Digital circuits

combination ckt	Sequential ckt
⇒ Present o/p is only depend on present I/p.	⇒ Present o/p → Present I/p, Previous o/p
⇒ No feedback	⇒ feedback.
⇒ No memory	⇒ Memory.
⇒ e.g. Half Adder (HA), FA, MUX, DEMUX	⇒ eg:- Flipflop (FF), Register, Counter.

COMBINATIONAL CIRCUIT

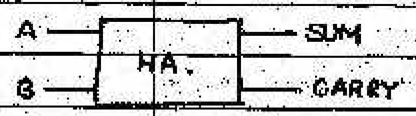
DATE

Procedure to Design :-

(i) Identity I/p and O/p.
(ii) Construct truth table
(iii) Write logical expression in SOP or POS form.
(iv) Minimize logical expression if possible
(v) Implement logic circuits.

(A) HALF ADDER (HA) :-

(i)



(ii) Truth table :-

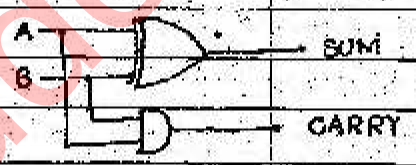
A	B	SUM	CARRY
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

(iii) logical expression :-

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

CARRY = AB.

(iv) Implement :-

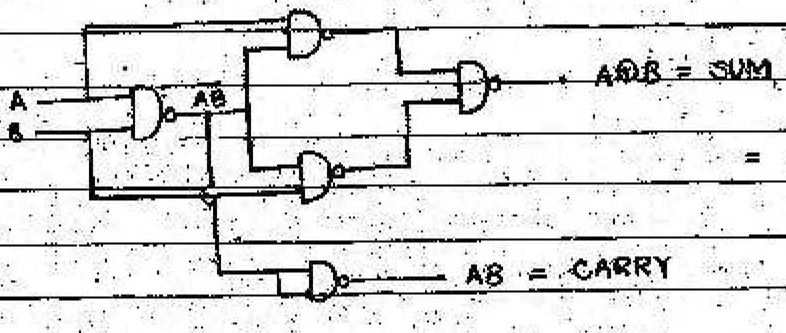


Important Ques :-

(i) logical Expression for SUM :- $A \oplus B$ CARRY : AB
(ii) Min. no. of NAND Gate : 5
(iii) Min no. of NOR Gate : 5
(iv) no. of MUX : 3
(v) no. of DECODER : 1 2x4 Decoder and 1 OR Gate

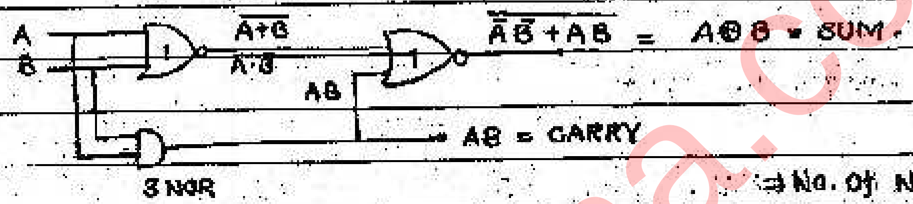
PAGE

HA using NAND gate :-



= no. of gate = 5.

HA using NOR gate :-



⇒ No. of NOR gate 5

Total no. of gate = 2+3 = 5.

(B) HALF SUBTRACTOR :-

(i)

(ii) Truth table :-

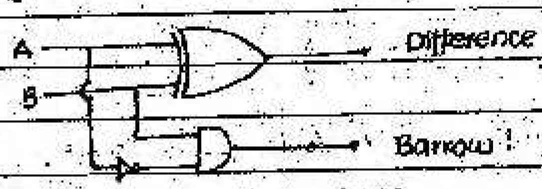
A	B	Diff	Barrow
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

(iii) logical expression :-

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

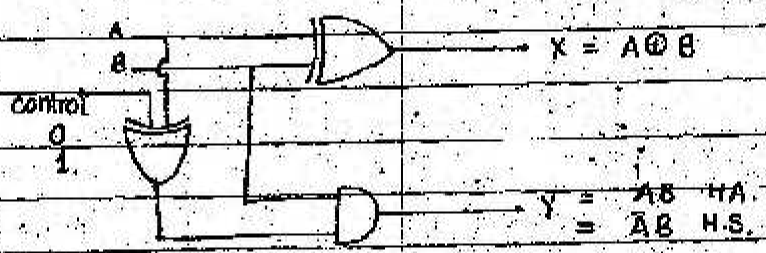
BARROW = $\bar{A}B$

(iv) Implement :-



DATE

(C)

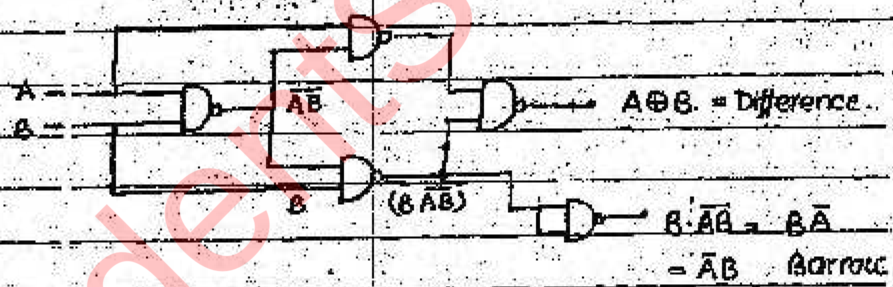


Note :- (i) if control = 0 then $A \oplus 0 = A$
then $Y = AB$ and ckt is HA.
(ii) if control = 1 then, $A \oplus 1 = \bar{A}$
then $Y = \bar{A}B$ and ckt is HS.

Important Ques :-

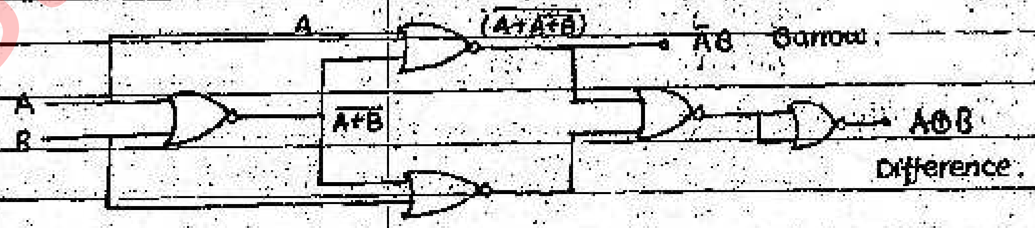
No. of NAND Gate = 5
No. of NOR Gate = 5
No. of MUX :- 3 (2x1 MUX)
No. of DECODER :- 1 (2x4) Decoder and 1 OR Gate.
logical expression for Difference = $A\bar{B} + \bar{A}B$, Borrow : $\bar{A}B$

HS using NAND gate :-



No. of NAND Gate = 5

HS using NOR Gate :-



Now, $\overline{A+\overline{A+B}} = \bar{A}(\overline{\bar{A}\cdot\bar{B}}) = \bar{A}(\bar{\bar{A}}+\bar{\bar{B}}) = \bar{A}B$

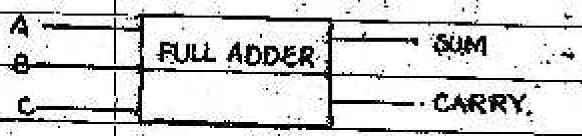
⇒ No of NOR gate = 5

PAGE

DATE

(C) FULL ADDER :-

(i)



(ii) Truth table :-

A	B	C	SUM	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

(iii) logical expression :-

$$SUM = \bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC = A \oplus B \oplus C$$

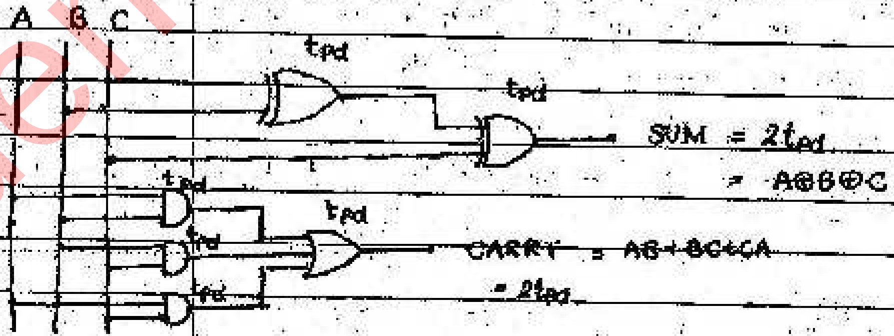
$$= \Sigma m(1,2,4,7)$$

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

$$= AB + BC + AC$$

⇒ The truth table of carry shows the majority of 1's function

$$= \Sigma m(3,5,6,7)$$



⇒ In full adder each logic gate have propogation delay of t_{pd} to provid sum or carry O/P, it requires to $2t_{pd}$ delay.

DATE

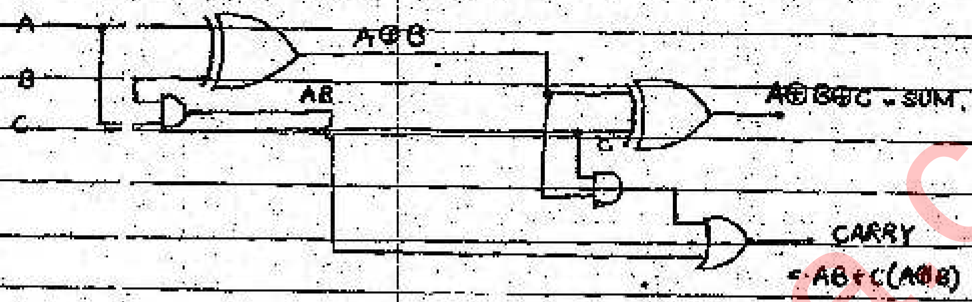
Now, CARRY $= \bar{A}BC + A\bar{B}C + AB\bar{C} + ABC$

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

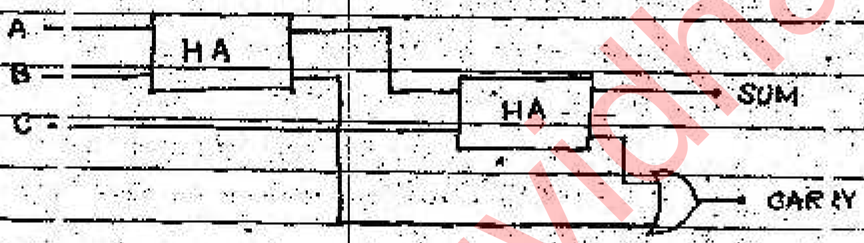
$= AB + C(A \oplus B)$ —(I)

$\boxed{CARRY = AB + C(A \oplus B)}$

Implementation:-



i.e.



Important ques:-

(i) logical expression for SUM $= A \oplus B \oplus C$ CARRY $= AB+BC+AC$

(ii) No. of HA and OR gate = 2HA, 1-OR

(iii) Min. no. of NAND = 9

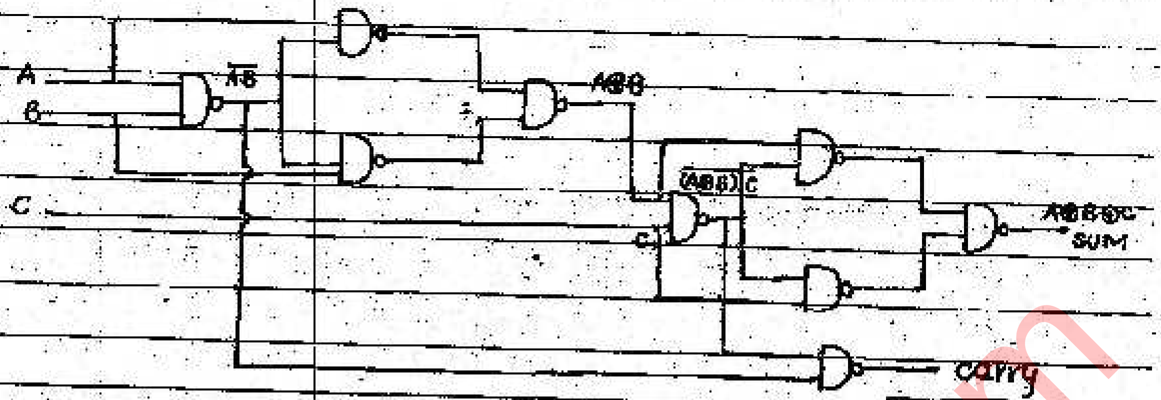
(iv) min. no. of NOR = 9

(v) No. of MUX

(vi) No. of DECODER = 1, (3×8) Decoder and 2-OR gate

DATE

(i) Implementation of Full adder using NAND gate :-

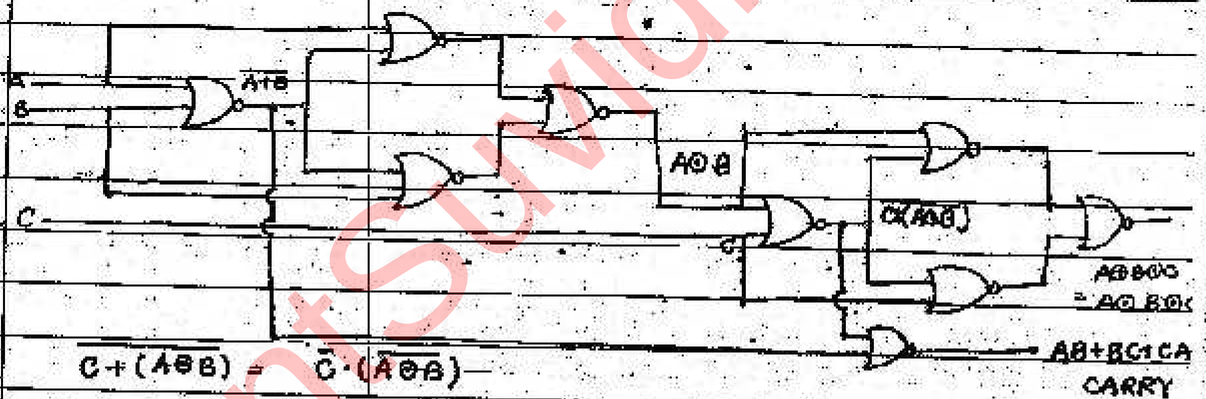


$\overline{\overline{AB} \cdot \overline{(C(A \oplus B))}}$

$= AB + C(A \oplus B)$

(ii). Implementation of Full adder using NOR gate :-

Since $A \oplus B \oplus C = A \odot B \odot C$. The the ckt is same only NAND is replaced by NOR.



$\overline{C + (A \oplus B)} = \overline{C} \cdot (\overline{A \oplus B})$

and,

$\overline{\overline{A+B} + \overline{C} \cdot (\overline{A \oplus B})} = \overline{(\overline{A+B})} \cdot \overline{\overline{C}(\overline{A \oplus B})}$

$= (A+B)(C + A \oplus B)$

$= AC + A\overline{A}B + A A \overline{B} + BC + B\overline{A}B + BA\overline{B}$

$= AC + A\overline{B} + BC + \overline{A}B$

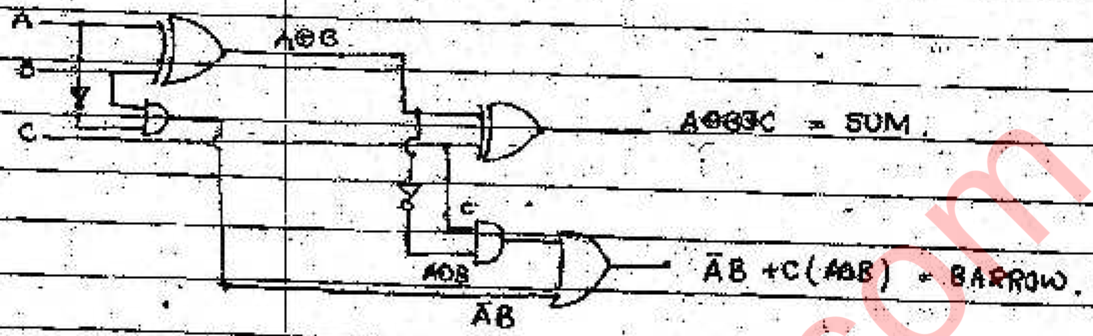
$= C(A+B) + AB$

CARRY $= AB + BC + CA$.

DATE

Barrow expression :-

$$\bar{A}\bar{B}C + \bar{A}B\bar{C} + \bar{A}BC + ABC$$
$$= \bar{A}B(C+\bar{C}) + C(\bar{A}\bar{B} + AB)$$
$$= \bar{A}B + C(\overline{A \oplus B})$$



⇒ Full subtractor will be implemented with 2-HS and 1 OR Gate.

Important Ques:-

no. of NAND gate = 9

no. of NOR gate = 9

logical expression for Difference = $A \oplus B \oplus C$

logical expression for Barrow = $\bar{A}B + \bar{A}C + BC$ or, $\bar{A}B + C(\overline{A \oplus B})$

no. of MUX :-

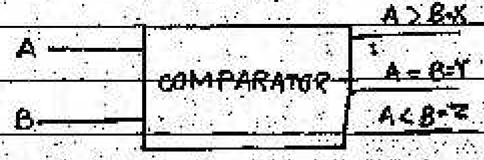
no. of Decoder :- 1 (3x8) Decoder and 2 OR gate

classmate

DATE

COMPARATOR :-

(i)



(ii) Truth table :-

A	B	X	Y	Z
0	0	0	1	0
0	1	0	0	1
1	0	1	0	0
1	1	0	1	0
		$X = A\bar{B}$	$Y = A\odot B$	$Z = \bar{A}B$

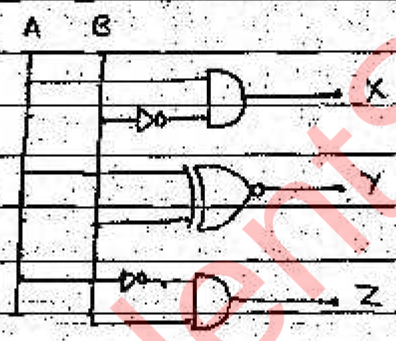
(iii) Expression :-

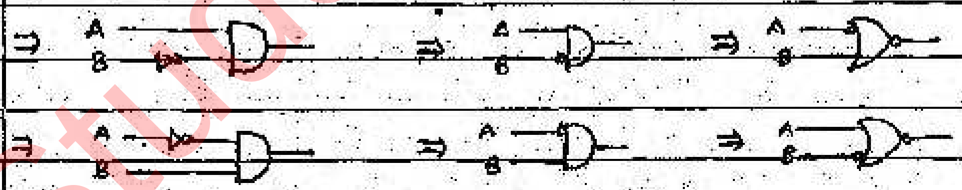
$X = A\bar{B}$

$Y = A\odot B = \bar{A}\bar{B} + AB$.

$Z = \bar{A}B$

(iv) Implementation :-





⇒ Note: for equality condition $A\odot B$, condition Holds.

⇒ If $A_3 A_2 A_1 A_1$ are equal to $B_3 B_2 B_1 B_0$

then the equality condition is.

$(A_3 \odot B_3)\ (A_2 \odot B_2)\ (A_1 \odot B_1)(A_0 \odot B_0)$

DATE

PARALLEL ADDER :-

There are three type of adder
1. Serial adder (we write with sequential ckt)
2. Parallel adder.
3. look ahead carry adder.

⇒ In serial adder only one Full adder (FA) is used to add group of bits.

⇒ It is slowest adder.

Parallel adder :-

⇒ For 4 bit adder
:- 3 FA and 1 HA required.
:- or 4 FA is required.

FA	FA	FA	HA
1	1	0	1
1	0	1	1
1	1	1	

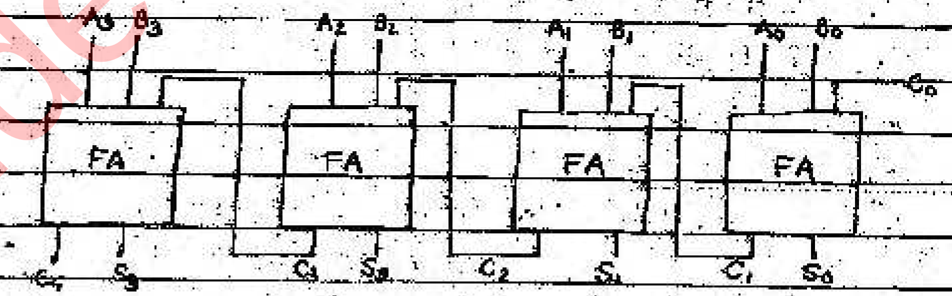
1 1 0 0 0

⇒ Parallel adder is used to add group of bits.

⇒ To add two N bit no. it requires (N-1) Full adder and 1 Half adder. or,
N Full adder . or,
(2N-1) Half adder and (N-1) OR gates required.

Now,

Diagram of Parallel adder :-



A_3	A_2	A_1	A_0
1	1	0	1
1	0	1	1
B_3	B_2	B_1	B_0

C_4 — CARRY $S_3\ S_2\ S_1\ S_0$ — SUM

DATE

⇒ Parallel adder is also called Ripple carry adder.

⇒ Propagation delay from i/p array to o/p array. Hence it is also known as Ripple carry adder.

⇒ In parallel adder each FA will provide 2 logic gate delay. In n bit parallel adder provide total delay of.

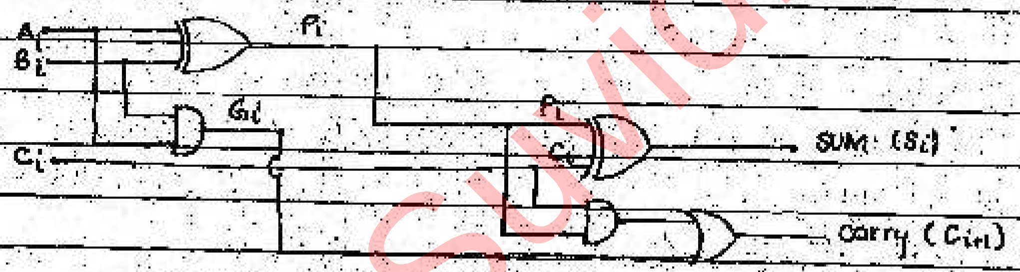
$$\boxed{T_{delay} = 2nt_{pd}}$$

LOOK AHEAD CARRY CIRCUIT :-

⇒ Disadvantage of parallel adder is carry propogation delay present.

⇒ As no. of bit increases - speed of operation reduced.

⇒ To avoid this look ahead carry adder is used.



P_i = Propagation

G_i = Generation term

$P_i = A_i \oplus B_i$

$G_i = A_i \cdot B_i = A_i B_i$

$S_i = P_i \oplus C_i$

$C_{i+1} = P_i C_i + G_i$

For four (4) bit look ahead carry adder :-

I/P. $A_3 \quad A_2 \quad A_1 \quad A_0$

$\quad B_3 \quad B_2 \quad B_1 \quad B_0$

Then $P_0 = A_0 \oplus B_0$

$P_1 = A_1 \oplus B_1$

$P_2 = A_2 \oplus B_2$

DATE

$G_0 = A_0 B_0$ $\quad S_0 = P_0 \oplus C_0$

$G_1 = A_1 B_1$ $\quad S_1 = P_1 \oplus C_1$

$G_2 = A_2 B_2$ $\quad S_2 = P_2 \oplus C_2$

$G_3 = A_3 B_3$ $\quad S_3 = P_3 \oplus C_3$

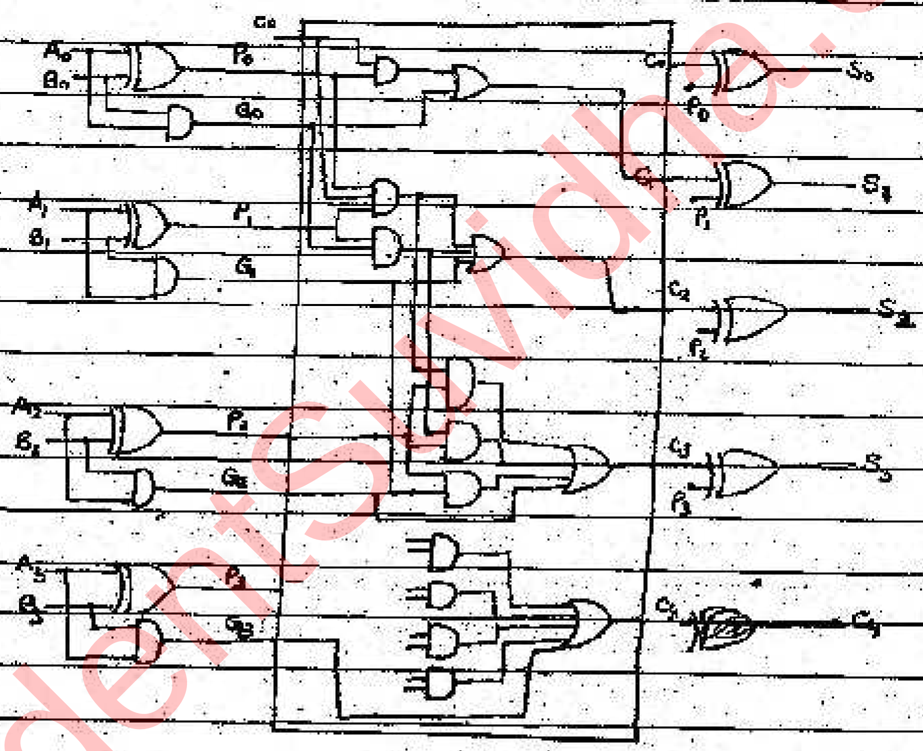
$\boxed{C_{i+1} = P_i C_i + G_i}$ look ahead carry generator expression.

$C_1 = P_0 C_0 + G_0$

$C_2 = P_1 C_1 + G_1 = P_1 (P_0 C_0 + G_0) + G_1 = P_1 P_0 C_0 + P_1 G_0 + G_1$.

$C_3 = P_2 C_2 + G_2 = P_2 P_1 P_0 C_0 + P_2 P_1 G_0 + P_2 G_1 + G_2$

$C_4 = P_3 C_3 + G_3 = P_3 P_2 P_1 P_0 C_0 + P_3 P_2 P_1 G_0 + P_3 P_2 G_1 + P_3 G_2 + G_3$.



⇒ Total no. of AND Gate inside $= 1+2+3+4 = \frac{n(n+1)}{2} = \frac{4 \times 5}{2}$

no. of AND Gate $= \frac{n(n+1)}{2}$.

no. of OR Gate $= n$.

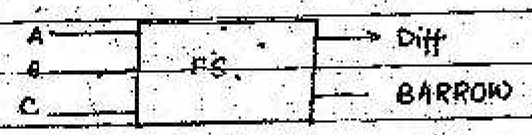
⇒ Total propogation delay $= 2t_{pd}$.

⇒ This is faster than parallel adder.

classmate

DATE

FULL SUBTRACTOR :-

(i) 

(ii) Truth table :-

A	B	C	Diff (A-B-C)	BARROW
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

(iii) logic expression :-

Diff :- $\Sigma m\,(1,2,4,7)$

$= A \oplus B \oplus C$

BARROW $= \bar A \bar B C + \bar A B \bar C + \bar A B C + ABC$

$= BC + \bar A\,(\bar B C + B\bar C)$

$= BC + \bar A\,(B \oplus C)$

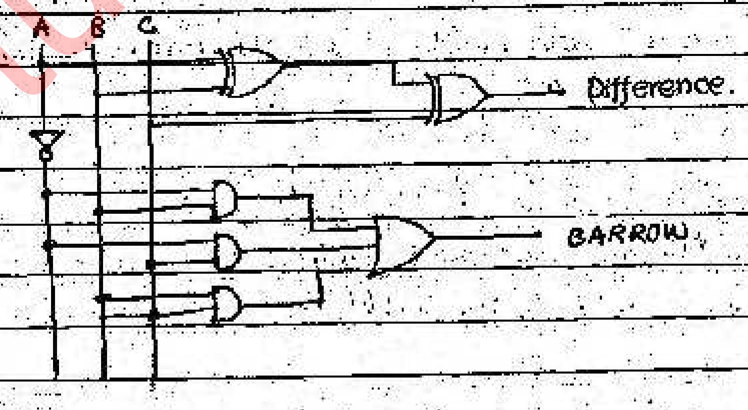
add $\bar A BC$ two more :-

$= \bar A B(\bar C + C) + (\bar A + A)BC + C\bar A\,(B + \bar B)$

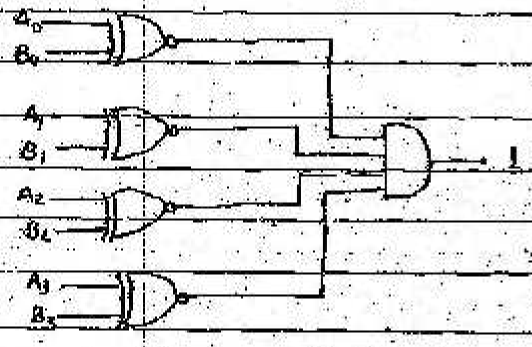
$= \bar A B + \bar A C + BC$

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

(iv) Implementation :-



Then the ckt is :-



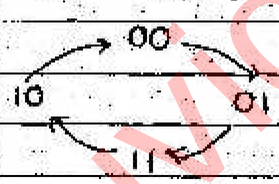
K-MAP :-

⇒ It is used when o/p is 0, 1, and X (don't care)

⇒ In K-MAP gray code representation is used.

⇒ K-map is graphical representation

⇒ Gray code representation



⇒ each successive term is changed by only one bit.

Two variable:-

A \ B (MSB \ LSB)	0	1
0	0 (00)	1 (01)
1	2 (10)	3 (11)

(For Two variable)

For Three variable :-

A \ BC (MSB \ LSB)	00	01	11	10
0	0 (00)	1 (01)	3 (11)	2 (10)
1	4	5	7	6

four variable :-

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

⇒ Minimize :-

Q:- $f(A,B) = \Sigma m(0,2,3)$

Sol:-

A \ B	0	1
0	1	
1	1	1

$f(A,B) = A + \bar{B}$ (+ is put due to SOP form)

Q:- $f(A,B) = \Sigma m(1,2,3)$

Sol:-

A \ B	0	1
0		1
1	1	1

$f(A,B) = A + B$.

Q:- $f(A,B) = \Sigma m(0,1,2,3)$

Sol:- $f(A,B) = 1$.

⇒ In k-map if all are one means the function is 1.

Q:- $f(A,B) = \Sigma m(1,3) + \Sigma d(2)$

Sol:-

A \ B	0	1
0		1
1	X	1

$f(A,B) = B$ (no need of any gate)

DATE

Q: $f(A,B) = \Sigma m(0,3) + \Sigma d(2)$

Sol:

A\B	0	1
0	1	
1	1	*

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

Q: $f(A,B) = \Sigma(0,3) + \Sigma d(2,1)$

Sol:

A\B		
	1	*
	*	1

$f(A,B) = 1$

⇒ In SOP form if all are 1's means o/p is 1.

⇒ All are don't care means dont care.

Three variable :-

Q: $f(A,B,C) = \Sigma m(1,3,5,7)$

Sol:

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

$f(A,B,C) = C$

Q: $f(A,B,C) = \Sigma m(0,1,3,6)$

Sol:

A\BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1	1	1	
A				1

$f(A,B,C) = \bar{A}\bar{B} + \bar{A}C + AB\bar{C}$

Q: $f(A,B,C) = \Sigma m(1,3,6,7)$

Sol:

A\BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$		1	1	
A			1	1

⇒ if we take BC then it is redundant term and it must be removed.

DATE

Procedure :-

(i) Octets
(ii) Quads
(iii) Pairs
(iv) Single term
(5) Remove redundant

↓ Priority.

Q :- $f(A,B,C) = \Sigma m(0,1,2,4,7)$

Sol^n :-

A \ BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1	1		1
A	1		1	

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

Q :- $f(A,B,C) = \Sigma m(0,1,5,6,7)$

Sol^n :

A \ BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1	1		
A		1	1	1

$$\left.\begin{aligned} f(A,B,C) &= \bar{A}\bar{B} + \bar{B}C + AB \\ &= \bar{A}\bar{B} + AB + AC \end{aligned}\right\} \text{two sol}^n$$

⇒ K-map provide minimize expression but not necessarily unique. ie two sol^n also.

Q :- $f(A,B,C) = \Sigma m(0,1,2,5,7) + \Sigma d(3,6)$

Sol^n :-

A \ BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1	1	X	1
A		1	1	X

$f(A,B,C) = \bar{A} + C$

Q :- $f(A,B,C) = \Sigma m(0,1,6,7) + \Sigma d(3,5)$

Sol:

A \ BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1	1	X	
A		X	1	1

$$f(A,B,C) = \bar{A}\bar{B} + AB$$

Q: $f(A,B,C) = \Sigma m(0,1,6,7) + \Sigma d(3,4,5)$

Sol:

A \ BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1	1	*	
A	*	*	1	1

$$f(A,B,C) = \bar{B} + AB$$

Four Variable :-

Q: $f(A,B,C,D) = \Sigma m(0,1,3,5,7,8,9,11,13,15)$

Sol:

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	1	1	1	
$\bar{A}B$		1	1	
AB		1	1	
$A\bar{B}$	1	1	1	

$$f(A,B,C,D) = D + \bar{B}\bar{C}$$

Q: $f(A,B,C,D) = \Sigma m(0,1,4,5,8,9,13,15)$

Sol:

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	1	1		
$\bar{A}B$	1	1		
AB		1	1	
$A\bar{B}$	1	1		

$$f(A,B,C,D) = \bar{A}\bar{C} + \bar{B}\bar{C} + ABD$$

Q: $f(A,B,C,D) = \Sigma m(0,2,8,10,14) + \Sigma d(5,15)$

DATE

Sol:-

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	1			1
$\bar{A}B$		*		
AB			*	1
$A\bar{B}$	1			1

$$f(A,B,C,D) = \bar{B}\bar{D} + AC\bar{D}$$

POS (Product of Sum) :-

Simplify :-

Q:- $f(A,B) = \pi M(0,2,3)$

Sol:-

A \ B	$\bar{B}$, 0	$\bar{B}$, 1
0, A	0	
1 A	0	0

$$f(A,B) = B \cdot \bar{A}$$

Q:- $f(A,B) = \pi M(0,3) + \pi d(1)$

Sol:-

A \ B	B	$\bar{B}$
A	0	X
$\bar{A}$		0

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

Q: $f(A,B,C) = \pi M(0,1,3,5,7)$

Sol:-

A \ B+C	B+C	B+$\bar{C}$	$\bar{B}+\bar{C}$	$\bar{B}$+C
A 0	1	1	1	
$\bar{A}$ 1		1	1	

$$f(A,B,C) = \bar{C} + (A+B)$$
$$= \bar{C}(A+B)$$

Gate-2013

Q:- for the K-map minimize POS expression is.

Sol":-

A \ BC	B+C	B+C̄	B̄+C̄	B̄+C
A	0	X	X	1
Ā	0	1	0	X

$f(A,B,C) = (B+C)(B+\bar{C})$.

⇒ The two function are same if the position of 1's are 0's are same in K-map. and if the 1's place 0 are placed and at 0's place 1's are placed then the function is complement to each other.

⇒ Problem - 26 - page - 13

Q:- $W = R + \bar{P}Q + \bar{R}S$ $X = PQ\bar{R}\bar{S} + \bar{P}\bar{Q}\bar{R}\bar{S} + P\bar{Q}\bar{R}\bar{S}$

PQ \ RS	R̄S̄	R̄S	RS	RS̄
P̄Q̄		1	1	1
P̄Q	1	1	1	1
PQ		1	1	1
PQ̄		1	1	1

PQ \ RS	R̄S̄	R̄S	RS	RS̄
P̄Q̄	1			
P̄Q				
PQ	1			
PQ̄	1			

$Y = RS + PR + P\bar{Q} + \bar{P}Q$ $Z = R + S + PQ + \bar{P}\bar{Q}\bar{R} + P\bar{Q}\bar{S}$

PQ \ RS	R̄S̄	R̄S	RS	RS̄
P̄Q̄	0	0	1	0
P̄Q	1	1	1	1
PQ	1	1	1	0
PQ̄	0	0	1	0

PQ \ RS	R̄S̄	R̄S	RS	RS̄
P̄Q̄	0	1	1	1
P̄Q	1	1	1	1
PQ	0	1	1	1
PQ̄		1	1	1

⇒ Then $W = Z = \bar{X}$

classmate

DATE

NOTE → If Truth table is :-

A	B	Y
0	0	0
0	1	1
1	0	0
1	1	C

(The method for writing the expression from Truth table)

Then,

$$Y = \bar{A}\bar{B}*0 + \bar{A}B*1 + A\bar{B}*0 + AB*C$$

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

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

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