A Library for Synchronous Control Systems in Modelica

Martin Otter Bernhard Thiele Hilding Elmqvist

DLR
Institute of System Dynamics and Control

Dassault Systèmes

Presented at the Modelica'2012 Conference
Munich, Sept. 3-5, 2012

This slide set has be updated to the changes of the library performed after the conference.

Content

Introduction

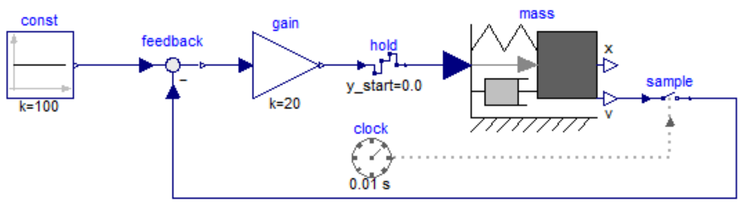
- Synchronous language elements of Modelica 3.3 are "low level":

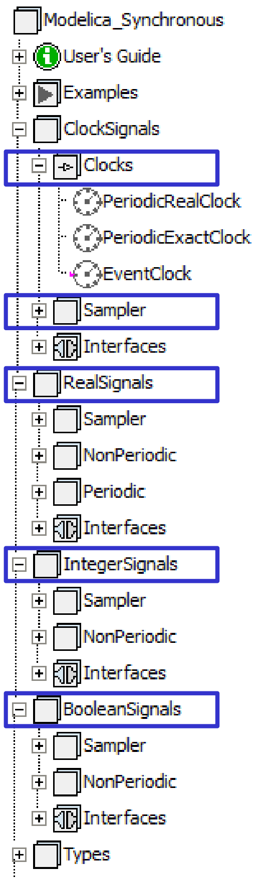
```
// speed sensor
vd = sample(v, Clock(0.01));

// P controller for speed
u = K*(vref-vd);

// force actuator
f = hold(u);
```

- Modelica_Synchronous library developed to access language elements in a convenient way graphically:





Blocks to generate clock signals

Blocks operating on clock signals
(e.g. sub-sampling a clock signal)

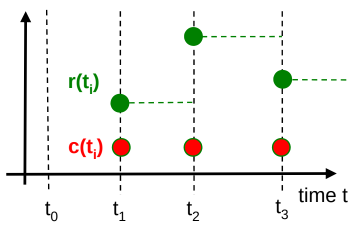
Blocks operating on clocked signals of type **Real**
(e.g. sub-sampling a Real signal, PI block, FIR filter)

Blocks operating on clocked signals of type **Integer**

Blocks operating on clocked signals of type **Boolean**

Clocks

New base data type: **Clock**
Variables associated to a clock have only a value at the clock tick.



c(t_i): Clock
r(t_i): Variable associated to c

Similar to Real, Integer, Boolean, introduced input/output **Clock connectors**:

```
connector ClockInput  = input Clock;

connector ClockOutput = output Clock;
```

Blocks that generate clock signals

periodicRealClock

0.02 s

Generates a periodic clock with a Real period

```
    parameter Modelica.SIunits.Time period;
    ClockOutput y;
  equation
    y = Clock(period);
```

periodicExactClock

20 ms

Generates a periodic clock as an integer multiple of a resolution (defined by an enumeration).

y (year)
d (day)
h (hour)
min (minutes)
s (seconds)
ms (milli seconds)
us (micro seconds)
ns (nano seconds)

Code for 20 ms period:

```
  y = superSample(Clock(20), 1000);
```

Clock with period 20 s

super-sample clock with 1000

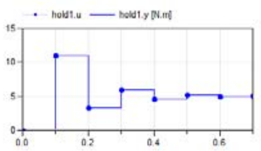
period = 20 / 1000 = 20 ms

eventClock

Generates an event clock: The clock ticks whenever the continuous-time Boolean input changes from false to true.

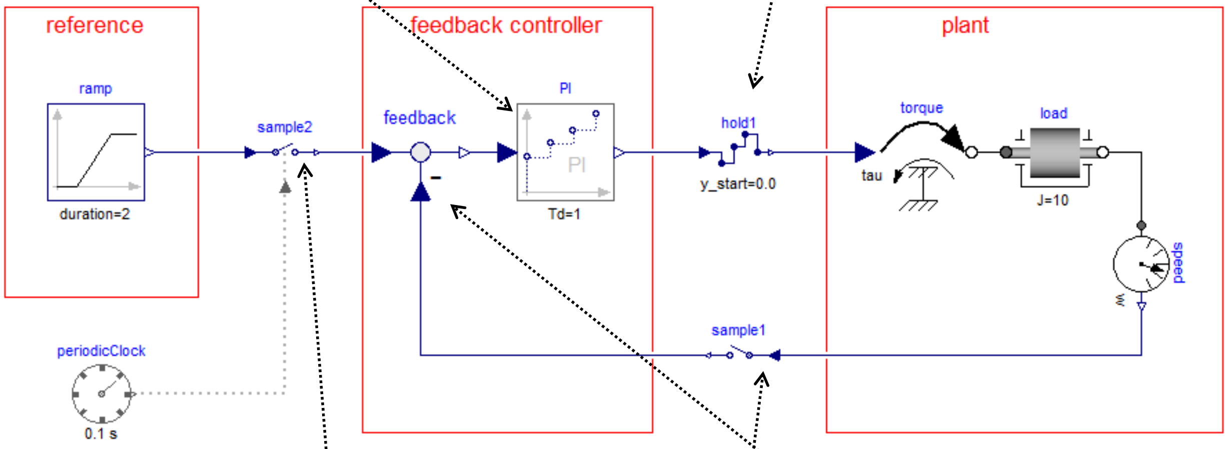
```
y = Clock(u);
```

Sample and Hold



Discrete-time PI controller

Holds a clocked signal and generates a continuous-time signal. Before the first clock tick, the continuous-time output y is set to parameter y_start;   `y = hold(u);`

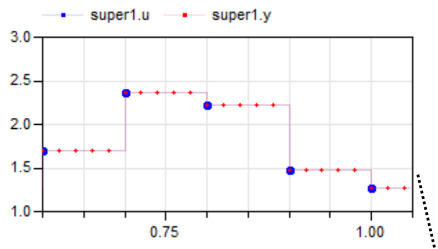


Samples a continuous-time signal and generates a clocked signal.

Purely algebraic block from Modelica.Blocks.Math

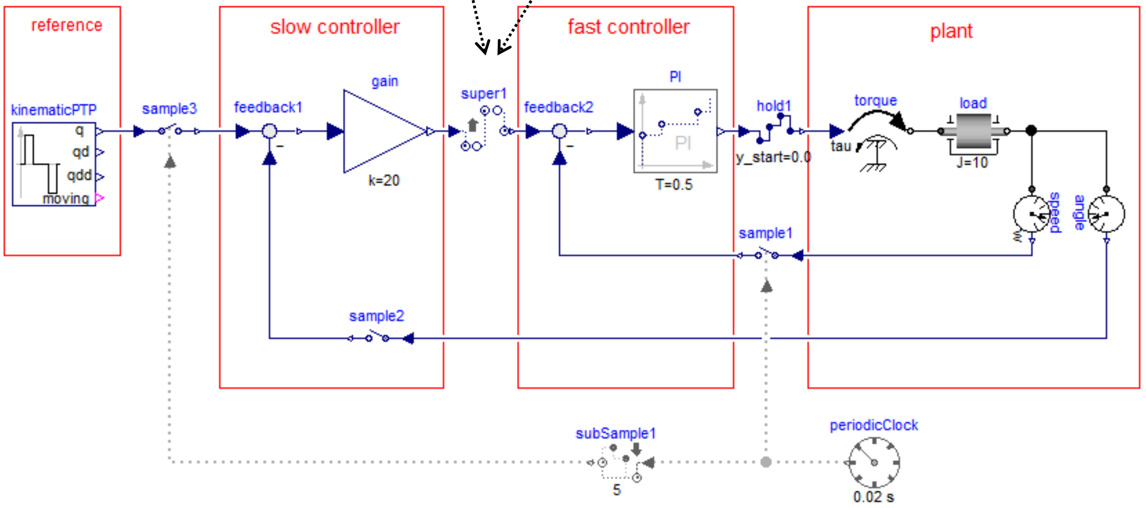
`y = sample(u, clock);`   `y = sample(u);`

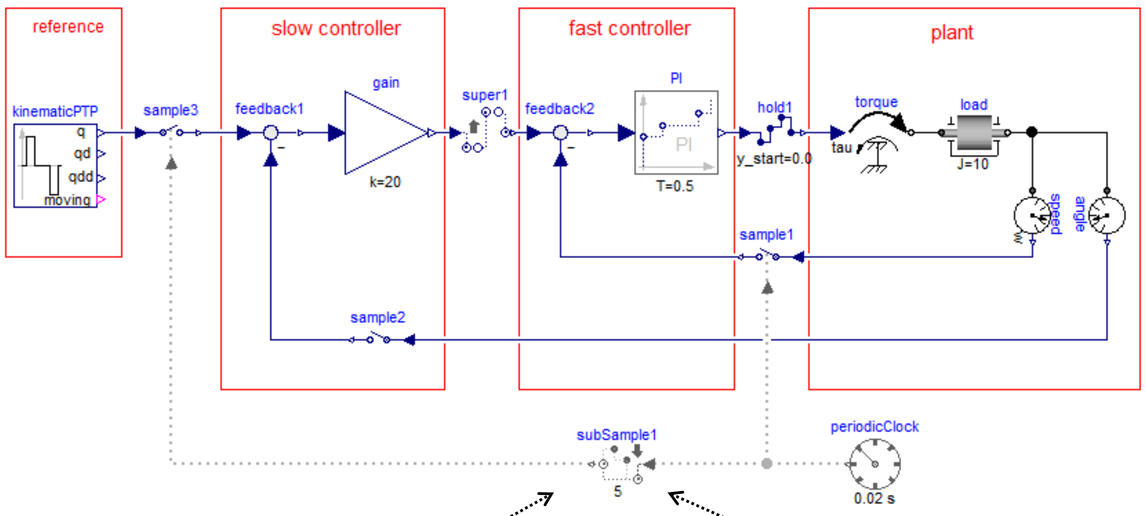
Sub- and Super-Sampling



Defines that the output signal is an integer factor faster as the input signal, using a “hold” semantics for the signal. By default, this factor is inferred. It can also be defined explicitly.

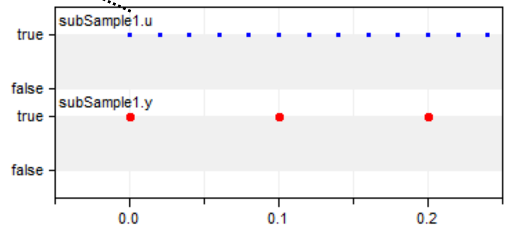
`y = superSample(u);`





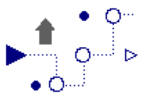
Defines that the output signal is an integer factor slower as the input signal, picking every n-th value of the input.

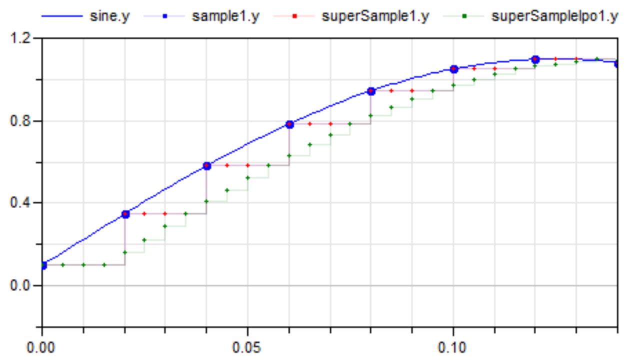
```
y = subSample(u,factor);
```



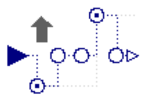
Several other blocks to change the clock of a signal, such as

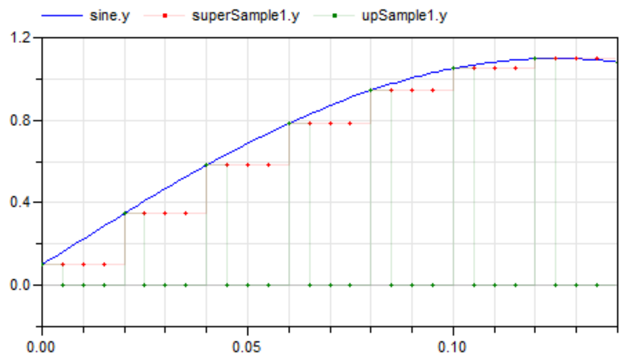
superSampleInterpolated





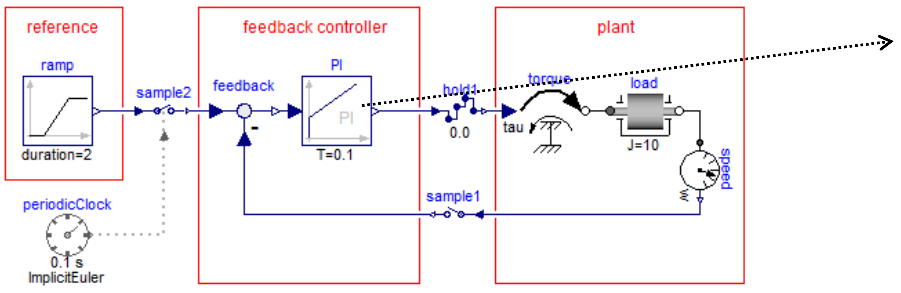
upSample



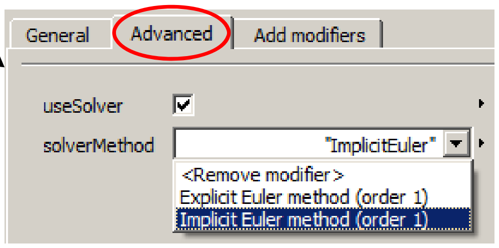


Discretizing Continuous Blocks

A clocked partition can consists of differential equations,
provided an integrator is associated to the corresponding clock
(the differential equations are solved at one clock tick with this integrator).



Continuous-time
PI controller



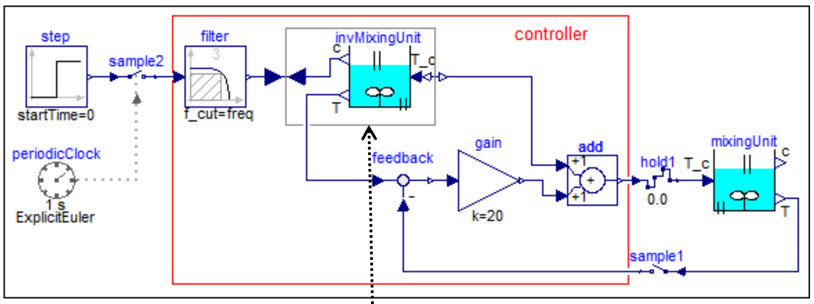
useSolver ☑

solverMethod "ImplicitEuler"

<Remove modifier>
Explicit Euler method (order 1)
Implicit Euler method (order 1)

Especially, inverse, continuous-time models can be discretized
(this is not possible with Modelica 3.2):

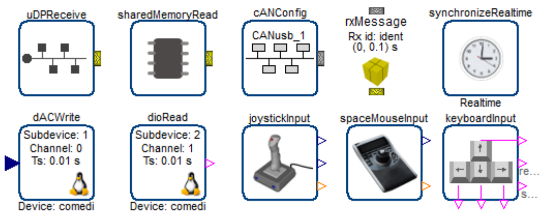
clocked controller

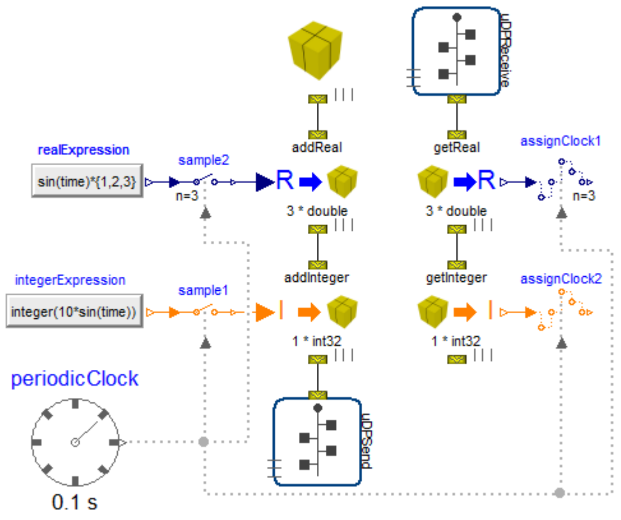


inverse plant model
(input T_c becomes output
output c becomes input)

Modelica_DeviceDrivers library

- New, free library by DLR that interfaces hardware drivers.
- Cross platform (Windows and Linux)
- Realtime synchronization, UDP, joystick, keyboard, etc.





- Basic functionality provided with Modelica functions.
- Convenience blocks based either on Modelica_Synchronous library or on Modelica 3.1 when-clauses.
- Generic packaging system, e.g. to pack 8 Booleans on 1 Integer.
- Currently supported for UDP, shared memory, and (prototypical) CAN bus

Conclusions (1)

Modelica_Synchronous library

- Main purpose:
  Encapsulating the Modelica 3.3 synchronous language elements with an easy to use graphical user interface (the code of most blocks is very simple!!)
  Makes definition of sampled-data systems much simpler and safer.
- Should work with every Modelica tool that supports Modelica 3.3.
- Shall be included in the Modelica Standard Library after an evaluation period.
- Available for MA members on internal svn server.
  Released version is stored publicly on MA web.

Conclusions (2)

Modelica_DeviceDrivers library

- Main purpose:
  Access device drivers on Windows and Linux PCs from a Modelica block.
- Should work with every Modelica tool that supports
  external Modelica functions (with C-code included in include annotation)
  synchronous elements of Modelica 3.3 (for Modelica 3.3 conveníence blocks).
- Shall be included in the Modelica Standard Library after an evaluation period.
- Available for MA members on internal svn server.
  Released version is stored publicly on MA web.