Tutorial 6 – Sample Solution
Sequential Circuit

CO 2206 Computer Organization

Task 1

- A sequential circuit with two D flip-flops, A and B; two inputs x and y, and one output z, is described by the following input and output equations:
  - A(t+1) = x'y + xA
  - B(t+1) = x'B + xA
  - z = B

a. Is the design in Mealy or Moore model?

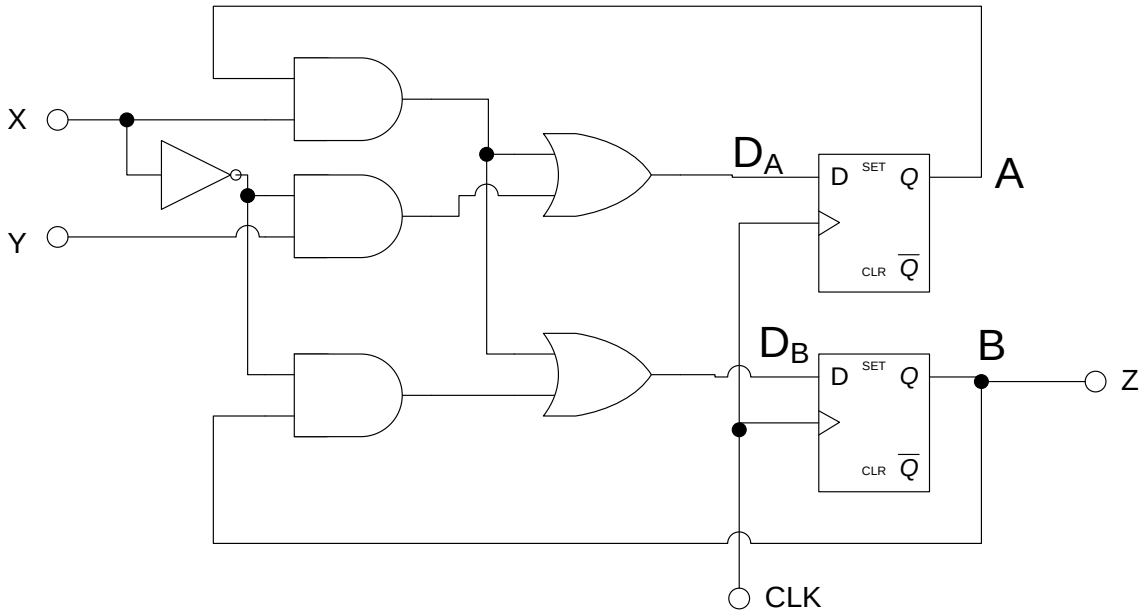
b. Draw the diagram for the circuit.

c. Derive the state table.

d. Derive the state diagram.

Task 1: Ans. a, b

- Moore model – output (z) depends only on state (B)
- Note DA = A(t+1) and DB = B(t+1)

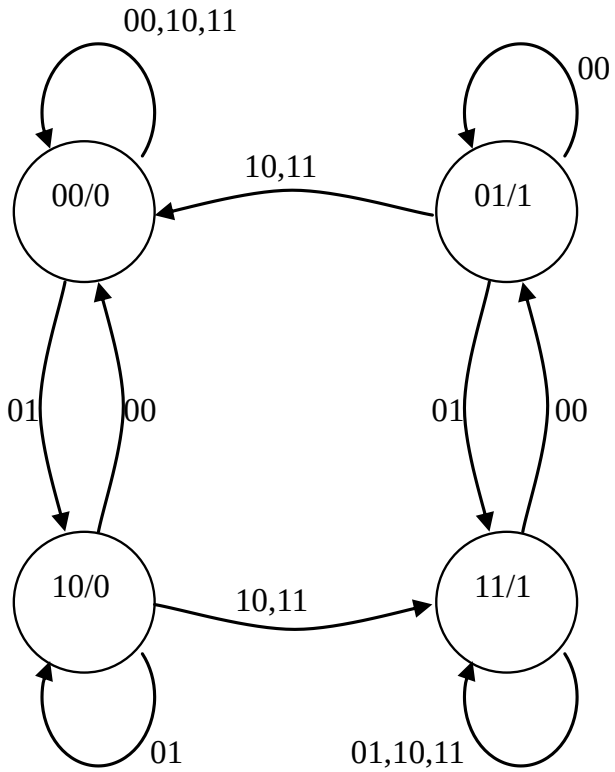


Task 1: Ans. c

Present State		Inputs		Next State		Output
A	B	X	Y	A(t+1)	B(t+1)	Z
0	0	0	0	0	0	0
0	0	0	1	1	0	0
0	0	1	0	0	0	0
0	0	1	1	0	0	0
0	1	0	0	0	1	1
0	1	0	1	1	1	1
0	1	1	0	0	0	1
0	1	1	1	0	0	1
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	1	1	0
1	1	0	0	0	1	1
1	1	0	1	1	1	1
1	1	1	0	1	1	1
1	1	1	1	1	1	1

Task 1: Ans. d

- Two state variables (A, B) hence 22 =4 states.



Task 2

- For the state table shown in next slide:
  a. Can the circuit be designed with Moore model? Why?
  b. Extend the table for design using JK flip-flops.
  c. Derive the flip-flop input equations and output equation.
  d. Draw the circuit diagram for the above design.

Task 2 (State Table)

Present State		Inputs		Next State		Output
A	B	X	Y	A(t+1)	B(t+1)	Z
0	0	0	0	0	0	0
0	0	0	1	0	1	0
0	0	1	0	1	0	1
0	0	1	1	1	1	1
0	1	0	0	0	1	1
0	1	0	1	1	0	1
0	1	1	0	1	0	0
0	1	1	1	0	0	0
1	0	0	0	1	1	1
1	0	0	1	1	1	0
1	0	1	0	1	1	1
1	0	1	1	1	0	0
1	1	0	0	0	0	0
1	1	0	1	0	0	1
1	1	1	0	0	0	0
1	1	1	1	0	1	1

Task 2: Ans. a, b

- No. The output (z) depends on both state and inputs, e.g. in state 00, the output can either be 0 (when inputs are 00 or 01) or 1 (when inputs are 10 or 11).
- In each row, look at changes in A & B from present to next state. Determine the required values for JA, KA, JB and KB to give the change, by referring to excitation table of JK flip-flop.

Task 2: Ans. b

Present State		Inputs		Next State		Output	FF Inputs			
A	B	X	Y	DA	DB	Z	JA	KA	JB	KB
0	0	0	0	0	0	0	0	x	0	x
0	0	0	1	0	1	0	0	x	1	x
0	0	1	0	1	0	1	1	x	0	x
0	0	1	1	1	1	1	1	x	1	x
0	1	0	0	0	1	1	0	x	x	0
0	1	0	1	1	0	1	1	x	x	1
0	1	1	0	1	0	0	1	x	x	1
0	1	1	1	0	0	0	0	x	x	1
1	0	0	0	1	1	1	x	0	1	x
1	0	0	1	1	1	0	x	0	1	x
1	0	1	0	1	1	1	x	0	1	x
1	0	1	1	1	0	0	x	0	0	x
1	1	0	0	0	0	0	x	1	x	1
1	1	0	1	0	0	1	x	1	x	1
1	1	1	0	0	0	0	x	1	x	1
1	1	1	1	0	1	1	x	1	x	0

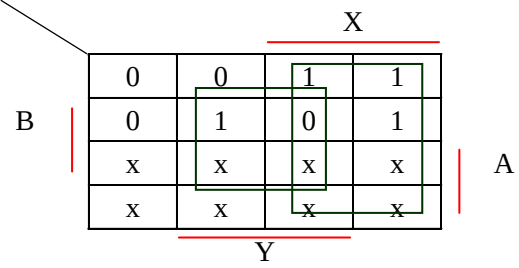
Excitation Table

Q(t)	Q(t + 1)	J	K	Operation
0	0	0	X	No change
0	1	1	X	Set
1	0	X	1	Reset
1	1	X	0	No Change

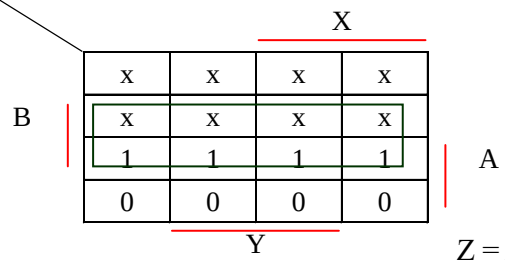
Task 2: Ans. c

- Five equations to determine: Z, JA, KA, JB, KB. Input variables are A, B, X and Y.

$J_A = BY \oplus X$

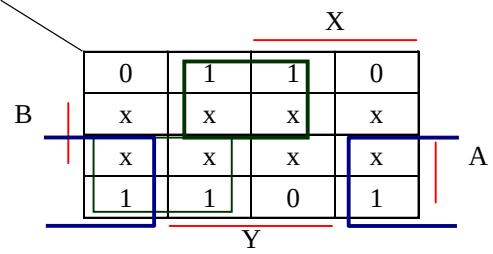


$K_A = B$

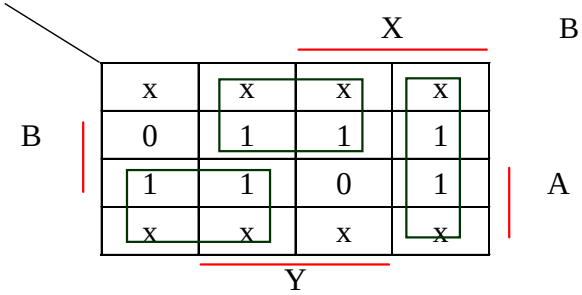


Alternative: $J_A = XY' + B'X + BX'Y$

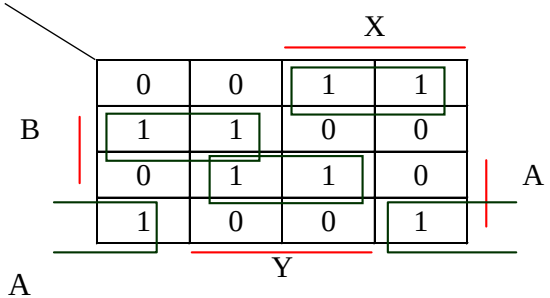
$J_B = YA' + A(X' + Y')$



$K_B = XY' + AX' + A'Y$



$Z = A'B'X + A'BX' + ABY + AB'Y'$



Task 2: Ans. d

- DIY. Take note of the common clock connection. The circuit will have two J/K flip-flops.

Task 3 & 4

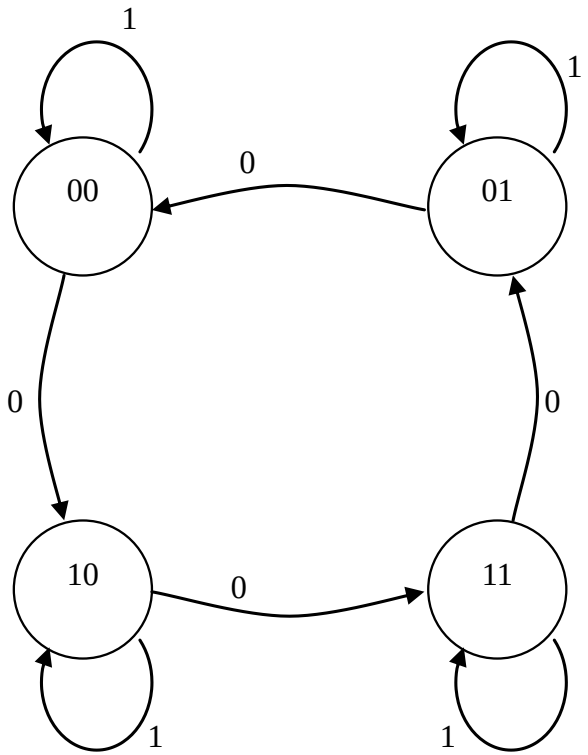
- **Task 3:** Design a sequential circuit with two D flip-flops A and B and one input X. When X = 1, the state of the circuit remains the same. When X = 0, the circuit goes through the state transitions from 00 to 10 to 11 to 01, back to 00, and then repeats.
- **Task 4:** Use 4-bit binary counter with synchronous parallel load (in block diagram) and logic gates to design the following counters:
  a. Modulo-3 that counts 0,1,2 repeatedly
  b. Modulo-6 that counts 2,3,4,5,6,7 repeatedly

Task 3: Ans. 1

- **Steps involved:**
  - Draw the state diagram based on requirements in the question
  - Draw the state table from the state diagram – define the necessary columns: A, B, X, DA, DB
  - Derive flip-flop input functions (DA, DB)
  - Draw the circuit diagram

Task 3: Ans. 2

- **State diagram:**



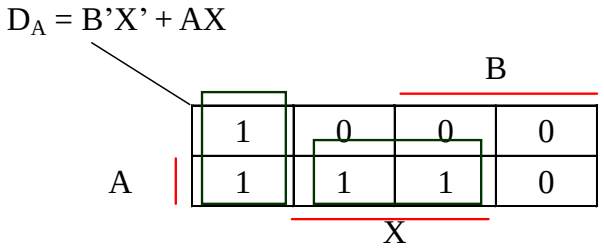
Task 3: Ans. 3

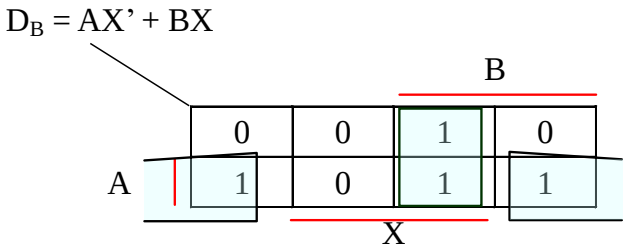
- **State table:**

Present State		Inputs	Next State	
A	B	X	DA	DB
0	0	0	1	0
0	0	1	0	0
0	1	0	0	0
0	1	1	0	1
1	0	0	1	1
1	0	1	1	0
1	1	0	0	1
1	1	1	1	1

Task 3: Ans. 4

- **Flip-flop input equations:**





- **Circuit diagram:** DIY. Take note of the common clock connection. There shall be 2 D flip-flops.