

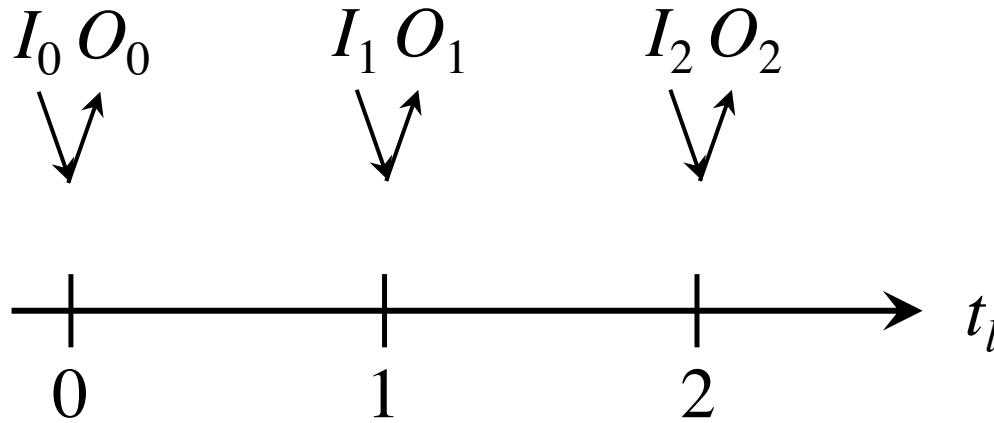


Real-Time Ticks for Synchronous Programming

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Discrete (Logical) Time in Synchronous Programming



- Synchrony Hypothesis:
Outputs are synchronous with inputs
- Computation "does not take time"
- Actual computation time does not influence result
- Sequence of outputs **determined** by inputs

Synchronous Execution

```
Initialize Memory
for each input event do
    Compute Outputs
    Update Memory
end
```

```
Initialize Memory
for each clock tick do
    Read Inputs
    Compute Outputs
    Update Memory
end
```

Fig. 1 Two common synchronous execution schemes: event driven (left) and sample driven (right).

[Benveniste et al., *The Synchronous Languages Twelve Years Later*, Proc. IEEE, 2003]

Multiform Notion of Time

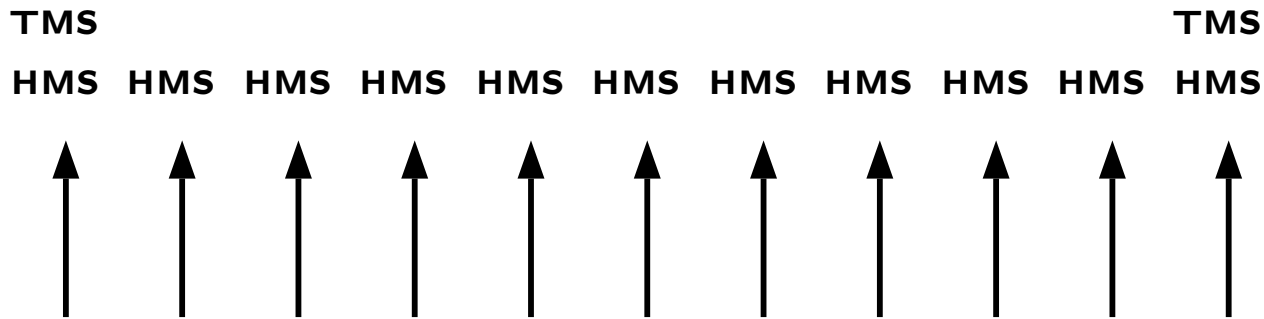
Only the simultaneity and precedence of events are considered.

This means that the physical time does not play any special role.

This is called multiform notion of time.

[<https://en.wikipedia.org/wiki/Esterel>]

Packaging Physical Time as Events



[Timothy Bourke, SYNCHRON 2009]

Event "HMS": 100 μ sec have passed since last HMS

Event "TMS": 1000 μ sec have passed since last TMS

A Problem With That ...

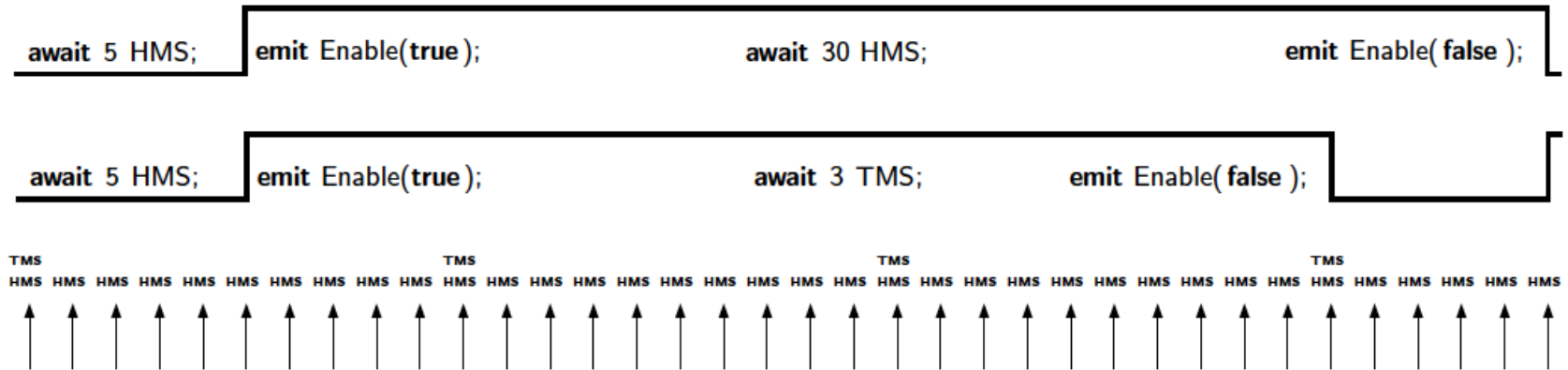
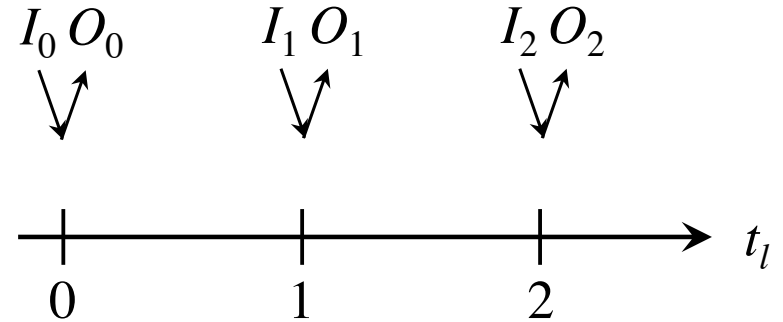


Fig. 4: Granularity of timing inputs

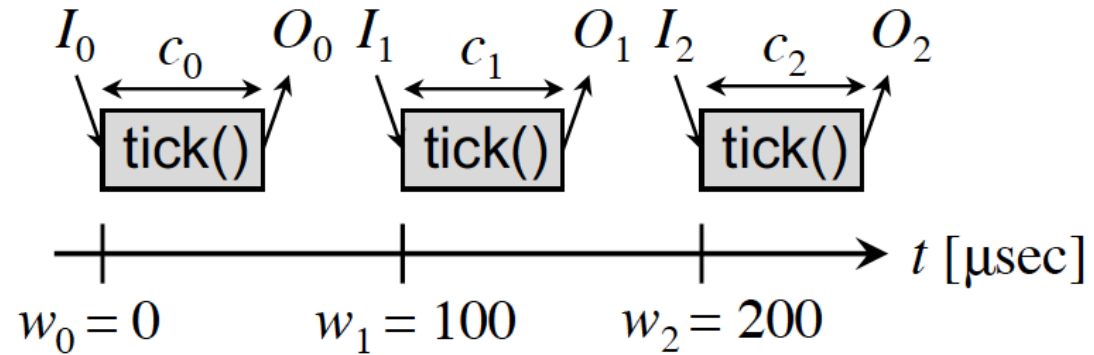
[Timothy Bourke, SYNCHRON 2009]

Dynamic Ticks

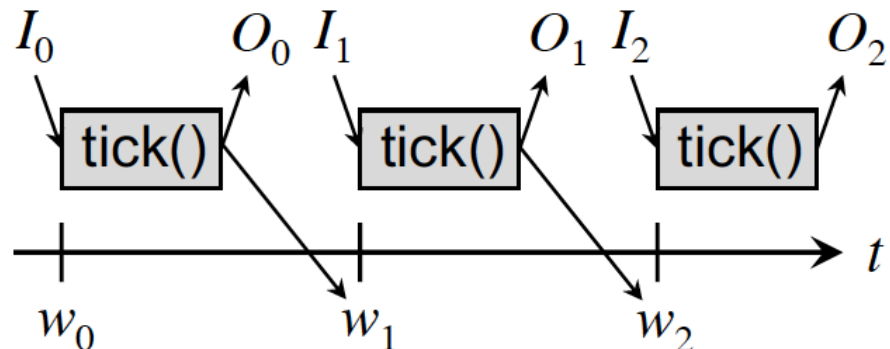
- Recall logical time:



- Physical time, time-triggered:



- Physical time, dynamic ticks:



Esterel

```
module PAUSE_USEC:

input current_usec : integer;           % Simulated time
input wait_usec : integer;             % Time of delay
function min(integer, integer) : integer;
output wake_usec : combine integer with min; % Time of next wake up
var my_wake_usec : integer in          % Local copy of wake_usec

% Compute physical time when PAUSE_USEC should terminate
my_wake_usec := ?current_usec + ?wait_usec;

% Loop until current_usec = my_wake_usec
trap done in
  loop
    emit wake_usec(my_wake_usec);
    pause;
    if ?current_usec = my_wake_usec then
      exit done;
    end if;
  end loop
end trap
end var
end module
```



```
int main()
{
    int notDone, prev_tick_end_usec = 0;

    RACE_reset(); // Reset automaton
    time_reset(); // Initialize time

    // Loop until tick function terminates
    do {
        // Set inputs
        RACE_I_current_wall_usec(get_current_wall_usec());
        RACE_I_prev_tick_end_usec(prev_tick_end_usec);

        notDone = RACE(); // Call tick function
        prev_tick_end_usec = get_current_wall_usec();

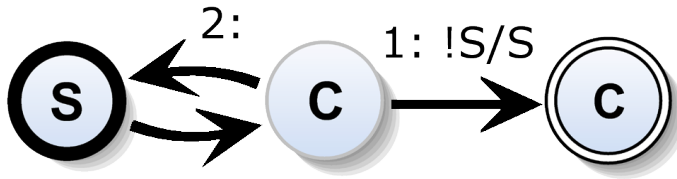
        // Wait until wake_usec
        microsleep(wake_usec - prev_tick_end_usec);
    } while (notDone);

    return 0;
}
```

Host Code

DEMO

Dynamic Ticks in SCCharts



SCCharts

<http://www.sccharts.com/>



KIELER

The Key to Efficient Modeling

<http://www.rtsys.informatik.uni-kiel.de/en/research/kieler>



Eclipse Layout Kernel

<https://www.eclipse.org/elk/>

All available as open source under EPL

SCCharts Textual Representation

```
// Controller for stepper motor
```

```
scchart MOTOR {  
    output int currentUsec = 0; // Current simulated time; when deployed,  
                               // this should be input  
    output int wakeUsec;      // Time for next wake-up  
  
    input bool accel, decel;  // Increase/decrease speed  
    input bool stop;         // Emergency stop - sets (angular) speeds to 0  
  
    output bool motor = false; // Motor pulse  
    output float v;           // [cm/sec] Robot speed  
    output int pUsec;        // [usec] Half period for motor  
  
    int pSetSpeedsUsec = 500000; // [usec] Period of speed control loop  
    float dV = 2;                // [cm/sec] Delta v applied during one  
                                // pSetSpeedsUsec  
    float vMax = 20;            // [cm/sec] Max speed of left/right motor  
    float cmPerHalfPeriod = 1; // [cm] Distance traveled by motor per half  
                                // period (duration of true or false)
```

```
// Controller for stepper motor

scchart MOTOR {
  output int currentUsec = 0; // Current simulated time; when deployed, this should be input
  output int wakeUsec; // Time for next wake-up

  input bool accel, decel; // Increase/decrease speed
  input bool stop; // Emergency stop - sets (angular) speeds to 0

  output bool motor = false; // Motor pulse
  output float v; // [cm/sec] Robot speed
  output int pUsec; // [uSec] Half period for motor

  int pSetSpeedsUsec = 500000; // [uSec] Period of speed control loop
  float dV = 2; // [cm/sec] Delta v applied during one pSetSpeedsUsec
  float vMax = 20; // [cm/sec] Max speed of left/right motor
  float cmPerHalfPeriod = 1; // [cm] Distance traveled by motor per half period (duration of true or false)

  // =====
  region SetSpeeds:

  initial state SetSpeeds "" {
    bool clk; // Local clock
  }
  // =====
  region ProcessInputs:

  initial state Init
  --> Running immediate;

  state Running {
    entry / v = 0;

    // =====
    region CalcV:

    initial state Pause
    --> Accel with clk & accel & !decel
    --> Decel with clk & decel & !accel;

    state Accel
    --> CheckMax immediate with / v += dV;

    state Decel
    --> CheckMin immediate with / v -= dV;

    state CheckMax
    --> SetPeriod immediate with v <= vMax
    --> SetPeriod immediate with / v = vMax;

    state CheckMin
    --> SetPeriod immediate with v >= -vMax
    --> SetPeriod immediate with / v = -vMax;

    state SetPeriod
    --> Pause immediate with v == 0 / pUsec = 0
    --> Pause immediate with / pUsec =
      '(int)(1000000 * cmPerHalfPeriod / v)';
  }
  o-> Running with clk & stop / pUsec = 0;
}
```

Now use KIELER to synthesize graphical SCChart with ELK and simulate...

```
// =====
region GenClk:

initial state GenClkState "" {
  int myWakeUsec; //entry / clk = true;

  initial state Init
  --> AssertWakeTime immediate with / myWakeUsec = currentUsec +
  pSetSpeedsUsec; clk = true;

  connector state AssertWakeTime
  --> Pause immediate with / wakeUsec = myWakeUsec; // Initialize wakeUsec

  @layout[layerConstraint] LAST
  state Pause
  --> AssertWakeTime with currentUsec < myWakeUsec / clk = false
  --> Init;
};

// =====
region IntrMotor:

initial state CtrlMotor "" {
  bool clk; // Local clock
}

// =====
region GenClk:

initial state GenClkState "" {
  int myWakeUsec;

  initial state Stopped
  --> AssertWakeTime immediate with / wakeUsec > 0 / myWakeUsec = currentUsec +
  pUsec; clk = true;

  connector state AssertWakeTime
  --> Running immediate with / wakeUsec min= myWakeUsec; // Initialize wakeUsec

  @layout[layerConstraint] LAST
  state RunLow
  --> ResetLock with / clk = false;

  connector state ResetClock
  --> AssertWakeTime with pUsec > 0 & currentUsec < myWakeUsec
  --> Stopped;
};

// =====
region Motor:

initial state Low
--> High with clk / motor = true;

state High
--> Low with clk / motor = false;
};

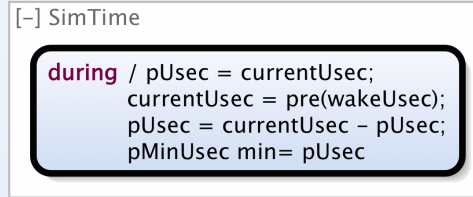
// =====
region SimTime:

initial state Pause
--> Pause with / currentUsec = pre(wakeUsec);
}
```

MOTOR



pre(wakeUsec)



currentUsec

[-] SetSpeeds

[-] GenClk

GenClkState

[-]

2:



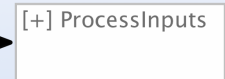
/ clk = true;
myWakeMinUsec = currentUsec +
pSetSpeedsMinUsec;
myWakeMaxUsec = currentUsec +
pSetSpeedsMaxUsec;

1: currentUsec < myWakeMinUsec
/ clk = false;



/ wakeUsec = myWakeMaxUsec;

clk

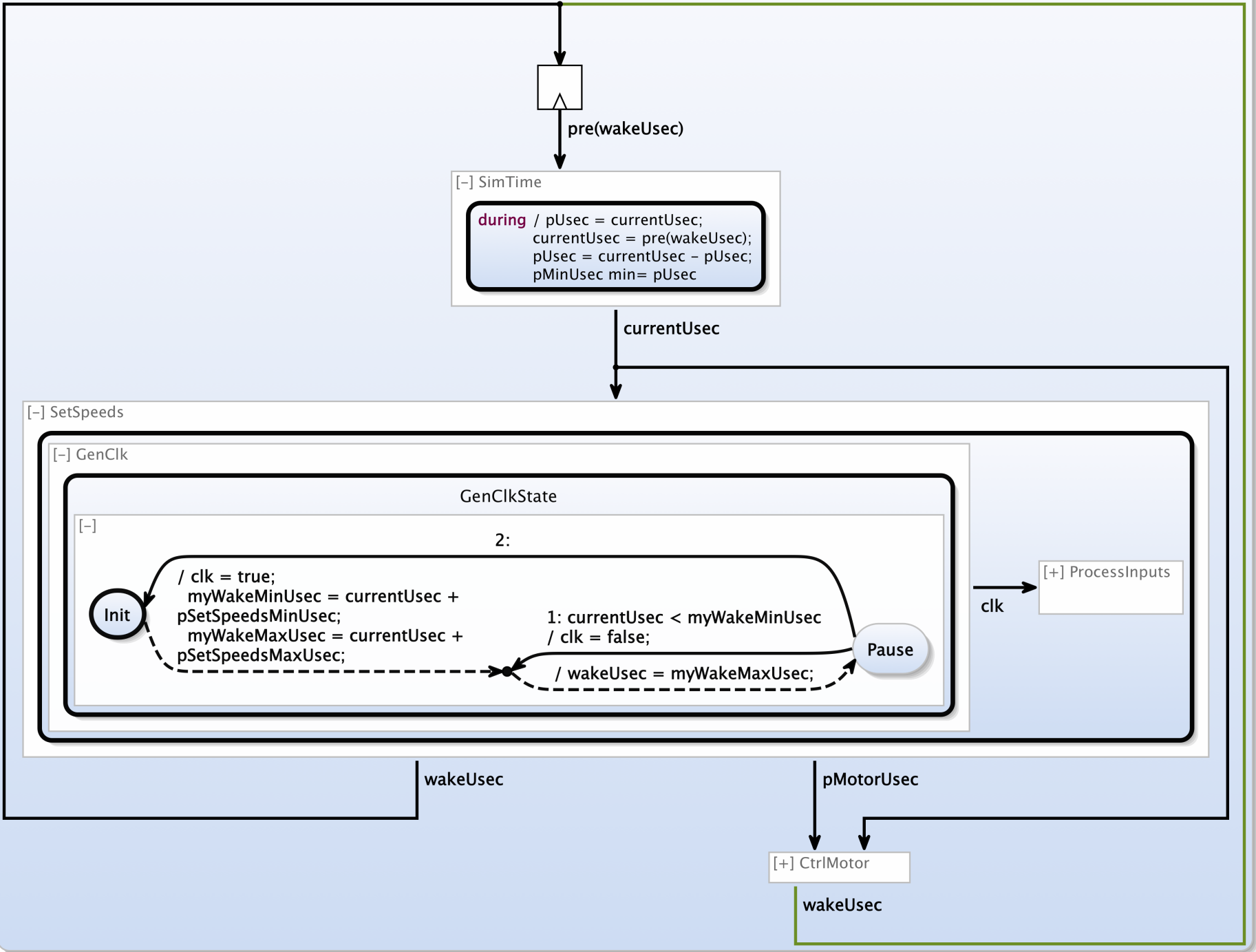


wakeUsec

pMotorUsec

[+] CtrlMotor

wakeUsec





Diagram



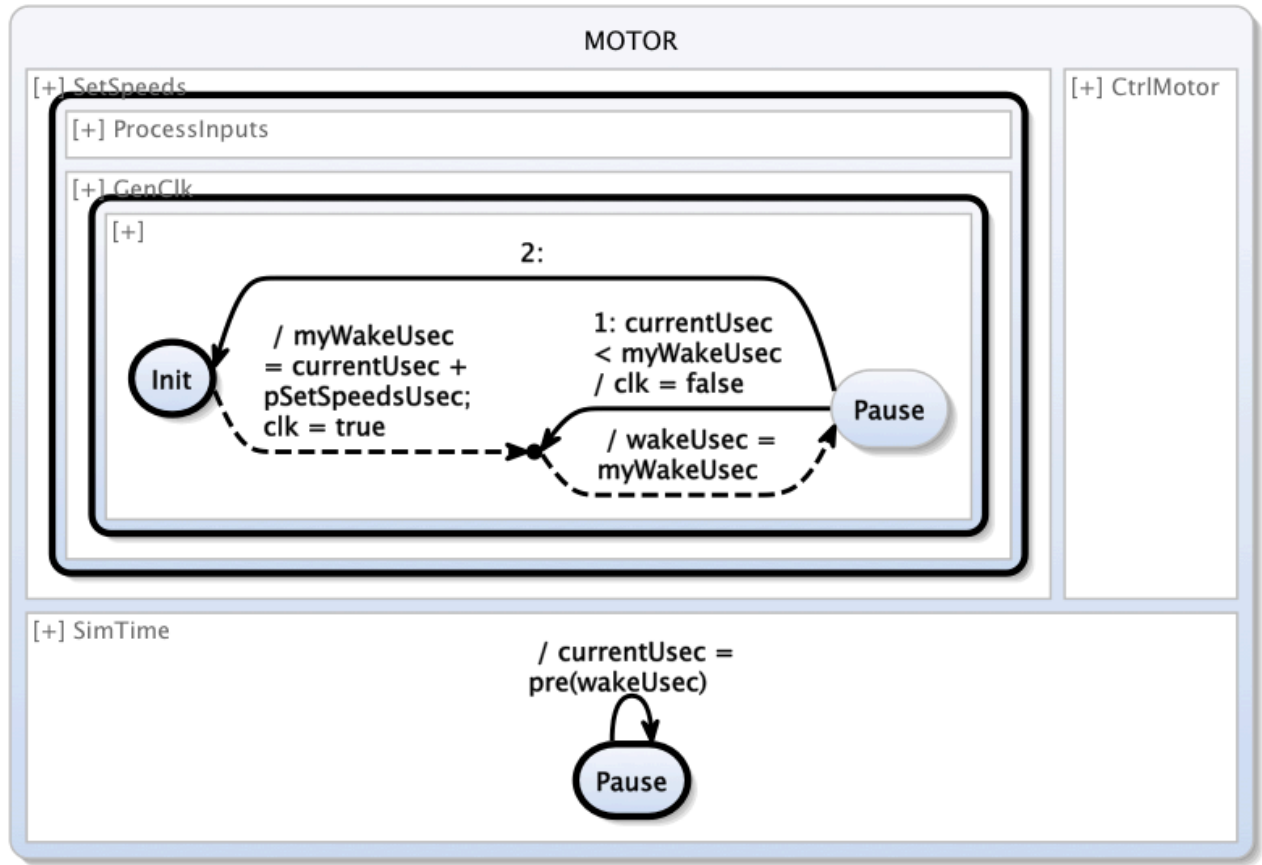
Synchronous Signal

KIEM Execution

- motor
- currentUsec
- stop
- wakeUsec
- v
- decel
- accel

Data Table

P	Key	Value
<input type="checkbox"/>	accel	
<input type="checkbox"/>	currentUsec	
<input type="checkbox"/>	decel	
<input type="checkbox"/>	motor	
<input type="checkbox"/>	pUsec	
<input type="checkbox"/>	stop	
<input type="checkbox"/>	v	
<input type="checkbox"/>	wakeUsec	



kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

[+] CtrlMotor

[+] SimTime

2:

Init

1: `currentUsec < myWakeUsec`
`clk = false`

Pause

`/ myWakeUsec = currentUsec + pSetSpeedsUsec;`
`clk = true`

`/ wakeUsec = myWakeUsec`

`/ currentUsec = pre(wakeUsec)`

Pause

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

Data Table

P	Key	Value
<input type="checkbox"/>	accel	
<input checked="" type="checkbox"/>	currentUsec	0
<input type="checkbox"/>	decel	
<input type="checkbox"/>	motor	false
<input checked="" type="checkbox"/>	pUsec	0
	state	"M5571191
<input type="checkbox"/>	stop	
	transition	"25436037
<input checked="" type="checkbox"/>	v	0
<input checked="" type="checkbox"/>	wakeUsec	500000

KIEM Execution

Logical time: 0

Physical time: 0 μ sec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

[+]

2:

Init

/ myWakeUsec = currentUsec + pSetSpeedsUsec; clk = true

1: currentUsec < myWakeUsec / clk = false

Pause

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] SimTime

/ currentUsec = pre(wakeUsec)

Pause

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input type="checkbox"/>	accel	
<input checked="" type="checkbox"/>	currentUsec	500000
<input type="checkbox"/>	decel	
<input type="checkbox"/>	motor	false
<input checked="" type="checkbox"/>	pUsec	0
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	0
<input checked="" type="checkbox"/>	wakeUsec	1000000

Logical time: 1

Physical time: 500,000 μ sec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Quick Access

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

[+] CtrlMotor

[+] SimTime

2:

Init

1: `currentUsec < myWakeUsec`
`clk = false`

Pause

`/ myWakeUsec = currentUsec + pSetSpeedsUsec;`
`clk = true`

`/ wakeUsec = myWakeUsec`

`/ currentUsec = pre(wakeUsec)`

Pause

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input type="checkbox"/>	accel	
<input checked="" type="checkbox"/>	currentUsec	1000000
<input type="checkbox"/>	decel	
<input type="checkbox"/>	motor	false
<input checked="" type="checkbox"/>	pUsec	0
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	0
<input checked="" type="checkbox"/>	wakeUsec	1500000

Logical time: 2

Physical time: 1,000,000 μ sec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Quick Access

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

clk & stop / pUsec = 0

Running

entry / v = 0

[+] CalcV

2: / pUsec = '(int) (1000000 * cmPerHalfPeriod / v)'

1: v == 0 / pUsec = 0

2: / v = -vMax

1: v >= -vMax

2: / v = vMax

1: v <= vMax

2: / v -= dV

1: v += dV

Decel

Accel

CheckMin

CheckMax

SetPeriod

Init

Pause

[+] CtrlMotor

[+] SimTime / currentUsec = pre(wakeUsec)

Pause

[+] GenClk

[+] 2:

1: currentUsec < myWakeUsec / clk = false

2: / myWakeUsec = currentUsec + pSetSpeedsUsec; clk = true

1: / wakeUsec = myWakeUsec

Init

Pause

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input type="checkbox"/>	accel	
<input checked="" type="checkbox"/>	currentUsec	1000000
<input type="checkbox"/>	decel	
<input type="checkbox"/>	motor	false
<input checked="" type="checkbox"/>	pUsec	0
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input checked="" type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	0
<input checked="" type="checkbox"/>	wakeUsec	1500000

Logical time: 2

Physical time: 1,000,000 μsec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Quick Access

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

clk & stop / pUsec = 0

Running

entry / v = 0

[+] CalcV

2: / pUsec = '(int) (1000000 * cmPerHalfPeriod / v)'

1: v == 0 / pUsec = 0

2: / v = -vMax

1: v >= -vMax

2: / v = vMax

1: v <= vMax

1: clk & decel & laccel / v -= dV

2: / v = -vMax

1: v >= -vMax

2: / v = vMax

1: v <= vMax

1: clk & accel & ldecel / v += dV

2: / v = vMax

1: v <= vMax

SetPeriod

Init

Pause

Decel

CheckMin

CheckMax

Accel

[+] GenClk

[+] CtrlMotor

[+] SimTime / currentUsec = pre(wakeUsec)

Pause

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input checked="" type="checkbox"/>	*accel	
<input checked="" type="checkbox"/>	currentUsec	1000000
<input type="checkbox"/>	decel	
<input type="checkbox"/>	motor	false
<input checked="" type="checkbox"/>	pUsec	0
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	0
<input checked="" type="checkbox"/>	wakeUsec	1500000

Logical time: 2

Physical time: 1,000,000 μsec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Quick Access

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

clk & stop / pUsec = 0

Running

entry / v = 0

[+] CalcV

2: / pUsec = '(int) (1000000 * cmPerHalfPeriod / v)'

1: v == 0 / pUsec = 0

2: / v = -vMax

1: v >= -vMax

2: / v = vMax

1: v <= vMax

1: clk & decel & laccel

/ v -= dV

CheckMin

SetPeriod

1: clk & accel & ldecel

/ v += dV

CheckMax

[+] CtrlMotor

[+] SimTime / currentUsec = pre(wakeUsec)

Pause

[+] GenCik

[+] 2:

/ myWakeUsec = currentUsec + pSetSpeedsUsec; clk = true

1: currentUsec < myWakeUsec / clk = false

/ wakeUsec = myWakeUsec

Pause

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input checked="" type="checkbox"/>	accel	
<input checked="" type="checkbox"/>	currentUsec	1500000
<input type="checkbox"/>	decel	
<input checked="" type="checkbox"/>	motor	true
<input checked="" type="checkbox"/>	pUsec	500000
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	2
<input checked="" type="checkbox"/>	wakeUsec	2000000

Logical time: 3

Physical time: 1,500,000 μ sec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

/ myWakeUsec = currentUsec + pSetSpeedsUsec; clk = true

1: currentUsec < myWakeUsec / clk = false

Pause

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

pUsec > 0 / myWakeUsec = currentUsec + pUsec; clk = true

1: pUsec > 0 & currentUsec < myWakeUsec / clk = false

Running

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input checked="" type="checkbox"/>	accel	
<input checked="" type="checkbox"/>	currentUsec	1500000
<input type="checkbox"/>	decel	
<input checked="" type="checkbox"/>	motor	true
<input checked="" type="checkbox"/>	pUsec	500000
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	2
<input checked="" type="checkbox"/>	wakeUsec	2000000

Logical time: 3

Physical time: 1,500,000 μ sec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

1: $currentUsec < myWakeUsec$
/ clk = false

Pause

/ myWakeUsec = currentUsec + pSetSpeedsUsec;
clk = true

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

1: $pUsec > 0 \ \& \ currentUsec < myWakeUsec$
/ clk = false

Running

$pUsec > 0$ / myWakeUsec = currentUsec + pUsec; clk = true

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

Synchronous Signal

motor

entUsec

stop

akeUsec

v

decel

accel

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

5

P	Key	Value
<input type="checkbox"/>	accel	
<input checked="" type="checkbox"/>	currentUsec	2000000
<input type="checkbox"/>	decel	
<input type="checkbox"/>	motor	false
<input checked="" type="checkbox"/>	pUsec	500000
	state	"M5571191
<input type="checkbox"/>	stop	
	transition	"45422814
<input checked="" type="checkbox"/>	v	2
<input checked="" type="checkbox"/>	wakeUsec	2500000

Logical time: 4

Physical time: 2,000,000 μ sec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

1: currentUsec < myWakeUsec / clk = false

Pause

/ myWakeUsec = currentUsec + pSetSpeedsUsec; clk = true

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

1: pUsec > 0 & currentUsec < myWakeUsec / clk = false

Running

pUsec > 0 / myWakeUsec = currentUsec + pUsec; clk = true

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

Data Table

P	Key	Value
<input type="checkbox"/>	accel	
<input checked="" type="checkbox"/>	currentUsec	2500000
<input type="checkbox"/>	decel	
<input checked="" type="checkbox"/>	motor	true
<input checked="" type="checkbox"/>	pUsec	500000
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	stop transition	"45422814
<input checked="" type="checkbox"/>	v	2
<input checked="" type="checkbox"/>	wakeUsec	3000000

KIEM Execution

Logical time: 5

Physical time: 2,500,000 μ sec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Quick Access

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

1: $currentUsec < myWakeUsec$
/ clk = false

Pause

/ myWakeUsec = currentUsec + pSetSpeedsUsec;
clk = true

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

1: $pUsec > 0 \ \& \ currentUsec < myWakeUsec$
/ clk = false

Running

$pUsec > 0$ / myWakeUsec = currentUsec + pUsec; clk = true

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input checked="" type="checkbox"/>	*accel	
<input checked="" type="checkbox"/>	currentUsec	2500000
<input type="checkbox"/>	decel	
<input checked="" type="checkbox"/>	motor	true
<input checked="" type="checkbox"/>	pUsec	500000
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	2
<input checked="" type="checkbox"/>	wakeUsec	3000000

Logical time: 5

Physical time: 2,500,000 μ sec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

1: currentUsec < myWakeUsec / clk = false

Pause

/ myWakeUsec = currentUsec + pSetSpeedsUsec; clk = true

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

1: pUsec > 0 & currentUsec < myWakeUsec / clk = false

Running

pUsec > 0 / myWakeUsec = currentUsec + pUsec; clk = true

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input checked="" type="checkbox"/>	accel	
<input checked="" type="checkbox"/>	currentUsec	3000000
<input type="checkbox"/>	decel	
<input type="checkbox"/>	motor	false
<input checked="" type="checkbox"/>	pUsec	250000
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	4
<input checked="" type="checkbox"/>	wakeUsec	3250000

Logical time: 6

Physical time: 3,000,000 μsec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Quick Access

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

/ myWakeUsec = currentUsec + pSetSpeedsUsec; clk = true

1: currentUsec < myWakeUsec / clk = false

Pause

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

pUsec > 0 / myWakeUsec = currentUsec + pUsec; clk = true

1: pUsec > 0 & currentUsec < myWakeUsec / clk = false

Running

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input type="checkbox"/>	accel	
<input checked="" type="checkbox"/>	currentUsec	3250000
<input type="checkbox"/>	decel	
<input checked="" type="checkbox"/>	motor	true
<input checked="" type="checkbox"/>	pUsec	250000
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	4
<input checked="" type="checkbox"/>	wakeUsec	3500000

Logical time: 7

Physical time: 3,250,000 μ sec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

1: currentUsec < myWakeUsec / clk = false

Pause

/ myWakeUsec = currentUsec + pSetSpeedsUsec; clk = true

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

1: pUsec > 0 & currentUsec < myWakeUsec / clk = false

Running

pUsec > 0 / myWakeUsec = currentUsec + pUsec; clk = true

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input type="checkbox"/>	accel	
<input checked="" type="checkbox"/>	currentUsec	3500000
<input type="checkbox"/>	decel	
<input type="checkbox"/>	motor	false
<input checked="" type="checkbox"/>	pUsec	250000
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	stop transition	"45422814
<input checked="" type="checkbox"/>	v	4
<input checked="" type="checkbox"/>	wakeUsec	3750000

Logical time: 8

Physical time: 3,500,000 μ sec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

1: currentUsec < myWakeUsec / clk = false

Pause

/ myWakeUsec = currentUsec + pSetSpeedsUsec; clk = true

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

1: pUsec > 0 & currentUsec < myWakeUsec / clk = false

Running

pUsec > 0 / myWakeUsec = currentUsec + pUsec; clk = true

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input checked="" type="checkbox"/>	*accel	
<input checked="" type="checkbox"/>	currentUsec	3500000
<input type="checkbox"/>	decel	
<input type="checkbox"/>	motor	false
<input checked="" type="checkbox"/>	pUsec	250000
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	4
<input checked="" type="checkbox"/>	wakeUsec	3750000

Logical time: 8

Physical time: 3,500,000 μsec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Quick Access

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

/ myWakeUsec = currentUsec + pSetSpeedsUsec; clk = true

1: currentUsec < myWakeUsec / clk = false

Pause

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

pUsec > 0 / myWakeUsec = currentUsec + pUsec; clk = true

1: pUsec > 0 & currentUsec < myWakeUsec / clk = false

Running

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

[+] SimTime

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input checked="" type="checkbox"/>	*accel	
<input checked="" type="checkbox"/>	currentUsec	3750000
<input type="checkbox"/>	decel	
<input checked="" type="checkbox"/>	motor	true
<input checked="" type="checkbox"/>	pUsec	250000
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	4
<input checked="" type="checkbox"/>	wakeUsec	4000000

Logical time: 9

Physical time: 3,750,000 μsec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

1: $currentUsec < myWakeUsec$
/ clk = false

Pause

/ myWakeUsec = currentUsec + pSetSpeedsUsec;
clk = true

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

1: $pUsec > 0 \ \& \ currentUsec < myWakeUsec$
/ clk = false

Running

$pUsec > 0$ /
myWakeUsec = currentUsec + pUsec;
clk = true

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input checked="" type="checkbox"/>	*accel	
<input checked="" type="checkbox"/>	currentUsec	4000000
<input type="checkbox"/>	decel	
<input type="checkbox"/>	motor	false
<input checked="" type="checkbox"/>	pUsec	166666
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	6
<input checked="" type="checkbox"/>	wakeUsec	4166666

Logical time: 10

Physical time: 4,000,000 μ sec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Quick Access

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

/ myWakeUsec = currentUsec + pSetSpeedsUsec; clk = true

1: currentUsec < myWakeUsec / clk = false

Pause

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

pUsec > 0 / myWakeUsec = currentUsec + pUsec; clk = true

1: pUsec > 0 & currentUsec < myWakeUsec / clk = false

Running

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input checked="" type="checkbox"/>	*accel	
<input checked="" type="checkbox"/>	currentUsec	4166666
<input type="checkbox"/>	decel	
<input checked="" type="checkbox"/>	motor	true
<input checked="" type="checkbox"/>	pUsec	166666
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	stop transition	"45422814
<input checked="" type="checkbox"/>	v	6
<input checked="" type="checkbox"/>	wakeUsec	4333332

Logical time: 11

Physical time: 4,166,666 μsec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Quick Access

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

/ myWakeUsec = currentUsec + pSetSpeedsUsec; clk = true

1: currentUsec < myWakeUsec / clk = false

Pause

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

pUsec > 0 / myWakeUsec = currentUsec + pUsec; clk = true

1: pUsec > 0 & currentUsec < myWakeUsec / clk = false

Running

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

13

P	Key	Value
<input checked="" type="checkbox"/>	*accel	
<input checked="" type="checkbox"/>	currentUsec	4333332
<input type="checkbox"/>	decel	
<input type="checkbox"/>	motor	false
<input checked="" type="checkbox"/>	pUsec	166666
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	6
<input checked="" type="checkbox"/>	wakeUsec	4499998

Logical time: 12

Physical time: 4,333,332 μ sec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Quick Access

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

1: currentUsec < myWakeUsec / clk = false

Pause

/ myWakeUsec = currentUsec + pSetSpeedsUsec; clk = true

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

1: pUsec > 0 & currentUsec < myWakeUsec / clk = false

Running

pUsec > 0 / myWakeUsec = currentUsec + pUsec; clk = true

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
	*accel	
<input checked="" type="checkbox"/>	currentUsec	4499998
<input type="checkbox"/>	decel	
<input checked="" type="checkbox"/>	motor	true
<input checked="" type="checkbox"/>	pUsec	166666
	state	"M5571191
<input type="checkbox"/>	stop	
	transition	"45422814
<input checked="" type="checkbox"/>	v	6
<input checked="" type="checkbox"/>	wakeUsec	4500000

Logical time: 13

Physical time: 4,499,998 μ sec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Quick Access

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

1: $currentUsec < myWakeUsec$
/ clk = false

Pause

/ myWakeUsec = currentUsec + pSetSpeedsUsec;
clk = true

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

1: $pUsec > 0 \ \& \ currentUsec < myWakeUsec$
/ clk = false

Running

$pUsec > 0$ / myWakeUsec = currentUsec + pUsec; clk = true

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

[+] SimTime

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

15

P	Key	Value
<input type="checkbox"/>	*accel	
<input checked="" type="checkbox"/>	currentUsec	4500000
<input type="checkbox"/>	decel	
<input checked="" type="checkbox"/>	motor	true
<input checked="" type="checkbox"/>	pUsec	166666
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	6
<input checked="" type="checkbox"/>	wakeUsec	4666664

Logical time: 14

Physical time: 4,500,000 μ sec

kieler-workspace - SCCharts Simulation - shared/sccharts-rvh/motor.sct - KIELER

Quick Access

Diagram

MOTOR

[+] SetSpeeds

[+] ProcessInputs

[+] GenClk

2:

Init

1: currentUsec < myWakeUsec / clk = false

Pause

/ myWakeUsec = currentUsec + pSetSpeedsUsec; clk = true

/ wakeUsec = myWakeUsec

[+] CtrlMotor

[+] GenClk

2:

Stopped

1: pUsec > 0 & currentUsec < myWakeUsec / clk = false

Running

pUsec > 0 / myWakeUsec = currentUsec + pUsec; clk = true

/ wakeUsec min = myWakeUsec

[+] Motor

Low

High

clk / motor = false

clk / motor = true

Synchronous Signal

motor

currentUsec

stop

wakeUsec

v

decel

accel

KIEM Execution

Data Table

P	Key	Value
<input type="checkbox"/>	*accel	
<input checked="" type="checkbox"/>	currentUsec	4666664
<input type="checkbox"/>	decel	
<input type="checkbox"/>	motor	false
<input checked="" type="checkbox"/>	pUsec	166666
<input type="checkbox"/>	state	"M5571191
<input type="checkbox"/>	stop	
<input type="checkbox"/>	transition	"45422814
<input checked="" type="checkbox"/>	v	6
<input checked="" type="checkbox"/>	wakeUsec	4833330

Logical time: 15

Physical time: 4,666,664 μ sec

Wrap-Up

- Dynamic ticks seamlessly integrate physical time with logical time
- Existing synchronous languages (Esterel, SCCharts) already provide all necessary features

Future work

- Timing analysis
- Multiclocking
- Language extensions

Thanks!