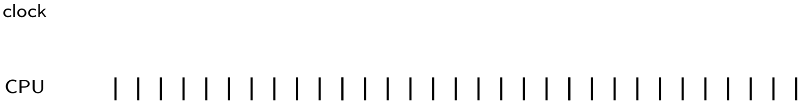
CS:5810 Formal Methods in Software Engineering

Reactive Systems and the Lustre Language[1]
Part 2

Adrien Champion   Cesare Tinelli

Design of **reactive** systems:

- run in an infinite loop, and
- produce an output every *n* milliseconds



Lustre: a synchronous dataflow language

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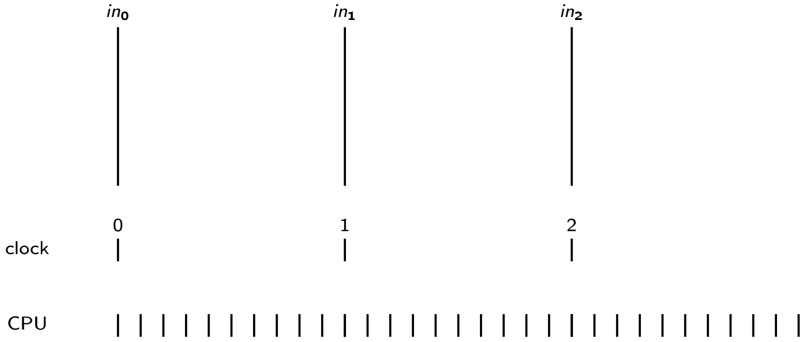

Lustre: a synchronous dataflow language

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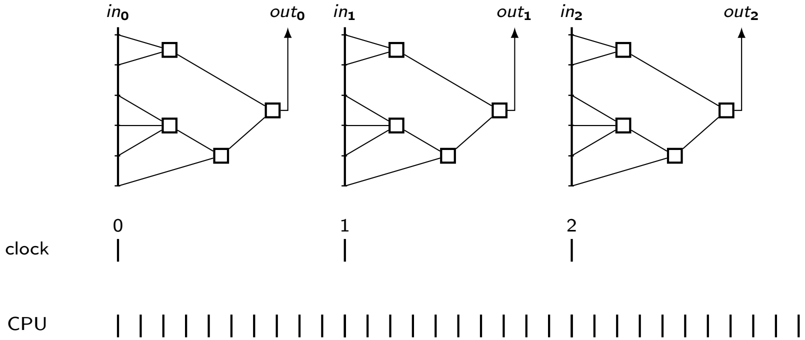

Exercises

Model a switch with two buttons, Set and Reset.

```
node Switch( Set, Reset, Init : bool ) returns (
    State : bool );
```

such that:

- pressing `Set` turns the switch on;
- pressing `Reset` turns the switch off;
- the initial position of the switch is determined by a third signal `Init` if `Set` and `Reset` are initially both unpressed.

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```
node Switch( Set, Reset, Init : bool )
returns ( X : bool );
let
    X =      if Set then true
        else if Reset then false
        else (Init -> pre X);
tel
```

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Equivalently:

```
node Switch( Set, Reset, Init : bool )
returns ( X : bool );
let
   X = Set or (not Reset and (Init -> pre X)) ;
tel
```

Exercises

```
node ??? (r,b: bool) returns (out: int);
let

   out =       if r then 0
          else if b then (0 -> pre out) + 1
          else           (0 -> pre out);
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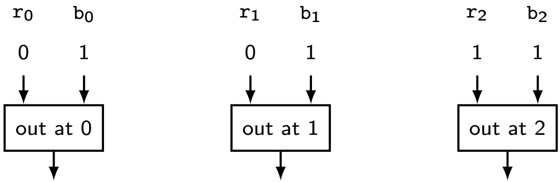

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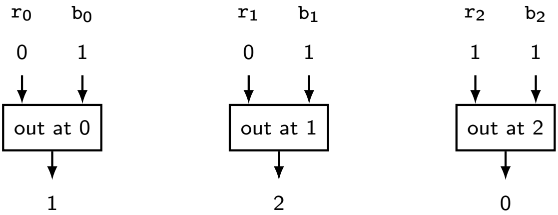

Exercises

Counter with reset:

```
node ??? (r,b: bool) returns (out: int);
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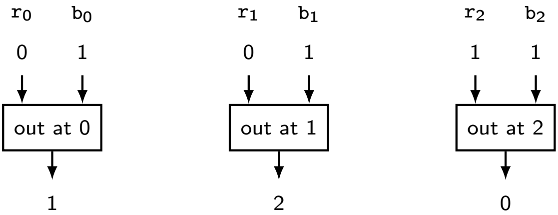
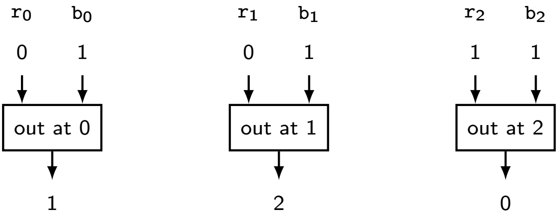


Exercises

Counter with reset:

```
node cnt (r,b: bool) returns (out: int);
var pre_out: int;
let pre_out = 0 -> pre out;
    out =        if r then 0
            else if b then pre_out + 1
            else           pre_out;
tel
```



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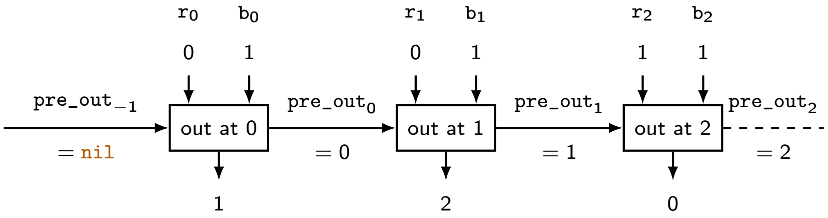

Modularity

Once defined, a node can be used as a basic operator

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What does `A` look like?

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X = true -> (pre A = 3)
A = cnt(X, true);
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X = true -> (pre A = 3)
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```

$A = 0,\ 1,\ 2,\ 3,\ 0,\ 1\ ,2,\ 3,\ 0,\ 1\dots$

Modularity

A node can have several outputs:

```
node MinMax( X : real ) returns ( Min, Max : real );
let
  Min = X -> if (X < pre Min) then X else pre Min ;
  Max = X -> if (X > pre Max) then X else pre Max ;
tel

node minMaxAverage ( X: real ) returns ( Y: real ) ;
var Min, Max: real ;
let
  Min, Max = MinMax(X) ;
  Y = (Min + Max)/2.0 ;
tel
```

Complete example: specification

Stopwatch:

- one integer output: `time` “to display”;
- three input buttons:

`on_off`	starts and stops the stopwatch,
`reset`	resets the stopwatch **if not running**,
`freeze`	freezes the displayed time **if running**, cancelled if stopped

Complete example: available nodes

```
-- Bistable switch
node switch (on, off: bool) returns (state: bool);
let
  state =
    if (false -> pre state) then not off else on;
tel

-- Counts steps if inc is true, can be reset
node counter (reset,inc: bool) returns (out: int);
let
  out =       if reset then 0
        else if  inc  then (0 -> pre_out) + 1
        else               (0 -> pre_out);
tel

-- Detects raising edges of a signal
node edge (in: bool) returns (out: bool);
let
  out = false -> in and (not pre in);
tel
```

Complete example: solution(s)

Unsatisfactory solution not using edge:

```
node stopwatch (on_off, reset, freeze: bool)
returns (time: int);
var actual_time: int;
    running, frozen: bool;

let




  running = switch(on_off, on_off);
  frozen = switch(
    freeze and running, freeze or on_off
  );
  actual_time = counter(reset and not running, running);
  time = if frozen then (0 -> pre time) else actual_time;
tel
```

Complete example: solution(s)

Satisfactory solution:

```
node stopwatch (on_off, reset, freeze: bool)
returns (time: int);
var actual_time: int;
    running, frozen,
    on_off_pressed, r_pressed, f_pressed: bool;
let
  on_off_pressed = edge(on_off);
  r_pressed  = edge(reset);
  f_pressed = edge(freeze);
  running = switch(on_off_pressed, on_off_pressed);
  frozen = switch(
    f_pressed and running, f_pressed or on_off_pressed
  );
  actual_time = counter(r_pressed and not running, running);
  time = if frozen then (0 -> pre time) else actual_time;
tel
```

Credits

Part of these notes are based on the following lectures notes:

The Lustre Language — Synchronous Programming
by Pascal Raymond and Nicolas Halbwachs
Verimag-CNRS