Hazards & Hazard - Free Realizations :-

Hazards are unwanted switching transients that may appear at the o/p of a circuit because different paths exhibit different propagation delays.

Such a transient is also called a glitch or spurious spikes, which is caused by hazardous behaviour of the logic circuit. Hazards occur in combinational circuits as well as in sequential circuits.

A hazard in a combinational circuit is a condition where a single variable change produces a momentary o/p change when no o/p change should occur. There are 2 types of hazards, namely static hazard and dynamic hazard.

Static hazard is of 2 types, namely

(i) Static 1 - hazard.

(ii) Static 0 - hazard.

→ Suppose all the i/ps to a logic ~~gate~~ circuit except one remain at their assigned levels and only one i/p say x changes from 0 to 1 or 1 to 0. If the o/p is expected to be 1 regardless of the changing variable, the spurious

0 level for a short interval is called a static 1-hazard. [Fig 1]

If the o/p is expected to be '0' regardless of changing variable, the spurious 1 level for a short-interval is called a static 0-hazard. [Fig 2]

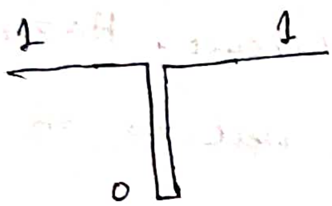


Fig: 1
(Static-1 Hazard)

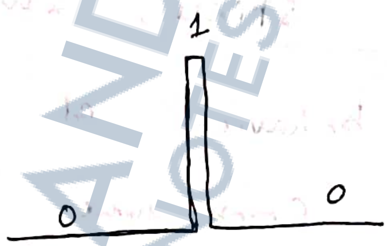


Fig 2:-
(Static-0 Hazard)

→ Static hazards can be eliminated by using redundant gates. When the o/p changes three or more times when it should change from 1 to 0 & 0 to 1 only once, it is called dynamic hazards. [Fig 3].

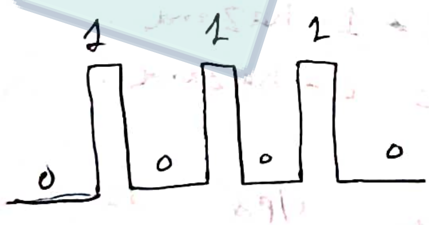


Fig 3: Dynamic Hazard

Dynamic hazards occur when the o/p changes for 2 adjacent i/p combinations. While changing, the o/p should ~~only~~ change only once, but it may change 3 or more times in short intervals because of differential delays in several paths. Dynamic hazards occurs only in multilevel circuits.

Static Hazards:

Consider the function $F(A,B,C) = \Sigma m(3,4,5,7)$ mapped in Fig 4. The minimal SOP realization

$$F_{min} = A\bar{B} + BC,$$

with logic gates implementation with is shown in fig 5, while the contact network is shown in fig 6.

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

$F_{min} = A\bar{B} + BC.$

Fig 4: Map for $A\bar{B}+BC$

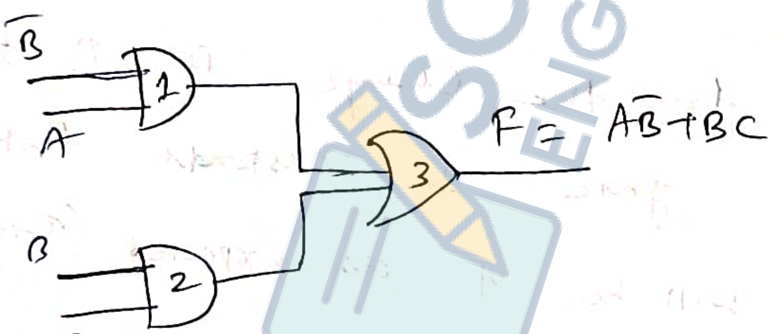


Fig 5:- Gate n/w

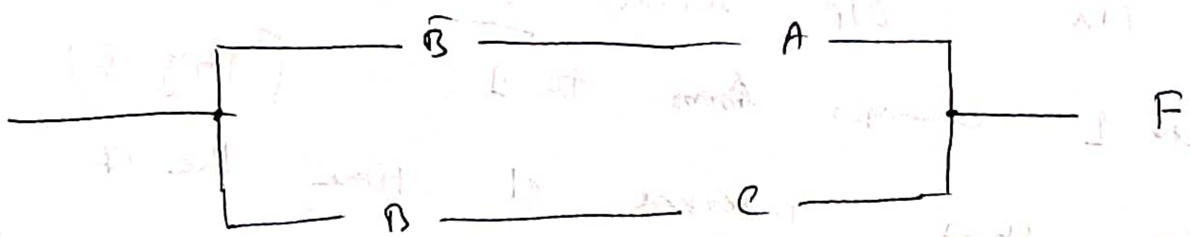


Fig 6:- Contact network.

Consider the situation when $A=1, B=1, C=1$

[Note:- i.e $ABC = 111 = 7$ i.e $\Sigma m(3,4,5,7)$]

and only B is changing from 1 to 0

[Note:- i.e $ABC \rightarrow 101 \rightarrow 5$ i.e $\Sigma m(3,4,5,7)$]

So O/P (F) should remain '1' by design.

<u>when ABC = 111</u>

Look at the gate circuit, when B = 1, the O/P of gate 2 is '1', the O/P of gate 1 is '0' & O/P F is 1.

<u>when ABC = 101</u>

when B changes to '0', the O/P of gate 2 becomes '0' but the O/P of gate 1 becomes 1 & O/P F remains at 1.

Now, for the change in B from 1 to 0, <u>if</u> gate 1 responds faster than gate 2, F will be 1 as expected. (Fig 7)

But if gate <u>2 is faster than</u> gate 1, its O/P becomes <u>zero</u>, before O/P of gate 1 changes to 1. (Fig 8)

And for a very short interval of time the O/P of gate 1 & gate 2 will be zero resulting in O/P of '0'.

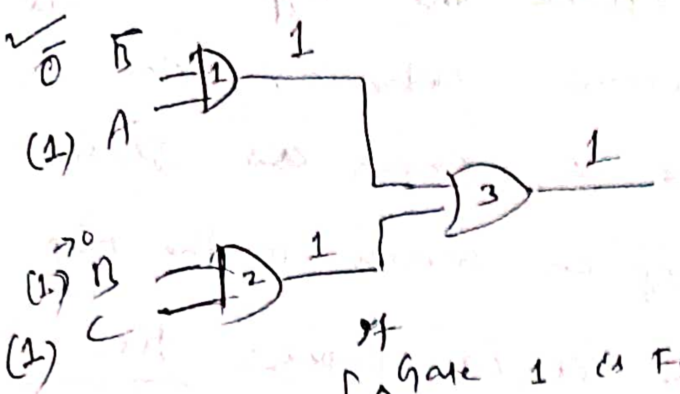
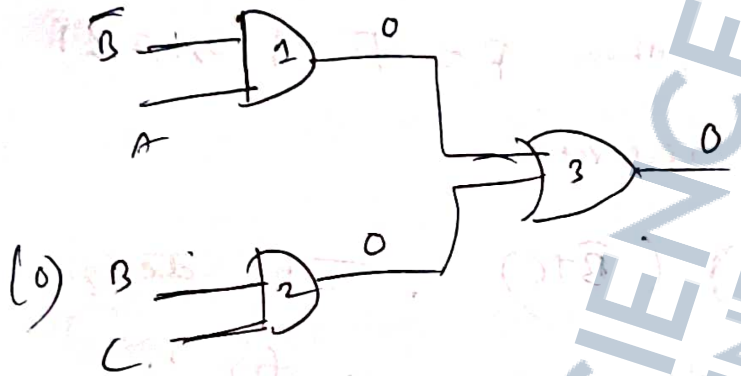


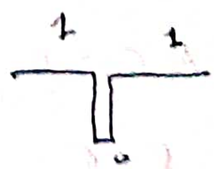
Fig 7:- [If Gate 1 is Faster, its O/P Comes 1 immediately
Gate '2' is slower, although B changed to $\to 0$, O/P
has not been '0' yet, it is at total 1 state]

So O/P is still '1'.



[Fig 8:- If Gate 2 is faster, O/P of Gate 2 'O'.
Initially B was 1, and $\overline{B} = 0$, O/P of Gate 1 was
~~slower $\overline{B}$ has not updated~~
'O'. Although B has been changed to $1 \to 0$,
the O/P of gate '1' has not changed,
because it is a slower gate.
∴ Both I/Ps to 'OR' are '0'
so O/P of gate 3 is Zero]

But after some time O/P of gate '1' is 1.
So O/P of gate 3 becomes 1.]



A little later of course the O/P goes to 1. This erratic behaviour is shown in fig 1, and is known as static 1 - hazard marked by an arrow in the map. With contact network it is called the set hazard.

Static 0-hazard :

If we consider the POS realization of the same function, then $F = \prod M(0,1,2,6)$.

The minimal POS realization

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

. The design is shown in fig 10.

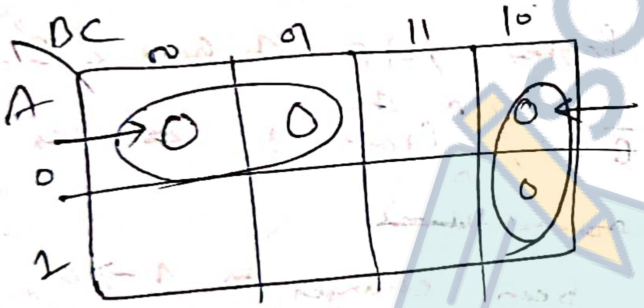


Fig 9 : Map for
$F = (A+B)(\bar{B}+C)$

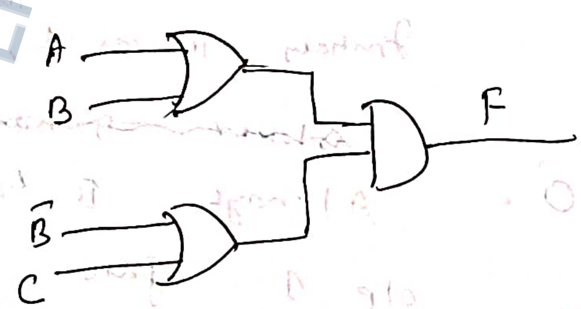
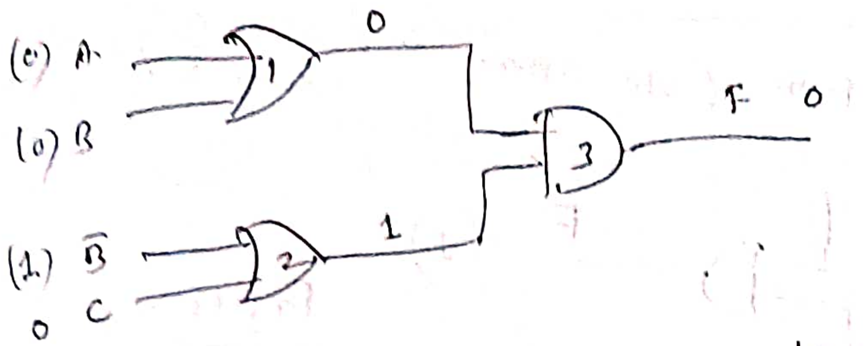


Fig 10 :- Gate n/w
for $F = (A+B)(\bar{B}+C)$

→ Consider the situation when $A=0$, $B=0$ & $C=0$ and only B changing from 0 to 1 [Fig 11) The O/P F ~~the~~ has to



← Fig 11:

remain at '0' by design.

B → 0 to 1.
A B C was 0 0 0
Now A B C 0 1 0
000 → 0, 010 → 0
as Π(0,1,2,4,6)

When B = 0, the o/p of gate 1 is 0, the o/p of gate 2 is 1 and the o/p F is 0.

~~When B changes to 1, the o/p of change (F)~~

~~In B from 0 to 1, if gate 2 responds faster than gate 1.~~

When B changes to 1, the o/p of gate 1 becomes '1' and o/p of gate 2 becomes '0' and so the o/p F remains 0.

If Gate 2 is faster :-

(Slower, Although B has been changed (1) o/p remains at 0)

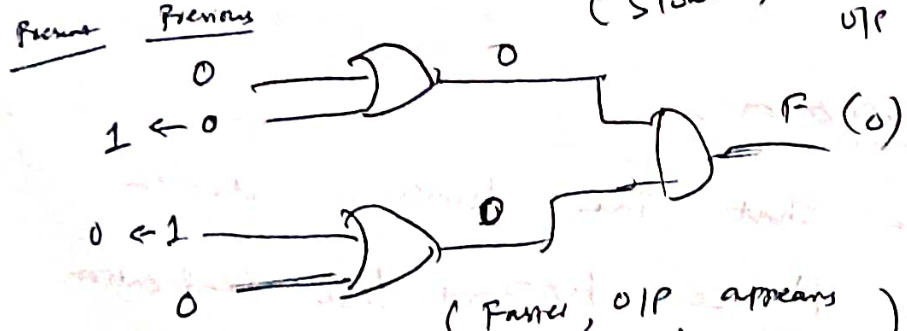


Fig 12 —

(Faster, o/p appears immediately)

If gate 2 is faster, F = 0. [As expected]

If gate 1 is faster

→ Faster (o/p appears as 1, when B become 1)

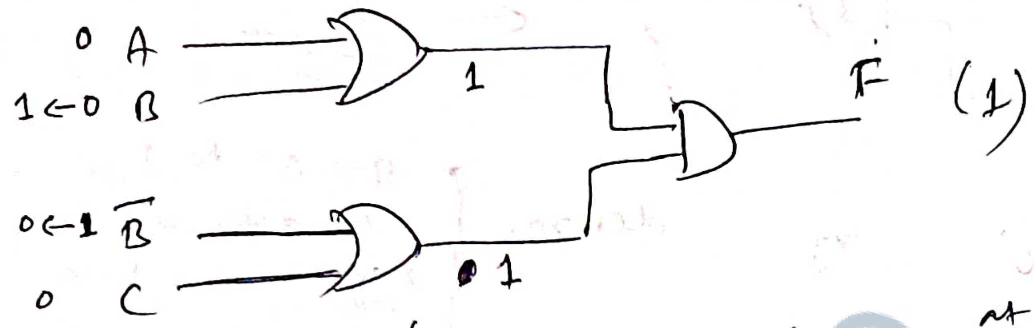


Fig 13:-

↘ (slower, o/p remain at 1 state at previous value)

If gate 1 is faster, than gate 2, it's o/p becomes 1 before the o/p of gate changes to 0 and for a very short time the o/p of both gates 1 & 2 will be 1 resulting F = 1.

(As shown in Fig 2:- previously)

This erratic behaviour is known as static 0-hazard. marked by arrows on the map of Fig 9. With contact n/w it is called Cut set hazard.

Hazard-free Realization:-

We should ensure that the functions don't contain hazards. Hence hazard-free realization is necessary. Notice in the map of Fig. 4, the static-1-hazard arises because two adjacent 1 are covered by different subcubes.

i.e

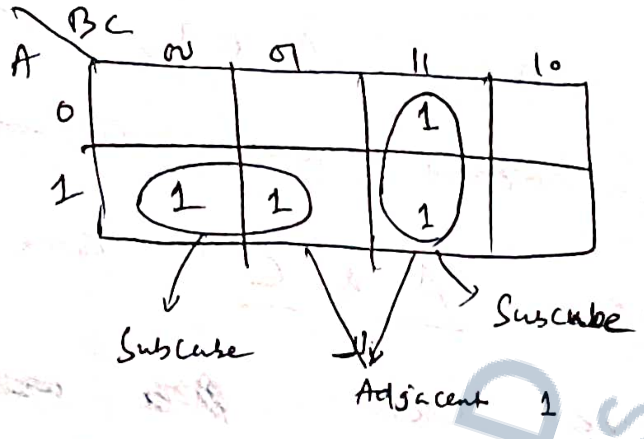


Fig 14:-

→ Minimal realization are more vulnerable to hazards. If we want to ensure that this pair of adjacent 1's covered by the same subcube a redundant term will come shown by dotted line.

i.e

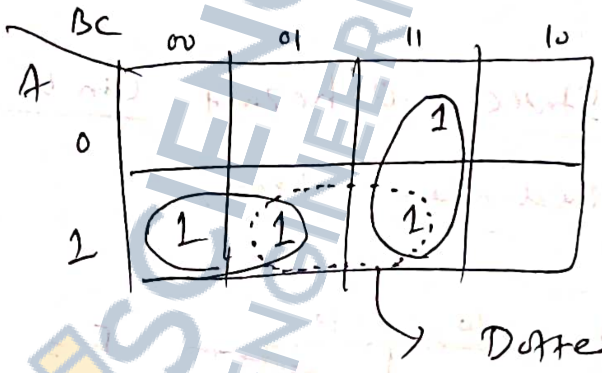


Fig 16:-

$F = A\bar{B} + AC + BC$

This realization will now have no static-1 hazard but the function contain a redundant term AC

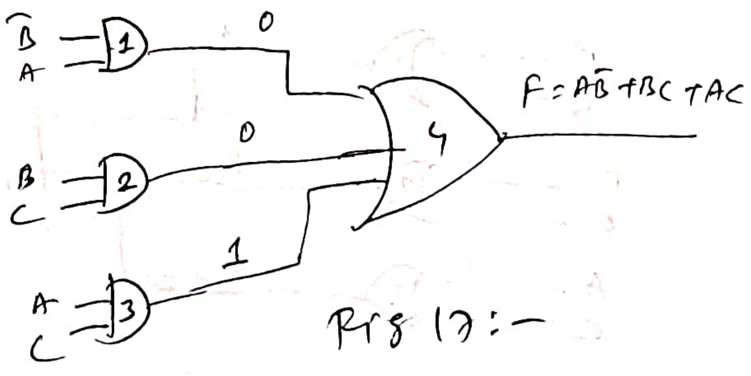
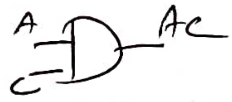


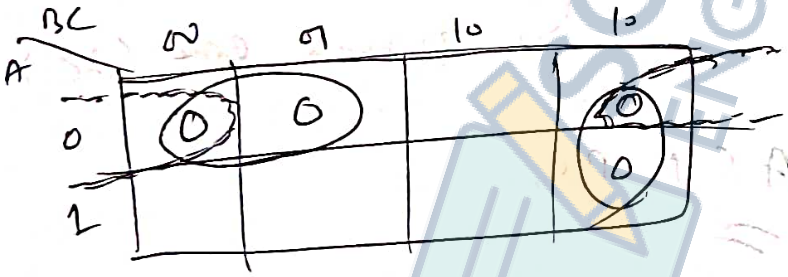
Fig 17:-

Now in this case, when ~~B was~~ A B C are 1 1 1 & B goes to 0 i.e ABC 1 0 1, in that case static 1-hazard was occuring.

Now since A & C are 1 1 in the above ckt 

AC = 1, so o/p of OR gate is 1 independent of gate 1 & gate 2 as shown in fig 8. [Fig. 17] [Static 1-hazard problem was occuring]

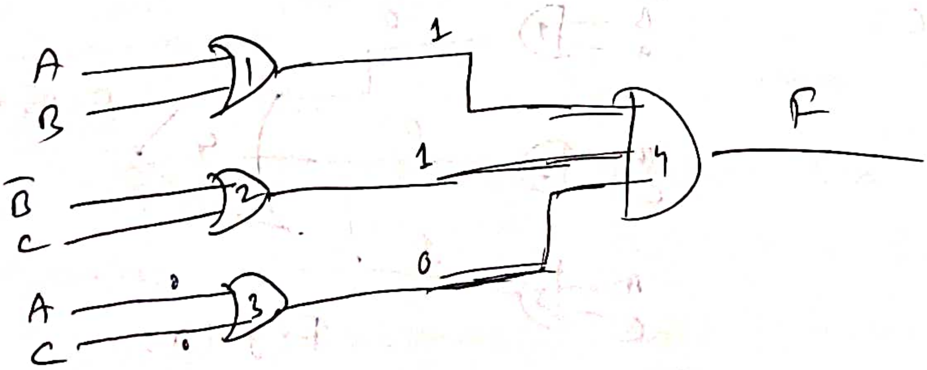
Similarly static 0-hazard can be resolved taking redundant term.



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

Taking the redundant term into account (shown in dotted line)

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



Although during hazard gate 1 & gate 2 o/p are 1 But (A+C) o/p is '0'. So F = 0. for As required POS

— o —