1. Consider the timing diagram in Figure 1(a). D and Clock are the inputs to the circuits in Figure 1(b). Draw the waveforms of the $Q_a$, $Q_b$, and $Q_c$. (15%)

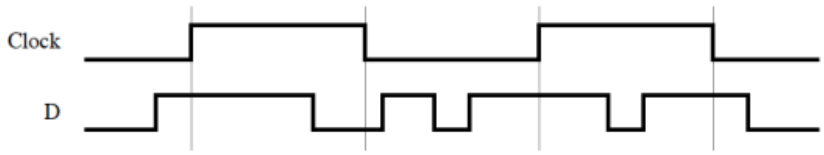



Figure 1(a)

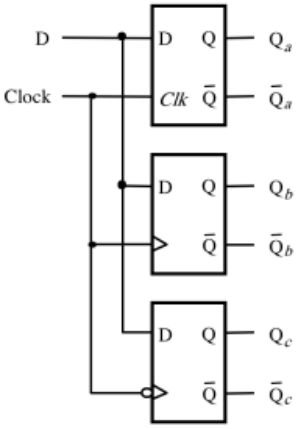
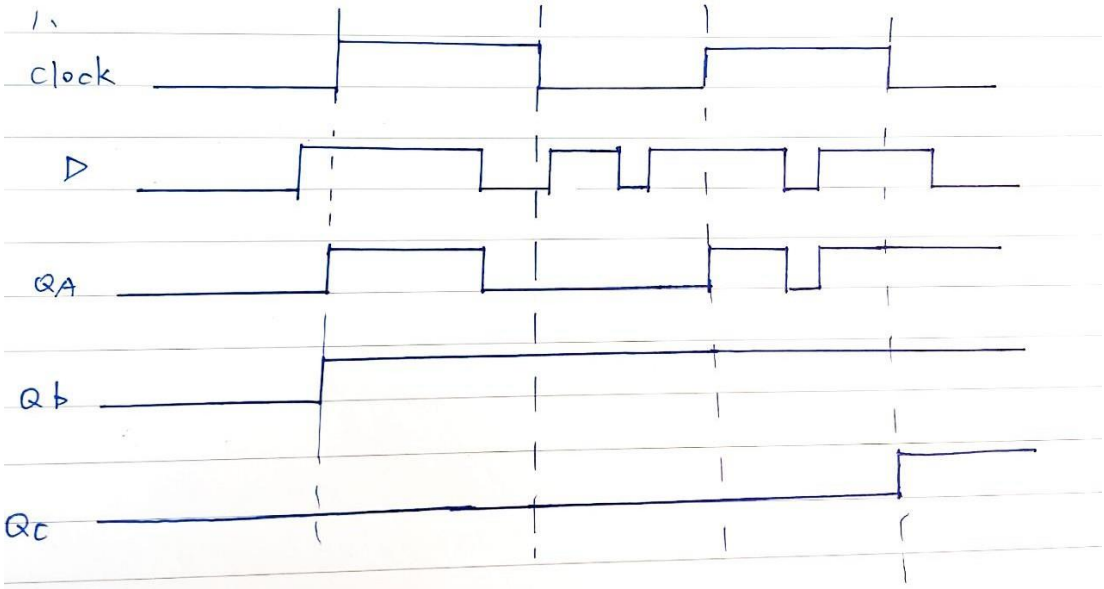
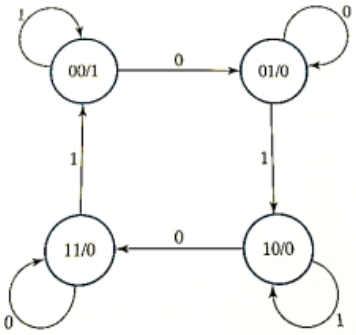



Figure 1(b)



2. A sequential circuit has two flip-flops A and B, one input x and one output z. The state diagram is shown in the following figure. Design the circuit with D flip-flops using one-hot state assignment. (15%)




Truth table

| | Y3 | Y2 | Y1 | Y0 | X | D3 | D2 | D1 | D0 | Z |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | x | x | x | x | x |
| 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 |
| 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 4 | 0 | 0 | 1 | 1 | 0 | x | x | x | x | x |
| 5 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 6 | 0 | 1 | 0 | 1 | 0 | x | x | x | x | x |
| 7 | 0 | 1 | 1 | 0 | 0 | x | x | x | x | x |
| 8 | 0 | 1 | 1 | 1 | 0 | x | x | x | x | x |
| 9 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 10 | 1 | 0 | 0 | 1 | 0 | x | x | x | x | x |
| 11 | 1 | 0 | 1 | 0 | 0 | x | x | x | x | x |
| 12 | 1 | 0 | 1 | 1 | 0 | x | x | x | x | x |
| 13 | 1 | 1 | 0 | 0 | 0 | x | x | x | x | x |
| 14 | 1 | 1 | 0 | 1 | 0 | x | x | x | x | x |
| 15 | 1 | 1 | 1 | 0 | 0 | x | x | x | x | x |
| 16 | 1 | 1 | 1 | 1 | 0 | x | x | x | x | x |
| 17 | 0 | 0 | 0 | 0 | 1 | x | x | x | x | x |
| 18 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 19 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 20 | 0 | 0 | 1 | 1 | 1 | x | x | x | x | x |
| 21 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 22 | 0 | 1 | 0 | 1 | 1 | x | x | x | x | x |
| 23 | 0 | 1 | 1 | 0 | 1 | x | x | x | x | x |
| 24 | 0 | 1 | 1 | 1 | 1 | x | x | x | x | x |
| 25 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 26 | 1 | 0 | 0 | 1 | 1 | x | x | x | x | x |
| 27 | 1 | 0 | 1 | 0 | 1 | x | x | x | x | x |
| 28 | 1 | 0 | 1 | 1 | 1 | x | x | x | x | x |
| 29 | 1 | 1 | 0 | 0 | 1 | x | x | x | x | x |
| 30 | 1 | 1 | 0 | 1 | 1 | x | x | x | x | x |
| 31 | 1 | 1 | 1 | 0 | 1 | x | x | x | x | x |
| 32 | 1 | 1 | 1 | 1 | 1 | x | x | x | x | x |

KMAP

D0,x=0

| Y3Y2 \ Y1Y0 | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | x | 0 | x | 0 |
| 01 | 0 | x | x | x |
| 11 | x | x | x | x |
| 10 | 0 | x | x | x |

D0,x=1

| Y3Y2 \ Y1Y0 | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | x | 1 | x | 0 |
| 01 | 0 | x | x | x |
| 11 | x | x | x | x |
| 10 | 1 | x | x | x |

D1,x=0

| Y3Y2 \ Y1Y0 | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | x | 1 | x | 1 |
| 01 | 0 | x | x | x |
| 11 | x | x | x | x |
| 10 | 0 | x | x | x |

D1,x=1

| Y3Y2 \ Y1Y0 | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | x | 0 | x | 0 |
| 01 | 0 | x | x | x |
| 11 | x | x | x | x |
| 10 | 0 | x | x | x |

D2,x=0

| Y3Y2 \ Y1Y0 | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | x | 0 | x | 0 |
| 01 | 0 | x | x | x |
| 11 | x | x | x | x |
| 10 | 0 | x | x | x |

D2,x=1

| Y3Y2 \ Y1Y0 | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | x | 0 | x | 1 |
| 01 | 1 | x | x | x |
| 11 | x | x | x | x |
| 10 | 0 | x | x | x |

D3,x=0

| Y3Y2 \ Y1Y0 | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | x | 0 | x | 0 |
| 01 | 1 | x | x | x |
| 11 | x | x | x | x |
| 10 | 1 | x | x | x |

D3,x=1

| Y3Y2 \ Y1Y0 | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | x | 0 | x | 0 |
| 01 | 0 | x | x | x |
| 11 | x | x | x | x |
| 10 | 0 | x | x | x |

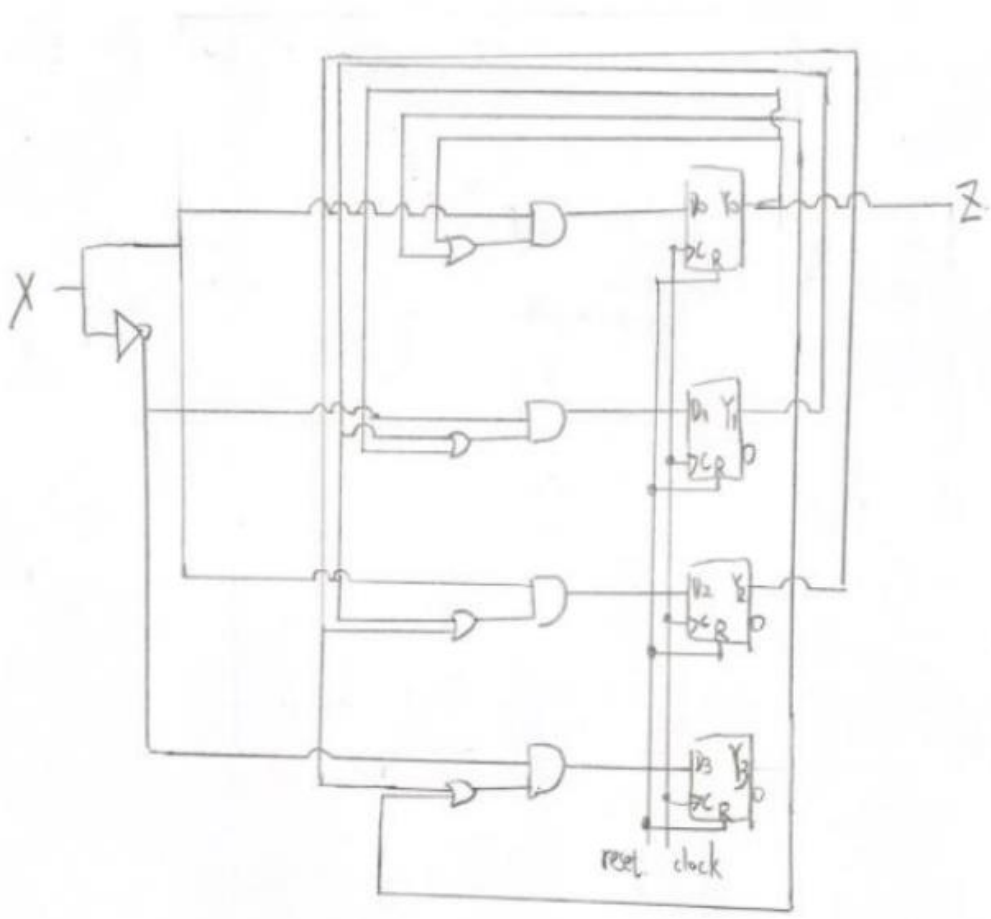
Z,x=0

| Y3Y2 \ Y1Y0 | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | x | 1 | x | 0 |
| 01 | 0 | x | x | x |
| 11 | x | x | x | x |
| 10 | 0 | x | x | x |

Z,x=1

| Y3Y2 \ Y1Y0 | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | x | 1 | x | 0 |
| 01 | 0 | x | x | x |
| 11 | x | x | x | x |
| 10 | 0 | x | x | x |

$$D_0 = X(Y_0 + Y_3)$$
$$D_1 = \overline{X}(Y_0 + Y_1)$$
$$D_2 = X(Y_1 + Y_2)$$
$$D_3 = \overline{X}(Y_2 + Y_3)$$
$$Z = Y_0$$

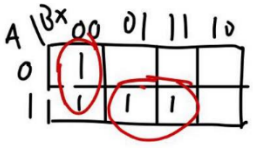



3. Design a sequential circuit with two *D* flip-flops *A* and *B* and one input *X*. When $X = 1$, the state of the circuit remains the same. When $X = 0$, the circuit goes through the state transitions from 00 to 10 to 11 to 01, back to 00, and then repeats. (15%)

3.

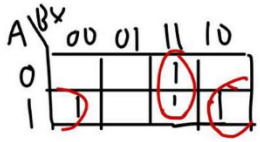
| present state A | present state B | Input X | Next state A+1 | Next state B+1 |
|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 1 |
| 1 | 0 | 1 | 1 | 0 |
| 1 | 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 1 | 1 |

A+1:

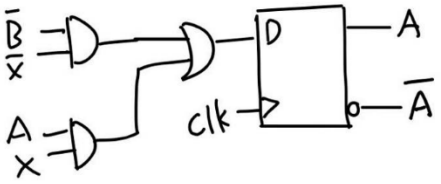


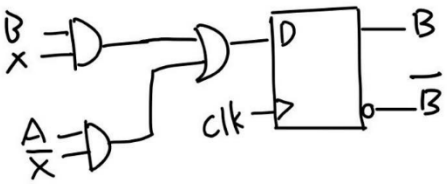

$D_A = B'x' + Ax$

B+1:

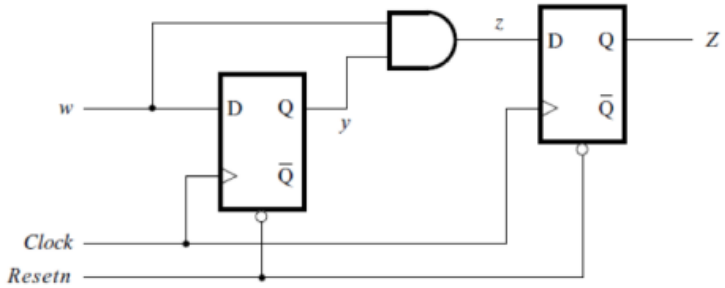



$D_B = Bx + Ax'$




4. Derive the state table, state diagram, and next-state and output equations ($y$, $z$, $Z$) of the following figure. (20%)



① state table :

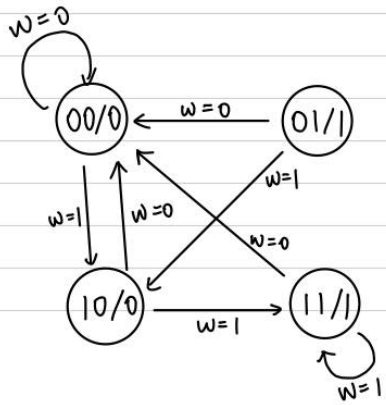
$z = wy$

$y(t+1) = w$

$Z(t+1) = z = wy$

| Present state | | next state | | | | output |
|---|---|---|---|---|---|---|
| | | $w=0$ | | $w=1$ | | |
| $y$ | $z$ | $y$ | $z$ | $y$ | $z$ | $Z$ |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| 1 | 1 | 0 | 0 | 1 | 1 | 1 |

② state diagram :




③ next state / output equation

$y(t+1) = w$

$z(t+1) = wy$

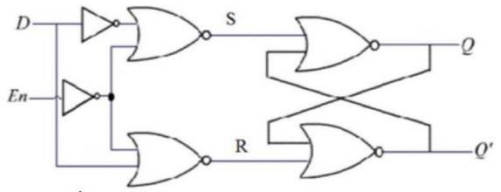
$Z_{,out} = z$

5. (a) Draw the gate level implementation of a gated (clocked) D latch using NORs or NANDs. Write its function table. (10%)

(b) Use gated D latch as a block, draw the logic diagram of an edge-triggered D flip-flop. Indicate whether the D flip-flop is positive or negative edge triggered. (10%)

5. (a)

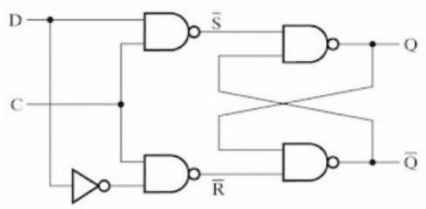
NORs




function table

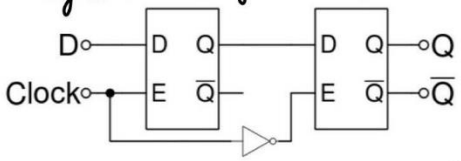
| Inputs | | Outputs | |
|---|---|---|---|
| C | D | Q | $\bar{Q}$ |
| 0 | X | NC | NC |
| 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 0 |

NANDs

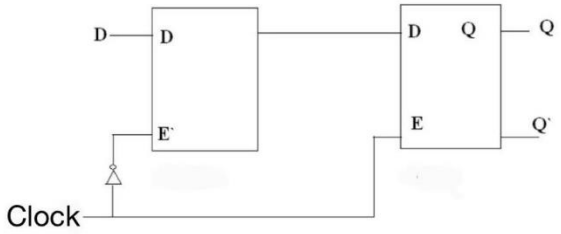



(b)

Negative edge triggered

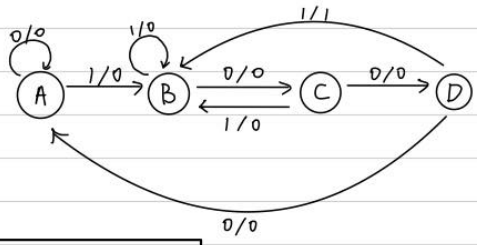



Positive edge triggered




6. Design a sequential circuit that recognize the sequence 1001. (15%)

# Mealy machine :




| present state a b | next state X=0 $a^+ b^+$ | next state X=1 $a^+ b^+$ | output (z) X=0 | output (z) X=1 |
|---|---|---|---|---|
| A 0 0 | 0 0 | 0 1 | 0 | 0 |
| B 0 1 | 1 0 | 0 1 | 0 | 0 |
| C 1 0 | 1 1 | 0 1 | 0 | 0 |
| D 1 1 | 0 0 | 0 1 | 0 | 1 |

A : reset
B : 1
C : 1 0
D : 1 0 0

$a^+$ :

| x \ ab | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | | 1 | | 1 |
| 1 | | | | |

$a^+ = \bar{x}\bar{a}b + \bar{x}a\bar{b}$

$b^+$ :

| x \ ab | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | | | | 1 |
| 1 | 1 | 1 | 1 | 1 |

$b^+ = x + a\bar{b}$

output : $z = xab$