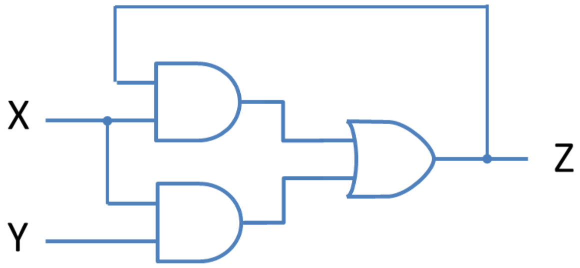
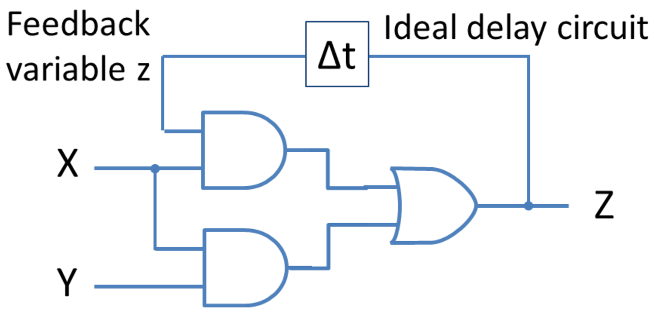
Fundamental-Mode Model

- An asynchronous system uses feedback to produce memory elements as does the synchronous state machine.
- The asynchronous machine generally uses gates rather than flip-flops.
- Figure demonstrates a simple asynchronous circuit.



- X and Y are the system inputs while Z is the system output.
- The signal Z is fed back, however, to a gate input and in this way helps determine its own value.
- When an X or Y change dictates a change in Z, this change occurs only after the cumulative propagation delay time through the gates.
- It is characteristic of asynchronous circuits that the feedback variables along with system inputs determine the values of these same feedback variables.
- An idealized model has been proposed to reflect this behavior. The above circuit is taken for the discussion.



- The gates are considered to have no delay in this model, while the delay element has an output that follows its input after a delay of Δt.
- The variable at the input of the delay element is called the excitation variable, while the feedback variable appears at the output of the delay element.
- In order to characterize the behavior of a circuit, we plot a map of excitation variable as a function of gate inputs.

z \ XY	00	01	11	10
0	0 a	0 c	1 e	0 g
1	0 b	0 d	1 f	1 h

Z

- It is important to realize that the value Z takes on will also be the value assumed by z after a delay of Δt.
- Thus, the information depicted by the map represents a dynamic situation.
- This can be demonstrated by supposing the system inputs are X = Y = 1 and z = 1, which leads to Z = 1. This is called a stable state since z = Z.
- If X is then changed to 0, the output Z changes to 0 as indicated by the map location corresponding to X = 0, Y = 1, and z = 1.
- This condition will persist for only Δt since z will assume a value of 0 at this time, moving the system to the X = 0, Y = 1, and z = 0 location.
- The location 011 is a transient state, while 010 is a stable state.
- The stable states are normally identified on the map by drawing a circle around the excitation variable such as in figure.

Problems of Asynchronous Circuits

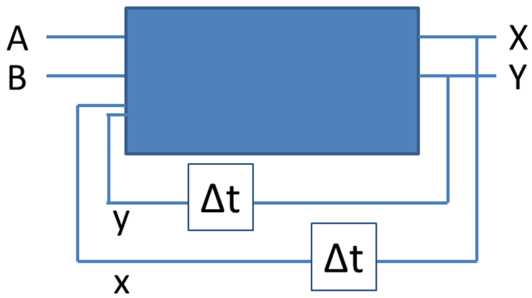
Oscillation Problem

x \ AB	00	01	11	10
0	0 a	1 c	0 e	1 g
1	1 b	0 d	0 f	1 h

- If the system is in state *a*, a change of input from B = 0 to B = 1 sends the system to state c.
- State c is a transient state, and thus the excitation variable X changes to 1.
- A short time later x changes to 1, moving the system to state d. This state is also a transient state changing X back to 0, followed by a change in x to 0.
- The system now oscillates between states *c* and *d*.
- Of course, this type of situation can be used to advantage in a clock circuit by adding a delaying network to control the delay time Δt to create the desired oscillation frequency.
- In most systems, the oscillation is unacceptable, and the situation depicted by states *c* and *d* of the map must be avoided.

Critical Race

- This situation can occur only when two or more feedback variables are present in the system.



- This system has two external inputs, A and B, and two excitation variables, X and Y, that are fed back to the input of the circuit.

xy \ AB	00	01	11	10
00	a 11	e 00	i 11	m 11
01	b 01	f 11	j 11	n 00
11	c 10	g 11	k 11	o 10
10	d 10	h 00	l 11	p 10

- One critical race occurs if the system starts in state *e* and input B changes from 1 to 0.
- The excitation variables begin to switch from XY = 00 toward XY = 11.
- Due to unequal propagation delays, one of the excitation variables will reach a value of 1 while the other has not changed from a value of 0.
- If the condition XY = 10 is reached, the system moves to stable state d.
- If the condition XY = 01 is reached rather than 10, the system moves to stable state *b*.
- The final stable state reached from this input condition depends on the relative switching speeds of variables X and Y. This situation is referred to as a critical race.