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e.g. CSEIndian Institute of Technology Kanpur
CS637 Embedded and Cyber-Physical Systems

Homework Assignment 2

Deadline: September 2, 2022

Total: 40 marks

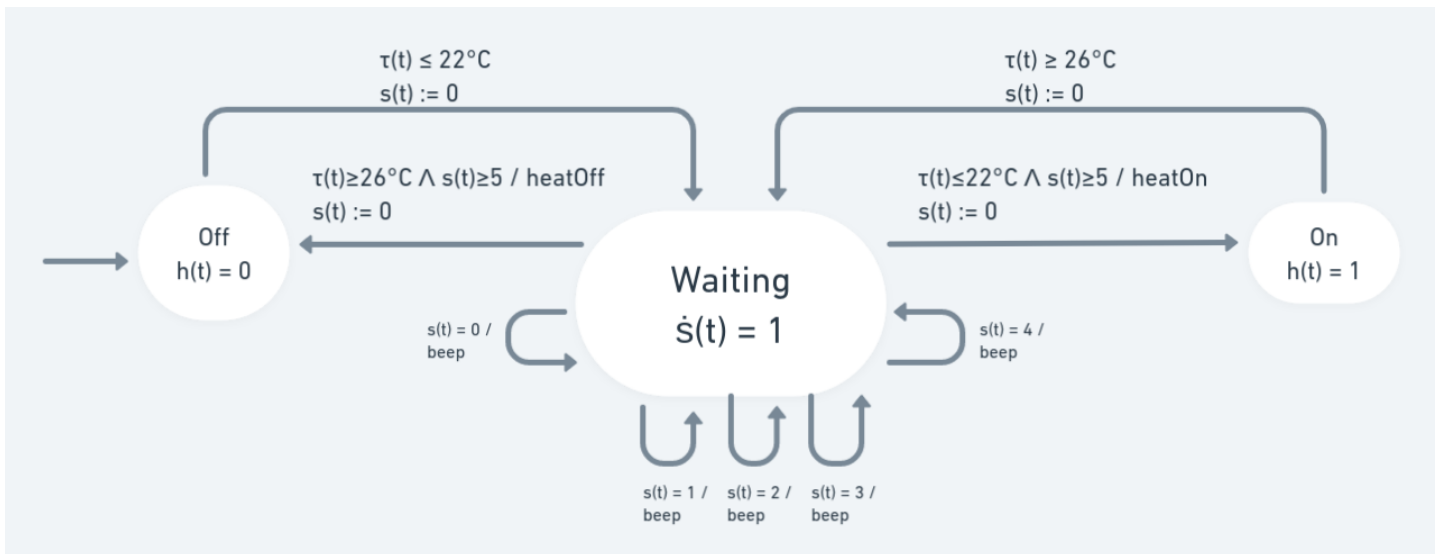
1. Write the answers **neatly** in the given boxes.
2. You may discuss the solutions with the other students, but you have to write them in your own words.

Problem 1. (10 points) Construct a timed automaton model of a thermostat where the heater will be switched on when the room temperature is less than 22°C and switched off when the temperature is above 26 Celsius. We also have the following additional requirement. Before switching on or off, it will generate a “beep” sound every second for 5 seconds as a warning. That means once the system senses that the temperature is less than 22°C, it will generate the warning first, and then the heater will be switched on. Similarly, a warning sound will be issued before switching off the heater after the temperature reaches 26°C.

Continuous Variable : $s(t) : \mathbb{R}; h(t) : \mathbb{R}$

Inputs : $\tau(t) : \mathbb{R}$

Outputs : heatOff, heatOn : *pure*



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Problem 2. (10 points) Consider the following protocol that ensures mutual exclusion among N processes using real-time clocks and a shared variable `lock`.

Initially `lock` is 0.

Every process follows the following process:

```

loop
  wait until lock = 0;
  wait for a delay <= 2;
  set lock to process id;
  wait for a delay >= 3;
  if lock = process id
    enter critical section;
  go back to the wait state
end

```

Draw a timed automaton to capture the behavior of a process that follows the protocol.

The timed automata consists of Asynchronous side-by-side actor models with n number of blocks. The higher level model consist of a shared variable **lock** which can take integer values and is initialised with 0 at start.

Inside each subsystem actor models, the following variables are used :

Continuous Variable : $s(t) : \mathbb{R}$

Inputs : $processid : Int; processed : pure$

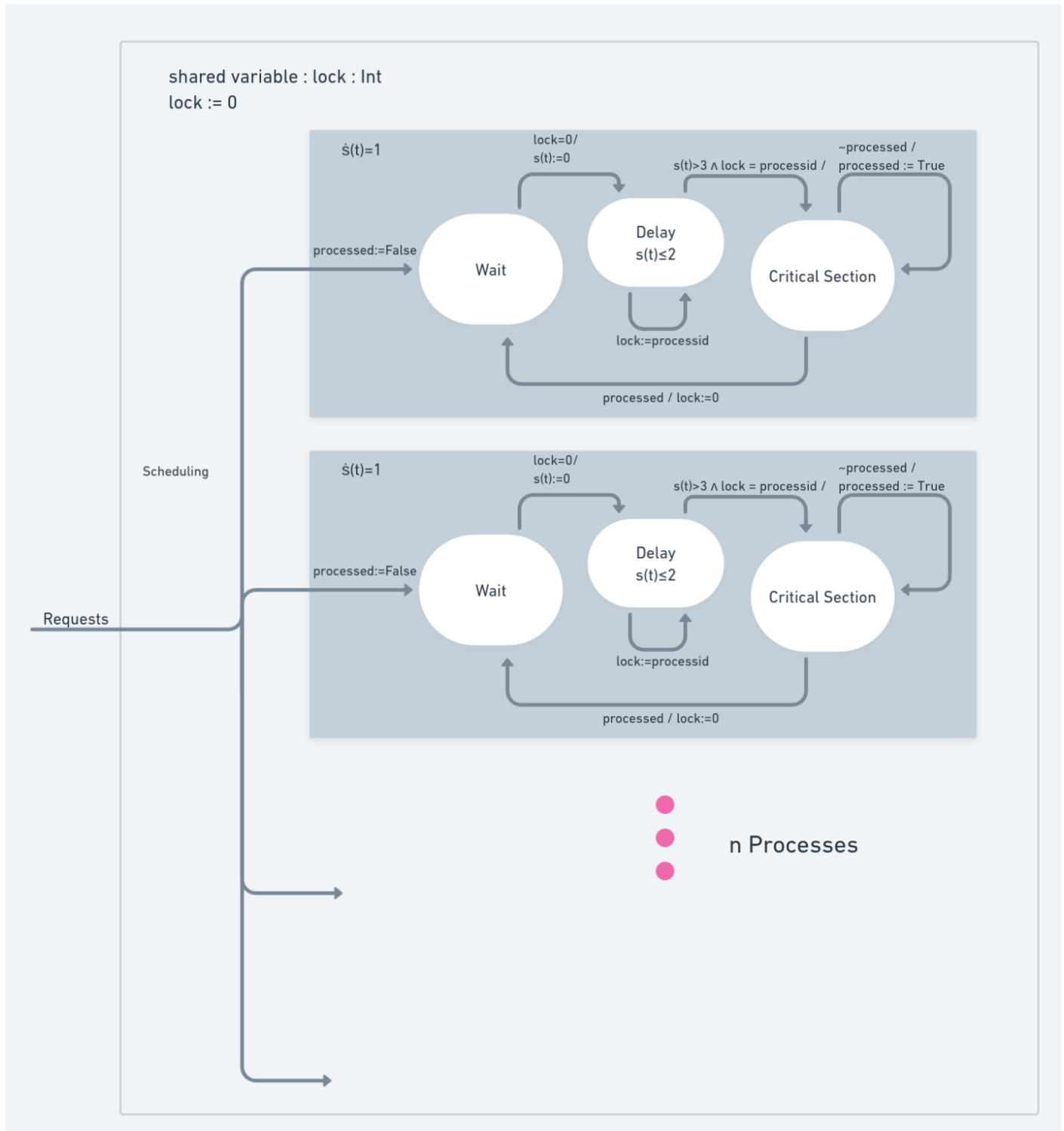
Outputs : none

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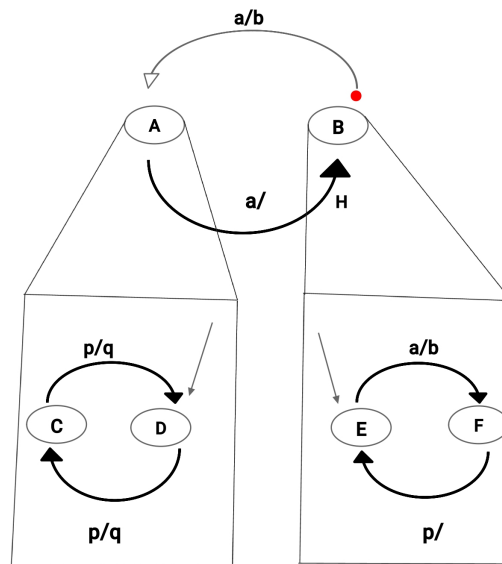
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Problem 3. (10 points) Construct an equivalent flat FSM giving the semantics of the hierarchy. Describe in words the input/output behavior of this machine.



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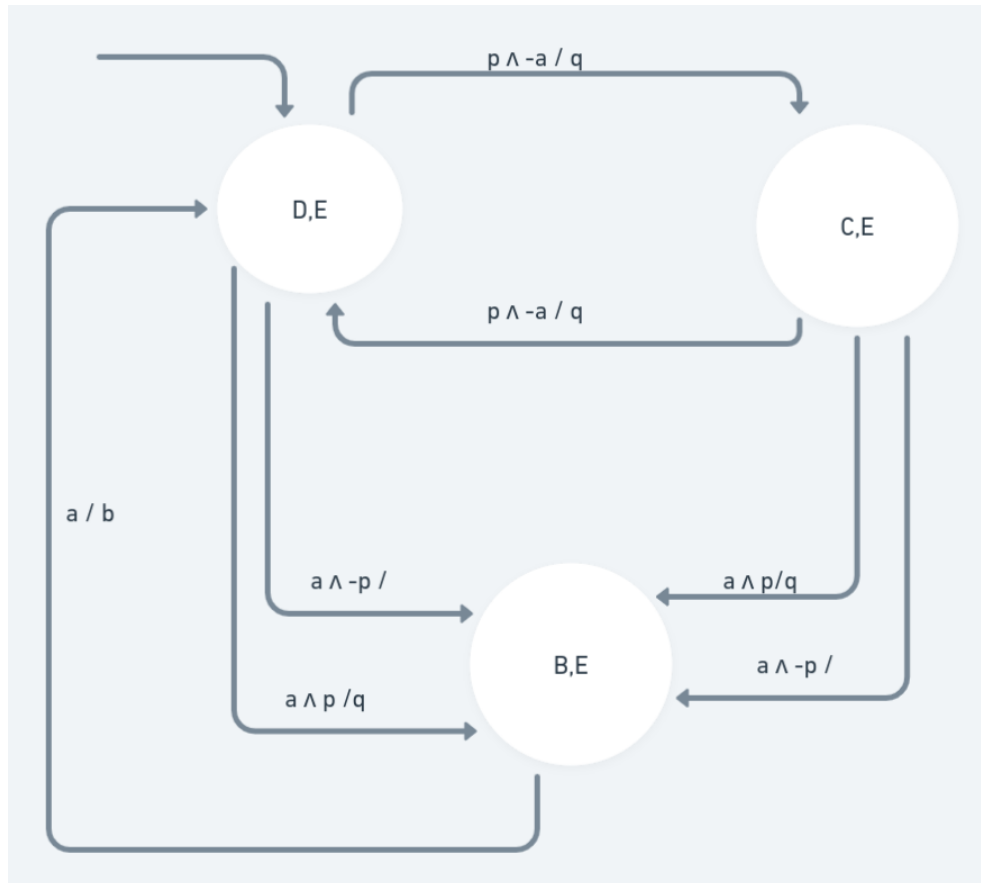
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Inputs : a, q : *pure***Outputs :** b, q : *pure*

The Flattened FSM is shown below :



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We have assumed that the initial state of the FSM is D in A.

When the input is a and not p, the state transitions from D to (B,E) and no output is produced.

If the input is a and p then the state transitions again from D to (B,E) and q as the output is produced.

When the input is p and not a, the state transitions from D to C and q as the output is produced.

With the same input from state C, we can go back to state D, and q as the output is produced.

From state C, with input as a and not p, the state transitions to (B,E) and no output is produced.

If input is a and p, then same transition happens and output q is produced.

From (B,E), with a as input transition happens to state D, with output b.

State (B,F) is not reachable in this hierarchical FSM, due to the preemptive transition which happens from (B,E) on the input of a.

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Deadline: September 2, 2022**Problem 4.** (10 points) Problem 8 in the Exercises of Chapter 6 in [LS15].[LS15] Edward A. Lee and Sanjit A. Seshia, Introduction to Embedded Systems, A Cyber-Physical Systems Approach, Second Edition, <http://LeeSeshia.org>, ISBN 978-1-312-42740-2, 2015.

(a) The balance equations are:

$$q_A = 3q_B$$

$$2q_B = 3q_C$$

Equating both the equations, we get:

$$\frac{q_A}{9} = \frac{q_B}{3} = \frac{q_C}{2} = k$$

So, the minimum positive integer solutions are:

$$q_A = 9; q_B = 3; q_C = 2$$

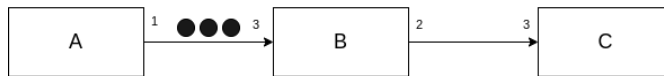
(b) Scheduling Sequence for minimum buffer size is:

$$A, A, A, B, A, A, A, B, C, A, A, A, B, C$$

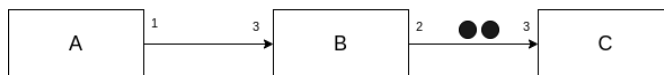
Maximum buffer memory in the above scheduling sequence will be 4.

Actor A will first fire three tokens, which will be put in the buffer between A and B. Actor B will then fire a single token, consume the tokens shot by A, then shoot two tokens, which will be stored in the buffer between B and C. Again, A will fire three tokens and store them in the buffer, and then B will fire, consume the tokens of A, and store a total of four B tokens. Therefore, the maximum buffer memory between A and B is 3, while between B and C it is 4.

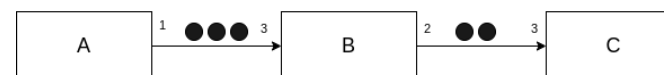
For the Firings A,A,A :



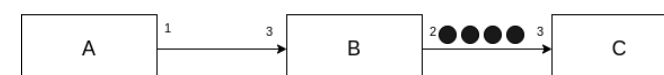
After A,A,A,B :



After A,A,A,B,A,A,A :



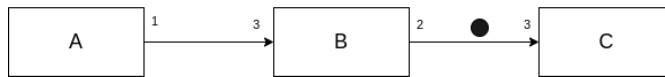
After A,A,A,B,A,A,A,B :



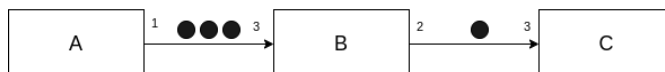
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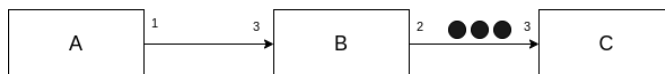
After A,A,A,B,A,A,A,B,C :



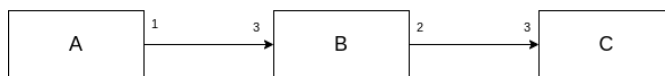
After A,A,A,B,A,A,A,B,C,A,A,A :



After A,A,A,B,A,A,A,B,C,A,A,A,B :



After A,A,A,B,A,A,A,B,C,A,A,A,B,C :



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