- Testing of digital circuits :

→ 2 approaches for testing

a. Functional testing " exhoustive testing"

b. Structural testing " non-exhoustive testing"

* In exhoustive testing with " 1 GHz" speed of testing cpu,

→ For example

if the circuit has 32 inputs :

$2^{32} = \underbrace{4 * 10^9}$, then we need "4 sec".

↳ Combination , or test vector, or test patterns.

** IF the circuit has 64 input

→ 2^{64} test vector ≈ 585 year , using 1 GHz speed

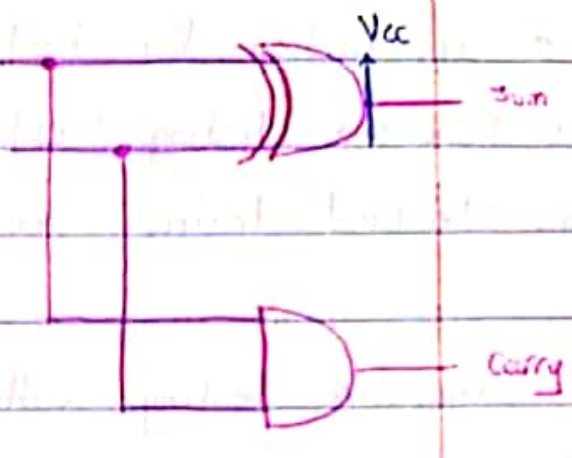
(1 GHz $= 10^9$)

* Basic testing procedure :

- Applay test input to the input of the circuit
- Observe the output as compare then with expected values

Ex: Half Adder

A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	1	1



⇒ Assume the sum is short circuited with Vcc

A	B	Sum	Carry
0	0	1	0
0	1	1	0
1	0	1	0
1	1	1	1

⇒

IF A & B : 01 or 10 , has no effect , we should use 11 or 00

∴

Sum / Vcc →	A	B
	0	0
	1	1

Carry / Vcc →	A	B
	0	0
	0	1
	1	0

→ Sum/G → A B

0	1
1	0

Carry/G → A B

1 1

we should choose :

1. 11. " Sum/Vcc , Carry/G " * 11,01 → 4/4
2. 01. " Sum/G , Carry/Vcc "

• Fault modeling :

most common is the signal stuck at faults

1. Nod is short circuited with Vcc → " S-a-1 , Sa1 "
2. Nod is short circuited with ground → " S-a-0 , Sa0 "

• Path sensitisation method (2. Value logic) :

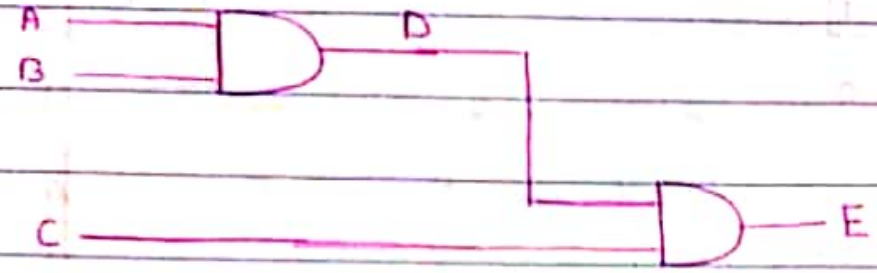
- procedure ⇒

For each nod in the circuits

a. Backtrace phase : drive the nod to the non-fault Condition.

b. Propagation phase : Steave the contant of the node to an output where we can Compare.

- Example:



→ To test nod D:

* Assume D is S-a-0

a. Backtrace: put 1 on nod D

→ $\overline{AB}$ = 11 , 1: fault

0: not fault

b. Propagation: C = 1

$\overline{ABC}$ = 111 , if E = 0 → Faulty

if E = 1 → not Faulty

* Assume D is S-a-1

a. Backtrace: put 0 on nod D

→ $\overline{AB}$, 00 , 01 , 10

b. Propagation: C = 1

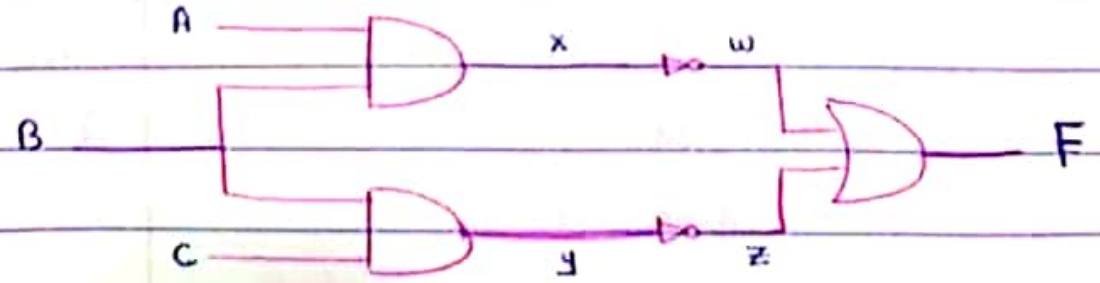
→ $\overline{ABC}$ = 001, 011, 101 — if E=1 → Faulty

if E=0 → Fault-Free

Fault	Test Vector $\overline{ABC}$	Fault Free	Faulty
A-Sa1	011	0	1
B-Sa1	101	0	1
C-Sa1	110	0	1
D-Sa1	001, 011, 101	0	1
E-Sa1	000, 001, 100, 011, 101, 110, 010	0	1
A-Sa0	111	1	0
B-Sa0	111	1	0
C-Sa0	111	1	0
D-Sa0	111	1	0
E-Sa0	111	1	0

* 4. Test Vector → 111, 011, 101, 110 (100%).

* Example :



a. Backtrace : Assume B Sa L

→ put 0 on B → 0 : if no faulty

1 : if faulty

A = 1 , z = 0 → y = 1 , $\overline{BC}$ = 1

B = 1

∴ Contradiction

b. Propagate : nad w to output F

* D- Algorithm (5-value logic)

→ 5- Values

1). 1 : Normal logic 1

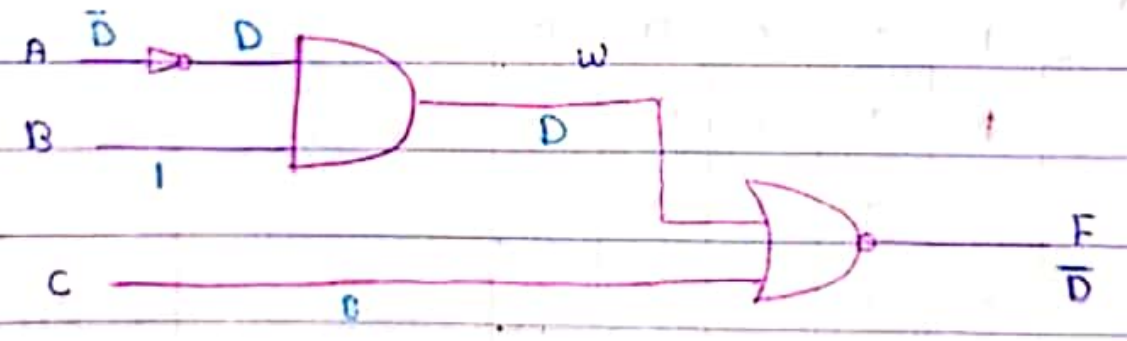
2). 0 : Normal logic 0

3). X : Unknown

4). D : represent "1" under fault "3" condition, and "0" under faulty condition.

5). $\bar{D}$: represent logic "0" under fault "3" condition, and "1" under faulty condition.

* Example :



Test A Sa1 →

put 0 in A (A . $\bar{D}$)

A B C → if F = 0 No fault

0 1 0 F = 1 fault

** Operation on 5- Value- logic :

1. Inverl (Not) → $Z = \bar{A}$

A	Z
0	1
1	0
D	$\bar{D}$
X	X
$\bar{D}$	D

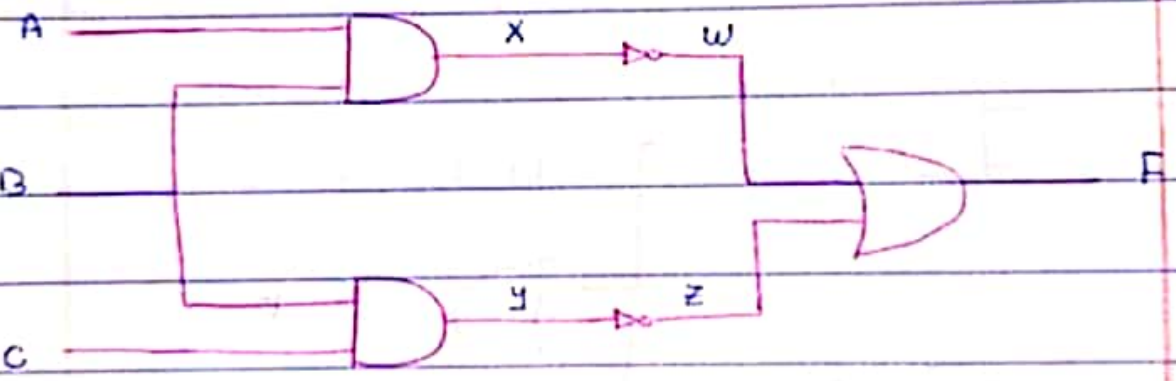
2. AND → $Z = A.B$

B \ A	1	0	X	D	$\bar{D}$
1	1	0	X	D	$\bar{D}$
0	0	0	0	0	0
X	X	0	X	X	X
D	D	0	X	D	0
$\bar{D}$	$\bar{D}$	0	X	0	$\bar{D}$

3. OR → $Z = A + B$

A / B	0	1	X	D	$\bar{D}$
0	0	1	X	D	$\bar{D}$
1	1	1	1	1	1
X	X	1	X	X	X
D	D	1	X	D	1
$\bar{D}$	$\bar{D}$	1	X	1	D

* Example :



To test B sa 1:

Put 0 on B → $B \cdot \bar{D}$

. Use both (BXWF)

A = 1 → $A \cdot \bar{D}$ → $W = D$

propagate from w to F → $Z = 0$ → $y = 1$

then $\overline{BC} = 1$

Conditions on the value of B.

- Use path ByzF : will fauld (symmetry).

- Try path BxwF and ByzF together

put 0 on B → B = $\bar{D}$

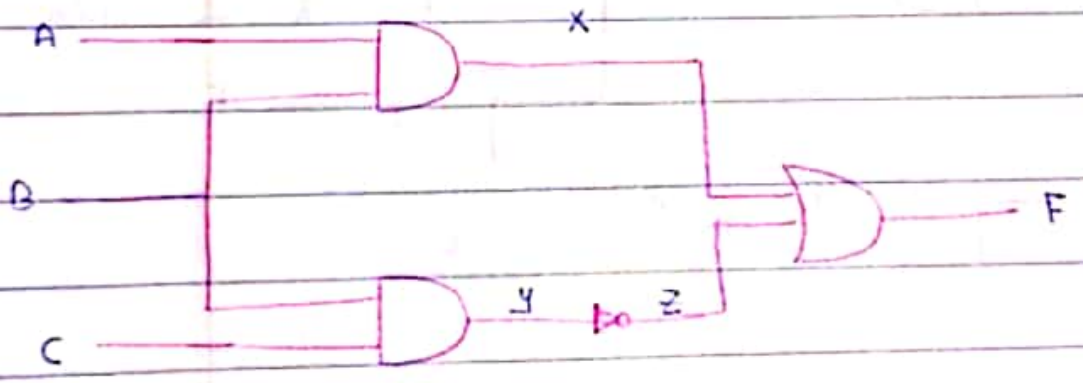
A = 1 → x = $\bar{D}$ → w = D → ∴ F = D

C = 1 → y = $\bar{D}$ → w = D

→ test vector ABC = 101 : if F = 1 → no fault

F = 0 → fault

* Example :



* Test B Sa0

- path BxF and ByzF together

put 1 on B → B = D

A = 1 → x = D → ∴ F = B = 1 , "Fals"

C = 1 → y = D → z = $\bar{D}$

- path fail

• Try path Bx.F :

put 1 on B → B = D

A . 1 → x . D

to propagate from nod x to output F

→ z . 0 → y . 1 → $\overline{BC}$. 11

∴ Contradiction . path fail

• Try path Byz.F :

put 1 on B → B = D

C . 1 → y . D → $\bar{z}$. $\bar{D}$ → $\boxed{F . \bar{D}}$

propagate from nod z to output F x . 0

AB . 00 . 01 . 10 ⇒ AB . 01

Test vector ABC . 011

* Fault Collapsing :

→ 2- Concept :

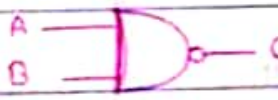
1). Fault equivelance

a.

→ A sa0 ≡ B sa0 ≡ C sa 0

AB = 11 AB = 11 AB = 11

b.



A sa0 ≡ B sa0 ≡ C sa1

11 11 00

c.

A sa1 ≡ B sa1 ≡ C sa1

00 00 00

d.

A sa1 ≡ B sa1 ≡ C sa 0

e. A ▷ B

A s-a-0 ≡ B s-a-1

A s-a-1 ≡ B s-a-0

2). Fault dominance

F_1 is said to dominate F_2 if the test vector for F_2 are subset of the test vector of F_1

A s-a-1

A B

0 1

B s-a-1

A B

1 0

C s-a-1

A B

0 0

0 1

1 0

∴ C s-a-1 dominal A s-a-1

dominal B s-a-1

A s-a-0

A B

1 0

B s-a-0

A B

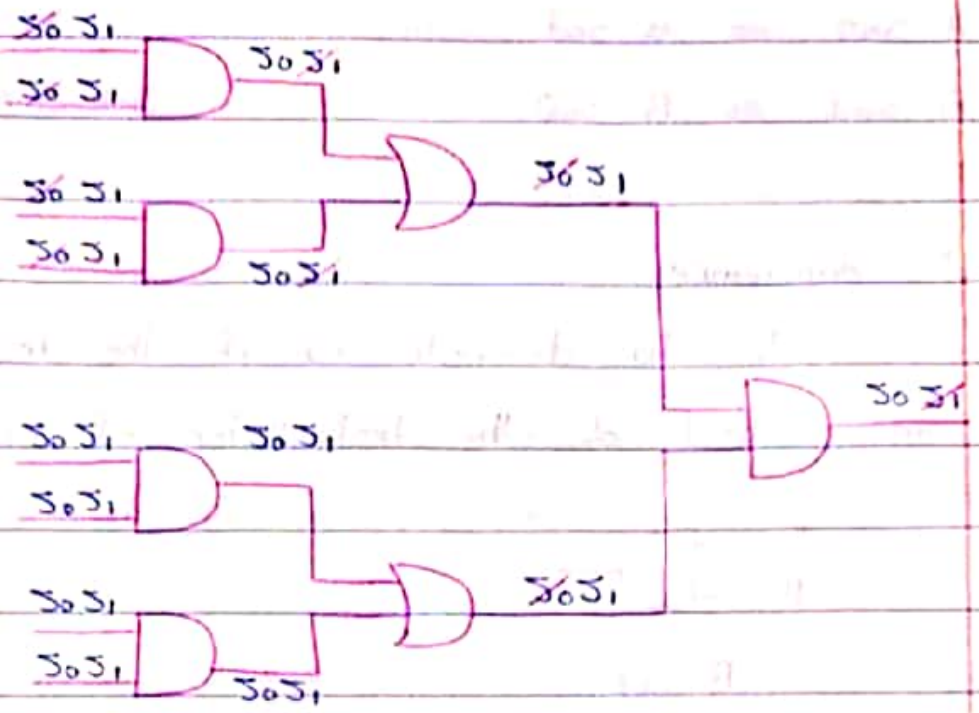
0 1

C s-a-0

A B

0 1, 1 0, 1 1

* Example :



1). Exchustive test

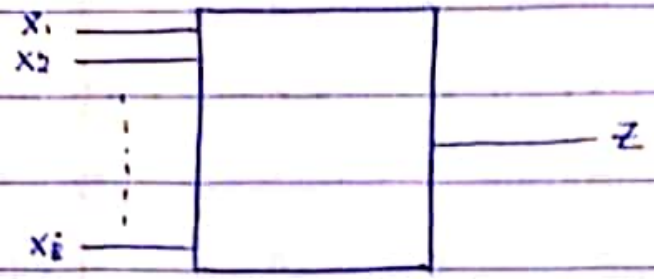
8 input → 2^8 = 256 test vector

2). Using fault model → 15 nod * 2 = 30

max 30 test vedor

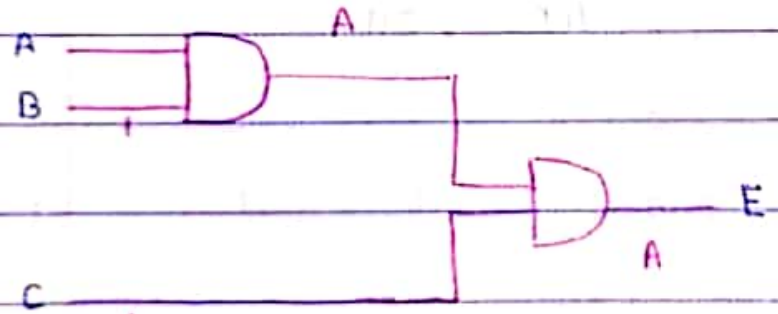
3). Use fault Collapsing → max 15

* Boolean Difference



→ $\frac{dz}{dx_i} = f(x_i = 0) \oplus f(x_i = 1)$

z if sensitive to x_i when $\frac{dz}{dx_i} = 1$



When E is sensitive to A

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

$\frac{dE}{dA} = f(A=0) \oplus f(A=1)$

$= 0 \oplus B.C$

$= B.C$

→ E is sensitive to A when $\frac{dE}{dA} = 1$ $(BC = 1)$

$\overline{BC} = 11.$

- To test x_i SaO

$$x_i \cdot \frac{\partial z}{\partial x_i} = 1$$

- To test x_i Sa1

$$(x_i)' \cdot \frac{\partial z}{\partial x_i} = 1$$

∴ A SaO

$$A \cdot \frac{\partial E}{\partial A} = 1$$

$$A \cdot (BC) = 1$$

$$\overline{ABC} = 111$$

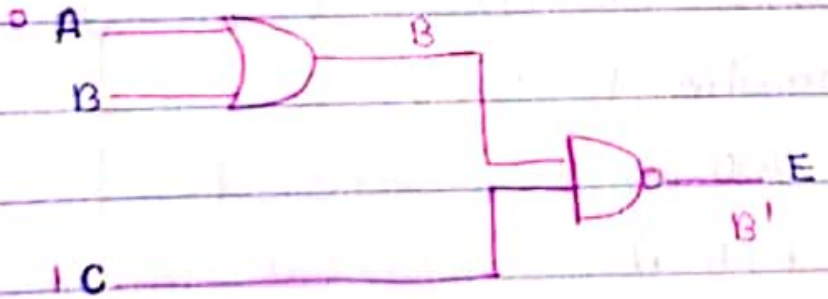
(A) Sa1

$$(A') \cdot \frac{\partial E}{\partial A} = 1$$

$$(A') \cdot (BC) = 1$$

$$\overline{A}BC = 011$$

* Example :



→ To test nod B

E sensitive to B when AC = 01

→ $E = [(A+B).C]'$

$\frac{\partial E}{\partial B} = F(B=0) \oplus F(B=1)$

$\frac{\partial E}{\partial B} = (A.C)' \oplus (C')$

A	B	(A.C)'	C'	$\frac{dE}{dB}$
0	0	1	1	0
0	1	1	0	1
1	0	1	1	0
1	1	0	0	0

→

E sensitive to B where $\frac{dE}{dB} = 1$ → AC = 01

A	C	(A.C)'	C'	(A.C)' ⊕ C'
0	0	1	1	0
0	1	1	0	1
1	0	1	1	0
1	1	1	0	0

E sensitive to B when $\frac{dE}{dB} = 1$

→ AC = 01

$(A.C)' \oplus C' = (A.C)'.C + (A.C)C'^{0}$

$= (A.C)'.C$

$= (A' + C').C$

$= A'C + C'C^{0}$

$= A'C \stackrel{?}{=} 1$ " AC = 01" ✓

. Test B sa0

$B \cdot \frac{dE}{dB} = 1$

$B \cdot A'C = 1$

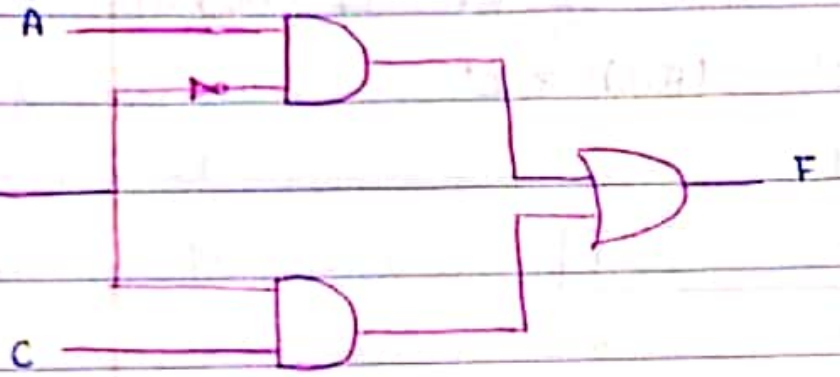
$\overline{ABC} = 011$

. Test B sa1

$B' \cdot A'C = 1$

$\overline{ABC} = 001$

* Example



* To test nod B

$F = AB' + BC$

$\frac{dF}{dB} = F(B=0) \oplus F(B=1)$

$= A \oplus C$

→

F is sensetive to B where $\frac{dF}{dB} = 1 \rightarrow A \oplus C = 1$

∴ A C

0 1

1 0

. B Sa.0

B. (A ⊙ C) . 1

A	B	C
0	1	1
1	1	0

. B Sa.1

B'. (A ⊙ C) . 1

A	B	C
0	0	1
1	0	0

* To test mod x

F = x + B.C

$\frac{dF}{dx}$ = F(x.0) ⊕ F(x.1)

= B.C ⊕ 1

= (BC)'

F is sensitive to x when (BC)' = 1

BC = 00, 01, 10

→ (AB') . (BC)' = 1

A	B	C	AB'	(BC)'	(AB').(BC)'
0	0	0	0	1	0
0	0	1	0	1	0
0	1	0	0	1	0
0	1	1	0	0	0
1	0	0	1	1	1
1	0	1	1	1	1
1	1	0	0	1	0
1	1	1	0	0	0

$\overline{ABC}$. 100 , 101

OR : $(AB').(BC)' \stackrel{?}{=} 1$

$= AB'.(B'+C')$

$= AB' + AB'C'$

$= AB'(1 + C')$

$= AB' \stackrel{?}{=} 1$

→ AB . 10 , ∵ C = X "Dont care"

ABC = 100 ↘ , ABC = 101 ↘

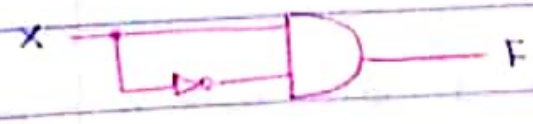
* Example :

$F = X'$

→ $\frac{dF}{dX} = F(X=0) \oplus F(X=1)$

$= 1 \oplus 0 = 1$

* Example :



$F = X.X' = 0$

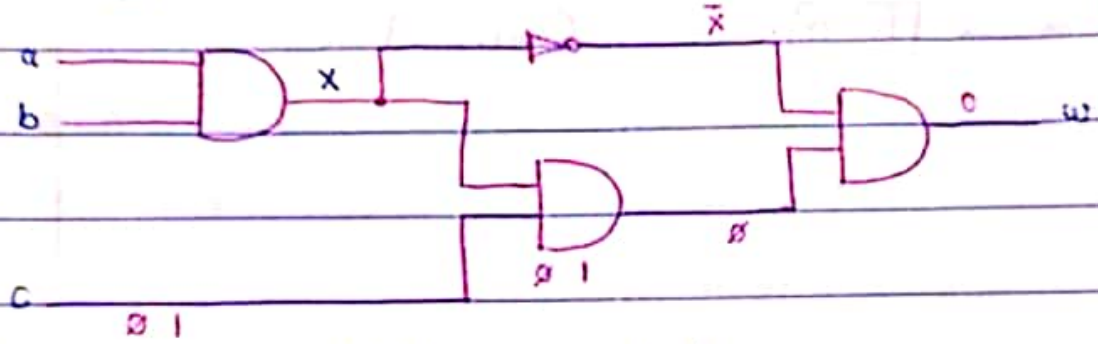
$\frac{dF}{dX} = F(X.0) \oplus F(X.1)$

$= 0 \oplus 0 = 0$, impossible

** Unteslable Faults

- Completely unteslable nods
- Partially unteslable nods

A). Completly unteslable faults



→ nod x is Combletely unstable

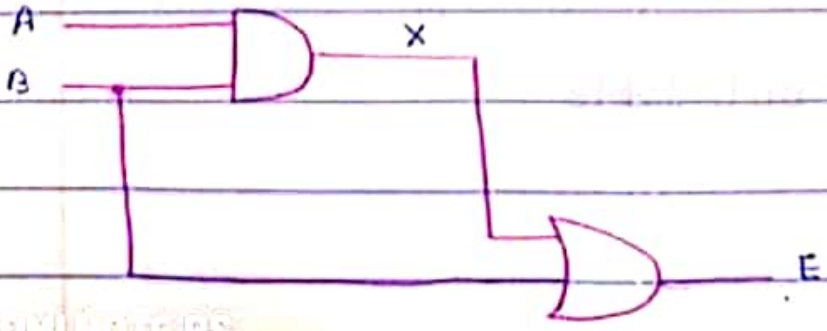
1). x sa0 unteslable x

2). x sa1 unteslable x

$w = x \cdot c \cdot \bar{x} = 0$

$\frac{dw}{dx} = 0$ → not sensitive

B). Partially unteslable Faults



E = AB + B

* X s-a-1

a. Backtrace → AB = ∴ X = D̄

0 0

0 1

1 0

b. Propagation → B = 0 ← Contradiction

→ test vector :

A	B
0	0
1	0

* X s-a-D

. A B , X = D → "Backtrace"

1 1

Contradiction

. B = 0 → "propagation"

∴ No test vector ∴ untestable

** Example : " Boolean difference "

$E = AB + B$

$E = X + B$

$\rightarrow \frac{dE}{dX} = f(X=0) \oplus f(X=1)$

$= B \oplus 1 = B'$

→ E is sensitive to X when

$B' = 1 \rightarrow B = 0$

. X Sa-a-0

$X \cdot \frac{dE}{dX} \stackrel{?}{=} 1$

$A \cdot B \cdot B' \stackrel{?}{=} 1$

$0 \stackrel{?}{=} 1$

∴ untestable

. X Sa1

$X' \cdot \frac{dE}{dX} \stackrel{?}{=} 1$

$(A \cdot B)' \cdot B' \stackrel{?}{=} 1$

$(A' + B') \cdot B' \stackrel{?}{=} 1$

$A'B' + B' = B'(1 + A')$

$= B'$

Test vector → $B' = 1$

$B = 0$

A B

X 0 → 00

↓ → 10

Don't care