Assignment 3

Question 1. Complete the following table giving values of expressions in column 1 for the first 5 cycles. The values of integer flows for the first 5 cycles are given in rows, labelled P and Q.

Expression\Cycle	0	1	2	3	4	...
P	2	7	5	1	3	...
Q	0	13	6	5	2	...
pre(P)						
Q+1						
P -> Q						
P -> (pre(Q)+1)						
P fby Q						

Question 2. Consider the following **Lustre** nodes

```
node foo(P: int) returns (Q, R: int)
var W, Y, Z: int;
let
    Q  =  W* Z;
    W = 0 -> (pre(Z) +1);
     Z = W + Y;
    Y =  sqr(W);
    R = Q + W;
tel

node sqr(A :int) returns (B: int)
let
    B = A*A;
tel
```

Is this program causally correct? What is the order in which values of variables Q,R,W,Y,Z are calculated in each cycle?

Question 3.

(a) Define a **Lustre** node returning the following sequence of values. **(Code required)**
1, 4, 13, 40, 121, ...
(**Hint**: Consider how the difference of two successive terms grows.)
Note: In lustre, zero input nodes are not allowed. If your node is properly simulated in heptagon you can submit it. But keep the extension as **.lus (Update Feb 12, 19.09 PM)**

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(b) Complete the definition of following **Lustre** node **(Code required)**

```
node gen(req:bool) returns (ack: bool)
...
```

such that ack is true in the current cycle if and only if req has been true for the last 3 cycles (including the current cycle).
(Hint: First count for how many previous cycles req has been true continuously.)

Question 4.
(a) Please describe in English the output produced by the following **Heptagon** node.

```
node t(x: bool^5) returns (y: bool);
let
    y = fold<<5>>(or)(x, false)
tel
```

(b) What happens if you change the equation to **`y = fold<<5>>(or)(x, true)`**?
Describe the output.

(c) Complete the definition of the following **Heptagon** node with parameter **n**.
(Code required)

```
node mutex<<n>>(ack: bool^n) returns (ok: bool)
...
```

The node should check for mutual exclusion of ack[i] and ack[j]. That is **ok is true provided expression ack[i] and ack[j] is false for all i, j pairs with i not= j.**

Question 5. Study the following **Heptagon** code for ripple adder.

```
node mxor(x, y: bool) returns (c: bool)
let
    c = (x and not y) or ((not x) and y);
tel

node fa(x, y, cin: bool) returns (z, cout: bool)
let
    z = mxor(mxor(cin, x), y);
    cout = if cin then (x or y) else (x and y);
tel

node rippleadd<<n:int>>(a: bool^n; b: bool^n) returns (c: bool^n;
over: bool)
let
    (c,over) = mapfold<<n>>fa(a, b, false);
tel
```

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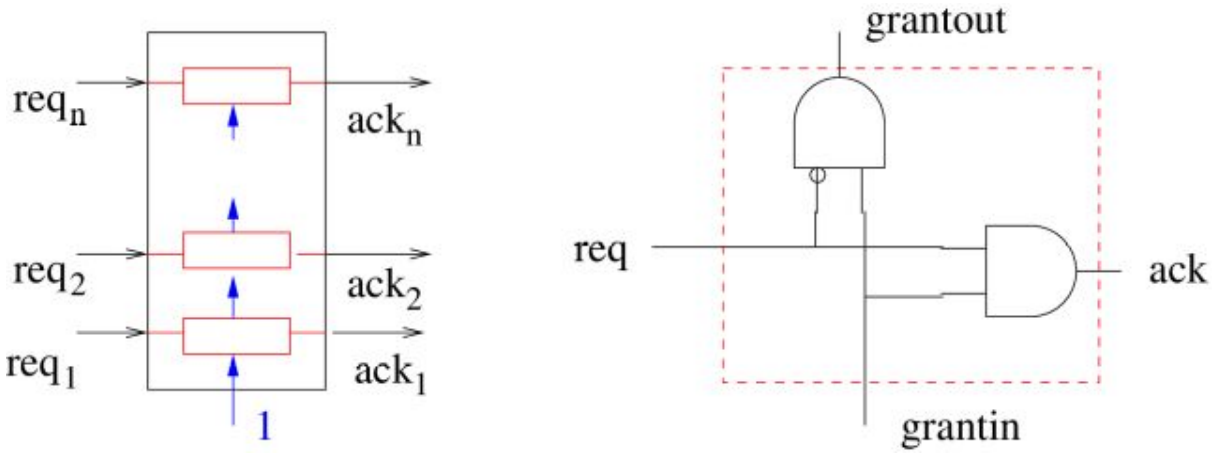
A sample code file with the above code simulating a 4-bit adder is given: Download File.

(a) Manually compute the output at 0th cycle of rippleadd for constants a=[0,1,1,0,1,1,1,0] and b=[1,1,0,1,0,1,1,1] given as input to rippleadd<<8>>(a,b).

(b) Using this node rippleadd, define a node **counter** which counts in binary modulo 64. (It should **output unsigned 8 bit binary numbers corresponding to the decimal numbers** 0, 1, 2, ..., 63, 0, 1, 2,.... in successive cycles). **(Code required)**

Question 6. (Synchronous Bus Arbiter) An arbiter arbitrates between multiple requests coming at each cycle and gives acknowledgement to at most one of them. Consider the arbiter circuit below. **(Code required)**



Each **red box** (denoting a cell) in the left hand side figure is expanded to the **cell** circuit given in the right hand side figure.

Using **Heptagon**, model each cell as a
`node cell(req, grantin: bool) returns (ack, grantout: bool)`

Model a 5 cell arbiter as an assembly of 5 cells as shown in the figure. Call this
`node arbiter(req:bool^5) returns (ack:bool^5)`

(**Hint**: See the implementation of rippleadd given in the previous question. Extra credit will be given if you can program this as an **n cell arbiter** with **parameter n**.)

Define a suitable **display node** to show the output. Simulate the arbiter using the tool **Heptagon** and check its functioning. Submit a screenshot of sample output using the sim2chro display.

Which of the following properties does this arbiter have?

- **(a)** Mutual exclusion of ack[i], ack[j] for i not= j.
- **(b)** No spurious ack, i.e. ack[i] => req[i]

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(c) No lost cycles, i.e. in any cycle, if there is at least 1 true request, the arbiter should have at least one true ack.

Question 7. A monitor node for a property S takes as input a set of flows to observe (e.g. p, q: bool). It outputs a single boolean flow ok. The idea is that at every clock cycle, ok is true if the property S holds for the past sequence of inputs (including the current cycle). For example:
Property S: “p is continuously true in the past” has the monitor node

```
node smonitor(p: bool) returns (ok: bool)
let
    ok = p -> (pre(ok) and p);
tel
```

Answer the following

(a) Give the output of the above **smonitor** node for the input flow
p = true true true false true false true true

(b) Give a monitor for the following property: *“p is continuously true in the past AND q has occured at least once in the past.”* **(Code required)**

(c) Give a monitor node for the following property: Assume that a, b, c are boolean flows. *“Everytime **a** occurs, **c** will remain continuously true from then on until a **b** occurs”.* Specify additional assumptions that you make in your design (E.g. what happens if a and b occur simultaneously). **(Code required)**

(d) Give a monitor node for the following property: Assume that req and ack are boolean flows. “If req has been true for the last 3 cycles (including the current cycle) then ack must be true in the current cycle.” **(Code required)**
Clarification: req and **ack** are both **input boolean flows. ok** is the **output flow. ok is true if the property is observed/followed. (Update Feb 12, 18.00 PM)**