Digital Electronics

$2^{\text{no. of bits}}$

$\therefore 2^3 = 8$ ($8 \rightarrow$ Octal)

$\therefore$ 3 bits in octal

$2^4 = 16$ ($16 \rightarrow$ Hex.)

4 bits in Hex.

Signed integer representation

1. Signed matrix / Magnitude
2. Diminished - Radix Complement
3. Radix Complement

1 Signed Matrix / Magnitude

Most Significant bit (MSB) used for sign of the no.

In Binary

(−) for 1

(+) for 0

$-5 = (1\,0000\,101)_2 = (85)_{16}$

$+5 = (00000101)_2 = (05)_{16}$

$+0 = (00000000)_2 = (00)_{16}$

$-0 = (10000000)_2 = (80)_{16}$

Total no.s represented by signed

$-(2^{n-1}-1)$ to $(2^{n-1}-1)$

One's Complement Method (Only do the Complement)

Two's Complement Method (Complement & add 1)

Morris (Mano) — Book

Codes

1. BCD ⟶ Binary coded decimal
2. Excess-3
3. Gray
4. Alphanumeric

Natural BCD Codes

Also 8, 4, 2, 1 code

1000 0100 0010 0001

Excess-3 Code

2 3

0010 0011

Add 3 to both digits

0010	0011
0011	0011
0101	0110

↓

56

Gray-Code ⟶ Only 0 & 1 have values 0, 1

→ Not a weighted code

→ Reflected code

0 —	000
1 —	001
2 —	011
3 —	010
4 —	110
5 —	111
6 —	101
7 —	100

— Reflection from this

Conversion of Binary to Gray Code

XOR of these 2 digits

Binary	1	1	0	1	0	0	1
Gray	1	0	1	1	1	0	1

MSB directly written

Similarly for Gray → Binary

Gray	1	0	1	1	1	0	1
Binary	1	1	0	1	0	0	1

XOR

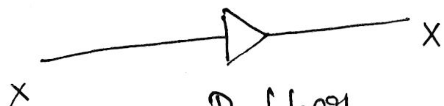
XOR

Negative logic used

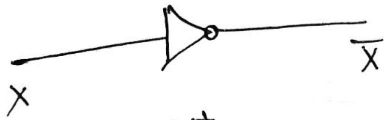
0V — 1
+5V — 0

not true logic

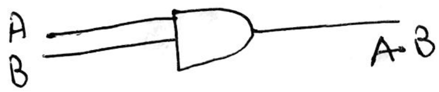
0V — 0
5V — 1



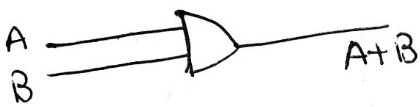
Buffer



Not

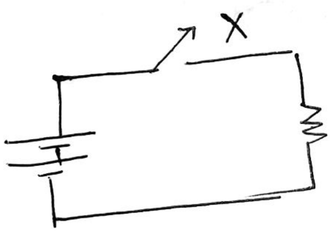


And



OR

Electrical Switches as logical Networks



X = 1 — Switch closed

X = 0 ⟶ Switch open

XOR

0	0	1
0	1	0
1	0	0
1	1	1

Minterms & Maxterms

1 complement is 0

complement is 1

x	y	z	Min°		Max°	
0	0	0	$x'y'z'$	m_0	$x+y+z$	M_0
0	0	1	$x'y'z$	m_1	$x+y+z'$	M_1
0	1	0	$x'yz'$	m_2	$x+y'+z$	M_2
0	1	1	$x'yz$	m_3	$x+y'+z'$	M_3
1	0	0	$xy'z'$	m_4	$x'+y+z$	M_4
1	0	1	$xy'z$	m_5	$x'+y+z'$	M_5
1	1	0	xyz'	m_6	$x'+y'+z$	M_6
1	1	1	xyz	m_7	$x'+y'+z'$	M_7

Minterms are complements of maxterms

eg°

$x'yz = m_3$

$m_3' = (x'yz)'$

$= (x+y'+z')$

$= M_3$

a)

x	y	z	F_1	F_2	F_3
0	0	0	0	0	0
0	0	1	0	1	1
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	1	1	0
1	1	1	0	1	0

$F_1 = m_6$

$F_2 = (m_1, m_4, m_5, m_6, m_7)$

$F_2 = \Sigma m(1,4,5,6,7)$

$F_2 = x'y'z + xy'z' + xy'z + xyz' + xyz$

This was Sum of Products (take 1)

Now Product of Sum

(take 0)

$F_1 = \pi M(0,1,2,3,4,5,7)$

$F_2 = \pi M(0,2,3)$

$F_2 = \cancel{xyz + xyz + xyz}$

$F_2 = (x+y+z).(x+y'+z).(x+y'+z')$

(R-1)'s Complement

R → Base

for -ve no.

$\boxed{\bar{N}} = (\underbrace{R^n}_{\text{no. of digits before decimal}} - \overbrace{R^{-m}}^{\text{no. of digits after decimal}}) - \boxed{N}$ — Number

Compo

R's Complement

for -ve no.

$N^* = R^n - N$

---

using 10's Complement (72532 − 3250)

$M = 72432$ $N = 03250$

∴ 10's Compo of $N = 10^5 - 03250$
$= \underbrace{96750}_{5 \text{ dig.}}$

Now $M+N = 1\,\underbrace{69282}_{5 \text{ dig.}}$

discard

$3250 - 72532$

$M = 03250$

$N = 72532$

10's Compl. of $N = 10^5 - 72532$
$= 27468$

100000
72532

$\therefore M + N = 30718$ (No Carry)

$\therefore$ Taking comp. of 30718

$10^5 - 30718$

$\therefore$ Put (-ve) in front of Comp.

(R-1)'s Compl. Use

$72532 - 3250$

$M = 72532$ $N = 03250$

$(R-1)'s = 9's$ Comp. $= 10^5 - 10^0 - 03250$
$= 96749$

$M + N = 169281$

Add 1

011 010

111 110

K-map

$wx \backslash yz$	00	01	11	10
00	m_0	m_1	m_3	m_2
01	m_4	m_5	m_7	m_6
11	m_{12}	m_{13}	m_{15}	m_{14}
10	m_8	m_9	m_{11}	m_{10}

Ex: $f(A, B, C, D) = A(C+D)'(B'+D') + C(B+C'+A'D)$

$= AB'C'D' + AC'D' + BC + A'CD$

$= AB'C'D' + AC'D'(B+B') + BC(A+A')(D+D') + A'CD(B+B')$

$= AB'C'D' + AC'D'(B+B') + BC[AD + AD' + A'D + A'D']$

$= AB'C'D' + AC'D'B + AC'D'B' + BC[AD + AD' + A'D + A'D']$

$\quad + A'CDB + A'B'CD$

$= \underbrace{AB'C'D'}_{8} + \underbrace{ABC'D'}_{9} + \underbrace{AB'C'D'}_{8} + \underbrace{ABCD}_{15} + \underbrace{ABCD'}_{13} + \underbrace{A'BCD}_{7}$

$+ \underbrace{A'BCD'}_{5} + \underbrace{A'BCD}_{7} + \underbrace{A'B'CD}_{3}$

$m_3 \; m_5 \; m_7 \; m_8 \; m_9 \; m_{13} \; m_{15}$

$AB \backslash CD$	00	01	11	10
00			1	
01		1	1	
11		1	1	
10	1	1		

$CD \backslash AB$				
	0	4	12	$\cancel{8}$
	1	$\cancel{5}$	$\cancel{13}$	$\cancel{9}$
	$\cancel{3}$	$\cancel{7}$	$\cancel{15}$	11
	2	6	14	10

Quine-McCluskey Method

Taking the corresponding minterms & grouping the nos acc. to the no. of 1's in those nos

$F(ABCDE) = \Sigma m(0, 2, 4, 6, 7, 8, 10, 11, 12, 13, 14, 16, 18, 19, 29, 30)$

	A	B	C	D	E
(0)	0	0	0	0	0
(2)	0	0	0	1	0
(4)	0	0	1	0	0
(8)	0	1	0	0	0
(16)	1	0	0	0	0
6	0	0	1	1	0
10	0	1	0	1	0
12	0	1	1	0	0
18	1	0	0	1	0
7	0	0	1	1	1
11	0	1	0	1	1
13	0	1	1	0	1
14	0	1	1	1	0
19	1	0	0	1	1
29	1	1	1	0	1
30	1	1	1	1	0

	A	B	C	D	E
(0,2)	0	0	0	-	0
(0,4)	0	0	-	0	0
(0,8)	0	-	0	0	0
(0,16)	-	0	0	0	0
(2,6)	0	0	-	1	0
(2,10)	0	-	0	1	0
(2,18)	-	0	0	1	0
(4,6)	0	0	1	-	0
(4,12)	0	-	1	0	0
(8,10)	0	1	0	-	0
(8,12)	0	1	-	0	0
(16,18)	1	0	0	-	0
	A	B	C	D	E
(6,7)	0	0	1	1	-
(6,14)	0	-	1	1	0
(10,11)	0	1	0	1	-
(10,14)	0	1	-	1	0
(12,13)	0	1	1	0	-
(12,14)	0	1	1	-	0
(18,19)	1	0	0	1	-
(13,29)	-	1	1	0	1
(14,30)	-	1	1	1	0

	A	B	C	D	E
(0, 2, 4, 6)	0	0	–	–	0
(0, 2, 8, 10)	0	–	0	–	0
(0, 2, 16, 18)	–	0	0	–	0
~~(0, 4, 2, 6)~~					
(0, 4, 8, 12)	0	–	–	0	0
~~(0, 8, 2, 10)~~					
~~(0, 8, 4, 12)~~					
~~(0, 16, 2, 18)~~					

	A	B	C	D	E
(2, 6, 10, 14)	0	–	–	1	0
~~(2, 10, 6, 14)~~					
(~~2, 10~~ 4, 6, 12, 14)	0	–	1	–	0
~~(4, 12, 6, 14)~~					
(8, 10, 12, 14)	0	1	–	–	0
~~(8, 12, 10, 14)~~					
(16, 18, 12, 14)					

	A	B	C	D	E
(0, 2, 4, 6, 8, 10, 12, 14)	0	–	–	–	0

Now we take the pairs which do no ~~ϕ~~ combine with any other pair

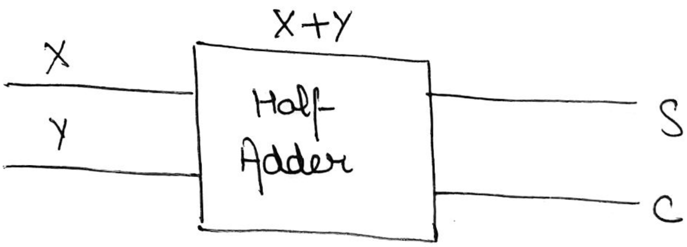
	0	2	4	6	7	8	10	11	12	13	14	16	18	19	29	30
✓ (6, 7)				×	$\boxed{\times}$											
✓ (10, 11)							×	$\boxed{\times}$								
(12, 13)									×	×						
✓ (18, 19)													×	$\boxed{\times}$		
✓ (13, 29)										×					$\boxed{\times}$	
✓ (14, 30)											×					$\boxed{\times}$
✓ (0, 2, 16, 18)	×	×										$\boxed{\times}$	×			
✓ (0, 2, 4, 6, 8, 10, 12, 14)	×	×	$\boxed{\times}$	×		$\boxed{\times}$	×		×		×					

Now we select the rows without boxes.

(0, 2, 4, 6, 8, 10, 12, 14), (0, 6, 16, 18), (14, 30), (13, 29)
(18, 19), (10, 11), (6, 7)

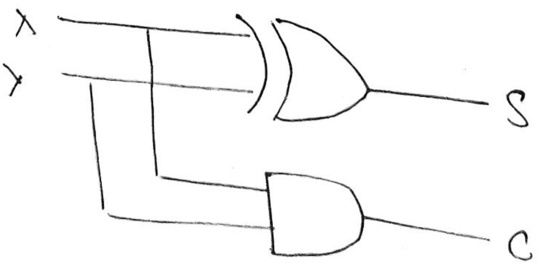
$\therefore \bar{A}\bar{E} + \bar{B}\bar{C}\bar{E} + BCD\bar{E} + BC\bar{D}\bar{E} + A\bar{B}\bar{C}D' +$
$AB\bar{C}D + \bar{A}\bar{B}CD$ Ans

SSI → Half Adder

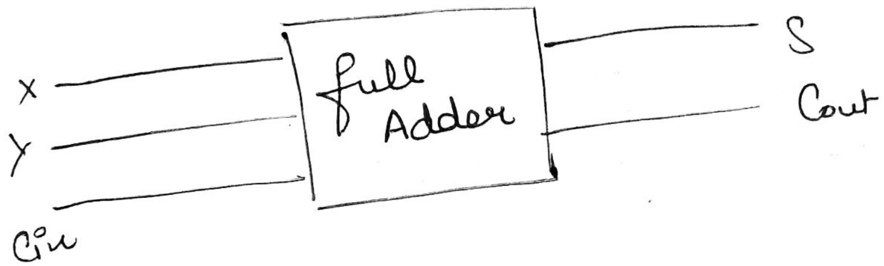


X	Y	C (carry bit)	S (sum bit)
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

$S = \bar{X}Y + X\bar{Y} \Rightarrow X \oplus Y$
$C = X \cdot Y$



(2) Full Adder



X	Y	Cin(Z)	S	Cout
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

$S = \bar{x}\bar{y}z + \bar{x}y\bar{z} + x\bar{y}\bar{z} + xyz$

$C = \bar{x}yz + x\bar{y}z + xy\bar{z} + xyz$

$S = \bar{y}.(\bar{x}z + x\bar{z}) + yz \quad = \bar{y}(x \oplus z) + yz$

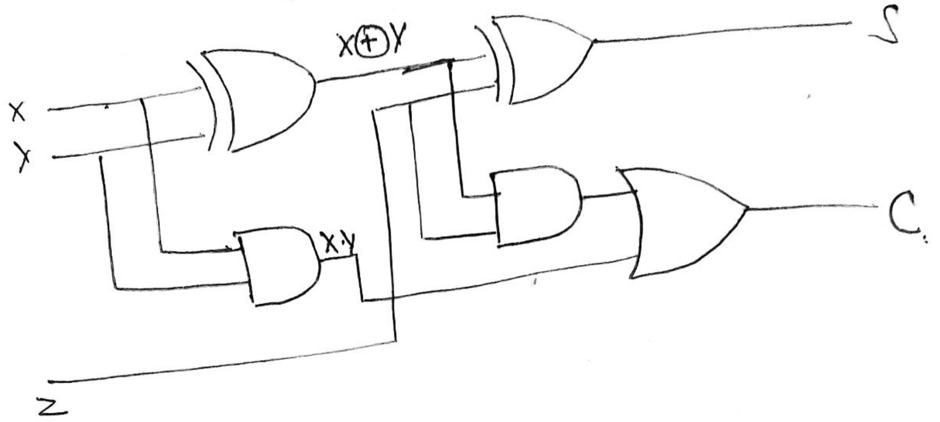
$C = yz + x(\bar{y}z + y\bar{z})$

$= yz + x.(y \oplus z)$

$C = x.y + (x \oplus y).z$

$S = x \oplus (y \oplus z)$

or $(x \oplus y) \oplus z$

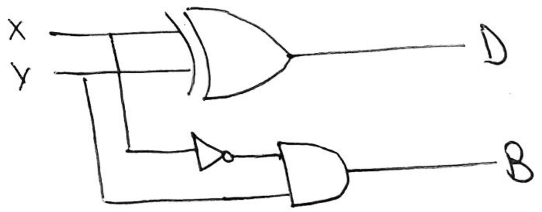


③ Half Subtractor

X	Y	Diff (D)	Borrow (B)
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

$D = \bar{X}Y + X\bar{Y} = X \oplus Y$

$B = \bar{X}Y$



Full Subractor

X	X	B_1	D	B_2
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

$$D = \bar{x}\bar{y}z + \bar{x}y\bar{z} + x\bar{y}\bar{z} + xyz$$

$$B = \bar{x}\bar{y}z + \bar{x}y\bar{z} + \bar{x}yz + xyz$$

$$= yz + \bar{x}(y \oplus z)$$

$$D = \bar{y}(x \oplus z) + y(\bar{x}\bar{z} + xz)$$

$$= \bar{y}(x \oplus z) + y(\overline{x \oplus z})$$

$$= \bar{y} \oplus (x \oplus z)$$

$\overline{x \oplus z}$

$\overline{x\bar{z} + \bar{x}z}$

$\overline{\bar{y}z + y\bar{z}}$

$\overline{\bar{y}z} \cdot \overline{y\bar{z}}$

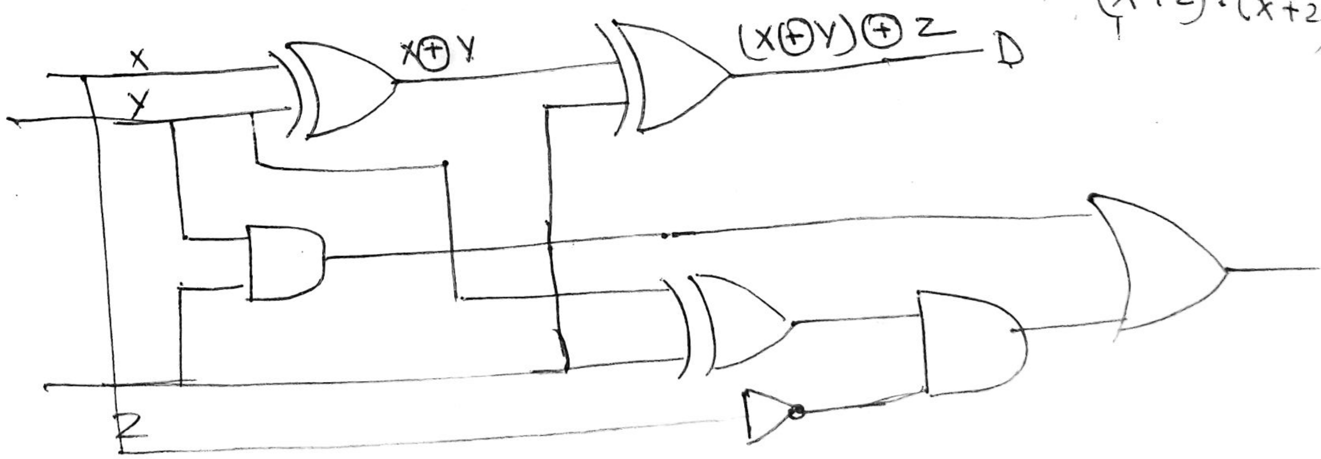
$(y+\bar{z}) \cdot (\bar{y}+z)$

$\cancel{y\bar{y}} + yz + \bar{z}\bar{y}$
$+ \cancel{\bar{z}z}$

$\overline{x\bar{z}} \cdot \overline{\bar{x}z}$

$(\bar{x}+z) \cdot (x+\bar{z})$

~~Multi~~



Multiplexer

It is a device which has

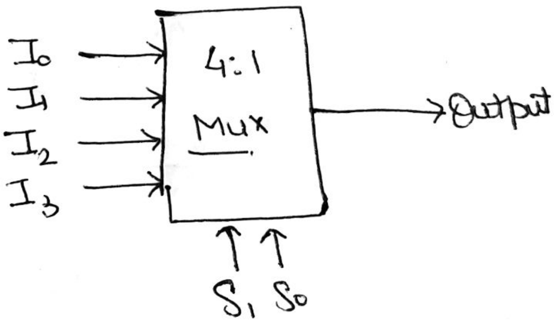
i) No. of input lines
ii) No. of selection lines
iii) Only one output line

It steers one of 2^n input to a single output line in n selection lines

$2^n : 1$

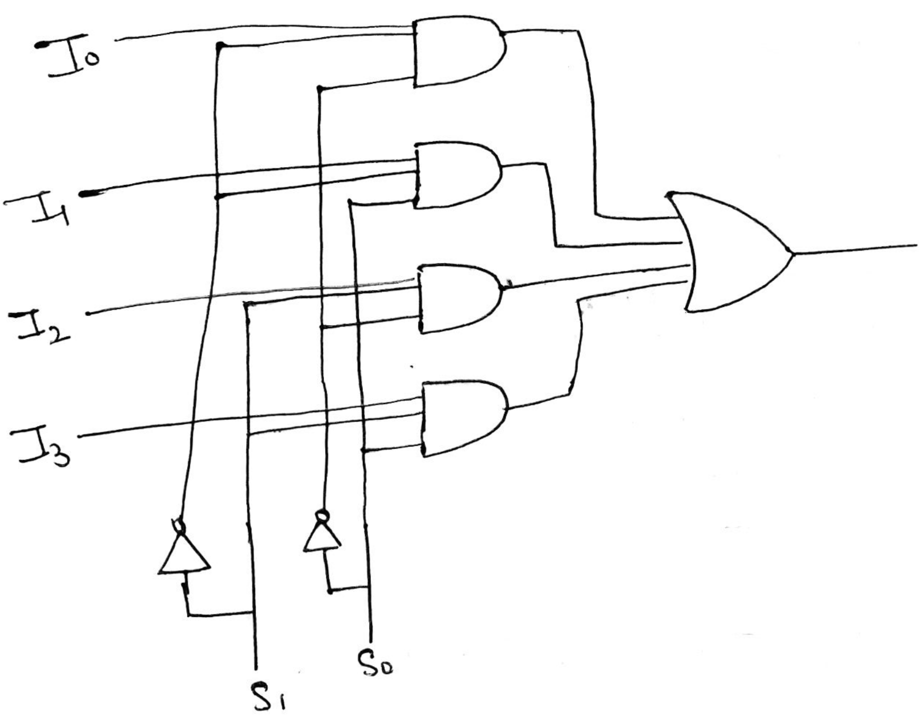
data selector

I_0	I_1	I_2	I_3	S_1	S_0	Y
d_0	d_1	d_2	d_3	0	0	d_0
d_0	d_1	d_2	d_3	0	1	d_1
d_0	d_1	d_2	d_3	1	0	d_2
d_0	d_1	d_2	d_3	1	1	d_3

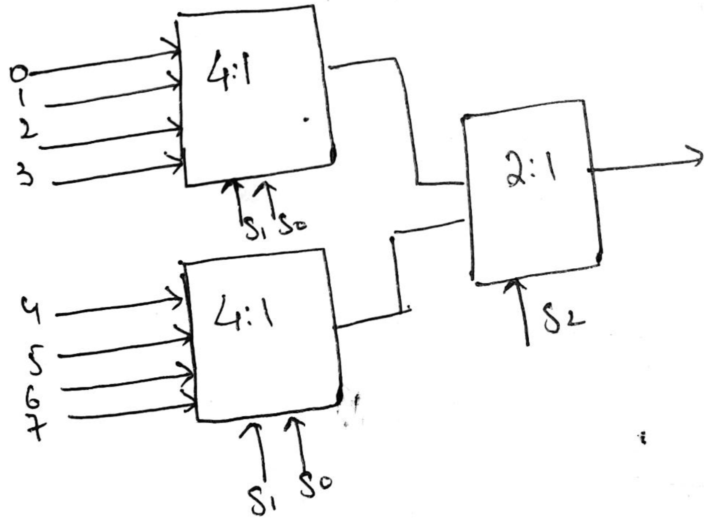


S_1	S_0	Y
0	0	I_0
0	1	I_1
1	0	I_2
1	1	I_3

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



Larger Multiplexer
from smaller multiplexers



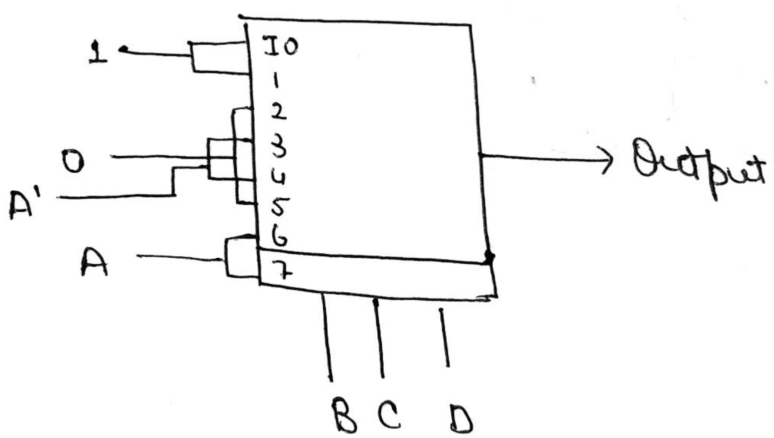
A	B	C	F	Mux input
0	0	0	1	I
0	0	1	1	
0	1	0	0	
0	1	1	1	
1	0	0	0	0
1	0	1	0	B' B
1	1	0	1	
1	1	1	0	

using B as input

$$F(A,B,C,D) = \Sigma m(0,1,3,4,8,9,14,15)$$

Implement using 8:1 Mux

	I0	I1	I2	I3	I4	I5	I6	I7
A'(0)	0	1	2	3	4	5	6	7
A (1)	8	9	10	11	12	13	14	15
	1	1	0	A'	A'	0	A	A



Decoders

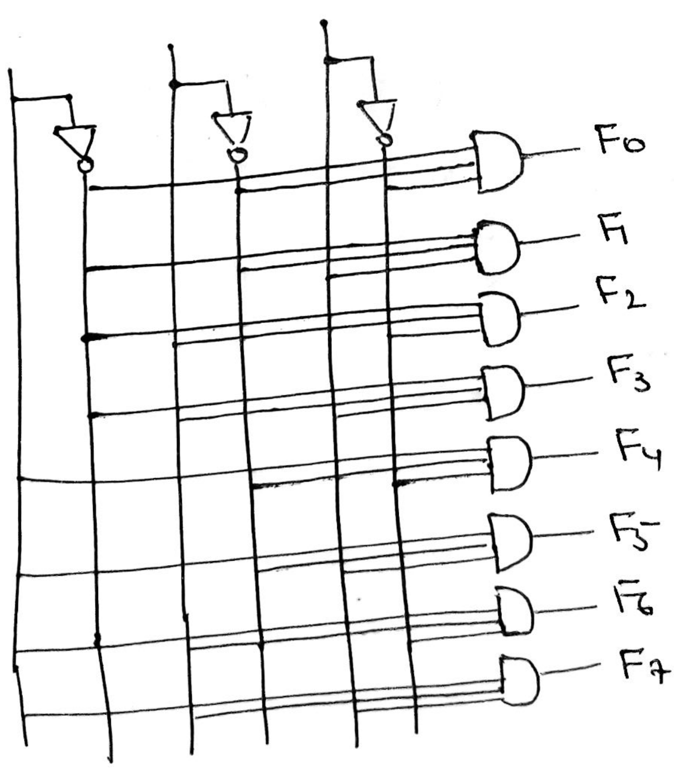
for n input lines there must be 2^n output lines.

Eg. Taking 2:4 decoder

X	Y	F_0	F_1	F_2	F_3
0	0	1	0	0	0
0	1	0	1	0	0
1	0	0	0	1	
1	1	0	0	0	1

3:8 Decoder

X	Y	Z	F_0	F_1	F_2	F_3	F_4	F_5	F_6	F_7
0	0	0	1	0	0	0	0	0	0	0
0	0	1	0	1	0	0	0	0	0	0
0	1	0	0	0	1	0	0	0	0	0
0	1	1	0	0	0	1	0	0	0	0
1	0	0	0	0	0	0	1	0	0	0
1	0	1	0	0	0	0	0	1	0	0
1	1	0	0	0	0	0	0	0	1	0
1	1	1	0	0	0	0	0	0	0	1

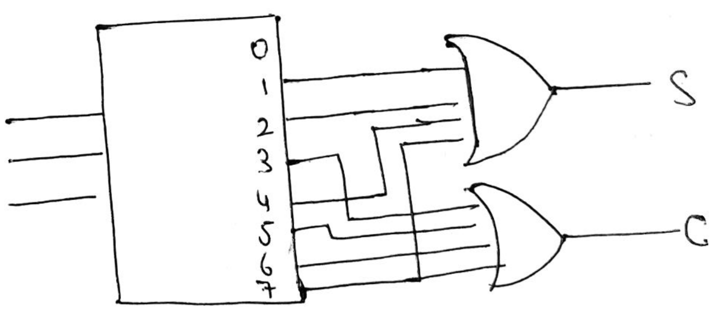


Decoders - Implementing functions

Ex: Full adder

$S(x,y,z) = \Sigma m(1,2,4,7)$
$C(x,y,z) = \Sigma m(3,5,6,7)$

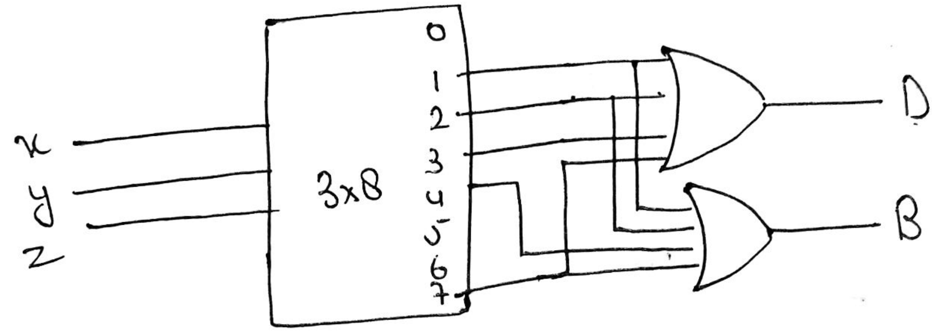
x	y	z	C	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1



Full Subtractor

x	y	z	B	D
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

$D = \Sigma m(1,2,3,7)$
$B = \Sigma m(1,2,4,7)$



Full Subtractor

Decoders with enable

The device gets activated if E = 1

E	x	y				
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
0	X	X	0	0	0	0

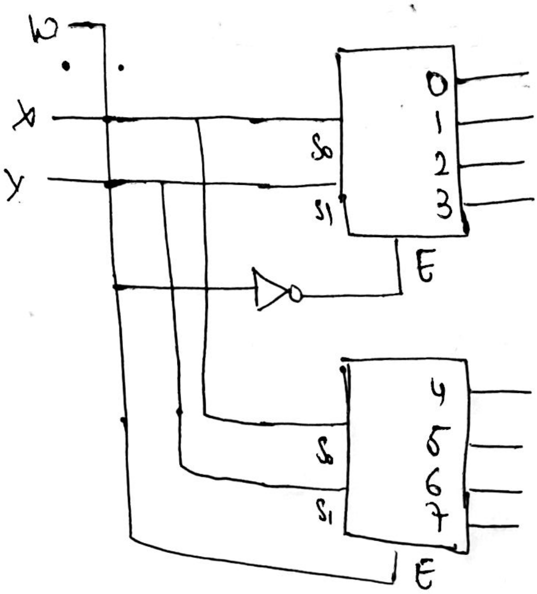
Decoder with enable 1

E	X	Y				
0	0	0	1	0	0	0
0	0	1	0	1	0	0
0	1	0	0	0	1	0
0	1	1	0	0	0	1
1	X	X	0	0	0	0

Decoder with enable 0

Larger decoders

3x8 with 2x4 decoders

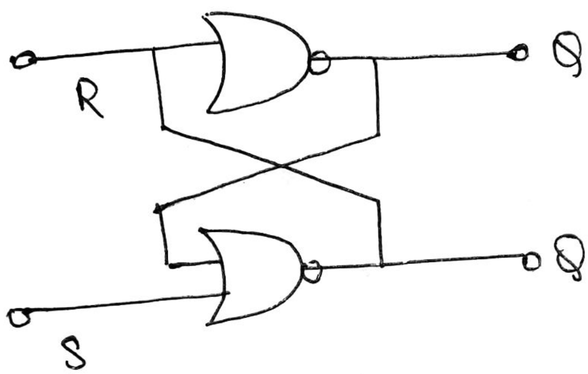


If upper E works then the lower one gets disabled & vice versa.

SR Latch

flip flop - Non-transparent element
latches - transparent / decision taken by it

Active-High input S-R latch



S	R	Q	Q'	
		1	0	initial
1	0	1	0	(after S=1, R=0)
0	0			(after S=0, R=1)
0	1	0	1	
0	0	0	1	
1	1	0	0	—— invalid

Gated - SR latch

characteristic eqⁿ

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

$$R \cdot S = 0$$