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eFMI® Tutorial – Agenda

Part 1: eFMI® motivation and overview (40 min)

Part 2: Running use-case introduction (10 min)

Part 3: Hands-on demonstration in Dymola and
Software Production Engineering (former name CATIA ESP) (25 min)

Coffee break (30 min)

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Part 4: Live demonstration in TargetLink (30 min)

Part 5: Short presentation of further tooling (5 min)

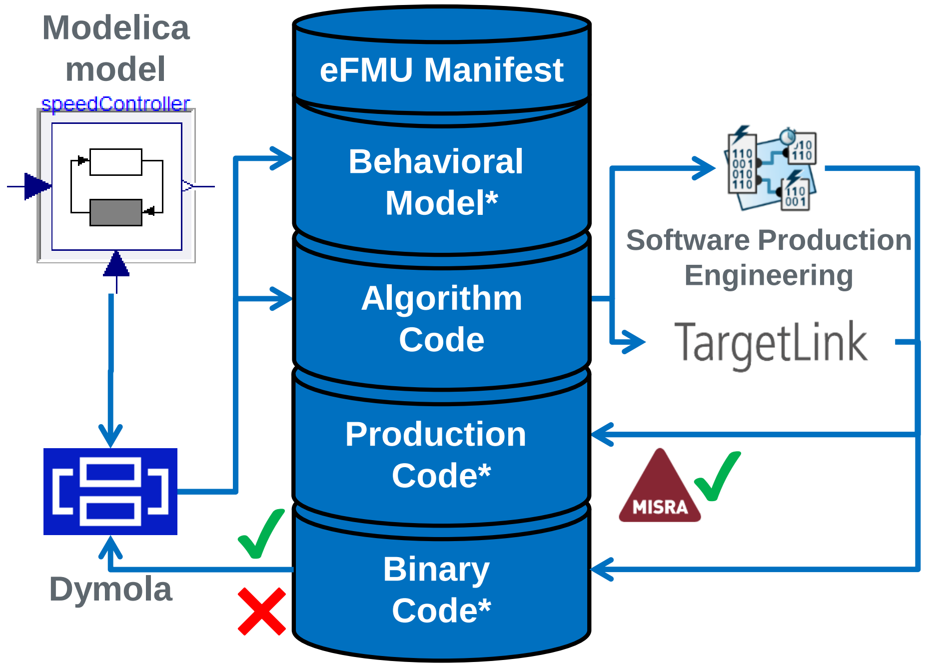
Part 6: Conclusion (5 min)

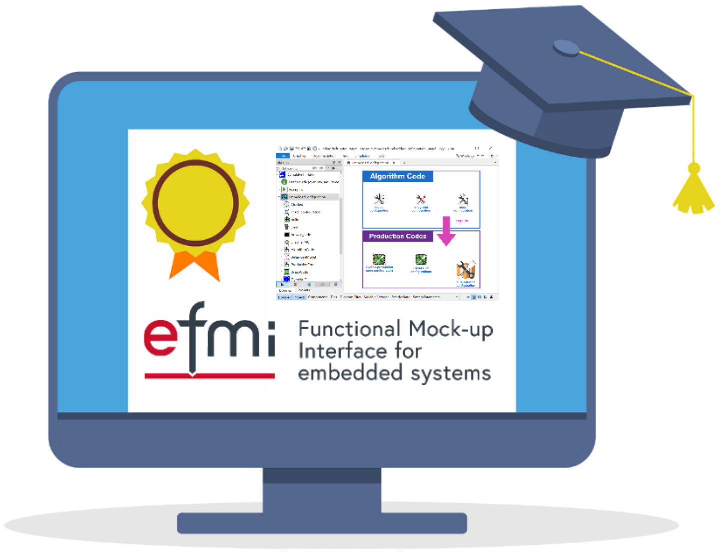
Tutorial leader:
Christoff Bürger
DASSAULT SYSTEMES

Presenter:
Oliver Lenord
BOSCH
Invented for life

Presenter:
Jörg Niere
dSPACE

efmi Functional Mock-up Interface for embedded systems





Part 2: Running use-case introduction

eFMI® Tutorial – 15th International Modelica Conference – 9th of October 2023

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Oliver Lenord
(presentation & use-case assessment)
BOSCH
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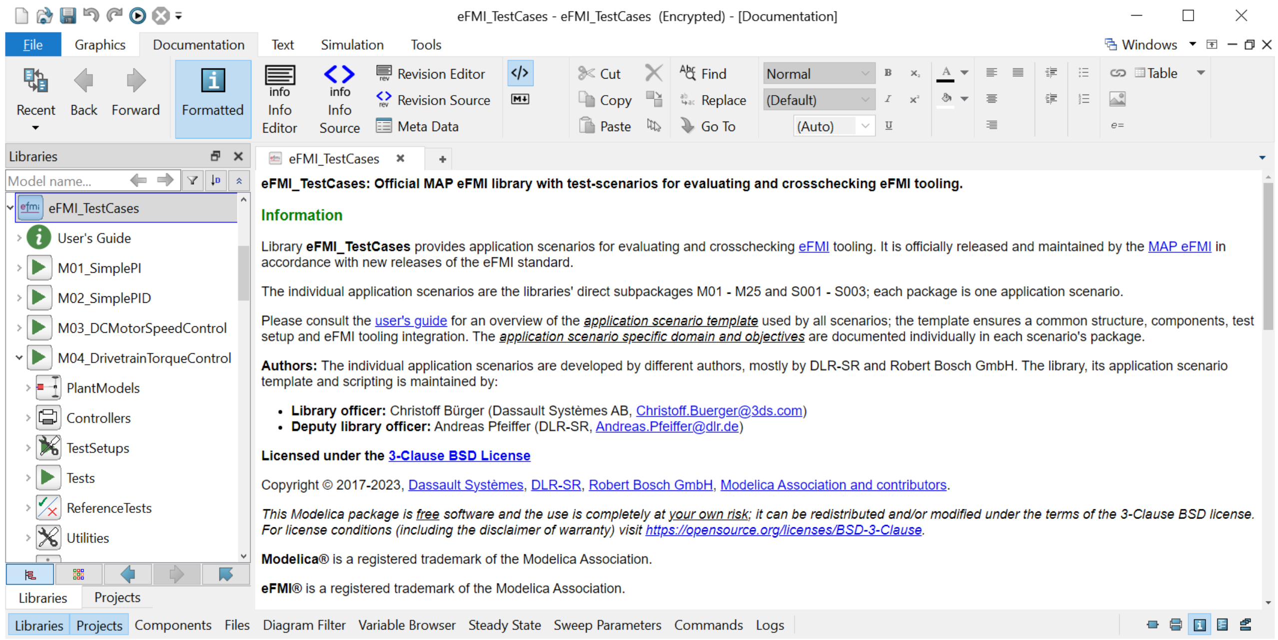
M04: Origin, scenario and objective

As running use-case of the tutorial we use M04 of the `eFMI_TestCases` library

- Open source Modelica library (https://github.com/modelica/efmi-testcases); MAP eFMI published & included in Dymola
- Used by MAP eFMI to conduct official eFMI tooling cross-checks
- Library is ordinary Modelica & tool agnostic
- M04: Developed by DLR & performance assessed by BOSCH



Functional Mock-up Interface for embedded systems

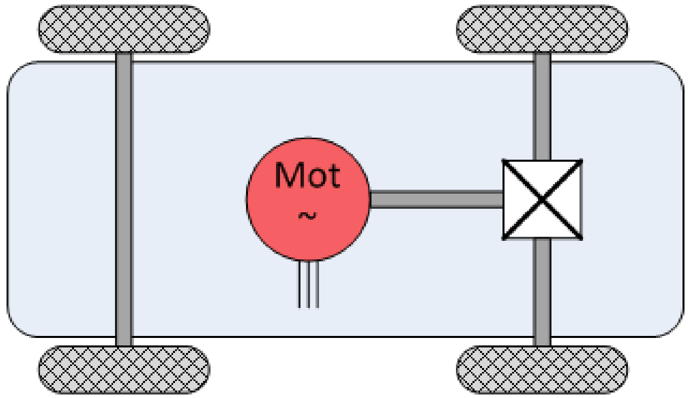
M04: Origin, scenario and objective

M04: Electric vehicle drivetrain torque controller to reduce drivetrain vibrations

- **Objective:** control of traction torque acting directly at the wheel hub (instead of motor torque, as common approach)
  - Control input: desired torque at wheel mounting
  - Sensor input: relative velocity between motor side & wheel speed (as common in ABS systems)
- **Challenge:** compensate torque oscillations due to gear elasticity & backlash; unknown load torque produced by tires
- **Solution:** use of inverse model of elastic drivetrain (virtual sensor) to feed simple PI controller
  - Inverse model (feed-forward controller): approximated, simple plant model ⇒ easy to model
  - PI controller (feed-back controller): model from stock/MSL ⇒ easy to parameterize (thanks to “correction” by virtual sensor input)

⇒ Combination of both controllers: robust performance, even if modeling errors & sensor noise exist

⇒ Production code (eFMU) = virtual drivetrain sensor + PI controller



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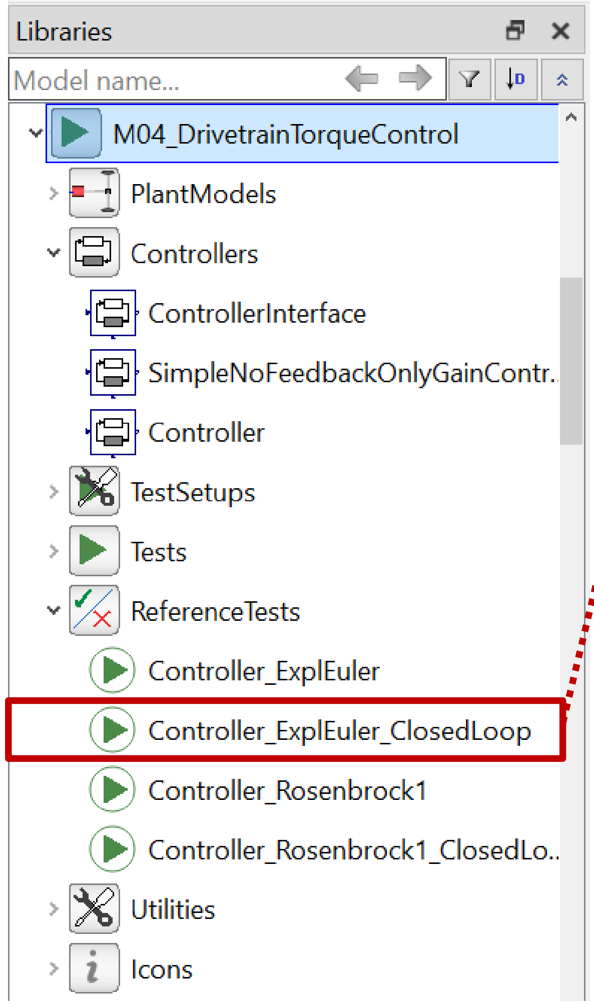
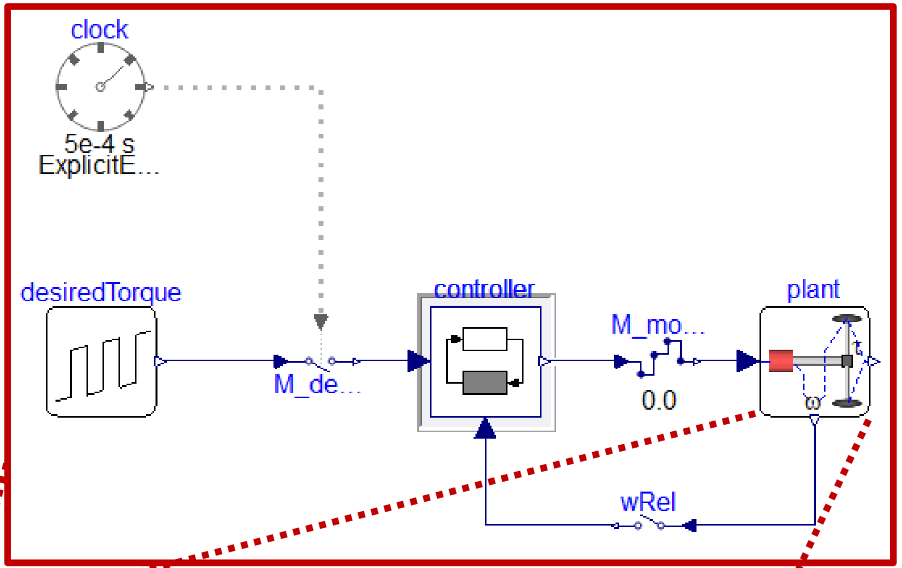
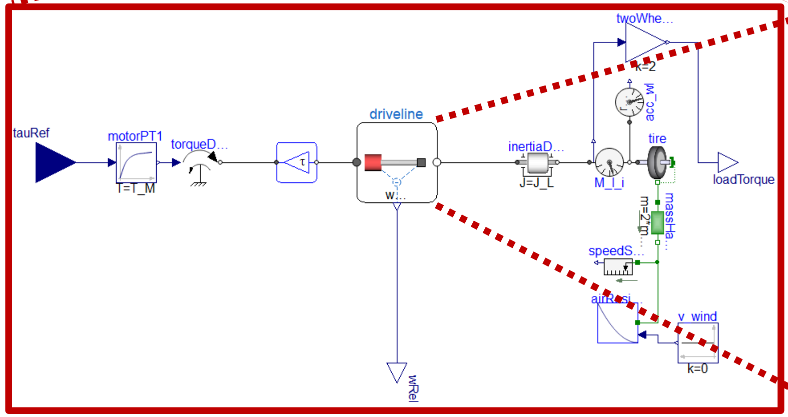
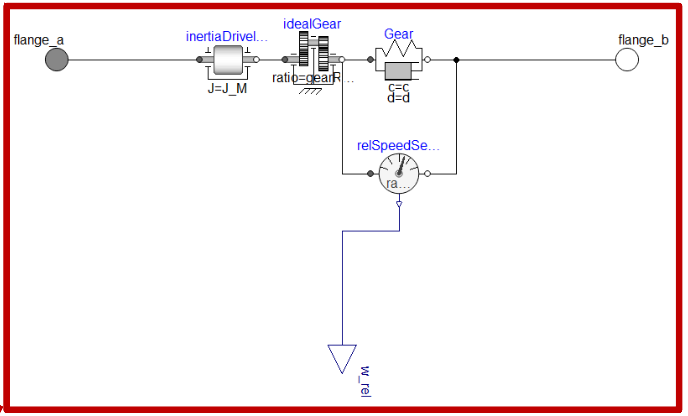
M04: Plant model & test scenario





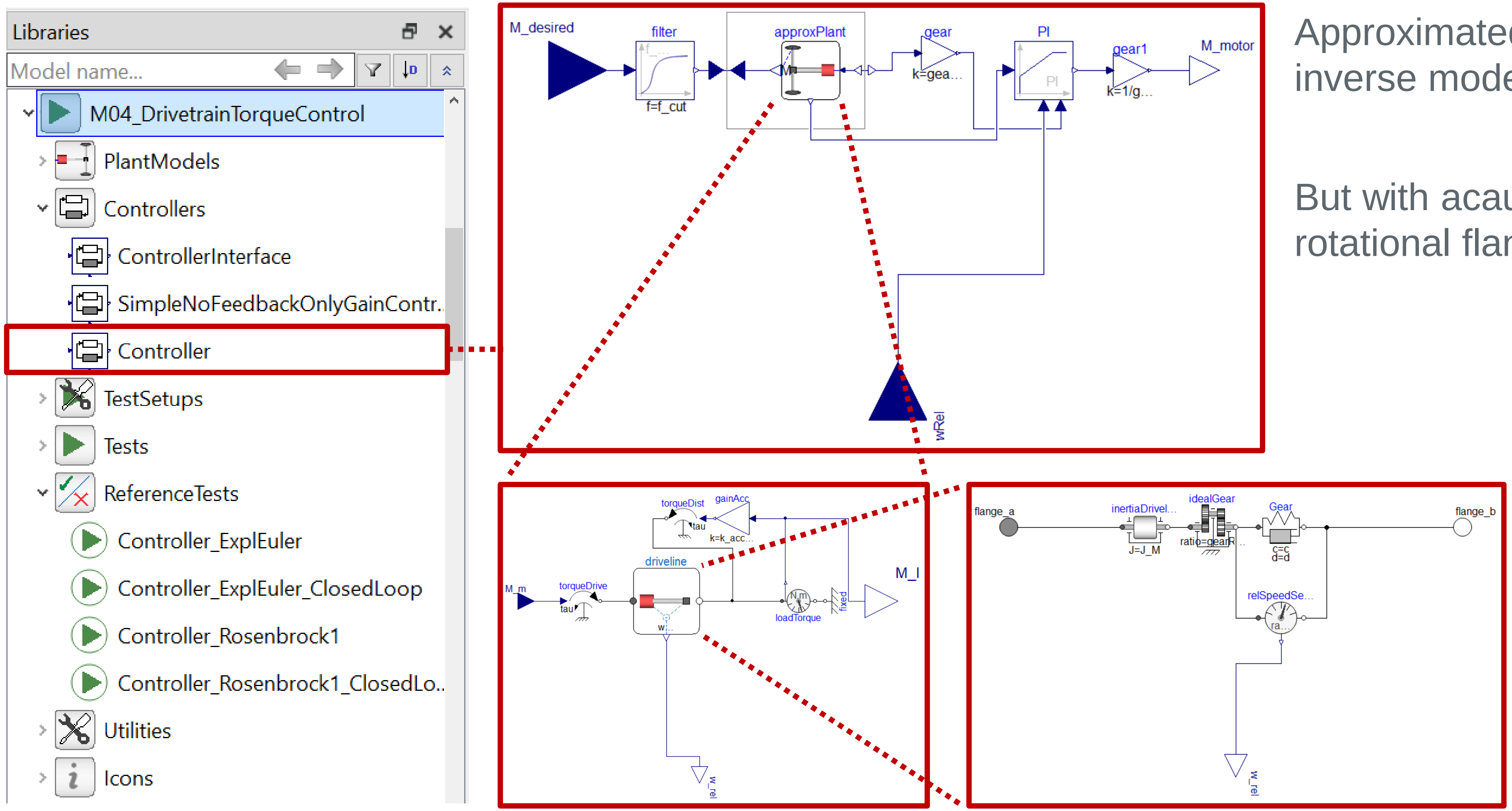




Closed loop with sampled controller and simple plant model just for eFMU testing.

Plant model not realistic industrial detail, but such is also not required to test correctness of eFMI *tooling*.

M04: Controller



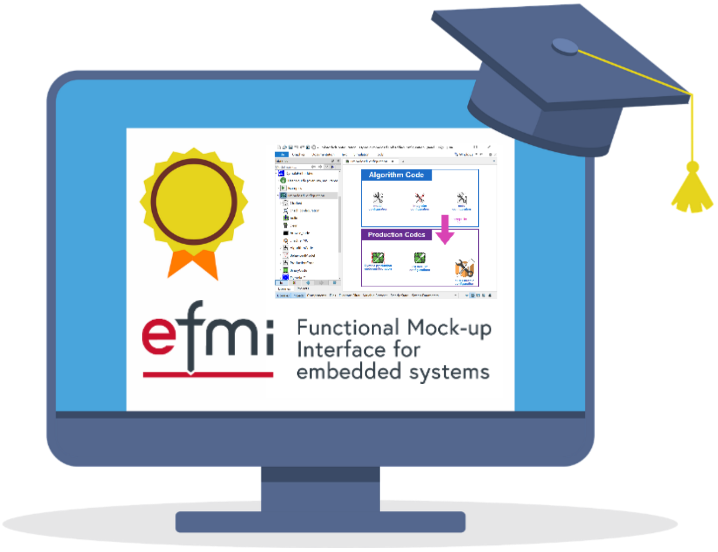
Approximated, i.e., reduced inverse model.

But with acausal physics (e.g., rotational flange connectors).

M04: A simple, but good eFMI introductory example

M04 is a good demonstrator to motivate eFMI:

- Simple ⇒ comprehensible generated manifests, GALEC & production codes
  (can be fully understood and related back to original model by humans)
- Not just imperative control, but also leverage on acausal physics
  (advantage of virtual sensor improving PI controller performance obvious)
- Scratches the need for *reduced* plant models as inverse model
  (general challange to address real-time requirements)
- Easy to foresee advantage for realistic industrial demonstrators
  (high-level graphical modeling scales development wise,
  acausal physics ease to model the right thing)
- We have successful eFMI applications with 20 000 and more equations yielding 12 MB GALEC code optimized to 290 kB target binaries, mixed system of equations, wild mix of imperative control in block diagram style & physics etc, but they are NDA protected!
  - E.g., EMPHYSIS demonstrator: full drivetrain as virtual sensor (Volvo Cars)



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