Verification of Digital Systems, Spring 2018

J. A. Abraham

Homework No. 4

Assigned: 03/09/19 Due: 03/25/19

Total Points: *200*

1. [**Symbolic Model Checking**] Answer the following questions based on this module definition:

```
module fair_arbiter(

input clk,
input rst_n,
input req0,
input req1,
output reg grant0,
output reg grant1
);
always @(posedge clk or negedge rst_n)
if (!rst_n)
begin
grant0 <= 0;
grant1 <= 1;
end
else
begin
grant0 <= req0 && ((!req1) || ((!grant0) && grant1));
grant1 <= req1 && ((!req0) || ((!grant1) && grant0));
end
assert property(!(grant0 && grant1));
endmodule
```

   (a) (**15 Points**) Describe some safety properties of this arbiter?

   (b) (**15 Points**) Describe some liveness properties of this arbiter?

   (c) (**40 Points**) Will the assert property mentioned in the code be satisfied? Use symbolic model checking to formally prove your answer.

2. [**Term Rewriting**] Consider the set of terms as (2NOR(), A, B, C, a, b, $\neg$, $\vee$, $\wedge$)

   (a) (**10 Points**) Write a set of rules for a 2-input NOR.

   (b) (**20 Points**) Apply the above rules to rewrite a 3-input NAND: $(\neg(A \wedge B \wedge C))$ using only 2NOR().

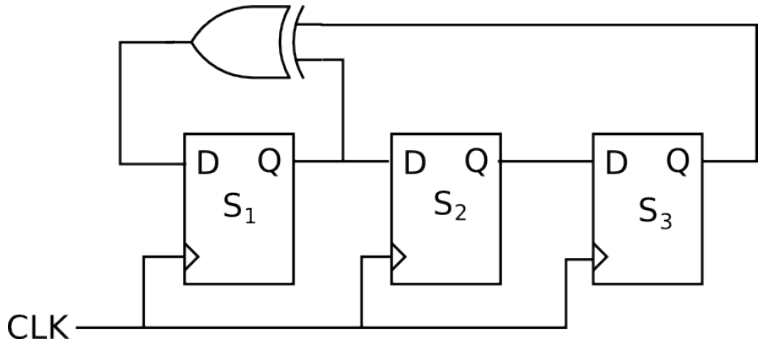
3. [**Data Representation**] (**10 Points**) We have n pigeons and m holes where (m=n-1). Each pigeon must be placed in a hole and no two pigeons must be placed in the same hole. Write the safety and liveness property of this trivial problem and represent both of them as a CNF (no other formats will be accepted.). Also state why SAT solvers would find it difficult to find a satisfying interpretation for this problem.
   (Use $P_{a,b}$ to represent putting pigeon a in hole b.)

4. **[Data Representation]** (**15 Points**) Write the CNF formulating representing the *one-hot* condition on the bits of the vector

$$X_1, X_2, X_3, X_4, X_5$$

5. **[Representing State Machines]** Consider the Pseudo-Random Sequence generator circuit below with current state $V = \langle S_1, S_2, S_3 \rangle$ and next state $V' = \langle S'_1, S'_2, S'_3 \rangle$.
Assume that the initial state of PN sequence generator is

$$I(V) = \langle S_1 = 1, S_2 = 0, S_3 = 0 \rangle$$



(a) (**15 Points**) Write the equations for the transition function for $S'_1, S'_2 \text{and} S'_3$

(b) (**10 Points**) Write the equation for the Transition Relation, $\widetilde{T}(V, V')$ (you may use the $\iff$ function).

(c) (**40 Points**) Which state of the Pseudo-Random Sequence Generator is not reachable. Prove your answer using symbolic model checking.

(d) (**10 Points**) What happens if the circuit is in the unreachable state? Write a SystemVerilog Assertion for checking this condition.