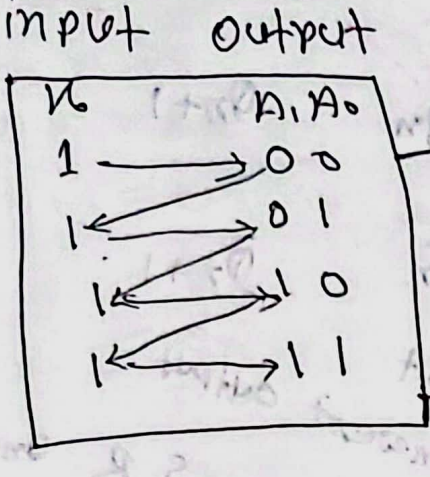
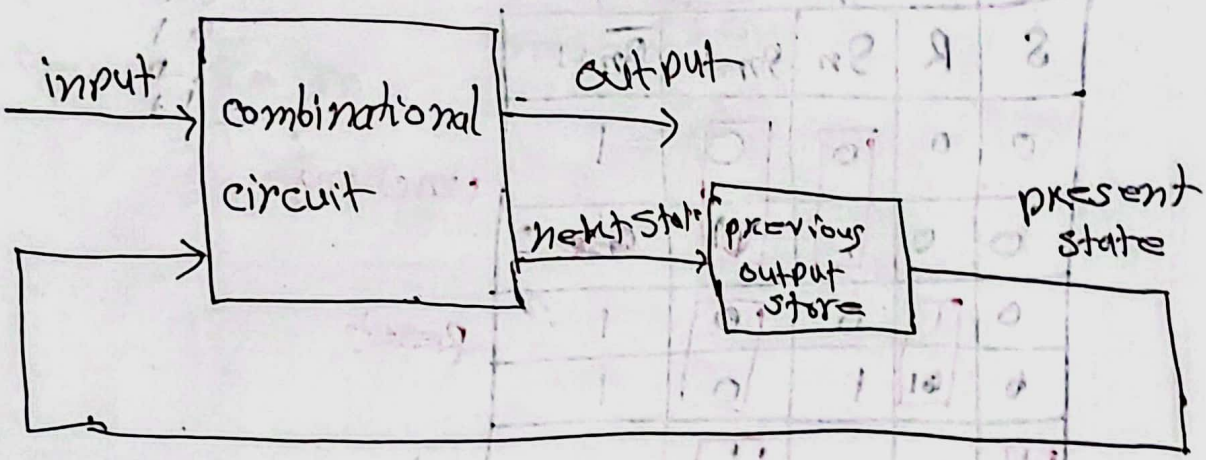
Sequential circuit



এটিতে নির্ভর করে previous output এর উপর; বর্তমান input এর উপর

Counter circuit



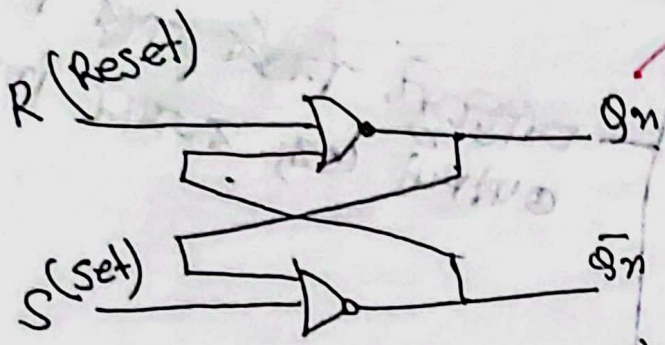
Circuit 2 প্রকার

Synchronous sequential circuit → Depend on time

Asynchronous sequential circuit → not depend on time

1 bit store / Latch

SR Latch (NOR)



previous → Q_n | main output → Q_{n+1}

S	R	Q_n	Q_{n+1}	$\bar{Q}_{n+1}$
0	0	0	0	1
0	0	1	1	0
0	1	0	0	1
0	1	1	0	1
1	0	0	1	0
1	0	1	1	0
1	1	0		
1	1	1		

priority → previous output → present output

unchange

Reset

set

} undefined

S	R	Q_{n+1}	$\bar{Q}_{n+1}$
0	0		
0	1		
1	0		
1	1		

S, R = 0 অবস্থায় Q_n যা আগে তাই।

Set, Reset এর ক্ষেত্রে SR Latch এর ক্ষেত্রে যেখানে 1 আছে তার সাথে compare করে নাম দিতে হবে।

Q_{n+1} এবং $\overline{Q_{n+1}}$ বের করতে হবে equal diagram থেকে।

$S=0, R=0$

$Q_{n+1} = R + \overline{Q_n}$

$Q_{n+1} = 0 + \overline{Q_n}$

$= \overline{Q_n}$

$= Q_n$

$= 0$

$S=0 \quad R=1$

$Q_{n+1} = \overline{R + \overline{Q_n}}$

$= \overline{1+1}$

$= 0$

$S=0 \quad R=0$

$\overline{Q_{n+1}} = \overline{0 + Q_n}$

$= \overline{0+Q_n}$

$= \overline{0}\,\overline{Q_n}$

$= 1$

$\overline{Q_{n+1}} = \overline{S + Q_n}$

$= \overline{0+0}$

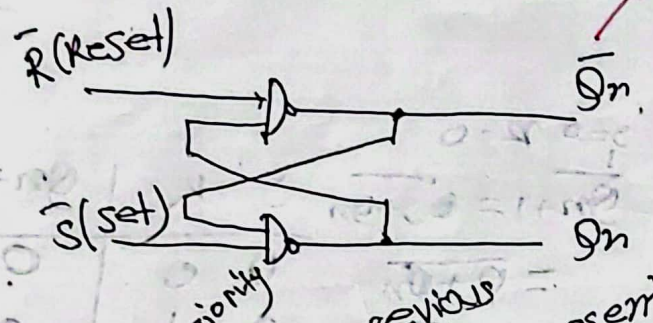
$= 1$

S	R	Q_{n+1}	$\overline{Q_{n+1}}$
0	0	0	1
0	1	0	1
1	0	1	0
1	1	1	1

↓ invalid

input		output	
S	R	Q_{n+1}	$\overline{Q_{n+1}}$
0	0	unchange	
0	1	0	1
1	0	1	0
1	1	undefined	

$\bar{S}\bar{R}$ Latch (NAND)



previous output → Q_n, $\bar{Q}_n$

present output → Q_{n+1}, $\bar{Q}_{n+1}$

priority → previous → present output

$\bar{S}$	$\bar{R}$	Q_n	Q_{n+1}	$\bar{Q}_{n+1}$	
0	0	0	1	1	} invalid
0	0	1	1	1	
0	1	0	0	1	} Reset
0	1	1	0	1	
1	0	0	1	0	} Reset
1	0	1	1	0	
1	1	0	0	1	} unchanged
1	1	1	0	1	

$\bar{S}$	$\bar{R}$
0	0
0	1
1	0
1	1

আমি আগের অভিজ্ঞতা সাপেক্ষে চাই হবে।

এটা SR gate (NOR) এর উল্টো

$\bar{S}=0, \bar{R}=0$, invalid যাবার $\bar{Q}_{n+1}$ এবং Q_{n+1} এর মান বিপরীত থাকার কথা কিন্তু এমন থাকে

Q_{n+1} and $\overline{Q_{n+1}}$ get from diagram

$S=0$ $R=0$

$Q_{n+1} = \overline{S + \bar{Q}_n}$

$= \overline{0 \cdot \bar{Q}_n}$

$= 1$

$\overline{Q_{n+1}} = \overline{R \cdot Q_n}$

$= \overline{0 \cdot Q_n}$

$= 1$

S	R	Q_{n+1}	$\overline{Q_{n+1}}$
0	0	undefind	
0	1		
1	0		
1	1		

$S=0$ $R=1$

$Q_{n+1} = \overline{S \cdot \bar{Q}_n}$

$= \overline{0 \cdot \bar{0}}$

$= 1$

$\overline{Q_{n+1}} = \overline{R \cdot Q_n}$

$= 1$

S	R	Q_{n+1}	$\overline{Q_{n+1}}$
0	0		
0	0		
0	0		
0	1		
0	1		
1	1		
1	1		

S	R	Q_{n+1}	$\overline{Q_{n+1}}$
0	0		
0	1		
1	0		
1	1		

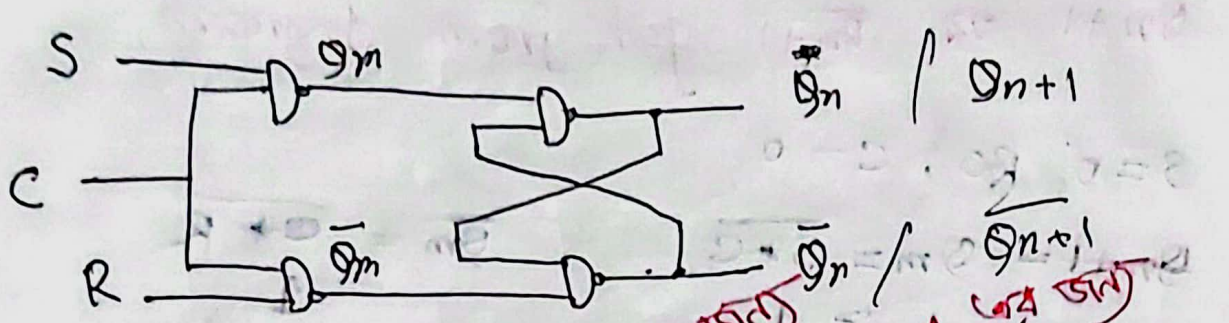
Q_{n+1}	$\overline{Q_{n+1}}$
invalid	
1	0
0	1

unchange

S	R	Q_{n+1}	$\overline{Q_{n+1}}$
0	1	1	0
1	1	1	0
1	0	0	1
1	1	0	1
0	0	1	1

possible NT

SR Latch with control / Flip-Flop



$C=0$ এর জন্য $C=1$ এর জন্য

C	S	R	Q_n	Q_{n+1} / $C=0$	Q_{n+1} / $C=1$
0	0	0	0	0	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
1	1	0	1	0	1
1	1	1	0	0	undefined
1	1	1	1	0	undefined

এখানে আমি সবেমাত্র SR Latch এর সাথে তুলনা করেছি তাহলে Q_n এবং $\bar{Q}_n$ কে S R এর সাথে তুলনা করতে হবে।

⊗ $C=0,\ S=0\ \ R=0\ \ Q_n=0$

$Q_m=1$

$Q_n=\overline{Q_m\cdot\overline{Q_n}}$

$=\overline{1\cdot1}$

$=0$

$\overline{Q_m}=1$

$\overline{Q_n}=\overline{\overline{Q_n}\cdot\overline{Q_m}}$

$=\overline{0\cdot1}$

$=1$

clock = 1

⊗ $C=0,\ S=0\ \ R=0,\ Q_n=0$

$Q_m=1$

$Q_n=\overline{Q_m\cdot\overline{Q_n}}$

$=0$

$\overline{Q_m}=1$

$\overline{Q_n}=\overline{Q_m\cdot Q_n}$

$=1$

$C=1,\ S=0,\ R=0,\ Q=0$

$Q_m=1$

$Q_n=\overline{Q_m\cdot\overline{Q_n}}$

$=\overline{1\cdot1}$

$=0$

$\overline{Q_m}=1$

$\overline{Q_n}=\overline{\overline{Q_m}\cdot Q_n}$

$=\overline{1\cdot0}$

$=1$

⊗ $C=0,\ S=1\ \ R=0,\ Q=0$

$Q_m=1$

$Q_n=\overline{Q_m\cdot\overline{Q_n}}$

$=\overline{1\cdot1}$

$=0$

$\overline{Q_m}=1$

$\overline{Q_n}=\overline{\overline{Q_m}\cdot Q_n}$

$=\overline{1\cdot0}$

$=1$

$C=1,\ S=0,\ R=1,\ Q=0$

$Q_m=1$

$Q_n=\overline{Q_m\cdot\overline{Q_n}}$

$=\overline{1\cdot1}$

$=0$

$\overline{Q_m}=0$

$\overline{Q_n}=\overline{\overline{Q_m}\cdot Q_n}$

$=\overline{0\cdot1}$

$=1$

⊗ $C=0,\ S=1,\ R=1,\ Q_n=0$

$Q_m=1$

$Q_n=\overline{Q_m\cdot\overline{Q_n}}$

$=0$

$\overline{Q_m}=1$

$\overline{Q_n}=\overline{Q_m\cdot Q_n}$

$=1.0$

$=1$

$C=1,\ S=1,\ R=0,\ Q_n=0$

$Q_m=0$

$Q_n=\overline{Q_m\cdot\overline{Q_n}}$

$=\overline{0\cdot1}$

$=1$

$\overline{Q_n}=1$

$\overline{Q_n}=\overline{Q_m\cdot Q_n}$

$=\overline{1\cdot1}$

$=0$

$Q_n=1$

⊗ $C=0,\ S=1,\ R=1,\ Q_n=0$

$Q_m=1$

$Q_n=\overline{Q_m\cdot\overline{Q_n}}$

$=0$

$\overline{Q_m}=1$

$\overline{Q_n}=\overline{Q_m\cdot Q_n}$

$=1.0$

$=1$

$C=1,\ S=1,\ R=1,\ Q_n=1$

$Q_m=0$

$Q_n=\overline{Q_m\cdot\overline{Q_n}}$

$=\overline{0\cdot0}$

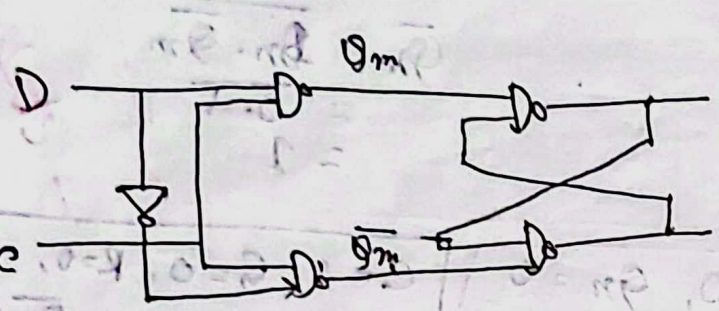
$\overline{Q_m}=0$

$\overline{Q_n}=\overline{Q_m\cdot Q_n}$

$=\overline{0\cdot1}$

Invalid ~~Unchanged~~

D Latch / Flip-Flop



D	Q_n	Q_m	$\bar{Q}_m$	Q_n	Q_{n+1}	$\overline{Q_{n+1}}$
0	0	1	1		0	1
0	1	1	1		0	1
1	0	1	0		1	0
1	1	0	1		1	0

~~C = 0 D~~

C	D	Q_n	$\bar{Q}_n$
0	X	unchanged	
1	0	0	1
1	1	1	0

D	Q_n	Q_{n+1}
0	0	0
0	1	0
1	0	1
1	1	1

$Q_n = 0$

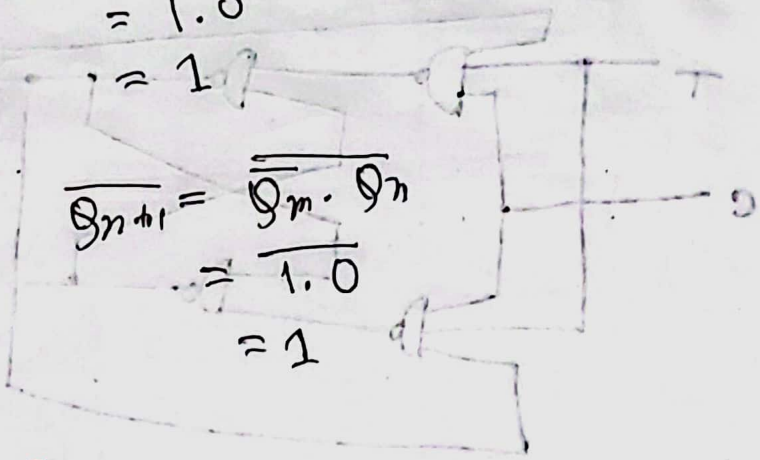
$C = 0 \quad D = 0$

$Q_m = \overline{D.C}$
$= \overline{0.0}$
$= 1$

$\overline{Q_m} = \overline{\overline{D.C}}$
$= 1.0$
$= 1$

$Q_{n+1} = \overline{\overline{Q_m}.\overline{Q_n}}$
$= \overline{1.1}$
$= 0$

$\overline{Q_{n+1}} = \overline{Q_m.Q_n}$
$= \overline{1.0}$
$= 1$



$C = 0, \quad D = 1 \quad Q = 0$

$Q_m = 1$

$Q_{n+1} = \overline{Q_m.\overline{Q_n}}$
$= \overline{1.1}$
$= 0$

$\overline{Q_m} = 1$

$\overline{Q_{n+1}} = \overline{Q_m.Q_n}$
$= \overline{1.0}$
$= 1$

Q_n	T
0	0
1	0
0	1
1	1

$C = 1 \quad D = 0, \quad Q = 0$

$Q_m = 1$

$Q_{m+1} = 0$

$Q_m = 0$

$\overline{Q_{n+1}} = 1$

$C = 1 \quad D = 1 \quad Q = 0$

$Q_m = 0$

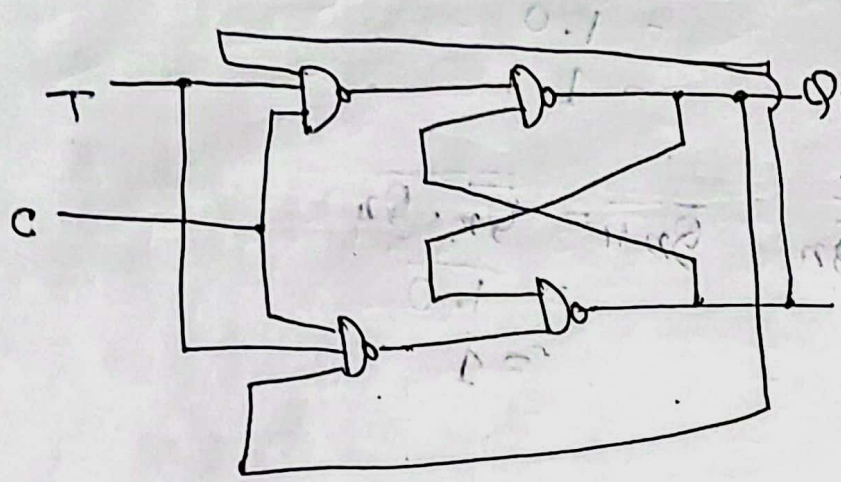
$Q_{n+1} = 1$

$\overline{Q_m} = 1$

$\overline{Q_{n+1}} = 0$

$Q_n = 1$
Q_{n+1} Toggle

T Latch



T	Q_n	Q_{n+1}
0	0	0
0	1	1
1	0	1
1	1	0

$T=0$ হলে Q_n আগের অবস্থায় থাকে

$T=1$ হলে Q_n Toggle

T	Q_n	Q_{n+1}
0	x	unchange
1	0	1
1	1	0

positive edge

negetive edge

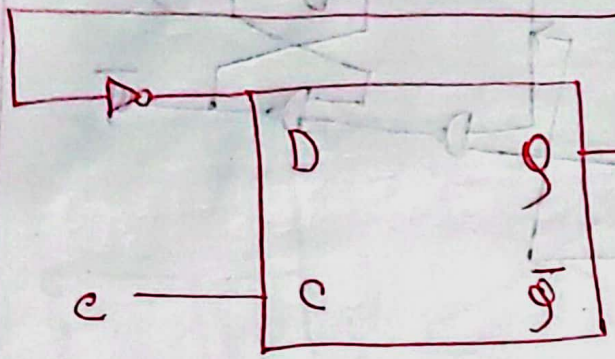
~~positive edge trigger~~

FF

C=0

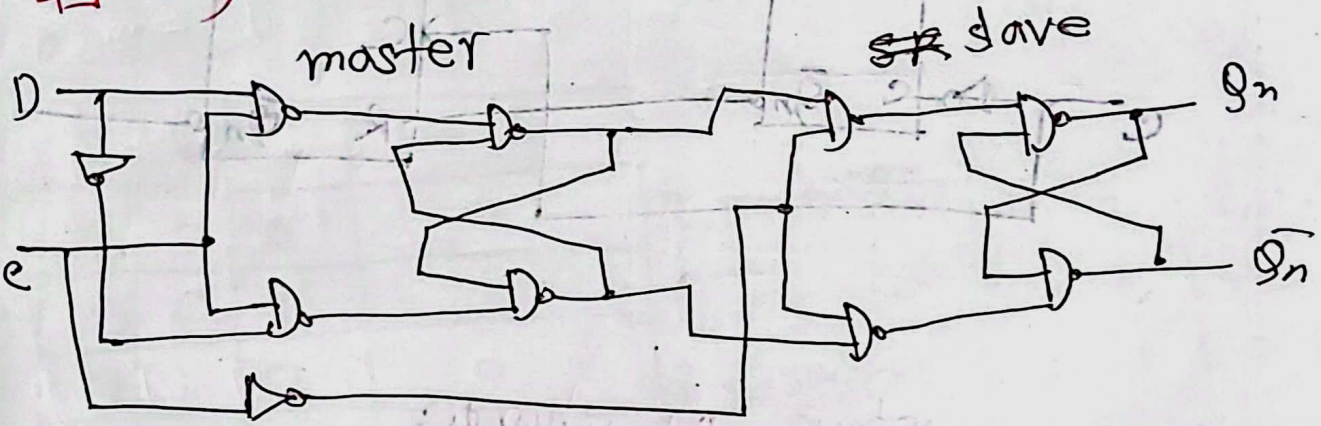
C=0

D FF

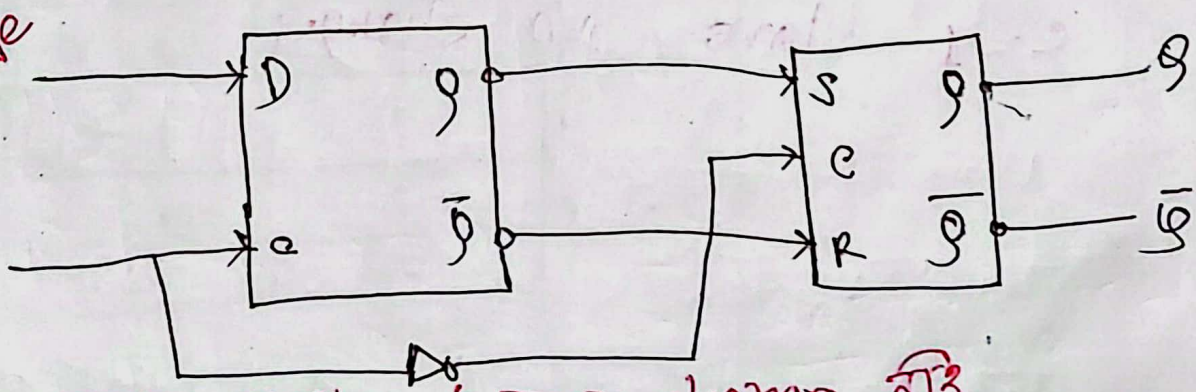


one bit memory

negative edge trigger D FF



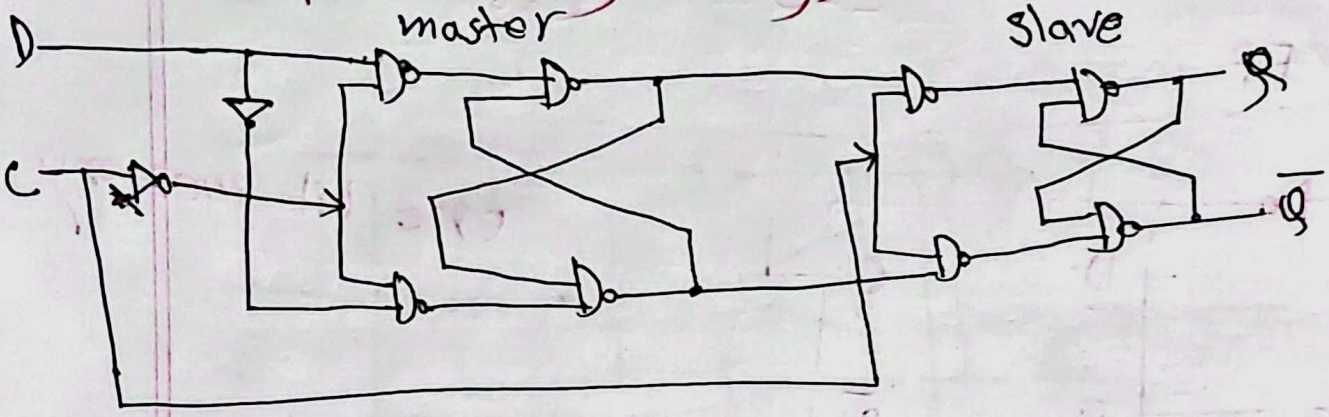
alternative

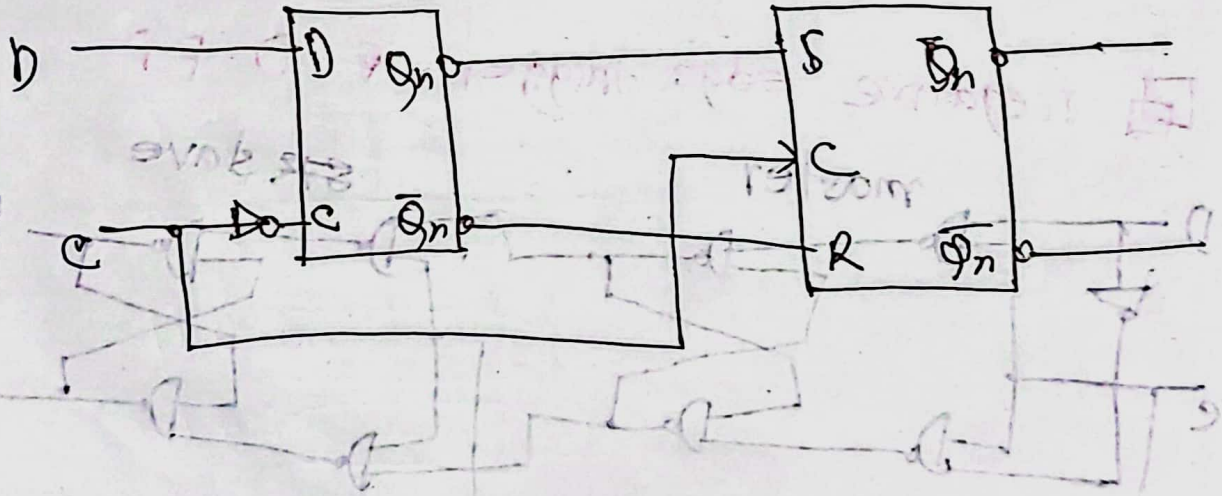


C = 0 থাকলে master এ কোন change নাই

C = 1 থাকলে slave এ কোন change নাই

Positive edge trigger D-FF



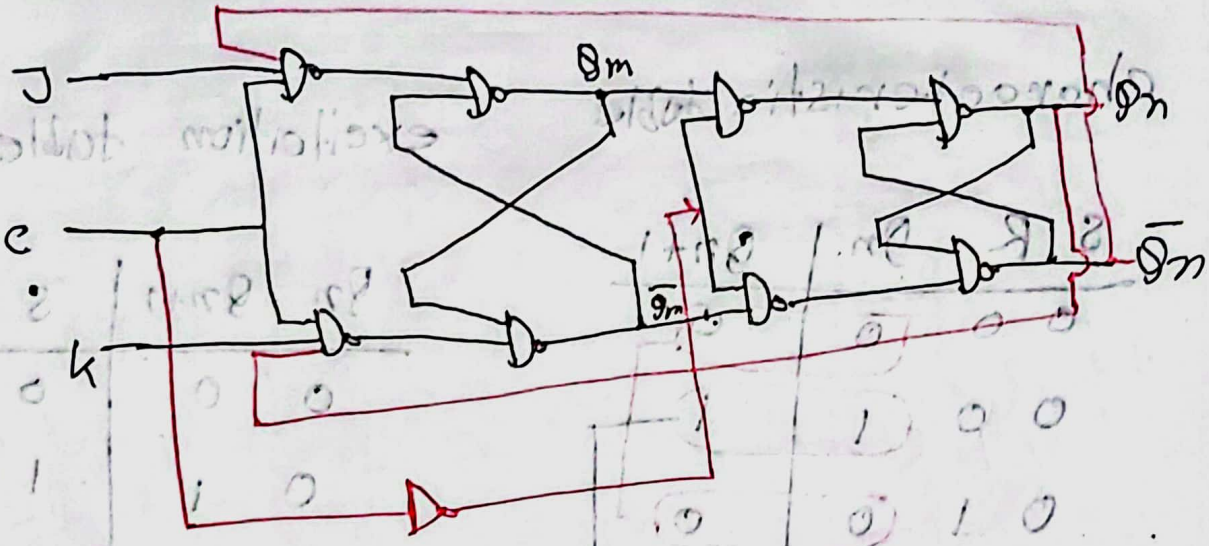


C = 0 master No change

C = 1 slave NO change

JK flip-flop

~~positive edge triggered D FF~~



J	K	Q_n	Q_{n+1}	
0	0	0	0	} nochange
0	0	1	1	
0	1	0	0	} reset
0	1	1	0	
1	0	0	1	} set
1	0	1	1	
1	1	0	1	} toggle
1	1	1	0	

J	K	Q_n $\bar{Q}_n$
0	0	nochange
0	1	0 1
1	0	1 0
1	1	Toggle

toggle

means যা আছে তার বিপরীত

Excitation table বের করার নিয়ম

SR Latch এর excitation table (XOR)

Characteristic table

S	R	Q_n	Q_{n+1}
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	invalid
1	1	1	

excitation table

Q_n	Q_{n+1}	S	R
0	0	0	X
0	1	1	0
1	0	0	1
1	1	X	0

প্রথম table থেকে দ্বিতীয় table বের করার সময় Q_n এবং Q_{n+1} এর মান দেখা করাতে হবে। যেটা যেমন আছে সেটা করবে। তারা থাকলে don't care করতে হবে।

D FF characteristic table & excitation table

Characteristic table

D	Q_n	Q_{n+1}
0	0	0
0	1	0
1	0	1
1	1	1

Excitation table

Q_n	Q_{n+1}	D
0	0	0
0	1	1
1	0	0
1	1	1

T FF characteristic table & excitation table

Characteristic table

T	Q_n	Q_{n+1}
0	0	0
0	1	1
1	0	1
1	1	0

Excitation table

Q_n	Q_{n+1}	T
0	0	0
0	1	1
1	0	1
1	1	0

All most ৪ XOR এর মতো

JK এর Excitation table

Characteristic table

J	K	Q_n	Q_{n+1}
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

Excitation table

Q_n	Q_{n+1}	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

T	Q_n	Q_{n+1}
0	0	0
1	1	0
1	0	1
0	1	1

Q_n	Q_{n+1}	T
0	0	0
1	1	0
0	1	1
1	0	1

যার থেকে যাবো তার excitation table
যেতে যাবো তার characteristic table

FF conversion

D To T এ FF conversion.

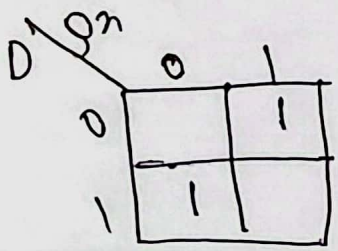
T	Q_n	Q_{n+1}	D
0	0	0	0
0	1	1	1
1	0	1	1
1	1	0	0

Q_n	Q_{n+1}	D
0	0	0
0	1	1
1	0	0
1	1	1

T to D FF conversion

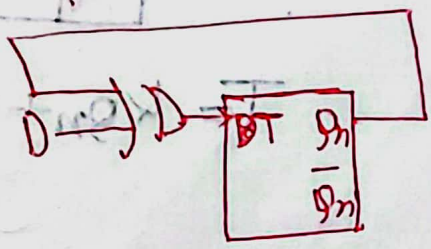
D	Q_n	Q_{n+1}	T
0	0	0	0
0	1	0	1
1	0	1	1
1	1	1	0

Q_n	Q_{n+1}	T
0	0	0
0	1	1
1	0	1
1	1	0



$T = \bar{D} Q_n + D \bar{Q}_n$

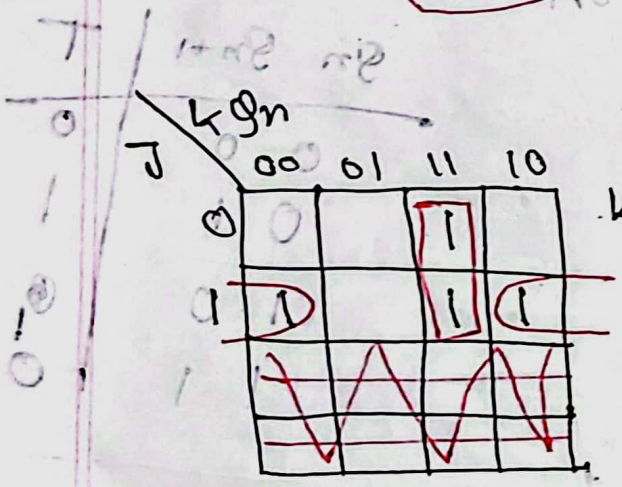
$= D \oplus Q_n$

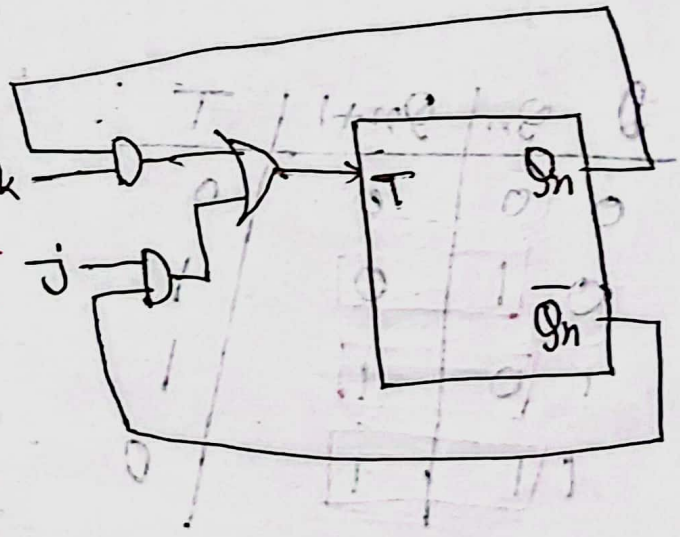


T to JK FF conversion

J	K	Q_n	Q_{n+1}	T
0	0	0	0	0
0	0	1	1	0
0	1	0	0	0
0	1	1	0	1
1	0	0	1	1
1	0	1	1	0
1	1	0	1	1
1	1	1	0	1

Q_n	Q_{n+1}	T
0	0	0
0	1	1
1	0	1
1	1	0



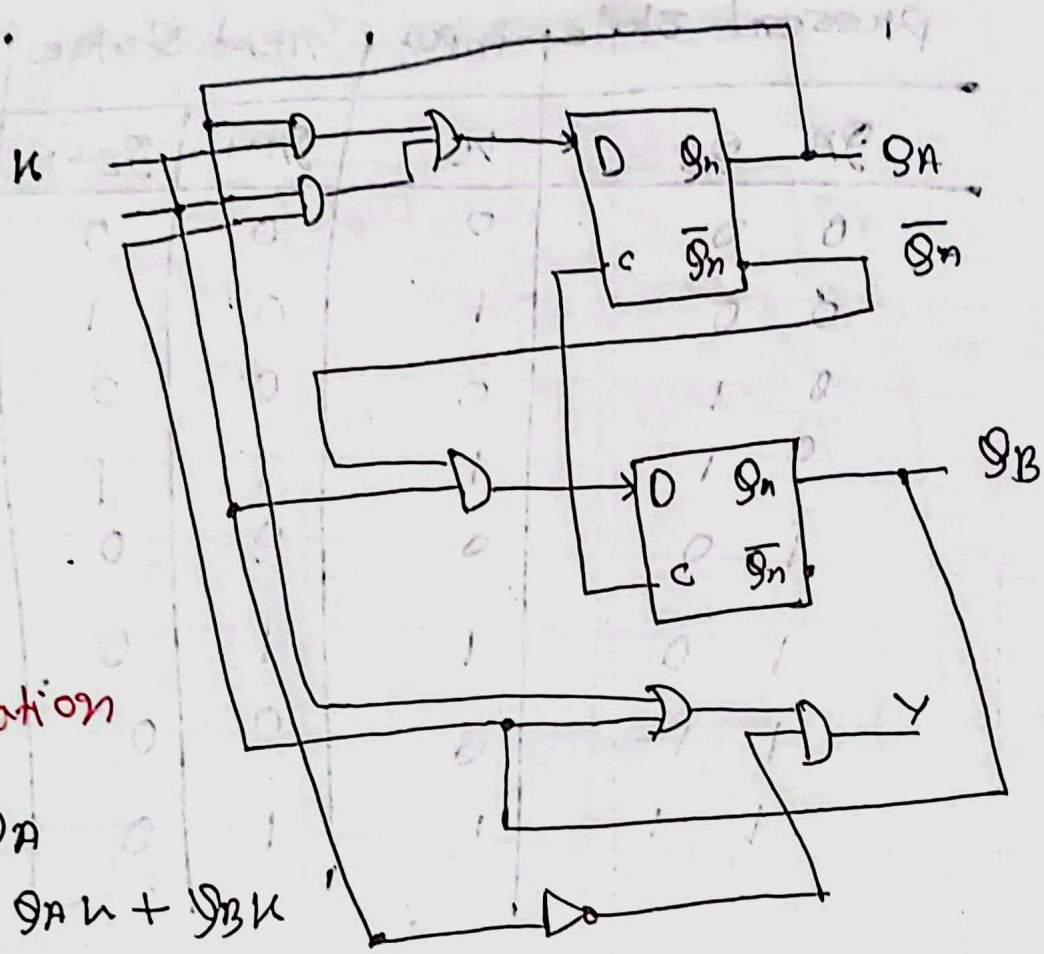


$T = K Q_n + J \bar{Q}_n$

problem

slide 43

Analysis of sequential circuit : state / transition equation



① State equation

$$Q_{A+1} = D_A$$
$$= Q_A x + Q_B x$$

$$Q_{B+1} = D_B$$
$$= \bar{Q}_n x$$

~~$Y = Q_B Q_A + \bar{x}$~~

$$Y = (Q_A + Q_B) x$$

ϕ diagram ba equation থাকলে ~~Q_{A+1}, Q_{B+1}~~

FF — equation থেকে যের করতে হবে। তা নাহলে

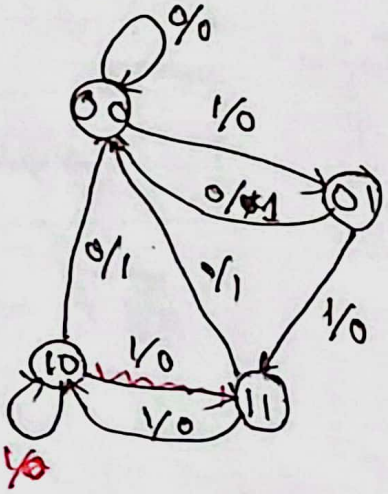
Q_{A+1} Q_{B+1} বের করতে হবে

D FF এর ক্ষেত্রে আমরা যেহেতু নিম্ন হয় নাই।

State table

present state		input	next state		output
Q_A	Q_B	x	Q_{A+1}	Q_{B+1}	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

State diagram



problem
Slide 48

$J_A = B \quad K_A = B\bar{x}$

$J_B = x' \quad K_B = A \oplus x$

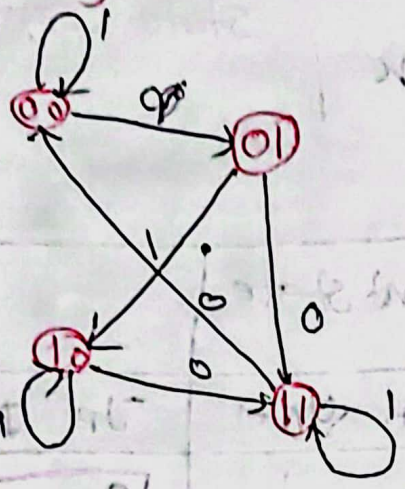
state equation

State table

present state		input	next state		FF			
Q_A	Q_B	x	Q_{A+1}	Q_{B+1}	J_A	K_A	J_B	K_B
0	0	0	0	1	0	0	1	0
0	0	1	0	0	0	0	0	1
0	1	0	1	1	1	1	1	0
0	1	1	1	0	1	0	0	1
1	0	0	1	1	0	0	1	1
1	0	1	1	0	0	0	0	0
1	1	0	0	0	1	1	1	1
1	1	1	1	1	1	0	0	0

J_A	K_A	$= Q_{n+1}$
0	0	memory
0	1	0
1	0	1
1	1	toggle

State diagram



problem

slide 50

~~$Q_{A+1} \Rightarrow T_A = B_n$~~

state equation

$T_A = B_n$

$T_B = n$

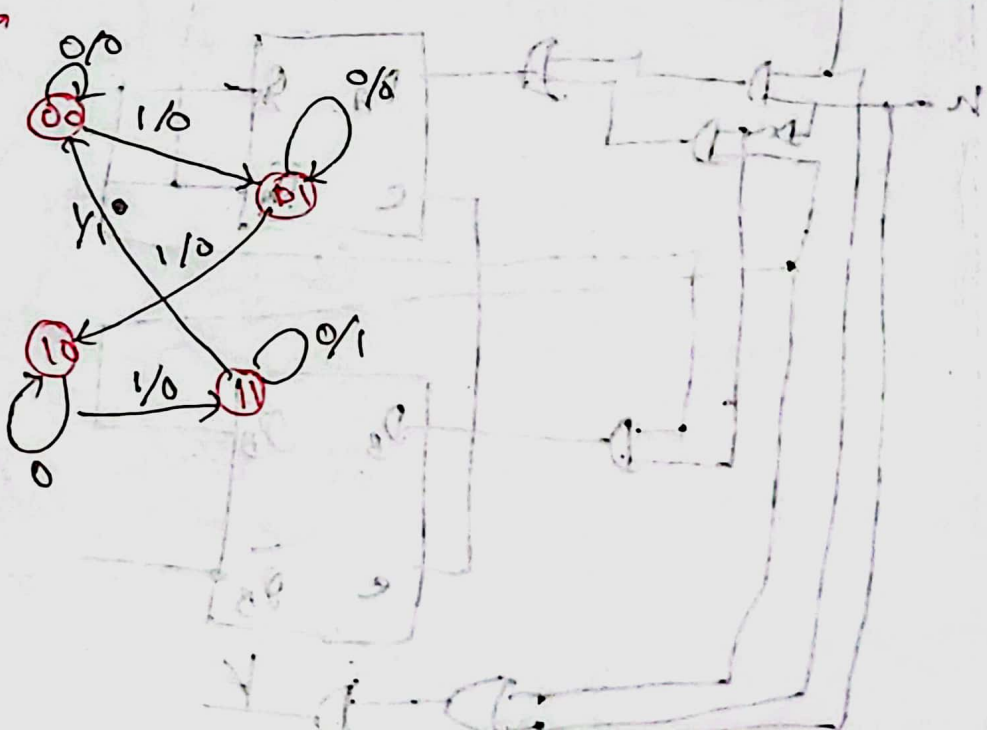
$Y = AB$

T	$Q_n = Q_{n+1}$
0	0 = memory
0	1 = "
1	0 = Togge
1	1 = "

state table

present state		input	next state		FF		output
Q_A	Q_B	x	Q_{A+1}	Q_{B+1}	T_A	T_B	Y
0	0	0	0	0	0	0	0
0	0	1	0	1	0	1	0
0	1	0	0	1	0	0	0
0	1	1	1	0	1	1	0
1	0	0	1	0	0	0	0
1	0	1	1	1	0	1	0
1	1	0	1	1	0	0	1
1	1	1	0	0	1	1	1

State daigram



Problem

A sequential circuit with two D flip-flops A and B, one input x, and one output Y, is specified by the following input equations

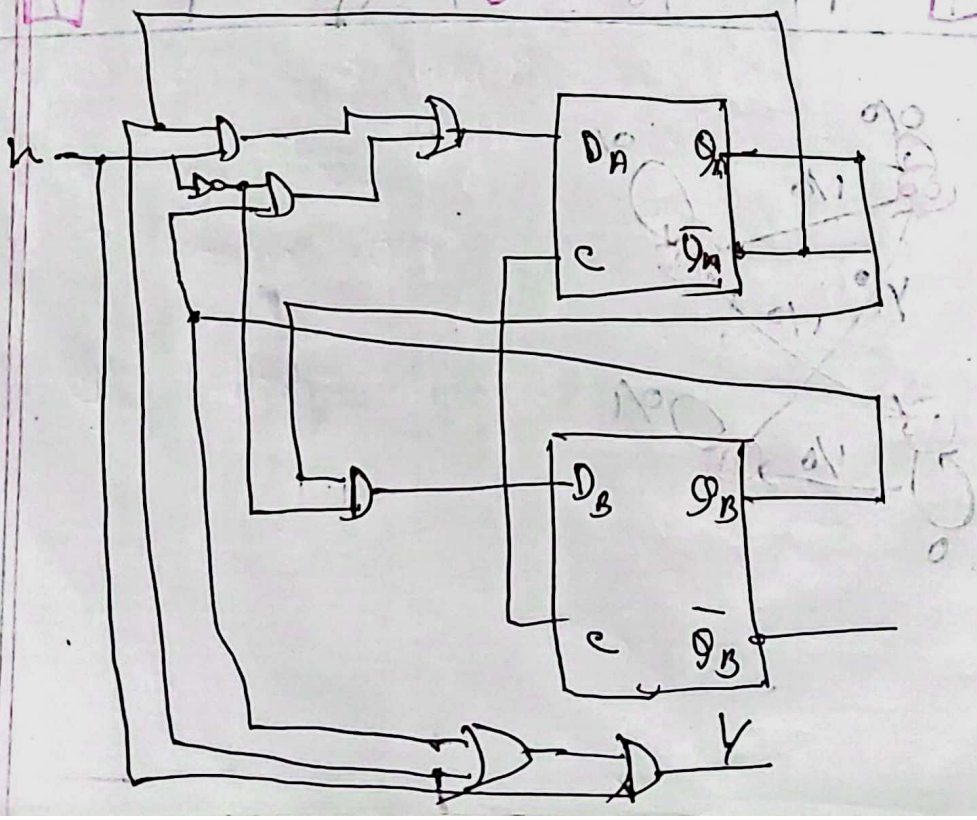
$D_A = \bar{A}x + B\bar{x}$

$D_B = A\bar{x}$

$Y = (\bar{A} + B)x$

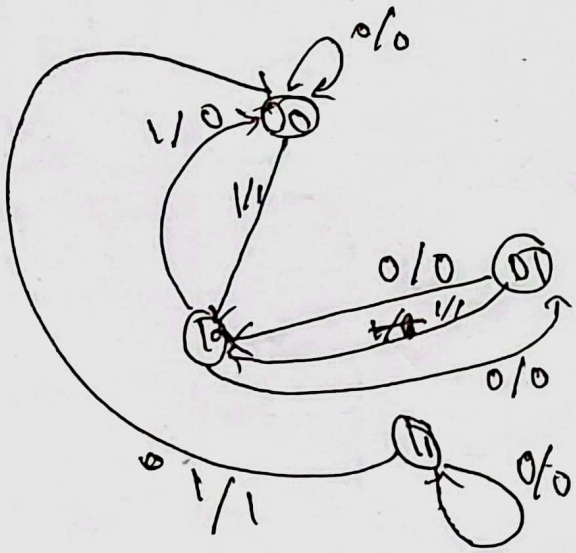
① Logic diagram
② state table
③ state diagram

Logic diagram



state table

present state		input	next state		output	FF	
Q_A	Q_B	x	Q_{A+1}	Q_{B+1}	Y	D_A	D_B
0	0	0	0	0	0	0	0
0	0	1	1	0	1	1	0
0	1	0	1	0	0	1	0
0	1	1	1	0	1	1	0
1	0	0	0	1	0	0	1
1	0	1	0	0	0	0	0
1	1	0	1	1	0	1	1
1	1	1	0	0	1	0	0



Sequence recognizer

~~1100~~ (1101)

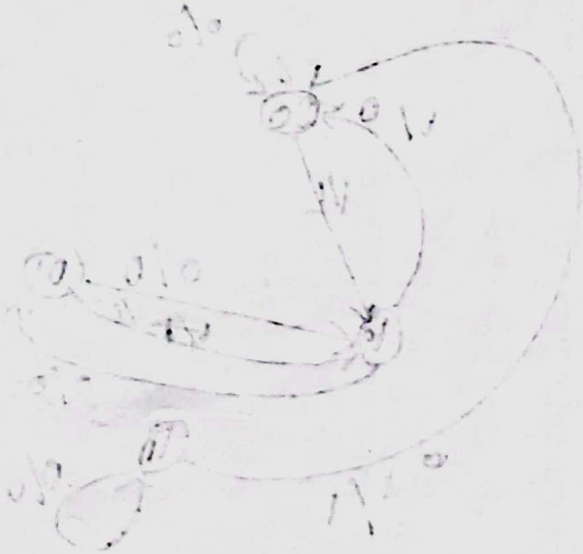
input 0 0 1 1 0 1 0 1

output 0 0 0 0 0 1 0 1

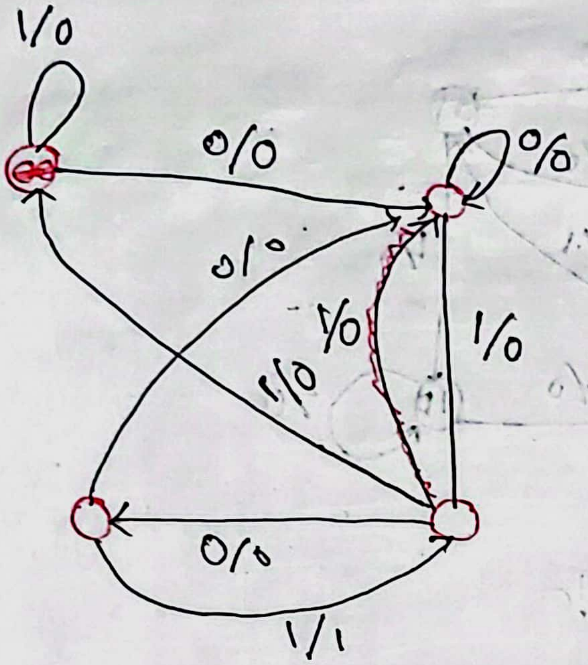
output দেওয়ার সময় দেখতে যদি previous input এর সাথে sequence মিলে না থাকলে output (0) আর যদি মিলে থাকলে (1)

For solve

① state diagram
② state table
③ equation
④ Logic diagram



0101 Recognize state Diagram

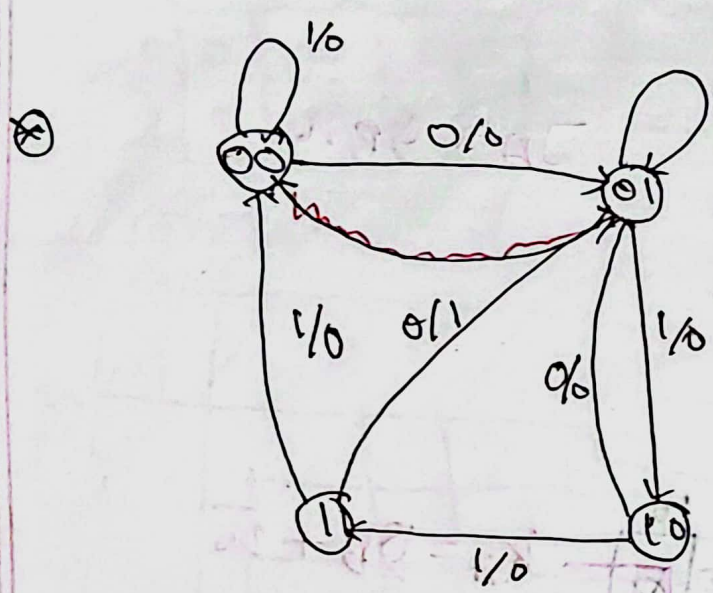


sequence অনুযায়ী আসাতে হবে। যদি Recognize করার সময় ও এ Recognize এর একটা পায় তাহলে তা পরের step এ আসাবে।

না হলে যে ~~স্থান~~ কোনটিতে গেলে এ Recognize এর value পাবে তাতেও যাবে।

problem 2

(0110) sequence Recognize (JK FF)



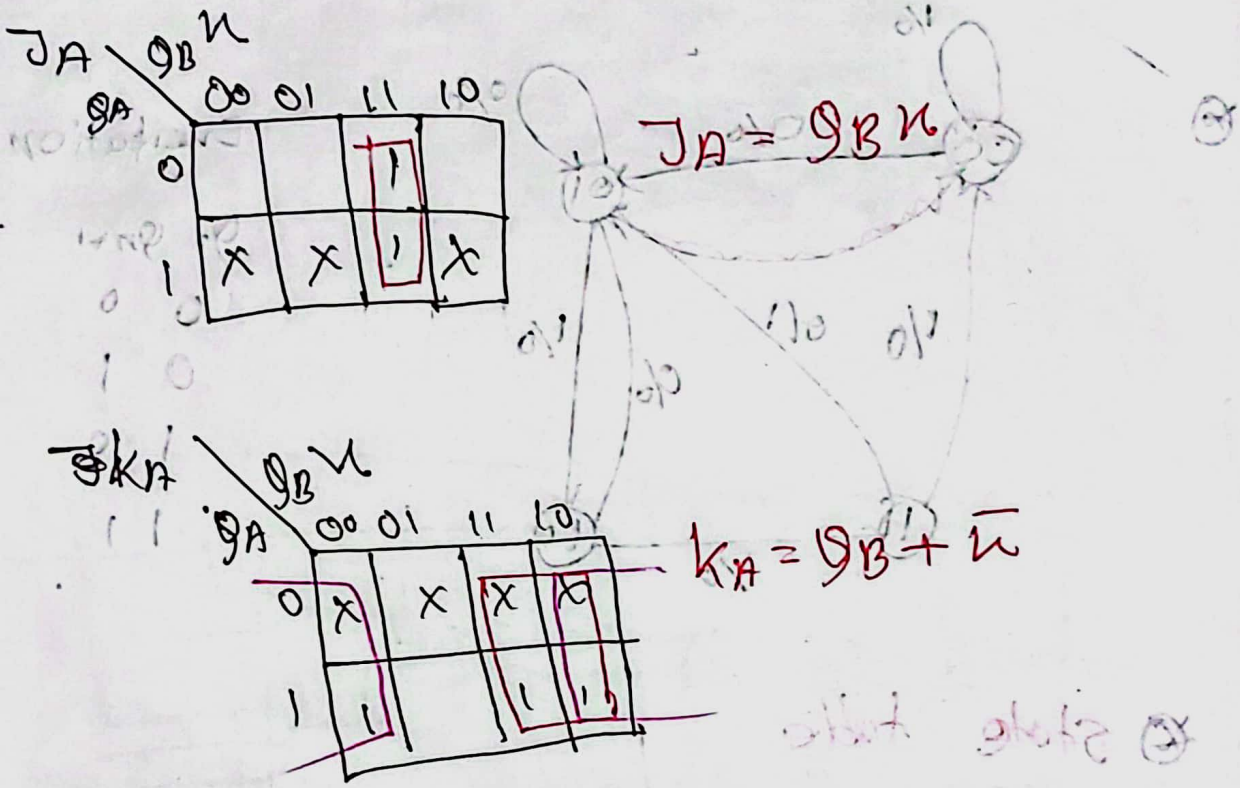
Excitation table

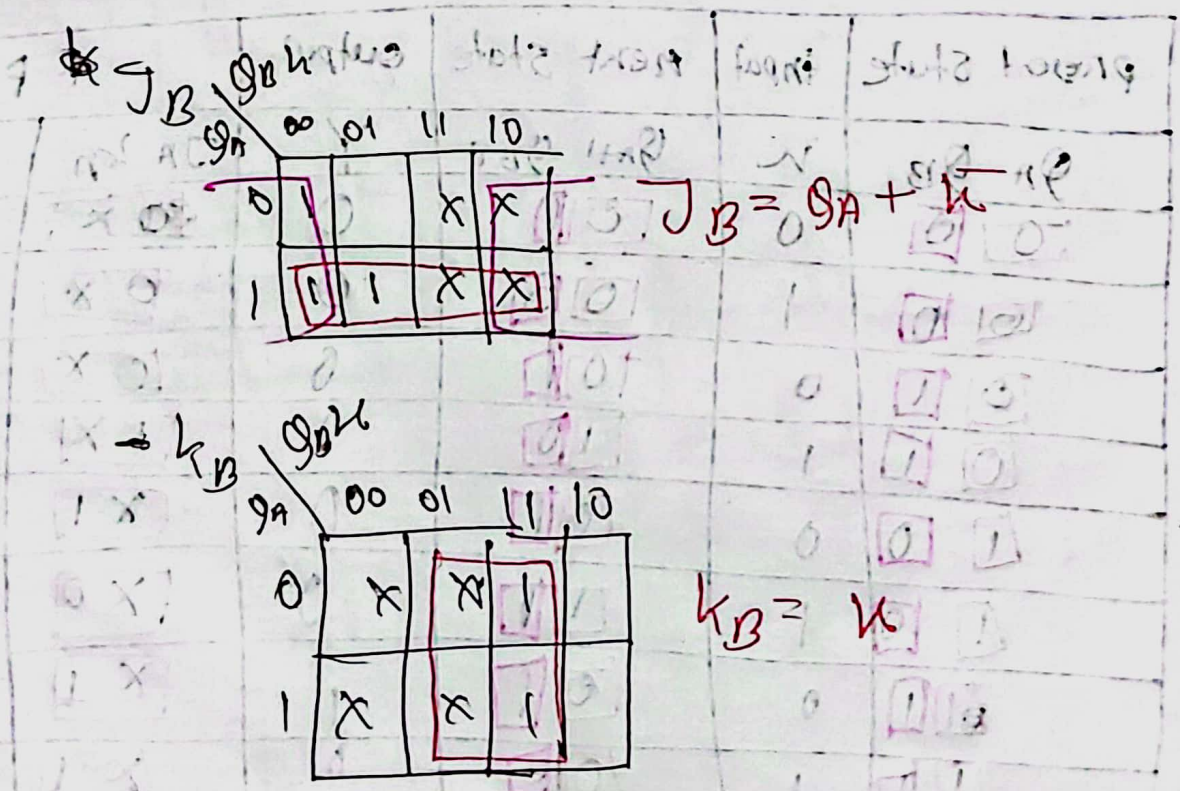
Q_n	Q_{n+1}	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

⊗ state table

present state		input	next state		output	FF	
Q_A	Q_B	x	Q_{A+1}	Q_{B+1}	Y	J_A K_A	J_B K_B
0	0	0	0	1	0	0 X	1 X
0	0	1	0	0	0	0 X	0 X
0	1	0	0	1	0	0 X	X 0
0	1	1	1	0	0	1 X	X 1
1	0	0	0	1	0	X 1	1 X
1	0	1	1	1	0	X 0	1 X
1	1	0	0	1	1	X 1	X 0
1	1	1	0	0	0	X 1	X 1

k-map


J_A
$Q_B\bar{x}$
Q_A
00 01 11 10
0
1
1
x x 1 x
$J_A = Q_B\bar{x}$
K_A
$Q_B\bar{x}$
Q_A
00 01 11 10
0
1
x x x x
1 1 1 1
$K_A = Q_B + \bar{x}$


J_B
$Q_B\bar{x}$
Q_A
00 01 11 10
0
1
1 x x
1 1 x x
$J_B = Q_A + \bar{x}$
K_B
$Q_B\bar{x}$
Q_A
00 01 11 10
0
1
x x 1
x x 1
$K_B = \bar{x}$

Y = $Q_B x$

Q_A \ $Q_B x$	00	01	11	10
0	0	0	0	0
1	0	0	0	1

$Y = Q_A Q_B \bar{x}$