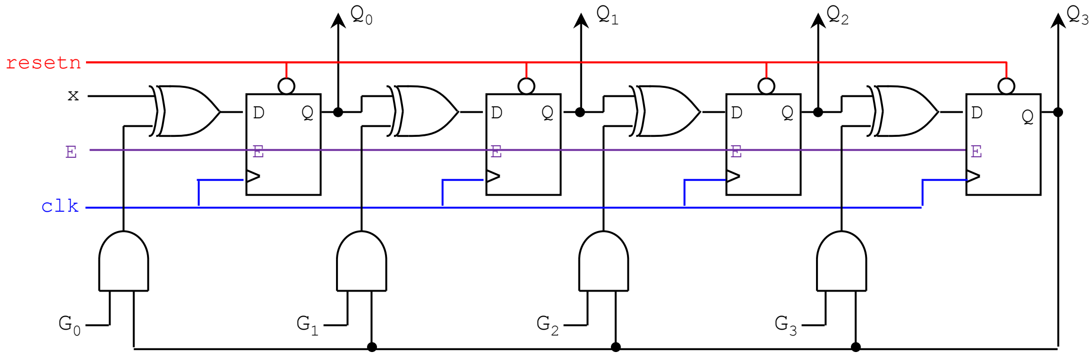
Solutions - Final Exam

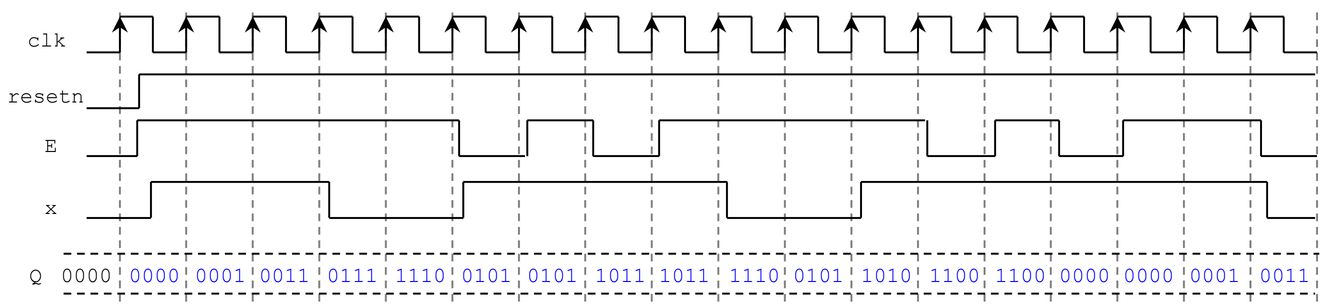
(December 12th @ 3:30 pm)

Presentation and clarity are very important! Show your procedure!

PROBLEM 1 (12 PTS)

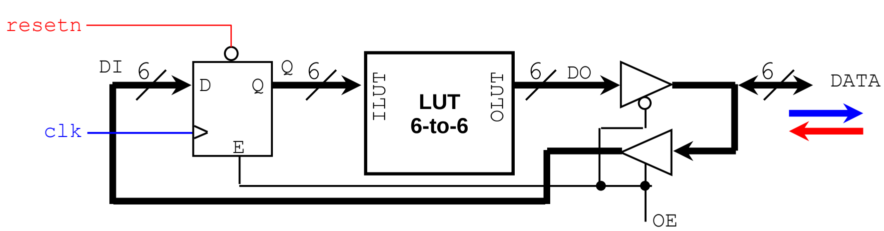
- Complete the timing diagram of the following circuit. $G = G_3G_2G_1G_0 = 1001$, $Q = Q_3Q_2Q_1Q_0$



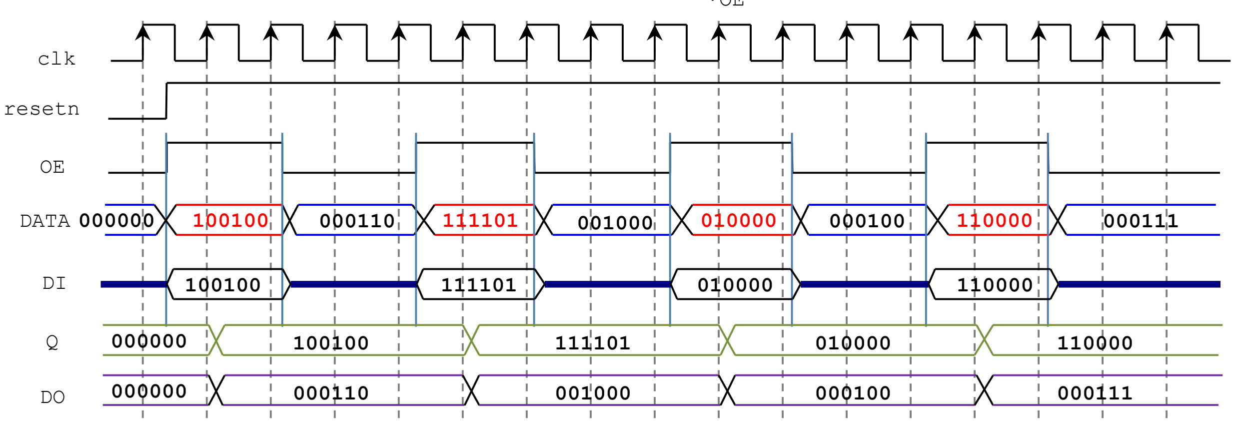


PROBLEM 2 (12 PTS)

- Given the following circuit, complete the timing diagram.
  The LUT 6-to-6 implements the following function: $OLUT = \lceil sqrt(ILUT) \rceil$, where $ILUT$ is a 6-bit unsigned number.
  For example $ILUT = 41\ (101001_2) \rightarrow OLUT = \lceil sqrt(41) \rceil = 7\ (000111_2)$

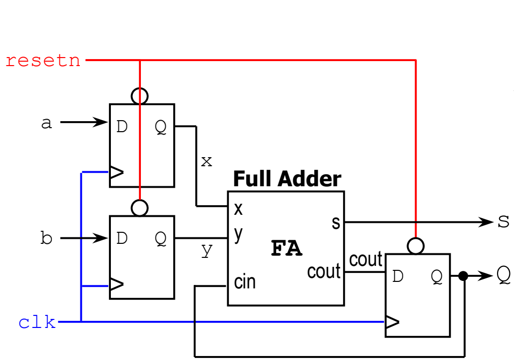


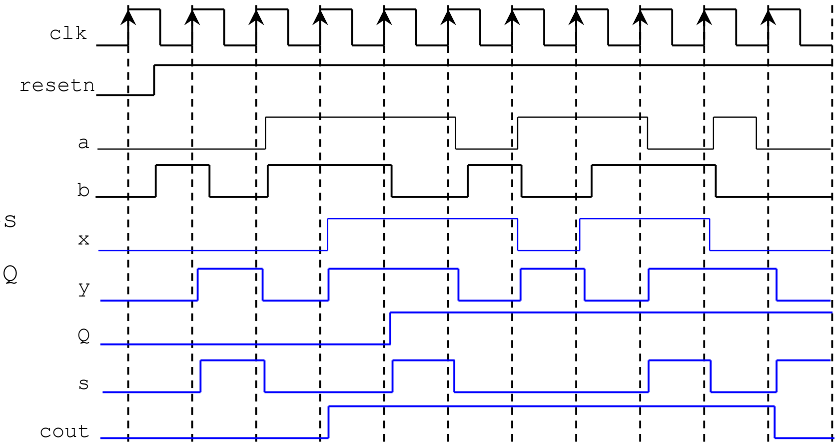
ceil(sqrt(36)) = 6
ceil(sqrt(61)) = 8
ceil(sqrt(16)) = 4
ceil(sqrt(48)) = 7



PROBLEM 3 (20 PTS)

- Complete the timing diagram of the circuit shown below: (8 pts)

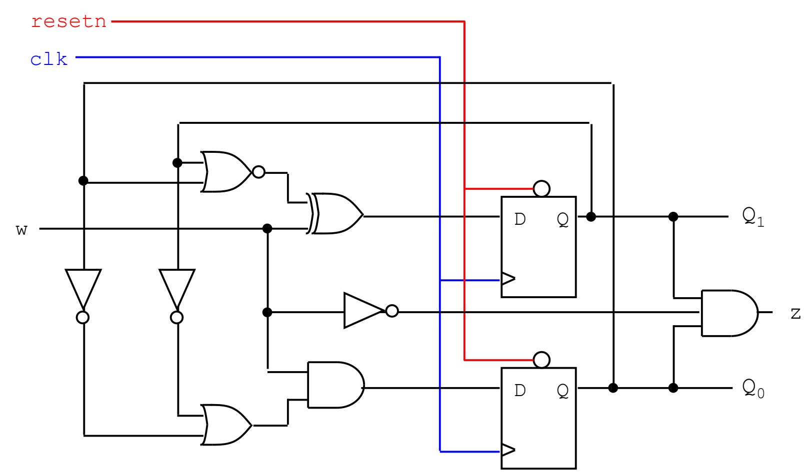




- Provide the State Diagram (any representation), the Excitation Table, and the Excitation equations of the following Finite State Machine: (12 pts)

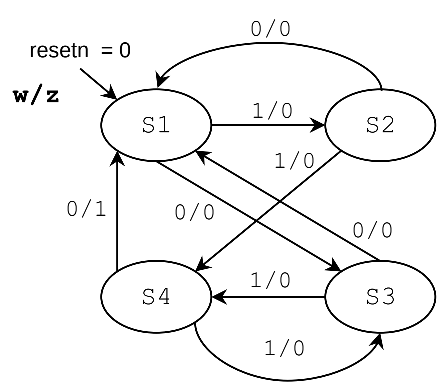
$Q_1(t+1) \leftarrow \overline{(Q_1+Q_0)\oplus w}$
$Q_0(t+1) \leftarrow \overline{Q_1 Q_0}w$
$z = \overline{w}Q_1Q_0$

State Assignment:
S1: Q=00 S2: Q=01
S3: Q=10 S4: Q=11



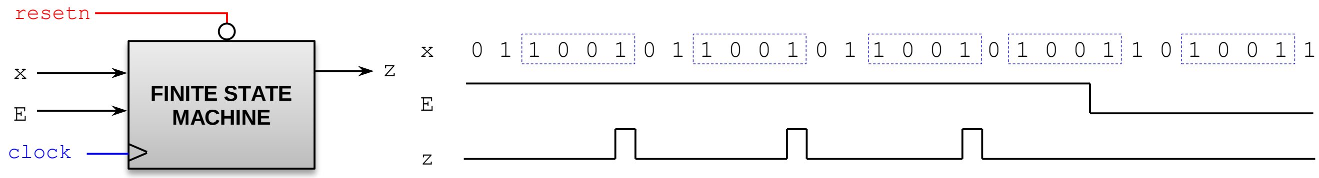
PRESENT STATE			NEXTSTATE		
w	Q_1	Q_0 (t)	Q_1	Q_0 (t+1)	z
0	0	0	1	0	0
0	0	1	0	0	0
0	1	0	0	0	0
0	1	1	0	0	1
1	0	0	0	1	0
1	0	1	1	1	0
1	1	0	1	1	0
1	1	1	1	0	0

w	PRESENT STATE	NEXT STATE	z
0	S1	S3	0
0	S2	S1	0
0	S3	S1	0
0	S4	S1	1
1	S1	S2	0
1	S2	S4	0
1	S3	S4	0
1	S4	S3	0



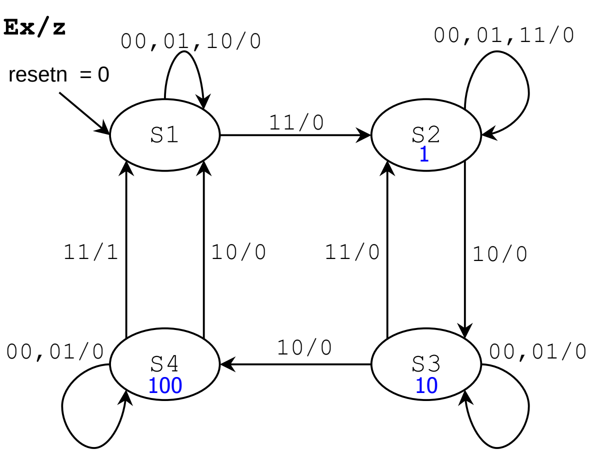
PROBLEM 4 (24 PTS)

- Sequence detector: The machine generates $z = 1$ when it detects the sequence 1001. Once the sequence is detected, the circuit looks for a new sequence.
- The signal E is an input enable: It validates the input x, i.e., if $E = 1$, x is valid, otherwise x is not valid.



- Draw the State Diagram (any representation) of this circuit with inputs E and x and output z. (7 pts.)
- Complete the State Table and the Excitation Table (8 pts.)
- Provide the excitation equations and the Boolean output equation (simplify your circuit: K-maps or the Quine-McCluskey)
- Sketch the circuit. (3 pts)
- Which type is this FSM? (Mealy) (Moore) Why? ______________________

- *State Diagram, State Table, and Excitation Table*:



E	x	PRESENT STATE	NEXT STATE	z
0	0	S1	S1	0
0	0	S2	S2	0
0	0	S3	S3	0
0	0	S4	S4	0
0	1	S1	S1	0
0	1	S2	S2	0
0	1	S3	S3	0
0	1	S4	S4	0
1	0	S1	S1	0
1	0	S2	S3	0
1	0	S3	S4	0
1	0	S4	S1	0
1	1	S1	S2	0
1	1	S2	S2	0
1	1	S3	S2	0
1	1	S4	S1	1

PRESENT STATE				NEXTSTATE		
E	x	Q_1	Q_0 (t)	Q_1	Q_0 (t+1)	z
0	0	0	0	0	0	0
0	0	0	1	0	1	0
0	0	1	0	1	0	0
0	0	1	1	1	1	0
0	1	0	0	0	0	0
0	1	0	1	0	1	0
0	1	1	0	1	0	0
0	1	1	1	1	1	0
1	0	0	0	0	0	0
1	0	0	1	1	0	0
1	0	1	0	1	1	0
1	0	1	1	0	0	0
1	1	0	0	0	1	0
1	1	0	1	0	1	0
1	1	1	0	0	1	0
1	1	1	1	0	0	1

State Assignment:
S1: Q=00 S2: Q=01
S3: Q=10 S4: Q=11

This is a Mealy Machine. The output 'z' depends on the input as well as on the present state.

- *Excitation equations, minimization, and circuit implementation*:

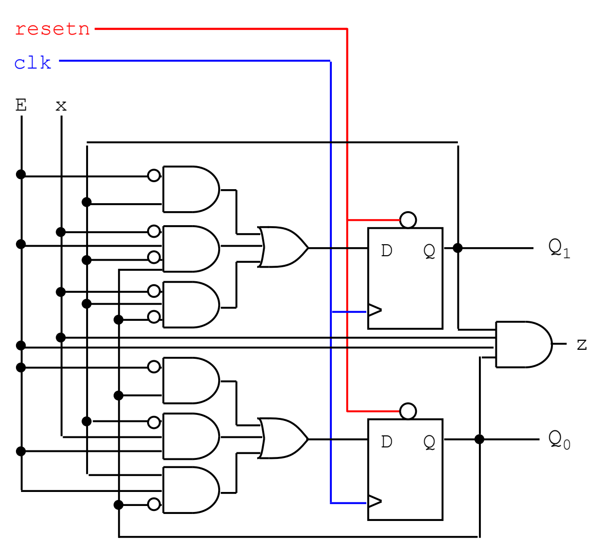
$Q_1(t+1) \leftarrow \bar{E}Q_1 + E\bar{x}\overline{Q_1}Q_0 + \bar{x}Q_1\overline{Q_0}$
$Q_0(t+1) \leftarrow \bar{E}Q_0 + Ex\overline{Q_1} + EQ_1\overline{Q_0}$
$z = ExQ_1Q_0$

$Q_1(t+1)$

Q_1Q_0 \ Ex	00	01	11	10
00	0	0	0	0
01	0	0	0	1
11	1	1	0	0
10	1	1	0	1

$Q_0(t+1)$

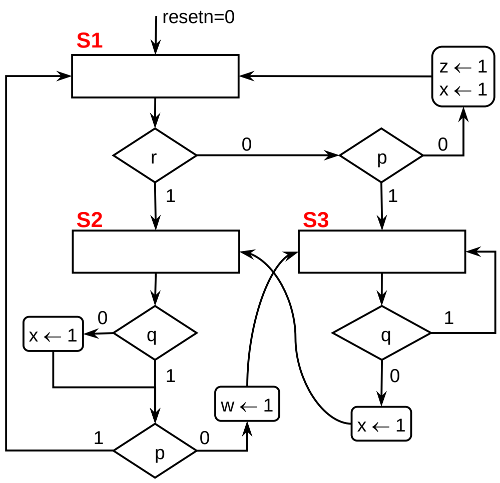
Q_1Q_0 \ Ex	00	01	11	10
00	0	0	1	0
01	1	1	1	0
11	1	1	0	0
10	0	0	1	1



PROBLEM 5 (14 PTS)

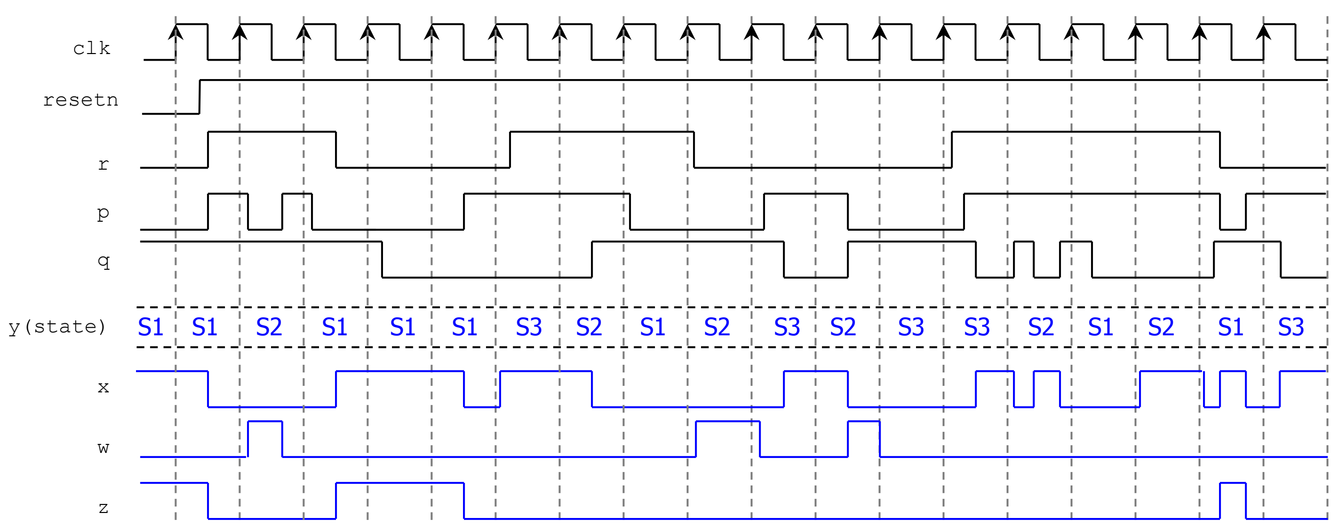
- Draw the State Diagram (in ASM form) of the FSM whose VHDL description in shown below. (6 pts.)
- Complete the Timing Diagram (7 pts.)
- Is it a Mealy or a Moore FSM?

```
library ieee;
use ieee.std_logic_1164.all;

entity myfsm is
   port ( clk, resetn: in std_logic;
          r, p, q: in std_logic;
          x, w, z: out std_logic);
end myfsm;
```




```
architecture behavioral of myfsm is
   type state is (S1, S2, S3);
   signal y: state;
begin
  Transitions: process (resetn, clk, r, p, q)
  begin
     if resetn = '0' then y <= S1;
     elsif (clk'event and clk = '1') then
        case y is
          when S1 =>
            if r = '1' then
               y <= S2;
            else
               if p = '1' then y <= S3; else y <= S1; end if;
            end if;

          when S2 =>
            if p = '1' then y <= S1; else y <= S3; end if;

          when S3 =>
            if q = '1' then y <= S3; else y <= S2; end if;

        end case;
     end if;
  end process;

  Outputs: process (y, r, p, q)
  begin
      x <= '0'; w <= '0'; z <= '0';
      case y is
         when S1 => if r = '0' then
                       if p = '0' then
                          z <= '1'; x <= '1';
                       end if;
                    end if;

         when S2 => if q = '0' then x <= '1'; end if;
                    if p = '0' then w <= '1'; end if;

         when S3 => if q = '0' then x <= '1'; end if;
      end case;
  end process;
end behavioral;
```

This is a Mealy Machine. The outputs 'x,w,z' depend on the input as well as on the present state.



PROBLEM 6 (18 PTS)

- "Counting 1's" Circuit: It counts the number of bits in register A that has the value of '1'.
  - ✓ Example: for $n = 8$: if $A = 10110110$, then $C = 0101$.
  - ✓ The digital system (FSM + Datapath) is depicted below. The behavior (on the clock tick) of the generic components is as follows:

m-bit counter (modulo-n+1): If E=0, the count stays.

```
if E = 1 then
   if sclr = 1 then
      Q ← 0
   else
      Q ← Q+1
  end if;
end if;
```

n-bit Parallel access shift register: If E=0, the output is kept.

```
if E = 1 then
   if s_l = '1' then
      Q ← D
   else
      Q ← shift in 'din'  (to the right)
  end if;
end if;
```

- Complete the timing diagram where $n = 8, m = 4$. A is represented in hexadecimal format, while C is in binary format.