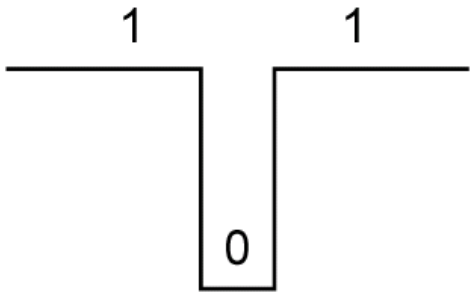
Hazards

Hazards

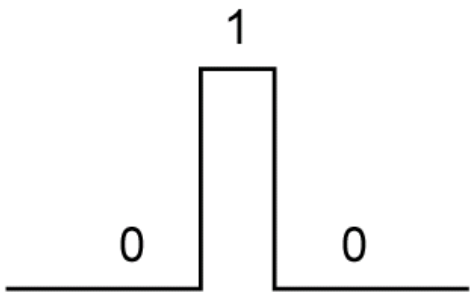
When the input to a combinational logic circuit changes, unwanted switching transients may appear on the output.

These transients occur when different paths from input to output have different propagation delays.

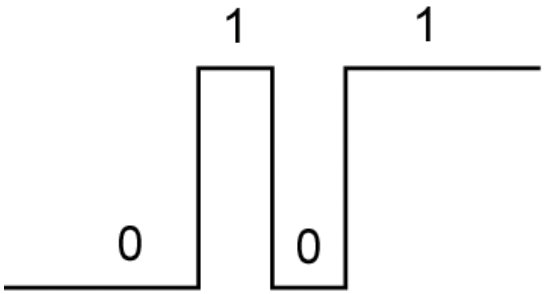
HAZARDS

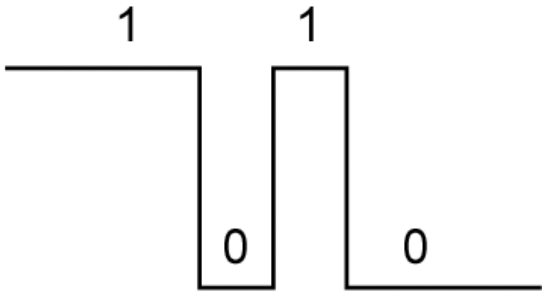


(a) Static 1-hazard



(b) Static 0-hazard





(c) Dynamic hazards

Hazards

- When analyzing combinational logic circuits for hazards we will consider the case where only one input changes at a time.
- Under this condition, a static 1-hazard occurs when the input change causes one product term (in a SOP expression) to transition from 1 to 0 and another product term to transition from 0 to 1.
- Both product terms can be transiently 0, resulting in the static 1-hazard.

Hazards

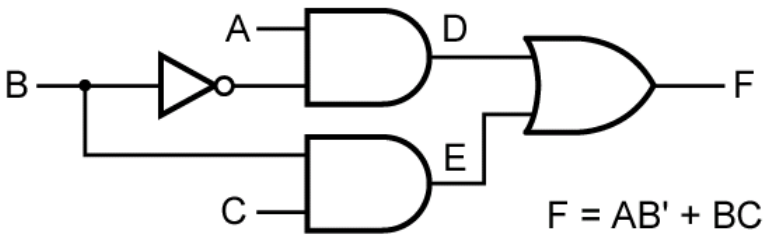
- Under the same condition, a static 0-hazard occurs when the input change causes one sum term (in a POS expression) to transition from 0 to 1 and another sum term to transition from 1 to 0.
- Both sum terms can be transiently 1, resulting in the static 0-hazard.

Detecting Static 1-Hazards

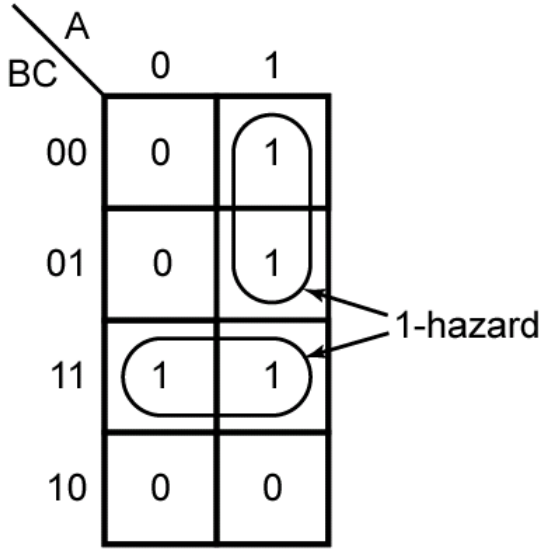
We can detect hazards in a two-level AND-OR circuit using the following procedure:

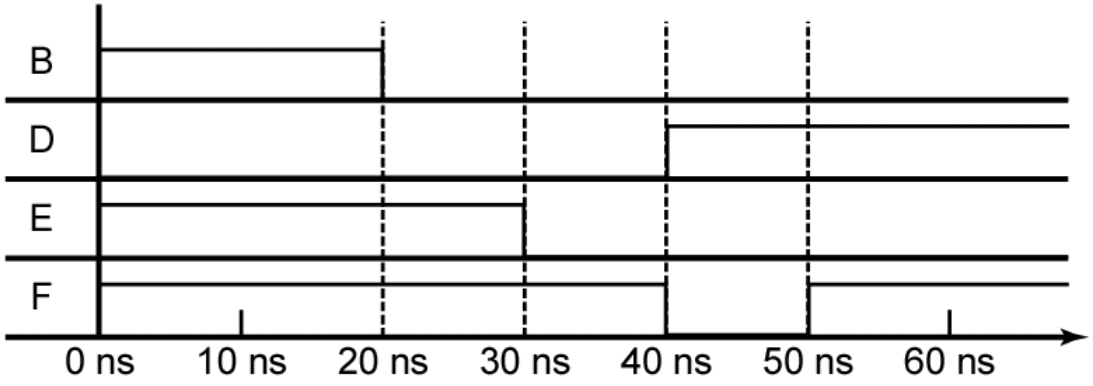
1. Write down the sum-of-products expression for the circuit.
2. Plot each term on the map and loop it.
3. If any two adjacent 1′s are not covered by the same loop, a 1-hazard exists for the transition between the two 1′s. For an n-variable map, this transition occurs when one variable changes and the other $n - 1$ variables are held constant.

Detecting Static 1-Hazards



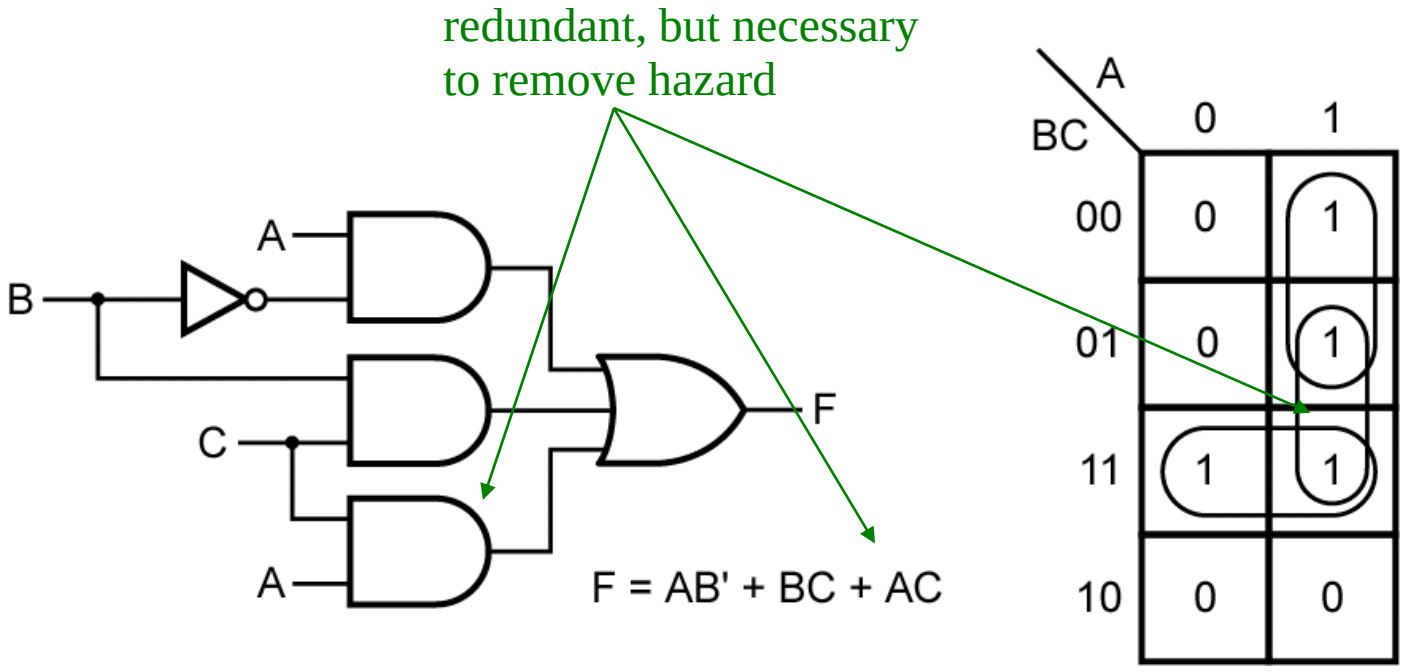
(a) Circuit with a static 1-hazard





(b) Timing chart

Removing Static 1-Hazards

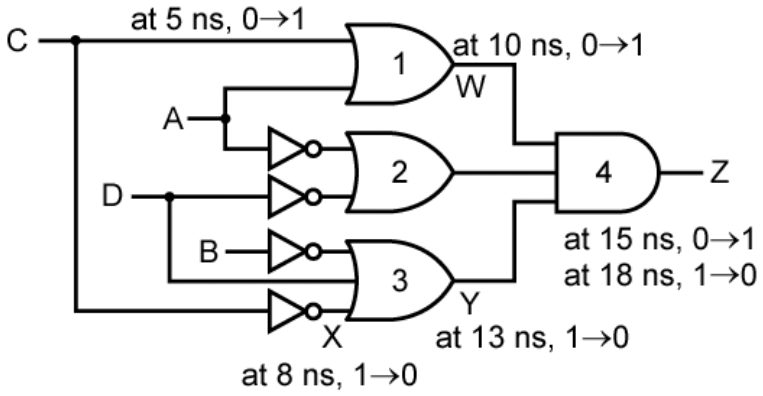


Detecting Static 0-Hazards

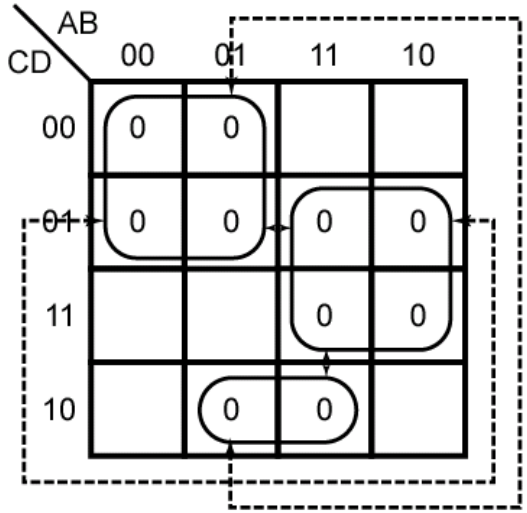
We can detect hazards in a two-level OR-AND circuit using the following procedure:

1. Write down the product-of-sums expression for the circuit.
2. Plot each sum term on the map and loop the zeros.
3. If any two adjacent 0′s are not covered by the same loop, a 0-hazard exists for the transition between the two 0′s. For an n-variable map, this transition occurs when one variable changes and the other $n - 1$ variables are held constant.

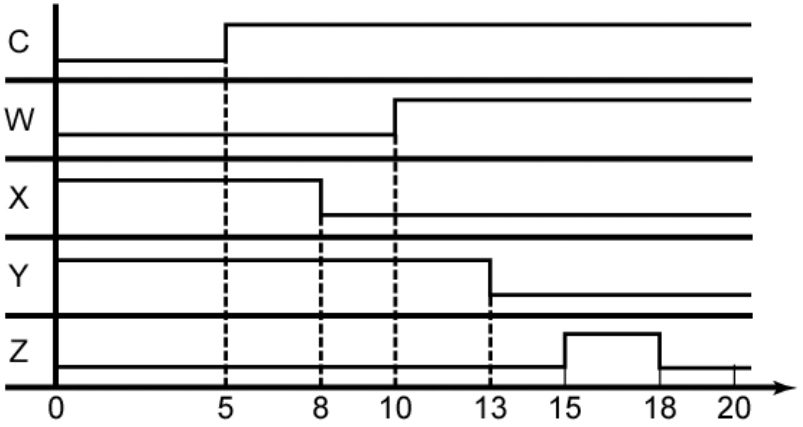
Detecting Static 0-Hazards



(a) Circuit with a static 0-hazard

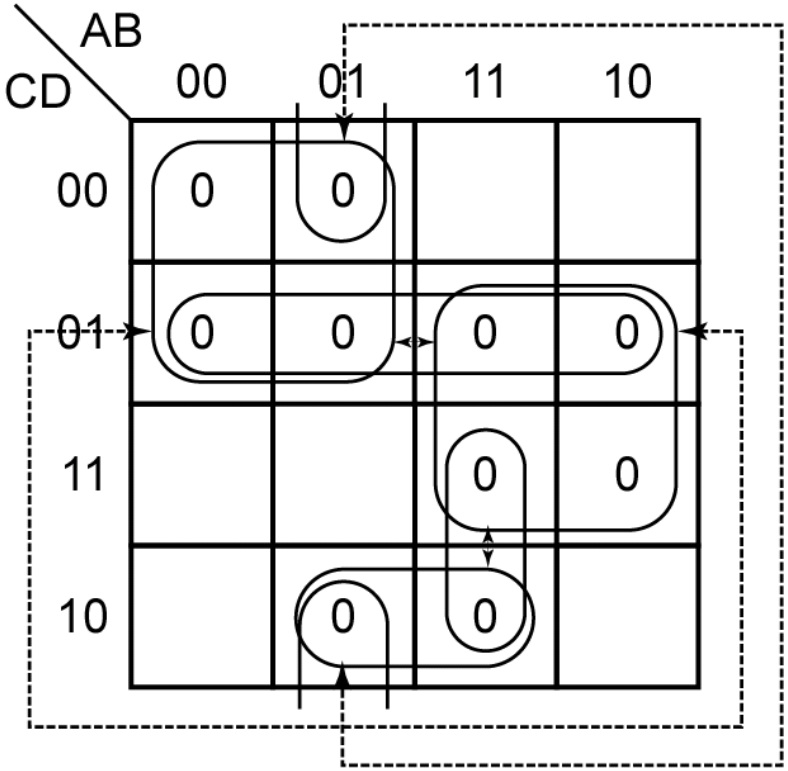


(b) Karnaugh map for circuit of (a)



(c) Timing diagram illustrating 0-hazard of (a)

Removing Static 0-Hazards



How many redundant gates are necessary to remove the 0-hazards?

Hazards

Exercise:

Design a hazard-free combinational logic circuit to implement the following logic function

$$F(A,B,C) = A'.C' + A.D + B.C.D'$$

Hazards

Exercise:

Design a hazard-free combinational logic circuit to implement the following logic function

$$F(A,B,C) = (A'+C').(A+D).(B+C+D')$$

Hazards

- Two-level AND-OR circuits (SOP) cannot have static 1-Hazards.
  - Why?
- Two-level OR-AND circuits (POS) cannot have static 0-Hazards.
  - Why?

Questions?

STATIC AND DYNAMIC HAZARD IN COMBINATIONAL NETWORK

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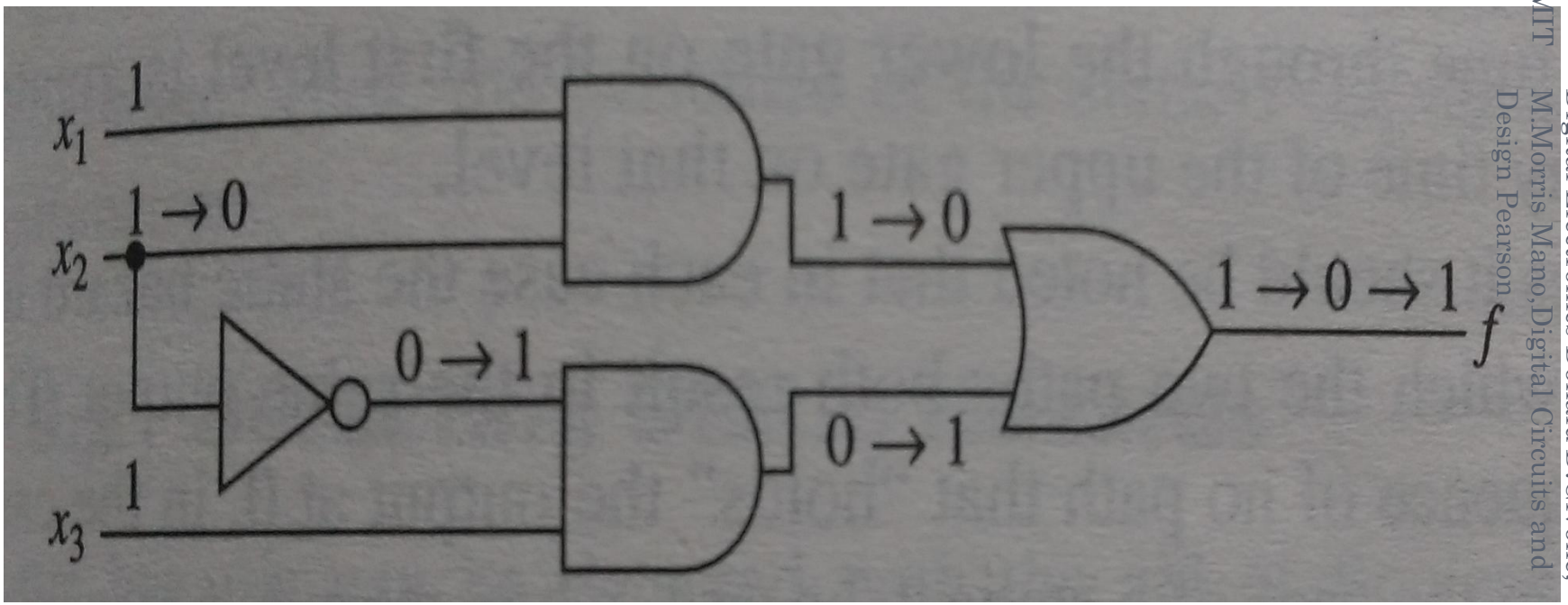
ESSENTIAL HAZARD



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$$f_{tr} = x_1x_2 + \bar{x}_2x_3$$

$$f_{tr} = \overline{\overline{(x_1x_2)}\ \overline{(\bar{x}_2x_3)}}$$

$$= \overline{\overline{(x_1x_2)}} + \overline{\overline{(\bar{x}_2x_3)}}$$

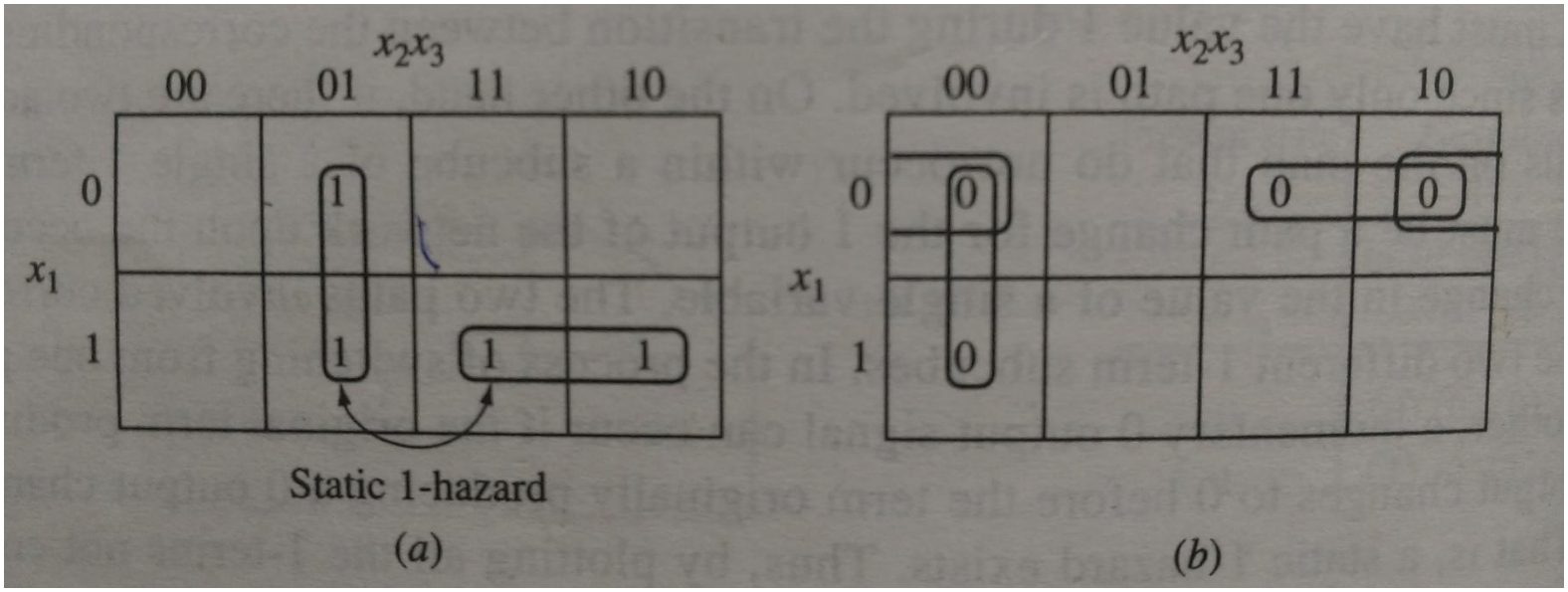
$$= x_1x_2 + \bar{x}_2x_3$$

$$f_{tr} = x_1x_2 + \bar{x}_2x_3$$

$$= (x_1 + \bar{x}_2x_3)(x_2 + \bar{x}_2x_3)$$

$$= (x_1 + \bar{x}_2)(x_1 + x_3)(x_2 + \bar{x}_2)(x_2 + x_3)$$

DETECTING STATIC HAZARD

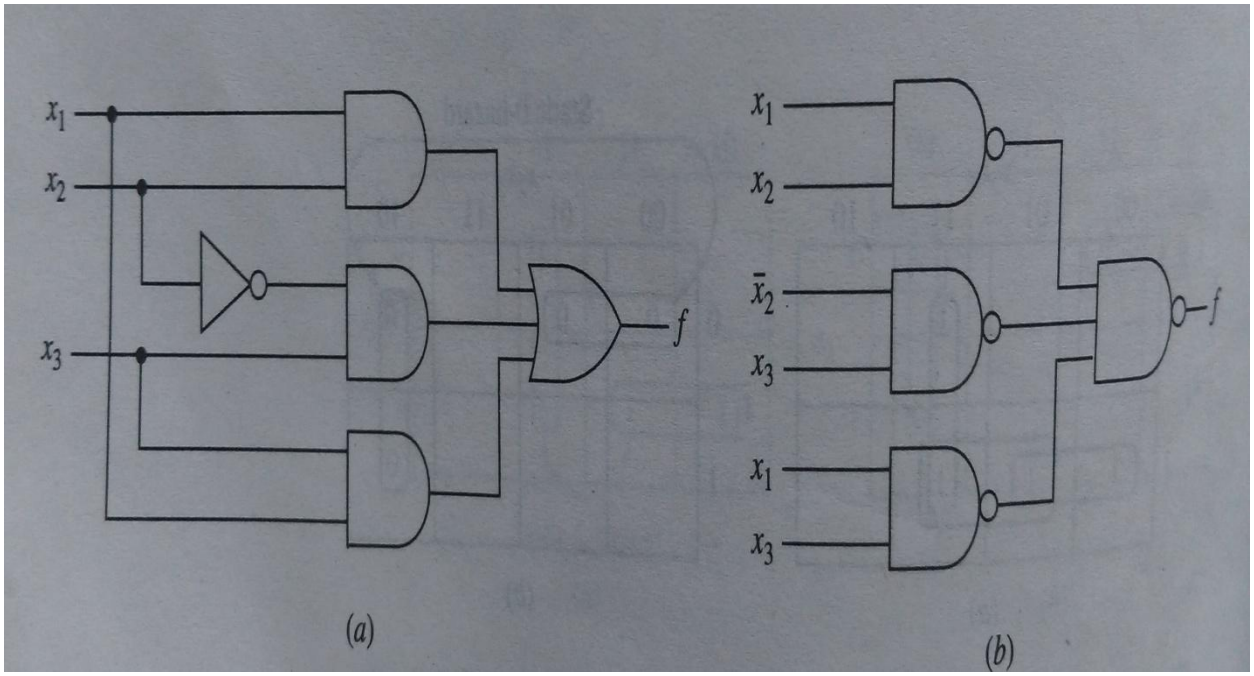


$$f_{tr} = (x_1 + x_2)(\bar{x}_2 + x_3)$$
$$= x_1\bar{x}_2 + x_1x_3 + x_2\bar{x}_2 + x_2x_3$$

$$f_{tr} = (x_1 + x_2)(\bar{x}_2 + x_3)$$

ELIMINATING STATIC HAZARD

$$f(x_1, x_2, x_3) = x_1x_2 + \bar{x}_2x_3 + x_1x_3$$



$$f(x_1,x_2,x_3) = x_1x_2 + x_3(x_1 + \bar{x}_2)$$

$$f(x_1,x_2,x_3) = \bar{x}_2x_3 + x_1(x_2 + x_3)$$

$$f(x_1,x_2,x_3) = (x_1 + x_2)(\bar{x}_2 + x_3)(x_1 + x_3)$$

$$f(x_1,x_2,x_3) = (x_1 + x_2)(x_3 + x_1\bar{x}_2)$$

$$f(x_1,x_2,x_3) = (\bar{x}_2 + x_3)(x_1 + x_2x_3)$$

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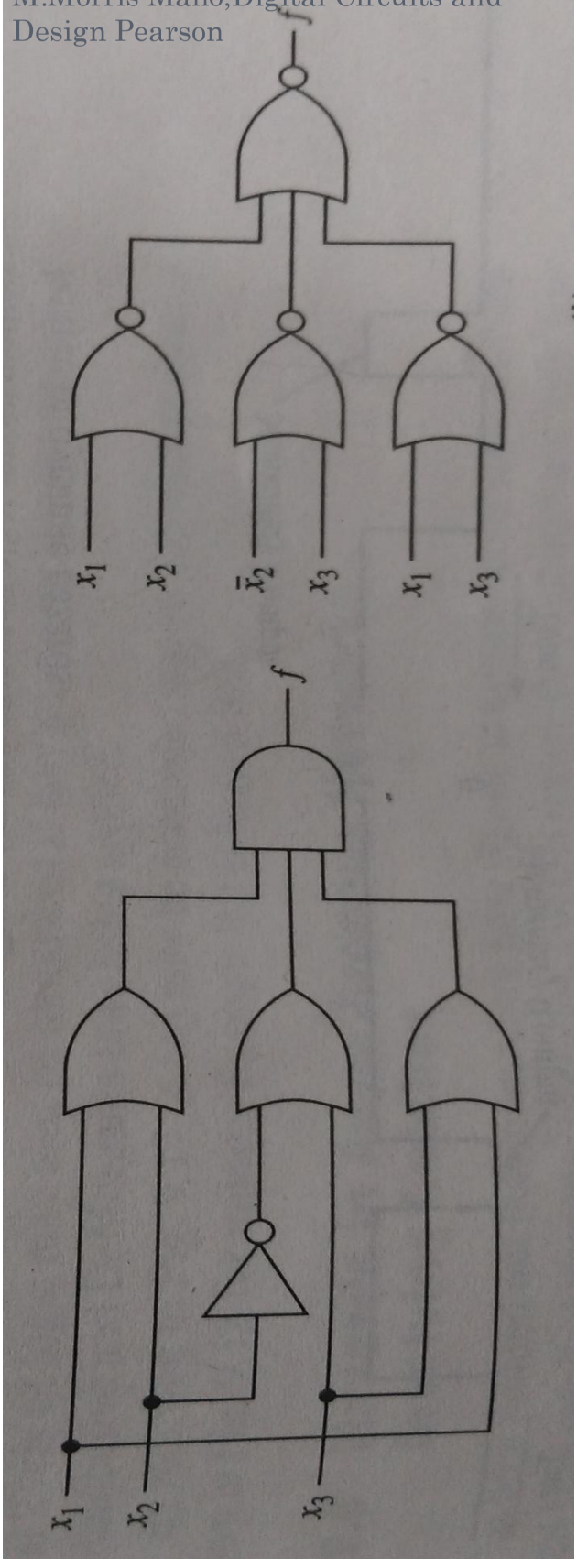
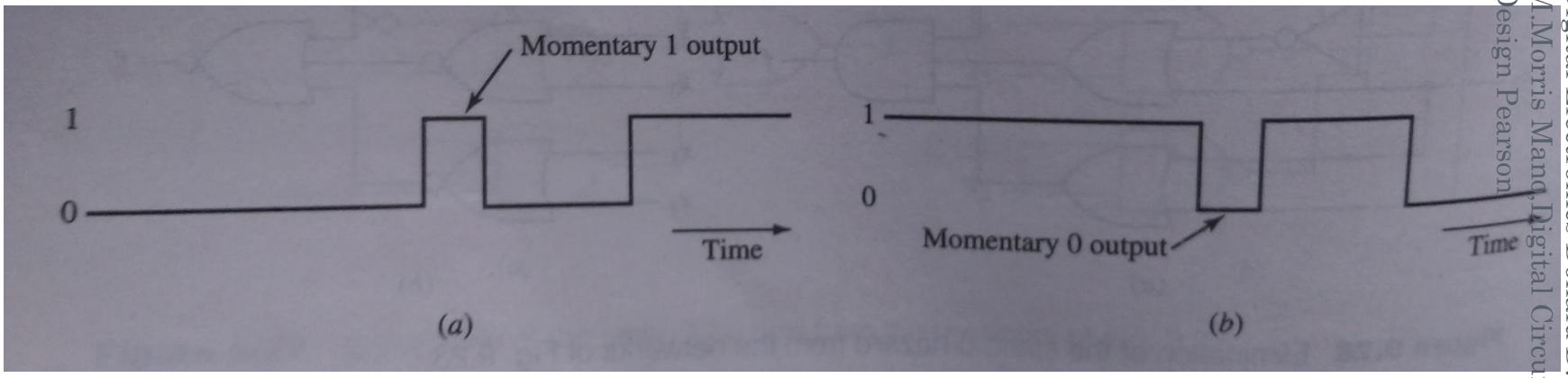


DYNAMIC HAZARD



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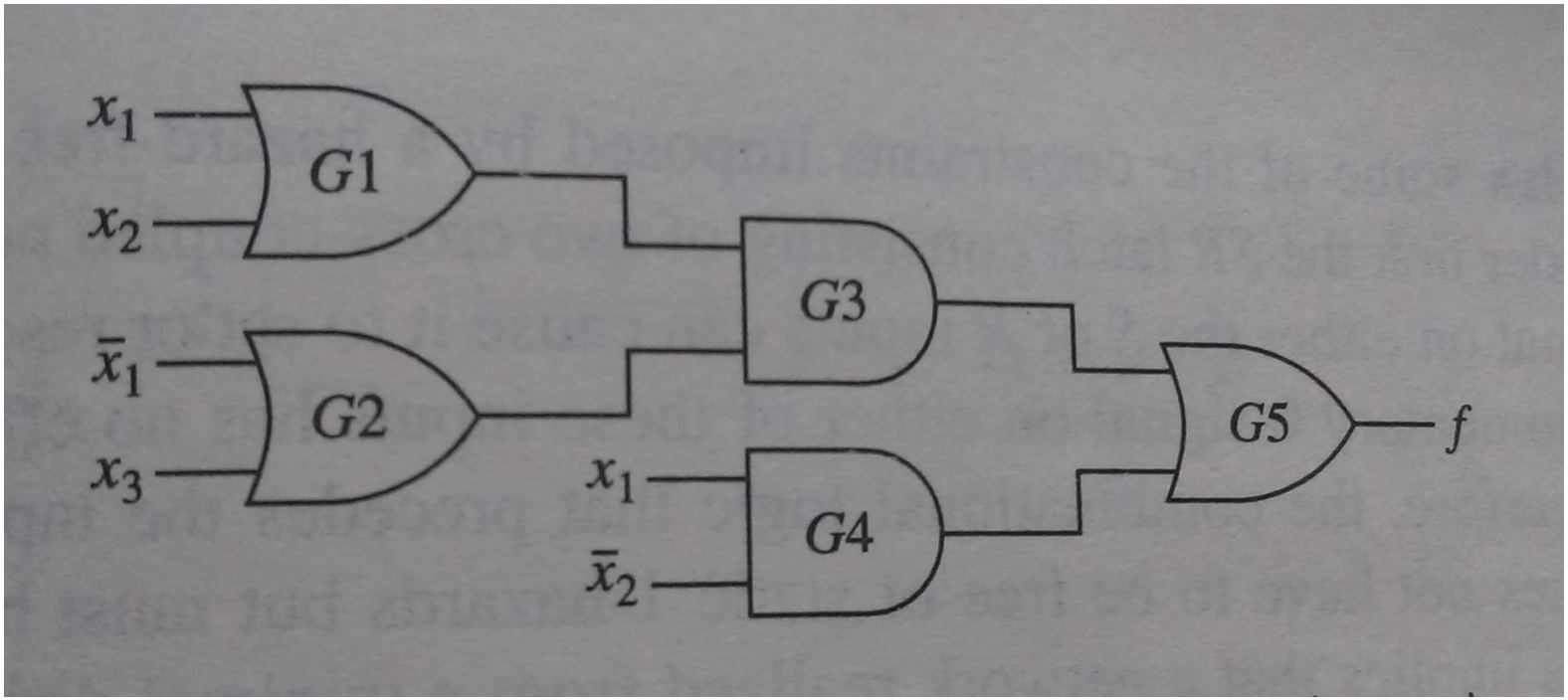
DYNAMIC HAZARD IN A GATE NETWORK



EXAMPLE OF ESSENTIAL HAZARD