)
- **15 continuous states**



45 New Components for the Modelica Standard Library



Conclusions and Outlook

Powerful library for different power train modeling tasks

- **Examination of gear shift dynamics**
- **Hardware-in-the-loop simulation**
- **Drive line studies**

Well-designed structuring

Planned for future:

- **3D Coupling with vehicle dynamics library**
- **Additional standard wheelsets, drivers, engines, ...**
- **Vendor gearboxes**
  (user does not need to identify gearbox, since complete model data set will be provided)