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UNIT-I

Book : Anand Kumar
P. Raja

## Number Systems

1. Binary (2) → 0, 1
2. Decimal (10) → 0, to 9
3. Octal (8) → 0 to 7
4. Hexadecimal (16) → 0 to 9, A to F

1. BINARY to

a) Decimal

$(11010)_2 = (\ )_{10}$

$= 16 + 8 + 0 + 2 + 0$

$= (26)_{10}$

b) Octal

| 4 | 2 | 1 | |
|---|---|---|---|
| 0 | 0 | 0 | → 0 |
| 0 | 0 | 1 | → 1 |
| 0 | 1 | 0 | → 2 |
| 0 | 1 | 1 | → 3 |
| 1 | 0 | 0 | → 4 |
| 1 | 0 | 1 | → 5 |
| 1 | 1 | 0 | → 6 |
| 1 | 1 | 1 | → 7 |

$(10101101)_2 = (\ )_8$

$\therefore 010$

$= (255)_8$

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c) Hexadecimal

| 8 | 4 | 2 | 1 | |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | → 0 |
| 0 | 0 | 0 | 1 | → 1 |
| 0 | 0 | 1 | 0 | → 2 |
| 0 | 0 | 1 | 1 | → 3 |
| 0 | 1 | 0 | 0 | → 4 |
| 0 | 1 | 0 | 1 | → 5 |
| 0 | 1 | 1 | 0 | → 6 |
| 0 | 1 | 1 | 1 | → 7 |
| 1 | 0 | 0 | 0 | → 8 |
| 1 | 0 | 0 | 1 | → 9 |
| 1 | 0 | 1 | 0 | → A |
| 1 | 0 | 1 | 1 | → B |
| 1 | 1 | 0 | 0 | → C |
| 1 | 1 | 0 | 1 | → D |
| 1 | 1 | 1 | 0 | → E |
| 1 | 1 | 1 | 1 | → F |

$(\underbrace{1010}\underbrace{1101})_2 = (\ )_{16}$

$= (AD)_{16}$

$= (AD)_H$

2. DECIMAL to

a) Binary

$(23)_{10} = (\ )_2$

| | | |
|---|---|---|
| 2 | 23 | 1 |
| 2 | 11 | 1 |
| 2 | 5 | 1 |
| 2 | 2 | 0 |
| | 1 | |

$= (10111)_2$

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a) $(0.625)_{10} = ( )_2$

$$\begin{array}{rl} 0.625 & \\ \times 2 & 1 \\ \hline 1.250 & \\ \times 2 & 0 \\ \hline 0.500 & \\ \times 2 & 1 \\ \hline 1.00 & \end{array}$$

$(.101)_2$

b) Octal

$(172)_{10} \rightarrow ( )_8$

$$\begin{array}{r|r|l} 8 & 172 & 4 \\ 8 & 21 & 5 \\ & 2 & \end{array}$$

$(254)_8$

$(0.878)_{10} \rightarrow ( )_8$

$$\begin{array}{rl} 0.878 & \\ \times 8 & 7 \\ \hline 0.024 & \\ \times 8 & 0 \\ \hline 0.192 & \\ \times 8 & 1 \\ \hline .536 & \\ \times 8 & 4 \\ \hline .288 & \end{array}$$

$(.7014)_8$

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a) $(0.625)_{10} = ()_2$

$$\begin{array}{r l}
0.625 & \\
\times 2 & 1 \\
\hline
1.250 & \\
\times 2 & 0 \\
\hline
0.500 & \\
\times 2 & 1 \\
\hline
1.00 &
\end{array}$$

$(.101)_2$

b) Octal

$(172)_{10} \rightarrow ()_8$

$$\begin{array}{r|l|l}
8 & 172 & 4 \\
8 & 21 & 5 \\
 & 2 &
\end{array}$$

$(254)_8$

$(0.878)_{10} \rightarrow ()_8$

$$\begin{array}{r l}
0.878 & \\
\times 8 & 7 \\
\hline
0.024 & \\
\times 8 & 0 \\
\hline
0.192 & \\
\times 8 & 1 \\
\hline
.536 & \\
\times 8 & 4 \\
\hline
.288 &
\end{array}$$

$(.7014)_8$

3. OCTAL TO

a) Binary

$(127)_8 = ( )_2$

$7 = 111$ $2 = 010$ $1 = 001$

$\therefore (1010111)_2$

b) Decimal

$(42)_8 = ( )_{10}$

$4 = 100$ $2 = 010$

$= 100010$

$4 \times 8^1 + 2 \times 8^0 = 32 + 2$

$= (34)_{10}$

c) Hexadecimal

Octal → Binary → Hexa

$(127)_8 = ( )_{16}$

$1 = 001$ $2 = 010$ $7 = 111$

$= (1010111)_2$

$\therefore 0101$

$(57)_{16}$

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Q $(3134)_5$
$+ (3133)_5$

## ADDITION

Valid inputs = 0, 1, 2, 3, 4

$$\begin{array}{rrrr} & 1 & & 1 \\ 3 & 1 & 3 & 4 \\ 3 & 1 & 3 & 3 \\ \hline 11 & 3 & 2 & 2 \end{array}$$

← Remainder
← Quotient

4+3 = 7

$$5 \overline{)\,7\,}^{\,1}$$
$$\underline{5}$$
$$2.$$

Q $1(\ 7\ F\ )_{16}$
$+ (\ B\ A\ )_{16}$
$(\cancel{1}\ \cancel{3}\ 9)_{16}$

F = 15
A = 10

8
11
19

$$16 \overline{)\,25\,}^{\,1}$$
$$\underline{16}$$
$$9$$

Q $(7342)_8$
$- (5164)_8$

## SUBTRACTION

Borrow the base

$$\begin{array}{rrrr} 6 & 8+2 & 8+3 & 8+2 \\ \cancel{7} & 3 & 4 & 2 \\ 5 & 1 & 6 & 4 \\ \hline (2 & 1 & 5 & 6)_8 \end{array}$$

Q

$$(2000)_{16}$$
$$- (1)_{16}$$
$$(1FFF)_{16}$$

9/8/17

K-Maps : Karnaugh Maps

$\boxed{2^n}$ → no. of variables
↳ No. of cells

m → minterms → Product terms   $\Sigma m(\cdots)$
M → Maxterms → Sum terms   $\Pi M(\cdots)$
single, pair, quart, octet

Gray code : one transition at a time

| AB \ C | 0 | 1 |
|---|---|---|
| 00 | $m_0$ | $m_1$ |
| 01 | $m_2$ | $m_3$ |
| 11 | $m_6$ | $m_7$ |
| 10 | $m_4$ | $m_5$ |

m (0,1,2,4,7)

| A \ BC | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | $m_0$ 1 | $m_1$ 1 | . | 1 $m_2$ |
| 1 | $m_4$ 1 | . | $m_7$ 1 | . |

$\bar{A}\bar{B} + \cancel{ABC} + \bar{B}\bar{C} + ABC + \bar{A}\bar{C}$

$m(0,1,3,5,7)$

| A \ BC | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | 1 | 1 | 1 | |
| 1 | | 1 | 1 | |

$\bar A \bar B + C$

$m(3,4,5,7,\cancel{11,12},13,15,14,9)$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | 0 | 1 | 1 (3) | 2 |
| 01 | 1 (4) | 1 (5) | 1 (7) | 6 |
| 11 | 12 | 1 (13) | 1 (15) | 1 (14) |
| 10 | 8 | 1 (9) | 11 | 10 |

~~$\bar A \bar B D + \bar A B \bar C + ABC$~~

$\bar A B \bar C + \bar A \bar C D + ABC + \bar A C D$

Redundancy

## 5 Variables

| BC \ DE | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | 0 | 1 | 3 | 2 |
| 01 | 4 | 5 | 7 | 6 |
| 11 | 12 | 13 | 15 | 14 |
| 10 | 8 | 9 | 11 | 10 |

A = 0

| BC \ DE | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | 16 | 17 | 19 | 18 |
| 01 | 20 | 21 | 23 | 22 |
| 11 | 28 | 29 | 31 | 30 |
| 10 | 24 | 25 | 27 | 26 |

A = 1

$m(0,1,3,5,7,9,11,17,19,21,23,30)$

| BC \ DE | | | | |
|---|---|---|---|---|
| | 1 (0) | 1 (1) | 1 (3) | |
| | | 1 (5) | 1 (7) | |
| | | | | |
| | | 1 (9) | 1 (11) | |

A = 0

| BC \ DE | | | | |
|---|---|---|---|---|
| | | 1 (17) | 1 (19) | |
| | | 1 (21) | 1 (23) | |
| | | | | 1 (30) |
| | | | | |

A = 1

Super impose both the maps

∴ An octet is formed

$m_1\ m_3\ m_5\ m_7\ m_{17}\ m_{19}\ m_{21}\ m_{23}$

$Y = \bar{B}E + \bar{A}\bar{B}\bar{C}\bar{D} + \bar{A}\bar{C}E + ABCD\bar{E}$

Q ⇒ Design a logic ckt with 4 inputs & 1 output. The output will produce 1 if the input is greater than 1000

| A | B | C | D |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 |
| 1 | 1 | 1 | 1 |

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | 0 | 1 | 3 | 2 |
| 01 | 4 | 5 | 7 | 6 |
| 11 | 1 (12) | 1 (13) | 1 (15) | 1 (14) |
| 10 | 8 | 1 (9) | 1 (11) | 1 (10) |

$Y = AB\bar{C} + AD + AC$

# STLD

## Imp: Quine Mc.Clusky Method / Q.M. Method

Qu Simplify $Y = \Sigma m(0,1,3,7,8,9,11,15)$ using Q.M. method

| | |
|---|---|
| 0 | 0000 |
| 1 | 0001 |
| 3 | 0011 |
| 7 | 0111 |
| 8 | 1000 |
| 9 | 1001 |
| 11 | 1011 |
| 15 | 1111 |

| Group | minterms | Variable ABCD |
|---|---|---|
| 0 | 0 | 0000 |
| 1 | 1 | 0001 |
| | 8 | 1000 |
| 2 | 3 | 0011 |
| | 9 | 1001 |
| 3 | 7 | 0111 |
| | 11 | 1011 |
| 4 | 15 | 1111 |

Adjaseent groups are checked, and only one transition is acceptable

| Group | Minterm | Variable |
|---|---|---|
| 0 | 0,1 | 000– |
| | 0,8 | –000 |
| 1 | 1,3 | 00–1 |
| | 1,9 | –001 |
| | 8,9 | 100– |
| 2 | 3,7 | 0–11 |
| | 3,11 | –011 |
| | 9,11 | 10–1 |
| 3 | 7,15 | –111 |
| | 11,15 | 1–11 |

Similarly

| Group | Minterm | Variable |
|---|---|---|
| 0 | 0,1,8,9 | –00– |
| | 0,8,1,9 | –00– |
| 1 | 1,3,9,11 | –0–1 |
| | 1,9,3,11 | –0–1 |
| 2 | 3,7,11,15 | ––11 |
| | 3,11,7,15 | ––11 |

~~3, 11, 7, 15~~ ~~11~~

Now check the variables

Group: 0 → $\bar{B}\bar{C}$
1 → $\bar{B}D$
2 → $CD$

} → **prime implicants**

| No. of tables = no. of variables − 1 |

| Prime implicant terms | Primary Value | 0 | 1 | 3 | 7 | 8 | 9 | 11 | 15 |
|---|---|---|---|---|---|---|---|---|---|
| | | Min terms | | | | | | | |
| $\bar{B}\bar{C}$ | 0,1,8,9 | X | X | | | X | X | | |
| $\bar{B}D$ | 1,3,9,11 | | X | X | | | X | X | |
| $CD$ | 3,7,11,15 | | | X | X | | | X | X |

$Y = \bar{B}\bar{C} + CD$

∴ $\bar{B}D$ is redundant

Q. $\Sigma m(0, 1, 2, 3, 5, 7, 8, 9, 11, 14)$ simplify using Q.M. method

0 − 0000
1 − 0001
2 − 0010
3 − 0011
5 − 0101
7 − 0111

8 − 1000
9 − 1001
11 − 1011
14 − 1110

~~3, 11, 7, 15~~ — 14

Now check the variables

group: 0 → $\bar{B}\bar{C}$
1 → $\bar{B}D$
2 → $CD$

} → **prime implicants**

| No. of tables = no. of variables − 1 |

| Prime implicant terms | Primary Value | 0 | 1 | 3 | 7 | 8 | 9 | 11 | 15 |
|---|---|---|---|---|---|---|---|---|---|
| $\bar{B}\bar{C}$ | 0,1,8,9 | X | X | | | X | X | | |
| $\bar{B}D$ | 1,3,9,11 | | X | X | | | X | X | |
| $CD$ | 3,7,11,15 | | | X | X | | | X | X |

$Y = \bar{B}\bar{C} + CD$

∴ $\bar{B}D$ is redundant

Q $\Sigma m(0, 1, 2, 3, 5, 7, 8, 9, 11, 14)$ simplify using Q.M. method

0 − 0000
1 − 0001
2 − 0010
3 − 0011
5 − 0101
7 − 0111

8 − 1000
9 − 1001
11 − 1011
14 − 1110

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| Group | Minterms | Variable |
|---|---|---|
| 0 | 0 | 0000 |
| 1 | 1 | 0001 |
| | 2 | 0010 |
| | 8 | 1000 |
| 2 | 3 | 0011 |
| | 5 | 0101 |
| | 9 | 1001 |
| 3 | 7 | 0111 |
| | 14 | 1110 |
| | 11 | 1011 |

| Group | Minterms | Variable |
|---|---|---|
| 0 | 0,8 | -000 |
| | 0,1 | 000- |
| | 0,2 | 00-0 |
| 1 | 1,3 | 00-1 |
| | 1,5 | 0-01 |
| | 1,9 | -001 |
| | 2,3 | 001- |
| | 8,9 | 100- |
| 2 | 3,7 | 0-11 |
| | 3,11 | -011 |
| | 5,7 | 01-1 |
| | 9,11 | 10-1 |

| Group | Minterms | Variable |
|---|---|---|
| 0 | 0 2 1 3 | 00-- |
| | 0 8 | |

| Group | Minterms | Variable |
|---|---|---|
| 0 | 0,1,2,3 | 00-- $\bar{A}\bar{B}$ |
| | 0,1,8,9, | -00- |
| | 0 2 1 3 | 00-- |
| | 0,8,1,9 | -00- $\bar{B}\bar{C}$ |

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| | | | |
|---|---|---|---|
| 1 | 1 3 5 7 | 0 - - 1 | $\bar{A}D$ |
| | 1 3 9 11 | - 0 - 1 | |
| | 1 5 3 7 | 0 - - 1 | $\bar{B}D$ |
| | 1 9 3 11 | - 0 - 1 | $\bar{B}D$ |

| Prime implicant | Primary Value | 0 | 1 | 2 | 3 | 5 | 7 | 8 | 9 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| $\bar{A}\bar{B}$ | 0, 1, 2, 3 | x | x | x | x | | | | | |
| $\bar{B}\bar{C}$ | 0, 1, 8, 9 | x | x | | | | | x | x | |
| $\bar{A}D$ | 1, 3, 5, 7 | | x | | x | x | x | | | |
| $\bar{B}D$ | 1, 3, 9, 11 | | x | | x | | | | x | x |

Minterms

**Q** Your minterms are (0, 2, 3, 5, 7, 9, 11, 14)
(1, 8, 11) dont care

| | 0 | 2 | 3 | 5 | 7 | 9 | 14 |
|---|---|---|---|---|---|---|---|
| $\bar{B}D$ | | | x | | | x | |
| $\bar{A}\bar{B}$ | x | x | x | | | | |
| $\bar{B}\bar{C}$ | x | | | | | x | |
| $\bar{A}D$ | | | x | x | x | | |

| | |
|---|---|
| $\bar{B}D$ | 1 3 9 11 |
| $\bar{A}\bar{B}$ | 0 1 2 3 |
| $\bar{B}\bar{C}$ | 0 1 8 9 |
| $\bar{A}D$ | 1 3 5 7 |

$\bar{A}\bar{B} + \bar{A}D$

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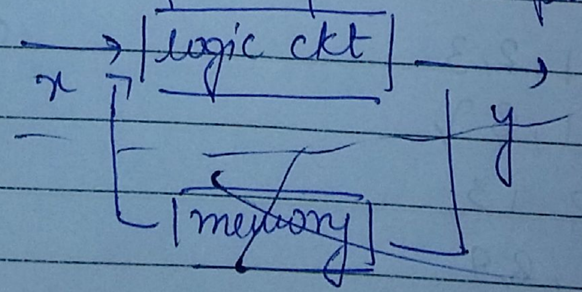
## Combinational Circuits

Works only on present input



| | | | |
|---|---|---|---|
| 1 | 1 3 5 7 | 0--1 | $\bar{A}D$ |
| | 1 3 9 11 | -0-1 | |
| | 1 5 3 7 | 0--1 | $\bar{B}D$ |
| | 1 9 3 11 | -0-1 | $\bar{B}D$ |

| Prime implicant | Primary Value | 0 | 1 | 2 | 3 | 5 | 7 | 8 | 9 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|
| $\bar{A}\bar{B}$ | 0, 1, 2, 3 | X | X | X | X | | | | | |
| $\bar{B}\bar{C}$ | 0, 1, 8, 9 | X | X | | | | | X | X | |
| $\bar{A}D$ | 1, 3, 5, 7 | | X | | X | X | X | | | |
| $\bar{B}D$ | 1, 3, 9, 11 | | X | | X | | | | X | X |

Q Your minterms are (0, 2, 3, 5, 7, 9, 14)
(1, 8, 11) dont care

| 0 | 2 | 3 | 5 | 7 | 9 | 14 |
|---|---|---|---|---|---|---|
| | | X | | | X | |
| X | X | X | | | | |
| X | | | | | X | |
| | | X | X | X | | |

| | |
|---|---|
| $\bar{B}D$ | 1 3 9 11 |
| $\bar{A}\bar{B}$ | 0 1 2 3 |
| $\bar{B}\bar{C}$ | 0 1 8 9 |
| $\bar{A}D$ | 1 3 5 7 |

$\bar{A}\bar{B} + \bar{A}D$

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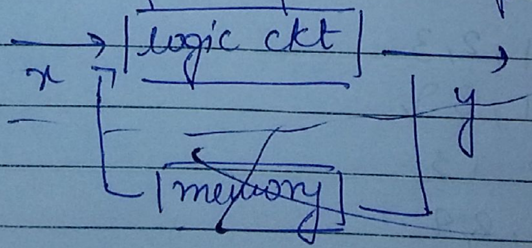
## Combinational Circuits

Works only on present input



## Adders

Addition of bits

### half adder

it adds 2 bit at a time $(A+B)$

| A | B | Sum | Carry |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 1 |

K-Maps for S & C

| A \ B | 0 | 1 |
|---|---|---|
| 0 | | 1 |
| 1 | 1 | |

| A \ B | 0 | 1 |
|---|---|---|
| 0 | | |
| 1 | | 1 |

$$Sum = \bar{A}B + A\bar{B}$$
$$= A \oplus B$$

$$Carry = AB$$

### Full adder

it adds 3 bit at a time $(A+B+C)$

| A | B | C | S | Carry |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 1 | 1 |

K-Maps

| A \ BC | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | | 1 | | 1 |
| 1 | 1 | | 1 | |

$S = \bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$

| A \ BC | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | | | 1 | |
| 1 | | 1 | 1 | 1 |

$C = BC + AC + AB$

## Subtracter

→ Half subtracter

$A-B$

| A | B | Di | Bi |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 |

K-Maps

| A \ B | 0 | 1 |
|---|---|---|
| 0 | | 1 |
| 1 | 1 | |

$D = A\bar{B} + \bar{A}B$

| A \ B | 0 | 1 |
|---|---|---|
| 0 | | 1 |
| 1 | | |

$B = \bar{A}B$

→ Full subtracter

$A-B-C$

| A | B | C | D | B |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 1 |
| 0 | 1 | 0 | 1 | 1 |
| 0 | 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 0 |
| 1 | 1 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 |

K-Maps

| A \ BC | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | | 1 | | 1 |
| 1 | 1 | 1 | 1 | |

| A \ BC | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | | 1 | 1 | 1 |
| 1 | | | 1 | |

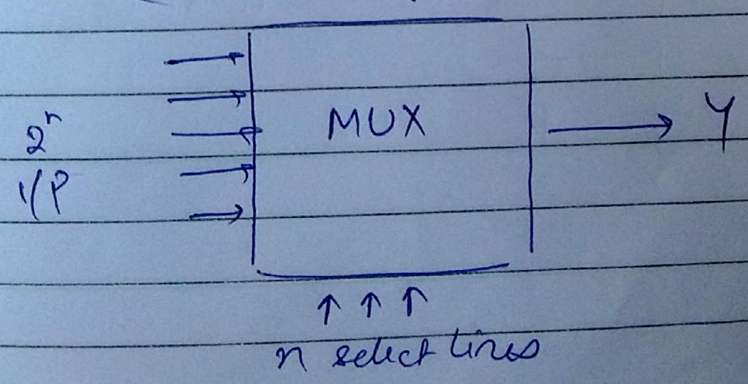
$D = A\bar{B}\bar{C} + \bar{A}\bar{B}C + \bar{A}B\bar{C} + ABC$ $B = \bar{A}C + \bar{A}B + BC$

Q Design a 4 bit parallel adder
Design a 4 bit look ahead carry generator

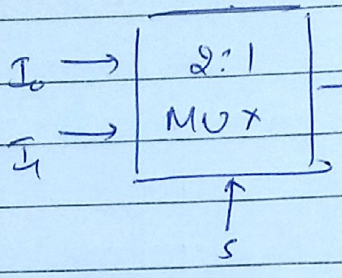
16/8/17 MULTIPLEXER (MUX)

They are used to increase the amount ~~of data that can be sent over the~~ network within a certain amt. of time by bandwidth

Converts parallel input data to serial output (many to single)

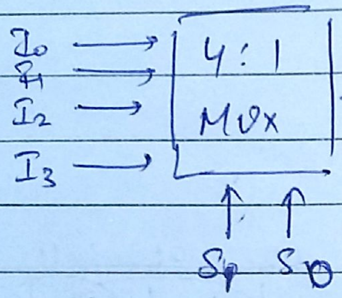



Also called a data selector, is a logic ckt. that accepts several data inputs and allows only one of them to get through to the output. Multiplexing means sharing. A multiplexer makes it possible ~~for several signals to share~~ one device ~~and~~ or resource




| S | Y |
|---|---|
| 0 | $I_0$ |
| 1 | $I_1$ |

$$\therefore Y = \bar{S} I_0 + S I_1$$




| $S_1$ | $S_0$ | Y |
|---|---|---|
| 0 | 0 | $I_0$ |
| 0 | 1 | $I_1$ |
| 1 | 0 | $I_2$ |
| 1 | 1 | $I_3$ |

$$\therefore Y = \bar{S_1} \bar{S_0} I_0 + \bar{S_1} S_0 I_1 + S_1 \bar{S_0} I_2 + S_1 S_0 I_3$$

Q Implement the following boolean funct<sup></sup>n using

a) 16:1 MUX

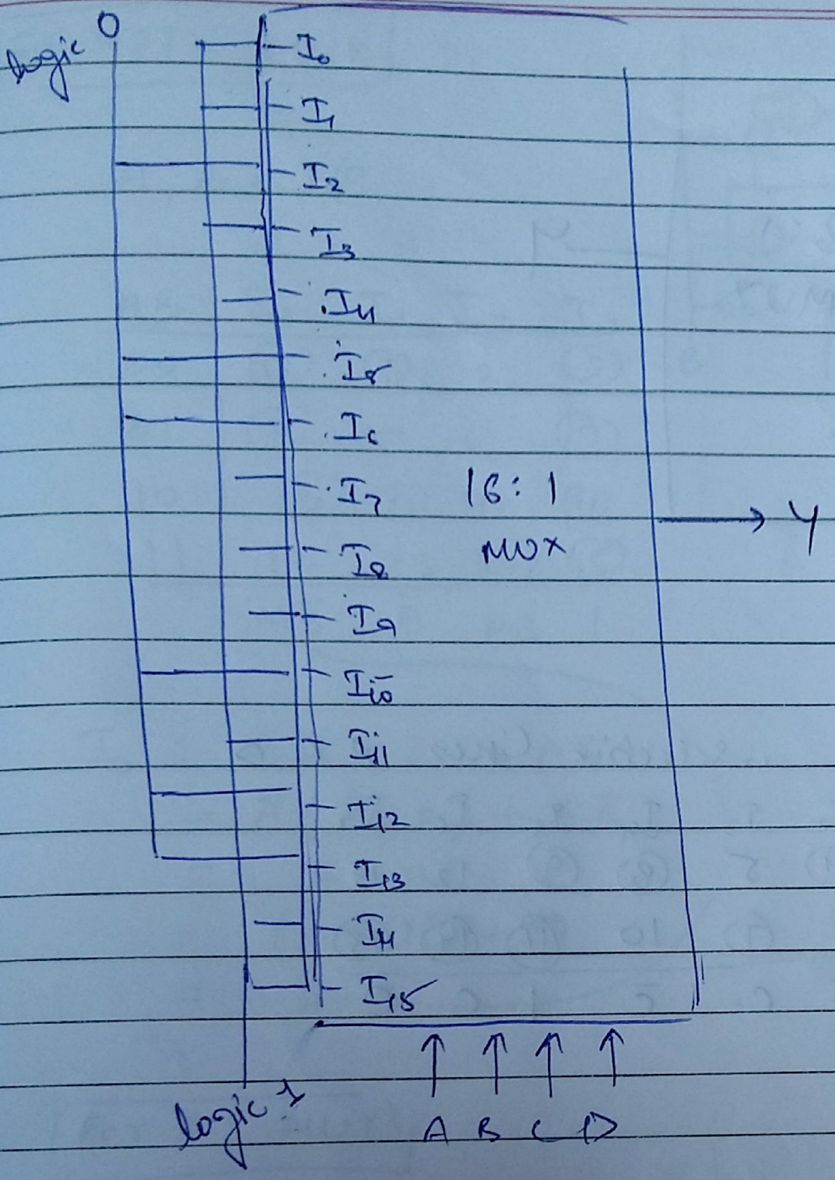
b) 8:1 MUX

c) 4:1 MUX

d) 2:1 MUX

$$f = \Sigma m(0,1,3,4,7,8,9,11,14,15)$$

Ans. 4 variable funct



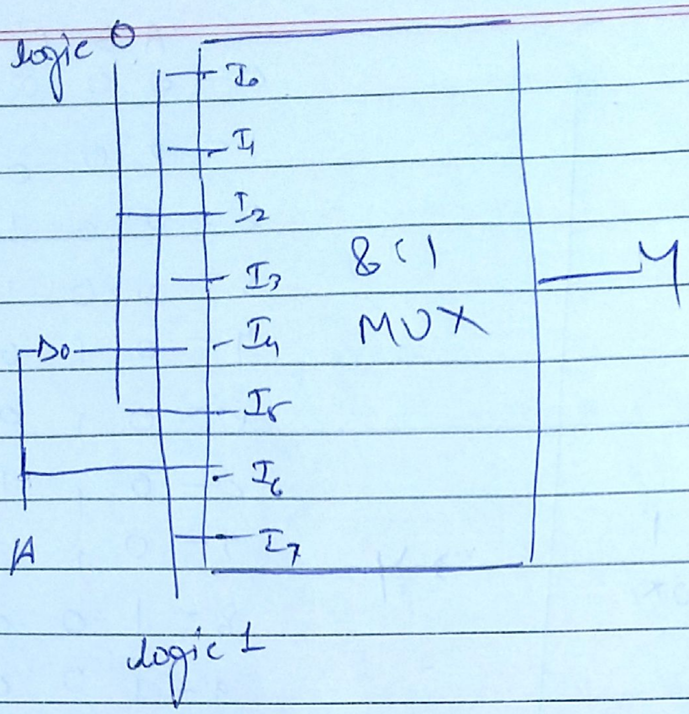

| | A | B | C | D |
|---|---|---|---|---|
| 0 – | 0 | 0 | 0 | 0 |
| 1 – | 0 | 0 | 0 | 1 |
| 2 – | 0 | 0 | 1 | 0 |
| 3 – | 0 | 0 | 1 | 1 |
| 4 – | 0 | 1 | 0 | 0 |
| 5 – | 0 | 1 | 0 | 1 |
| 6 – | 0 | 1 | 1 | 0 |
| 7 – | 0 | 1 | 1 | 1 |
| 8 – | 1 | 0 | 0 | 0 |
| 9 – | 1 | 0 | 0 | 1 |
| 10 – | 1 | 0 | 1 | 0 |
| 11 – | 1 | 0 | 1 | 1 |
| 12 – | 1 | 1 | 0 | 0 |
| 13 – | 1 | 1 | 0 | 1 |
| 14 – | 1 | 1 | 1 | 0 |
| 15 – | 1 | 1 | 1 | 1 |

**For 8:1 MUX**

A = I/P ∴ B, C, D : select lines

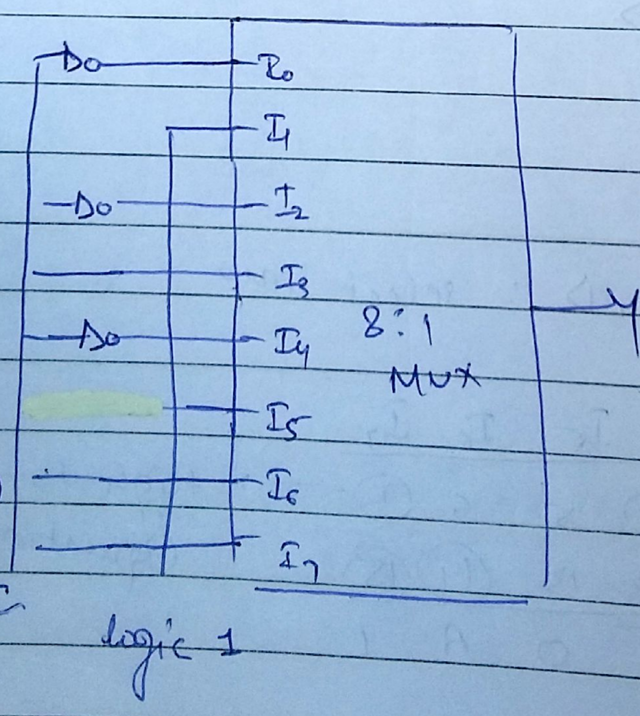
| | $I_0$ | $I_1$ | $I_2$ | $I_3$ | $I_4$ | $I_5$ | $I_6$ | $I_7$ |
|---|---|---|---|---|---|---|---|---|
| $\bar{A}$ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| A | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| | 1 | 1 | 0 | 1 | $\bar{A}$ | 0 | A | 1 |

→ High terms (question)




Input = C     $\therefore$ selective lines A B D

| | $I_0$ | $I_1$ | $I_2$ | $I_3$ | $I_4$ | $I_5$ | $I_6$ | $I_7$ |
|---|---|---|---|---|---|---|---|---|
| $\bar{C}$ | 0 | 1 | 4 | 5 | 8 | 9 | 12 | 13 |
| $C$ | 2 | 3 | 6 | 7 | 10 | 11 | 14 | 15 |
| | $\bar{C}$ | 1 | $\bar{C}$ | $C$ | $\bar{C}$ | 1 | $C$ | $C$ |



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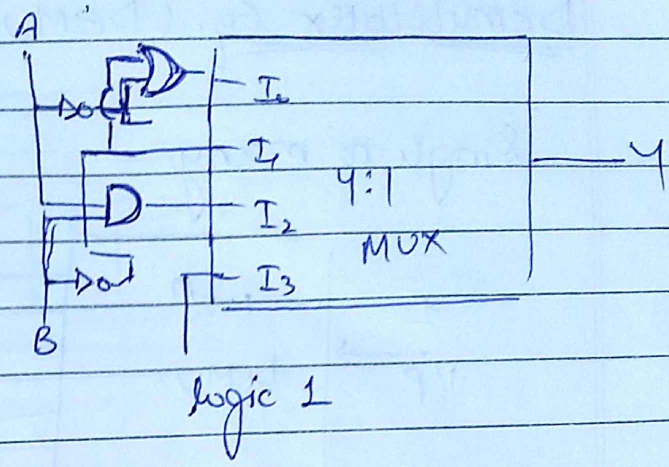
For 4:1 MUX

A, B = I/P

| AB | $I_0$ | $I_1$ | $I_2$ | $I_3$ |
|---|---|---|---|---|
| 00 | 0 | 1 | 2 | 3 |
| 01 | 4 | 5 | 6 | 7 |
| 10 | 8 | 9 | 10 | 11 |
| 11 | 12 | 13 | 14 | 15 |
| | $\bar{A}+\bar{B}$ | $\bar{B}$ | $AB$ | 1 |




$I_0$ : $\bar{A}\bar{B} + \bar{A}B + A\bar{B}$

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

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

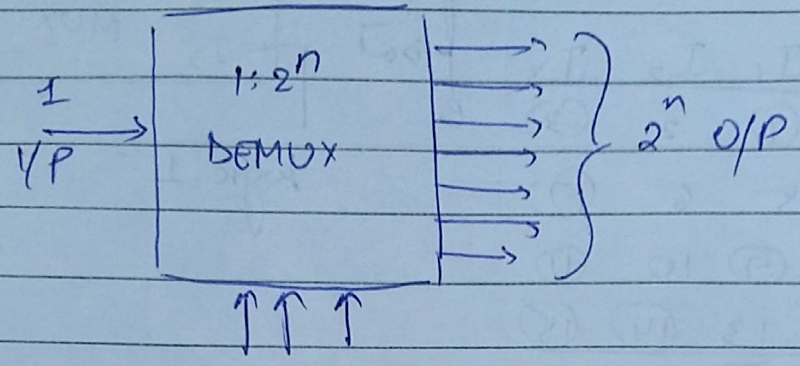
$= (\bar{A}+A)(\bar{A}+\bar{B})$

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

For 2:1 MUX

# Demultiplexer (DEMUX)  called data distributer

Single to many




'n' select lines

1 : 2

| I/P | SL | O/P | |
|---|---|---|---|
| I | S | $Y_0$ | $Y_1$ |
| I | 0 | I | 0 |
| I | 1 | 0 | I |

$Y_0 = \bar{S} I$

$Y_1 = S I$

1 : 4

| I/P | $S_1$ | $S_0$ | $Y_0$ | $Y_1$ | $Y_2$ | $Y_3$ |
|---|---|---|---|---|---|---|
| I | 0 | 0 | I | 0 | 0 | 0 |
| I | 0 | 1 | 0 | I | 0 | 0 |
| I | 1 | 0 | 0 | 0 | I | 0 |
| I | 1 | 1 | 0 | 0 | 0 | I |

Q. Design a full ~~sub~~ $\boxed{\text{adder}}$ using DEMUX

$S = \sum m(1, 2, 4, 7)$

$C = \sum m(3, 5, 6, 7)$

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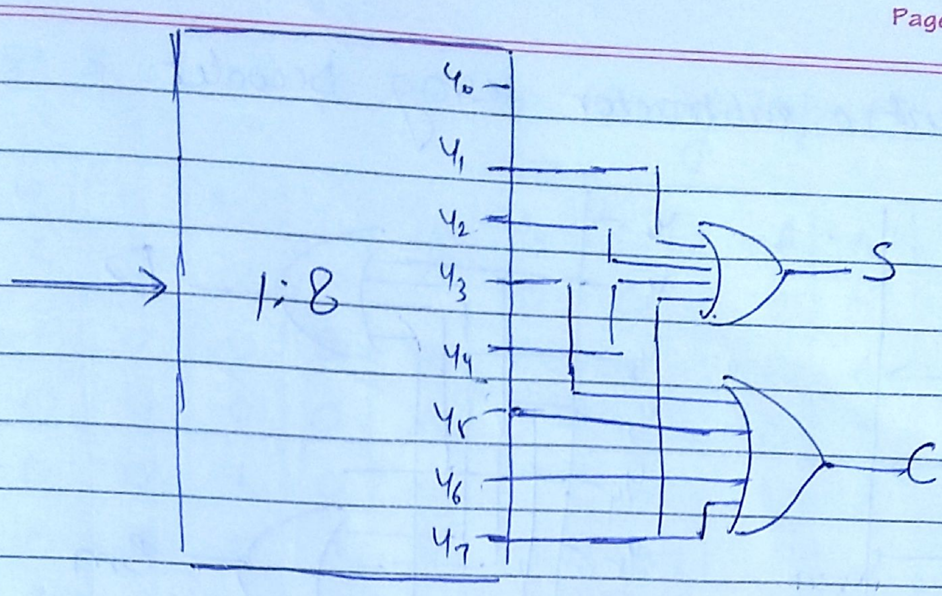
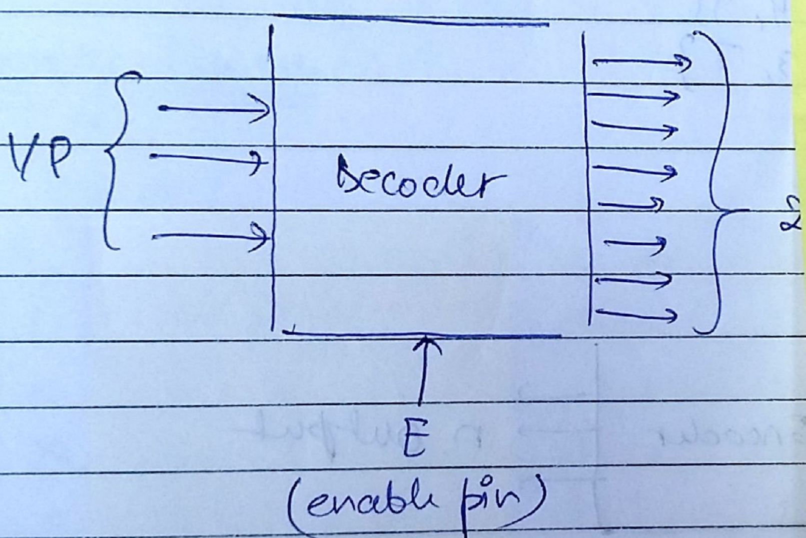



DECODER

It converts n inputs into $2^n$ outputs

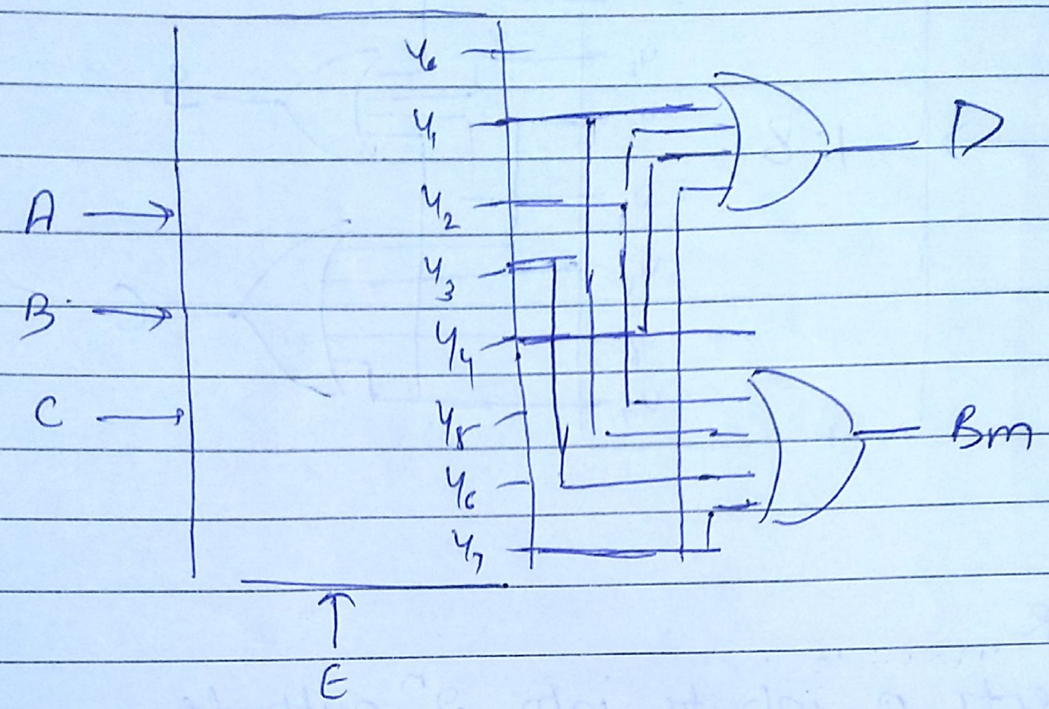



DECODER
It is a combinational logic ckt. that converts a binary integer value to an associated pattern of output bits.
Used in data demultiplexing, memory address decoding.

2 to 4

| E | A | B | $Y_0$ | $Y_1$ | $Y_2$ | $Y_3$ |
|---|---|---|---|---|---|---|
| 0 | x | x | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| 1 | 1 | 0 | 0 | 0 | 1 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 1 |

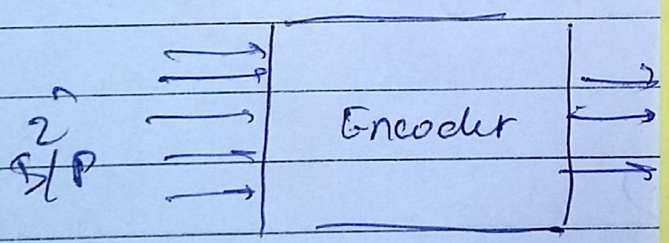
Q Impliment a subtracter using Decoder




$D = \{1, 2, 4, 7\}$

$B_m = \{1, 2, 3, 7\}$

## ENCODER

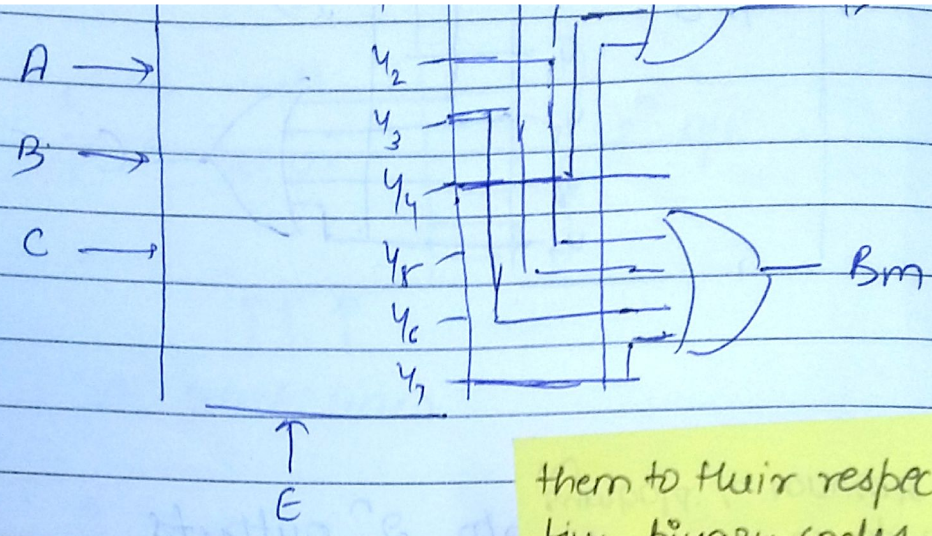



**ENCODER**

It is a device / ckt. that converts info. from one format or code to another for the purpose of standardization, speed or compressions. It recieves digits, alphabets, or special symbols & converts

4 : 2

| E | A | B | C | D | Y | |
|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 | | |
| 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| 1 | 0 | 0 | 0 | 1 | 1 | 1 |



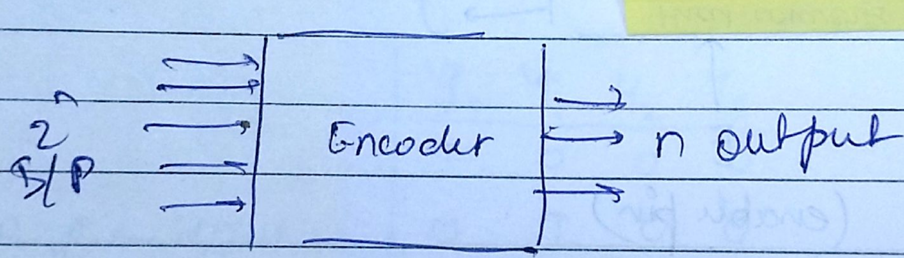

$D = \{1, 2, 4, 7\}$

$B_m = \{1, 2, 3, 7\}$

them to their respective binary codes

$2^n$ : I/P $\rightarrow$ n : O/P

## ENCODER




4 : 2

| E | A | B | C | D | $Y_0$ | $Y_1$ | ~~$Y_3$~~ |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | |
| 1 | 0 | 1 | 0 | 0 | 0 | 1 | |

8 : 3 Octal to binary input

| $Y_0$ | $Y_1$ | $Y_2$ | $Y_3$ | $Y_4$ | $Y_5$ | $Y_6$ | $Y_7$ | A | B | C | E |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |

## Priority Encoder

4 : 2

| $Y_0$ | $Y_1$ | $Y_2$ | $Y_3$ | A | B | E |
|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| x | 1 | 0 | 0 | 0 | 1 | 1 |
| X | x | 1 | 0 | 1 | 0 | 1 |
| x | x | x | 1 | 1 | 1 | 1 |

PRIORITY ENCODER
It is a ckt. that compresses multiple binary inputs to into a smaller number of outputs.
— x — x — x — x —
A single bit 4 to 2 encoder, where highest priority I/P's are to the left i.e. 'X' indicates an

| $Y_0Y_1 \backslash Y_2Y_3$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | 1 | 1 | 1 |
| 01 | | 1 | 1 | 1 |
| 11 | | 1 | 1 | 1 |
| 10 | | 1 | 1 | 1 |

$Y_3$

| | | | |
|---|---|---|---|
| X | X | X | 1 |
| 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 |

01 10
10 10
11 10

$$Y = Y_2 + Y_3$$

...al to binary input

| $Y_5$ | $Y_6$ | $Y_7$ |
|---|---|---|
| | 0 | 0 |
| | 0 | 0 |
| | 0 | 0 |
| | 0 | 0 |
| | 0 | 0 |
| | 0 | 0 |
| | 1 | 0 |
| | 0 | 1 |

irrelevant value, i.e any I/P there yields same O/P since it is superseded by higher priority I/P

| $I_3$ | $I_2$ | $I_1$ | $I_0$ | $Q_1$ | $Q_0$ | E |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | x | x | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 0 | 0 | 1 | x | 0 | 1 | 1 |
| 0 | 1 | x | x | 1 | 0 | 1 |
| 1 | x | x | x | 1 | 1 | 1 |

| B | E |
|---|---|
| 0 | 1. |
| 1 | 1 |
| | 1 |
| | 1 |

$Y_2$

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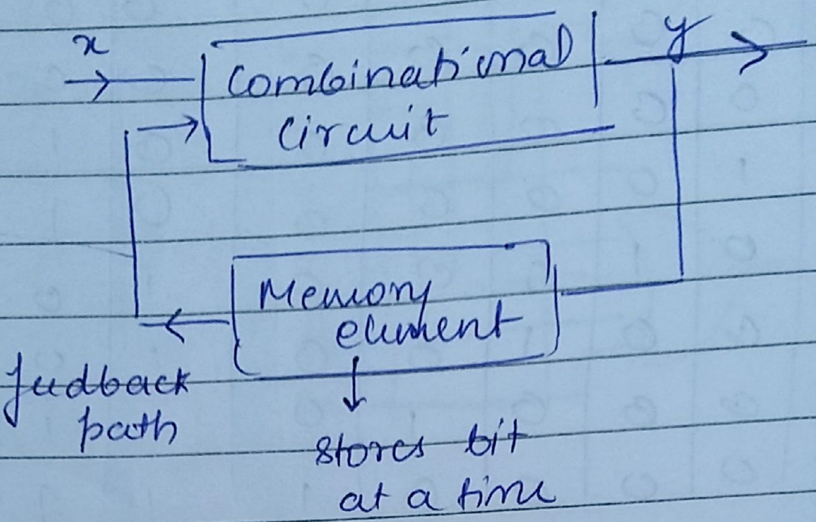
# UNIT – II

## Sequential Circuits




Register = combination of no. of flip flops
(1 flip flop stores 1 bit at a time)

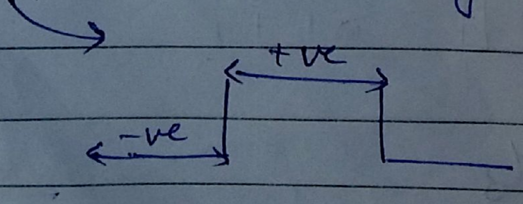
### Types

① Synchronous S.C.
(clocked)
input and output are synchronised.

② Asynchronous S.C.
(unclocked)
↓
latch

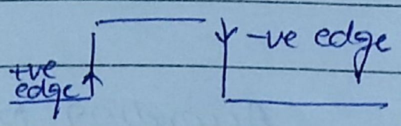
Triggering → level +ve, -ve
→ edge +ve, -ve

clockpulse : wave of square chain




edge triggering

edge triggering

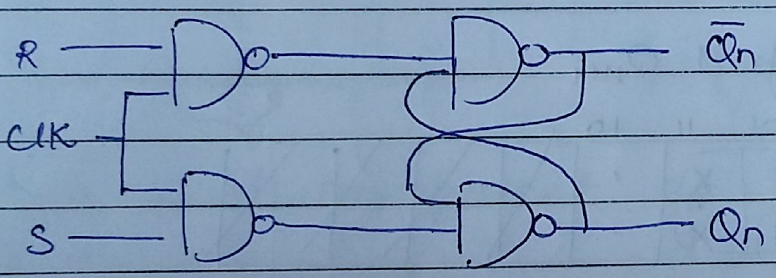



* Difference b/w a latch and a flip-flop

Types of flip flop

RS D JK T

① RS: Reset / Set flip flop ⟶ limitation: we cannot give 1 1 in RS




Truth table: tells the present state → $Q_n$

Characteristic table: ~~tells~~ tells next state

Excitation table

Truth Table

| C | R | S | $Q_n$ | $\bar{Q}_n$ | |
|---|---|---|---|---|---|
| 1 | 0 | 0 | $Q_n$ | $\bar{Q}_n$ | no change state |
| 1 | 0 | 1 | 1 | 0 | set state |
| 1 | 1 | 0 | 0 | 1 | Reset state |
| 1 | 1 | 1 | x | x | Prohibited state |

## Characteristic Table

| Present I/P R | Present I/P S | Present state $Q_n$ | Next state $Q_{n+1}$ |
|---|---|---|---|
| 0 | 0 | 0 | $Q_n = 0$ |
| 0 | 0 | 1 | $Q_n = 1$ |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | x → dont care |
| 1 | 1 | 1 | x |

According to the values of R & S, the values of $Q_n$ is substituted in $Q_{n+1}$ and then the value of $Q_n$ is checked (from Truth Table)

K-Map to find $Q_{n+1}$

| $Q_n$ \ RS | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | | 1 | X | |
| 1 | 1 | 1 | X | |

$$S + \bar{R}Q_n$$

## Excitation Table

| $Q_n$ | $Q_{n+1}$ | R | S |
|---|---|---|---|
| 0 | 0 | X ← {0, 1} | 0 |
| 0 | 1 | 0 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | {0, 1} X |

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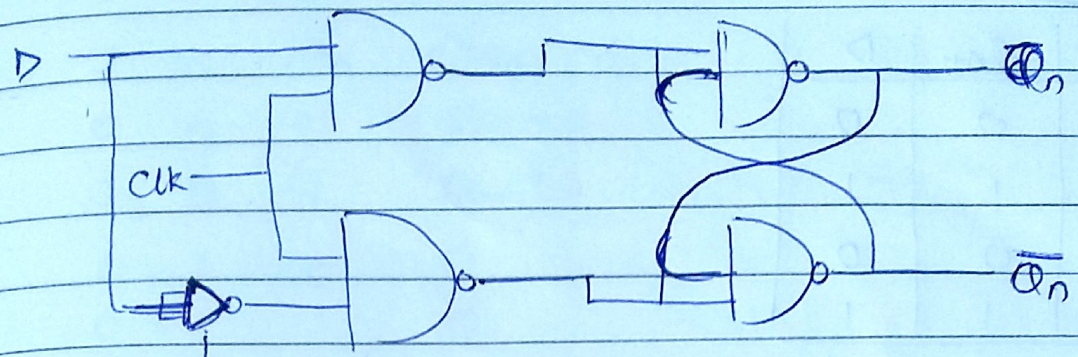
③ D : Delay flip flop




→ no same input can be given

Truth Table

| C | D | $Q_n$ | $\overline{Q_n}$ |
|---|---|---|---|
| 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 0 |

$\overline{Q_n}$ Since the output is reversed of input D

It is called transparent as input = output

21/8/17

② D Delay

Characteristic Table

| D | $Q_n$ | $Q_{n+1}$ |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

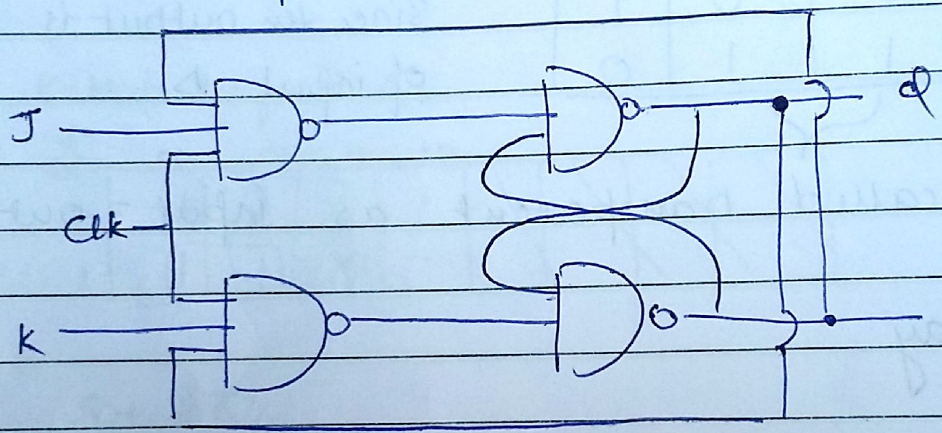
$$\boxed{Q_{n+1} = D}$$

Excitation Table

| Qn | Qn+1 | D |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

③ JK : Jack Kilsty

It is the modified version of RS flip flop




Truth Table

| C | J | K | Q | $\bar{Q}$ | |
|---|---|---|---|---|---|
| 1 | 0 | 0 | Q | $\bar{Q}$ | → No change state |
| 1 | 0 | 1 | 0 | 1 | → Reset state |
| 1 | 1 | 0 | 1 | 0 | → Set state |
| 1 | 1 | 1 | $\bar{Q}$ | Q | → Toggle state (inverse of last output) |

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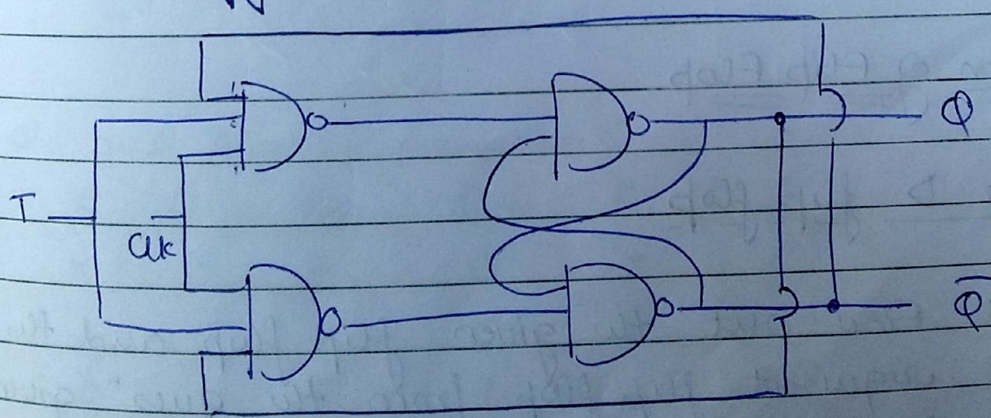
## Characteristic Tabl

| J | K | $Q_n$ | $Q_{n+1}$ |
|---|---|---|---|
| 0 | 0 | 0 | $Q_n = 0$ |
| 0 | 0 | 1 | $Q_n = 1$ |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | $\bar{Q}_n = 1$ |
| 1 | 1 | 1 | $\bar{Q}_n = 0$ |

## Excitation Tabl

| $Q_n$ | $Q_{n+1}$ | J | K |
|---|---|---|---|
| 0 | 0 | 0 | $\left.\begin{matrix}0\\1\end{matrix}\right\} x$ |
| 0 | 1 | 1 | $\left.\begin{matrix}0\\1\end{matrix}\right\} x$ |
| 1 | 0 | $x \left\{\begin{matrix}0\\1\end{matrix}\right.$ | 1 |
| 1 | 1 | $x \left\{\begin{matrix}0\\1\end{matrix}\right.$ | 0 |

④ T : Toggle



Truth Table

| C | T | Q | $\overline{Q}$ |
|---|---|---|---|
| 1 | 0 | $Q_n$ | $\overline{Q}_n$ |
| 1 | 1 | $\overline{Q}_n$ | $Q_n$ |

Characteristic Table

| T | $Q_n$ | $Q_{n+1}$ |
|---|---|---|
| 0 | 0 | 0 ($Q_n$) |
| 0 | 1 | 1 ($Q_n$) |
| 1 | 0 | 1 ($\overline{Q_n}$) |
| 1 | 1 | 0 ($\overline{Q}_n$) |

Excitation Table

| $Q_n$ | $Q_{n+1}$ | T |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

Q Conversion of Flip Flop

① RS to D flip flop

* Step 1 : Find out the given flip flop and the required flip flop from the ques^n given

Step 2 : Design a excitation table of given flip flop.

Step 3: Design a characteristic table of required flip flop

Step 4: Make a conversion table using these two tables

Step 5: Find out the required expression of required flip flops using k-map

Step 6: Design block diagram of required flip flop

## Rs to D

1 Rs → Given D → Required

2

| $Q_n$ | $Q_{n+1}$ | R | S |
|---|---|---|---|
| 0 | 0 | x | 0 |
| 0 | 1 | 0 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | x |

3.

| D | $Q_n$ | $Q_{n+1}$ |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

4 $Q_n$ and $Q_{n+1}$ is common

| D | $Q_n$ | $Q_{n+1}$ | R | S |
|---|---|---|---|---|
| 0 | 0 | 0 | x | 0 |
| 0 | 1 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 | x |

5. We take present value not futuristic

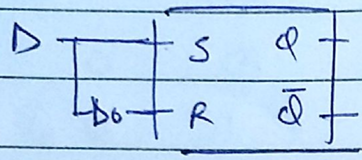
| D \ Q | 0 | 1 |
|---|---|---|
| 0 | X | 1 |
| 1 | | |

$R = \bar{D}$

| D \ Q | 0 | 1 |
|---|---|---|
| 0 | X | |
| 1 | X | 1 |

$S = D$

6




② JK to T

1. $JK \longrightarrow T$

2.

| $Q_n$ | $Q_{n+1}$ | J | K |
|---|---|---|---|
| 0 | 0 | 0 | X |
| 0 | 1 | 1 | X |
| 1 | 0 | X | 1 |
| 1 | 1 | X | 0 |

3

| T | $Q_n$ | $Q_{n+1}$ |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

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4.

| T | $Q_n$ | $Q_{n+1}$ | J | K |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | x |
| 1 | 0 | 1 | 1 | x |
| 1 | 1 | 0 | x | 1 |
| 0 | 1 | 1 | x | 0 |

5.

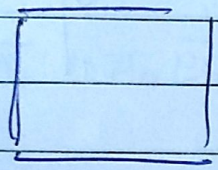
| T\Q | 0 | 1 |
|---|---|---|
| 0 | | X |
| 1 | 1 | X |

| T\Q | 0 | 1 |
|---|---|---|
| 0 | X | |
| 1 | X | 1 |

J = T

K = T

6



Q What is race around condition and how do we eliminate it

- Race - around condition is due to level triggering
- Master - slave flip flop
  we apply 2 flip flops

# Comparator

## 1- bit magnitude comparator

| A | B | A > B | A = B | A < B |
|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 | 0 |

$A > B = A\bar{B}$

| A\B | 0 | 1 |
|---|---|---|
| 0 | | |
| 1 | 1 | |

$A = B : \bar{A}\bar{B} + AB$
$= A \odot B$

| A\B | 0 | 1 |
|---|---|---|
| 0 | 1 | |
| 1 | | 1 |

$A < B = \bar{A}B$

| A\B | 0 | 1 |
|---|---|---|
| 0 | | 1 |
| 1 | | |

## 2- bit magnitude comparator

| A | | B | | A > B | A = B | B > A |
|---|---|---|---|---|---|---|
| $A_1$ | $A_0$ | $B_1$ | $B_0$ | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| 1 | 0 | 1 | 1 | 0 | 0 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 | 0 | 1 | 0 |

A > B

| $A_1A_0$ \ $B_1B_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | | |
| 01 | 1 | | | |
| 11 | 1 | 1 | | 1 |
| 10 | 1 | 1 | | |

A = B

| $A_1A_0$ \ $B_1B_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | 1 | | | |
| 01 | | 1 | | |
| 11 | | | 1 | |
| 10 | | | | 1 |

$= A_1\overline{B_1} + A_0\overline{B_0}\,\overline{B_1} + A_1A_0\overline{B_0}$ =

A < B

| $A_1A_0$ \ $B_1B_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | | 1 |
| 01 | | | | |
| 11 | | | | |
| 10 | | | | |

4-bit magnitude comparator

Code converter

① Binary to BCD (Binary Coded Decimal)

BCD: Valid from 0 to 9

Binary

| | | |
|---|---|---|
| 2 | 24 | 0 |
| 2 | 12 | 0 |
| 2 | 6 | 0 |
| 2 | 3 | 1 |
| | 1 | |

$(11000)_2$

24

BCD

24

0010 0100

$(100100)_{BCD}$

① 4-bit binary code

| | A | B | C | D | $B_4$ | $B_3$ | $B_2$ | $B_1$ | $B_0$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 3 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 4 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 5 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| 6 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| 7 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| 8 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 9 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| 10 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 11 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 |
| 12 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 13 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| 14 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 |
| 15 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 |

000/115

$B_4$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | | |
| 01 | | | | |
| 11 | 1 | 1 | 1 | 1 |
| 10 | | | 1 | 1 |

$= AB + AC$

$B_3$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | | |
| 01 | | | | |
| 11 | | | | |
| 10 | 1 | 1 | | |

$= A\bar{B}\bar{C}$

$B_2$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | | |
| 01 | 1 | 1 | 1 | 1 |
| 11 | | | 1 | 1 |
| 10 | | | | |

$= \bar{A}B + BC$

$B_1$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | 1 | 1 |
| 01 | | | 1 | 1 |
| 11 | 1 | 1 | | |
| 10 | | | | |

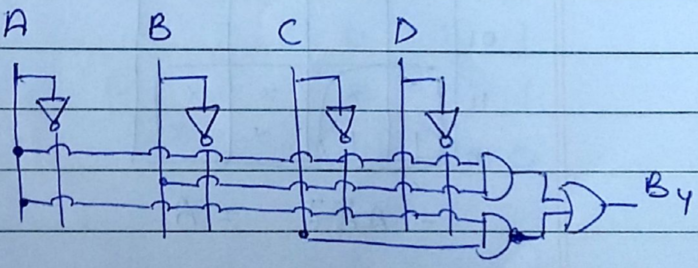
$AB\bar{C} + \bar{A}C$

$B_0$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | 1 | 1 | |
| 01 | | 1 | 1 | |
| 11 | | 1 | 1 | |
| 10 | | 1 | 1 | |

$= D$

$B_4$

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(2) BCD to Binary

| | A | B | C | D | $B_3$ | $B_2$ | $B_1$ | $B_0$ |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 2 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 3 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 4 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 5 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 6 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 7 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| 8 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 9 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| 10 | x | x | x | x | x | x | x | x |
| 11 | x | | | | x | | | |
| 12 | x | | | | x | | | |
| 13 | x | | | | x | | | |
| 14 | x | | | | x | | | |
| 15 | x | x | x | x | x | x | x | x |

$B_3$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | | |
| 01 | | | | |
| 11 | x | x | x | x |
| 10 | 1 | 1 | x | x |

$= \cancel{A\bar{B}\bar{C}} \quad = A$

$B_2$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | | |
| 01 | 1 | 1 | 1 | 1 |
| 11 | x | x | x | x |
| 10 | . | . | x | x |

$= B$

Date

Page

# Binary to Gray / Reflecting Code / Unit Distance Code

| A | B | C | D |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 |
| 1 | 1 | 1 | 1 |

| $G_3$ | $G_2$ | $G_1$ | $G_0$ |
|---|---|---|---|
| A. | A+B | B+C | C+D |

Here in

$1+1=10$

∴ 0 is taken &

1 is rejected

| $G_3$ | $G_2$ | $G_1$ | $G_0$ | |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 1 | 2 |
| 0 | 0 | 1 | 0 | 3 |
| 0 | 1 | 1 | 0 | 4 |
| 0 | 1 | 1 | 1 | 5 |
| 0 | 1 | 0 | 1 | 6 |
| 0 | 1 | 0 | 0 | |
| 1 | 1 | 0 | 0 | |
| 1 | 1 | 0 | 1 | |
| 1 | 1 | 1 | 1 | |
| 1 | 1 | 1 | 0 | |
| 1 | 0 | 1 | 0 | |
| 1 | 0 | 1 | 1 | |
| 1 | 0 | 0 | 1 | |
| 1 | 0 | 0 | 0 | |

$G_3$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | | |
| 01 | | | | |
| 11 | 1 | 1 | 1 | 1 |
| 10 | 1 | 1 | 1 | 1 |

$= A$

$G_2$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | | |
| 01 | 1 | 1 | 1 | 1 |
| 11 | | | | |
| 10 | 1 | 1 | 1 | 1 |

$= \bar{A}B + A\bar{B}$ $\quad A \oplus B$

$G_1$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | 1 | 1 |
| 01 | 1 | 1 | | |
| 11 | 1 | 1 | | |
| 10 | | | 1 | 1 |

$= B\bar{C} +$

$\bar{B}C$

$B \oplus C$

$G_0$

$= \bar{C}D + C\bar{D}$

$C \oplus D$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | 1 | | 1 |
| 01 | | 1 | | 1 |
| 11 | | 1 | | 1 |
| 10 | | 1 | | 1 |

## Grey to Binary

| $G_B$ | $G_2$ | $G_1$ | $G_0$ | A | B | C | D |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 |
| 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |

$$G_B + G_2 + G_1 + G_0$$

**A**

| $G_3G_2 \backslash G_1G_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | | |
| 01 | | | | |
| 11 | 1 | 1 | 1 | 1 |
| 10 | 1 | 1 | 1 | 1 |

$= \cancel{A}\ G_3$

**B**

| $G_3G_2 \backslash G_1G_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | | |
| 01 | 1 | 1 | 1 | 1 |
| 11 | | | | |
| 10 | 1 | 1 | 1 | 1 |

$= \bar{G}_3 G_2 + G_3 \bar{G}_2$

*

$G_3 \oplus G_2 \oplus G_1$

**C**

| $G_3G_2 \backslash G_1G_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | 1 | 1 |
| 01 | 1 | 1 | | |
| 11 | | | 1 | 1 |
| 10 | 1 | 1 | | |

$\bar{G}_3 \bar{G}_2 G_1 +$

$\bar{G}_3 G_2 \bar{G}_1 +$

$G_3 G_2 G_1 +$

$G_3 \bar{G}_2 \bar{G}_1$

**D**

*

$G_3 \oplus G_2 \oplus G_1 \oplus G_0$

| $G_3G_2 \backslash G_1G_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | 1 | | 1 |
| 01 | 1 | | 1 | |
| 11 | | 1 | | 1 |
| 10 | 1 | $ | 1 | |

# BCD to Excess-3

| | A | B | C | D | | $E_3$ | $E_2$ | $E_1$ | $E_0$ |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0+3 → | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 0 | 1 | 1+3 → | 0 | 1 | 0 | 0 |
| 2 | 0 | 0 | 1 | 0 | 2+3 → | 0 | 1 | 0 | 1 |
| 3 | 0 | 0 | 1 | 1 | | 0 | 1 | 1 | 0 |
| 4 | 0 | 1 | 0 | 0 | | 0 | 1 | 1 | 1 |
| 5 | 0 | 1 | 0 | 1 | | 1 | 0 | 0 | 0 |
| 6 | 0 | 1 | 1 | 0 | | 1 | 0 | 0 | 1 |
| 7 | 0 | 1 | 1 | 1 | | 1 | 0 | 1 | 0 |
| 8 | 1 | 0 | 0 | 0 | | 1 | 0 | 1 | 1 |
| 9 | 1 | 0 | 0 | 1 | | 1 | 1 | 0 | 0 |
| 10 | 1 | 0 | 1 | 0 | → 10 → 13 | X | X | X | X |
| 11 | 1 | 0 | 1 | 1 | | ↓ | ↓ | ↓ | ↓ |
| 12 | 1 | 1 | 0 | 0 | | ↓ | ↓ | ↓ | ↓ |
| 13 | 1 | 1 | 0 | 1 | | X | X | X | X |
| 14 | 1 | 1 | 1 | 0 | | X | X | X | X |
| 15 | 1 | 1 | 1 | 1 | | X | X | X | X |

$\boxed{E_3}$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | | | |
| 01 | | 1 | 1 | 1 |
| 11 | X | X | X | X |
| 10 | 1 | 1 | X | X |

$= A + BC + BD$

$\boxed{E_2}$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | | 1 | 1 | 1 |
| 01 | 1 | X | | |
| 11 | X | X | X | X |
| 10 | ~~X~~ | 1 | X | X |

$= B\bar{C}\bar{D} + \bar{B}D + \bar{B}C$

$\boxed{E_1}$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | 1 | | 1 | |
| 01 | 1 | | 1 | |
| 11 | X | X | X | X |
| 10 | 1 | | X | X |

$= \bar{C}\bar{D} + CD$

| AB \ CD | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | 1 | | | 1 |
| 01 | 1 | | | 1 |
| 11 | X | X | X | X |
| 10 | 1 | | X | X |

$= \bar{D}$

Self complimenting ↑

## Excess - 3 to BCD

| $E_3$ | $E_2$ | $E_1$ | $E_0$ | A | B | C | D |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 |
| 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |
| 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |

$\underbrace{0, 1, 2, 13, 14, 15}$

Dont care as in Excess-3 it starts with 3 and ends with 12

$\boxed{A}$

| $E_3E_2$ \ $E_1E_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | X | X | | X |
| 01 | | | | |
| 11 | 1 | X | X | X |
| 10 | | | 1 | |

$= E_3E_2 + E_3E_1E_0$

$\boxed{B}$

| $E_3E_2$ \ $E_1E_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | X | X | | X |
| 01 | | | 1 | |
| 11 | | X | X | X |
| 10 | 1 | 1 | | 1 |

$= \bar{E_2}\bar{E_0} + E_2E_1E_0 + \bar{E_2}\bar{E_1} = \cancel{\bar{E_1}\bar{E_2} + E_2E_1E_0} + E_3E_1\bar{E_0}$

$\boxed{C}$

| $E_3E_2$ \ $E_1E_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | X | X | | X |
| 01 | | 1 | | 1 |
| 11 | | X | X | X |
| 10 | | 1 | | 1 |

$= E_1\bar{E_0} + E_0\bar{E_1}$

$\boxed{D}$

| $E_3E_2$ \ $E_1E_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | X | X | | X |
| 01 | 1 | | | 1 |
| 11 | 1 | X | X | X |
| 10 | 1 | | | 1 |

$= \bar{E_0}$

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# Registers

↳ Arrangement of Flip Flops

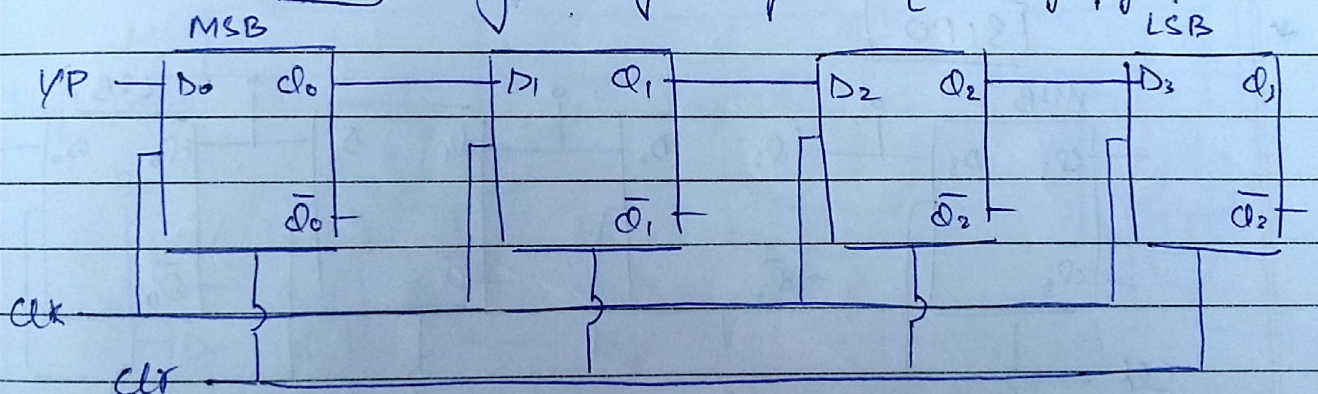
1 Flip flop stores 1 bit
1001 ⟶ 4-bit register

↓

a) on the basis of data movement
- right shift
- left shift
- bidirectional

b) on the basis of mode selection
- SISO → Serial in Serial out
- SIPO → Serial in Parallel out
- PIPO
- PISO
- Universal

* 4-bit → $\boxed{\text{SISO}}$ : Right Shift Register [in D flip flop I/P = O/P]




To store 1001

1001
MSB ↙ ↘ LSB

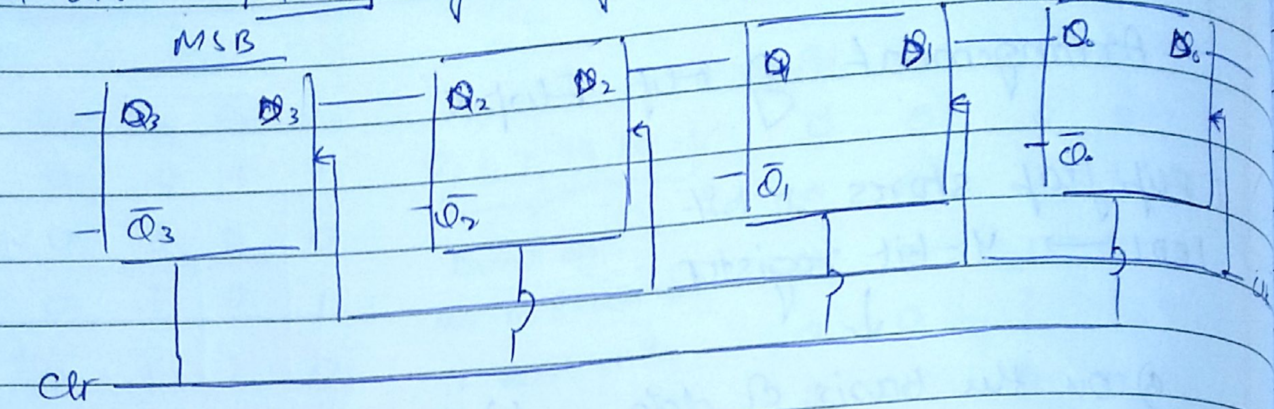
| | $Q_0$ | $Q_1$ | $Q_2$ | $Q_3$ | |
|---|---|---|---|---|---|
| CLR | 0 | 0 | 0 | 0 | |
| → | 1 | 0 | 0 | 0 | 0 |
| → | 0 | 1 | 0 | 0 | 0 |
| → | 1 | 0 | 1 | 0 | 0 |
| → | 1 | 1 | 0 | 1 | 0 |

Here, first we give LSB as input

Asynchronous : Clock (...) Preset & clr (reset)

Date
Page

4-bit → $\boxed{\text{SISO}}$ Left Shift Register




~~1001~~

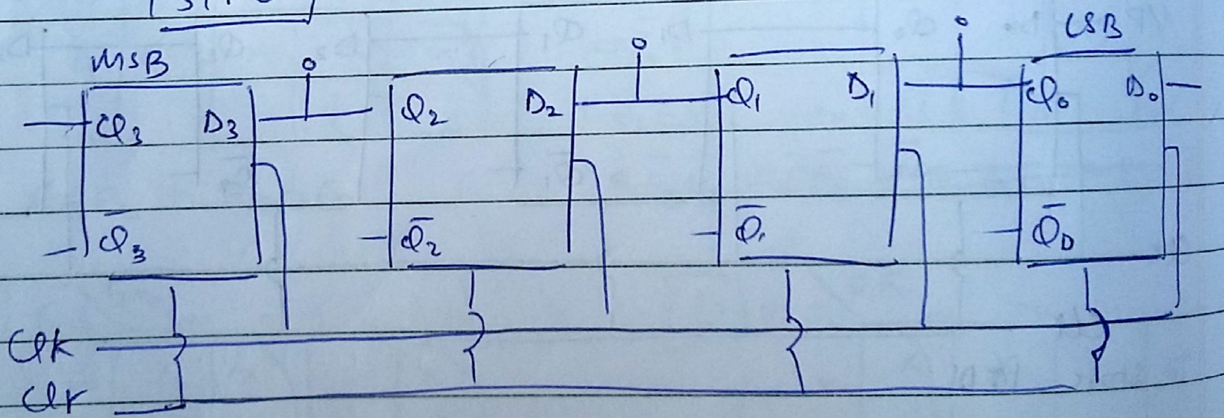
MSB LSB

1001

| | $Q_3$ | $Q_2$ | $Q_1$ | $Q_0$ | |
|---|---|---|---|---|---|
| | 0 | 0 | 0 | 0 | clr |
| | 0 | 0 | 0 | 1 | ← |
| | 0 | 0 | 1 | 0 | ← |
| | 0 | 1 | 0 | 1 | ← |
| | 1 | 0 | 1 | 1 | |

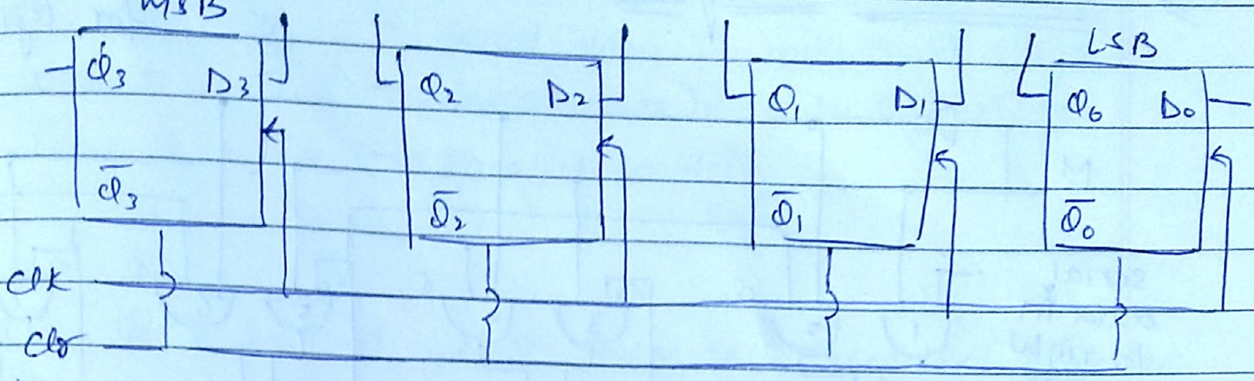
Here first we give MSB as I/P

* $\boxed{\text{SIPO}}$




In this we can check the output of each block simultaneously $Q_3$ $Q_2$ $Q_1$ $Q_0$

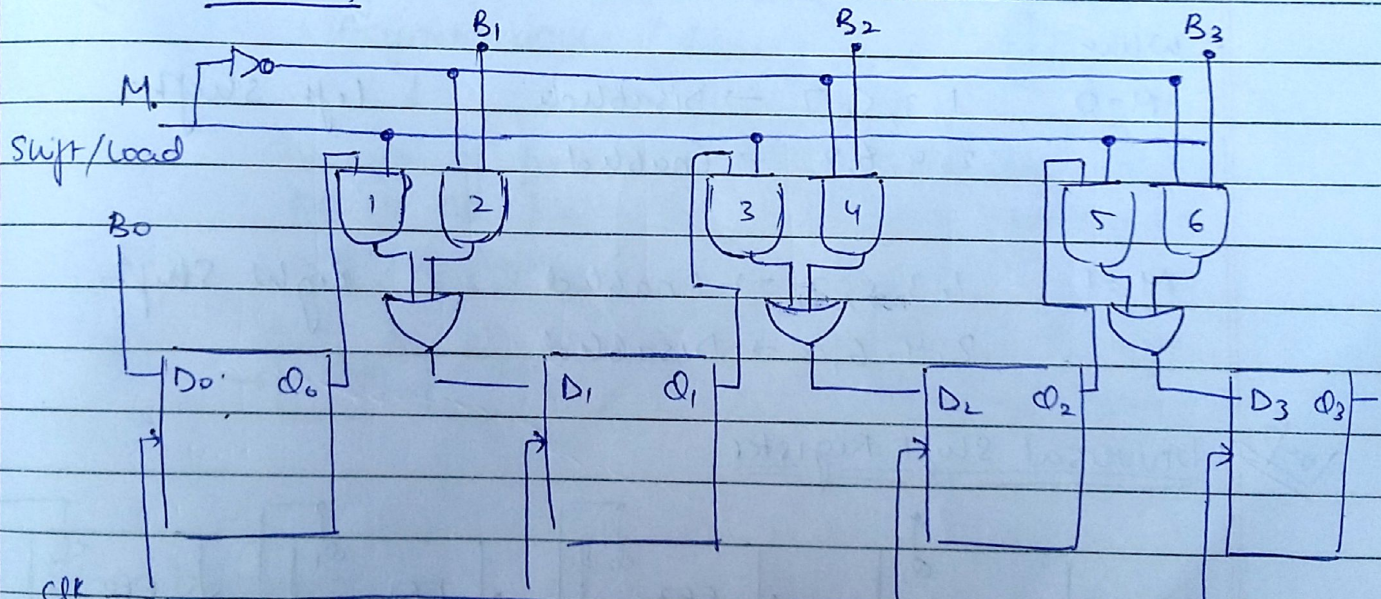
* PIPO




1011

| $Q_3$ | $Q_2$ | $Q_1$ | $Q_0$ | |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | Clr |
| 1 | 0 | 1 | 1 | |

* PISO

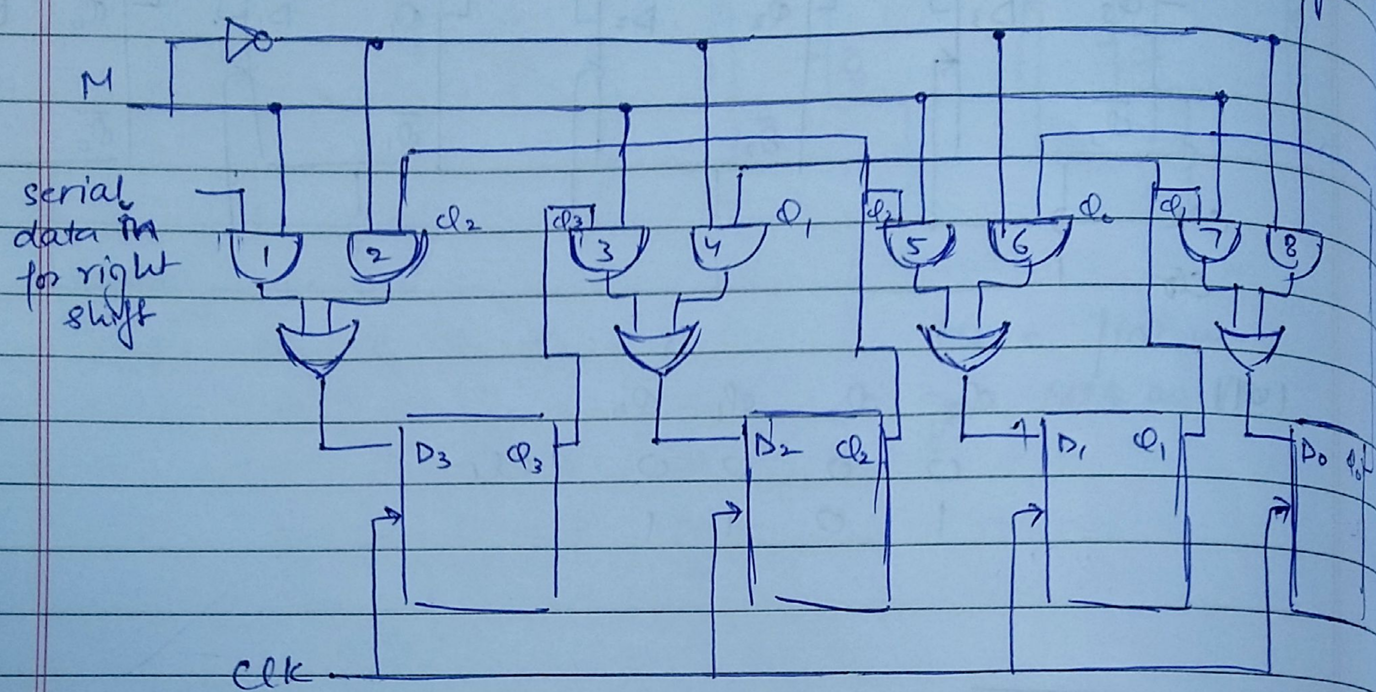



When

| | | |
|---|---|---|
| M=0 | 1,3,5 → Disabled<br>2,4,6 → enabled | Parallel loading |
| M=1 | 1,3,5 → enabled<br>2,4,6 → Disabled | Right shift / left shift |

~~Birecto~~

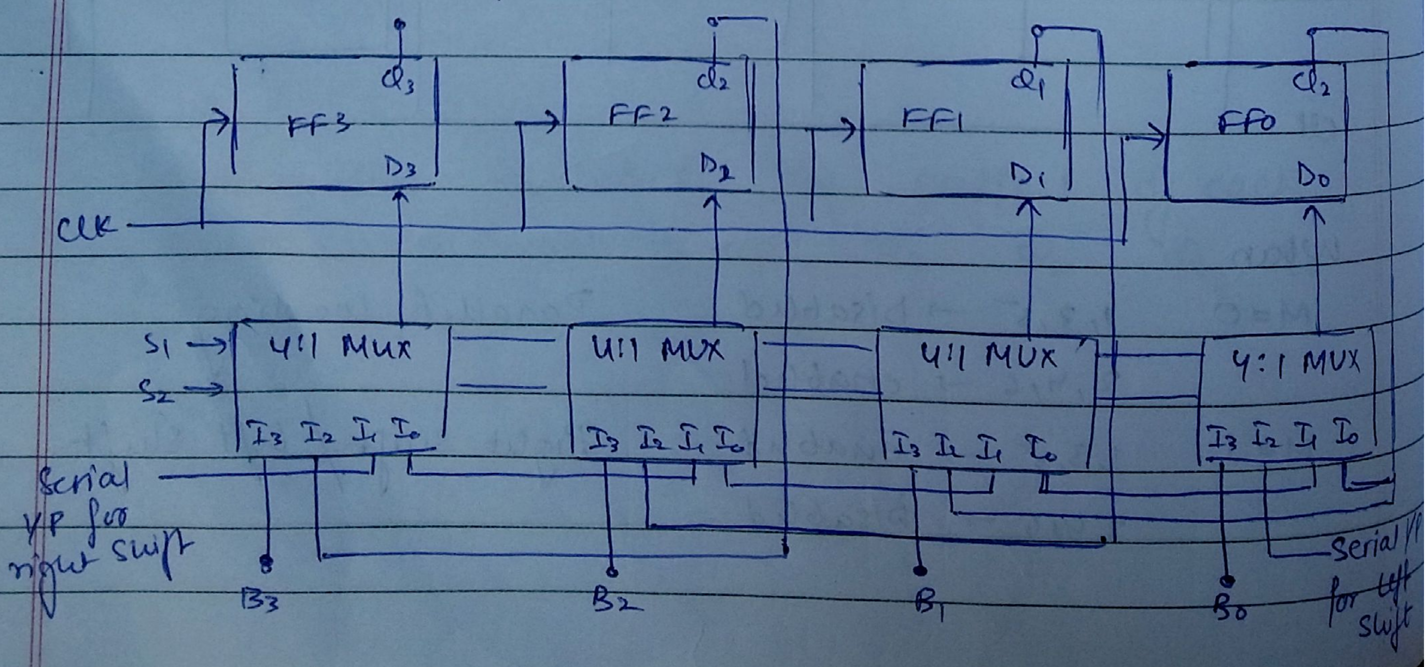
## Imp Bidirectional Register




When

| | | |
|---|---|---|
| M=0 | 1, 3, 5, 7 → Disabled | Left shift |
| | 2, 4, 6, 8 → Enabled | |
| M=1 | 1, 3, 5, 7 → Enabled | Right shift |
| | 2, 4, 6, 8 → Disabled | |

## Imp Universal Shift Register



| $S_2$ | $S_1$ | Y | |
|---|---|---|---|
| 0 | 0 | $I_0$ | → Hold state (holds the last output) |
| 0 | 1 | $I_1$ | → Serial data in with right shift |
| 1 | 0 | $I_2$ | → Serial data in with left shift |
| 1 | 1 | $I_3$ | → Parallel loading |

Test: Q-N Method, MUX, DEMUX, Decoder, Encoder
Comparator, Code converter

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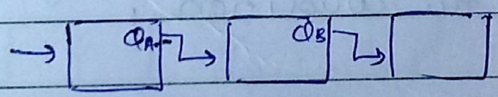
## Counters

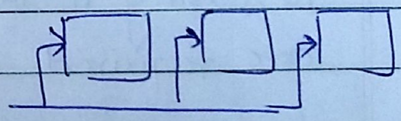
Counts the no. of clk. pulses arriving at the ckt.

Types → Synchronous (Parallel)
Asynchronous (Ripple)

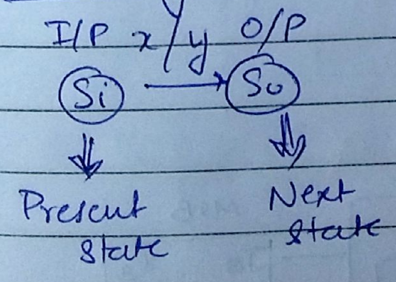
The o/p of present flip flop is clk pulse for 2nd flip flop

The clk. impulse is synchronised



## State Diagram



| $S_2$ | $S_1$ | Y | |
|---|---|---|---|
| 0 | 0 | $I_0$ | → Hold state (holds the last output) |
| 0 | 1 | $I_1$ | → Serial data in with right shift |
| 1 | 0 | $I_2$ | → Serial data in with left shift |
| 1 | 1 | $I_3$ | → Parallel loading |

Test: Q-N Method, MUX, DEMUX, Decoder, Encoder Comparator, Code converter

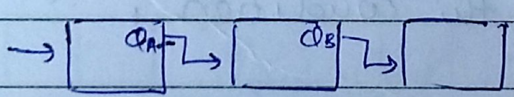
4/9/17

## Counters

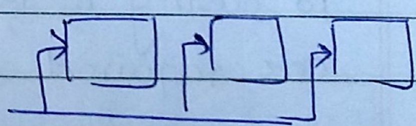
counts the no. of clk. pulses arriving at the ckt.

Types → Synchronous (Parallel)
Asynchronous (Ripple)

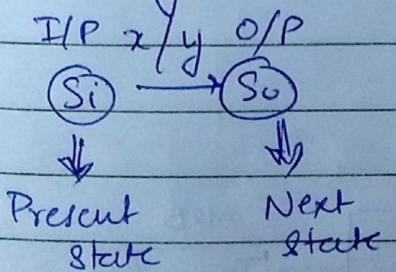
Asynchronous (Ripple) ↓ The o/p of present flip flop is clk pulse for 2nd flip flop




Synchronous (Parallel) ↓ The clk. impulse is synchronised



### State Diagram

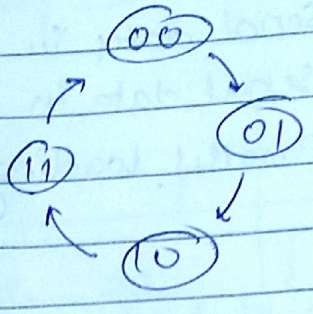


+ve clk pulse

−ve clk pulse

## For 2 bit

| | A | B |
|---|---|---|
| 4 states | 0 | 0 |
| | 0 | 1 |
| | 1 | 0 |
| | 1 | 1 |




### State Table

| P.S. | N.S. | F/F I/P |
|---|---|---|
| 00 | 01 | |
| 01 | 10 | |
| 10 | 11 | |
| 11 | 00 | |

MOD Number : counts the no. of states

check $\boxed{2^n \geq N}$ — CONDITION

n → no. of bits / flip flop

To desing a MOD 'N' counter, 'n' no. of flip flops are required through the condition.

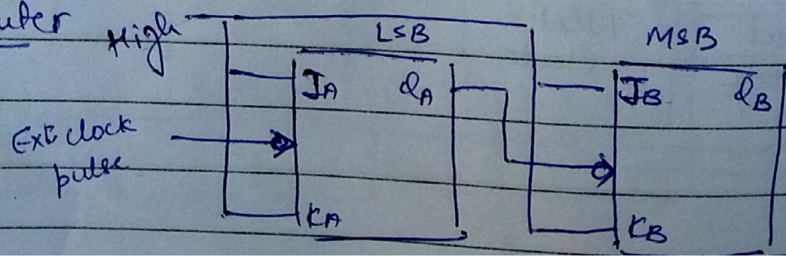
## Asynchronous Counters

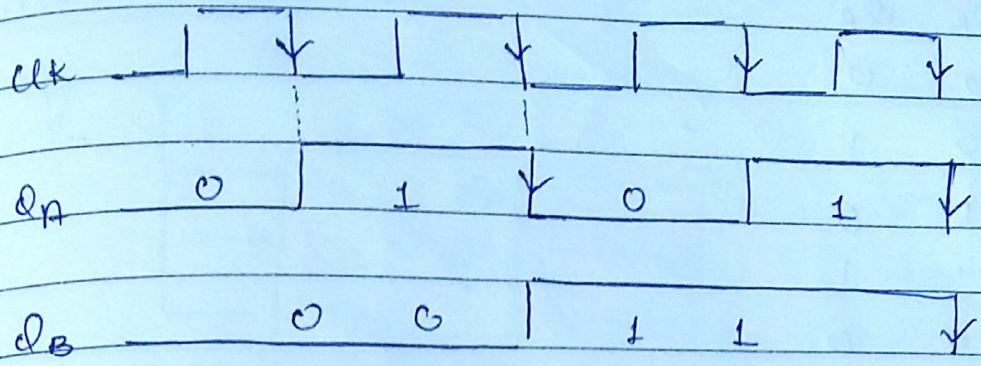
Up-counter : inc. order

Down counter : dec. order

→ 2 bit Up Counter

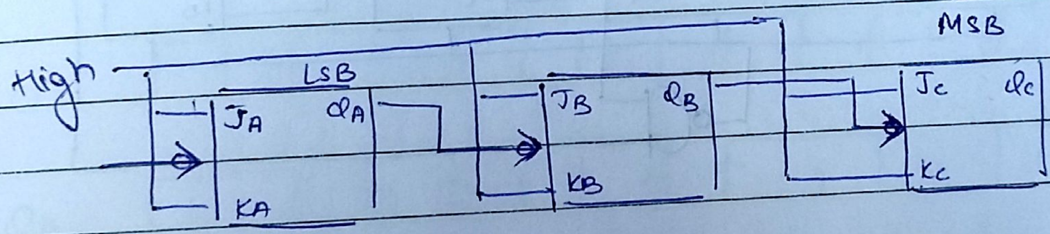
−ve clock pulse

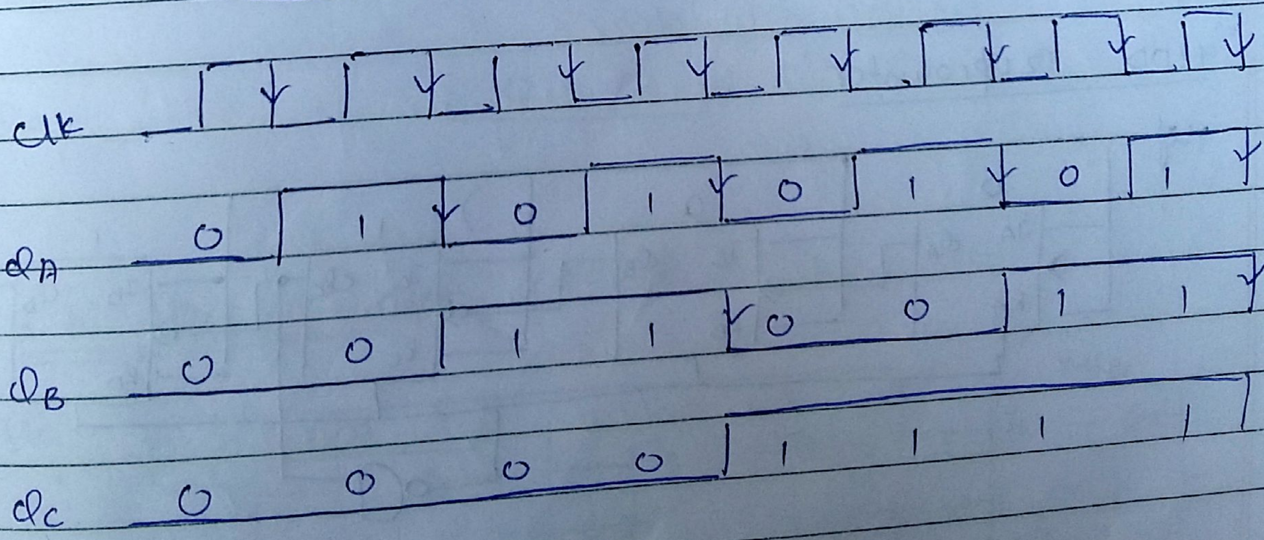





| MSB | LSB |
|---|---|
| $Q_B$ | $Q_A$ |
| 0 | 0 |
| 0 | 1 |
| 1 | 0 |
| 1 | 1 |

→ 3-bit up counter

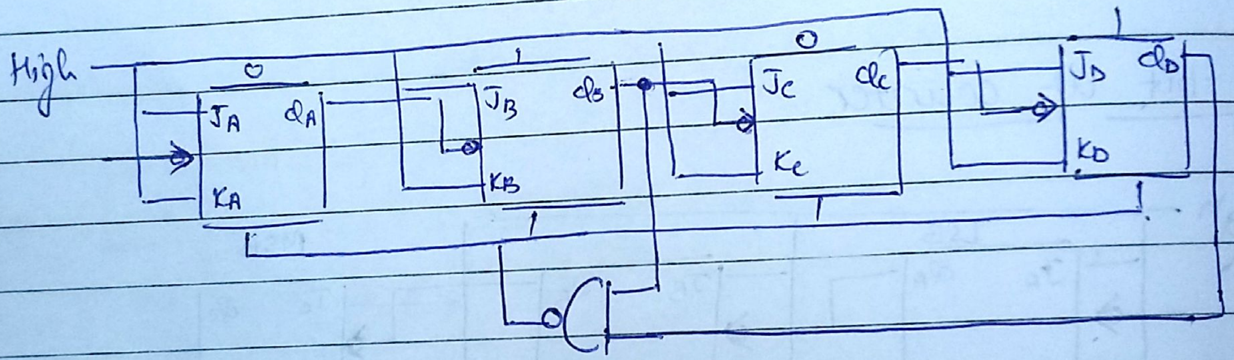


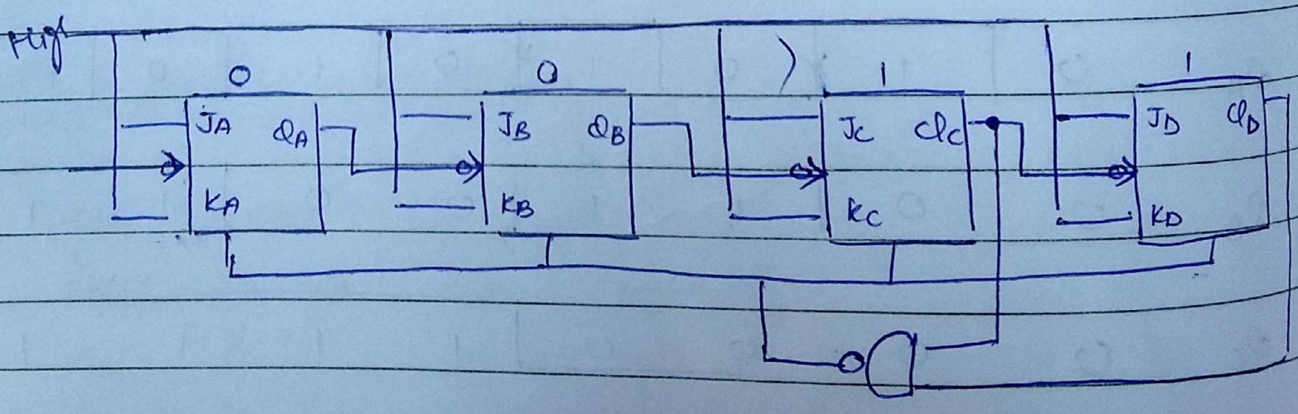
| $Q_C$ | $Q_B$ | $Q_A$ |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |
| 1 | 1 | 1 |

4-bit up counter

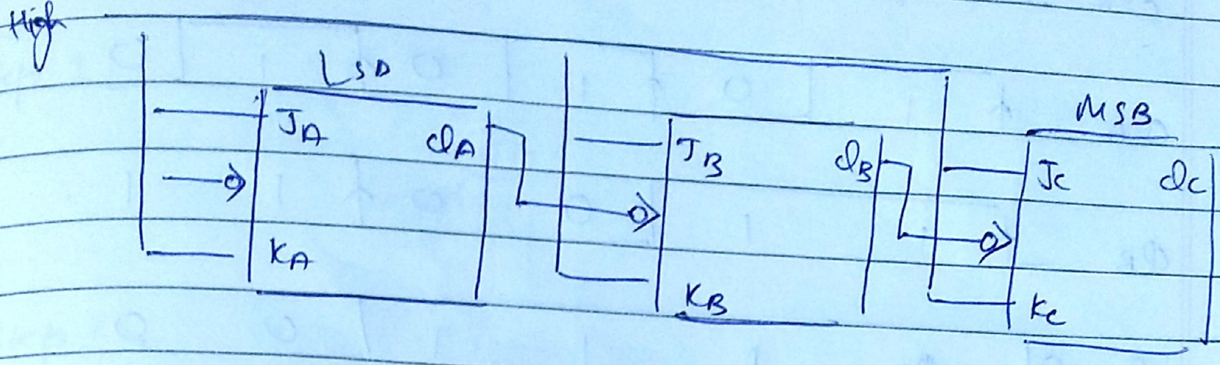
* MOD 10 upcounter



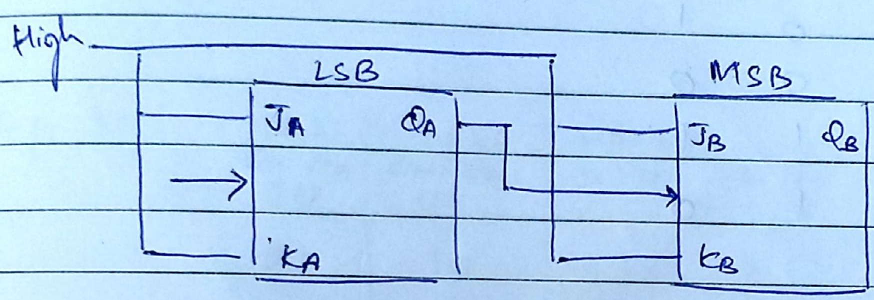

MOD 12 upcounter



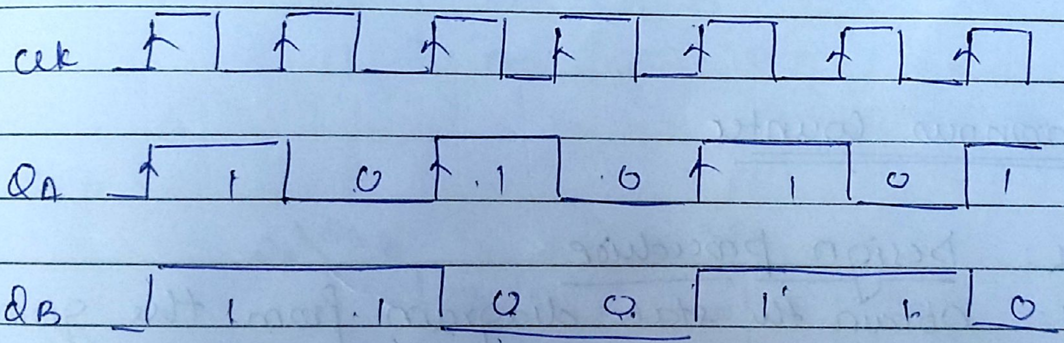
## MOD 5 Upcounter



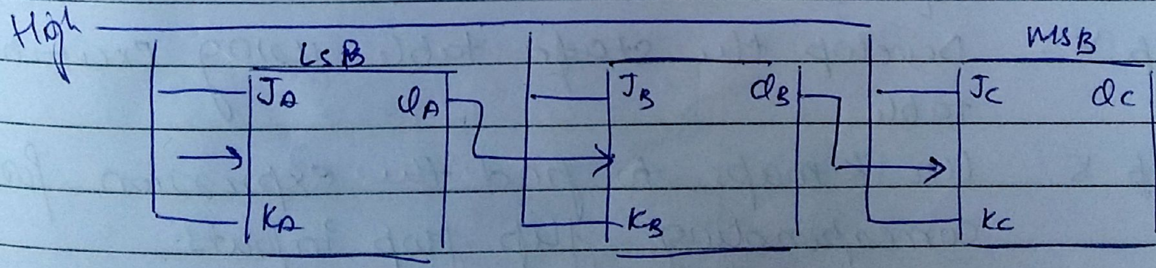

## 2 bit Down Counter

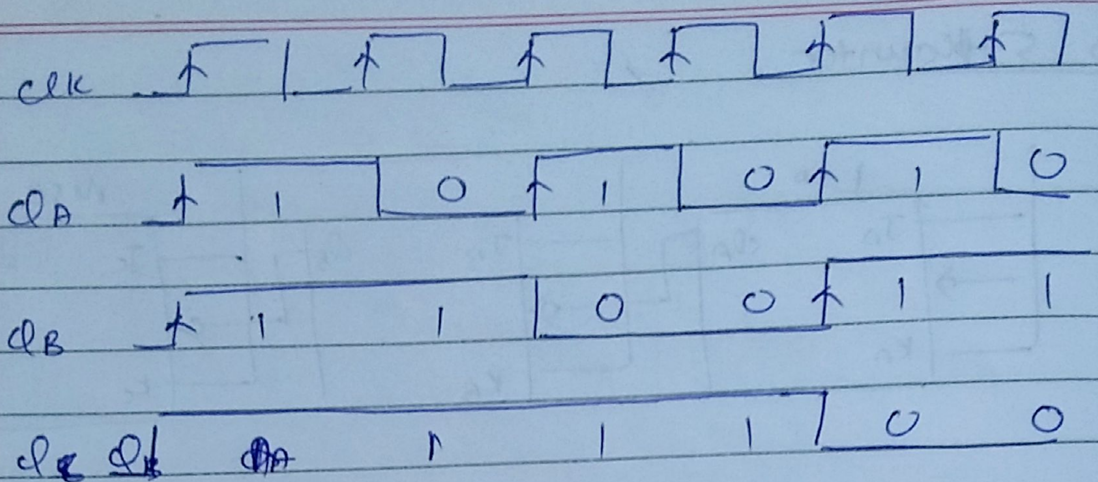



| $Q_B$ | $Q_A$ |
|---|---|
| 1 | 1 |
| 1 | 0 |
| 0 | 1 |
| 0 | 0 |
| 1 | 1 |
| 1 | 0 |




## 3 bit Down Counter (MOD 8)






| $Q_C$ | $Q_B$ | $Q_A$ |
|---|---|---|
| 1 | 1 | 1 |
| 1 | 1 | 0 |
| 1 | 0 | 1 |
| 1 | 0 | 0 |
| 0 | 1 | 1 |
| 0 | 1 | 0 |

## Synchronous Counter

~~Step 1~~: Design procedure

Step 1: Obtain the state diagram from the given information

Step 2: Determine the no. of flip flops required

Step 3: Write the excitation table of flip flops required

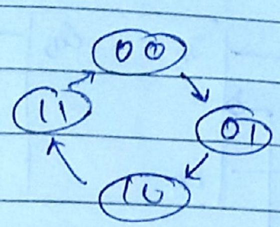
Step 4: Develop the state table using excitation table

Step 5: Use K-maps to find the expression for corresponding flip flop inputs

Step 6: Draw the counter ckt. using flip flops and required gates

# MOD-4 counter – 2bit (up-counter)

Step 1:




Step 2: $n = 2$ (using JK)

Step 3:

| $Q_n$ | $Q_{n+1}$ | J | K |
|---|---|---|---|
| 0 | 0 | 0 | x |
| 0 | 1 | 1 | x |
| 1 | 0 | x | 1 |
| 1 | 1 | x | 0 |

Step 4: State Table

| P.S. | | N.S. | | FF. I/P | | | |
|---|---|---|---|---|---|---|---|
| $Q_A$ | $Q_B$ | $Q_{A+1}$ | $Q_{B+1}$ | $J_A$ | $K_A$ | $J_B$ | $K_B$ |
| 0 | 0 | 0 | 1 | 0 | x | 1 | x |
| 0 | 1 | 1 | 0 | 1 | x | x | 1 |
| 1 | 0 | 1 | 1 | x | 0 | 1 | x |
| 1 | 1 | 0 | 0 | x | 1 | x | 1 |

Step 5:

| $Q_A \backslash Q_B$ | 0 | 1 |
|---|---|---|
| 0 | | 1 |
| 1 | x | x |

$J_A = Q_B$

| $Q_A \backslash Q_B$ | 0 | 1 |
|---|---|---|
| 0 | x | x |
| 1 | | 1 |

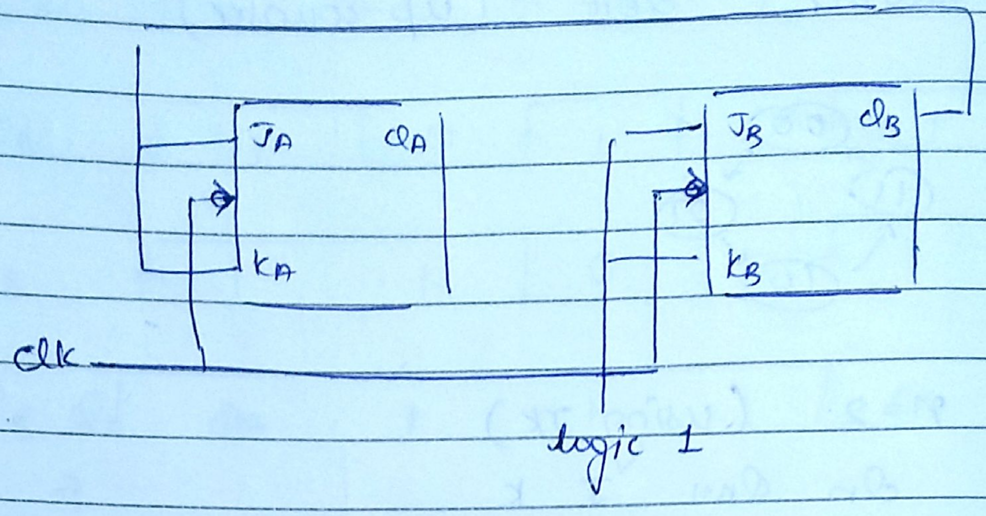
$K_A = Q_B$

| $Q_A \backslash Q_B$ | 0 | 1 |
|---|---|---|
| 0 | 1 | x |
| 1 | 1 | x |

$J_B = 1$

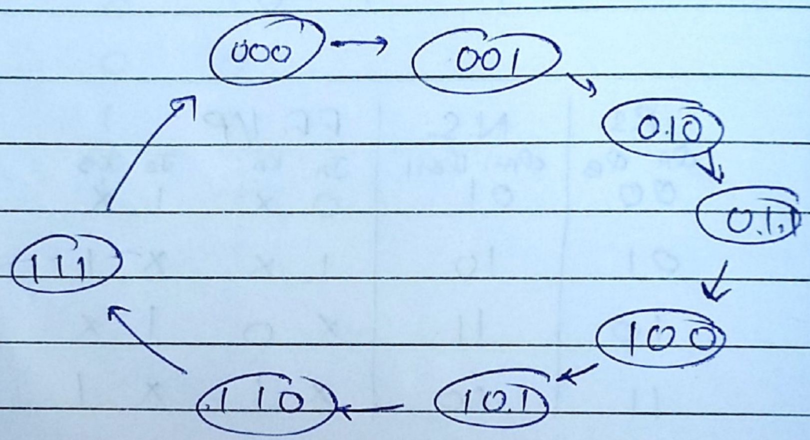
| $Q_A \backslash Q_B$ | 0 | 1 |
|---|---|---|
| 0 | x | 1 |
| 1 | x | 1 |

$K_B = 1$




## 3 bit up counter

Step 1:




Step 2: $n = 3$ (JK)

Step 3:

| $Q_n$ | $Q_{n+1}$ | J | K |
|---|---|---|---|
| 0 | 0 | 0 | X |
| 0 | 1 | 1 | X |
| 1 | 0 | X | 1 |
| 1 | 1 | X | 0 |

Step 4:

| P.S. | | | NS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $Q_A$ | $Q_B$ | $Q_C$ | $Q_{A+1}$ | $Q_{B+1}$ | $Q_{C+1}$ | $J_A$ | $K_A$ | $J_B$ | $K_B$ | $J_C$ | $K_C$ |
| 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 |

Step 5

| $Q_A \backslash Q_B Q_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | | | 1 | |
| 1 | x | x | x | x |

$J_A = Q_B Q_C$

| $Q_A \backslash Q_B Q_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | x | x | x | x |
| 1 | | | 1 | |

$K_A = Q_B Q_C$

| $Q_A \backslash Q_B Q_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | | 1 | x | x |
| 1 | | 1 | x | x |

$J_B = Q_C$

| $Q_A \backslash Q_B Q_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | x | x | 1 | |
| 1 | x | x | 1 | |

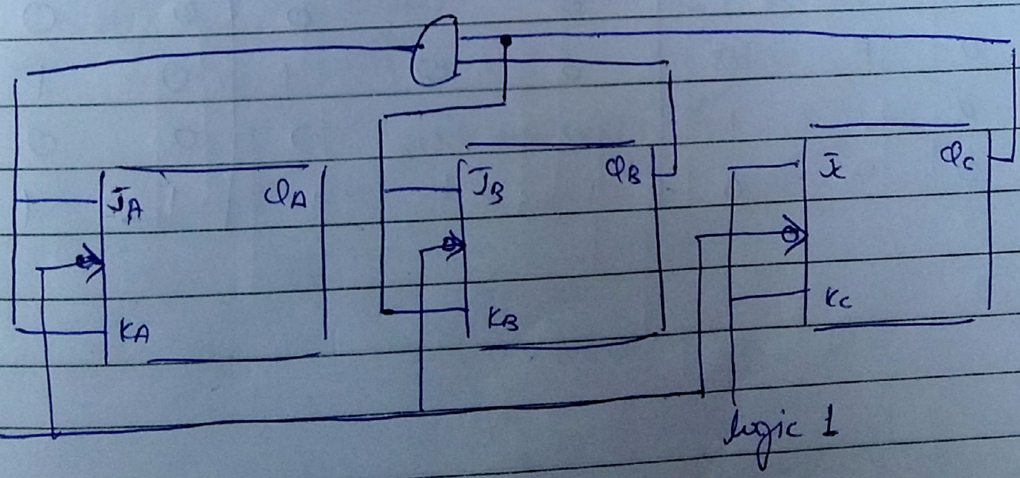
$K_B = Q_C$

| $Q_A \backslash Q_B Q_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | 1 | x | x | 1 |
| 1 | 1 | x | x | 1 |

$J_C = 1$

| $Q_A \backslash Q_B Q_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | x | 1 | 1 | x |
| 1 | x | 1 | 1 | x |

$K_C = 1$



Date 7/9/17
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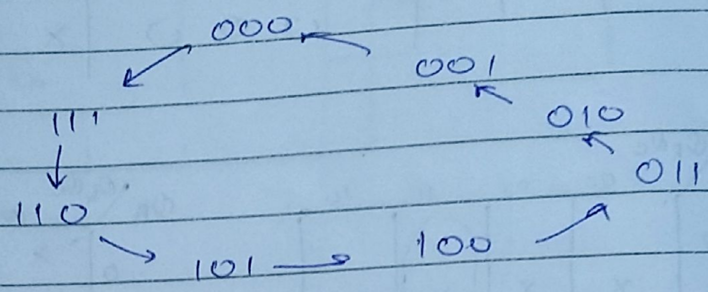
## 3 bit down counter

Using T




$n = 3$

| $Q_n$ | $Q_{n+1}$ | T |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

| PS | | | NS | | | | | |
|---|---|---|---|---|---|---|---|---|
| $Q_A$ | $Q_B$ | $Q_C$ | $Q_{A+1}$ | $Q_{B+1}$ | $Q_{C+1}$ | $T_A$ | $T_B$ | $T_C$ |
| 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 |
| 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 |
| 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 |
| 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |

| $Q_A \backslash Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | 1 | | | |
| 1 | 1 | | | |

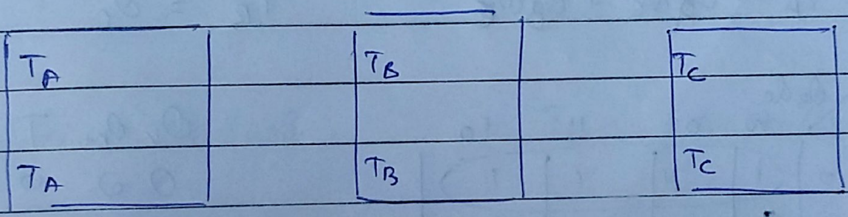
$T_A = \bar{Q}_B \bar{Q}_C$

| $Q_A \backslash Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | 1 | | 1 | 1 |
| 1 | 1 | | 1 | 1 |

~~$T_B = \bar{Q}_B\bar{Q}_C + Q_B\bar{Q}_C$~~ $T_B = \bar{Q}_C$

| $Q_A \backslash Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 |

$T_C = 1$




**MOD-5 counter** up counter

000 → 001 → 010 → 011 → 100 → 000

111

110

101

| $Q_n$ | $Q_{n+1}$ | T |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

| $Q_A$ | $Q_B$ | $Q_C$ | $Q_{A+1}$ | $Q_{B+1}$ | $Q_{C+1}$ | $T_A$ | $T_B$ | $T_C$ |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 1 | X | X | X | X | X | X |
| 1 | 1 | 0 | X | X | X | X | X | X |
| 1 | 1 | 1 | X | X | X | X | X | X |

| $Q_A \backslash Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | | | 1 | |
| 1 | 1 | X | X | X |

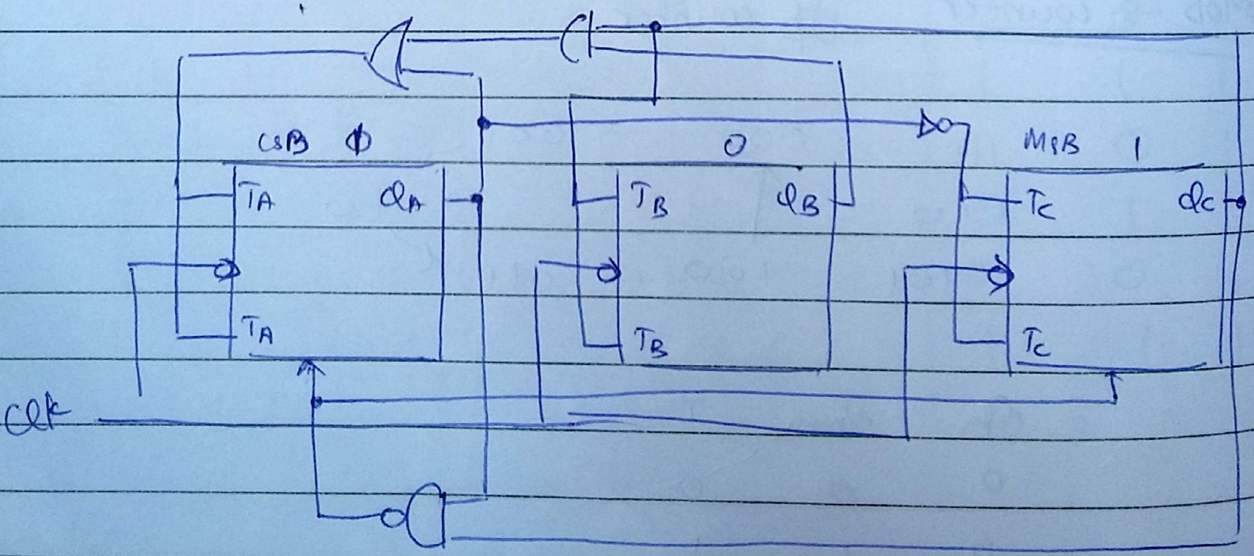
| $Q_A \backslash Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | | 1 | 1 | |
| 1 | | X | X | X |

$T_A = Q_A + Q_B Q_C$ $\qquad$ $T_B = Q_C$

| $Q_A \backslash Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | 1 | 1 | 1 | 1 |
| 1 | | X | X | X |

| $Q_n$ | $Q_{n+1}$ | T |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

$T_C = \overline{Q}_A$



Design a MOD-6 Gray code counter using T-flip flop

| $Q_A$ | $Q_B$ | $Q_C$ | $Q_{A+1}$ | $Q_{B+1}$ | $Q_{C+1}$ | $T_A$ | $T_B$ | $T_C$ |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 1 | 0 | 1 | x | x | x | x | x | x |
| 1 | 0 | 0 | x | x | x | x | x | x |

| $Q_A$ \ $Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | | | | 1 |
| 1 | x | x | 1 | |

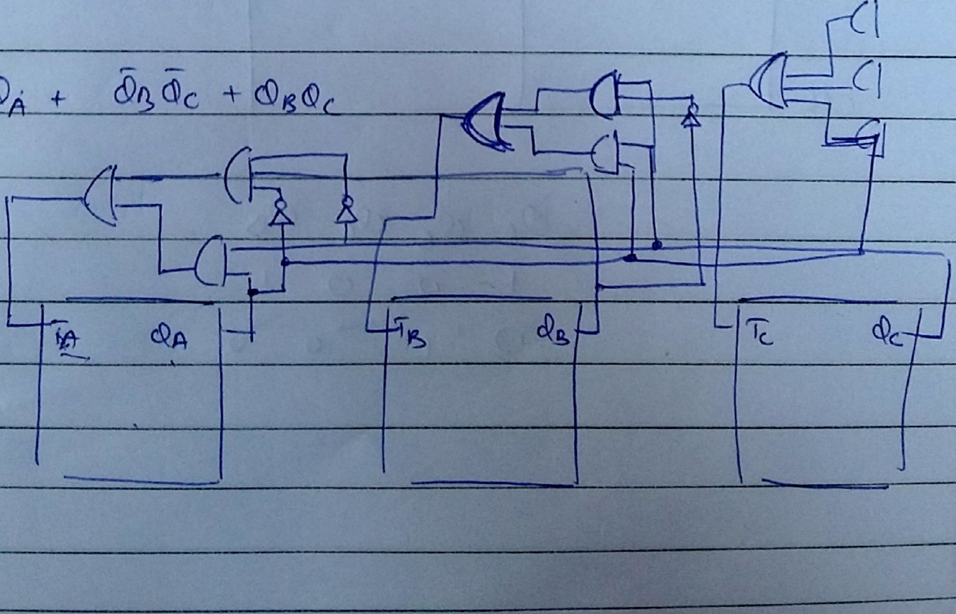
| $Q_A$ \ $Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | | 1 | | |
| 1 | x | x | 1 | |

$T_A = Q_A Q_C + \bar{Q}_A Q_B \bar{Q}_C$

$T_B = Q_A \cdot Q_C + \bar{Q}_B Q_C$

| $Q_A$ \ $Q_BQ_C$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | 1 | | 1 | |
| 1 | x | x | 1 | 1 |

$T_C = Q_A + \bar{Q}_B \bar{Q}_C + Q_B Q_C$



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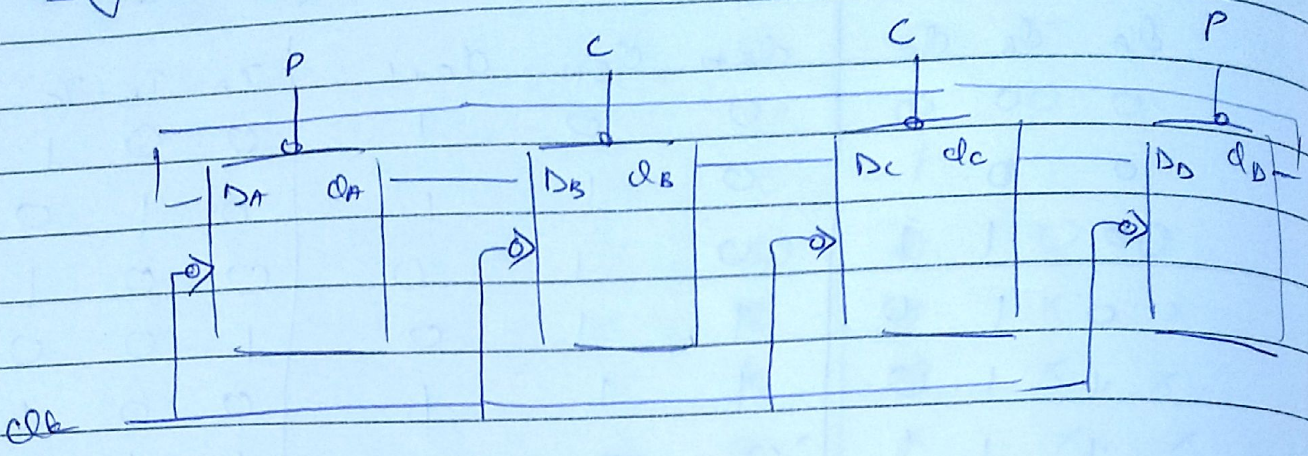
Preset → 1

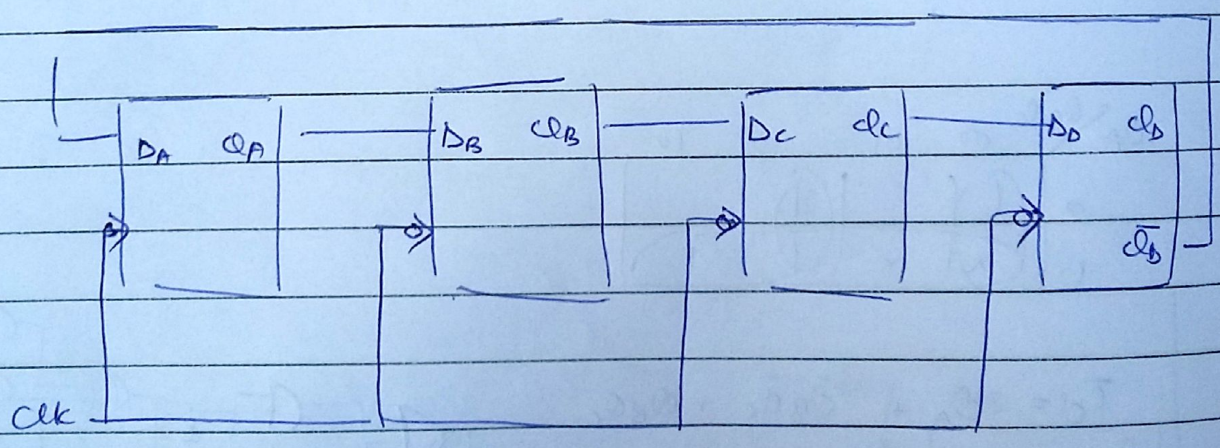
clear → 0

## Ring Counter




| $Q_A$ | $Q_B$ | $Q_C$ | $Q_D$ |
|---|---|---|---|
| 1 | 0 | 0 | 1 |
| 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |

## Johnson Counter




| $Q_A$ | $Q_B$ | $Q_C$ | $Q_D$ |
|---|---|---|---|
| 1 | 0 | 0 | 1 |
| 0 | 1 | 0 | 0 |