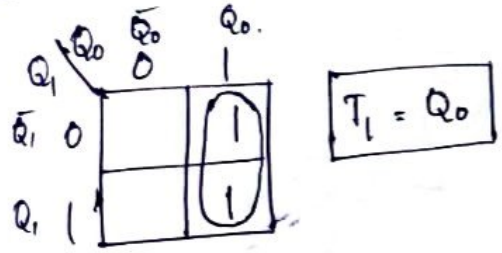
2-bit Synchronous Counter:- (T- flip-flop)

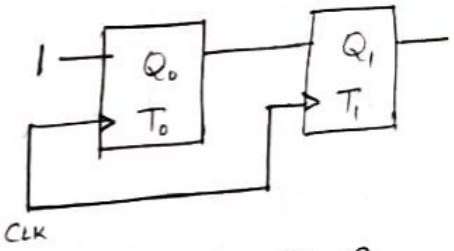
Present State		Next State		inputs	
Q_1	Q_0	Q_1	Q_0	T_1	T_0
0	0	0	1	0	1
0	1	1	0	1	1
1	0	1	1	0	1
1	1	0	0	1	1

$T_0 = 1$

Characteristic equation:-



$T_1 = Q_0$

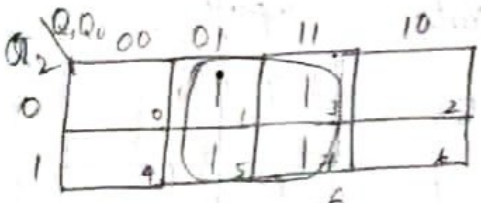


3-bit Synchronous Counter:- (T- flip flop)

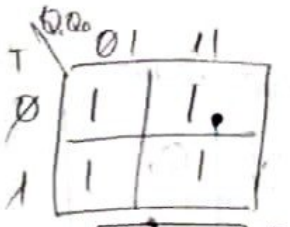
	Present State			Next State			Inputs		
	Q_2	Q_1	Q_0	Q_2^+	Q_1^+	Q_0^+	T_2	T_1	T_0
0	0	0	0	0	0	1	0	0	1
1	0	0	1	0	1	0	0	1	1
2	0	1	0	0	1	1	0	0	1
3	0	1	1	1	0	0	1	1	1
4	1	0	0	1	0	1	0	0	1
5	1	0	1	1	1	0	0	1	1
6	1	1	0	1	1	1	0	0	1
7	1	1	1	0	0	0	1	1	1

$T_0 = 1$

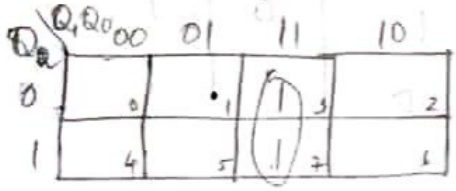
Characteristic Equation



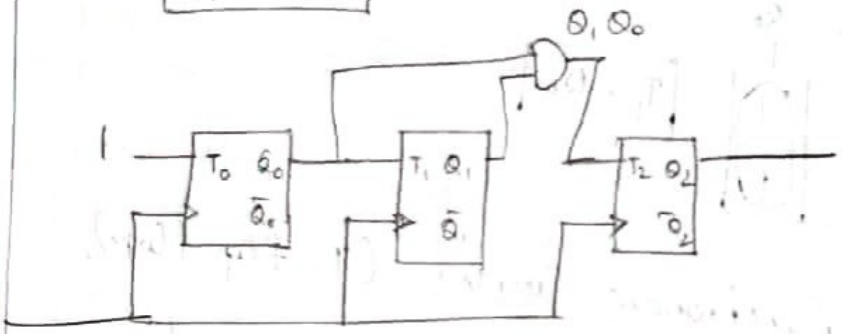
$T_1 = Q_0$



$T_1 = Q_0$



$T_2 = Q_1 Q_0$



Q.C

$$2^{N-1}+1 \leq \text{mod} \leq 2^N$$

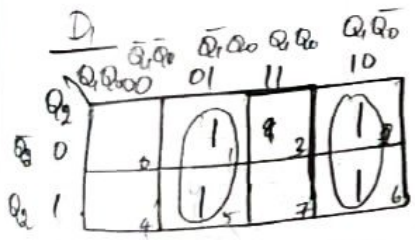
N-Bit/ff	Min	Max
1	2	2
2	3	4
3	5	8
4	9	16

Design a mod 5 - Synchronous Counter using D- flip flop.

Present State			Next State			Inputs		
Q_2	Q_1	Q_0	Q_2^+	Q_1^+	Q_0^+	D_2	D_1	D_0
0	0	0	0	0	1	0	0	1
0	0	1	0	1	0	0	1	0
0	1	0	0	1	1	0	1	1
0	1	1	1	0	0	1	0	0
1	0	0	1	0	1	1	0	1
1	0	1	1	1	0	1	1	0
1	1	0	1	1	1	1	1	1
1	1	1	0	0	0	0	0	0

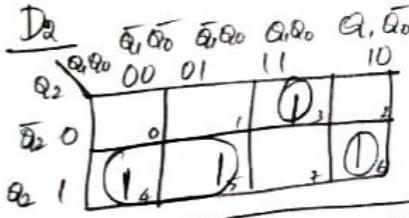
K-map → Present & Inputs

$$D_0 = \overline{Q_0}$$



$$D_1 = \overline{Q_1} Q_0 + Q_1 Q_0'$$

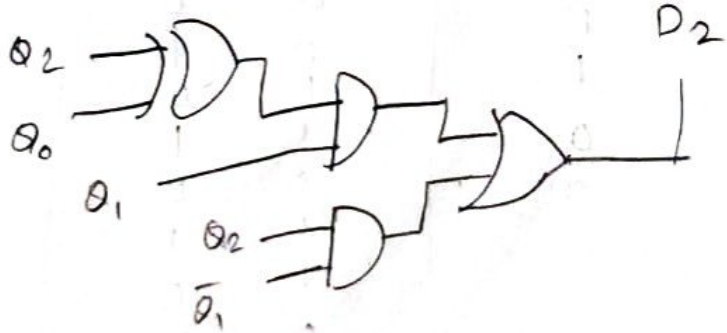
$$D_1 = Q_1 \oplus Q_0$$

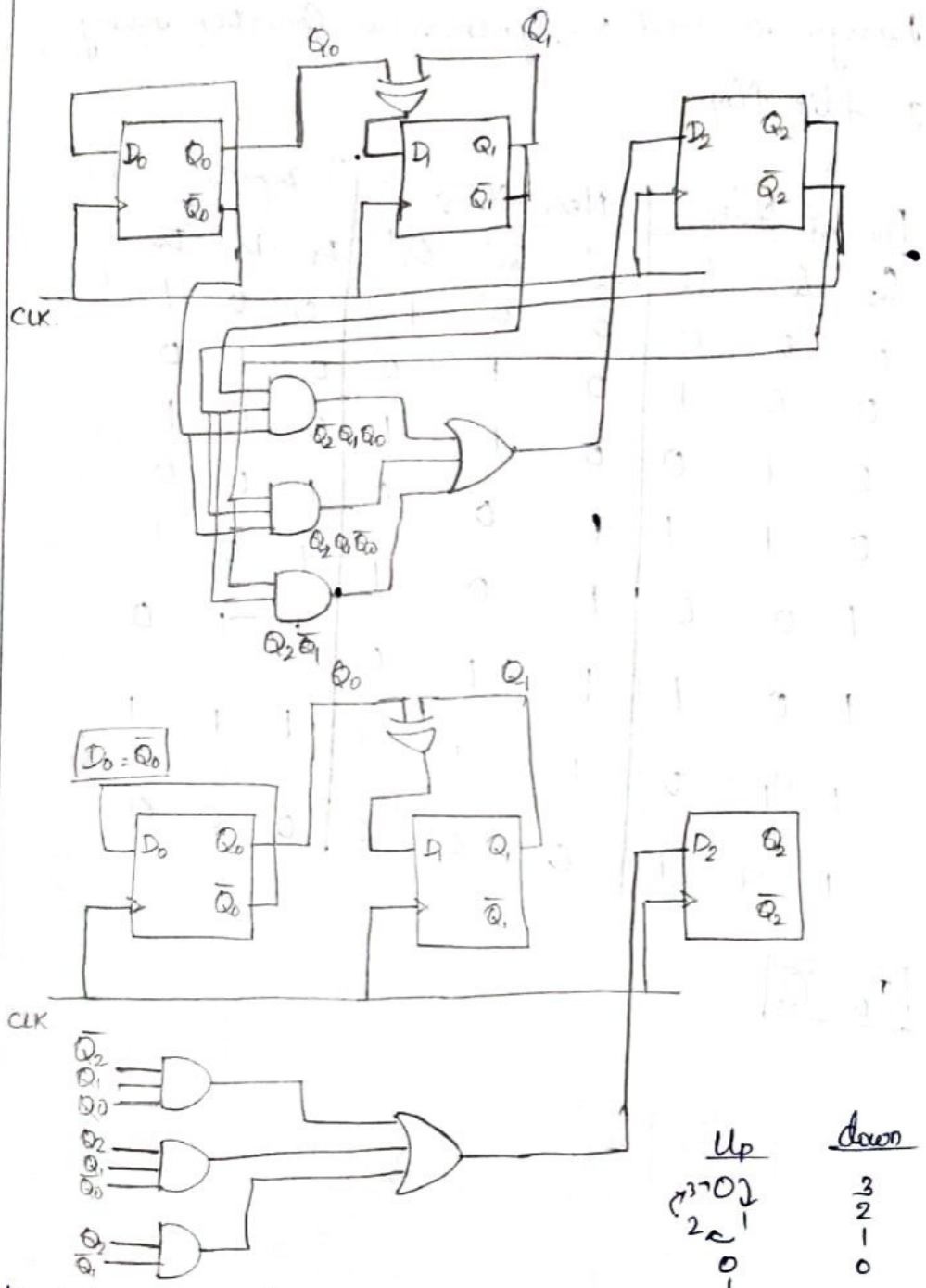


$$D_2 = \overline{Q_2} Q_1 Q_0 + Q_2 Q_1 \overline{Q_0} + Q_2 \overline{Q_1}$$

$$Q_1 (\overline{Q_2} Q_0 + Q_2 \overline{Q_0})$$

$$Q_1 (Q_2 \oplus Q_0) + Q_2 \overline{Q_1}$$





Up/down Counter :-

Up/down	Present State		next State	
	Q_1	Q_0	Q_1^+	Q_0^+
1	0	0	0	1
1	0	1	1	0
1	1	0	1	1
1	1	1	0	0
0	0	0	1	1
0	1	1	1	0
0	1	0	0	1
0	0	1	0	0

3-bit Sync. Counter Using JK Flip Flop:-

Present State	Next State	Inputs J	Inputs K
0	0	0	x
0	1	1	x
1	0	x	1
1	1	x	0

Present State			Next State			Inputs					
Q_2	Q_1	Q_0	Q_2^+	Q_1^+	Q_0^+	J_2	K_2	J_1	K_1	J_0	K_0
0	0	0	0	0	1	0	x	0	x	1	x
0	0	1	0	1	0	0	x	1	x	x	1
0	1	0	0	1	1	0	x	x	0	1	x
0	1	1	1	0	0	1	x	x	1	x	1
1	0	0	1	0	1	x	0	0	x	1	x
1	0	1	1	1	0	x	0	1	x	x	1
1	1	0	1	1	1	x	0	x	0	1	x
1	1	1	0	0	0	x	1	x	1	x	1

K-Map:

J_0

Q_2 \ Q_1Q_0	00	01	11	10
0	1_0	x_1	x_3	1_2
1	1_4	x_5	x_7	1_6

$J_0 = 1$

K_0

Q_2 \ Q_1Q_0	00	01	11	10
0	x_0	1_1	1_3	x_2
1	x_4	1_5	1_7	x_6

$K_0 = 1$

J_1

Q_2 \ Q_1Q_0	$\bar{Q}_1\bar{Q}_0$ 00	$\bar{Q}_1Q_0$ 01	Q_1Q_0 11	$Q_1\bar{Q}_0$ 10
$\bar{Q}_2$ 0	0	1_1	x_3	x_2
Q_2 1	4	1_5	x_7	x_6

up → $J_1 = Q_0$ down → $J_1 = Q_0'$

K_1

Q_2 \ Q_1Q_0	$\bar{Q}_1\bar{Q}_0$ 00	$\bar{Q}_1Q_0$ 01	Q_1Q_0 11	$Q_1\bar{Q}_0$ 10
$\bar{Q}_2$ 0	x_0	x_1	1_3	2
Q_2 1	x_4	x_5	1_7	6

up → $K_1 = Q_0$; down → $K_1 = Q_0'$

J_2

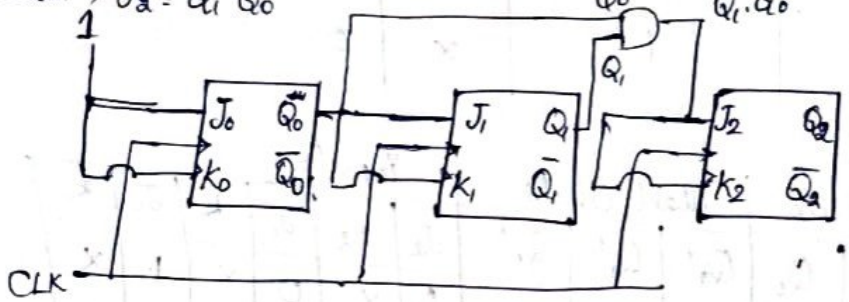
Q_2 \ Q_1Q_0	$\bar{Q}_1\bar{Q}_0$ (00)	$\bar{Q}_1Q_0$ (01)	Q_1Q_0 (11)	$Q_1\bar{Q}_0$ (10)
$\bar{Q}_2$ (0)	0	1	1 (3)	2
Q_2 (1)	X (4)	X (5)	X (7)	X (6)

K_2

Q_2 \ Q_1Q_0	$\bar{Q}_1\bar{Q}_0$ (00)	$\bar{Q}_1Q_0$ (01)	Q_1Q_0 (11)	$Q_1\bar{Q}_0$ (10)
$\bar{Q}_2$ (0)	X (0)	X (1)	X (3)	X (2)
Q_2 (1)	0 (4)	0 (5)	1 (7)	0 (6)

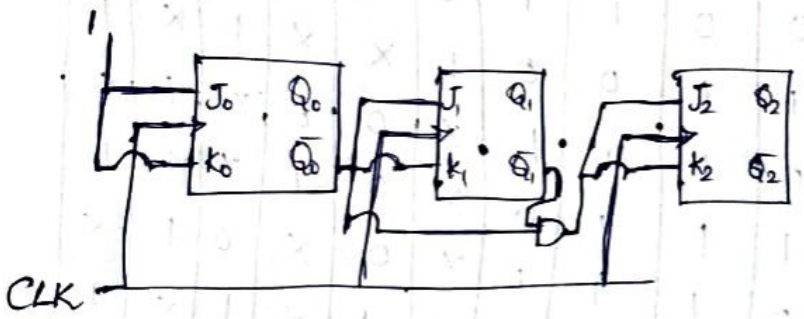
Up → $J_2 = Q_1Q_0$
down → $J_2 = Q_1'Q_0'$

up → $K_2 = Q_1Q_0$
down → $K_2 = Q_1'Q_0'$



Up-Counter

Down-counter → $J_3 = Q_2Q_1Q_0$ $K_3 = Q_2Q_1Q_0$



JK Ch. Table

J (S)	K (R)	Q	Q^+	
0	0	0	0	Hold
0	0	1	1	
0	1	0	0	clear / store
0	1	1	0	
1	0	0	1	set state
1	0	1	1	
1	1	0	1	Toggle state
1	1	1	0	

Excitation Table.

P.S	N.X	I/P.S	
Q	Q^+	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

up :-

$J_0 = K_0 = 1$

$J_1 = K_1 = Q_0$

$J_2 = K_2 = Q_1 Q_0$

down

$J_0 = K_0 = 1$; $J_1 = K_1 = Q_0'$

$J_2 = K_2 = Q_1' Q_0'$