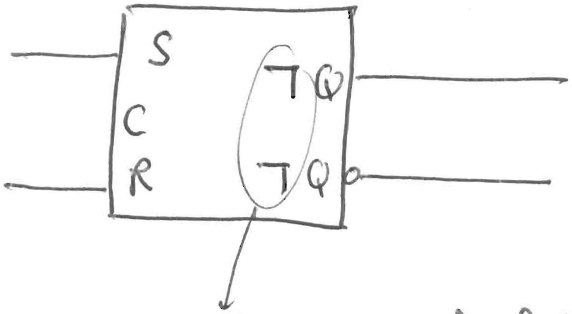
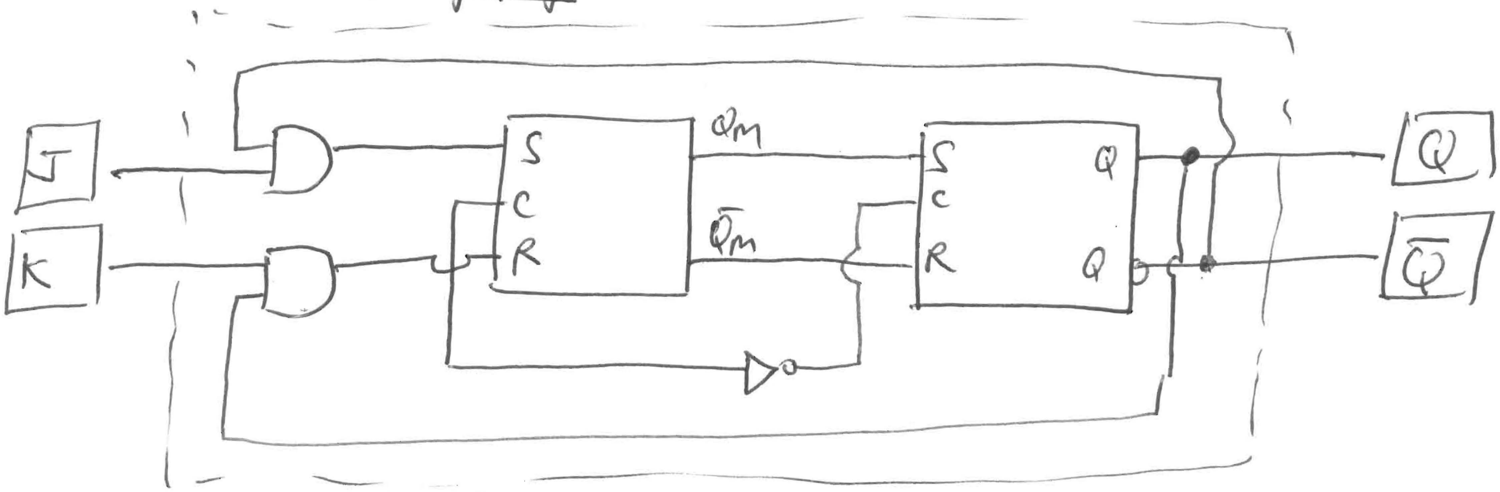
MS SR Flip Flop



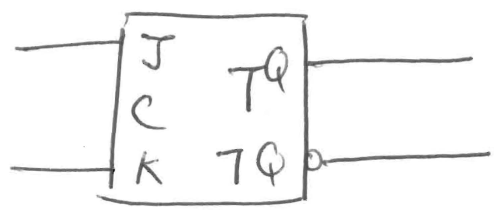
output is activated on the right edge of clock pulse (when input → output)

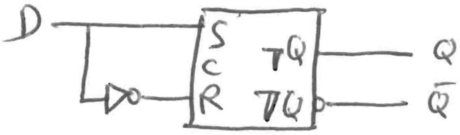
MS - JK Flip flops



MS-JK

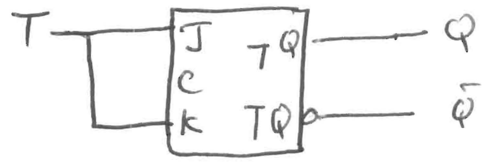
S	R	C	Q	$\bar{Q}$
—	—	0	Q	$\bar{Q}$
0	0	1	Q	$\bar{Q}$
0	1	1	0	1
1	0	1	1	0
1	1	1	$\bar{Q}$	Q





MS D Flip-flops : add an inverter b/w S & R in the MS-SR

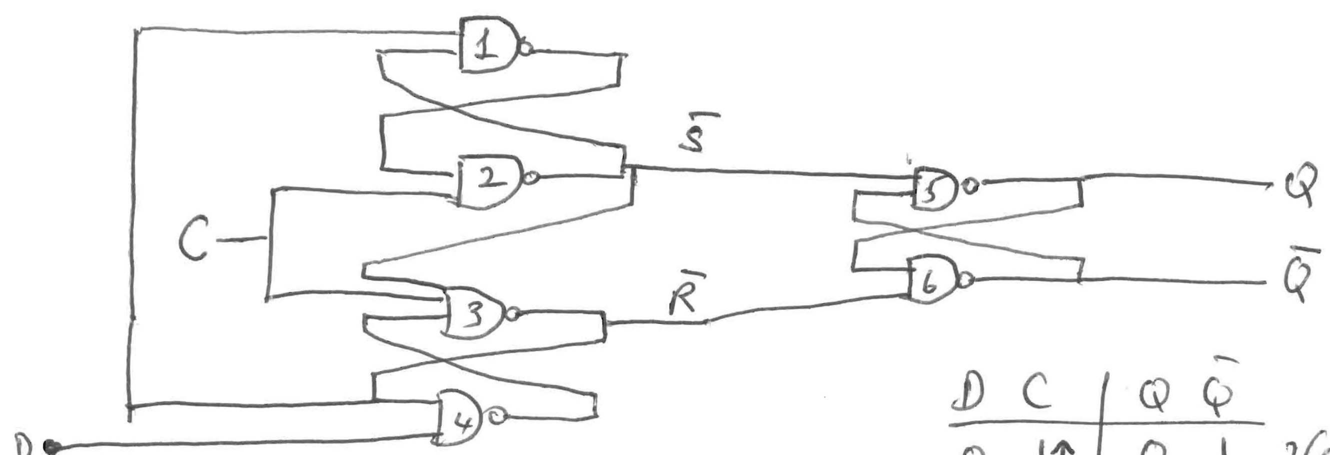
MS T Flip-flops : same as MS-JK with J & K connected.

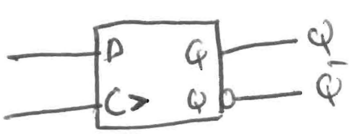


Edge-Triggered D-Flip Flops :

Setting & resetting of flip flop occurs during an edge of the clock pulse (normally the rising edge or positive edge).

Logic diagram with 6 NAND's.





D	C	Q	$\bar{Q}$	
0	↑	0	1	(C rising to 1)
1	↑	1	0	
—	0	Q	$\bar{Q}$	
—	1	Q	$\bar{Q}$	(C at 1 → D is not transferred)

D input goes to output only during the positive edge of C (↑ increasing). When C at high (or 1): D is not transferred to the output, which will keep the same state it was in.

Characteristic Equations

M&S Flip flops

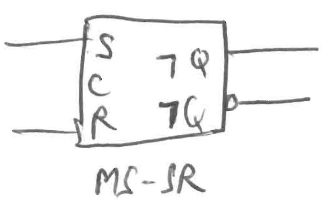
- Pulse-Triggered
  - MS-SR: $Q^+ = S + \bar{R}Q$
  - MS-JK: $Q^+ = \bar{Q}J + Q\bar{K}$
  - MS-D: $Q^+ = D$
  - MS-T: $Q^+ = Q \oplus T$
- Edge-Triggered : D

Current state: Q ($\bar{Q}$) Next state: Q^+ ($\bar{Q}^+$)

$\boxed{\text{MS-SR}}$

S	R	Q	Q^+	
0	0	0	0	Bistable
0	0	1	1	
0	1	0	0	MS-D
0	1	1	0	
1	0	0	1	
1	0	1	1	
1	1	0	–	Unpredictable
1	1	1	–	

SR	$Q\bar{Q}$
00	Bistable
10	10
01	01
11	unpredictable.



MS-SR

Q^+ k-map : MS-SR

Q^+ \ SR	00	01	11	10
Q = 0	0	0	–	1
Q = 1	1	0	–	1

Groups of ones & unknowns.
4, 2

$$\boxed{Q^+ = S + Q\bar{R}}$$

Characteristic equation for MS-SR (next state from current state & inputs SR)

J	$\bar{Q}$	$S = J \cdot \bar{Q}$
0	0	0
0	1	0
1	0	0
1	1	1

K	Q	$R = K \cdot Q$
0	0	0
0	1	0
1	0	0
1	1	1

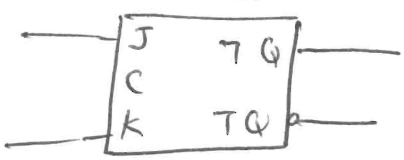
$\boxed{\text{MS-JK}}$: MS-SR with 2 AND's

J	K	Q	Q^+	
0	0	0	0	Bistable.
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	

MS-T

J	K	$\bar{Q}$	Q	S	R
0	0	0 1	1 0	0 0	0 0
0	1	0 1	1 0	0 0	1 0
1	0	0 1	1 0		
1	1	0 1	1 0		

MS-JK



$\boxed{\text{MS-JK}}$

To compare with MSSR:

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

(C=1)

Q^+ K-map for $\boxed{\text{MS-JK}}$:

Q^+ (Q \ JK)	00	01	11	10
0	0	0	1	1
1	1	0	0	1

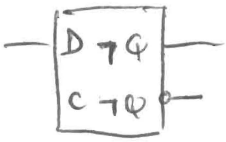
$$\boxed{Q^+ = \bar{Q}J + Q\bar{K}}$$

Groups of ones & unknowns:
2 groups of two ones each

$\boxed{\text{MS-D}}$: inverter b/w S & R in MS-SR →

True table for MS-D is a subtable of MS-SR!

<u>K-map</u>: <u>MS-D</u>.



Q^+		SR = 01	SR = 10
Q	0	0	1
	1	0	1

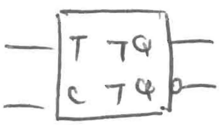
Note: $S = \overline{R} \equiv D$

$$\boxed{Q^+ = D}$$

$\boxed{\text{MS-T}}$: Same as MS-JK with J = K.

See subtable for MS-T.

$$\boxed{Q^+} = \overline{Q} \cdot T + Q\overline{T} = \boxed{T \oplus Q}$$

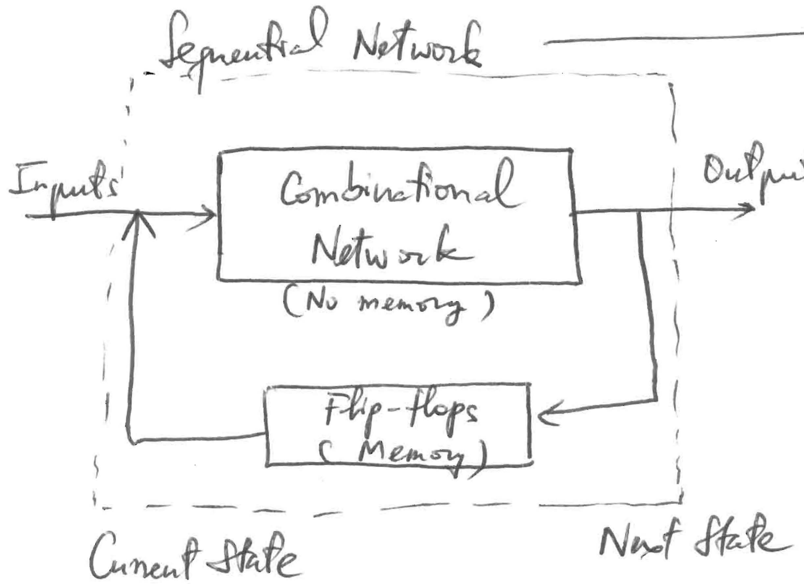


Q^+		JK = 00	JK = 11
Q	0	0	$\boxed{1}$
	1	$\boxed{1}$	0

<u>Next class</u>:

Network
- <u>Combinational</u>: outputs only depend on current inputs
- <u>Sequential</u>: outputs depend on current & previous inputs: or the network has memory (Ch 7)

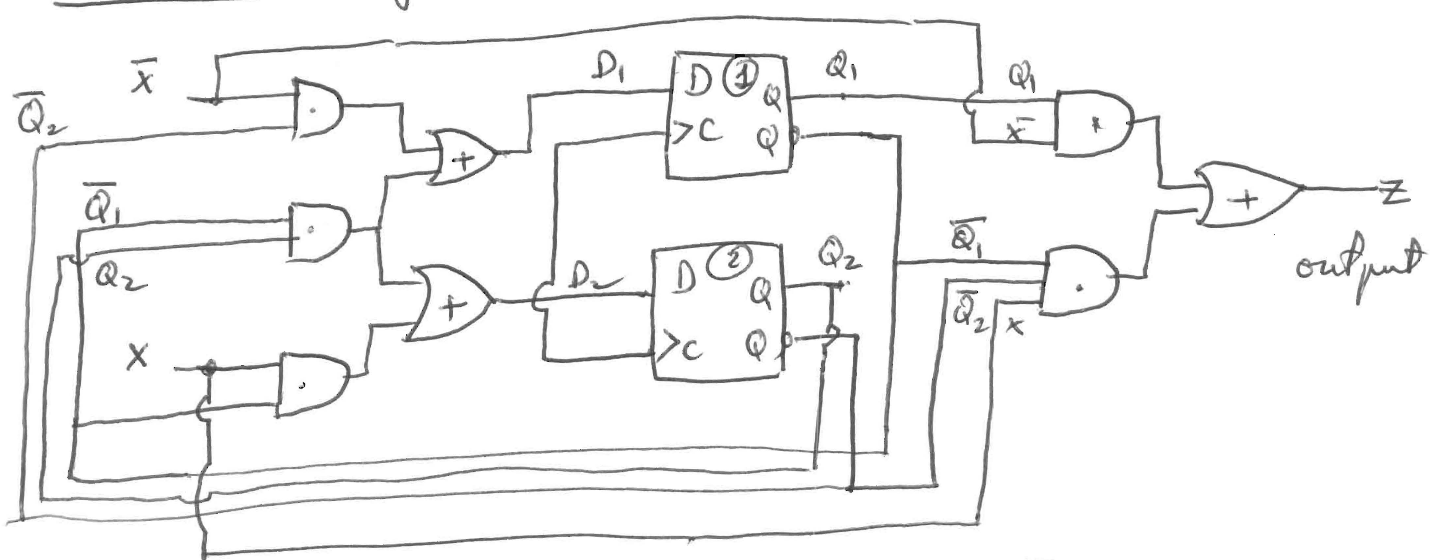
Ch 7: Synchronous Sequential Network:



- Excitations & Output Expressions
- Transition equations & Tables
- Excitation Tables
- State Tables
- State diagrams

Example: seq. network using D Flip-flops (characteristic eq. $Q^+ = D$)

Same Clocks → synchronous network.



Excitations: D_1 & D_2

From the network diagram

$$\begin{cases} D_1 = \bar{x}\cdot\bar{Q}_2 + \bar{Q}_1\cdot Q_2 \\ D_2 = x\cdot\bar{Q}_1 + \bar{Q}_1\cdot Q_2 \end{cases}$$

Output: $z = Q_1\cdot\bar{x} + \bar{Q}_1\cdot\bar{Q}_2\cdot x \quad (3)$

Transition equations: relate inputs to outputs @ flip-flops

Characteristic eq for D flip-flops.

$$Q_1^+ = D_1 = \bar{x}\cdot\bar{Q}_2 + \bar{Q}_1\cdot Q_2 \quad (1)$$

$$Q_2^+ = D_2 = x\cdot\bar{Q}_1 + \bar{Q}_1\cdot Q_2 \quad (2)$$

Next states

Transition table: shows current state, next state, output.

Present state (Q_1, Q_2)	Next state (Q_1^+, Q_2^+) Input (x) = 0	Input (x) = 1	Output (z) Input (x) = 0	Input (x) = 1
	(1)(2)	(1)(2)		
0 0	1 0	0 1	0	1
0 1	1 1	1 1	0	0
1 0	1 0	0 0	1	0
1 1	0 0	0 0	1	0

(1) $Q_1^+ = \bar{Q}_2 + \bar{Q}_1\cdot Q_2$ (1) $Q_1^+ = \bar{Q}_1\cdot Q_2$

(2) $Q_2^+ = \bar{Q}_1\cdot Q_2$ (2) $Q_2^+ = \bar{Q}_1 + \bar{Q}_1\cdot Q_2$

(3): $z = Q_1$ (3) $z = \bar{Q}_1\cdot\bar{Q}_2$

Excitation Table: shows current state, excitation, output.

Present state (Q_1, Q_2)	Excitation (D_1, D_2) input (x) = 0	input (x) = 1	Output (z) input (x) = 0	input (x) = 1
0 0	1 0	0 1	0	1
0 1	1 1	1 1	0	0
1 0	1 0	0 0	1	0
1 1	0 0	0 0	1	0
	$D_1 = Q_1^+ = \bar{Q}_2 + \bar{Q}_1\cdot Q_2$ $D_2 = Q_2^+ = \bar{Q}_1\cdot Q_2$	$D_1 = Q_1^+ = \bar{Q}_1\cdot Q_2$ $D_2 = Q_2^+ = \bar{Q}_1 + \bar{Q}_1\cdot Q_2$		

In this example, since $\begin{cases} D_1 = Q_1^+ \\ D_2 = Q_2^+ \end{cases}$ The transition table is identical to the Excitation Table!

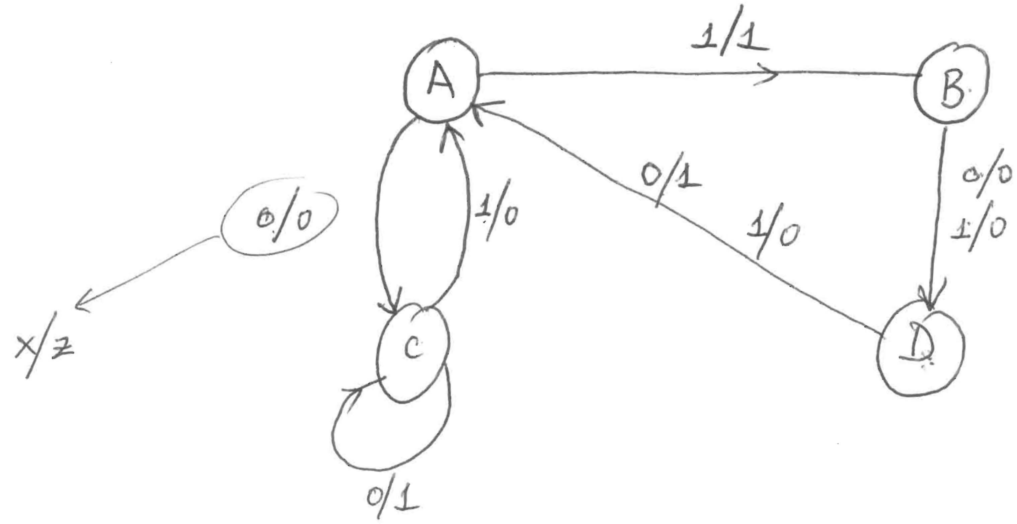
State Table: Transition Table with a letter notation for states

Present State (Q_1, Q_2)	Next State (Q_1^+, Q_2^+) input (x)		Output (Z) input (x)	
	0	1	0	1
00 → A	C	B	0	1
01 → B	D	D	0	0
10 → C	C	A	1	0
11 → D	A	A	1	0

Abbreviated version:

Present State (Q_1, Q_2)	Next State (Q_1^+, Q_2^+)/output (Z) input (x)	
	0	1
A	C, 0	B, 1
B	D, 0	D, 0
C	C, 1	A, 0
D	A, 1	A, 0

State Diagram (for our synchronous sequential network)



Using the State Table.

Network Terminal Behavior : time output ($z(t)$) for a given input sequence.

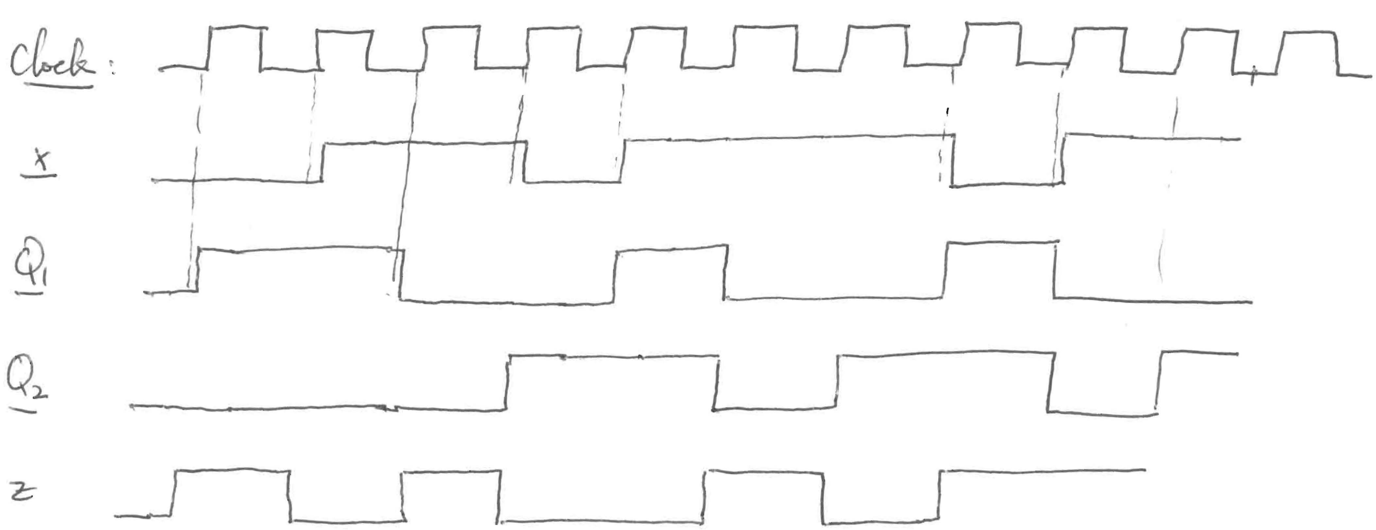
x = 0 0 1 1 0 1 1 1 0 1 (input sequence)

state = A C C A B D A B D A B (state sequence) → using state diagram & input sequence.
(Starts @ A)

z = 0 1 0 1 0 0 1 0 1 1 (output sequence)

Use state diagram To write the state sequence given the input sequence
- Initial state is A & input x=0, next state is C.
- Current state is C & input is 0, next state is C
- Current state C & input is 1, next state is A
- ...

* D-Flip Flops are positive edge-triggered



Another example of SSN (Synchronous Seq. Network)

Sequence Recognizer for two 4-bit numbers: $\boxed{011}0$ or $\boxed{100}1$:

Output a 1 if current input is 0 given the previous three inputs were $\boxed{011}$ or if current input is 1 and previous three inputs were $\boxed{100}$

Given an input sequence: → They can overlap!

x = 0011011100101011100110 0101

z = 0000100000100000101

State Diagram:

$\boxed{011}0$ or $\boxed{100}1$

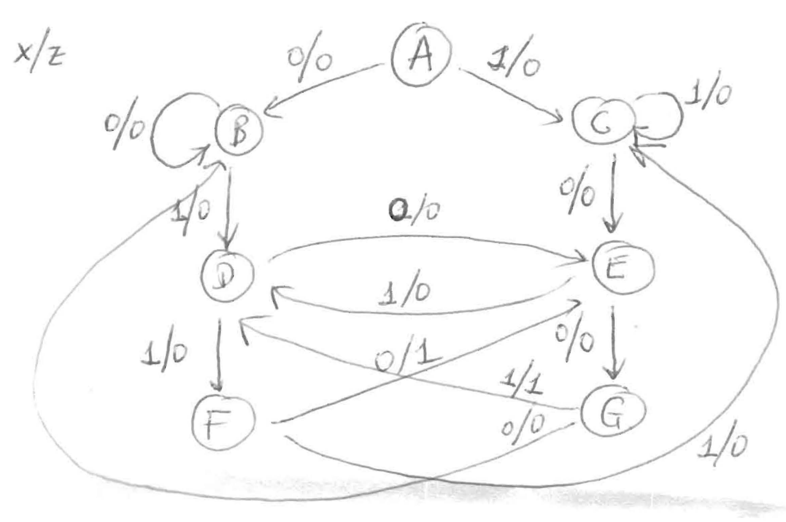
↑ current (B) ↑ current (C)

Define state based on sequences of interest

- A : no input is received
- B : last input was a 0
- C : last input was a 1
- D : last two inputs were 01
- E : last two inputs were 10
- F : last three inputs were 011
- G : last three inputs were 100

Related

Related.



Connections: (A) { x=0 → (B) ; x=1 → (C) }

Output z: will be 0 unless { @F & x=0 ; @G & x=1 }

(F) { x=0 → $01\boxed{10}$ → z=1 → (E) ; x=1 → $01\boxed{1}$ → z=0 → (C) }

State Table (For our 0110 or 1001 sequence recognizer)

Using the state diagram:

Present State	Next State Input x = 0	Next State Input x = 1	Output Input x = 0	Output Input x = 1
A	B	C	0	0
B	B	D	0	0
C	E	C	0	0
D	E	F	0	0
E	G	D	0	0
F	E	C	1	0
G	B	D	0	1

Handling of unused states.

Example: 3 binary inputs → 8 different states.

If only five states are defined (e.g. A,B,C,D,E) → 3 are unused.

We'd like design a network based on the following state table

Present State	Next State Input x = 0	Next State Input x = 1	Output Input x = 0	Output Input x = 1
A	A	B	0	0
B	C	D	1	0
C	A	D	0	1
D	E	A	1	1
E	C	B	0	0

K-map: we need our states into binary inputs:

		Q_1	Q_2	Q_3
A	→	0	0	0
B	→	0	0	1
C	→	0	1	0
D	→	0	1	1
E	→	1	0	0

Rewrite State Table using binary bits:

Present State $Q_1Q_2Q_3$	Next State $Q_1^+Q_2^+Q_3^+$, $x=0$	Next State $Q_1^+Q_2^+Q_3^+$, $x=1$	Output z, $x=0$	Output z, $x=1$
000 ✓	000	001	0	0
001 ✓	010	011	1	0
010 ✓	000	011	0	1
011	100	000	1	1
100	010	001	0	0
101	—	—	—	—
110	—	—	—	—
111	—	—	—	—

Unknowns (rows 101, 110, 111)

4 Kmaps: Q_1^+, Q_2^+, Q_3^+, z with 4 inputs each: Q_1, Q_2, Q_3, x

Q_1^+

Q_1Q_2 \ Q_3x	00	01	11	10
00	0	0	0	0
01	0	0	0	1
11	—	—	—	—
10	0	0	—	—

Q_2^+

Q_1Q_2 \ Q_3x	00	01	11	10
00	0	0	1	1
01	0	1	0	0
11	—	—	—	—
10	1	0	—	—

Q_3^+

Q_1Q_2 \ Q_3x	00	01	11	10
00	0	1	1	0
01	0	1	0	0
11	—	—	—	—
10	0	1	—	—

z

Q_1Q_2 \ Q_3x	00	01	11	10
00	0	0	0	1
01	0	1	1	1
11	—	—	—	—
10	0	0	—	—

Characteristic equations for Q_1^+, Q_2^+, Q_3^+, z:

$Q_1^+ = Q_2 Q_3 \bar{x}$; $Q_2^+ = \cancel{Q_1 \bar{Q_3} \bar{x}} + \cancel{Q_2 \bar{Q_3} x} + \cancel{\bar{Q_1} \bar{Q_2} Q_3}$

$Q_1 \bar{x} + \bar{Q_2} Q_3 + Q_2 \bar{Q_3} x$

$Q_3^+ = \bar{Q_3} x + \bar{Q_2} x$; $z = Q_2 x + Q_3 \bar{x}$

Use D- flip flops :
(Three of them for the 3 bits)

$$Q_1^+ = D_1 = Q_2 Q_3 \bar{x}$$

$$Q_2^+ = D_2 = Q_1 \bar{x} + \bar{Q}_2 Q_3 + Q_2 \bar{Q}_3 x$$

$$Q_3^+ = D_3 = \bar{Q}_3 x + \bar{Q}_2 x$$

$$z = Q_2 x + Q_3 \bar{x}$$