4.3 HAZARDS

In designing asynchronous sequential circuits, care must be taken to conform to certain restrictions and precautions to ensure that the circuits operate properly. The circuit must be operated in fundamental mode with only one input changing at any time and must be free of critical races. In addition, there is one more phenomenon called a hazard that may cause the circuit to malfunction.

Hazards are unwanted switching transients that may appear at the output of a circuit because different paths exhibit different propagation delays. Hazards occur in combinational circuits, where they may cause a temporary false output value. When they occur in asynchronous sequential circuits hazards may result in a transition to a wrong stable state.

Hazards In Combinational Circuits

A hazard is a condition in which a change in a single variable produces a momentary change in output when no change in output should occur.

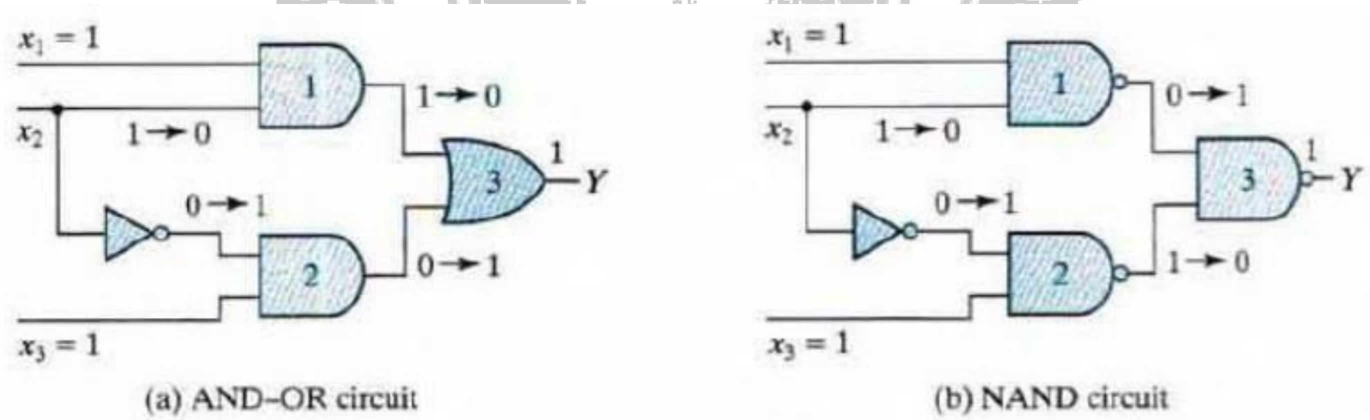

Fig 4.3.1 Circuits with Hazards

Assume that all three inputs are initially equal to 1. This causes the output of gate 1 10 be 1, that of gate 2 to be 0 and that of the circuit to be 1. Now consider a change in x 2 from 1 to 0. Then the output of gate 1 changes to 0 and that of gate 2 changes to 1, leaving the output at 1. However, the output may momentarily go to 0 if the propagation delay through the inverter is taken into consideration. The delay in the inverter may cause the output of gate 1 to change to 0 before the output of gale 2 changes to 1.

The two circuits shown in Fig implement the Boolean function in sum-of-products form:

$$Y = x_1x_2 + \overline{x_2}x_3 \qquad\qquad Y = (x_1 + \overline{x_2})(x_2 + x_3)$$

This type of implementation may cause the output to go to 0 when it should remain a 1. If however, the circuit is implemented instead in product-of-sums form namely, then the output may momentarily go to 1 when it should remain 0. The first case is referred to as **static 1-hazard** and the second case as **static 0-hazard**.

A third type of hazard, known as **dynamic hazard**, causes the output to change three or more times when it should change from 1 to 0 or from 0 to 1.

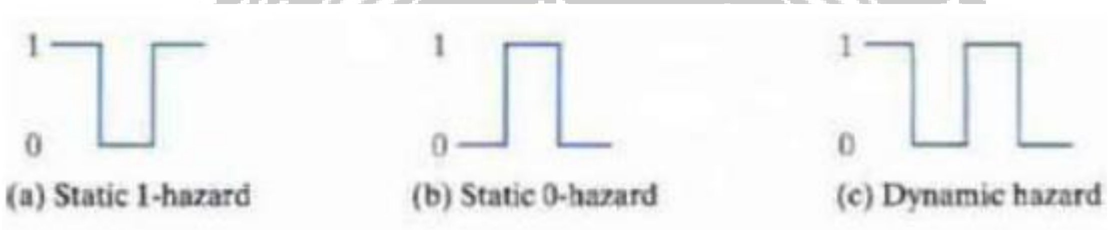

Fig 4.3.2 Types of hazards

The change in x2 from 1 to 0 moves the circuit from minterm 111 to minterm 101. The hazard exists because the change in input results in a different product term covering the two minterm.

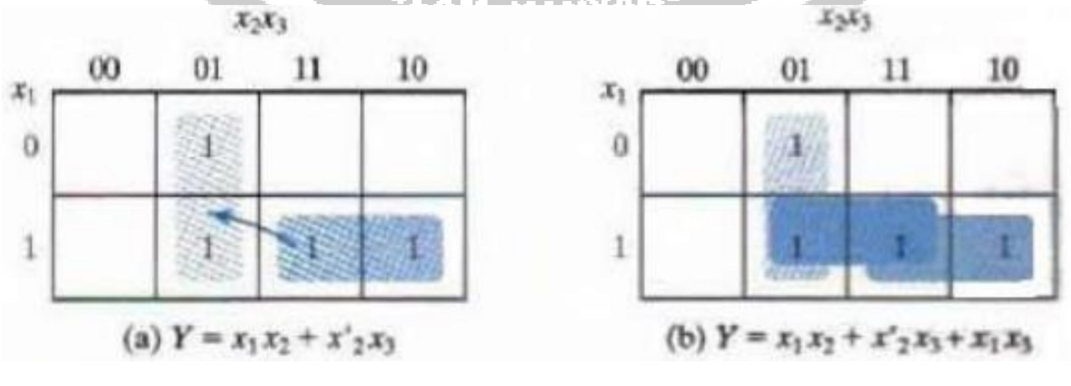

Fig 4.3.3 Illustrates hazard and its removal

Minterm 111 is covered by the product term implemented in gate 1 and minterm 101 is covered by the product term implemented in gate 2. The remedy for eliminating a hazard is to enclose the two minterms with another product term that overlaps both groupings. The hazard-free circuit obtained by such a configuration is shown in figure below.

The extra gate in the circuit generates the product term x_1x_3. In general, hazard s in combinational circuits can be removed by cove ring any two minterms that may produce a hazard with a product term common to both. The removal of hazards requires the addition of redundant gates to the circuit.

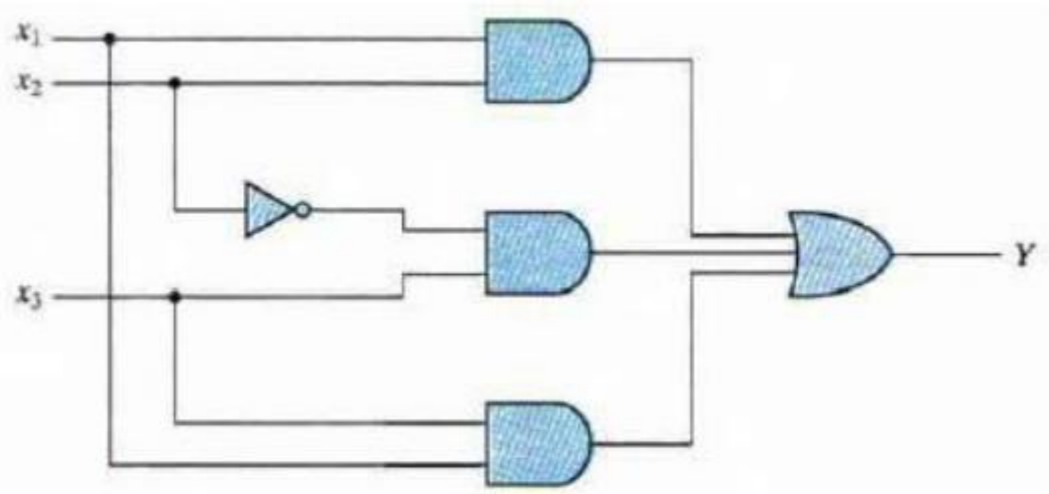

Fig 4.3.4 Hazard free circuit

Essential Hazards

Another type of hazard that may occur in asynchronous sequential circuits is called an **essential hazard**. This type of hazard is caused by unequal delays along two or more paths that originate from the same input. An excessive delay through an inverter circuit in comparison to the delay associated with the feedback path may cause such a hazard.

Essential hazards cannot be corrected by adding redundant gates as in static hazards. The problem that they impose can be corrected by adjusting the amount of delay in the affected path. To avoid essential hazards, each feedback loop must be handled with individual care to ensure that the delay in the feedback path is long enough compare d with delays of other signals that originate from the input terminals.