Static Hazards in Digital Logic

A **hazard**, if exists, in a digital circuit causes a temporary fluctuation in the output of the circuit. In other words, a hazard in a digital circuit is a temporary disturbance in the ideal operation of the circuit which if given some time, gets resolved itself. These disturbances or fluctuations occur when different paths from the input to output have different delays and due to this fact, changes in input variables do not change the output instantly but do appear at the output after a small delay caused by the circuit-building elements, i.e., logic gates. There are three different kinds of hazards found in digital circuits

IN OTHER WORDS,

Consider a logic circuit that is expected to give a logic -1 output momentarily becomes logic-0, because of finite propagation delays of various gates this unwanted switching transient is called HAZARDS.

1. Static hazard
2. Dynamic hazard

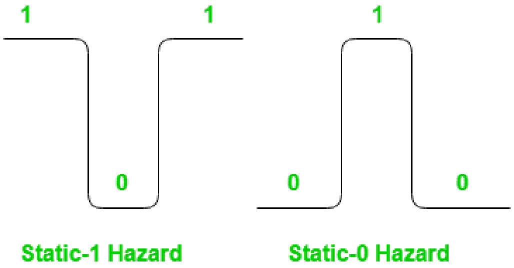
We will discuss only static hazards here to understand them completely. Formally, a **static hazard** takes place when the change in input causes the output to change momentarily before stabilizing to its correct value. Based on what is the correct value, there are two types of static hazards, as shown below in the image:

- **Static-1 Hazard:** Static-1 Hazards occur in SOP (SUM-OF-PRODUCT) circuit.

1. If the output is currently at logic state 1 and after the input changes its state, the output momentarily changes to 0 before settling on 1, then it is a Static-1 hazard.
2. In response to an input change & for some combination of PROPAGATION DELAY a logic circuit may go to zero (0) when it should remain constant at one (1) this transient is called a STATIC-1 Hazards as shown in the figure below.

- **Static-0 Hazard:** Static-0 Hazards occur in the POS (PRODUCT-OF-SUM) circuit.

1. If the output is currently at logic state 0 and after the input changes its state, the output momentarily changes to 1 before settling on 0, then it is a Static-0 hazard.
2. In response to an input change & for some combination of PROPAGATION DELAY a logic circuit may go to one (1) when it should remain constant at zero (0) this transient is called a STATIC-1 Hazards as shown in the figure below.



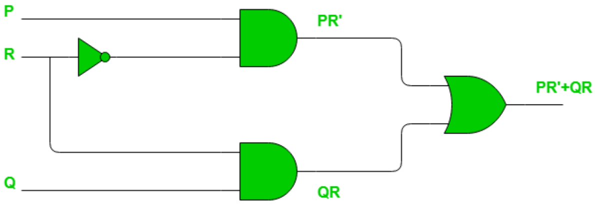
Detection of Static hazards using K-map:

Let us consider static-1 hazard first.

To detect a static-1 hazard for a digital circuit following steps are used:

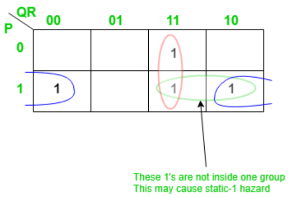
- **Step-1:** Write down the output of the digital circuit, say **Y**.
- **Step-2:** Draw the K-map for this function **Y** and note all adjacents 1's.
- **Step-3:** If there exists any pair of cells with 1's which do not occur to be in the same group (i.e. prime implicant), it indicates the presence of a static-1 hazard. Each such pair is a static-1 hazard.

Let's have an example: **Example** – Consider the circuit shown below.



We have output, say F,

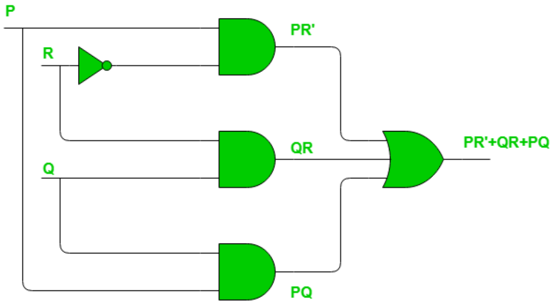
as: Lets draw the K-map for this



Boolean function as follows:

The pair of 1's encircled as green is not part of the grouping/pairing provided by the output of this Boolean function. This will cause a static-1 hazard in this circuit. **Removal of static-1 hazard:** Once detected, a static-1 hazard can be easily removed by introducing some more terms (logic gates) to the function (circuit). The most common idea is to add the missing group in the existing Boolean function, as adding this term would not affect the function by any means but it will remove the hazard. Since in the above example the pair of 1's encircled with blue color causes the static-1 hazard, we just add this as a prime implicant to the existing function as follows:

Note that there is no difference in the number of minterms of this function. The reason is that the static-1 hazards are based on how we group 1's (or 0's for static-0 hazard) for a given set of 1's in the K-map. Thus it does not make any difference in the number of 1's in the K-map. The circuit would look as shown below with the change made for the removal of the static-1 hazard.

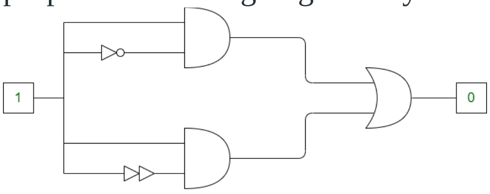


Similarly, for **Static-0 Hazards,** we need to consider 0's instead of 1's, and if any adjacent 0's in K-map are not grouped into the same group that may cause a static-0 hazard. The method to detect and resolve the static-0 hazard is completely the same as the one we followed for the static-1 hazard except that instead of SOP, POS will be used as we are dealing with 0's in this case.

What is a Dynamic Hazard?

When the output changes several times then it should change from 1 to 0 or 0 to 1 only once, it is called dynamic hazard. Dynamic hazard occur when the output changes for two adjacent input combinations while changing, the output should change only once. But it may change

three or more times in short intervals because of different delays in several paths. Dynamic hazards occur only in multilevel circuit.
How Dynamic Hazards Occur
Static hazards are simpler than dynamic and most time they are produced in circuits with multiple transitions so it is difficult to avoid them. These hazards can only be avoided by proper circuit designing and layout adjustments where necessary.



Block Diagram for Dynamic Hazard

Difference between Static and Dynamic Hazard

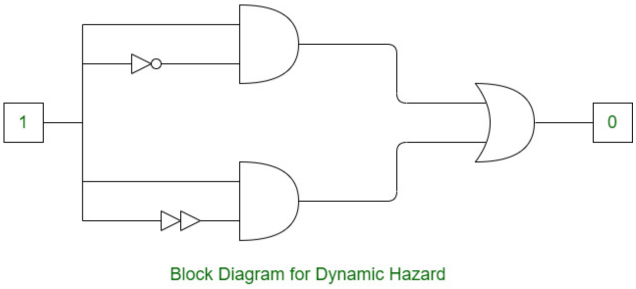
STATIC HAZARD	DYNAMIC HAZARD
Static hazard occur when an input changes and it causes the output to change at the same moment before output becomes stable.	Dynamic hazard occur when output changes for two adjacent inputs while the output should change only once.
Static hazard occur in combinational circuits.	Dynamic hazard occur only in multilevel circuits.
Static hazard is easy to resolve.	Dynamic hazard is complex to resolve.
It can be eliminated by using redundant gates.	Removal of static-1 hazard ensures no occurrence of dynamic hazard.
Static hazard is further classified as Static-1 and Static-0.	Dynamic hazard is not further classified.
It causes temporary false output value.	It results in a transition to a wrong stable state.
Result in a momentary glitch in the output signal.	Result in a glitch that persists for some time.
Can be eliminated by adding delay elements such as buffers.	Cannot be eliminated by adding delay elements.

STATIC HAZARD	DYNAMIC HAZARD
Occur due to logical errors in the design or implementation of the circuit.	Occur due to the changing input conditions or signal delays.
Can be minimized by using simpler logic gates and reducing the number of stages.	Can be minimized by using properly designed synchronous circuits with appropriate clocking and edge-triggered flip-flops.
Example of static Hazard is multiplexer.	Example of dynamic Hazard is solid arrow.

When the output changes more than once as a consequence of a single change in its input, which is referred to as "dynamic risk." The presence of dynamic risks is common in bigger logic circuits when there are several pathways to the final output state (from the input). While the output changes for two nearby inputs instead it should only change once, this is referred to as **dynamic hazard**. The presence of dynamic risks is common in bigger logic circuits when there are several pathways to the final output state (from the input). Once it is established that each route has a distinct delay, it becomes immediately apparent that there is the possibility for output values to change and diverge from the needed/anticipated output.

Detection of Dynamic Hazard:

When the output changes numerous times, the value should only move from 1 to 0 or 0 to 1 once. This is referred to as a dynamic hazard in mathematics. *When the output changes for two neighboring input combinations at the same time, this is referred to as be a **dynamic hazard***. However, the output should only change once. Dynamic hazards are a sequence of changes in the state of a signal that occur numerous times in succession while the signal is supposed to change status only once. It is possible for the output to change more than once as a consequence of one change in its input, which is referred to as "dynamic risk."
Example: An intended logic circuit changes the output state from 1 to 0 but instead changes the output state from 1 to 0 then 1, before eventually resting at the proper value of 0. This is an example of a dynamic danger. The resolution of dynamic hazards is more difficult in general, however, it is important to remember that if all static hazards have been removed from a circuit, then dynamic hazards cannot emerge.



Dynamic Hazard

Elimination of the Dynamic Hazard:
In general, the term "dynamic" refers to anything that is energetic, capable of action and/or change, or powerful. Only multilayer circuits are susceptible to dynamic dangers. It is difficult to resolve a dynamic danger. It may be avoided entirely by using duplicate gates.

In the workplace, elimination is the process of eliminating a Dynamic hazard from the work environment. It is the most effective method of risk management since the danger is no longer present in the environment. In most cases, it is the most effective method of hazard management and should be employed whenever practicable. The last word on dynamic risks: it should be emphasized that if all static hazards have been removed from a circuit, then it is impossible for dynamic hazards to exist from the circuit.