Modelica Libraries

Modelica Standard Library

Modelica Standard Library (called `Modelica`) is a standardized predefined package developed by Modelica Association

It can be used freely for both commercial and noncommercial purposes under the conditions of *The Berkeley License.*

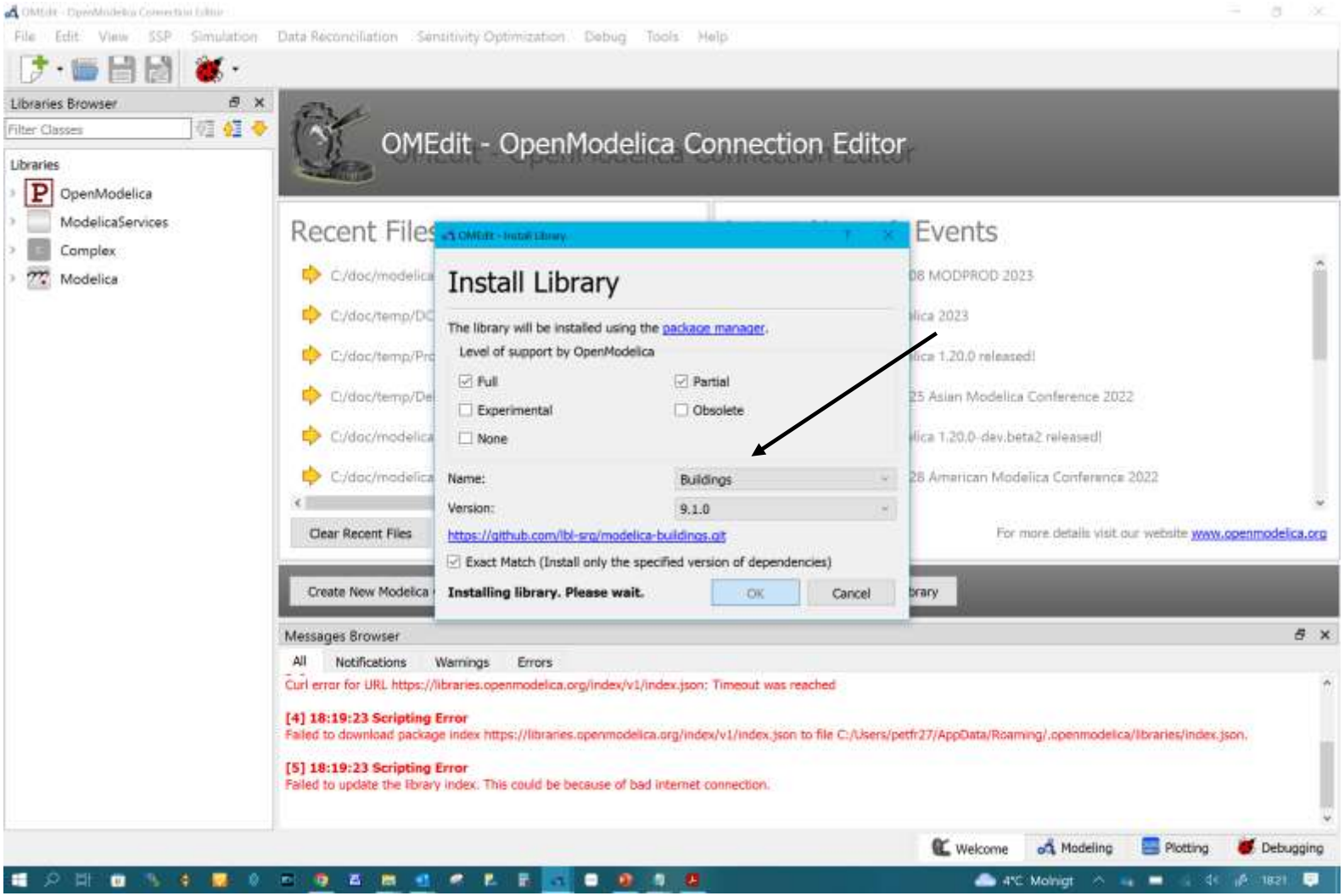
Modelica libraries are available online including documentation and source code from http://www.modelica.org/library/library.html.

Modelica Standard Library cont'

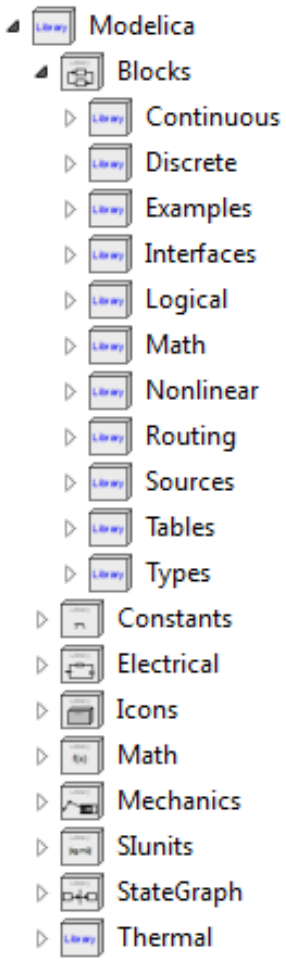
The Modelica Standard Library contains components from various application areas, including the following sublibraries:

- Blocks — Library for basic input/output control blocks
- Constants — Mathematical constants and constants of nature
- Electrical — Library for electrical models
- Icons — Icon definitions
- Fluid — 1-dim Flow in networks of vessels, pipes, fluid machines, valves, etc.
- Math — Mathematical functions
- Magnetic — Magnetic – for magnetic applications
- Mechanics — Library for mechanical systems
- Media — Media models for liquids and gases
- SIunits — Type definitions based on SI units according to ISO 31-1992
- Stategraph — Hierarchical state machines (analogous to Statecharts)
- Thermal — Components for thermal systems
- Utilities — Utility functions especially for scripting

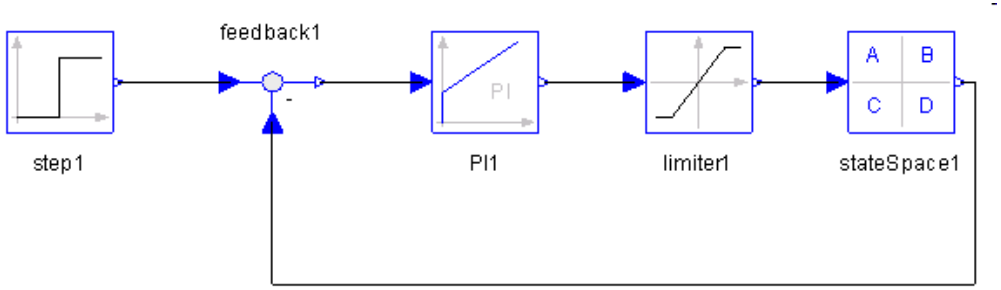
How to Open a Library using the OpenModelica Package Manager



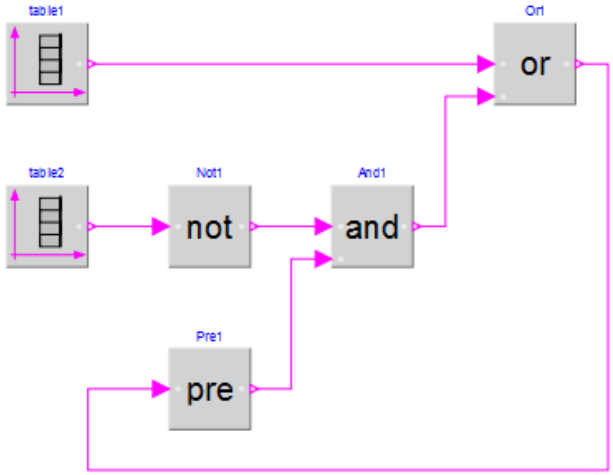
Modelica.Blocks



Continuous, discrete, and logical input/output blocks to build block diagrams.



Examples:



Modelica.Constants

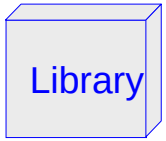
A package with often needed constants from mathematics, machine dependent constants, and constants of nature.

Examples:

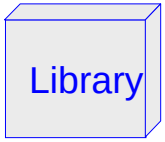
```
constant Real pi=2*Modelica.Math.asin(1.0);

constant Real small=1.e-60 "Smallest number such that small and -small
                            are representable on the machine";

constant Real G(final unit="m3/(kg.s2)") = 6.673e-11 "Newtonian constant
                                                      of gravitation";

constant Real h(final unit="J.s") = 6.62606876e-34 "Planck constant";

constant Modelica.SIunits.CelsiusTemperature T_zero=-273.15 "Absolute
                                                             zero temperature";
```

Modelica.Electrical

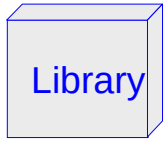
Electrical components for building analog, digital, and multiphase circuits



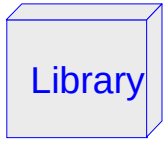
Analog



Digital

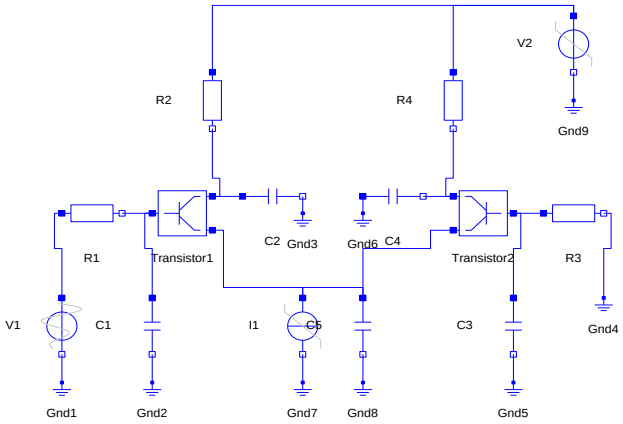


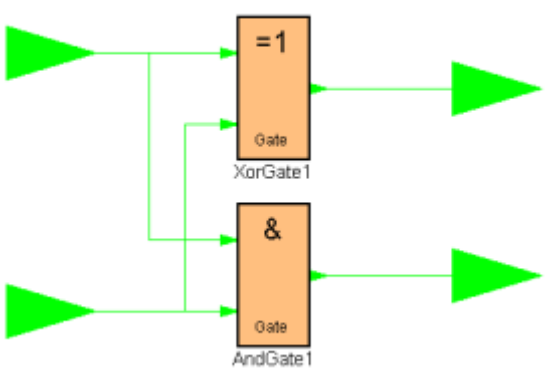
Machines

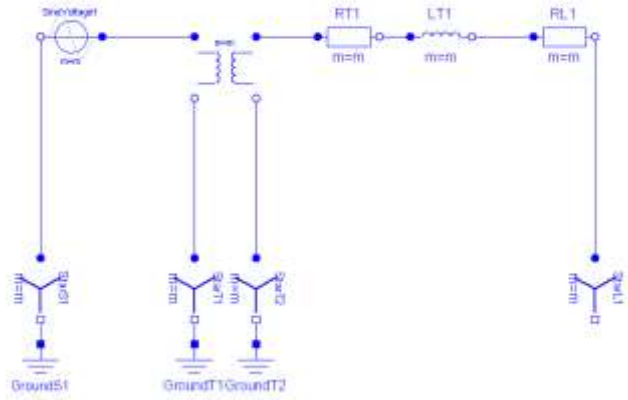


MultiPhase

Examples:







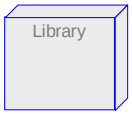
Modelica.Icons

Package with icons that can be reused in other libraries

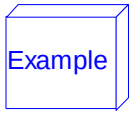
Examples:

Info

Library1



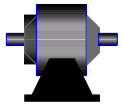
Library2



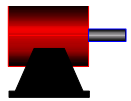
Example

RotationalSensor

TranslationalSensor



GearIcon



MotorIcon

Modelica.Math

Package containing basic mathematical functions:

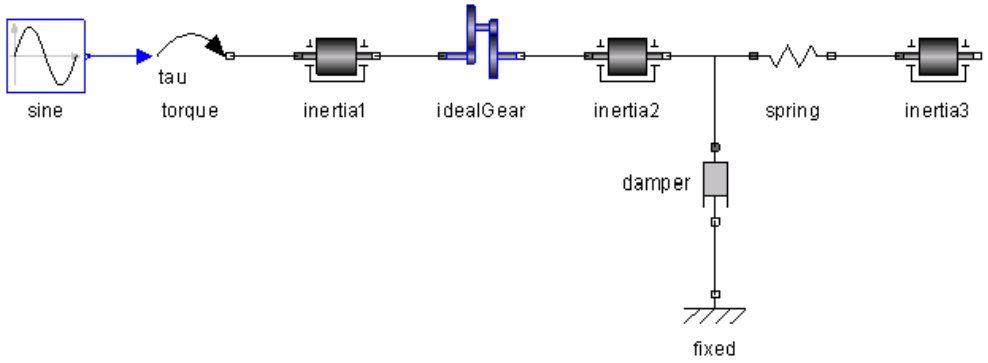
sin(*u*)	sine
cos(*u*)	cosine
tan(*u*)	tangent (*u* shall not be: …,-π/2, π/2, 3π/2,…)
asin(*u*)	inverse sine ($-1 \le u \le 1$)
acos(*u*)	inverse cosine ($-1 \le u \le 1$)
atan(*u*)	inverse tangent
atan2(*u1*, *u2*)	four quadrant inverse tangent
sinh(*u*)	hyperbolic sine
cosh(*u*)	hyperbolic cosine
tanh(*u*)	hyperbolic tangent
exp(*u*)	exponential, base *e*
log(*u*)	natural (base *e*) logarithm ($u > 0$)
log10(*u*)	base 10 logarithm ($u > 0$)

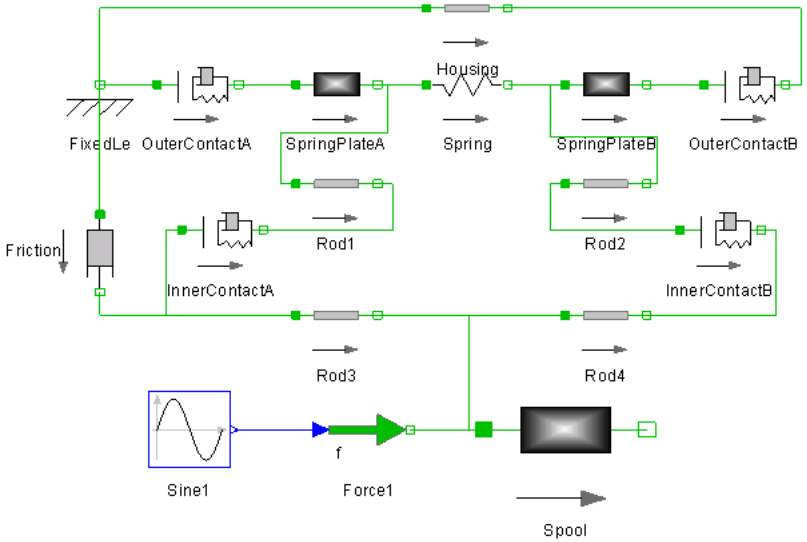
Modelica.Mechanics

Package containing components for mechanical systems

Subpackages:

- Rotational — 1-dimensional rotational mechanical components
- Translational — 1-dimensional translational mechanical components
- MultiBody — 3-dimensional mechanical components





Modelica.SIunits

This package contains predefined types based on the international standard of units:

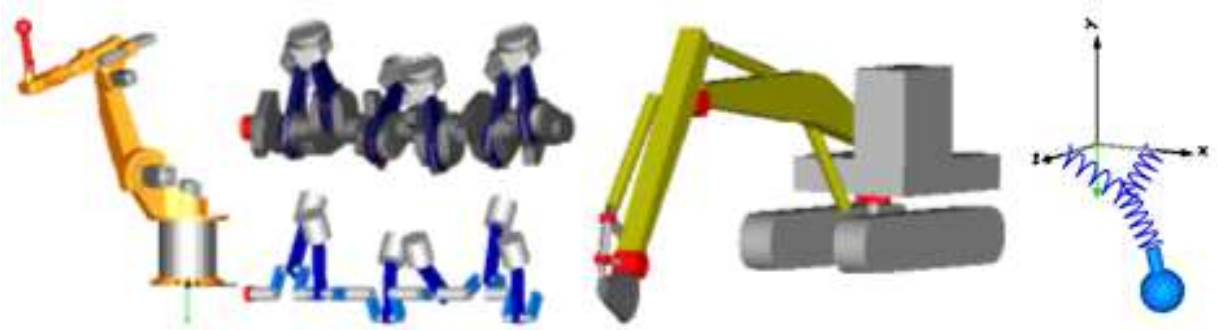
- ISO 31-1992 “General principles concerning quantities, units and symbols”
- ISO 1000-1992 “SI units and recommendations for the use of their multiples and of certain other units”.

A subpackage called `NonSIunits` is available containing non SI units such as `Pressure_bar`, `Angle_deg`, etc

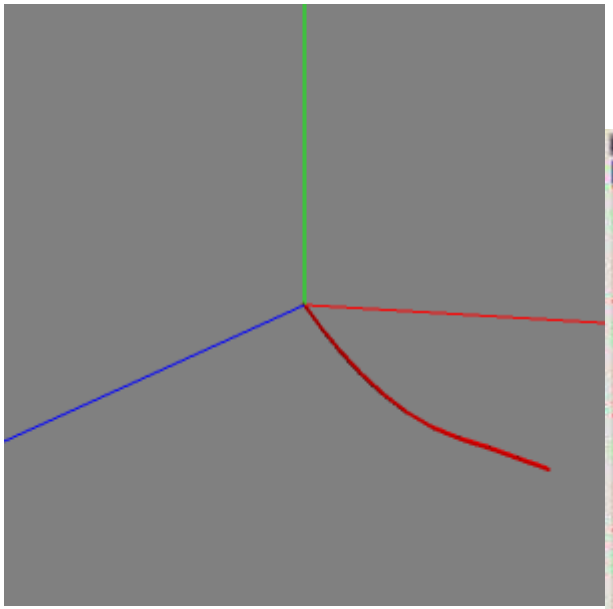
Modelica.Mechanics.Multibody

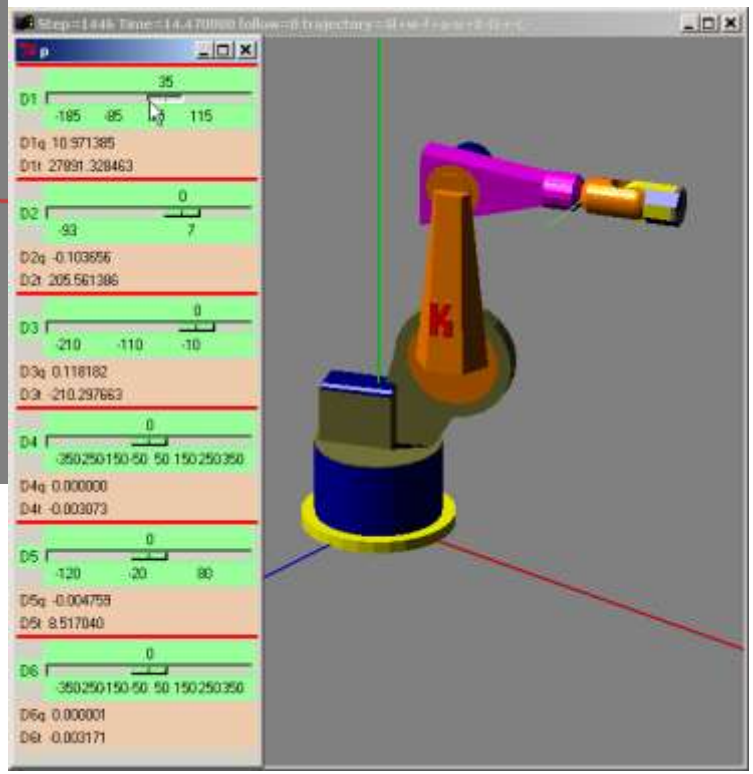
This is a Modelica library to model 3D Mechanical systems including visualization

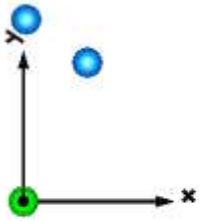
- Easy to use
- Automatic handling of kinematic loops.
- Built-in animation properties for all components



MultiBody (MBS) - Example Animations



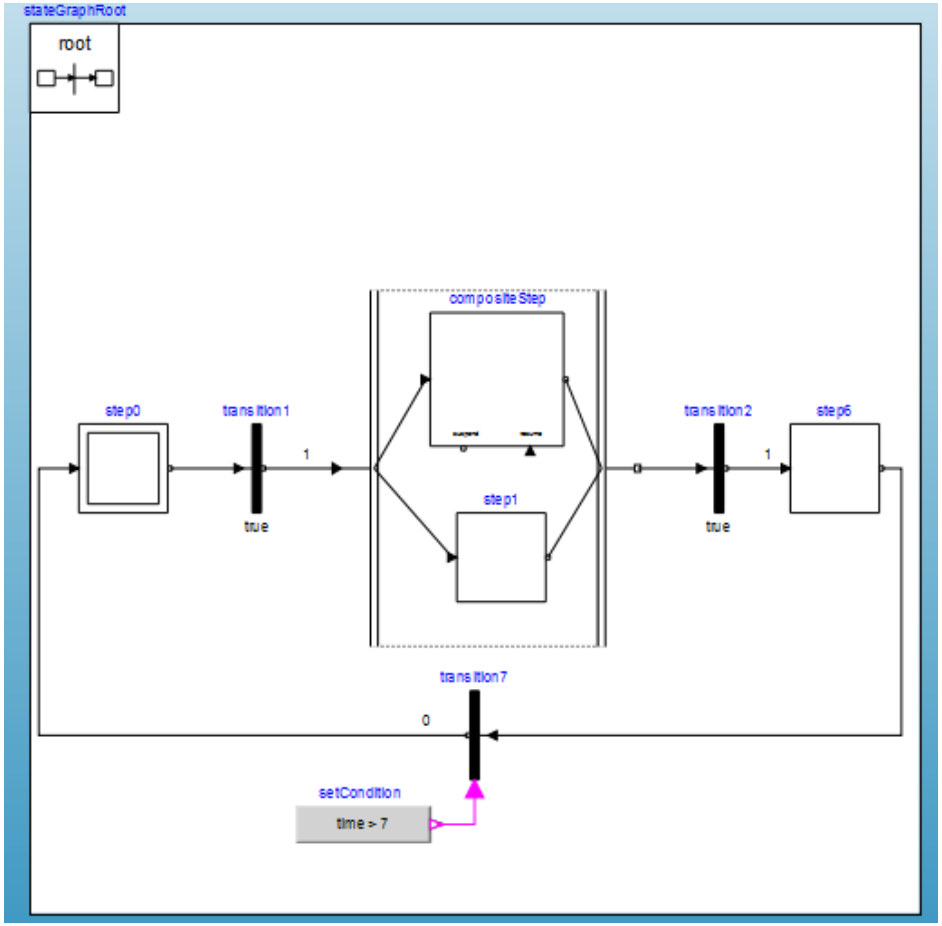




Modelica.Stategraph

- Modelica
  - Blocks
  - Constants
  - Electrical
  - Icons
  - Math
  - Mechanics
  - SIunits
  - StateGraph
    - Examples
    - Interfaces
    - Temporary
    - UsersGuide
    - Alternative
    - InitialStep
    - InitialStepWithSignal
    - Parallel
    - PartialCompositeStep
    - StateGraphRoot
    - Step
    - StepWithSignal
    - Transition
    - TransitionWithSignal
  - Thermal

Hierarchical state machines (similar to Statecharts)

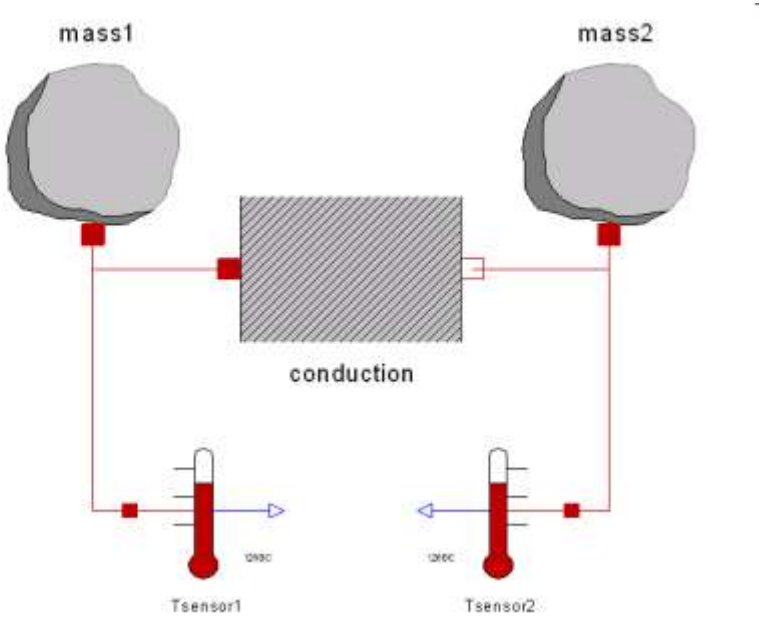


Modelica.Thermal

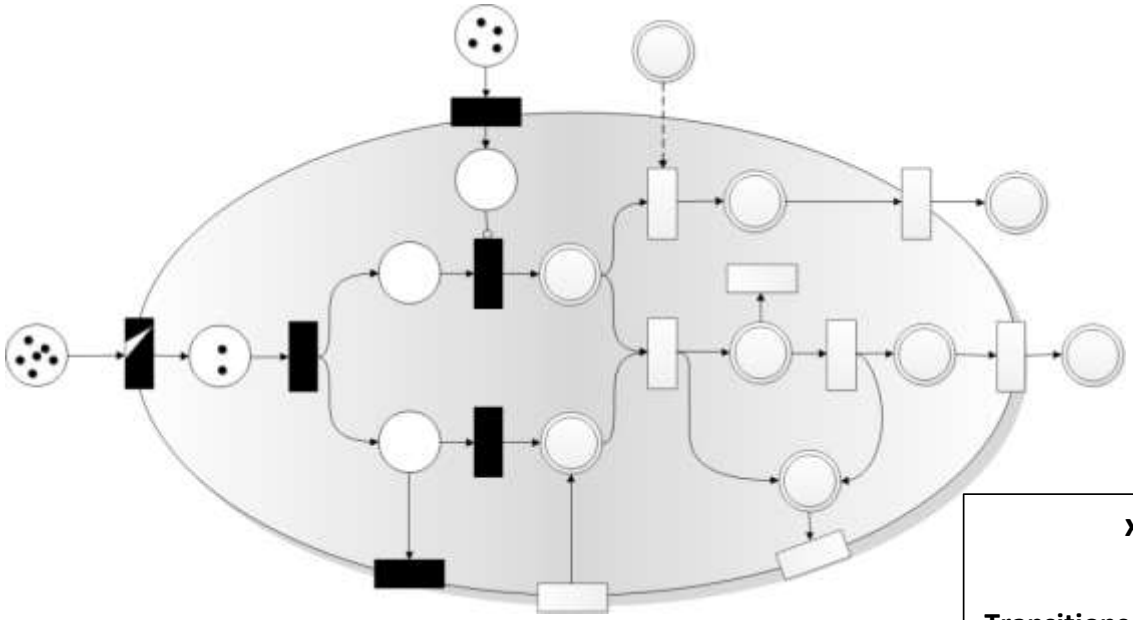
Subpackage `FluidHeatFlow` with components for heat flow modeling.

Sub package `HeatTransfer` with components to model 1-dimensional heat transfer with lumped elements

Example:



PNlib - An Advanced Petri Net Library for Hybrid Process Modeling including Stochastics



xHPN: Extended Hybrid Petri Nets

Transitions

- (time-)discrete process (event)
- stochastic process (random event)
- continuous process (flow)

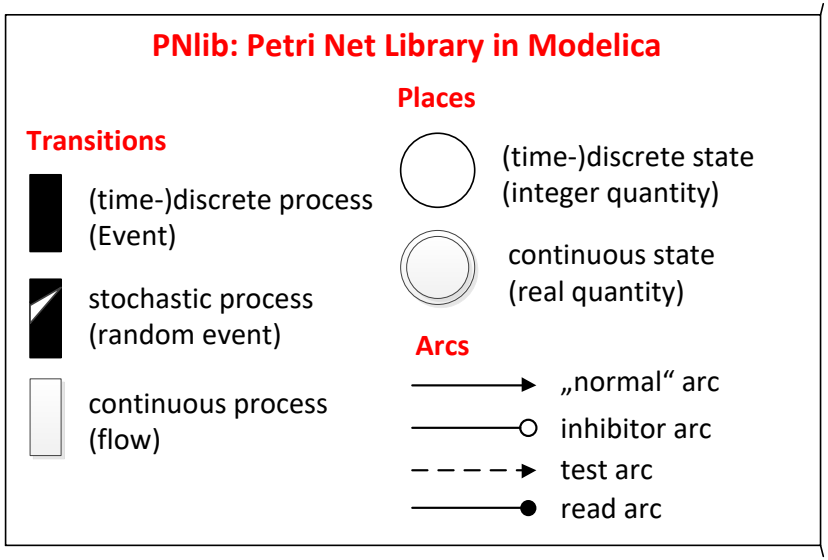
Places

- (time-)discrete state (integer quantity)
- continuous state (real quantity)

Arcs

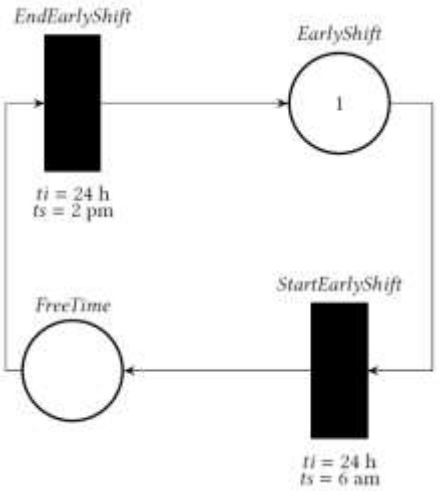
- „normal“ arc
- inhibitor arc
- test arc
- read arc

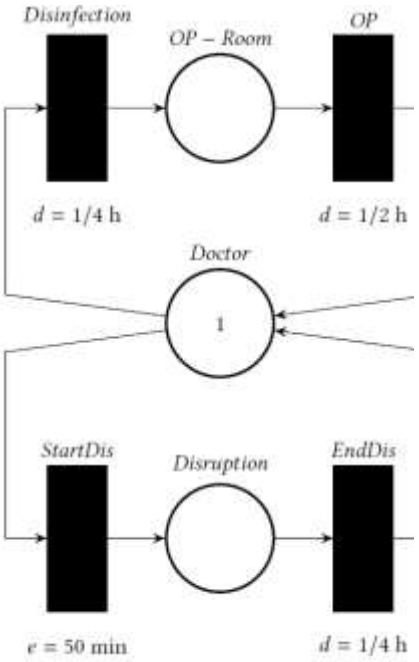
PNLib Cont

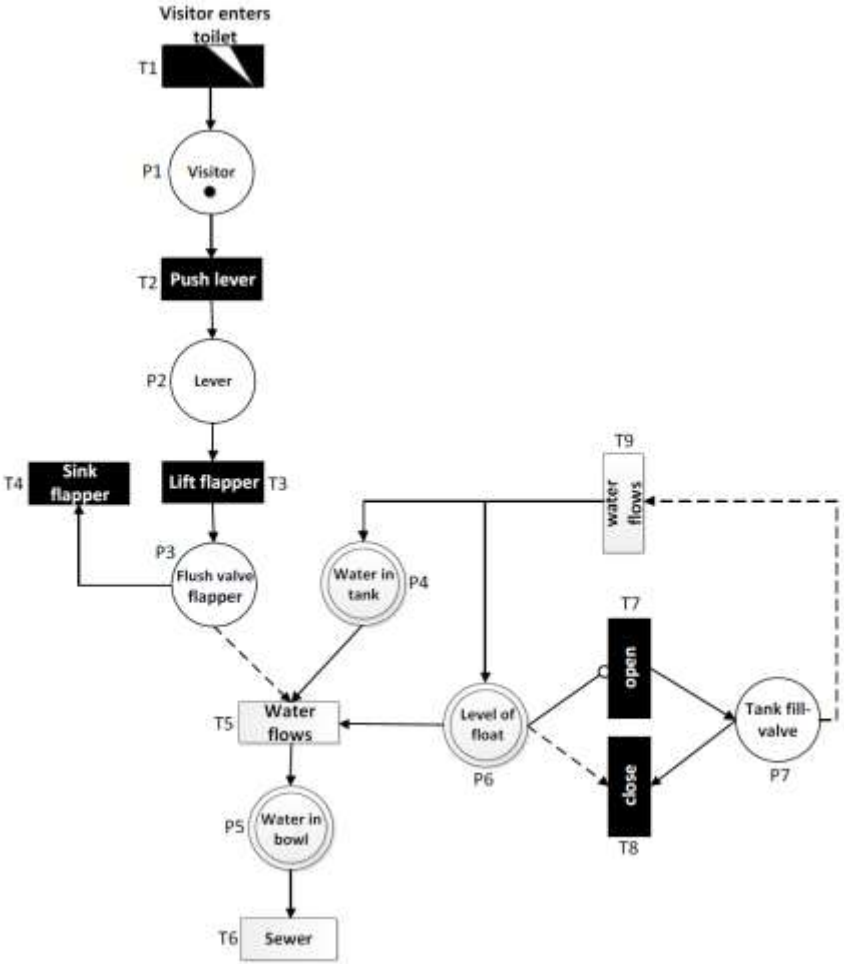



```
model PetriNetComponent1
   parameter1;
   parameter2;
    …
   variable1;
   variable2;
    …
equation
   equation1;
   equation2;
   …
//event-based equations
   when condition then
    …
   end when;
//differential equations
   der(t) = rightSide;
//algebraic equations
   a+b=c;
algorithm
   statement1;
   statement2;
   …
end PetriNetComponent1 ;
```

PNLib Simple Example Models







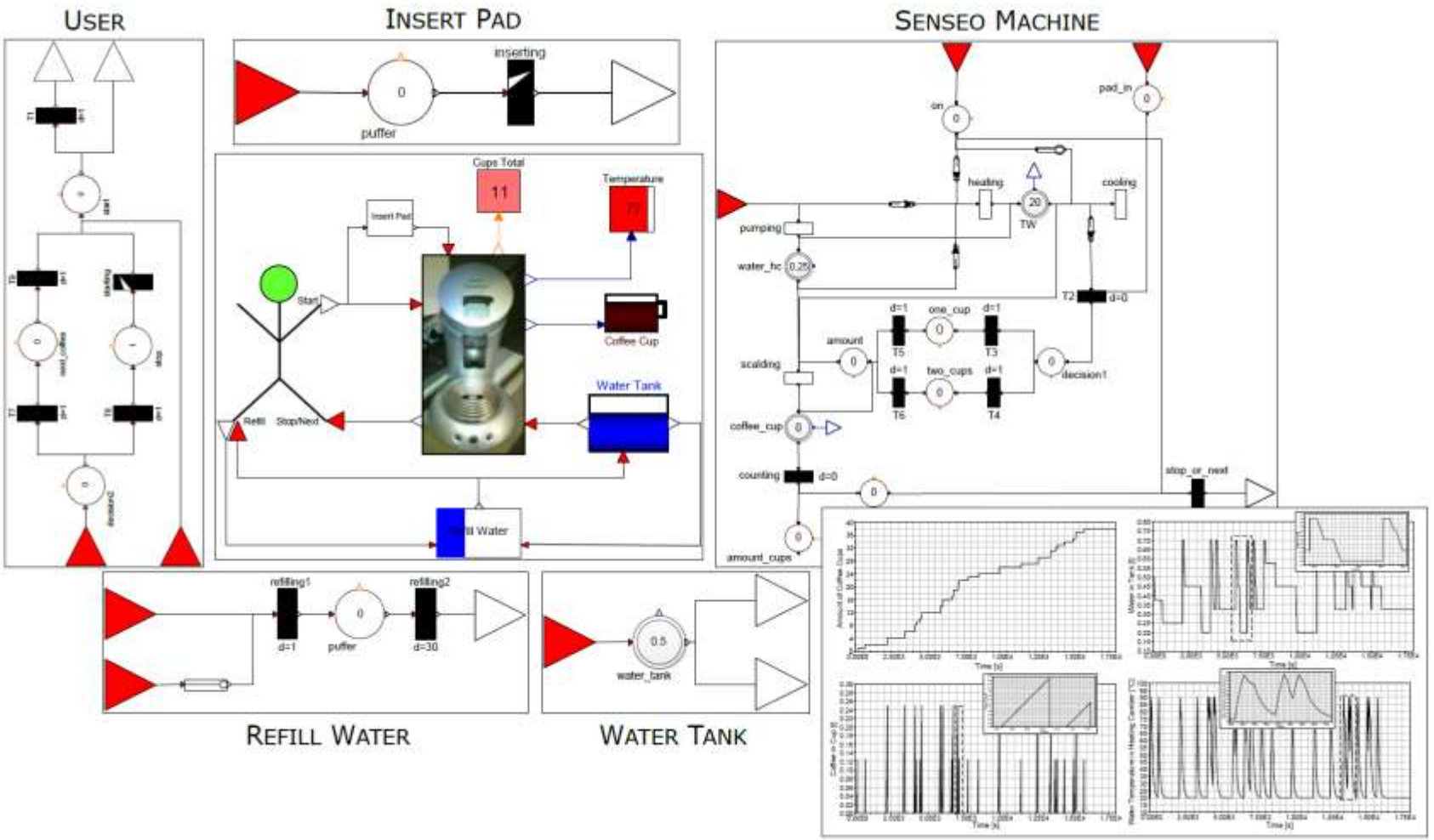
Workshift model

Hand disinfection model

Flush toilet model

PNLib Large Example Model

Hierarchical model of a Senseo coffee machine and simulation results

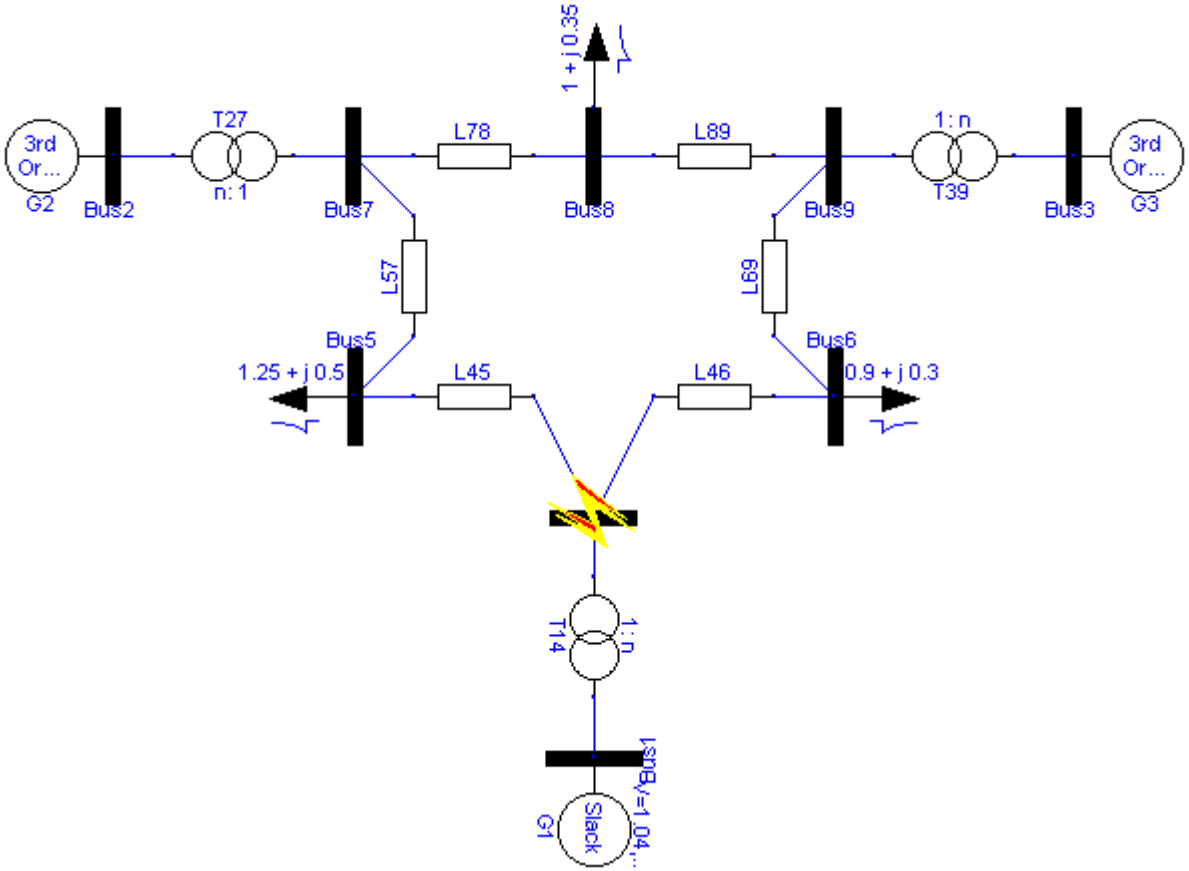


Other Free Libraries

- WasteWater — Wastewater treatment plants, 2003
- Buildings — Large library for Building simulation and control (2023)
- MotorCycleDymanics — Dynamics and control of motorcycles, 2009
- NeuralNetwork — Neural network mathematical models, 2006
- VehicleDynamics — Dynamics of vehicle chassis (obsolete), 2003
- SPICElib — Some capabilities of electric circuit simulator PSPICE, 2003
- SystemDynamics — System dynamics modeling a la J. Forrester, 2007
- BondLib — Bond graph modeling of physical systems, 2007
- MultiBondLib — Multi bond graph modeling of physical systems, 2007
- ModelicaDEVS — DEVS discrete event modeling, 2006
- ExtendedPetriNets — Advanced hybrid Petri net and process modeling, 2022
- External.Media Library — External fluid property computation, 2008
- VirtualLabBuilder — Implementation of virtual labs, 2007
- PowerSystems — Power systems in transient and steady-state mode
- PowerGrids — Power Grids, balance of power in grids, 2020
- ...

Power System Stability - PowerSystems

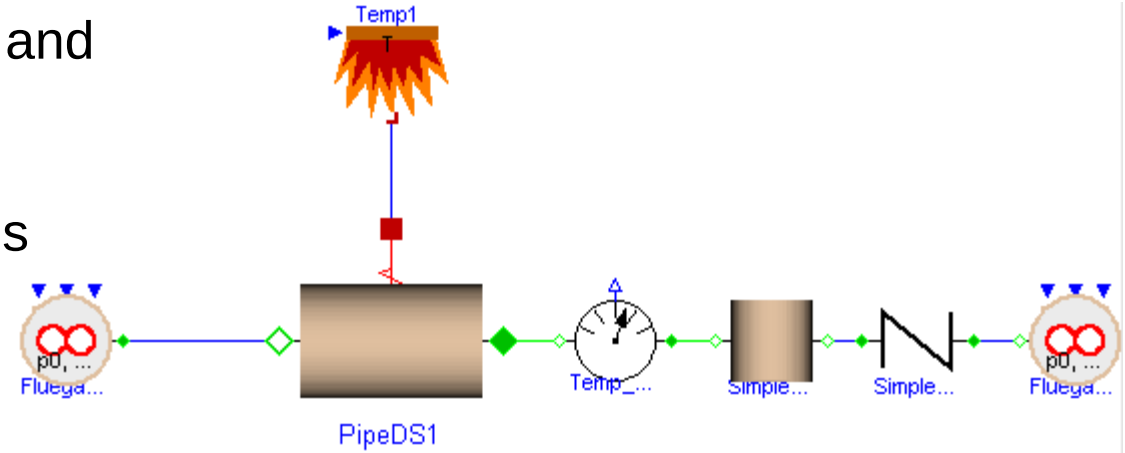
The PowerSystems package is a Modelica Library for Power Systems Voltage and Transient stability simulations



Fluid and Media Libraries

Modelica base libraries for Media and Fluid models

- Includes models that describe the basic physics of flows of fluid and heat, medium property models for water, gases and some refrigerants, and also simple components for system modeling.
- Handles static and dynamic momentum balances
- Robust against backwards and zero flow
- The discretization method is a first-order, finite volume method.



Open Source Modelica Buildings Library

Developed by Lawrence Berkeley Lab; Berkeley open source license

- Model repository for building and district energy simulation.
- Home page: https://simulationresearch.lbl.gov/modelica/

- **Example Applications**
- Model-based design process.
  - Spawn of EnergyPlus, see https://lbl-srg.github.io/soep/.
  - Development of 5th generation district heating and cooling and URBANopt, see https://www.nrel.gov/buildings/urbanopt.html.
- Repository of control sequences in the Control Description Language (CDL).
  - OpenBuildingControl, see https://obc.lbl.gov/.
- Controls design and performance evaluation.
  - Building Optimization Testing Framework (BOPTEST) see https://github.com/ibpsa/project1-boptest

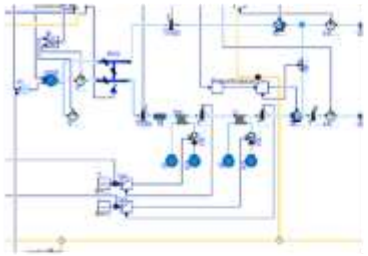
Slide content acknowledgement: LBL Buildings intro tutorial

- Michael Wetter, Wangda Zuo, Thierry S. Nouidui and Xiufeng Pang. Modelica Buildings library. Journal of Building Performance Simulation, 7(4):253-270, 2014.

Buildings Library Model Repository

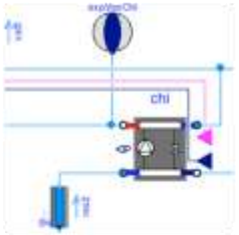
Open-source repository of more than 1000 models and functions

ir-based HVAC

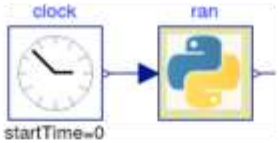


Hydronic heating

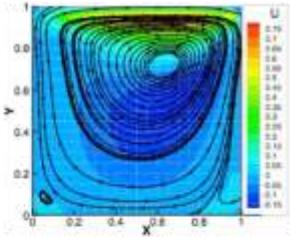
Chiller plants



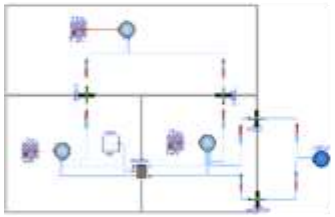
Embedded Python



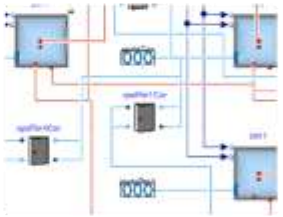
Room air flow



Natural ventilation, multizone air exchange, contaminant transport



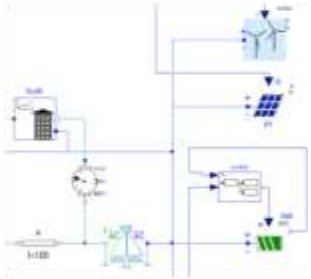
Room heat transfer, incl. window (TARCOG)



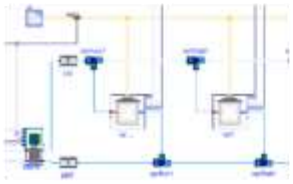
Solar collectors

FLEXLAB

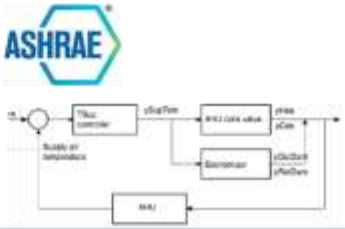
Electrical systems



District heating and cooling systems



Control design & deployment, including ASHRAE G36



Co-develop with IBPSA Modelica library as core, including district heating and cooling systems

IBPSA Project 1

https://ibpsa.github.io/project1/

Slide content acknowledgement: LBL Buildings intro tutorial M. Wetter et al

Buildings Library Content

Package Content

Name	Description
UsersGuide	User's Guide
Air	Package with models that are configured to use with air-based HVAC systems
Airflow	Package to compute airflow and contaminant transport between rooms
Applications	Package with models for different application domains
BoundaryConditions	Package with models for boundary conditions
Controls	Package with models for controls
Electrical	Package with models for electrical systems
Fluid	Package with models for fluid flow systems
HeatTransfer	Package with heat transfer models
Media	Package with medium models
Occupants	Package with models to simulate building occupant behaviors
ThermalZones	Models for BuildingPhysics
Utilities	Package with utility functions such as for I/O
Types	Package with type definitions
Examples	Collection of models that illustrate model use and test models
Experimental	Package with experimental models
BaseClasses	Package with base classes for the Buildings library
Obsolete	Classes that are obsolete and will be removed in later versions

Slide content acknowledgement: LBL Buildings intro tutorial
M. Wetter et al

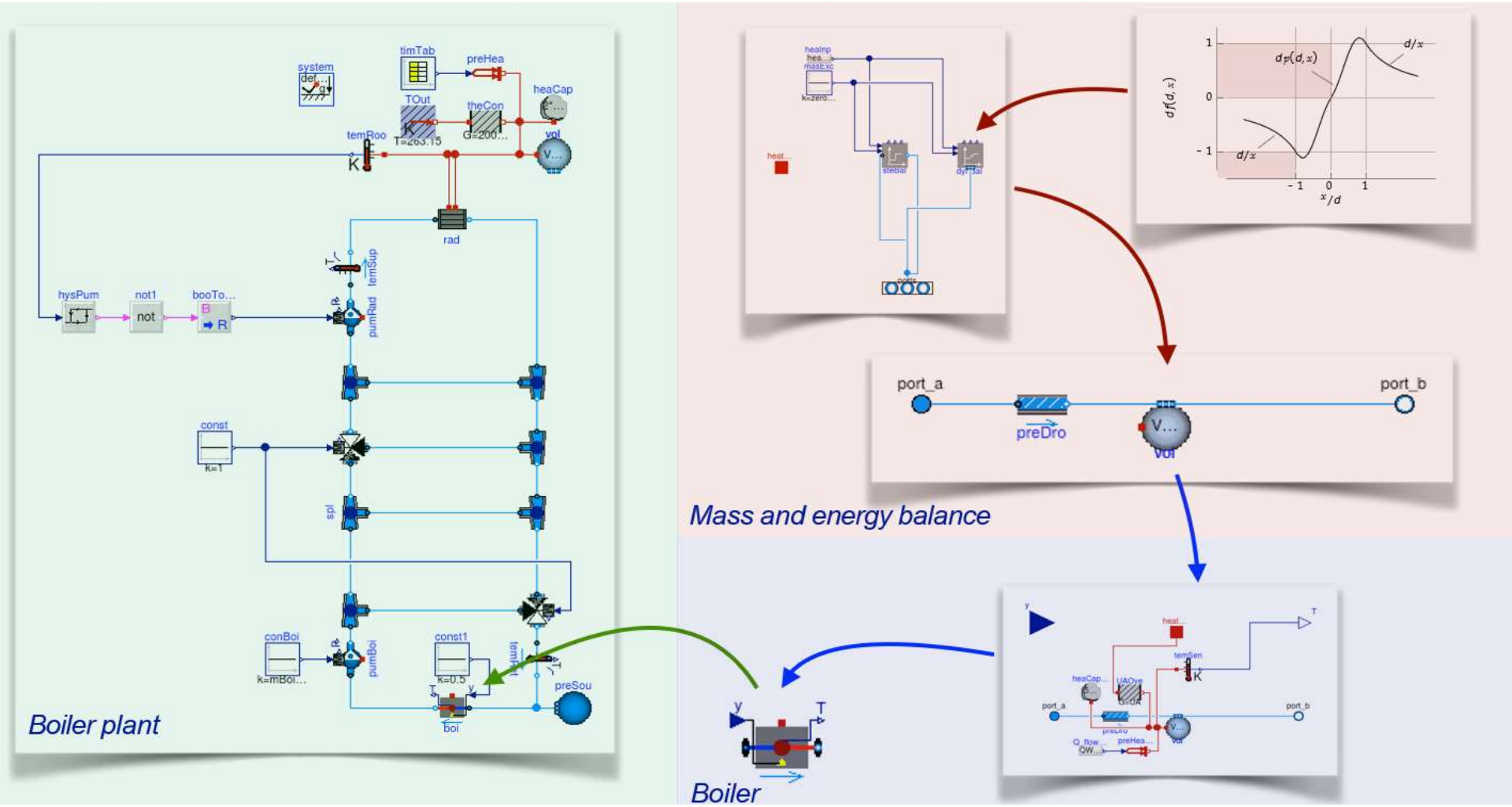
Buildings Main Modeling Assumptions

Media	• Can track moisture (X) and contaminants (C).
HVAC equipment	• Most equipment based on performance curve, or based on nominal conditions and similarity laws. • Vapor compression cycle mostly not modeled. • Most equipment either steady-state or 1st order transient.
Flow resistances	• Based on m_flow_nominal and dp_nominal plus similarity law. • Optional flag to linearize or to set dp=0.
Room model	• Any number of rooms and constructions are possible. • Layer-by-layer window model (similar to Window 6). • Optional flag to linearize radiation and/or convection. • Spawn of EnergyPlus uses EnergyPlus envelope model
Electrical systems	• DC. • AC 1-phase and 3-phase (dq, dq0). • Quasi-stationary or dynamic phase angle (but not frequency).
Special Consideration	• Numerical stability around zero-flow.

Slide content acknowledgement: LBL Buildings intro tutorial M. Wetter et al

Buildings Usage

Separation between library developer, component developer, and end user



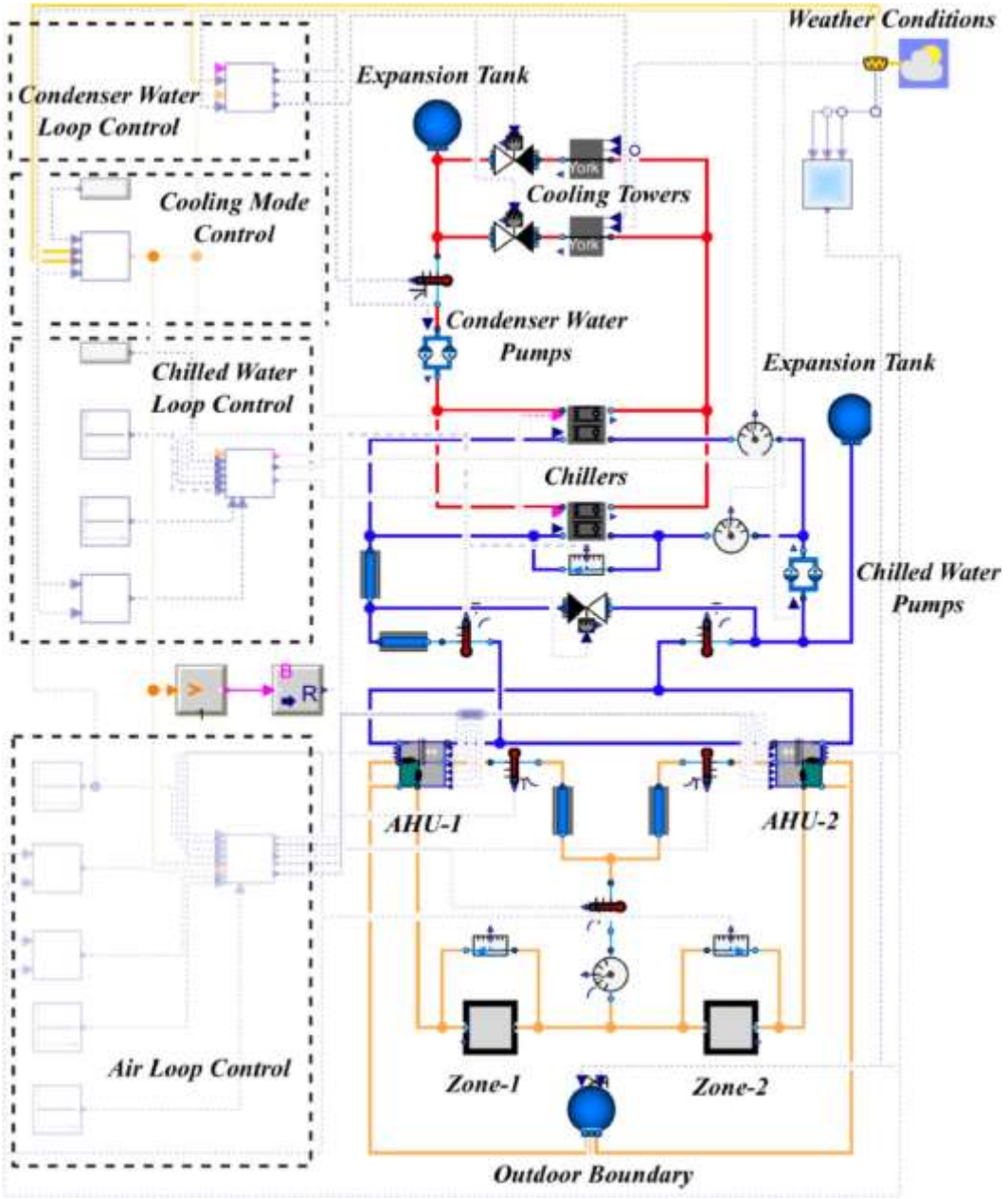
Library developer: Base class implementations (e.g. stable mass and energy balance

Component developer: Use base classes to develop component models (e.g. equipment)

End user: Use component models to develop system model (e.g. hydronic heating system

Slide content acknowledgement: LBL Buildings intro tutorial M. Wetter et al

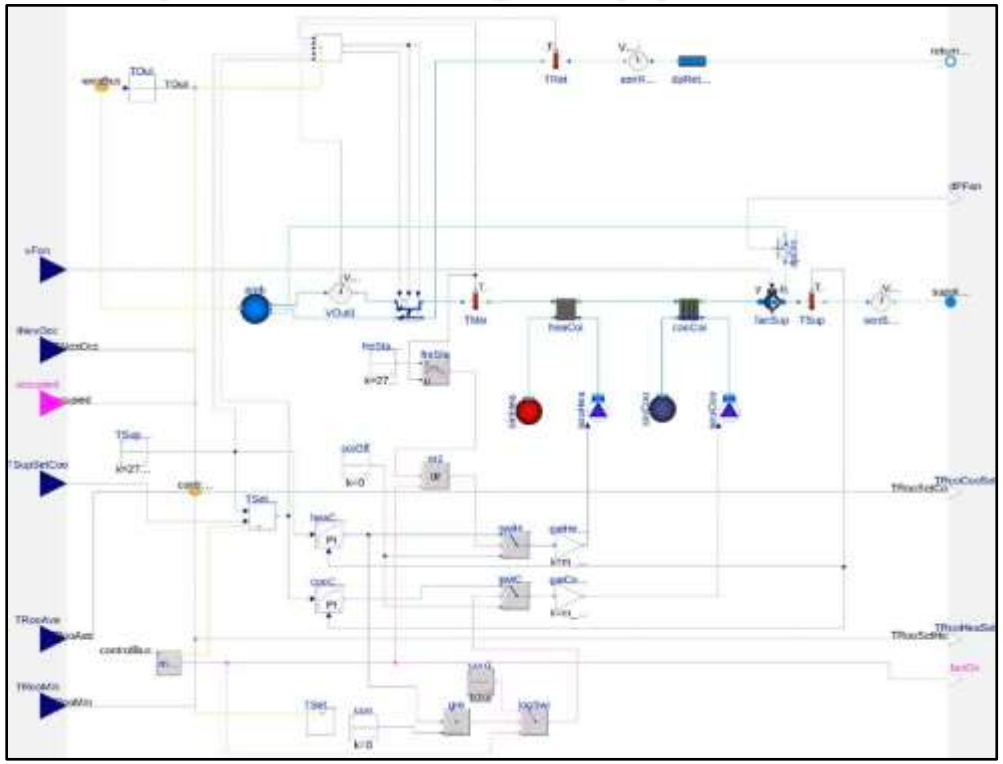
Example Buildings Application: Cooling Plant for Data Center



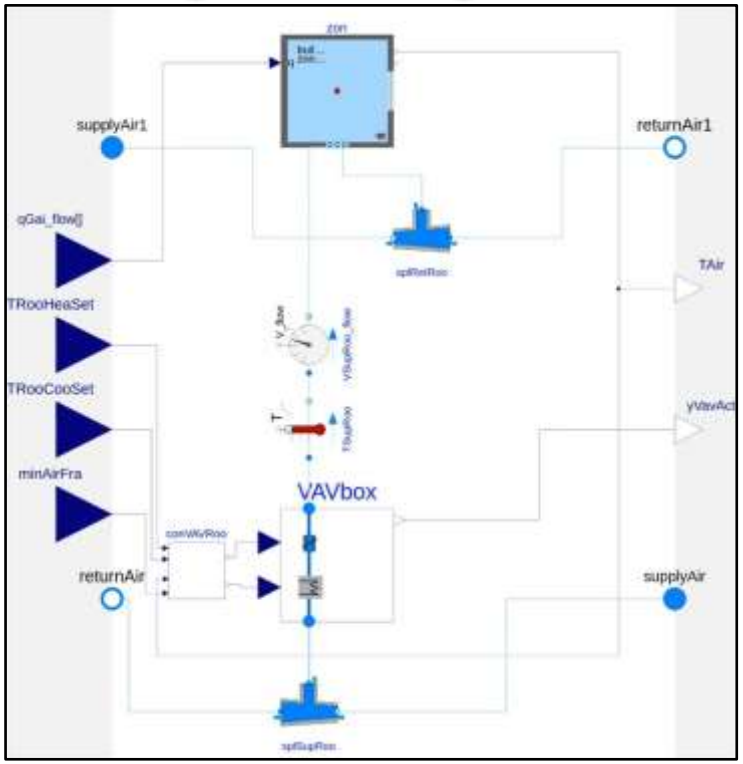
Fu et al. 2019. Equation- based object-oriented modeling and simulation for data center cooling: A case study. *Energy and Buildings 186.* https://doi.org/10.1016/j.enbuild.2019.01.018

Slide content acknowledgement: LBL Buildings intro tutorial
M. Wetter et al

Example Buildings Application: Evaluating Building Controls

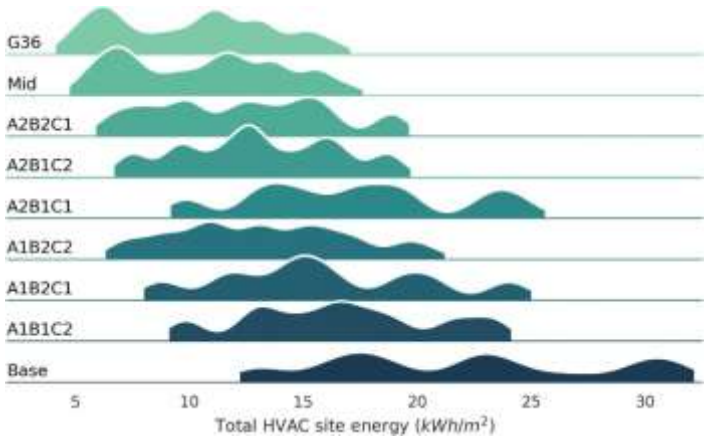


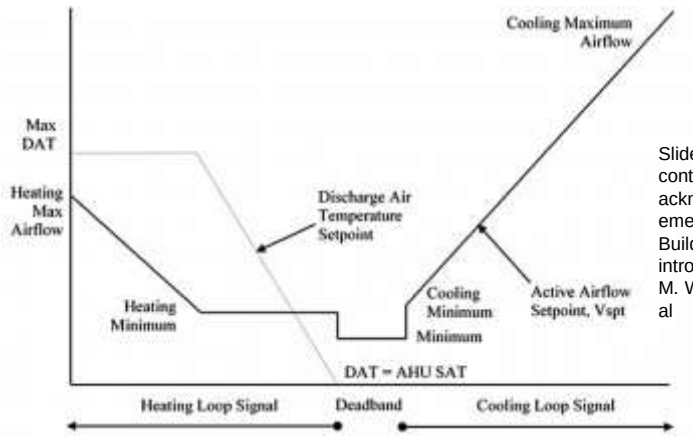
Air Handling Unit



Terminal Unit and Zone

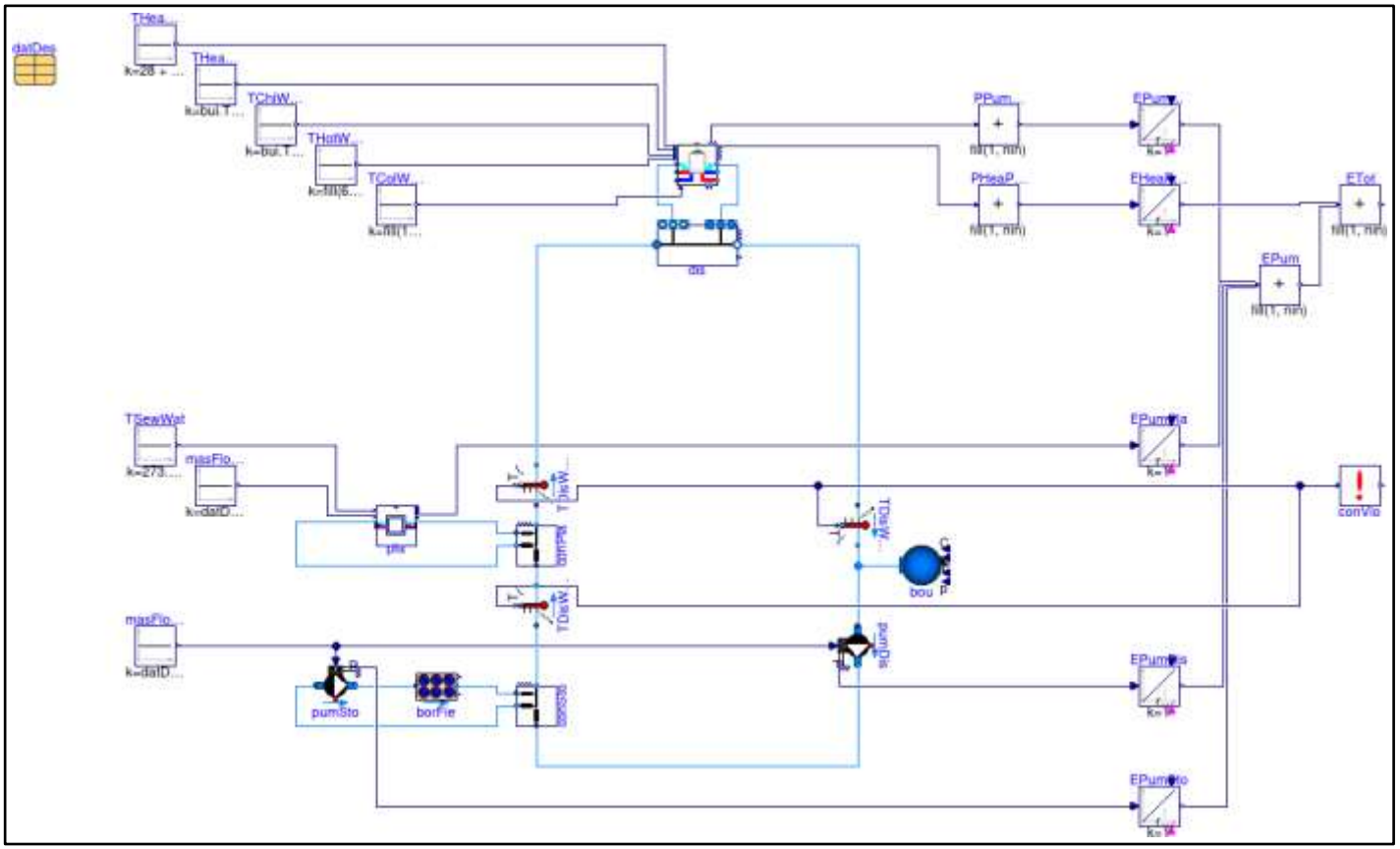
Zhang et al. 2022. Estimating ASHRAE Guideline 36 energy savings for multi-zone variable air volume systems using Spawn of EnergyPlus. *Journal of Building Performance Simulation* 15(2). https:// doi.org/ 10.1080/19401493.2021.2021286

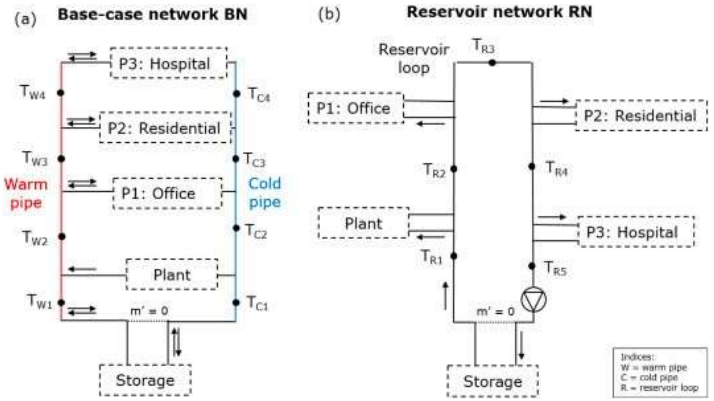




Slide content acknowledgement: LBL Buildings intro tutorial M. Wetter et al

Example Buildings Application: Innovative District Energy Simulation





Sommer et al. 2021. The reservoir network: A new network topology for district heating and cooling. *Energy* 199. https://doi.org/10.1016/j.energy.2020.117418

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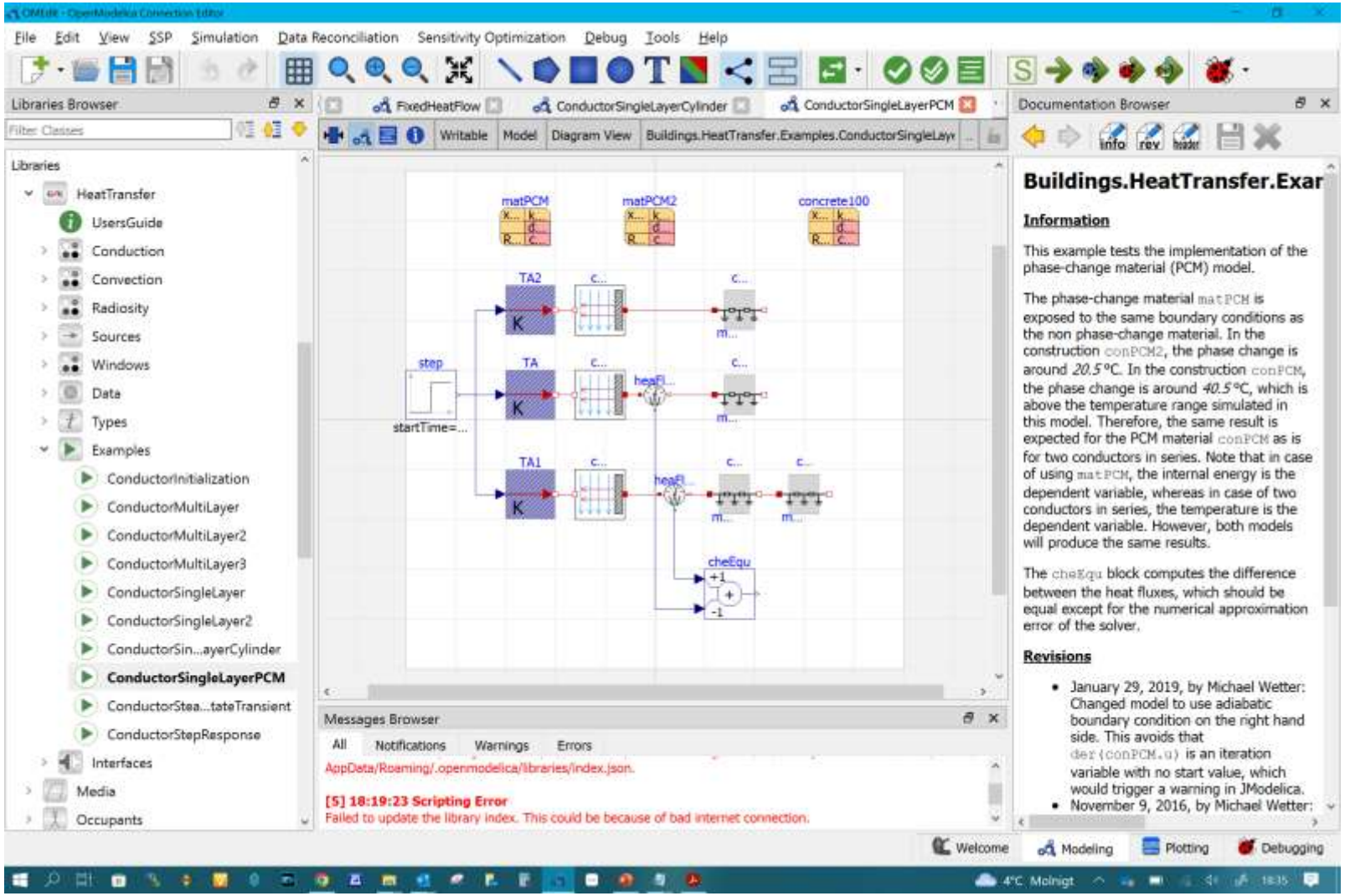
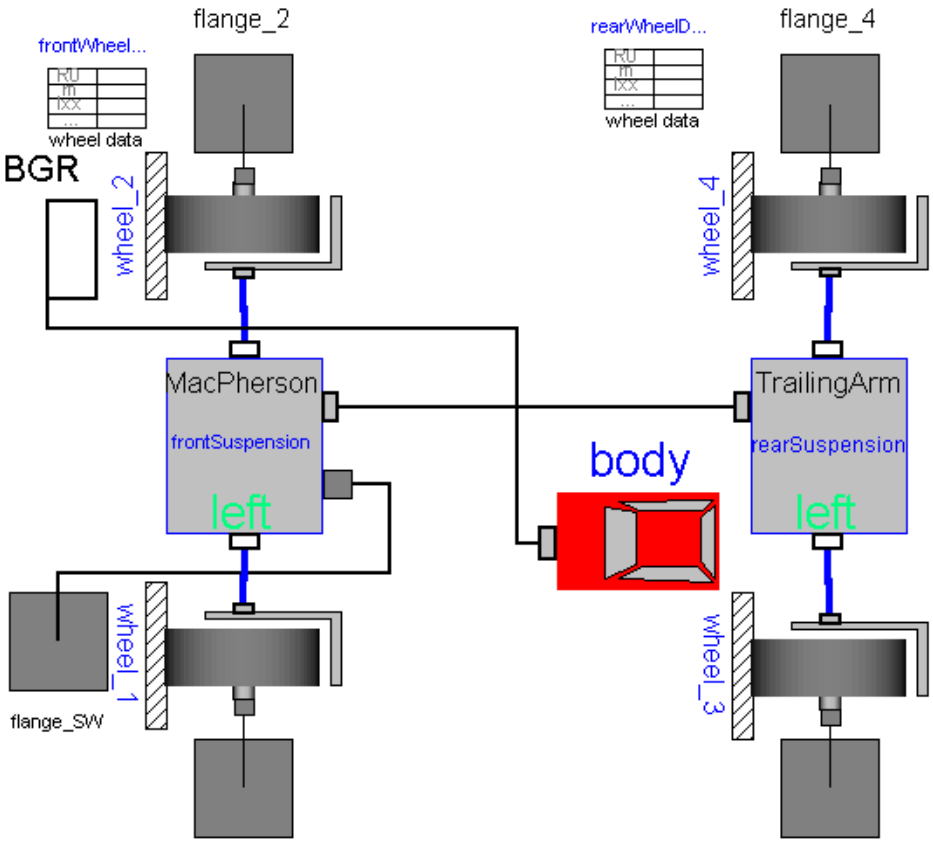
M. Wetter et al

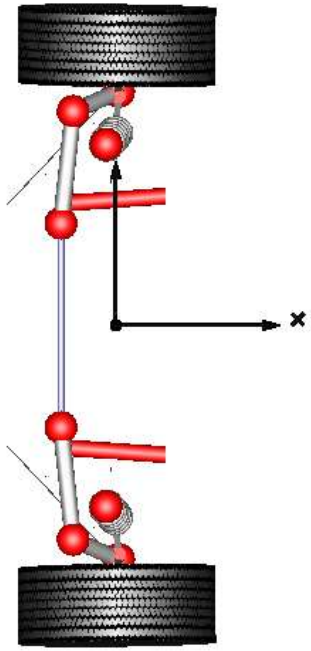
Browsing the Buildings Library using OpenModelica



Vehicle Dynamics Library – `VehicleDynamics` There is a Greatly Extended Commercial Version

This library is used to model vehicle chassis



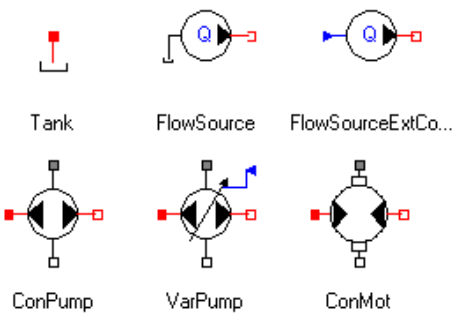


Some Commercial Libraries

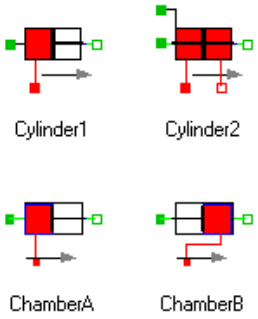
- Powertrain
- SmartElectricDrives
- VehicleDynamics
- AirConditioning
- HyLib
- PneuLib
- CombiPlant
- HydroPlant
- …
- (there are many more)

Hydraulics Library `HyLib`

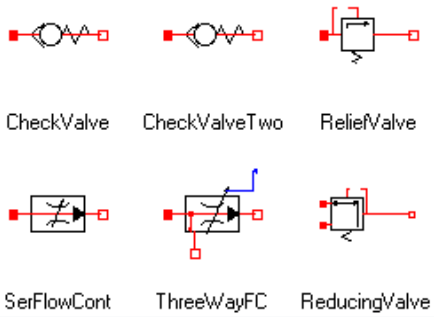
- Licensed Modelica package developed originally by Peter Beater
- More than 90 models for
  - Pumps
  - Motors and cylinders
  - Restrictions and valves
  - Hydraulic lines
  - Lumped volumes and sensors
- Models can be connected in an arbitrary way, e.g. in series or in parallel.
- `HyLibLight` is a free subset of `HyLib`
- More info: www.hylib.com



Pumps



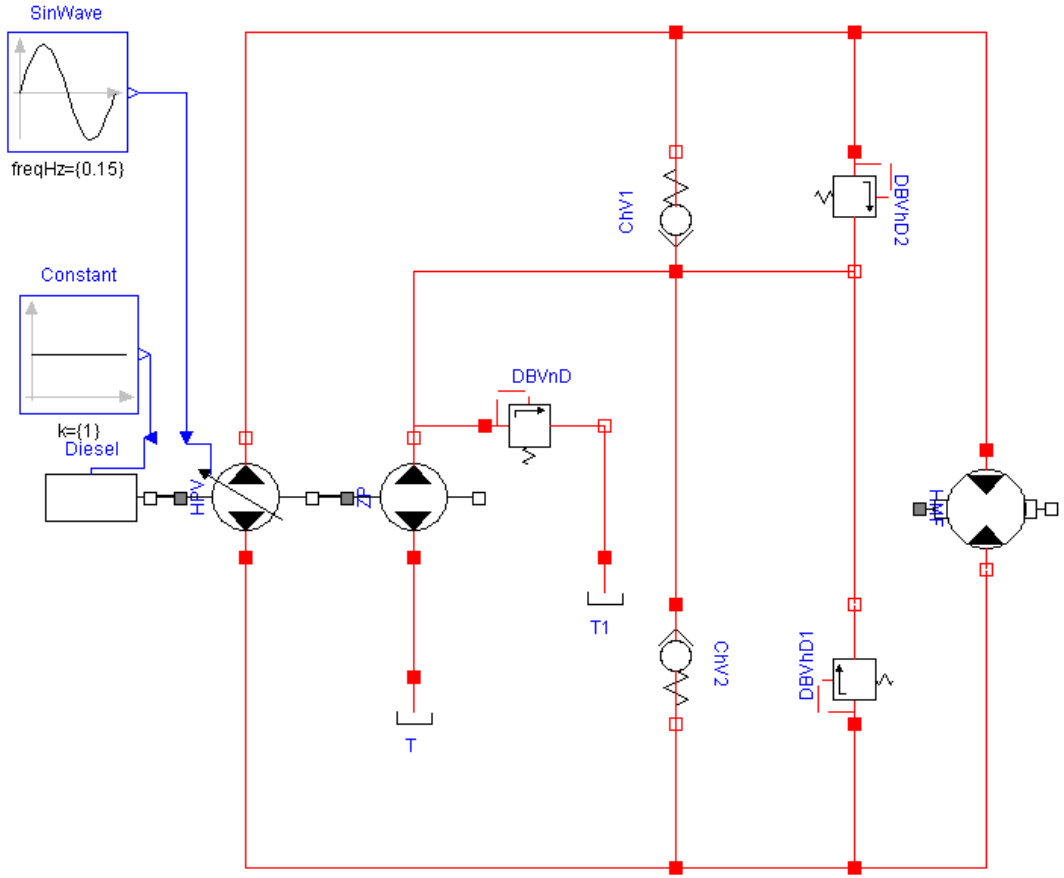
Cylinders



Valves

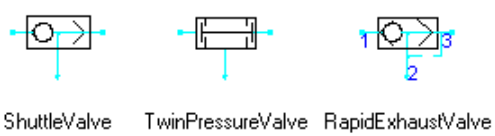
HyLib - Example

Hydraulic drive system with closed circuit

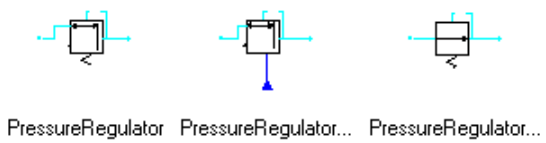


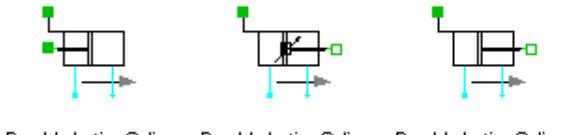
Pneumatics Library `PneuLib`

- Licensed Modelica package developed by Peter Beater
- More than 80 models for
  - Cylinders
  - Motors
  - Valves and nozzles
  - Lumped volumes
  - Lines and sensors
- Models can be connected in an arbitrary way, e.g. in series or in parallel.
- `PneuLibLight` is a free subset of `PneuLib`.
- More info: www.pneulib.com

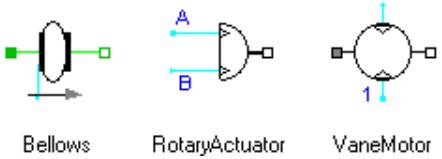


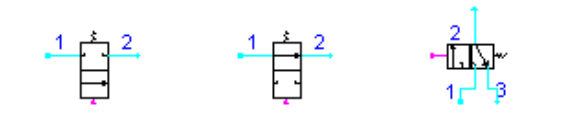
Directional valves



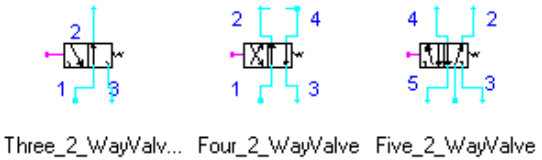


Flow control valves



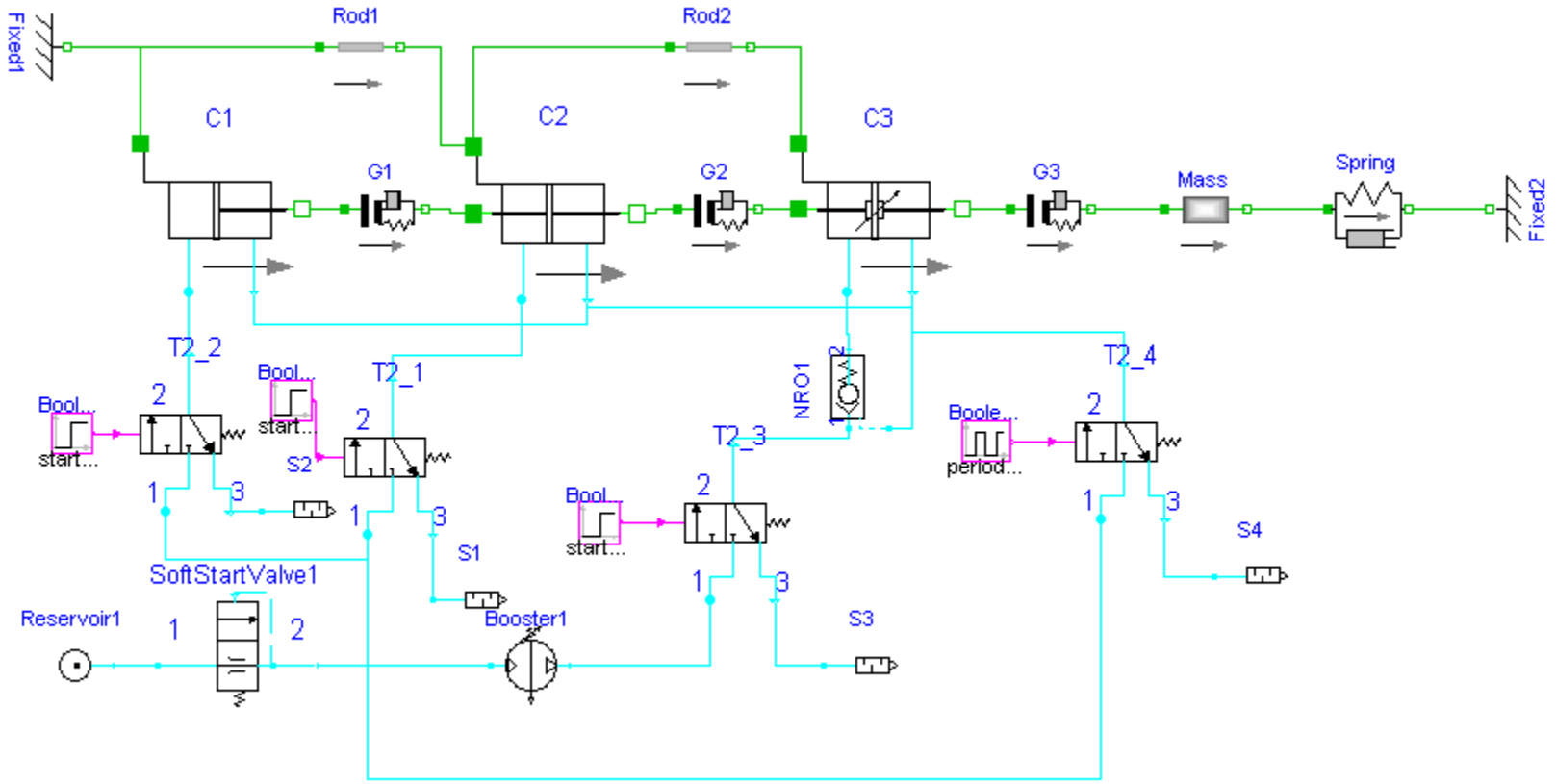


Cylinders



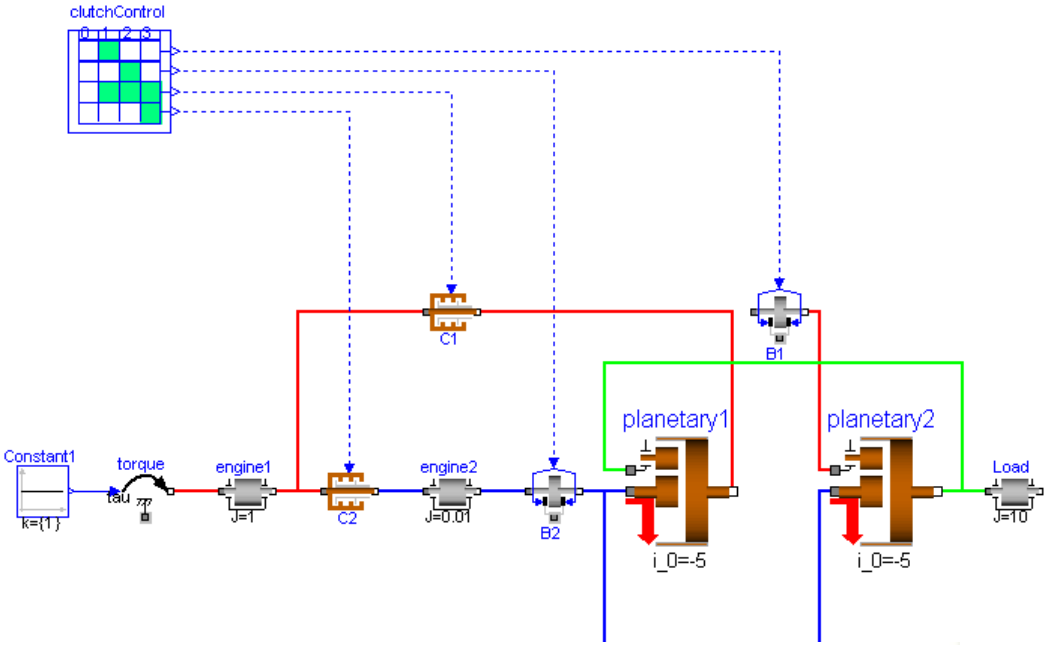
PneuLib - Example

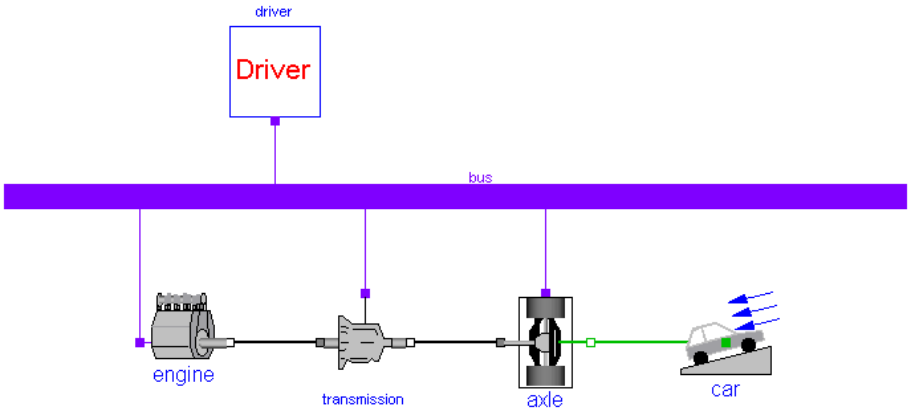
Pneumatic circuit with multi-position cylinder, booster and different valves

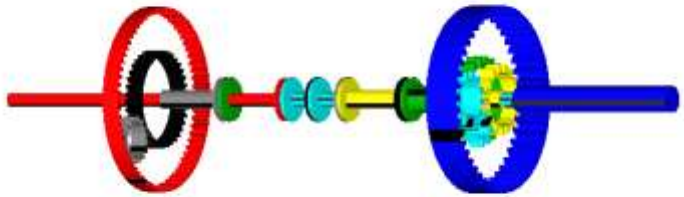


Powertrain Library - Powertrain

- Licensed Modelica package developed by DLR
- Speed and torque dependent friction
- Bus concept
- Control units
- Animation





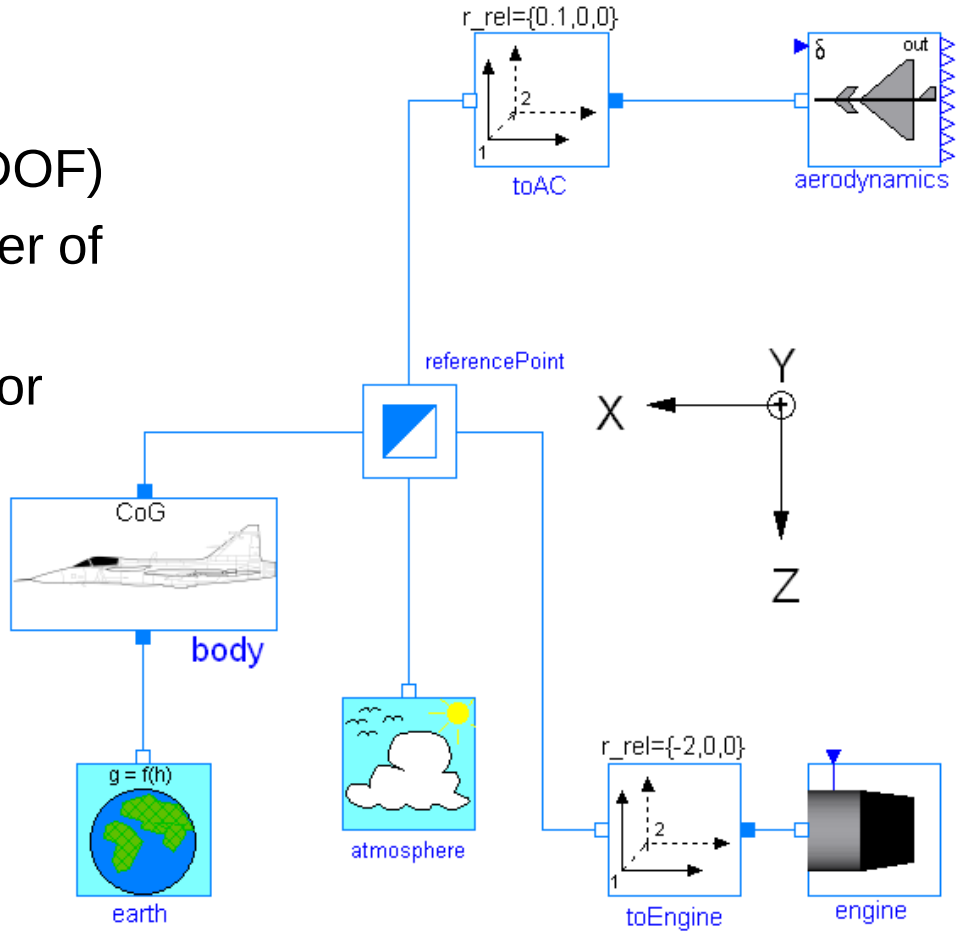


Some Modelica Applications

Example Fighter Aircraft Library

Custom made library, `Aircraft`*, for fighter aircraft applications

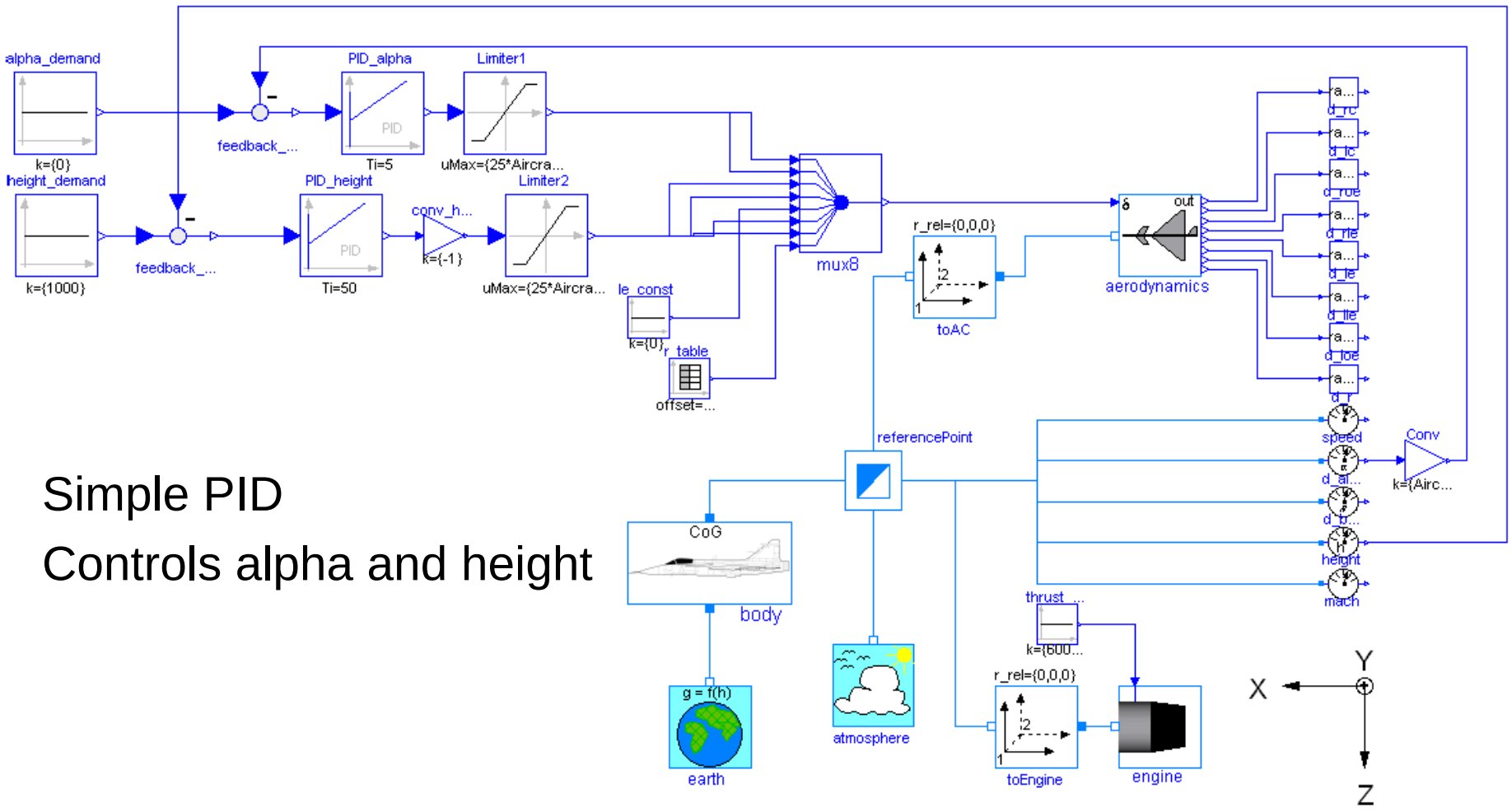
- Six degrees of freedom (6 DOF)
- Dynamic calculation of center of gravity (CoG)
- Use of Aerodynamic tables or mechanical rudders



*Property of FOI (The Swedish Defence Institute)

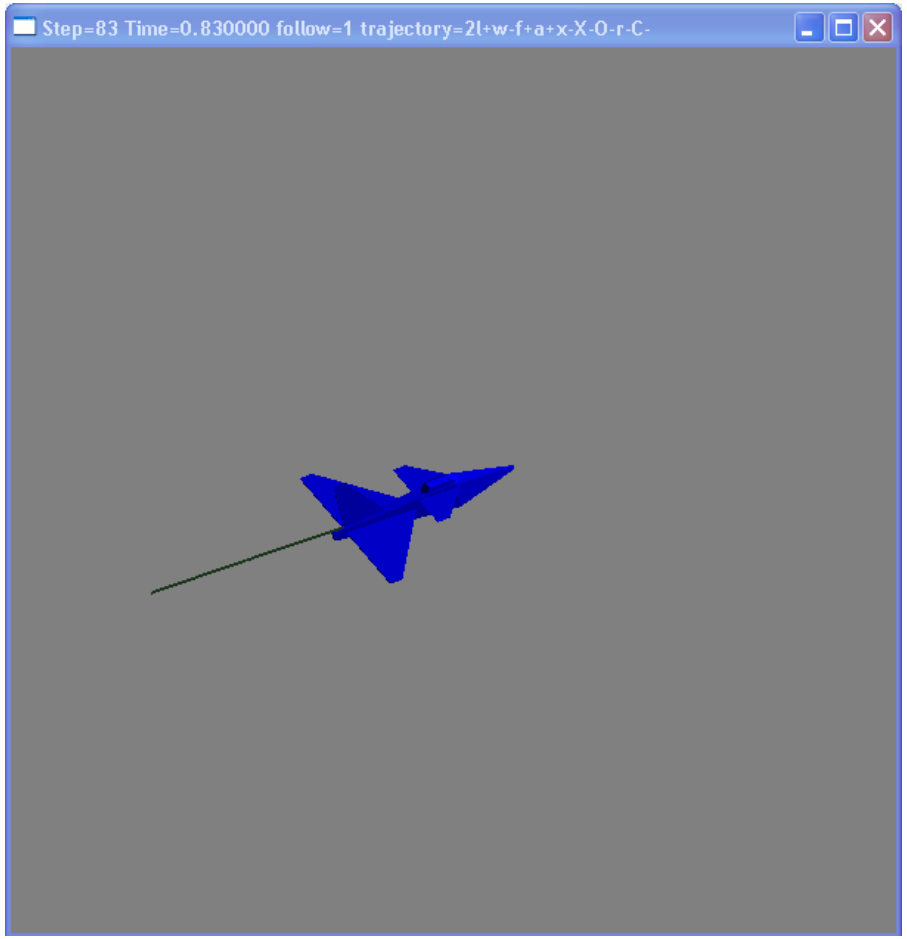
Aircraft with Controller

- Simple PID
- Controls alpha and height



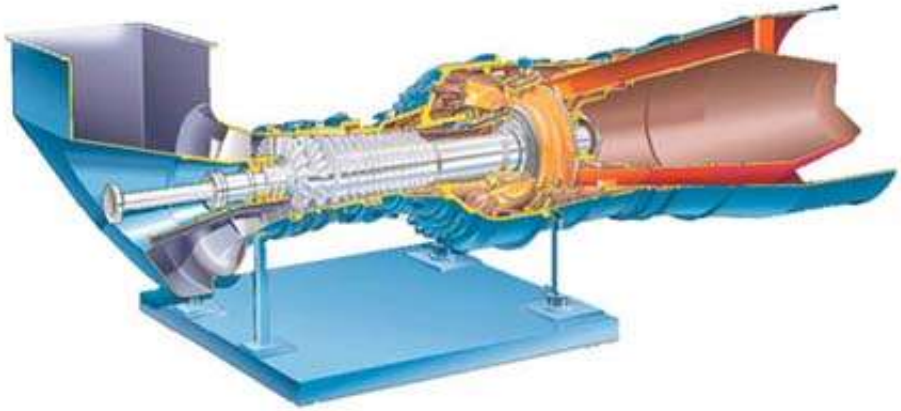
Example Aircraft Animation

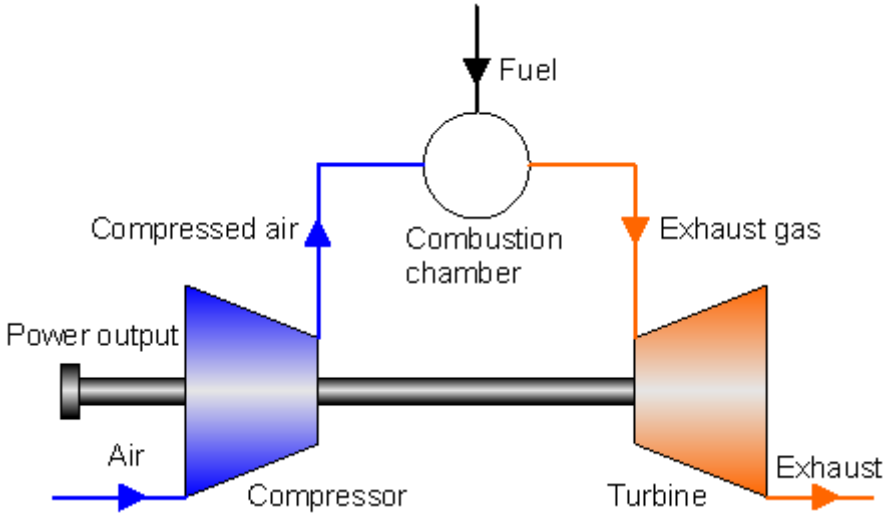
Animation of fighter aircraft with controller



Example Gas Turbine

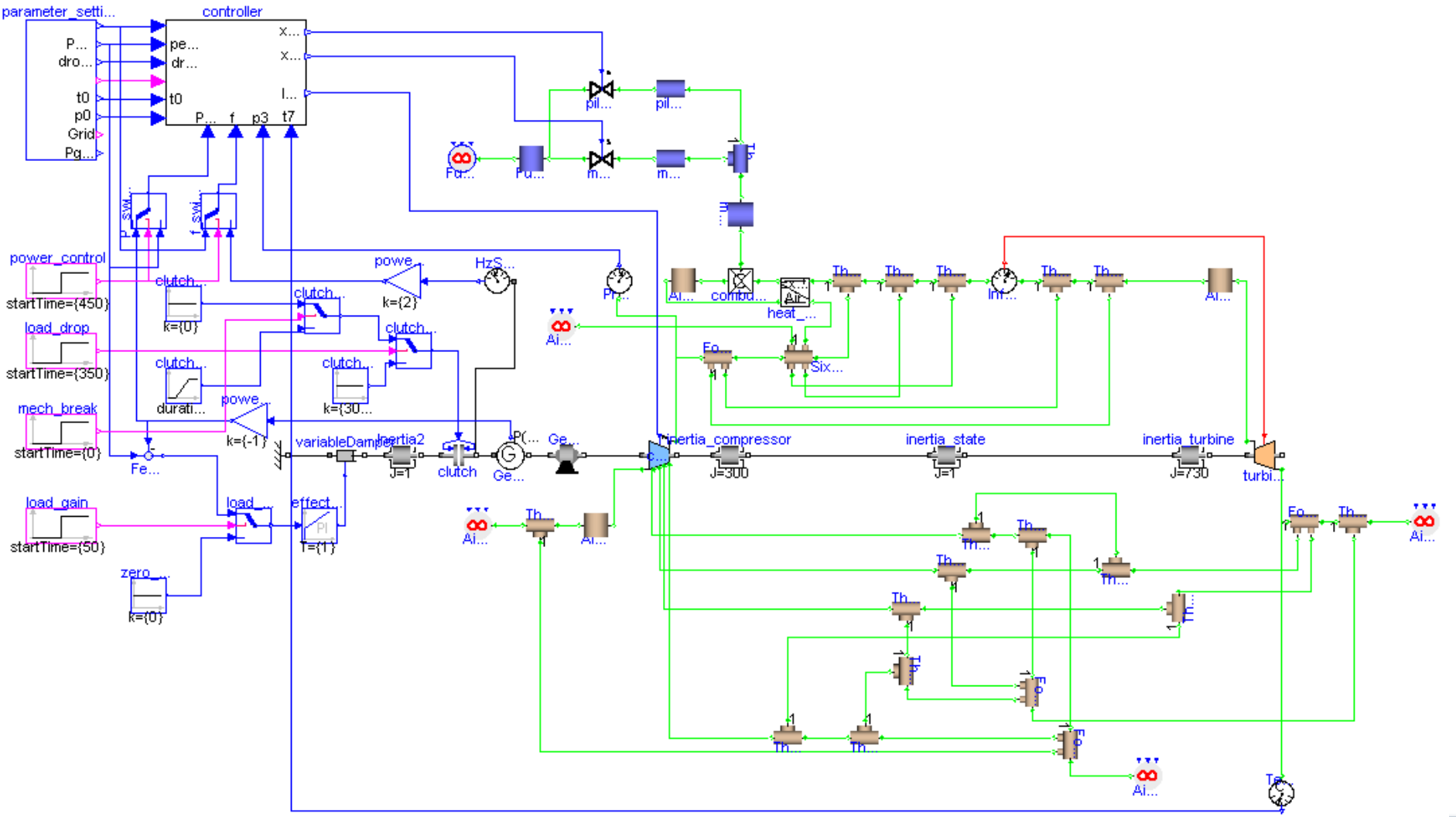
42 MW gas turbine (GTX 100) from Siemens Industrial Turbomachinery AB, Finspång, Sweden





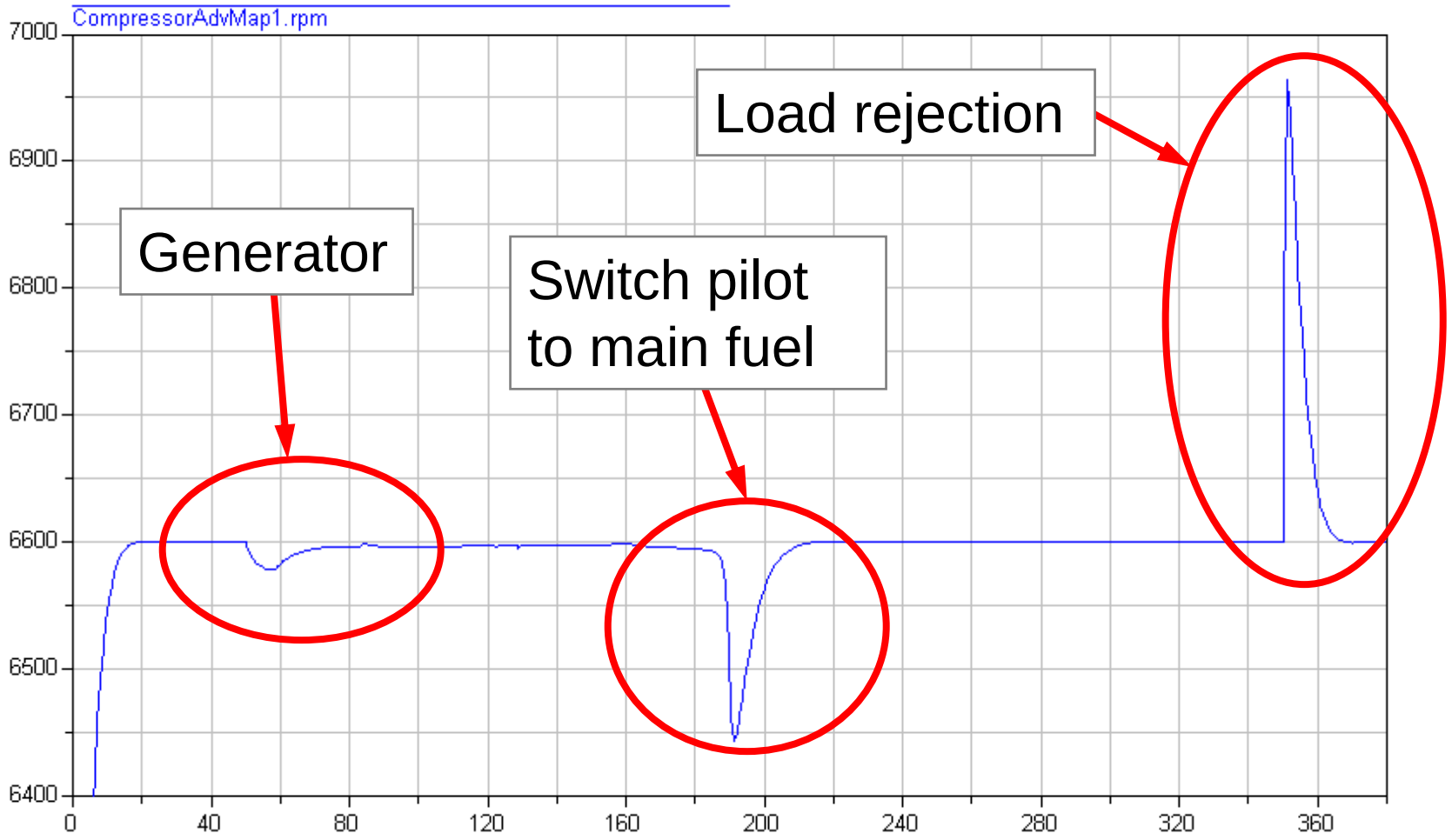
Courtesy Siemens Industrial Turbines AB

Example Gas Turbine

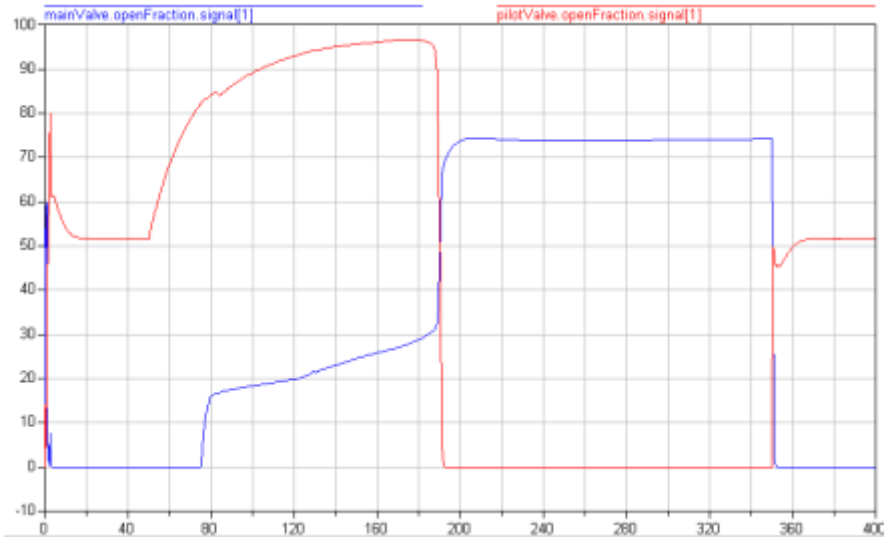


Example Gas Turbine – Load Rejection

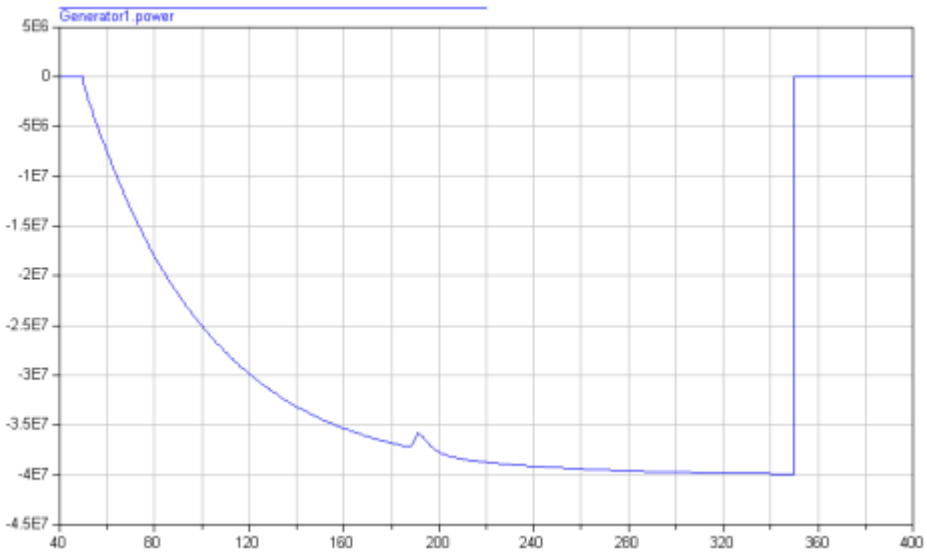
Rotational speed (rpm) of the compressor shaft



Example Gas Turbine – Load Rejection



Percentage of fuel valve opening (red = pilot, blue = main)



Generated power to the simulated electrical grid

Large-scale ABB OpenModelica Application
Generate code for controlling 7.5 to 10% of German Power Production

ABB OPTIMAX PowerFit

- Real-time optimizing control of large-scale virtual power plant for system integration
- **Software including OpenModelica** now used in managing more than 2500 renewable plants, total up to 1.5 GW

High scalability supporting growth

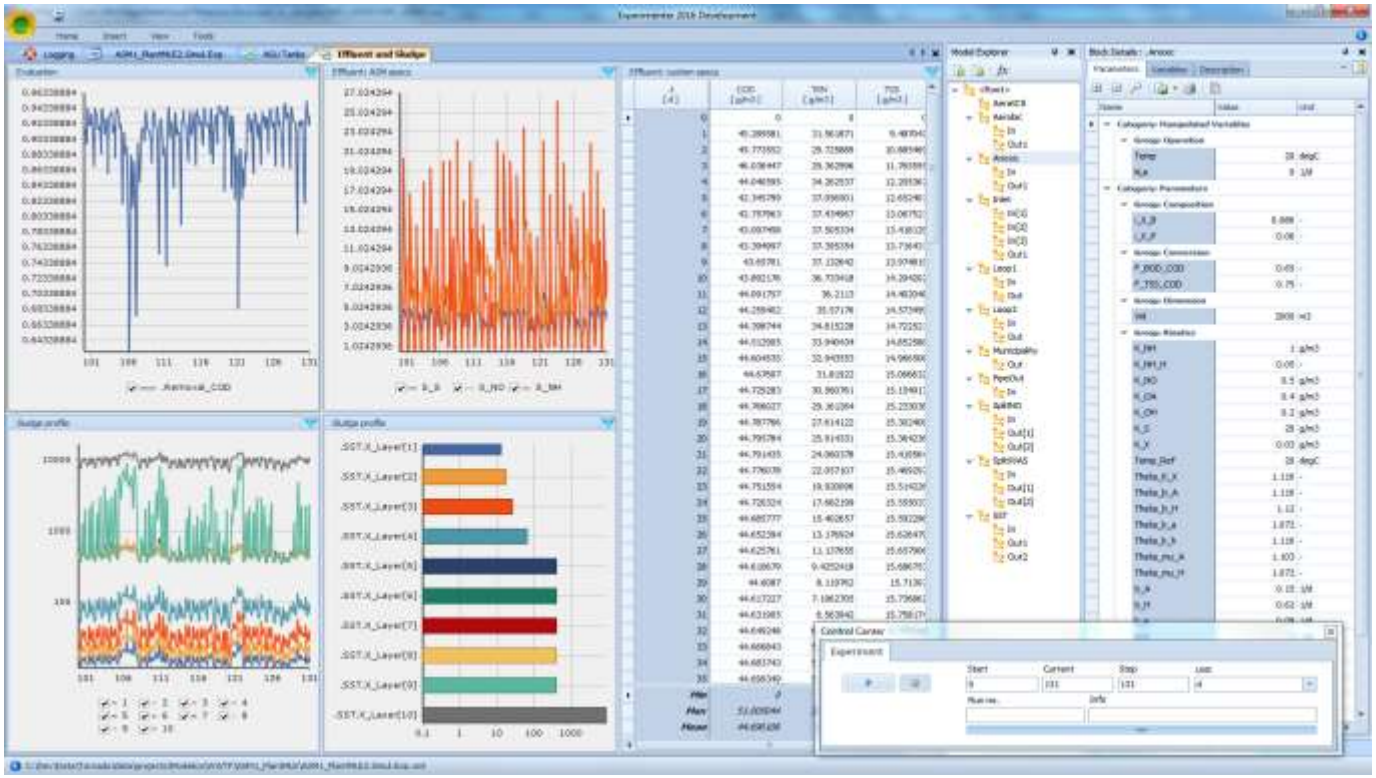
- 2012: initial delivery (for 50 plants)
- 2013: SW extension (500 plants)
- 2014: HW+SW extension (> 2000)
- 2015: HW+SW extension, incl. OpenModelica generating optimizing controller code in FMI 2.0 form

Manage 7.5% - 10% of German Power

- 2015, Aug: OpenModelica Exports FMUs for real-time optimizing control (seconds) of about **5.000 MW (7.5%) of power in Germany**

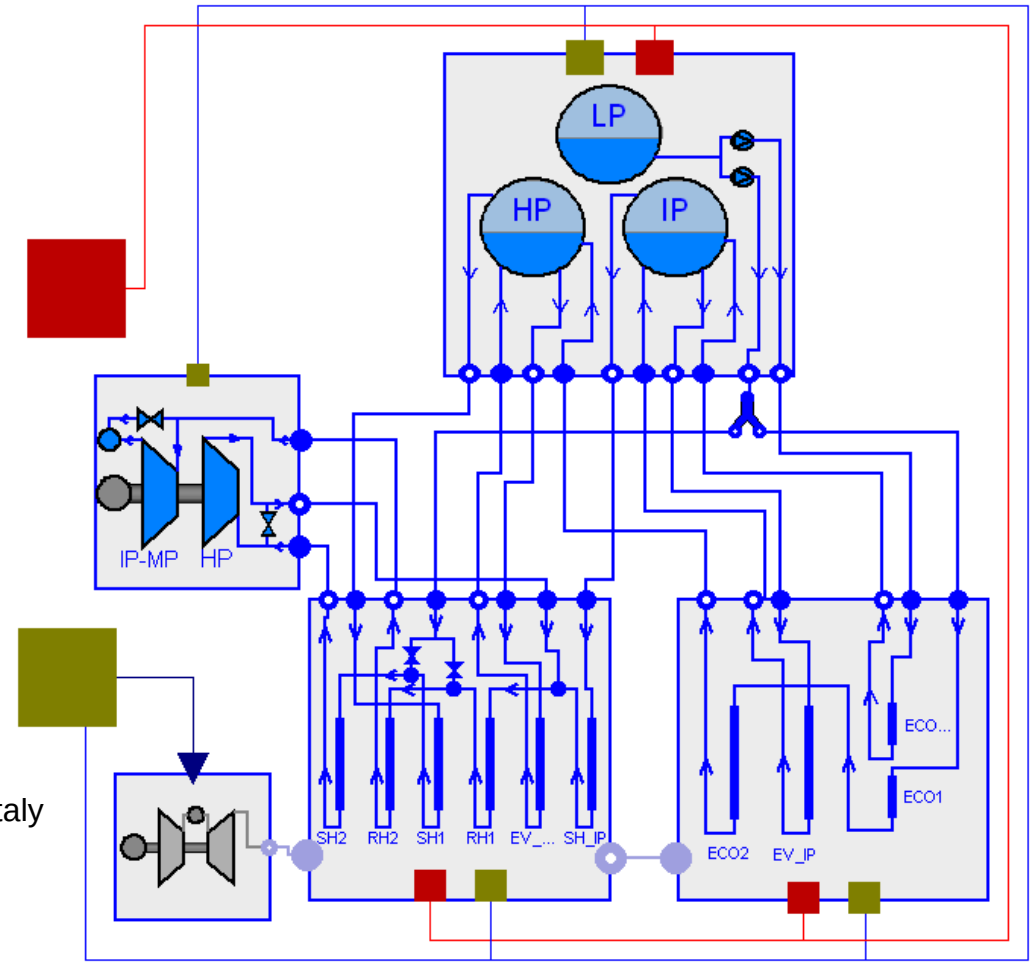
Industrial Product with OEM Usage of OpenModelica –
MIKE by DHI, WEST Water Quality, Water Treatment and Sludge

- **MIKE by DHI**, www.mikebydhi.com, **WEST Water Quality** modeling and simulation environment
- Includes a large part of the OpenModelica compiler using the OEM license.
- Here a water treatment effluent and sludge simulation.



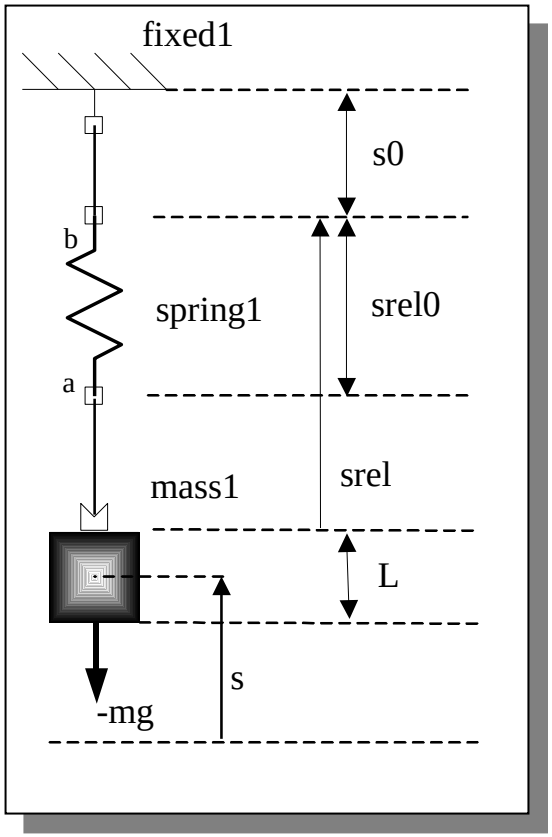
Combined-Cycle Power Plant
Plant model – system level

- GT unit, ST unit, Drum boilers unit and HRSG units, connected by thermo-fluid ports and by signal buses
- Low-temperature parts (condenser, feedwater system, LP circuits) are represented by trivial boundary conditions.
- GT model: simple law relating the electrical load request with the exhaust gas temperature and flow rate.

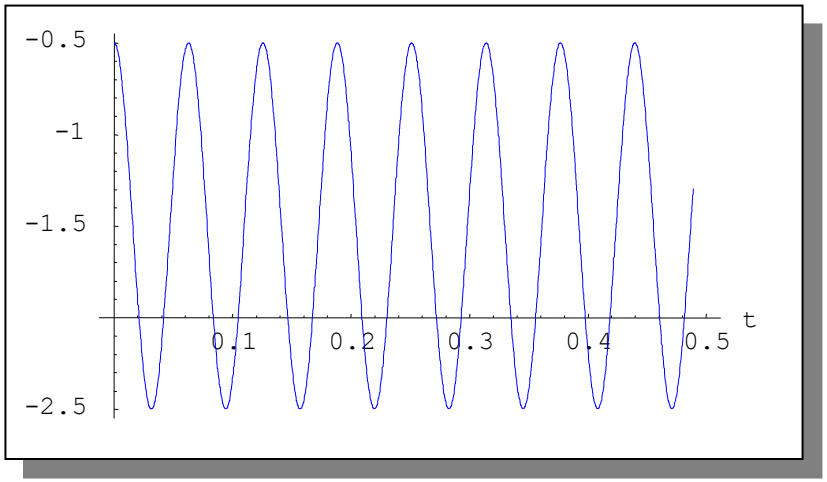


Courtesy Francesco Casella, Politecnico di Milano – Italy and Francesco Pretolani, CESI SpA - Italy

Example: Oscillating Mass Connected to a Spring Using the Mechanical.Translational library




```
model Oscillator
  Mass     mass1(L=1, s(start=-0.5));
  Spring   spring1(srel0=2, c=10000);
  Fixed    fixed1(s0=1.0);
equation
  connect(spring1.flange_b, fixed1.flange_b);
  connect(mass1.flange_b, spring1.flange_a);
end Oscillator;
```



Exercise

- Locate the Oscillator model in DrModelica using OMNotebook!
- Simulate and plot the example. Do a slight change in the model e.g. different elasticity c, re-simulate and re-plot.

- Draw the `Oscillator` model using the graphic connection editor e.g. using the library `Modelica.Mechanical.Translational`
- Including components `SlidingMass`, `Force`, `Blocks.Sources.Constant`

- Simulate and plot!