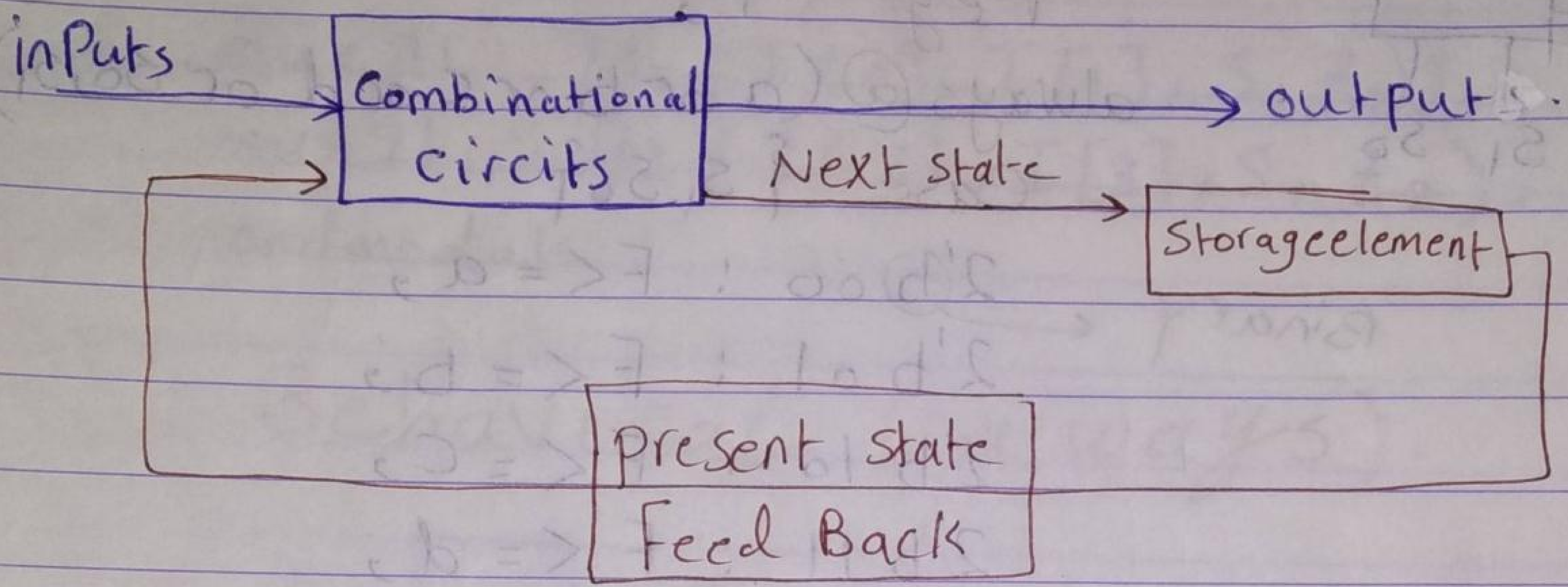
Chapter 5

· متزامن synchronous sequential Circits.

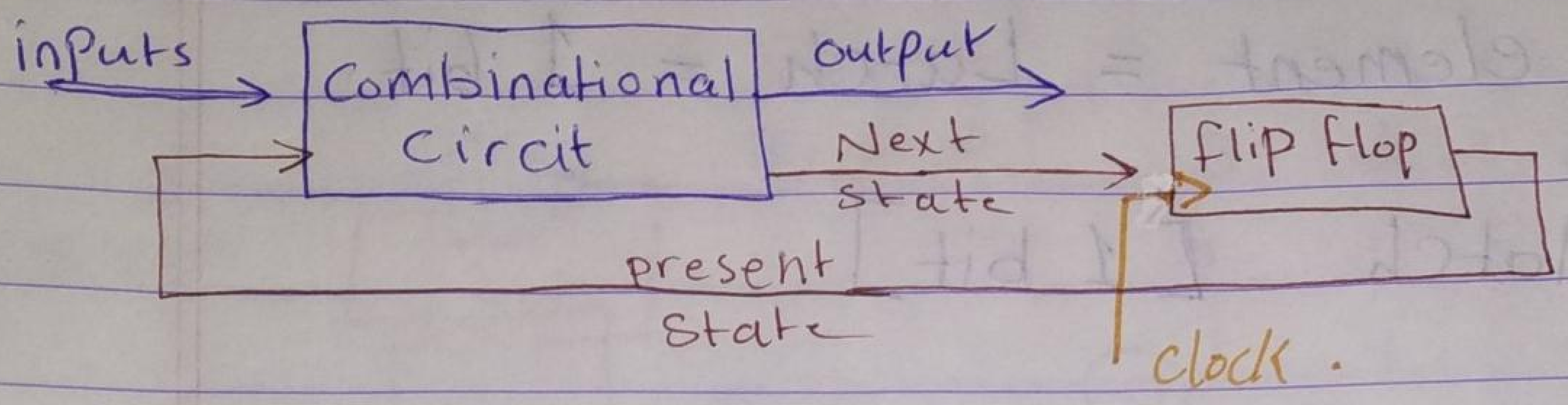


* outputs depends on inputs and previous outputs.

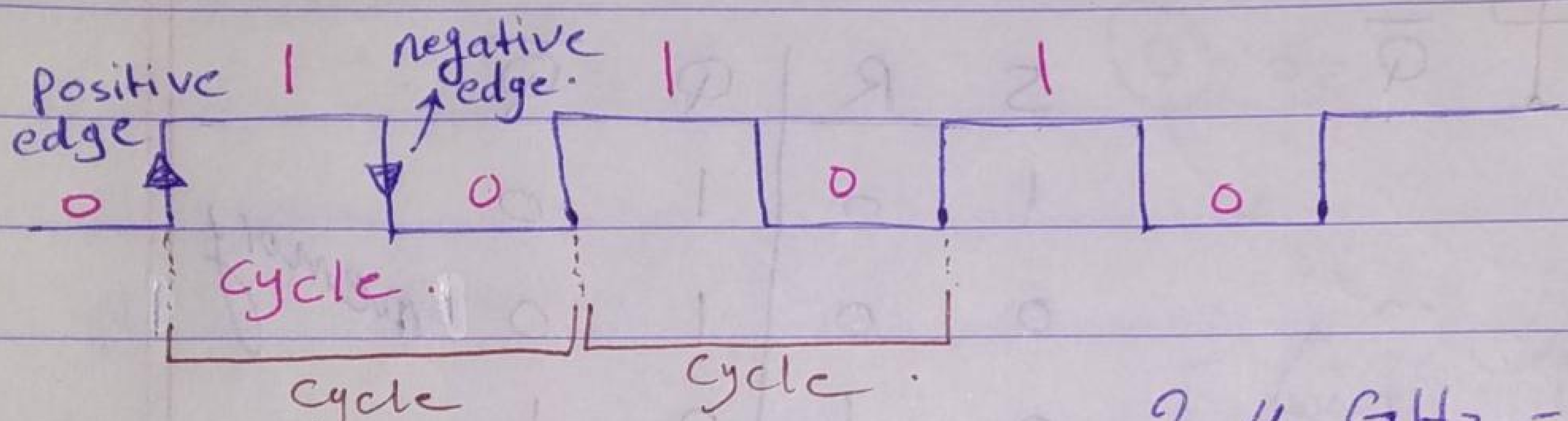
Electrical circits.

- Analog circit
- Digital circit.
  - Sequential circits
    - Ch5 — متزامن synchronous clocks
    - غير متزامن Asynchronous clocks
  - Ch4 — Combinational circits.

* Synchronous Sequential circit :-



Flip flop = memory 1 bit.

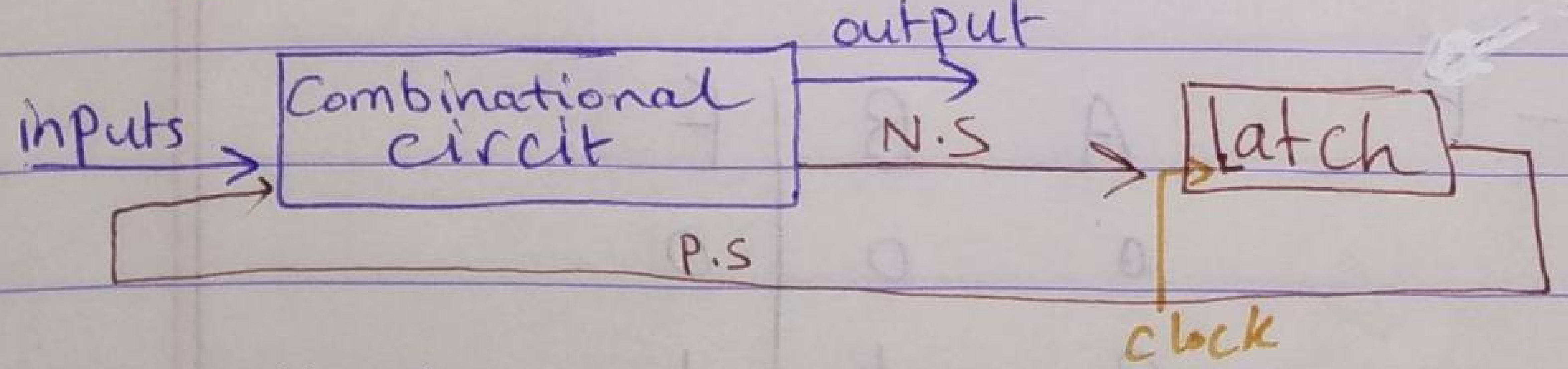


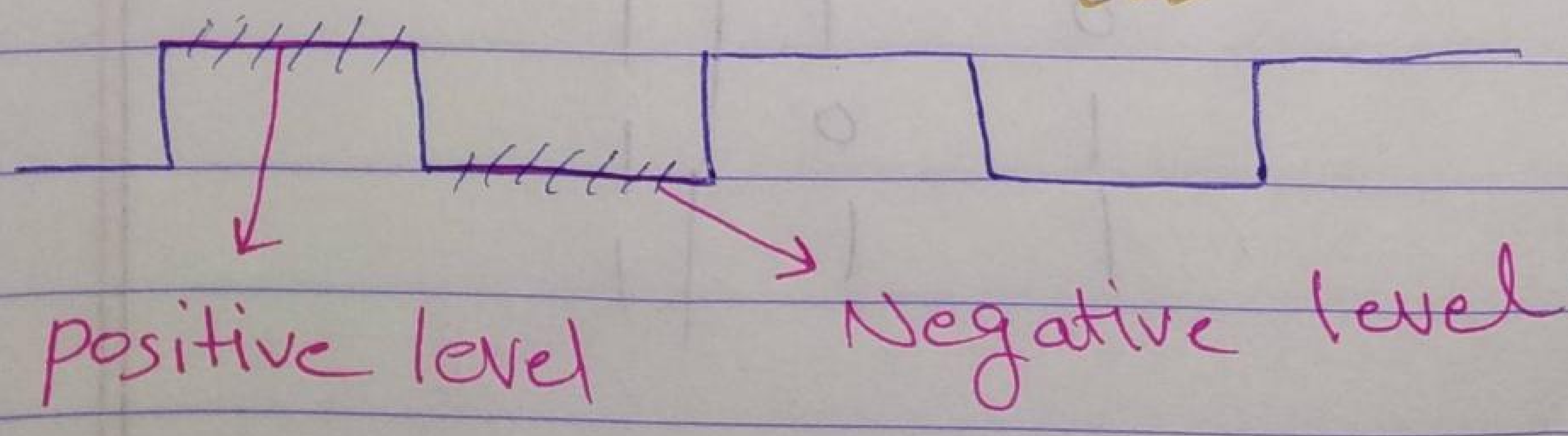
$2.4\ GHz = 2.4 \times 10^{9}\ \frac{1}{s}$.

$\text{frequency} = \frac{1}{\text{Time}}$.

* positive edge :- 1 ← 0 من
* Negative edge :- 0 ← 1 من

* Asynchronous Circits :-

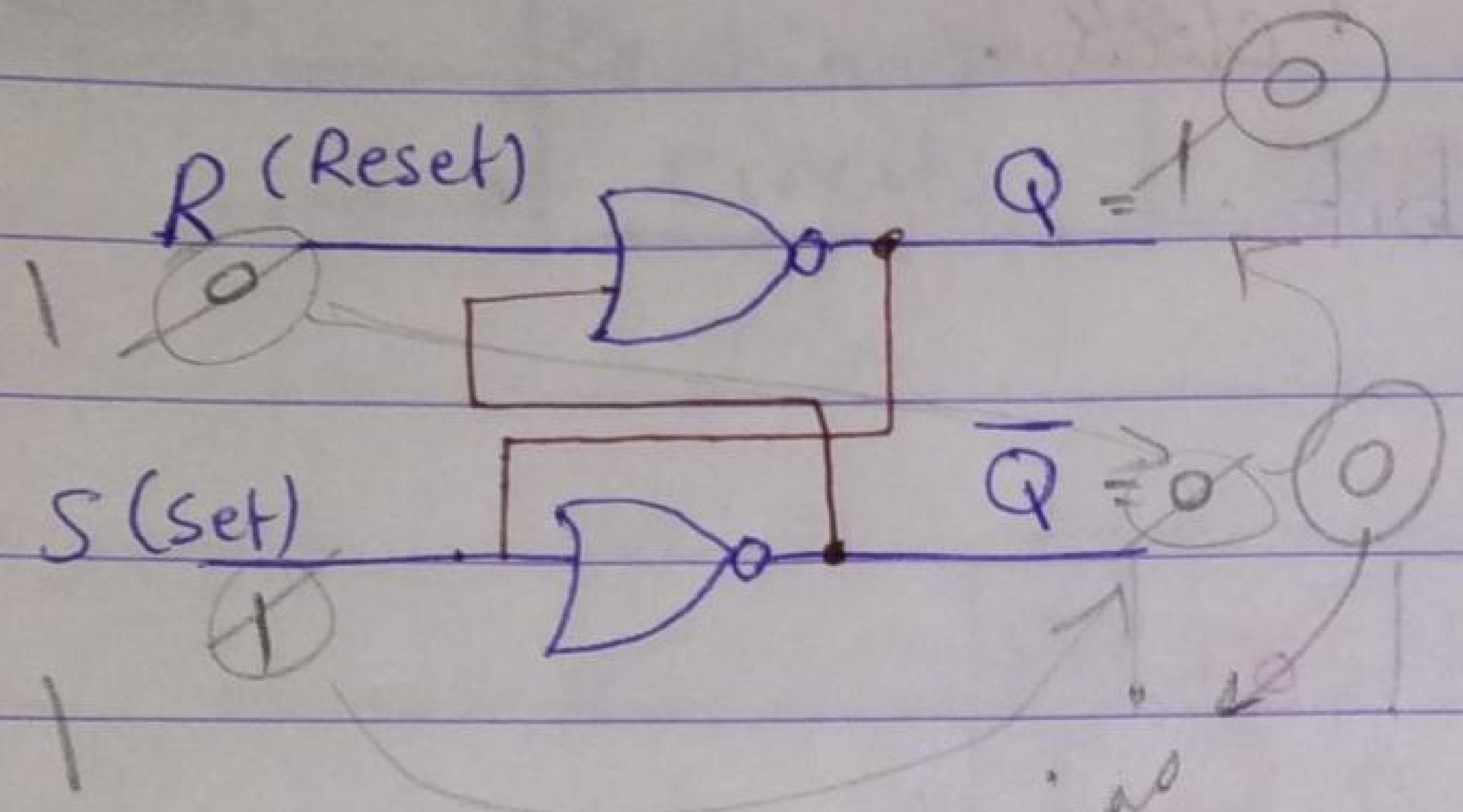




✱ Asynchronous Circit :-

memory element = Latch = 1 bit.

① SR - latch [1 bit] :



feed back → P.S

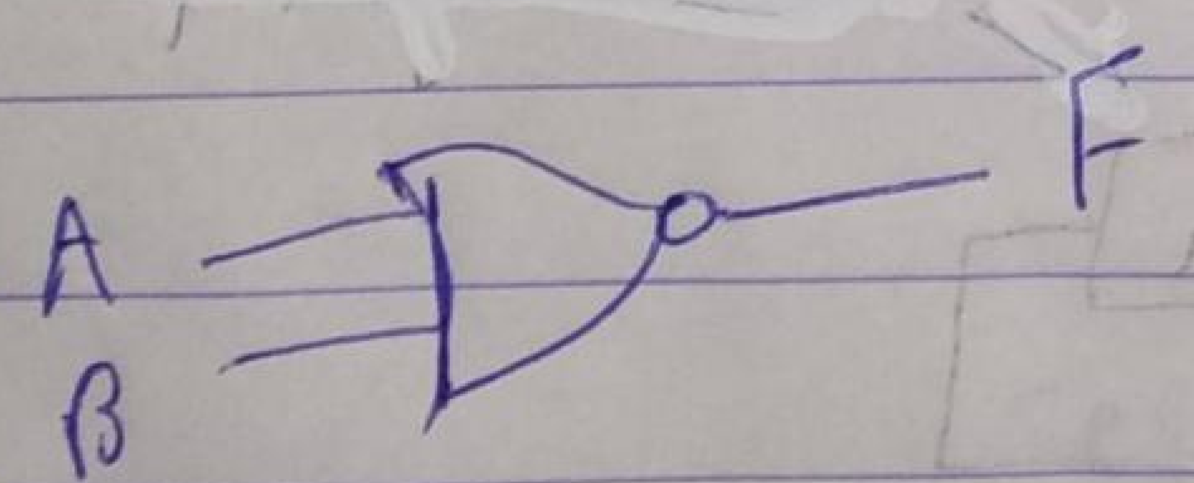
ممنوع يطلع نفس نفس

[forbidden]

S	R	Q	$\overline{Q}$	
1	0	1	0	
0	0	1	0	memory.
0	1	0	1	
0	0	0	1	memory.
1	1	0	0	[forbidden].

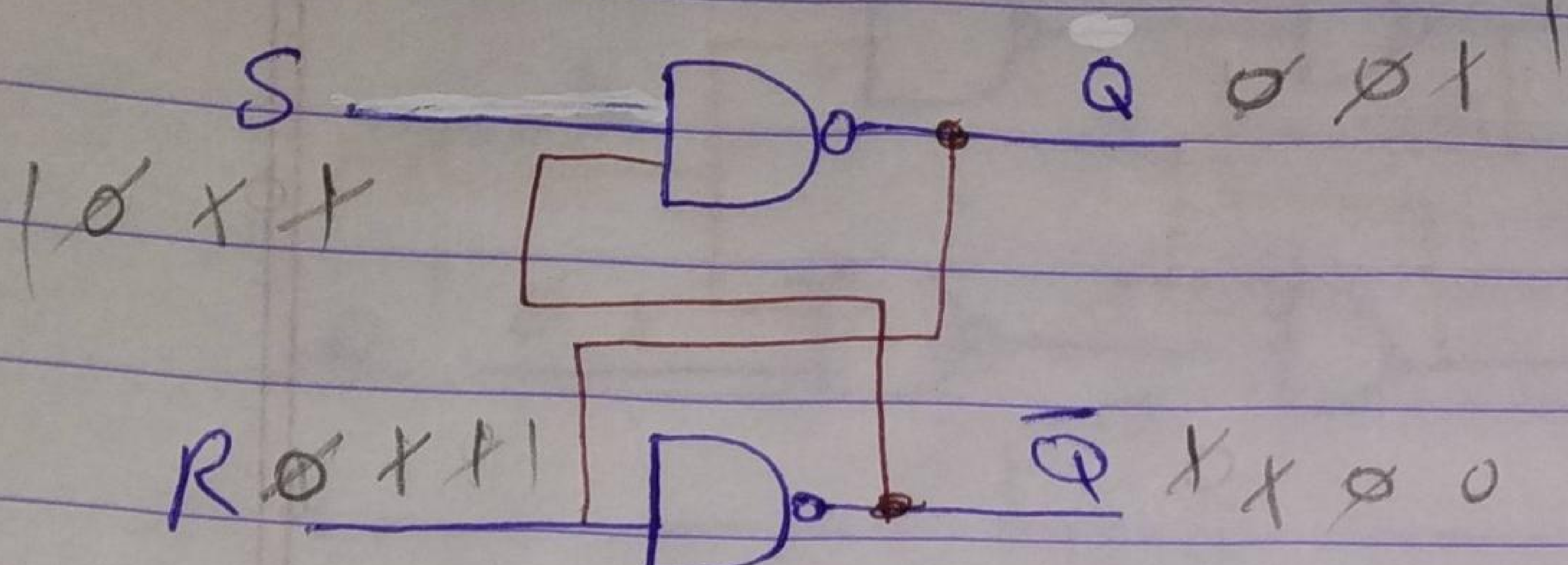
✓ Function Table

X ~~truth table~~ وليس



A	B	F
0	0	0
0	1	1
1	0	1
1	1	1

② SR-Latch with NAND gate.

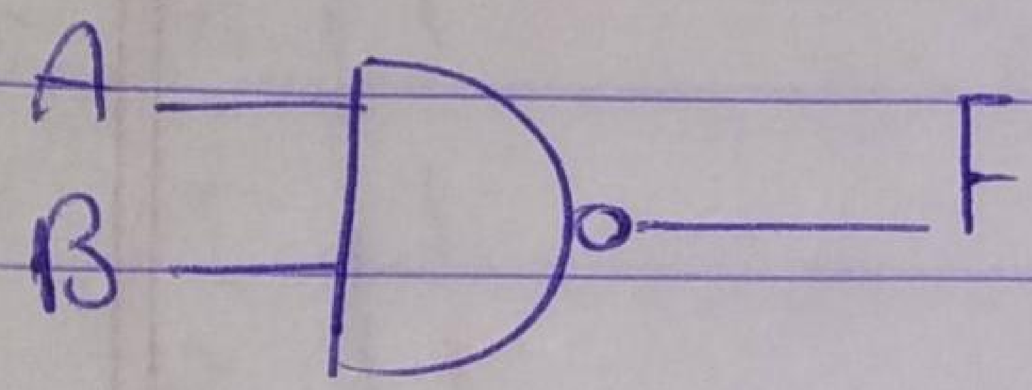


0 nand 1

1 nand 1

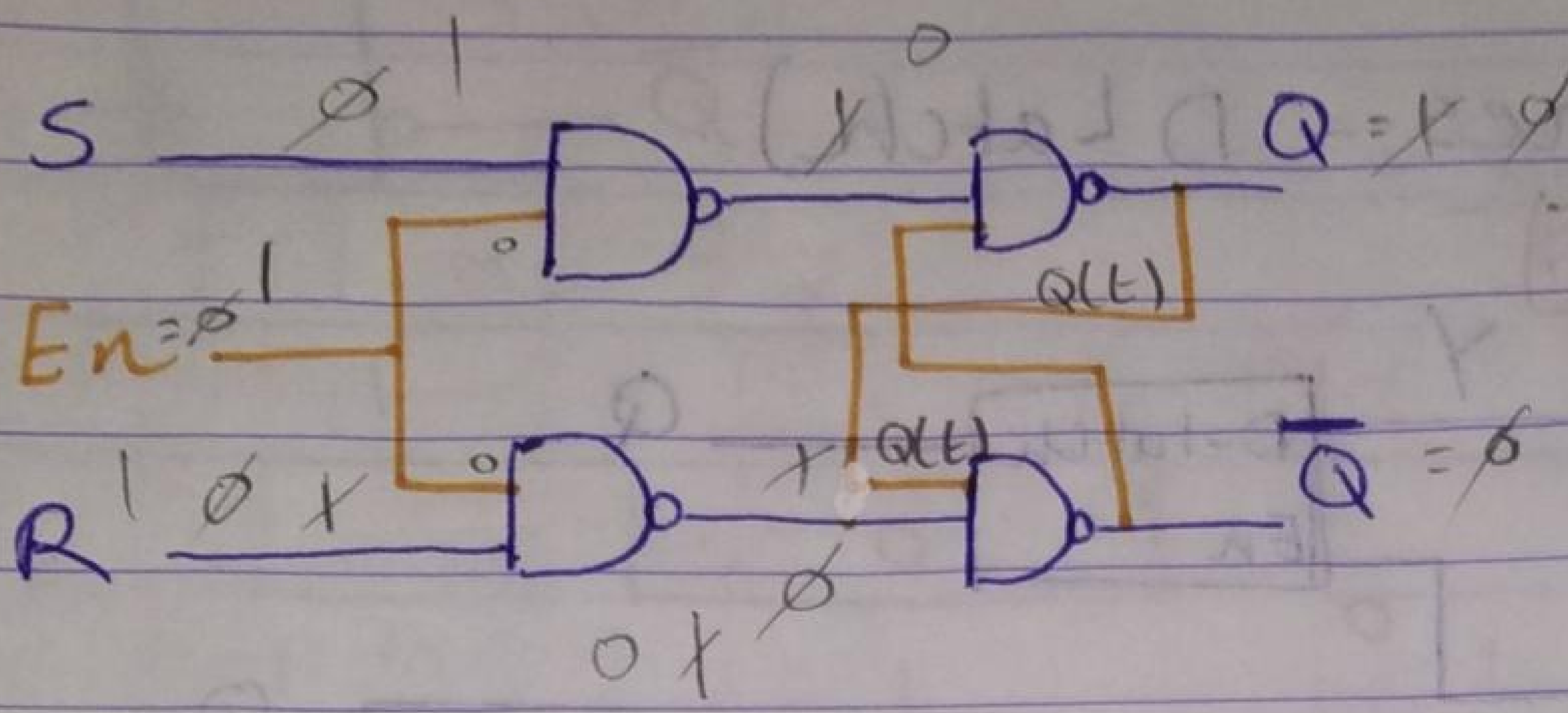
S	R	Q	$\overline{Q}$	
1	0	1	0	
1	1	0	1	memory
0	1	1	0	
1	1	1	0	memory
0	0	1	1	[forbidden]

Function Table.

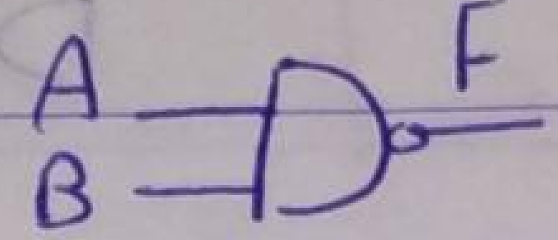


A	B	F
0	0	1
0	1	1
1	0	1
1	1	0

③ SR Latch with enable



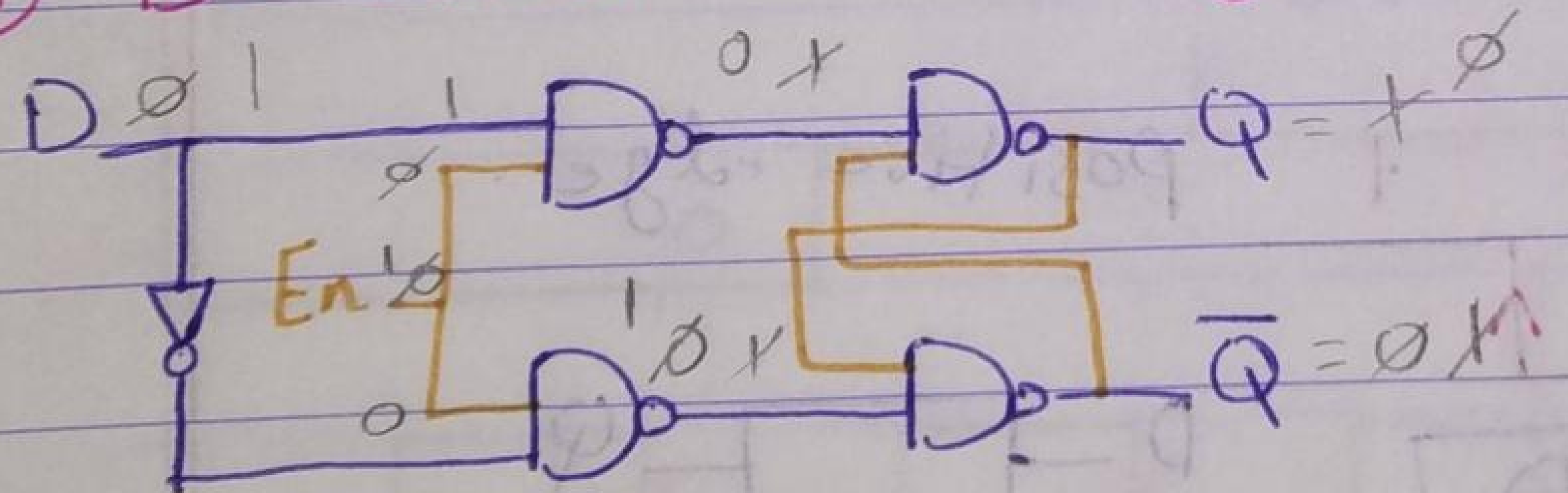
NAND gate



A	B	F
0	0	1
0	1	1
1	0	1
1	1	0

En	S	R	
0	X	X	No change → Q(t+1) = Q(t). (memory)
1	0	0	No change → Q(t+1) = Q(t).
1	0	1	Q[t+1] = 0.
1	1	0	Q(t+1) = 1.
1	1	1	Forbidden.

④ D-Latch - memory element Asynchronous



En	D	
0	X	No change (Q(t+1) = Q(t).
1	0	Q(t+1) = 0
1	1	Q(t+1) = 1

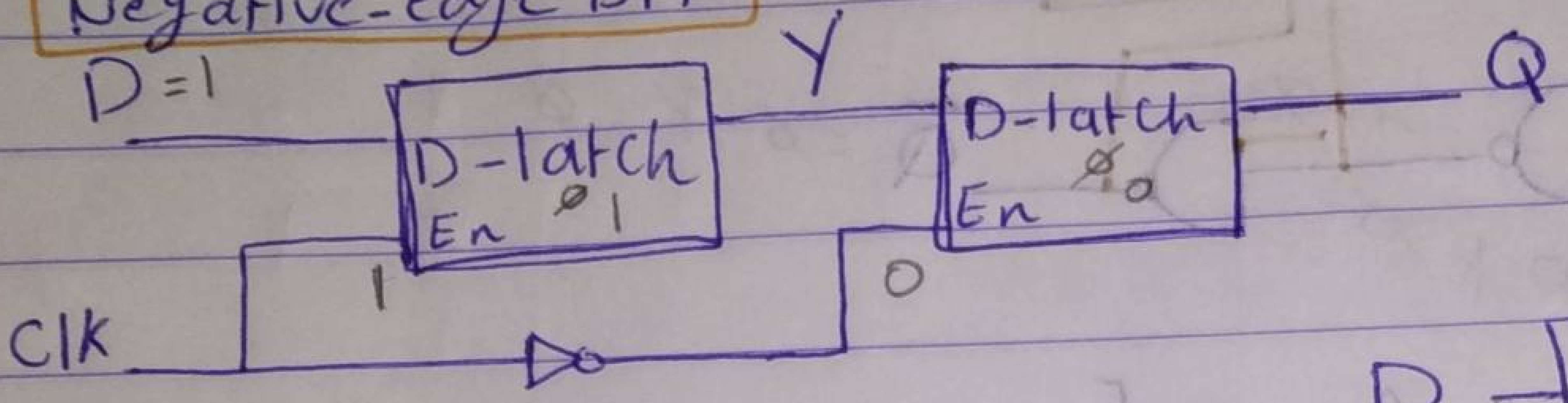
أهمية. [فش forbidden لأنه input واحد.]

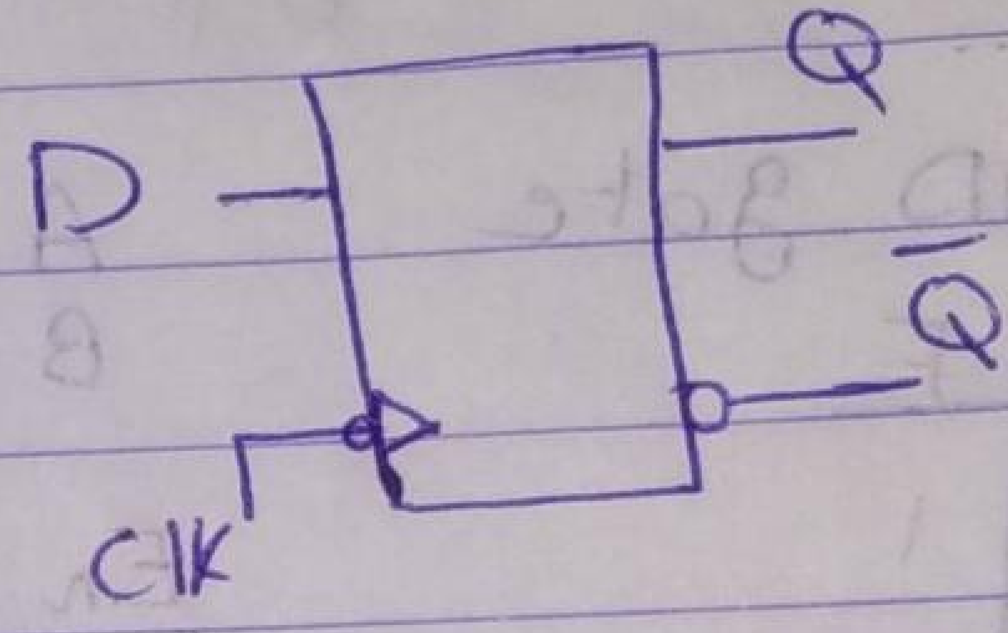
① Edge - Triggered D - Flip Flop.

DFF

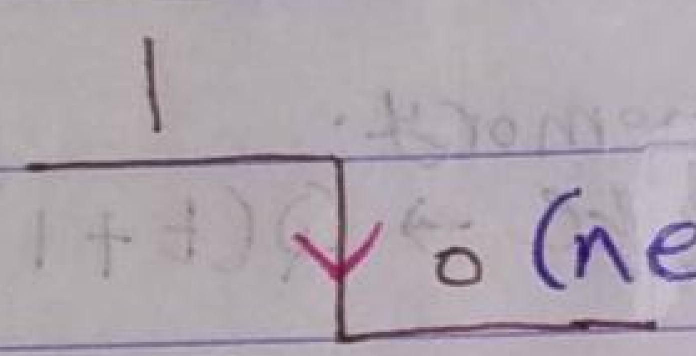
(Two Latches - D Latch).

Negative-edge DFF.





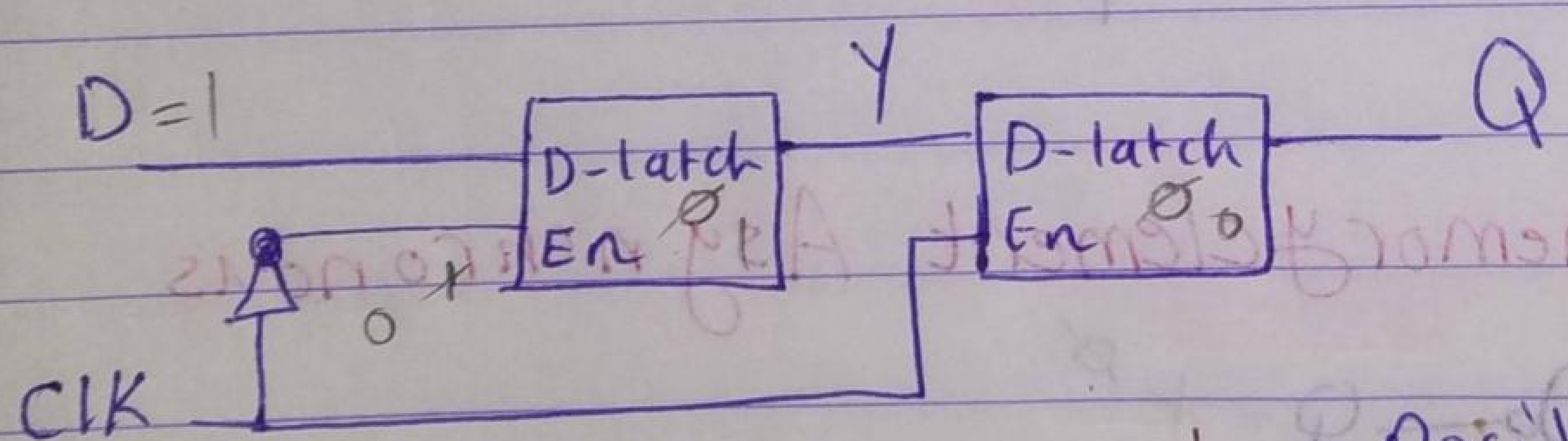
if clk = 1



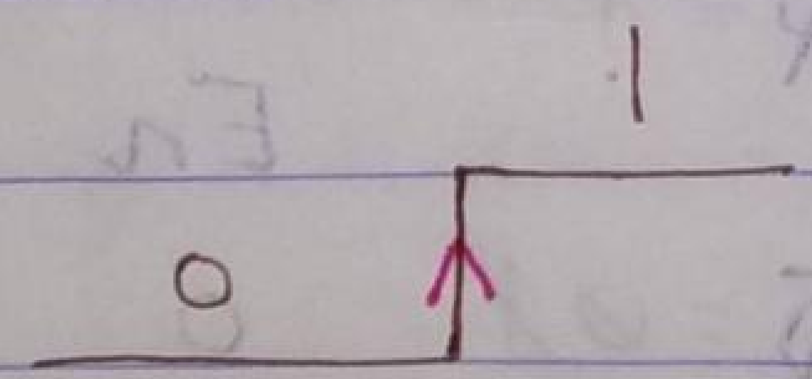
0 (negative edge).

$Q(t+1) = D$

positive-edge DFF.

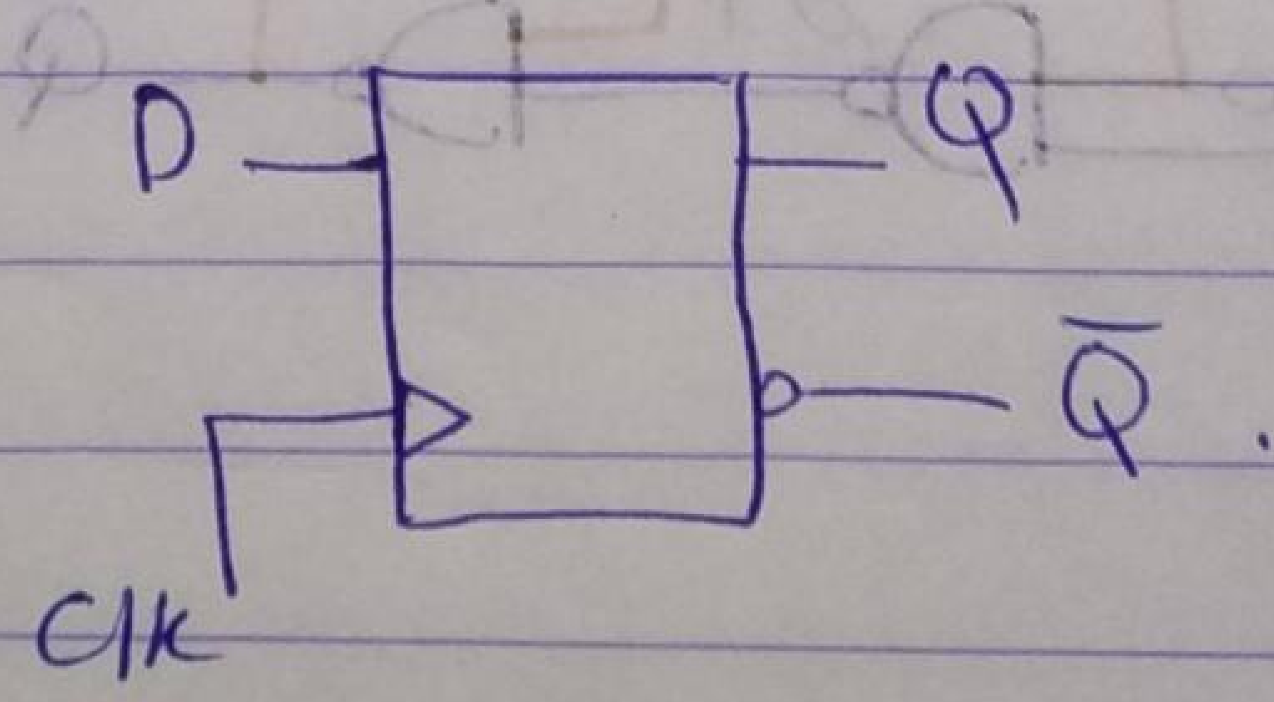


positive edge.

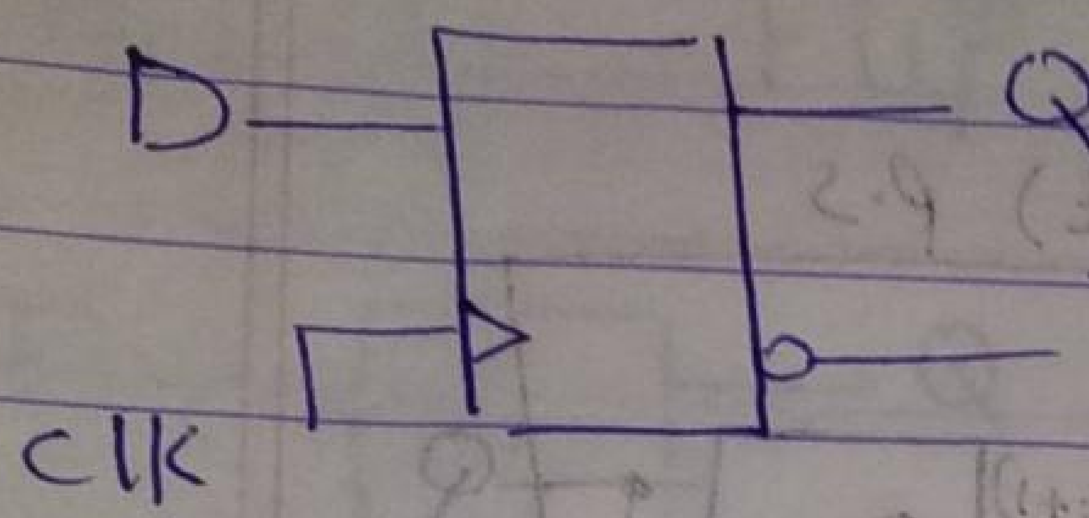


Clk = 0

$\boxed{Q(t+1) = D}$

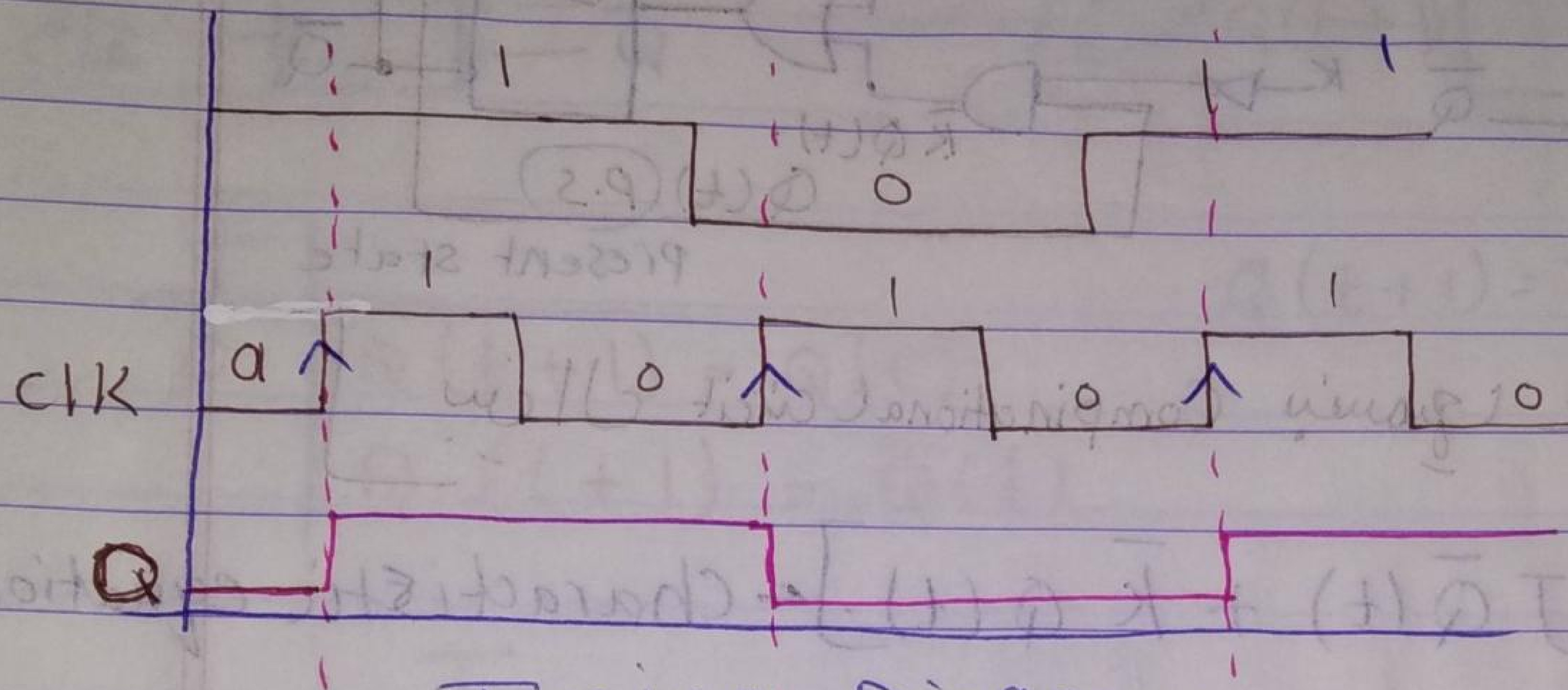


Positive edge



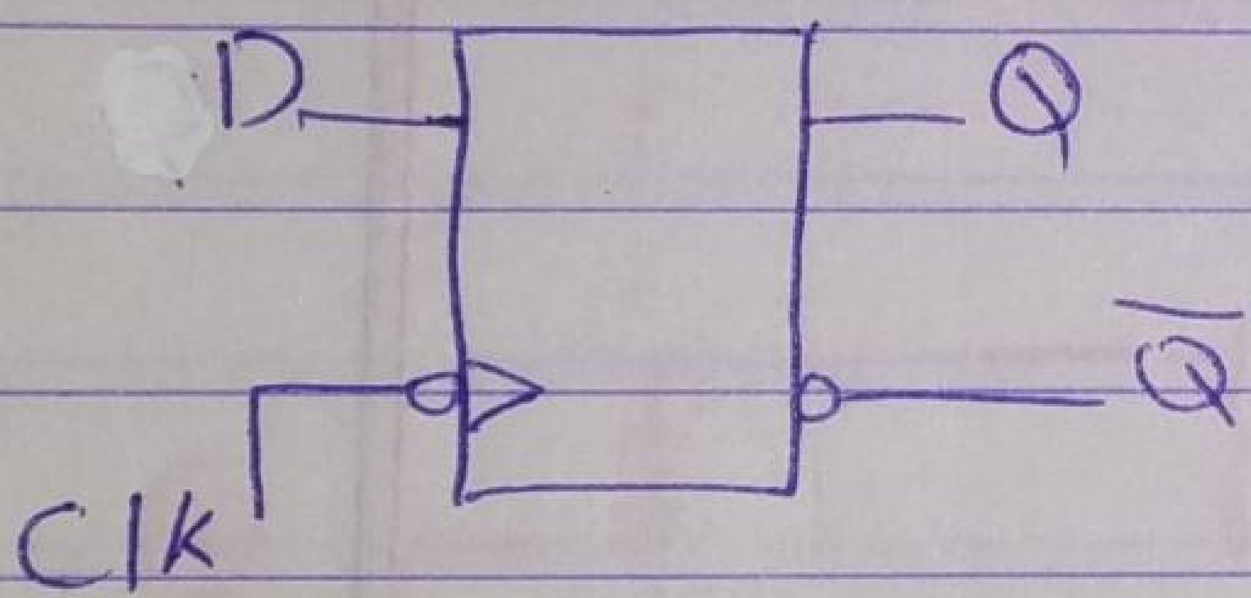
D	Q(t+1)
0	0
1	1

Charasteristic table.

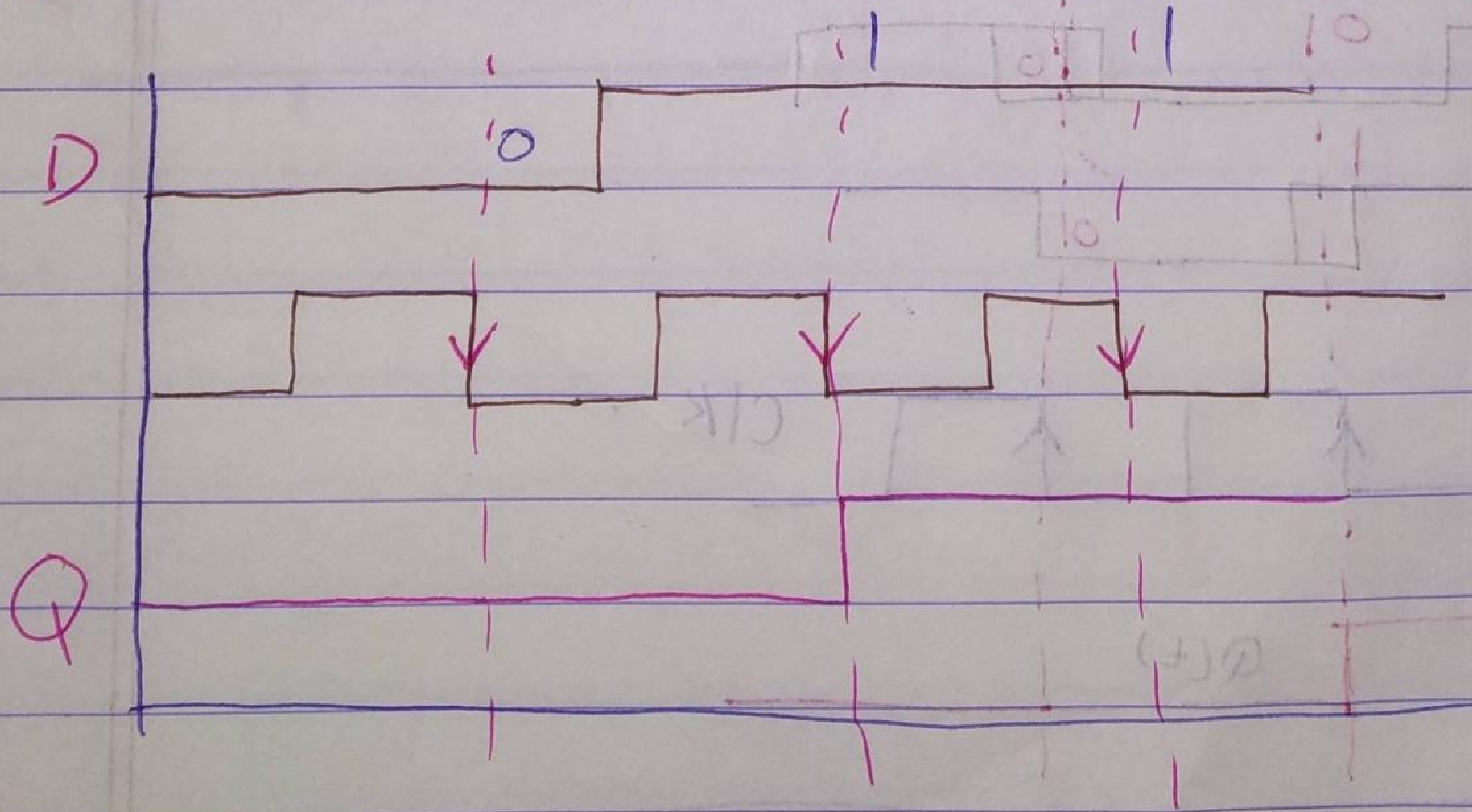


Timing Diagram-

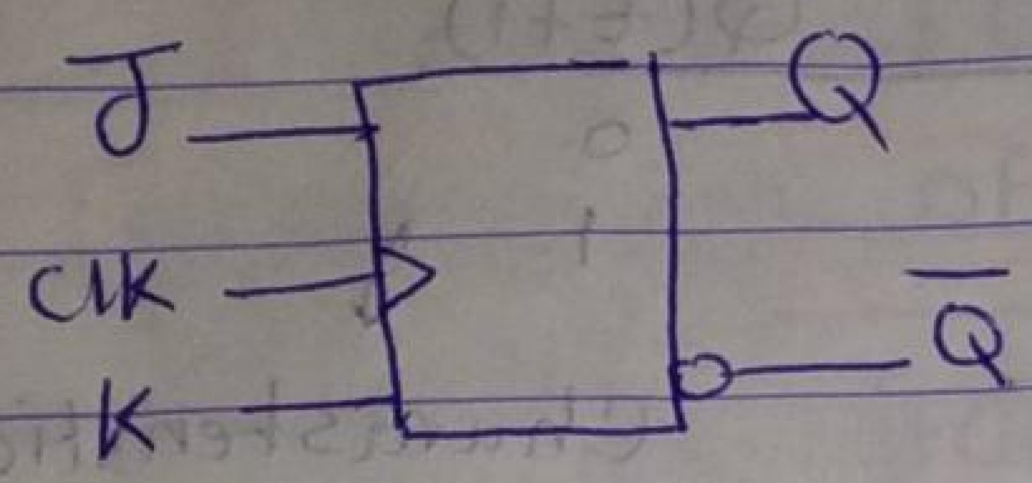
Negative edge

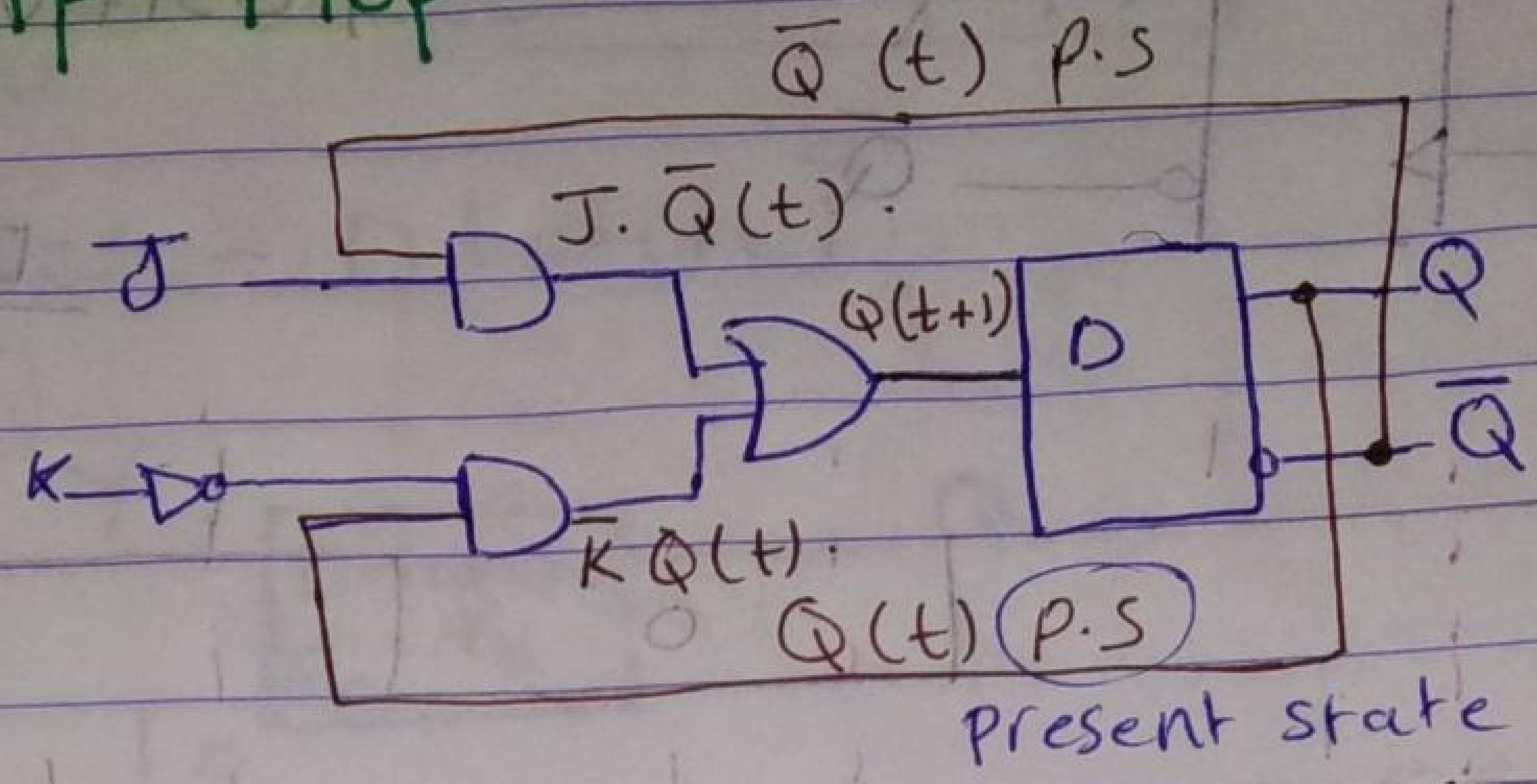


$$Q(t+1) = D$$



② JK Flip Flop.

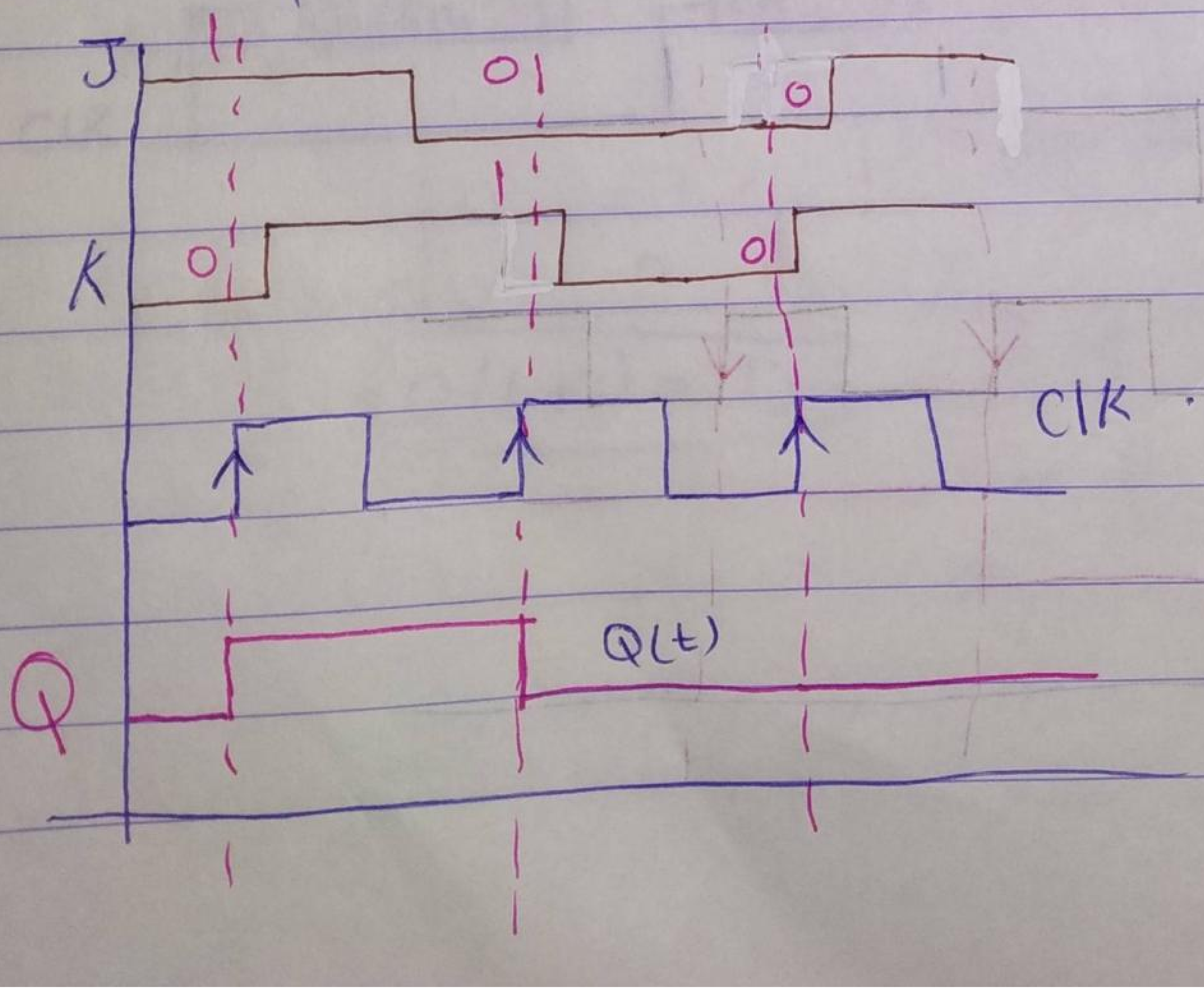




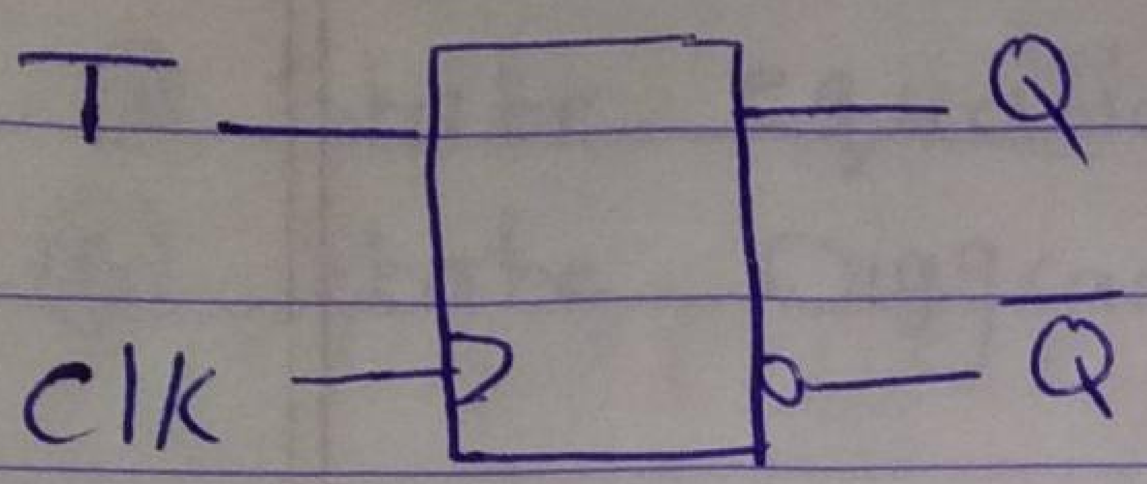
Next State بنستخدم Compinational circit بين ال

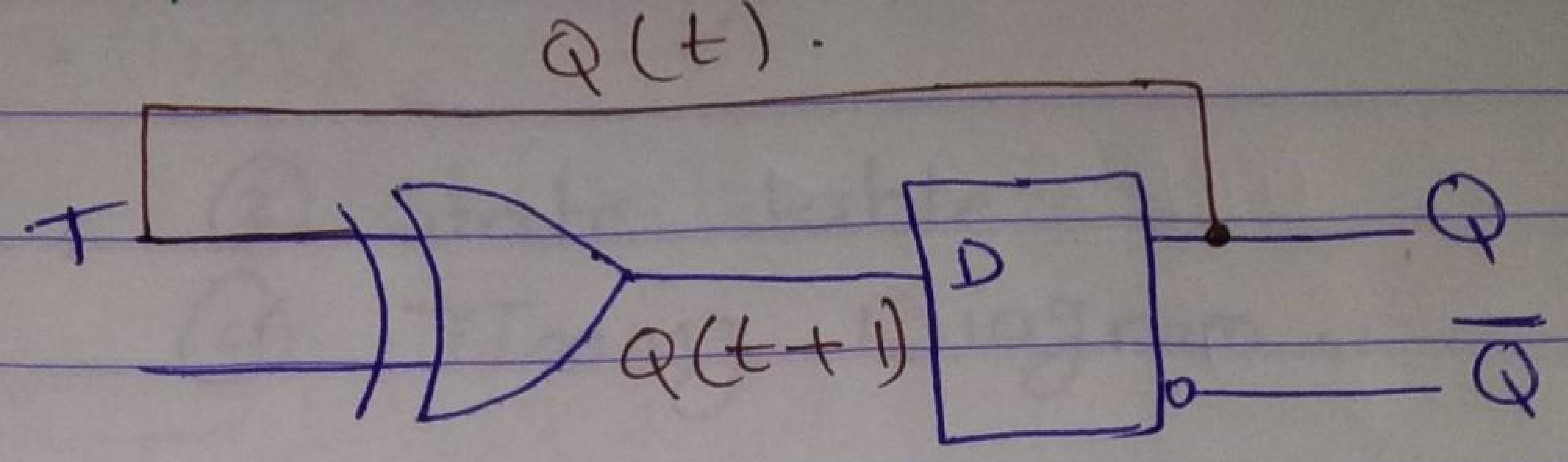
$$\boxed{Q(t+1) = J\bar{Q}(t) + \bar{K}Q(t).}$$ ← Characteristic equation.

J	K	
0	0	$Q(t+1) = Q(t)$ ← (No change).
0	1	$Q(t+1) = 0$
1	0	$Q(t+1) = 1$
1	1	$Q(t+1) = \bar{Q}(t)$.



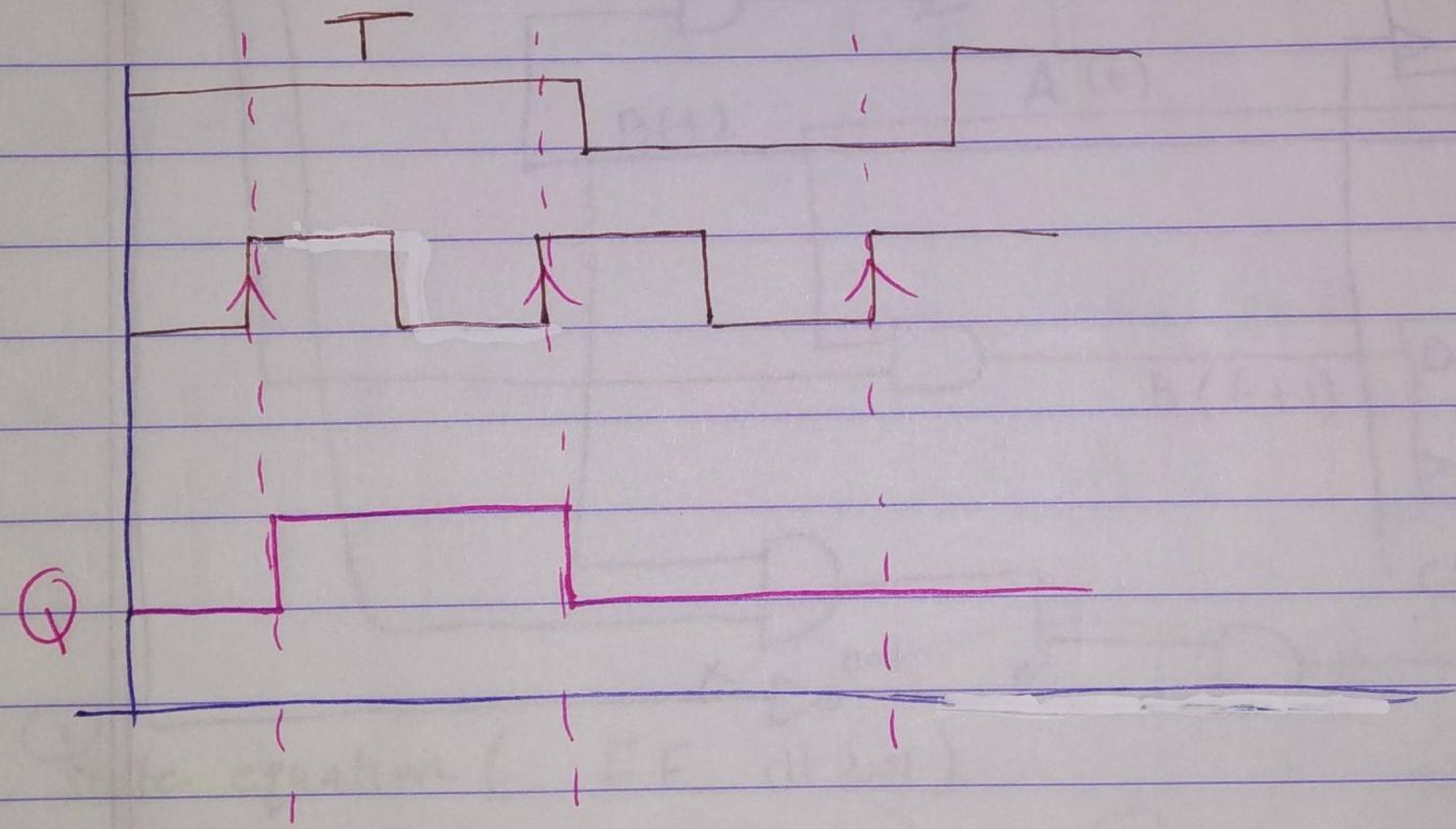
③ T Flip Flop.





$$Q(t+1) = T \oplus Q(t).$$

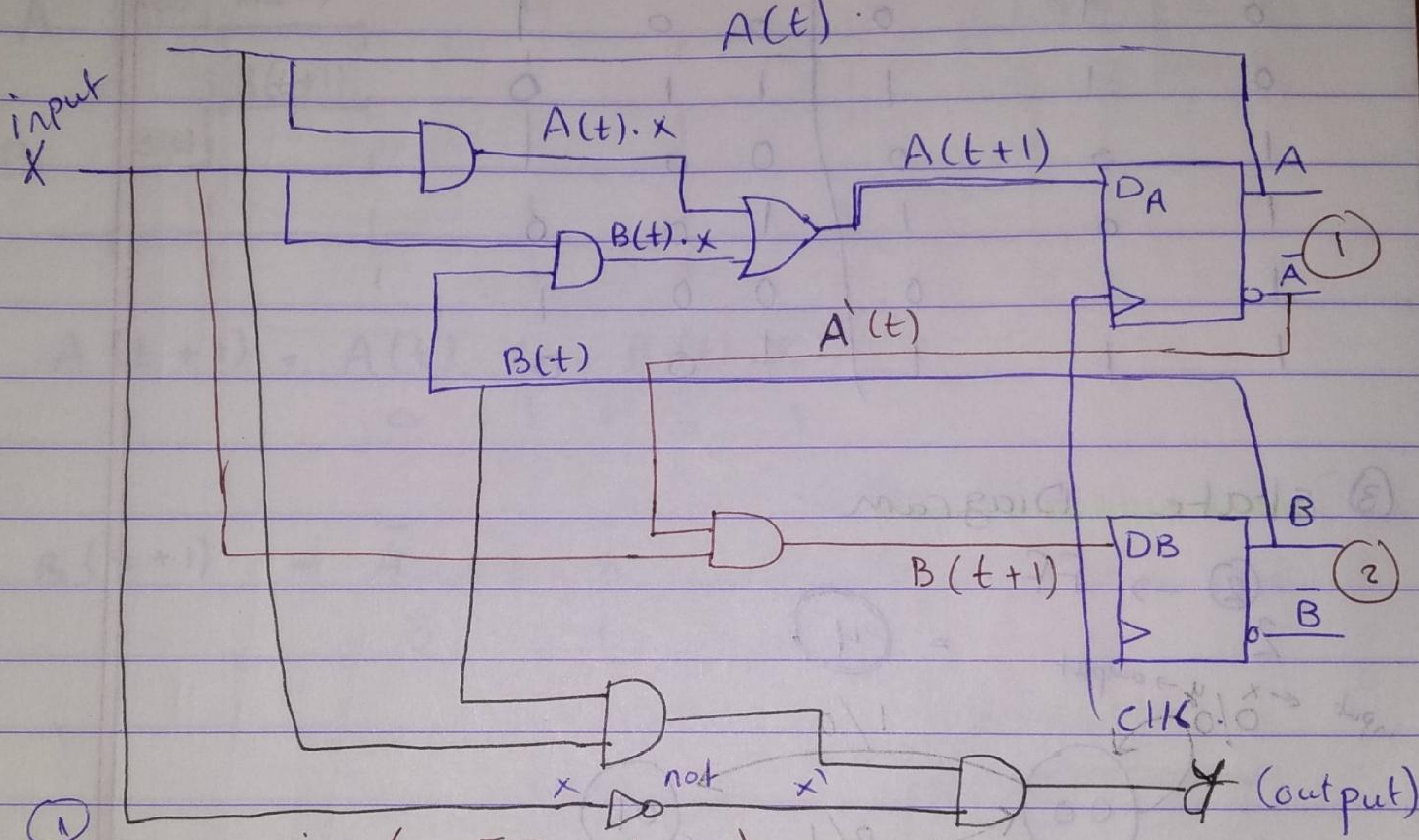
T	
0	$Q(t+1) = Q(t)$.
1	$Q(t+1) = \overline{Q}(t)$



Analysis For clocked sequential circit.

1. State equation,
2. State table.
3. State Diagram.
4. Timing Diagram.

ex



1. state equation (FF بعد ال).

$$\begin{cases} A(t+1) = A(t) \cdot x + B(t) \cdot x & (1) \\ B(t+1) = \bar{A}(t) \cdot x & (2) \end{cases}$$

$y = [A(t) + B(t)] \cdot x'$ [P.S + input].

(2) State table :

$A(t+1) = A(t) \cdot x + B(t) \cdot x$

$\quad\quad\quad\quad\quad\quad 0 \cdot 0 + 0 \cdot 0$

P.S		input	N.S		output
A	B	x	A	B	y
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	0	1
0	1	1	1	1	0
1	0	0	0	0	1
1	0	1	1	0	0
1	1	0	0	0	1
1	1	1	1	0	0

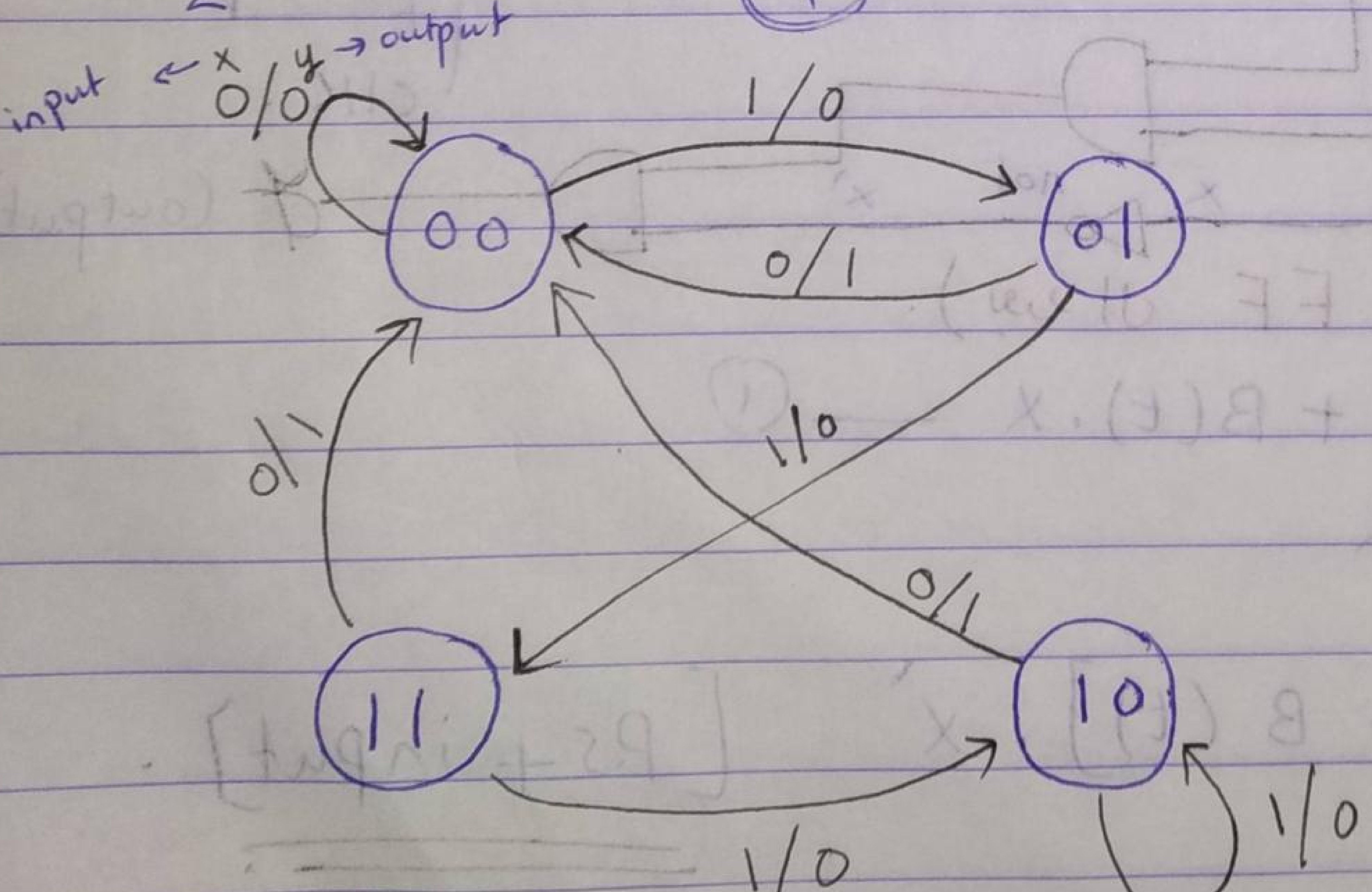
$B(t+1) = \bar{A}(t) \cdot x$

$y = [A(t) + B(t)] \cdot x'$

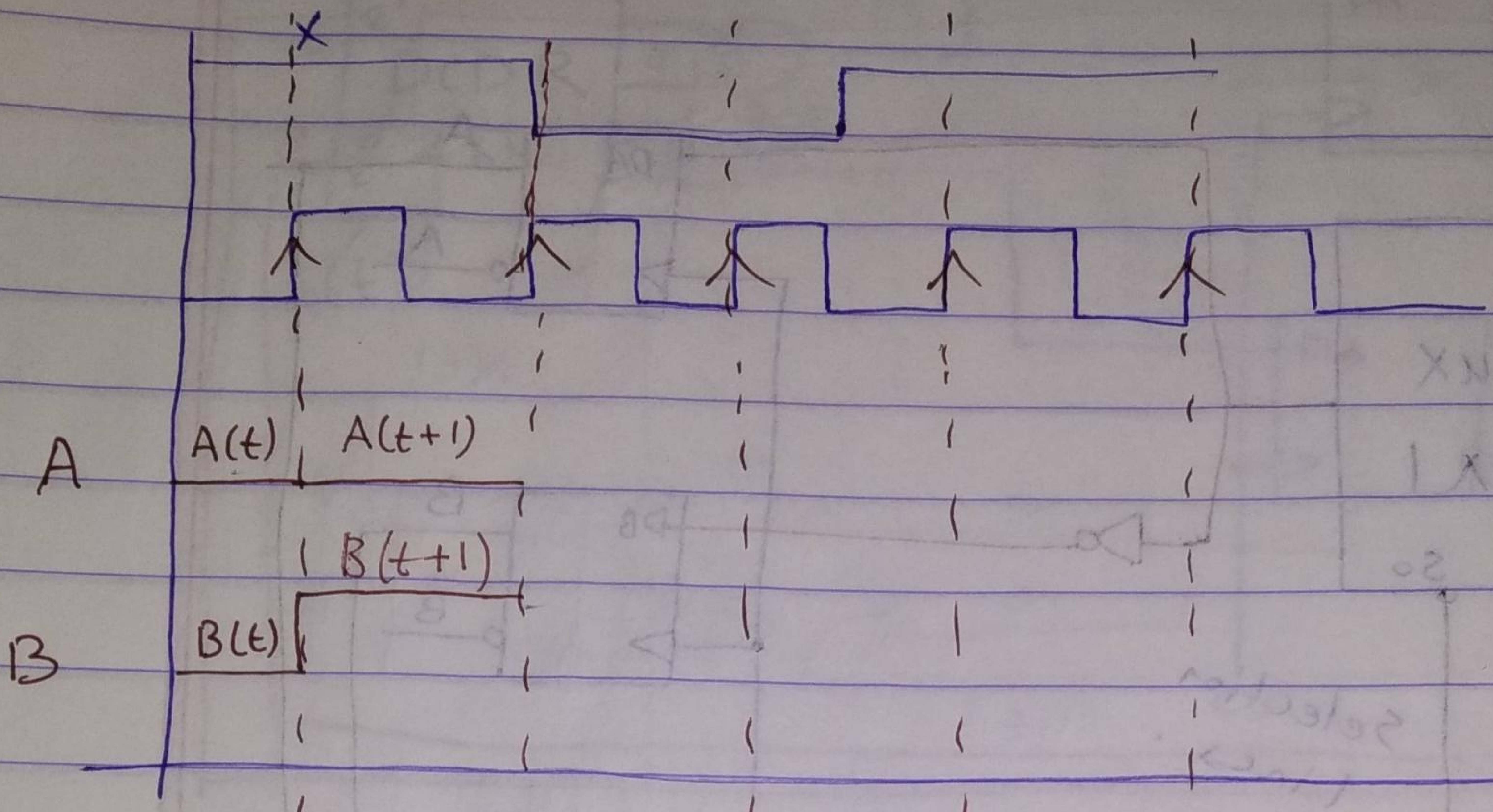
(3) State Diagram .

(2) → FF .

$2^2 = 4$



④ Timing Diagram.

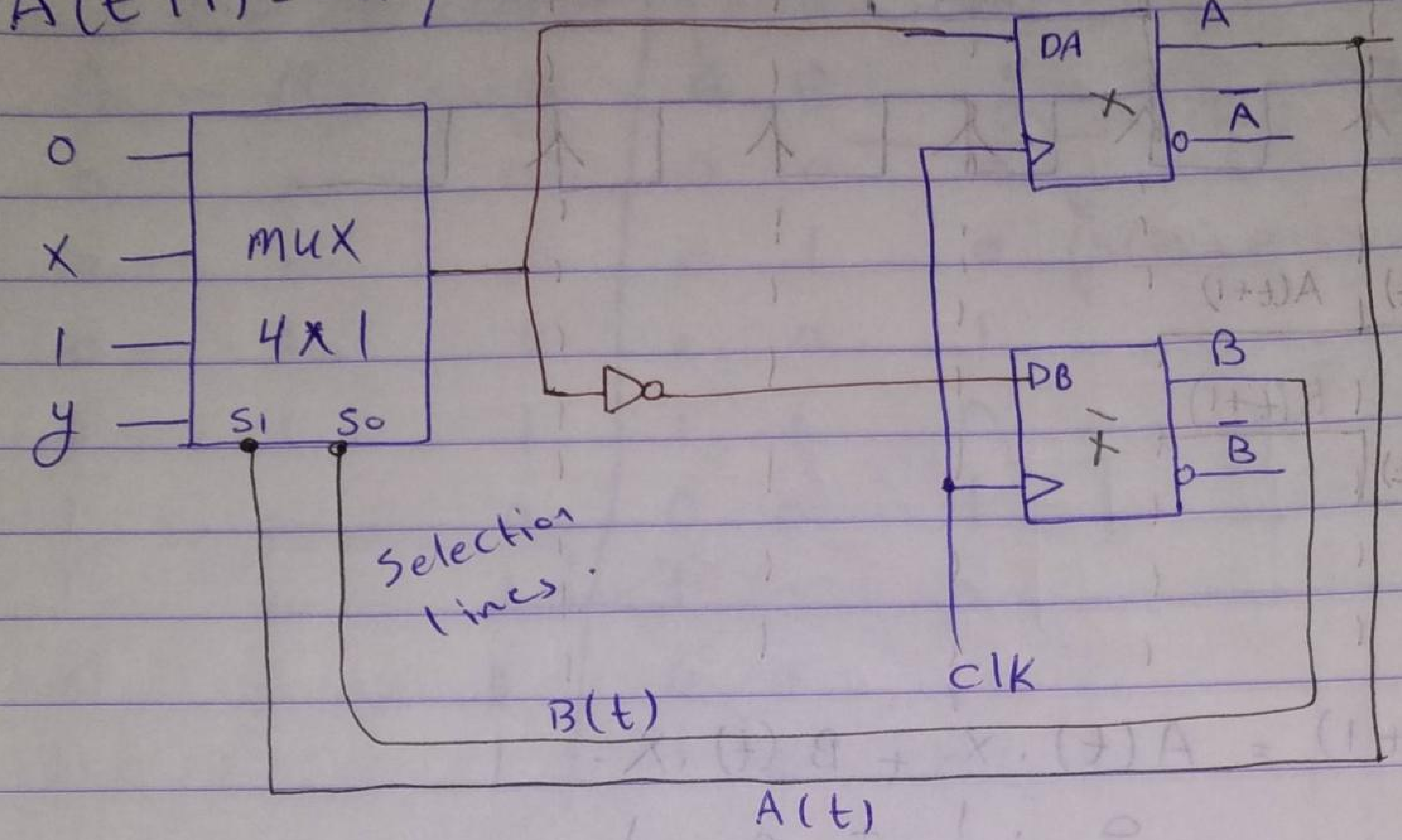


$$A(t+1) = A(t) \cdot x + B(t) \cdot x$$
$$0 \cdot 1 + 0 \cdot 1$$

$$B(t+1) = \bar{A}(t) \cdot x$$
$$\bar{0} \cdot 1$$

ex

A(t+1) = DA / B(t+1) = DB.

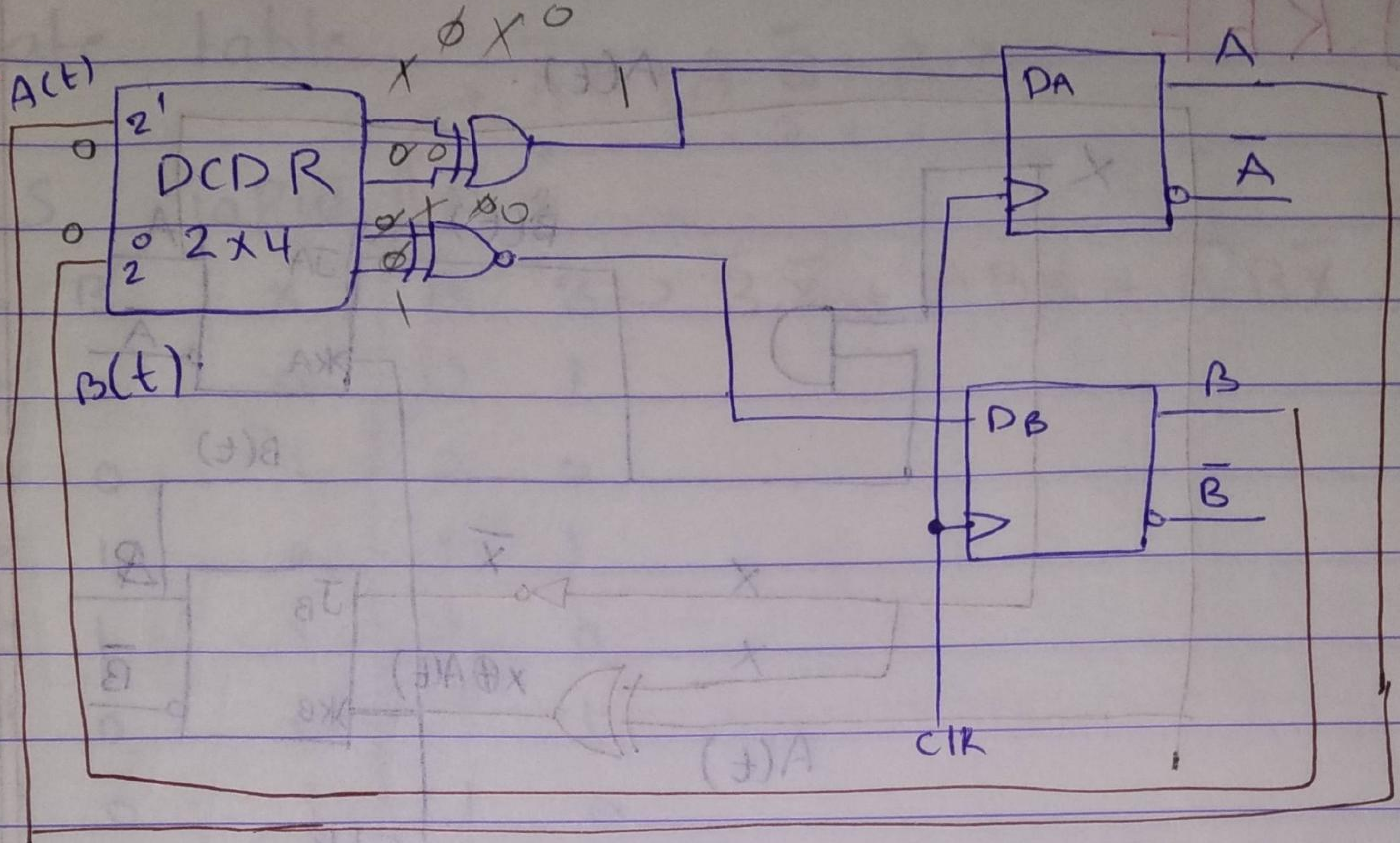


P.S A	P.S B	input x	input y	N.S A	N.S B
0	0	0	0	0	1
0	0	0	1	0	1
0	0	1	0	0	1
0	0	1	1	0	1
0	1	0	0	0	1
0	1	0	1	0	1
0	1	φ	0	1	0
0	1	1	1	1	0
1	0	0	0	1	0
1	0	0	1	1	0
1	0	1	0	1	0
1	0	1	1	1	0
1	1	0	0	0	1
1	1	0	1	1	0
1	1	1	0	0	1
1	1	1	1	1	0

x

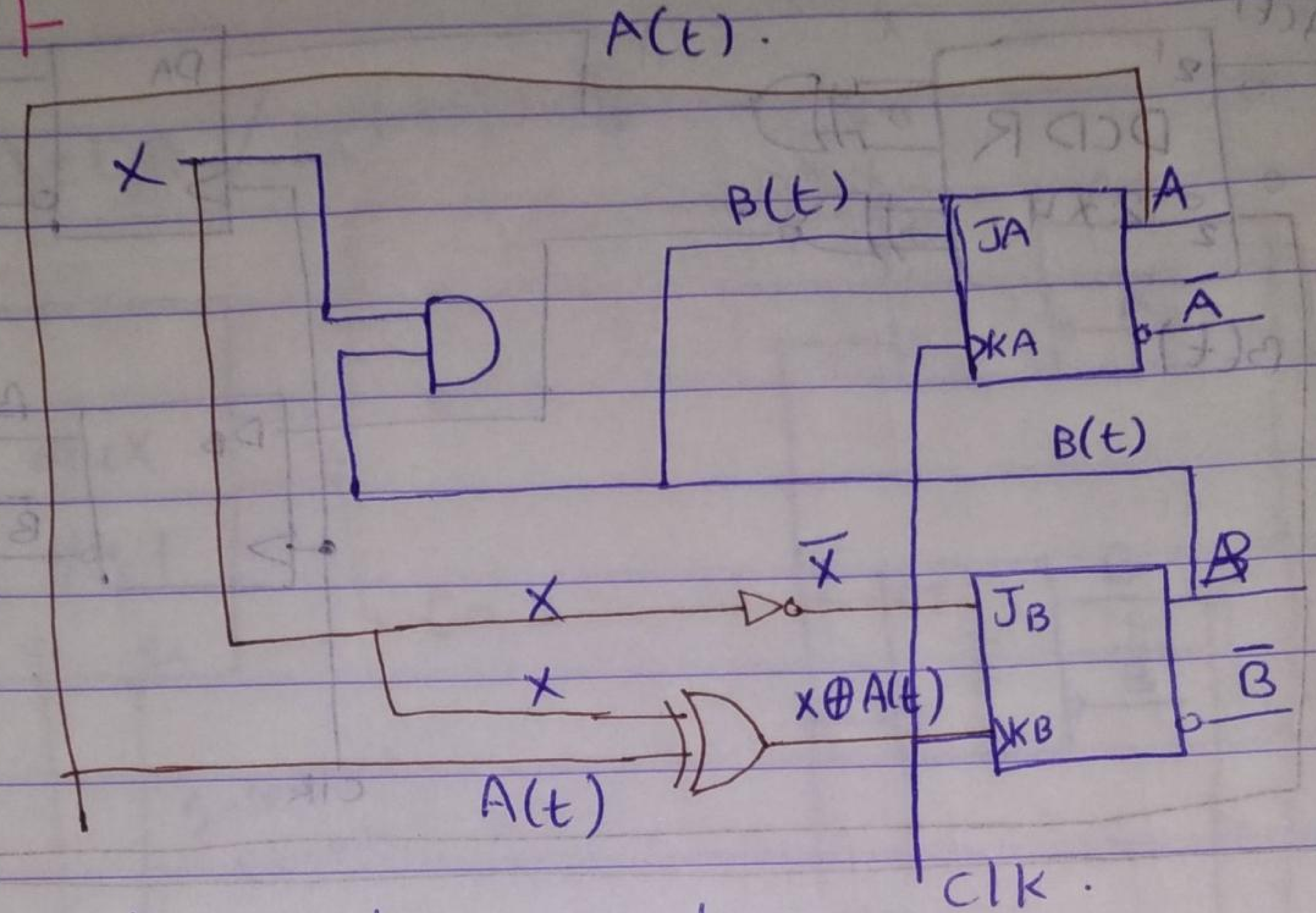
	00	01	11	10
00				
01			1	1
11				
10				

ex



P.S		N.S	
A	B	A	B
0	0	1	1
0	1	1	1
1	0	0	0
1	1	0	0

JKFF



– what is the state equation
Two state eqn..

$$A(t+1) = J_A \bar{A}(t) + \bar{K}_A A(t).$$
$$= B(t) \cdot \bar{A}(t) + [x \cdot B(t)] . A(t).$$
$$A(t+1) = A'B + A\bar{B} + A.x \quad — \quad 1$$

$$B(t+1) = J_B . \bar{B}(t) + \bar{K}_B B(t).$$
$$= \bar{x} \cdot \bar{B}(t) + (x \oplus A(t))' B(t).$$
$$= \bar{X} \cdot \bar{B}(t) + [\bar{X} \cdot A + x\bar{A}]' B(t).$$
$$= \bar{B}\bar{X} + ABX + \bar{A}B\bar{X}. \quad — \quad 2.$$

② State table.

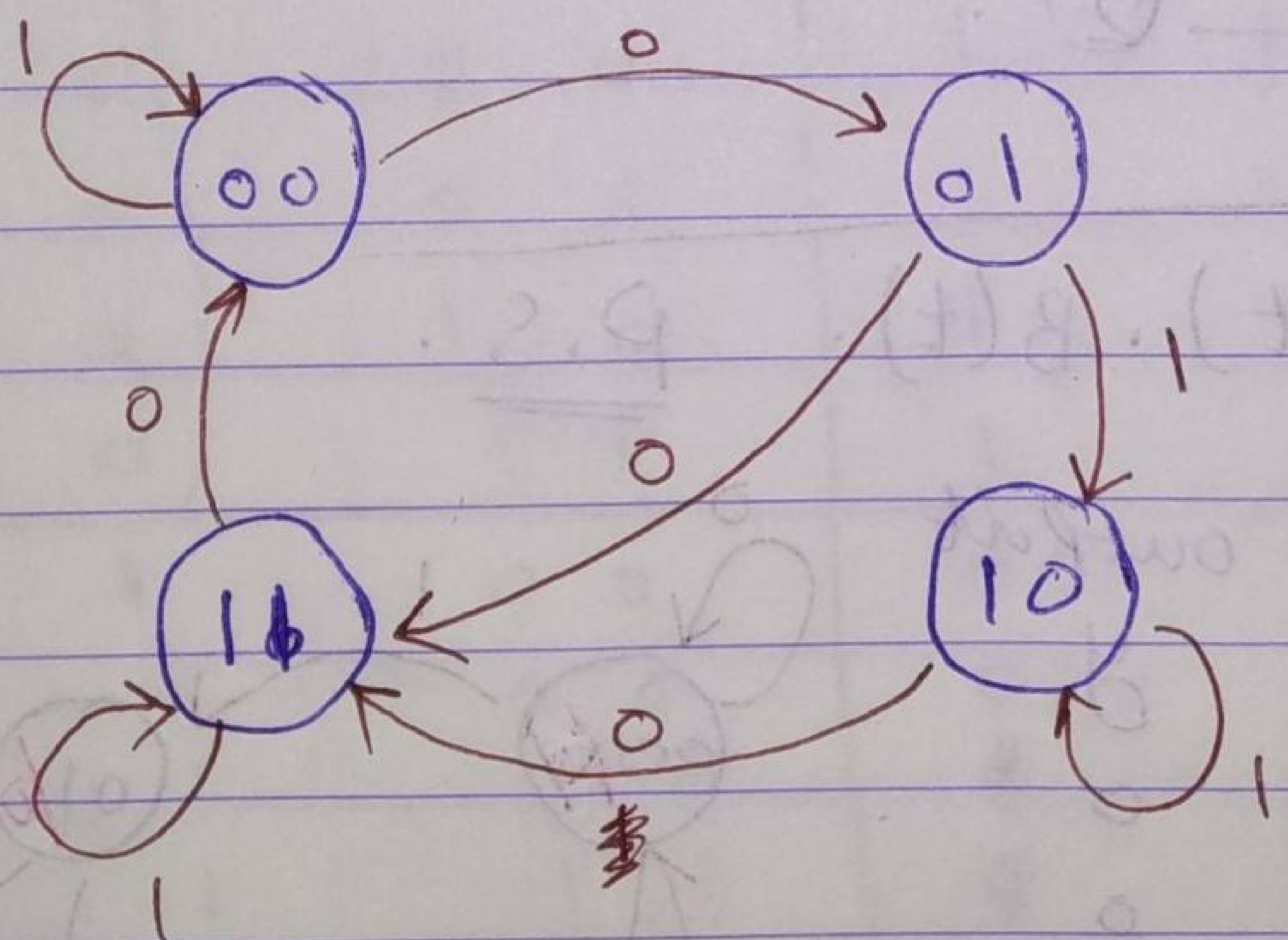
$\bar{A}\cdot B + A\cdot\bar{B} + A\cdot X$.

$\bar{0}\cdot 0 + 0\cdot\bar{0} + 0\cdot 1$

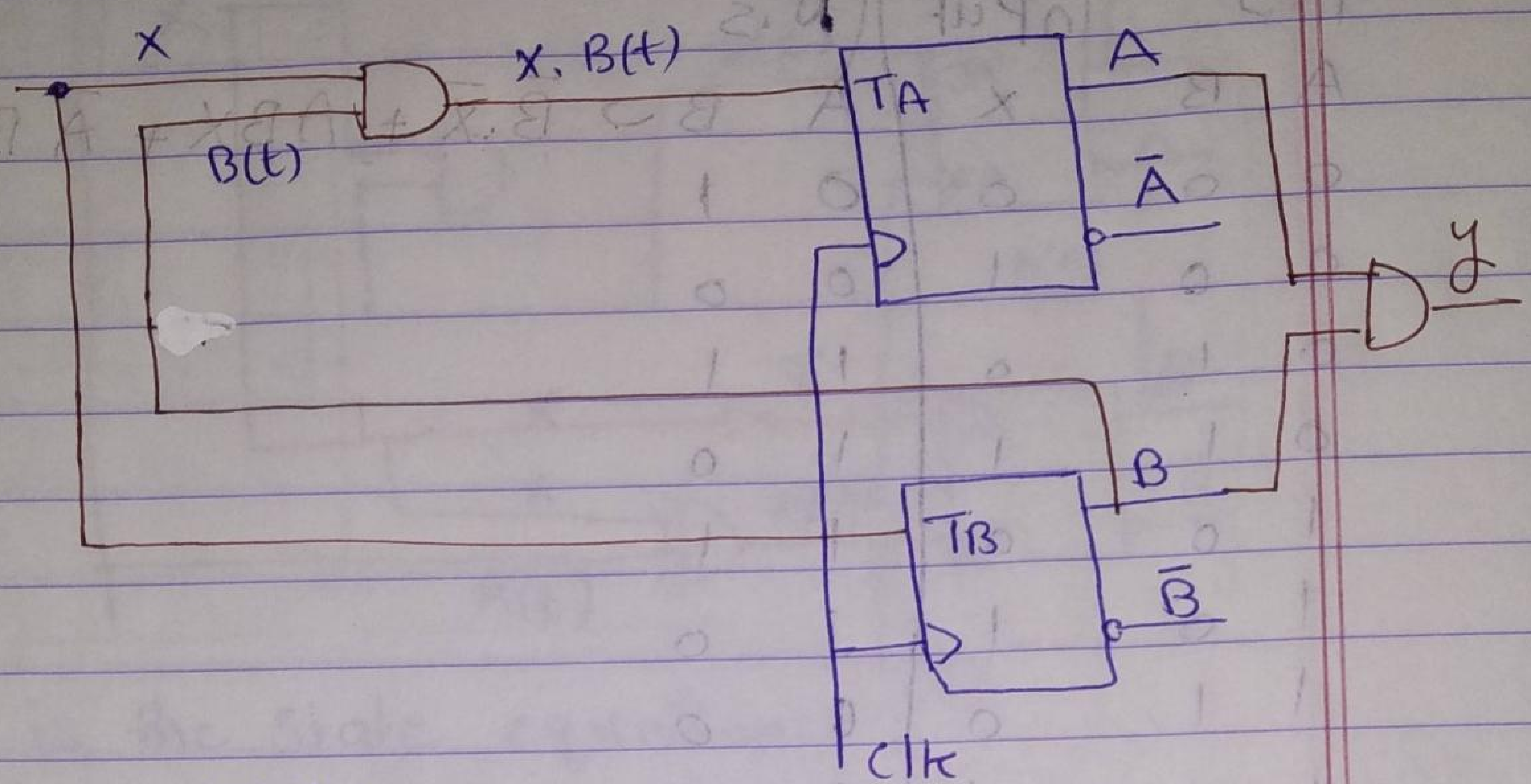
P.S		input	N.S	
A	B	x	A	B
0	0	0	0	1
0	0	1	0	0
0	1	0	1	1
0	1	1	1	0
1	0	0	1	1
1	0	1	1	0
1	1	0	0	0
1	1	1	1	1

B → $\bar{B}\cdot\bar{X} + ABX + \bar{A}B\bar{X}$.

③ State Diagram.



ex



$A(t+1) = T_A \oplus A(t).$

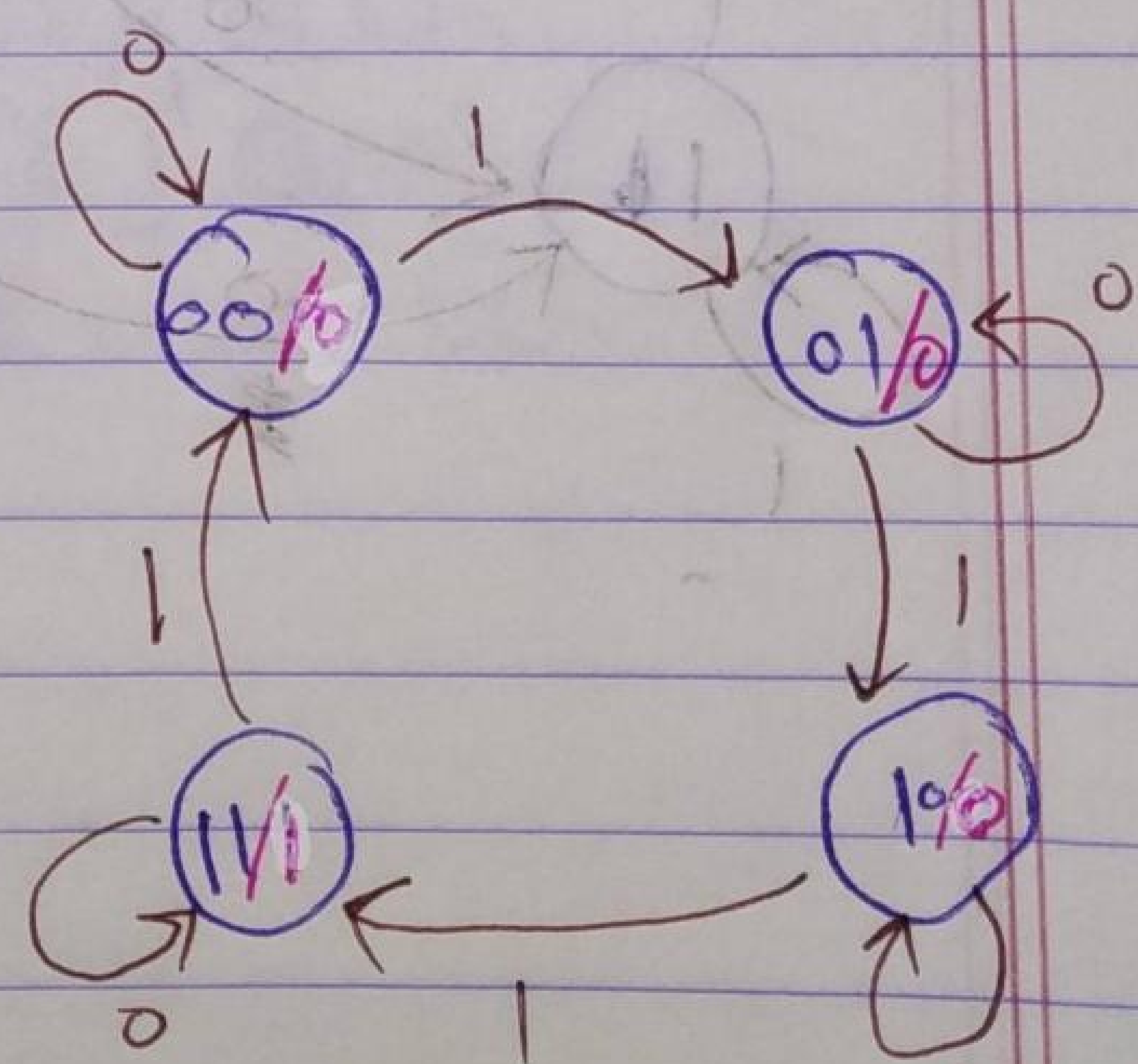
$A(t+1) = [X.B] \oplus A$ —— ①

$B(t+1) = T_B \oplus B(t).$

$= X \oplus B$ —— ②.

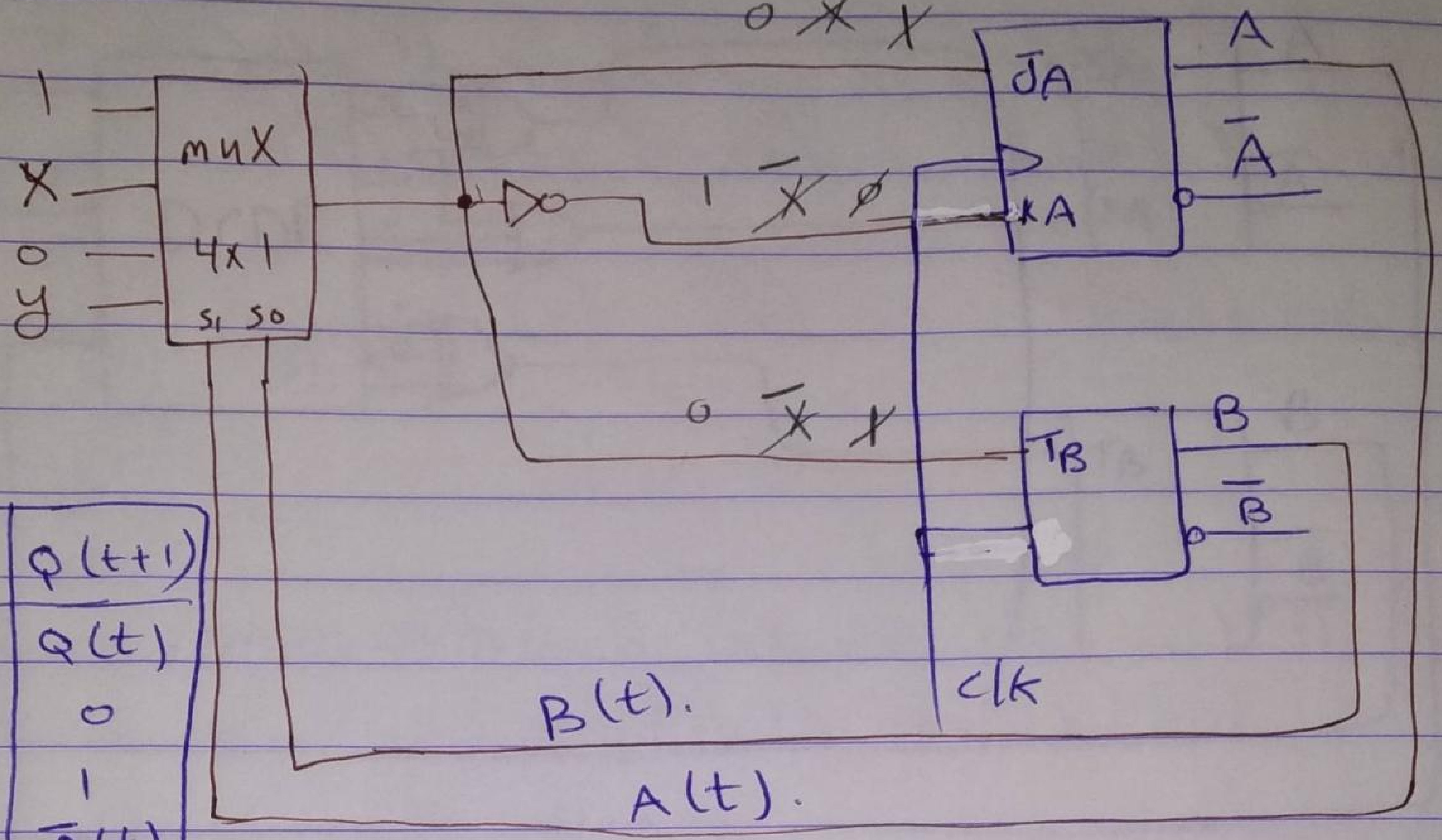
output $y = A(t) . B(t).$ P.S.

P.S A	P.S B	input x	N.S A	N.S B	output y
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	1	0
0	1	1	1	0	0
1	0	0	1	0	0
1	0	1	1	1	0
1	1	0	1	1	1
1	1	1	0	0	1



حطينا ال output داخل الدوائر لأنه يعتمد على p.s فقط.

ex

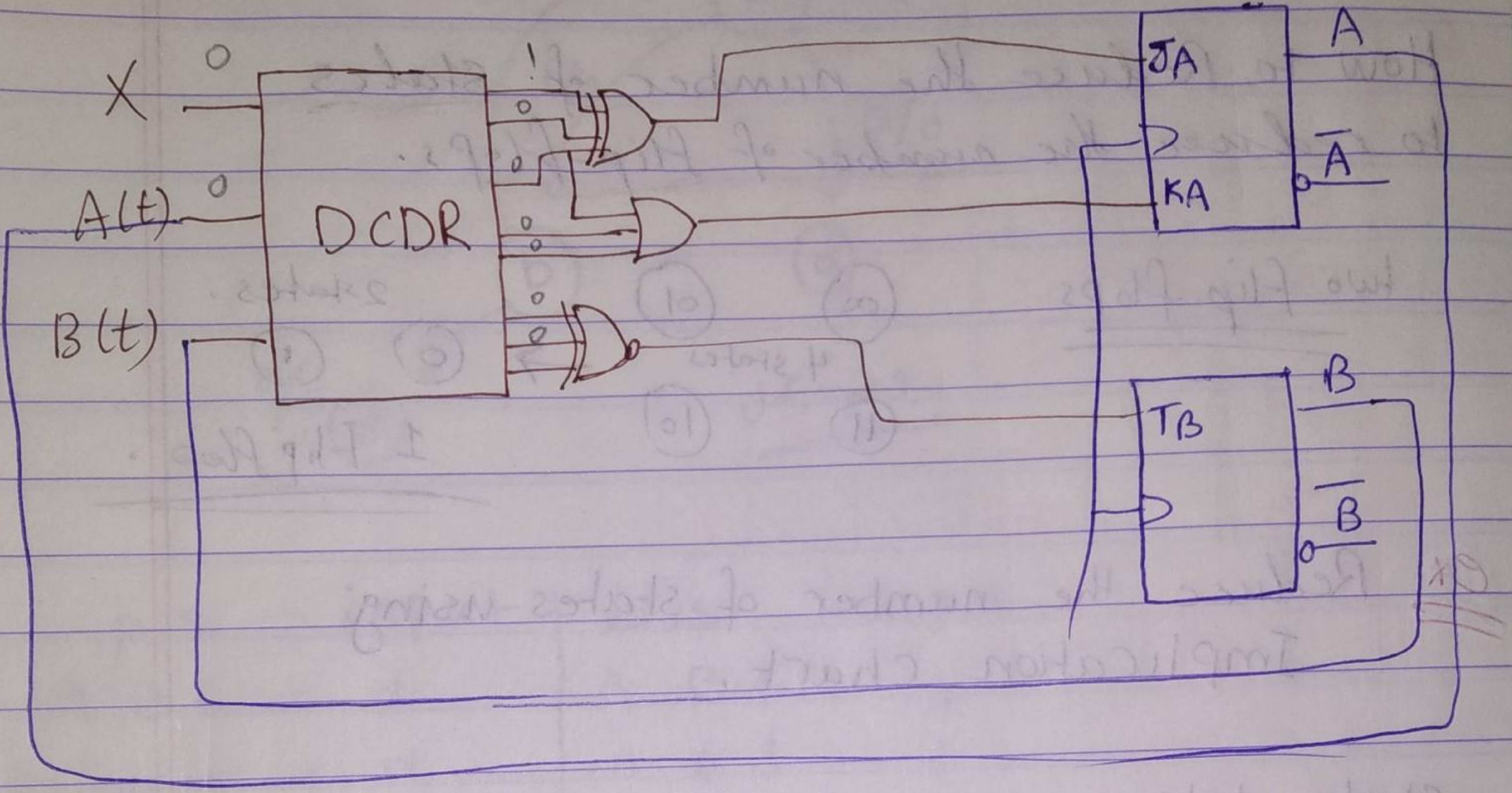


J	K	Q(t+1)
0	0	Q(t)
0	1	0
1	0	1
1	1	$\bar{Q}(t)$

T	Q(t+1)
0	Q(t)
1	$\bar{Q}(t)$

P.S		input		N.S	
^{s_1}A	B^{s_0}	x	y	A	B
0	0	0	0	1	1
0	0	0	1	1	1
0	0	1	0	1	1
0	0	1	1	1	1
0	1	0	0	0	1
0	1	0	1	0	1
0	1	1	0	0	0
0	1	1	1	0	0
1	0	0	0	0	0
1	0	0	1	0	0
1	0	1	0	0	0
1	0	1	1	0	0
1	1	0	0	1	0
1	1	0	1	0	1
1	1	1	0	1	0
1	1	1	1	0	1

مش متأكدة
منها .
(اذا غلط احكولي
٨_٨).



input	P.S		N.S	
X	A	B	A	B
0	0	0	1	1
0	0	1	1	0
0	1	0	0	1
0	1	1	0	0
1	0	0	0	1
1	0	1	0	1
1	1	0	1	0
1	1	1	1	1

J	K	Q (t+1)
0	0	Q (t)
0	1	0
1	0	1
1	1	$\bar{Q}$ (t).

T	Q (t+1)
0	Q (t)
1	$\bar{Q}$ (t).

طريقة الدارع.

Implication chart for State Reduction.

How to Reduce the number of states to reduce the number of flip-flops.

two flip-flops

00 01

4 states →

11 10

2 states.

0 1

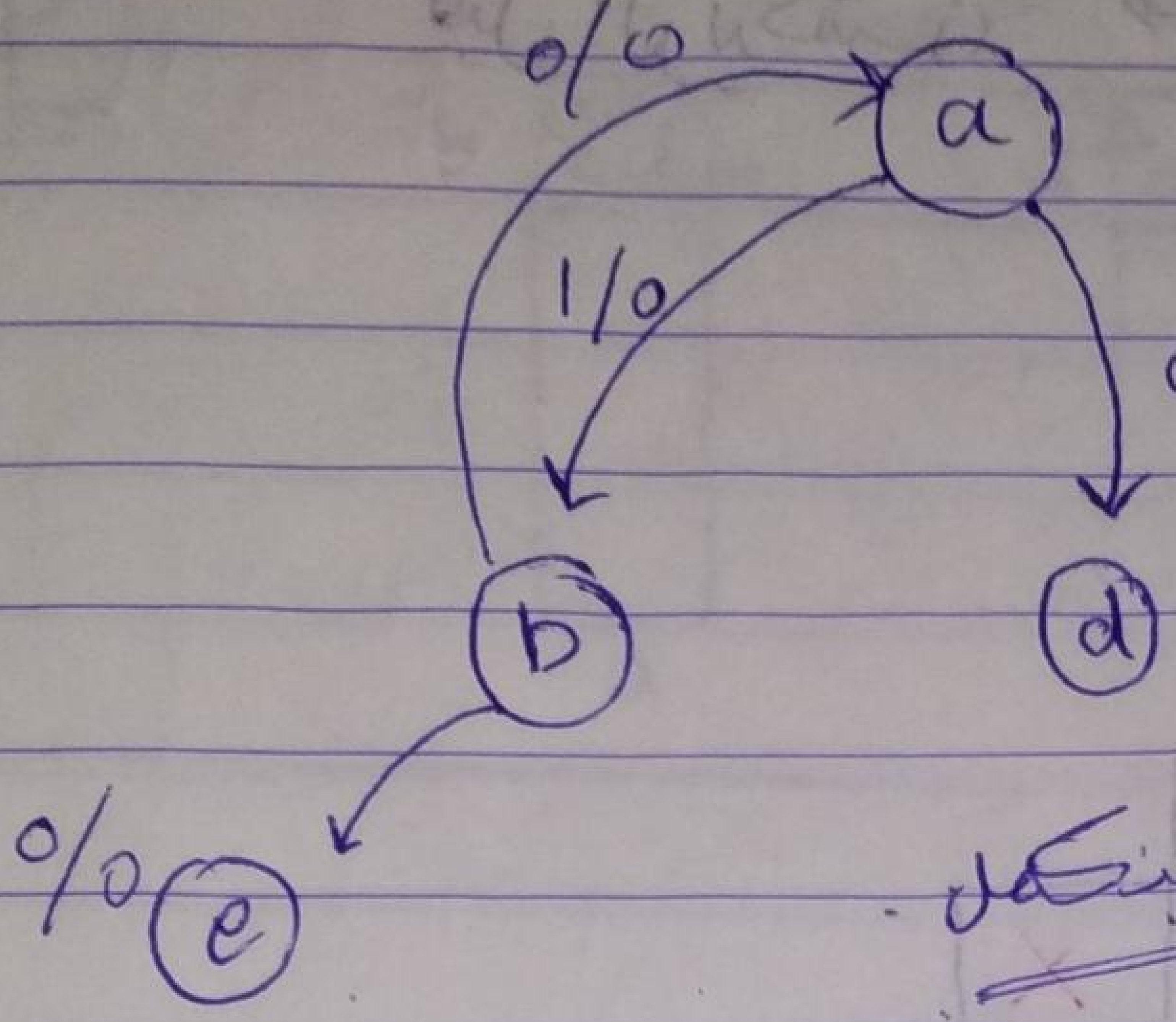
1 flip flop.

Reduce the number of states using Implication chart.

State table

P.S		N.S x=0	N.S x=1	output x=0	output x=1
000	a	d	b	0	0
001	b	e	a	0	0
010	c	g	f	0	1
011	d	a	d	1	0
100	e	a	d	1	0
101	f	c	b	0	0
110	g	a	e	1	0

⟹



ونكمل .

p.s			input	N.S			output
A	B	C	x	A	B	C	y
0	0	0	0	0	ϕ	1	0
0	0	0	1	0	0	1	0
0	0	1	0	1	0	0	0
0	0	1	1	0	0	0	0
0	1	0	0				
		⋮					
1	1	1	1				

7 flip flops ⇝ قبل الريدكشن

b	d,e ~~a,b~~ ✓					
c	X	X				
d	X	X	X			
e	X	X	X	✓		
f	c,d ~~b,b~~ X	c,e a,b X	X	X	X	
g	X	X	X	~~a,a~~ d,e ✓	~~a,a~~ d,e ✓	X
	a	b	c	d	e	f

• different output بيطلعوا two state ال اذا كانوا X بحط ①

② two state ⇒ same output & same next state. (✓)

(a,b) , (d,e) , (d,g) , (e,g) equivalent

(a,b) (d,e,g) ⇐

a ≡ b

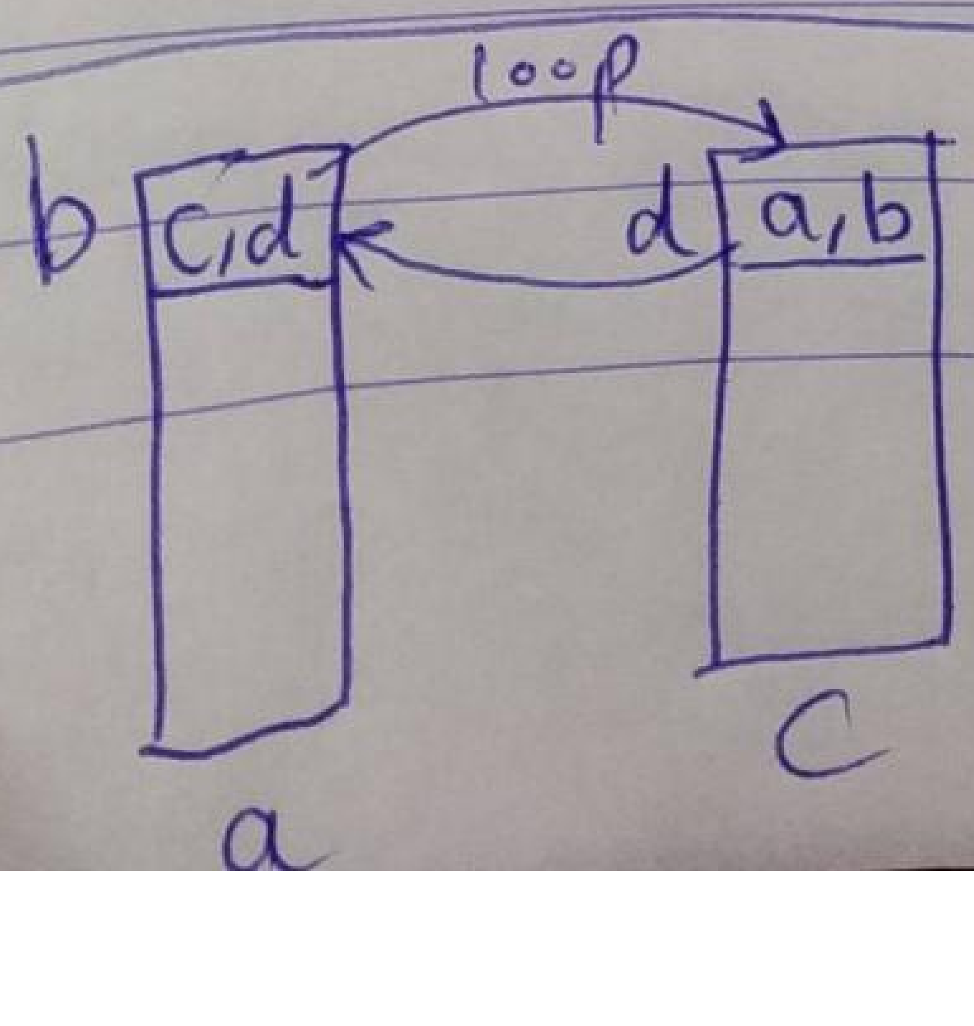
d ≡ e ≡ g.

p.s	N.S	output
a	d a	0 0
c	d f	0 1
d	a d	1 0
f	c a	0 0

4 state

بدل 7

loop

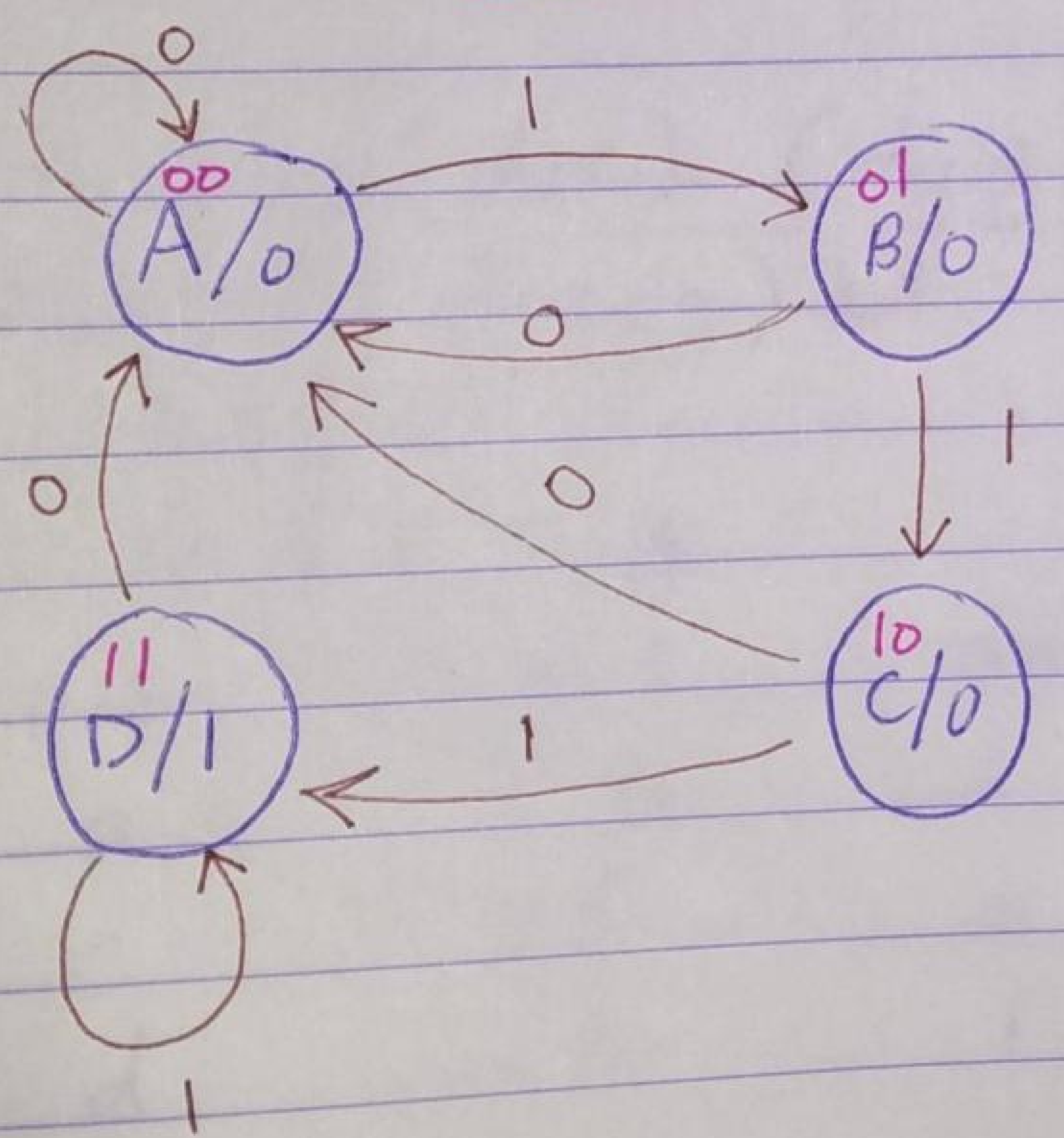


* Design procedure. المراحل

1. Read the problem carefully
2. Derive the State Diagram.
3. Assign Binary values to the states.
4. State Table.
5. Determine the type of flip flop.
6. Derive the input equation.
7. Draw the circit.

ex Design asequential cercit that detects three or more consecutive one's? DFF

111 ✓ 1011 ✗



p.s A	p.s B	input X	N.S A (DA)	N.S B (DB)	output y
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	0	0
0	1	1	1	0	0
1	0	0	0	0	0
1	0	1	1	1	0
1	1	0	0	0	1
1	1	1	1	1	1

ال output يعتمد فقط على ال p.s لأنه more

11/1 10/0 01/0 00/0

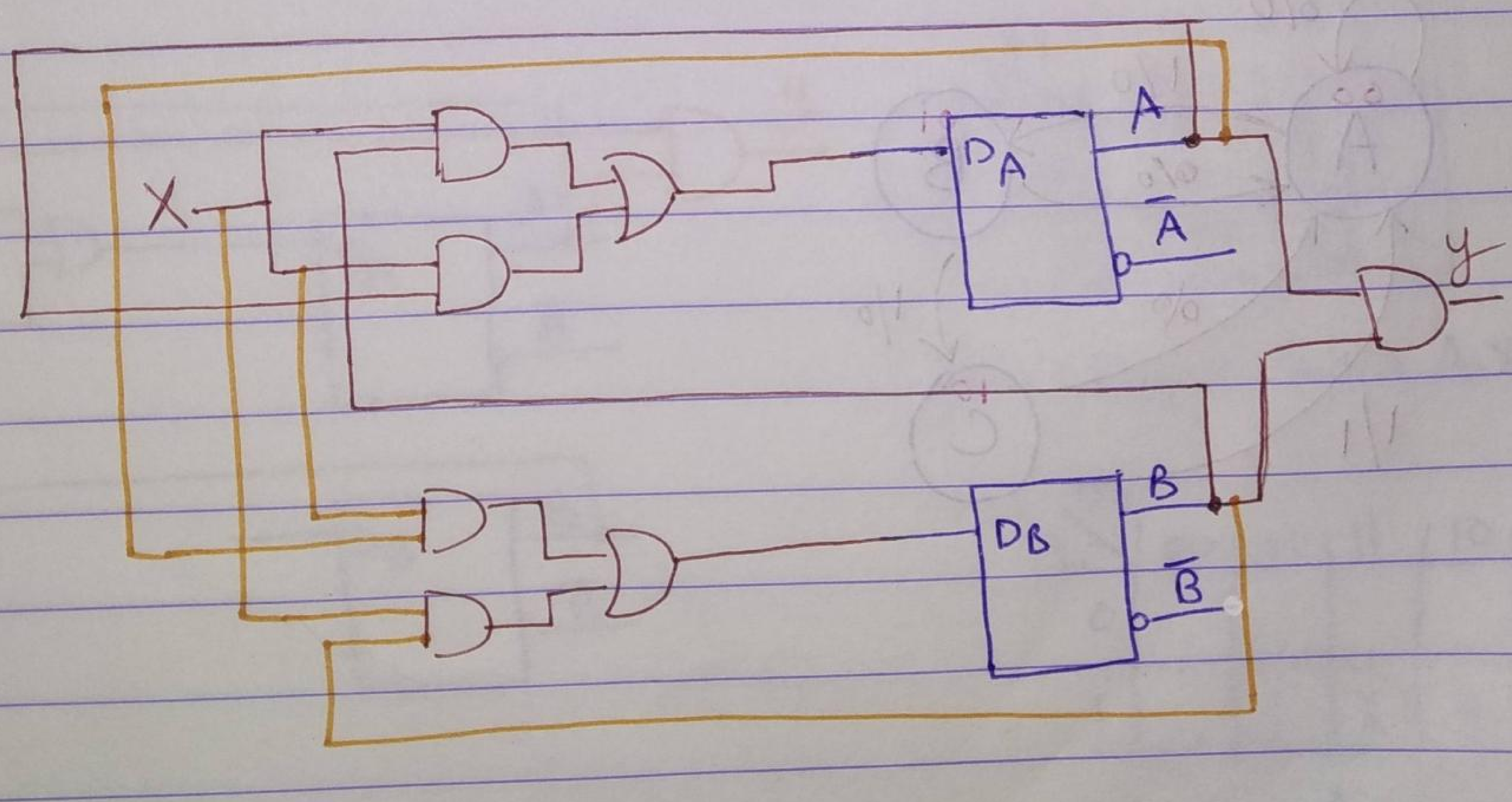
A(t) \ B(t)x	00	01	11	10
0			1	
1		1	1	

$D(A) = A(t+1)$.

$DA = B.X + A.X$

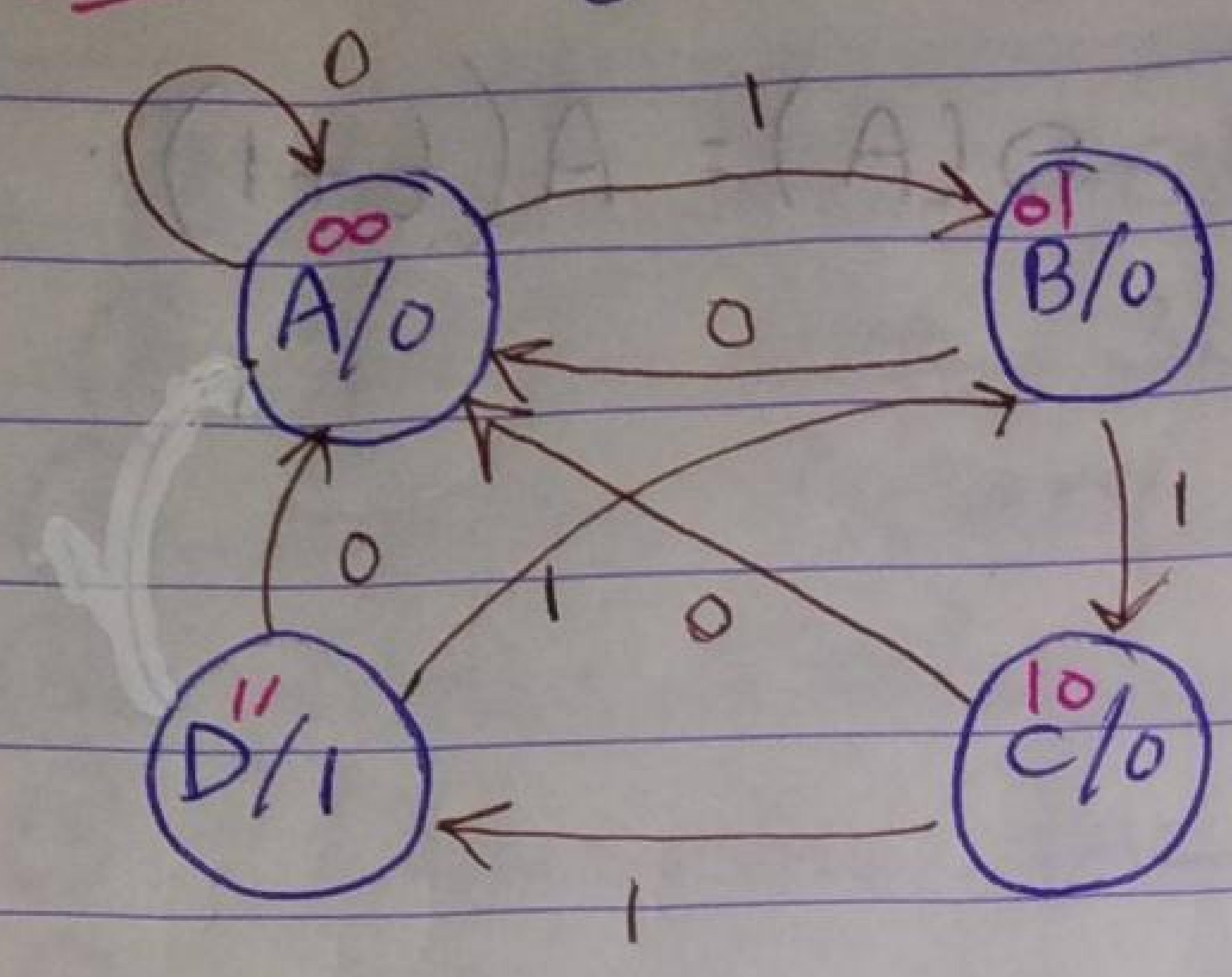
A \ BX	00	01	11	10
0		1		
1		1	1	

$B(t+1) = DB = \bar{B}X + AX$.



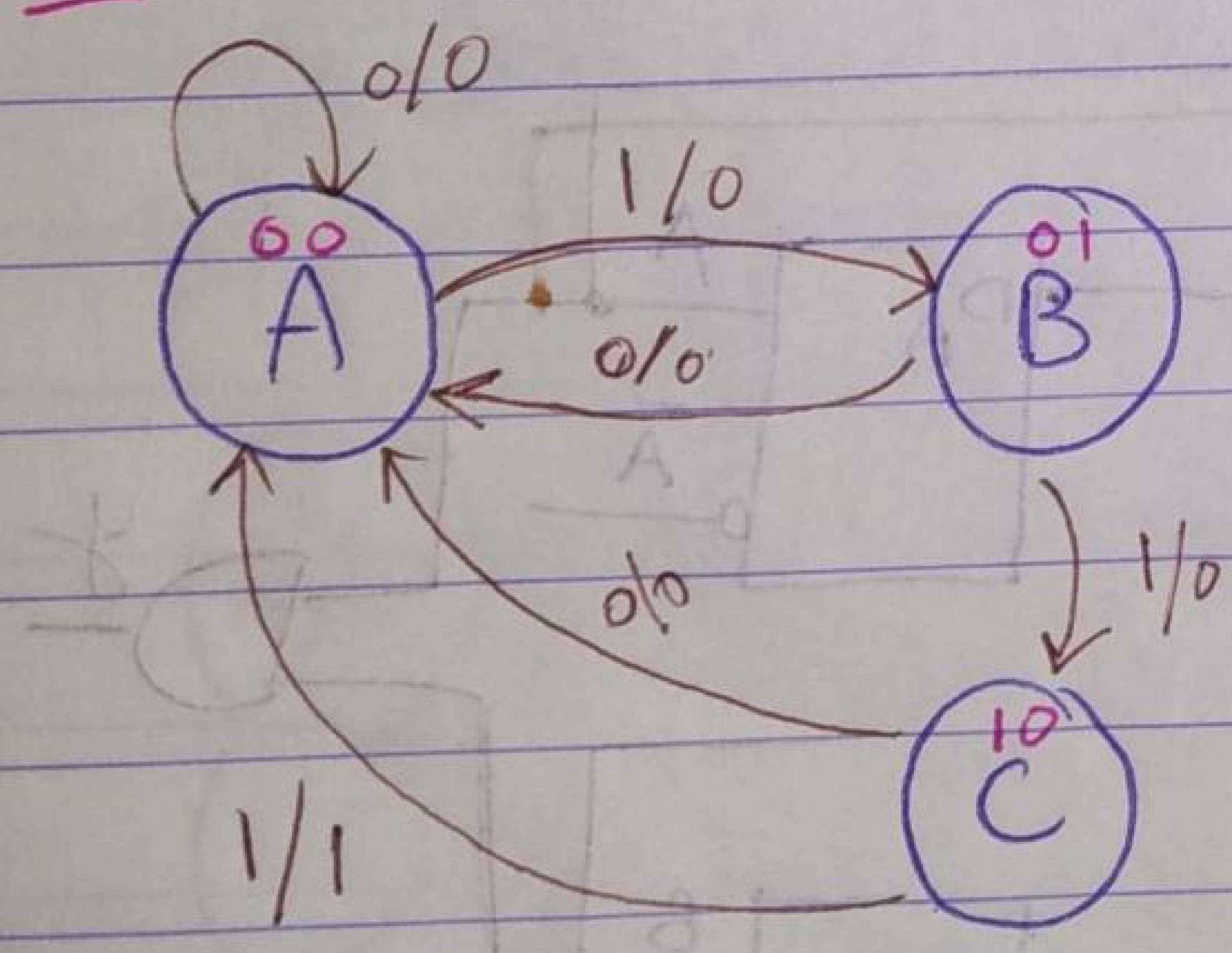
ex Design to detect three Consecutive ones ?

$\underbrace{11}_{1}1$ $\quad 1\underbrace{11}_{1}$



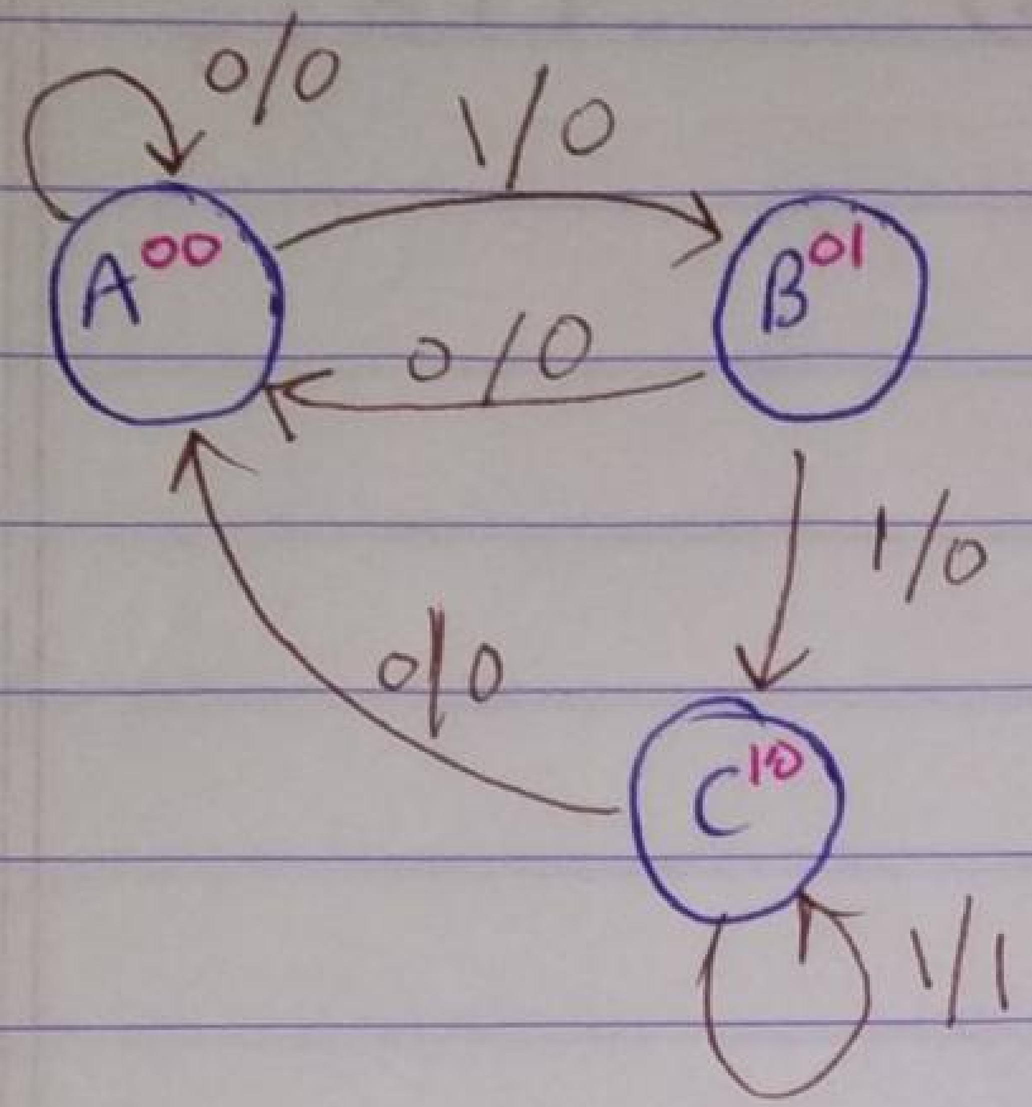
P.S A	P.S B	input X	N.S A	N.S B	output y
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	0	0
0	1	1	1	0	0
1	0	0	0	0	0
1	0	1	1	1	0
1	1	0	0	0	1
1	1	1	0	1	1

ex Design a circit to detect 3 consecutive ones ? **Mealy**



ex Design synchronous sequential circit to detect three or more consecutive ones?

mealy



P.S A	P.S B	input x	N.S A	N.S B	output y
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	0	0
0	1	1	1	0	0
1	0	0	0	0	0
1	0	1	1	0	1
1	1	0	X	X	X
1	1	1	X	X	X

مش موجودة .

D-ff.

$A(t+1) = D_A$

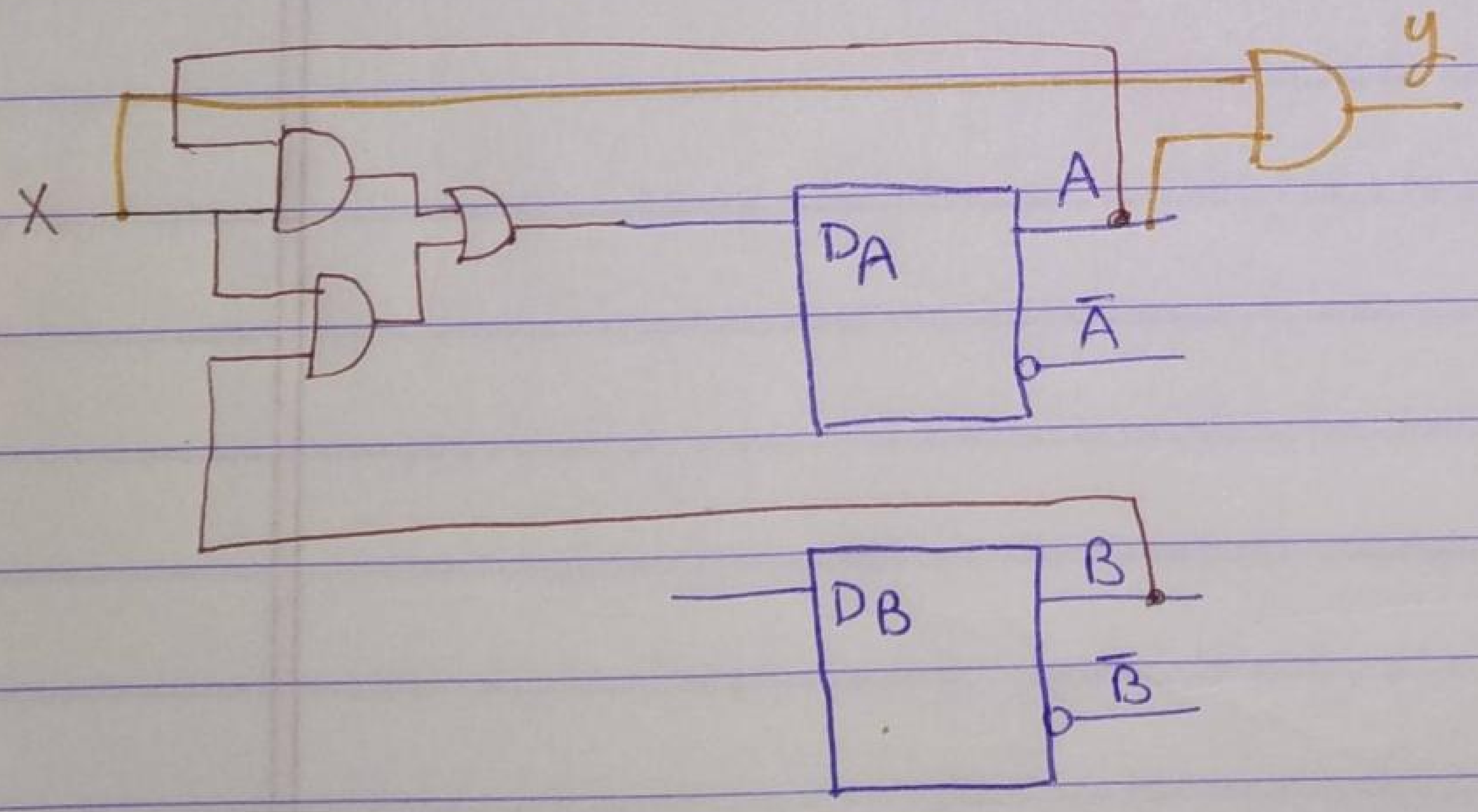
$B(t+1) = D_B$

A \ BX	00	01	11	10
0		.	1	
1		1	X	X

$D_A = B.X + A.X$

A \ BX	00	01	11	10
0				
1		1	X	X

$y = A.X$



ex Design synchronous circit to detect three or more ones? Consecutive فقط