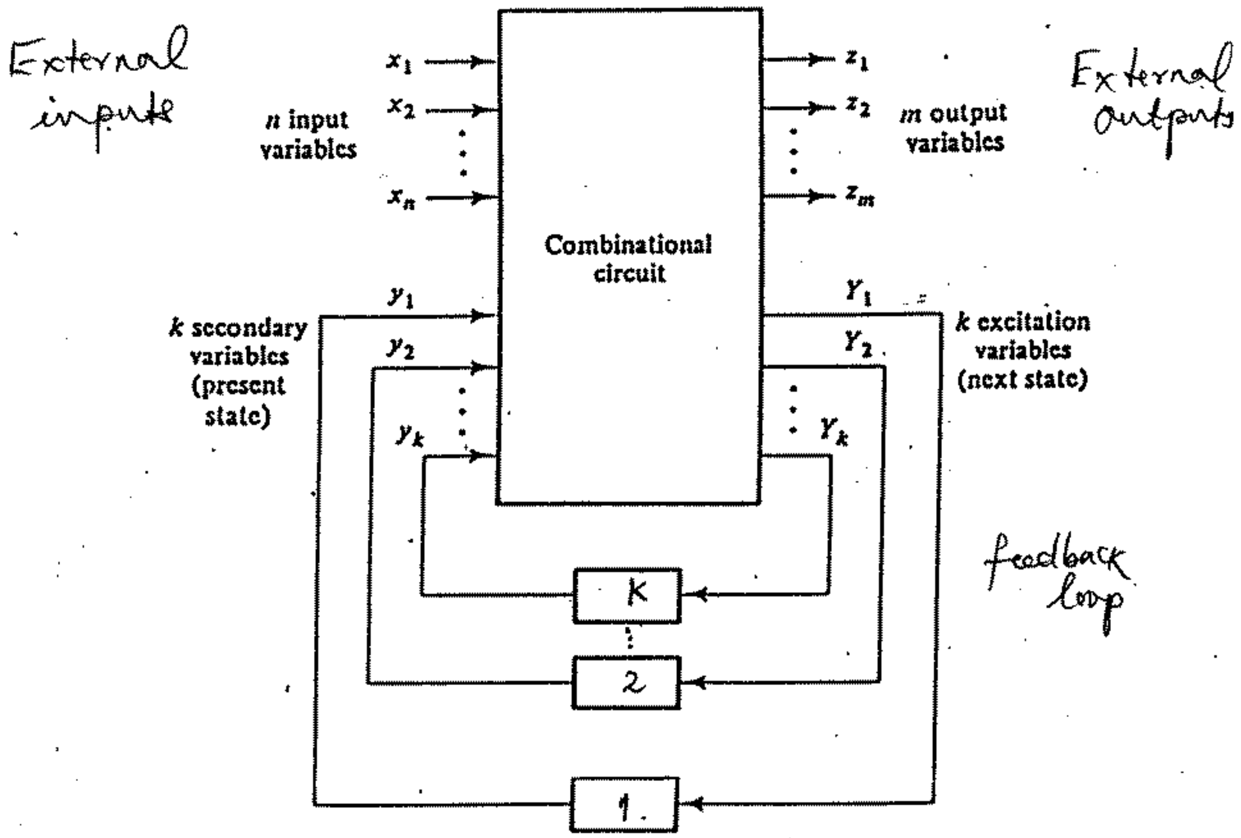
SEQUENTIAL CIRCUITS



* Content of k memory cells = **STATE** of the sequential circuit

e.g., k = 3 ⇒ [] [] []

* Since each memory cell stores one bit (0 or 1), there are 2^k possible states of the sequential circuit

e.g., k = 3 ⇒ 2^3 possible states

⇒ 2^3 possible contents of 3 memory cells

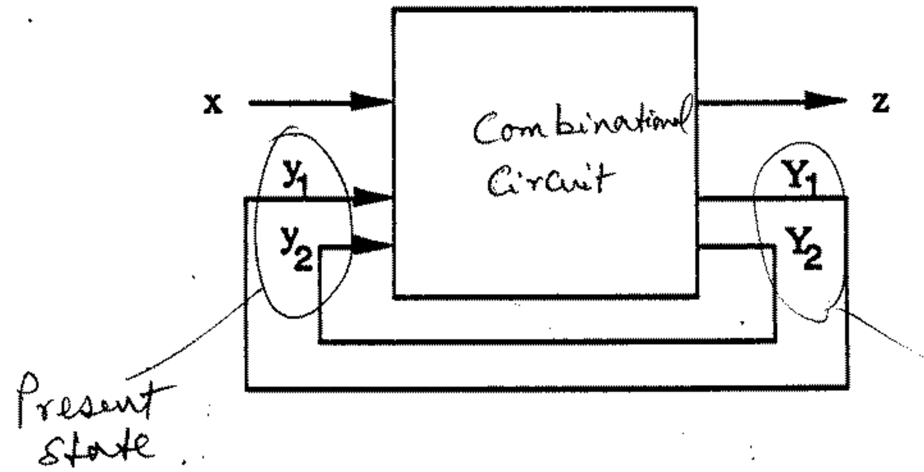
⇒ 000, 001, 010, 011, 100, 101, 110, 111

* present content of k memory cells = PRESENT STATE ⇒ $y_1 y_2 \ldots y_k$
* next content of k memory cells = NEXT STATE ⇒ $Y_1 Y_2 \ldots Y_k$

* $z_i = f(y_1, y_2, \ldots, y_k, x_1, x_2, \ldots, x_n), 1 \le i \le m$

$Y_j = f(\underbrace{y_1, y_2, \ldots, y_k}_{\text{present state}}, \underbrace{x_1, x_2, \ldots, x_n}_{\text{external inputs}}), 1 \le j \le k$

e.g., Every output is a function of all inputs



$$z = f_1(y_1, y_2, x)$$
$$Y_1 = f_2(y_1, y_2, x)$$
$$Y_2 = f_3(y_1, y_2, x)$$

ASYNCHRONOUS SEQUENTIAL CIRCUITS

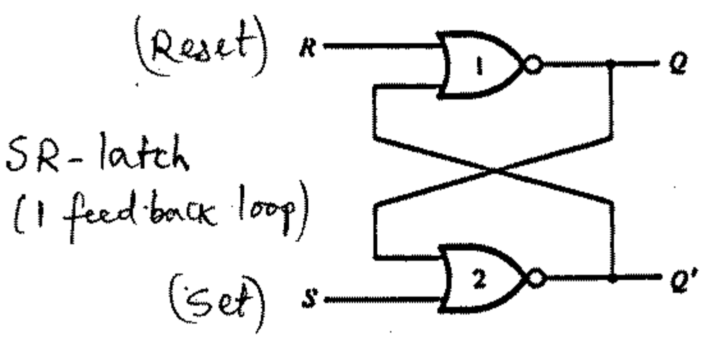
RESPONDS TO A CHANGE IN ONE OF THE INPUTS

OPERATES IN THE **FUNDAMENTAL MODE:**

(input signals change one at a time and only when the circuit is in a stable state) $y_i = Y_i \quad 1 \le i \le k$

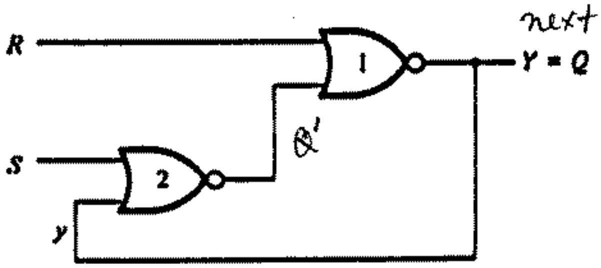
MEMORY ELEMENTS: LATCHES

SR-latch (1 feed back loop)



Crossed-coupled circuit

S	R	Q	Q'	
1	0	1	0	set state
0	0	1	0	(After SR = 10)
0	1	0	1	Reset state
0	0	0	1	(After SR = 01)
1	1	0	0	undefined



Circuit showing feedback

next state

$$Y = Q = f(y, S, R) = ((S+y)' + R)' = (S+y)R' = SR' + R'y$$

If it is ensured that both R & S will never be 1 then →

			S	S
			x	1
y	1		x	1
		R	R	

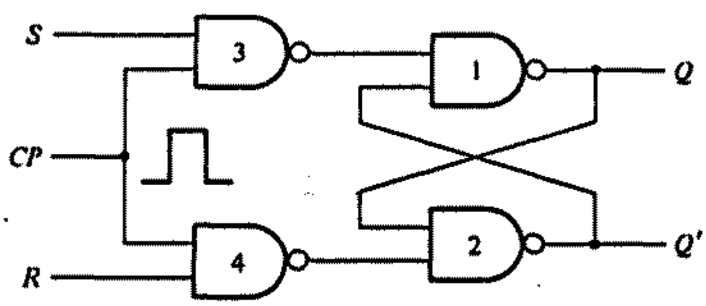
$$Y = S + R'y$$

SYNCHRONOUS SEQUENTIAL CIRCUITS

RESPONDS TO THE CLOCK PULSE (CP)

MEMORY ELEMENTS: FLIPFLOPS

RS - Flipflop



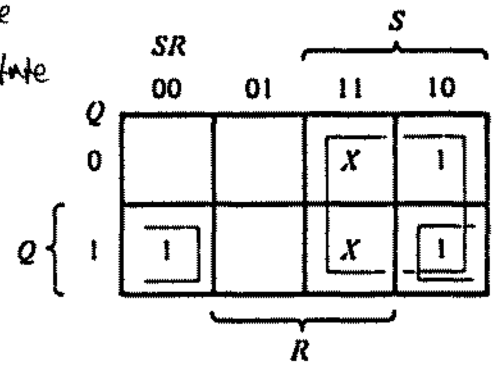
(a) Logic diagram

S	R	Q(t + 1)	
0	0	Q(t)	No change
0	1	0	Reset
1	0	1	Set
1	1	?	Unpredictable

present state → Q(t); next state → Q(t + 1)

Q(t)	S	R	Q(t + 1)
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	Indeterminate
1	0	0	1
1	0	1	0
1	1	0	1
1	1	1	Indeterminate

(b) Characteristic tables

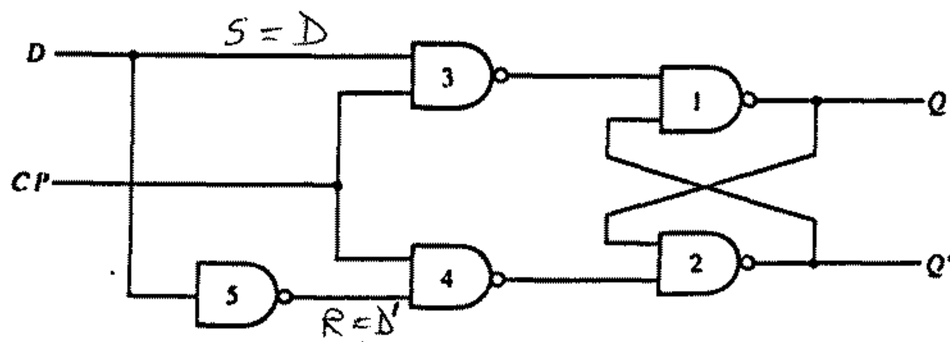


$Q(t + 1) = S + R'Q(t)$

when $SR = 0$

(c) Characteristic equation

D - Flipflop

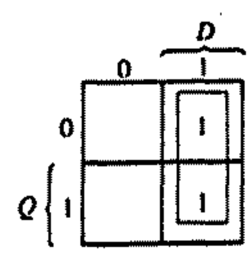


(a) Logic diagram

D	Q(t + 1)	
0	0	Reset
1	1	Set

Q(t)	D	Q(t + 1)
0	0	0
0	1	1
1	0	0
1	1	1

(b) Characteristic tables

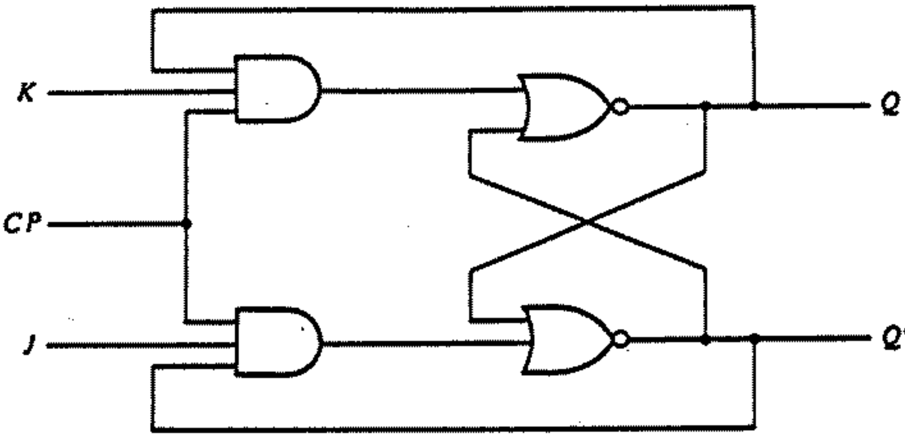


$Q(t + 1) = D$

(c) Characteristic equation

JK - Flipflop

when J=1 & K=1
$Q(t+1) = Q'(t)$

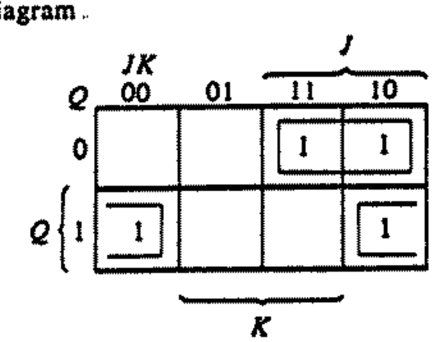


(a) Logic diagram

J	K	Q(t + 1)	
0	0	Q(t)	No change
0	1	0	Reset
1	0	1	Set
1	1	Q'(t)	Complement

Q(t)	J	K	Q(t + 1)
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	0
1	1	0	1
1	1	1	0

(b) Characteristic tables

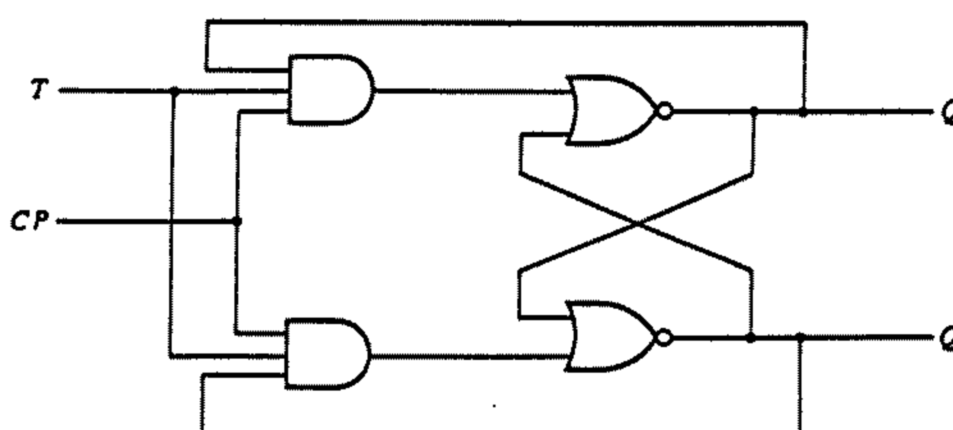


$Q(t+1) = JQ'(t) + K'Q(t)$

(c) Characteristic equation

T - Flipflop

Single input version of JK-FF.
when T = 1,
$Q(t+1) = Q'(t)$

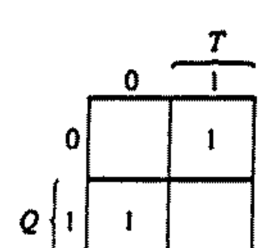


(a) Logic diagram

T	Q(t + 1)	
0	Q(t)	No change
1	Q'(t)	Complement

Q(t)	T	Q(t + 1)
0	0	0
0	1	1
1	0	1
1	1	0

(b) Characteristic tables



$Q(t+1) = TQ'(t) + T'Q(t)$

(c) Characteristic equation

FLIP FLOP CHARACTERISTIC TABLES

Flip-Flop Characteristic Tables

JK Flip-Flop

J	*K*	$Q(t+1)$	
0	0	$Q(t)$	No change
0	1	0	Reset
1	0	1	Set
1	1	$Q'(t)$	Complement

RS Flip-Flop

S	*R*	$Q(t+1)$	
0	0	$Q(t)$	No change
0	1	0	Reset
1	0	1	Set
1	1	?	Unpredictable

D Flip-Flop

D	$Q(t+1)$	
0	0	Reset
1	1	Set

T Flip-Flop

T	$Q(t+1)$	
0	$Q(t)$	No change
1	$Q'(t)$	Complement

Given present state $Q(t)$ & inputs, find next state $Q(t+1)$

FLIP FLOP EXCITATION TABLES

Flip-Flop Excitation Tables

$Q(t)$	$Q(t+1)$	*S*	*R*
0	0	0	*X*
0	1	1	0
1	0	0	1
1	1	*X*	0

(a) *RS*

$Q(t)$	$Q(t+1)$	*J*	*K*
0	0	0	*X*
0	1	1	*X*
1	0	*X*	1
1	1	*X*	0

(b) *JK*

$Q(t)$	$Q(t+1)$	*D*
0	0	0
0	1	1
1	0	0
1	1	1

(c) *D*

$Q(t)$	$Q(t+1)$	*T*
0	0	0
0	1	1
1	0	1
1	1	0

(b) *T*

Given present state $Q(t)$ & next state $Q(t+1)$, find inputs.