# Digital System Design

## Lecture 15

# Sequential Circuits Design

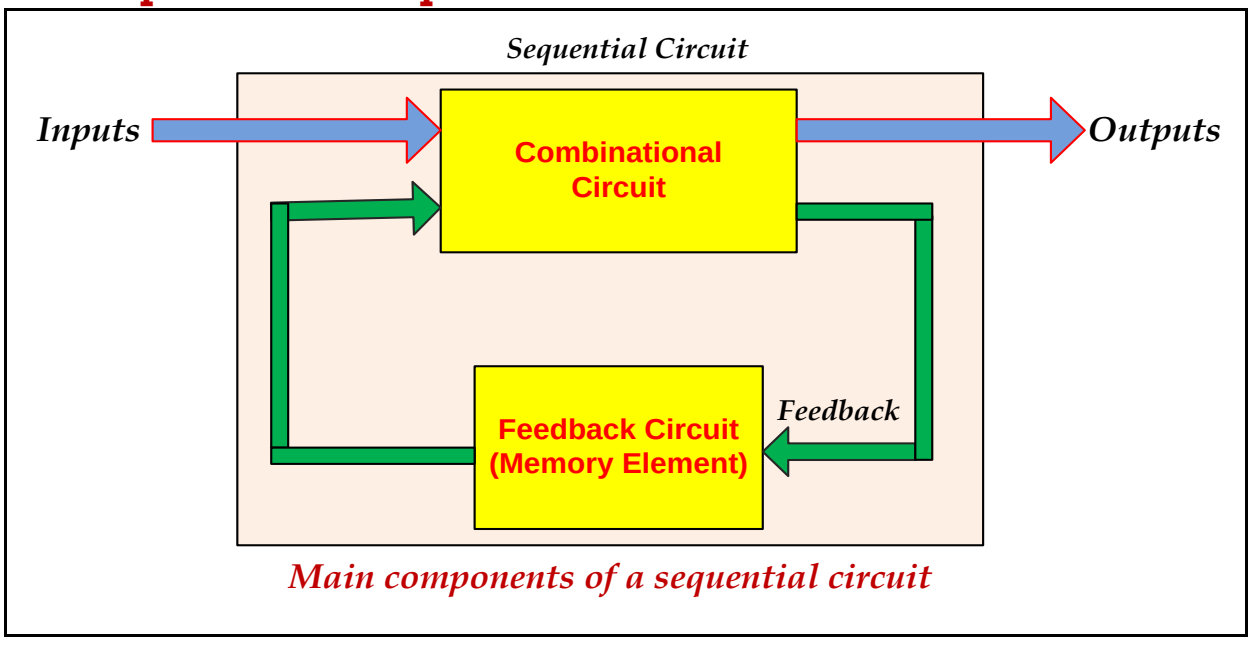
**Objectives:**

1. ***Introduction to Sequential Circuits: Concepts and Definitions.***
2. ***Asynchronous sequential circuit.***
3. ***Synchronous sequential circuits.***
4. ***Latches and Flip-Flops (Introduction).***

### *1. Introduction to Sequential Circuits: Concepts and Definitions.*

- Digital electronics is classified into combinational logic and sequential logic. Combinational logic output depends on the current inputs, whereas sequential logic output depends on current as well as past inputs, so we need "memory".
- Sequential circuit consists of:
  - ✓ ***Combinational circuit.***
  - ✓ ***Feedback circuit*** (Simple feedback or Memory elements such as flip flops and latches).

**Main components of a sequential circuit:**

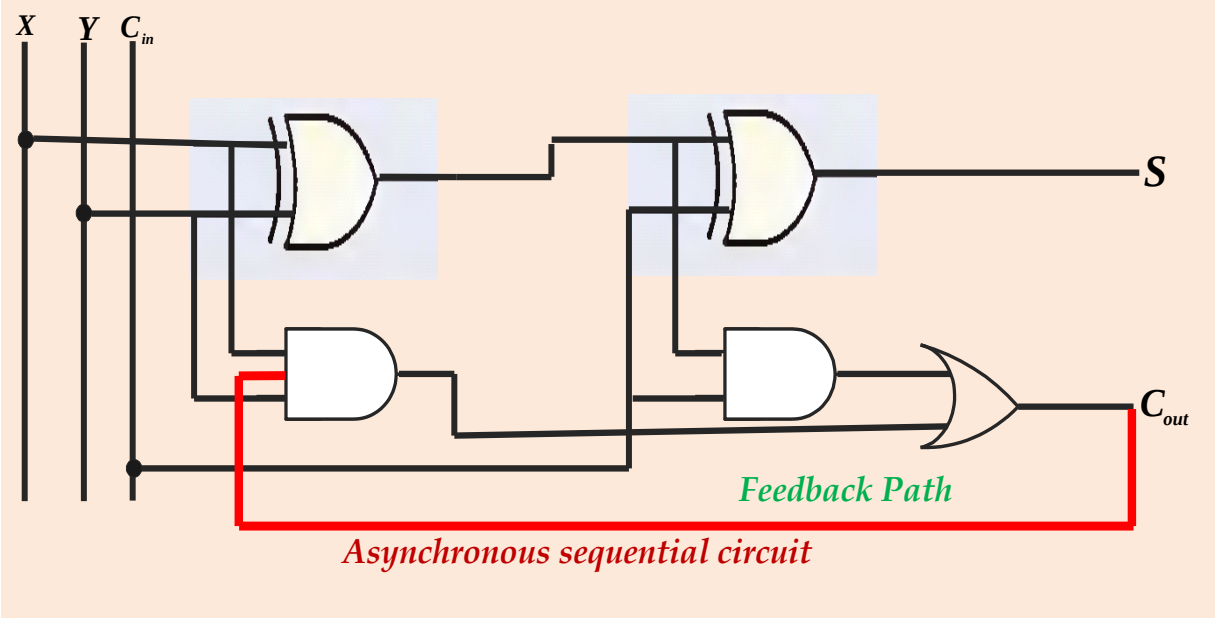



*Main components of a sequential circuit*

- The memory elements are devices capable of storing binary information. The binary info stored in the memory elements at any given time defines the state of the sequential circuit (previous state, present state, next state).
- There are two types of sequential circuits:
  - ***Asynchronous sequential circuit.***
  - ***Synchronous sequential circuits.***

## *2. Asynchronous sequential circuit*

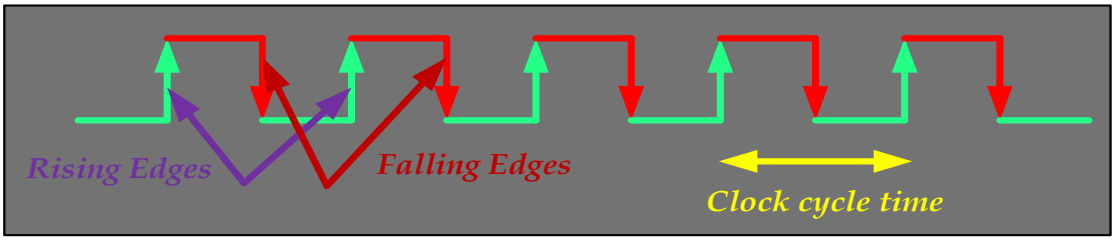
- Asynchronous systems are basically combinational circuits with **feedback paths**. Because of the feedback among logic gates, the system may, at times, become **unstable**.



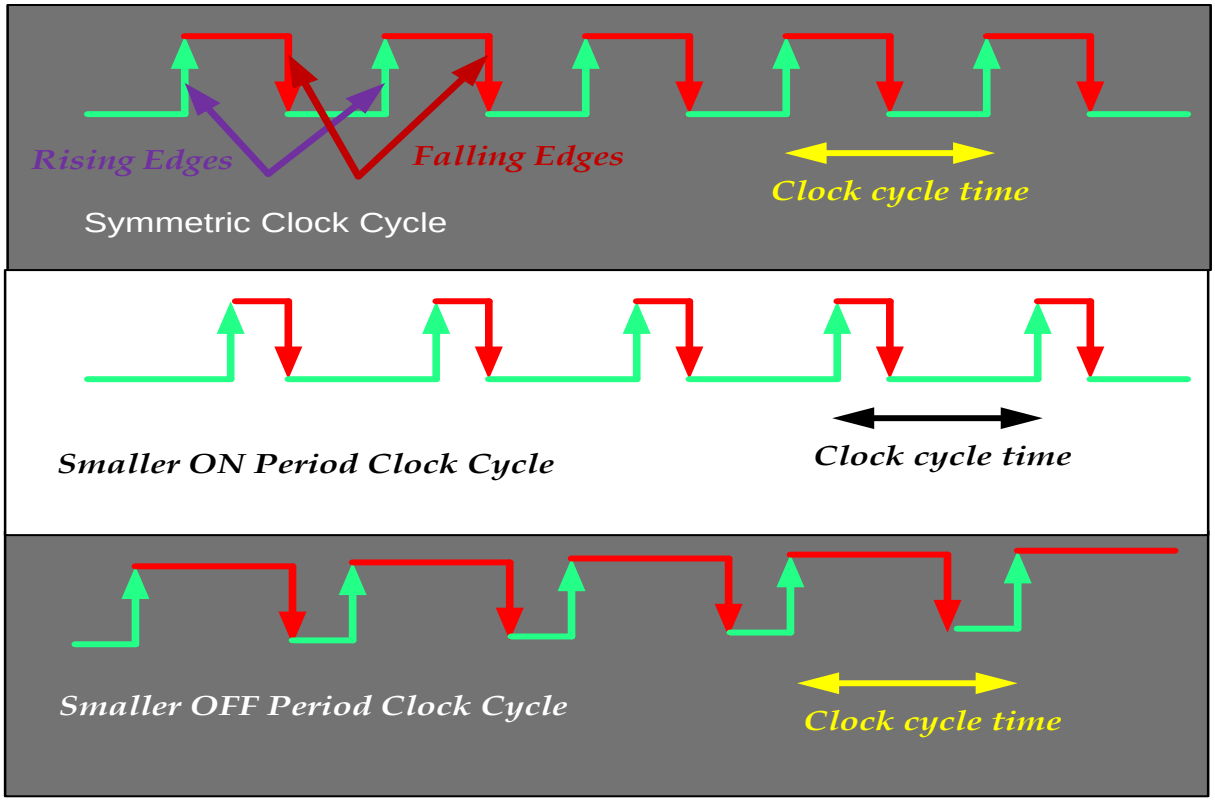

## *3. Synchronous sequential circuits*

- Synchronous sequential circuits use storage elements called flip-flops and latches that are employed to change their binary value only at discrete instants of time.
- Examples of flip-flops and latches are:
  - ***RS Latch and RS flip-flops.***
  - ***RS Latch and flip-flops with Clock.***
  - ***D Latch.***
  - ***JK Latch.***
  - ***T Latch.***
  - ***JK Master Slave Flip-Flop.***

- Synchronous sequential circuits have a clock signal as one of their inputs, the circuit change their state when the clock value is either 0 or 1 (***Level-sensitive device***) or happen at the rising (positive) or falling (negative) edges (***Edge-sensitive device***).
- ***Synchronization*** is achieved by a timing device called a clock pulse generator.
- Synchronous sequential circuits that use clock pulses in the inputs are called clocked-sequential circuits. They are stable.

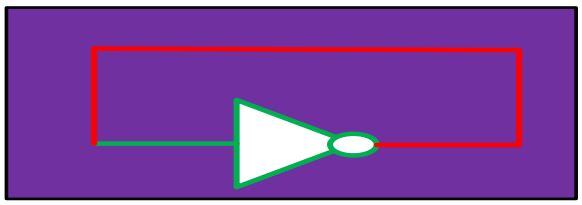



- A clock signal is a periodic square wave that indefinitely switches from 0 to 1 and from 1 to 0 at fixed intervals.
- Clock cycle time or clock period: the time interval between two consecutive rising or falling edges of the clock.
- Clock Frequency = 1 / clock cycle time (measured in cycles per second or Hz).
- Example: Clock cycle time = 10ns then clock frequency = 100 MHz.

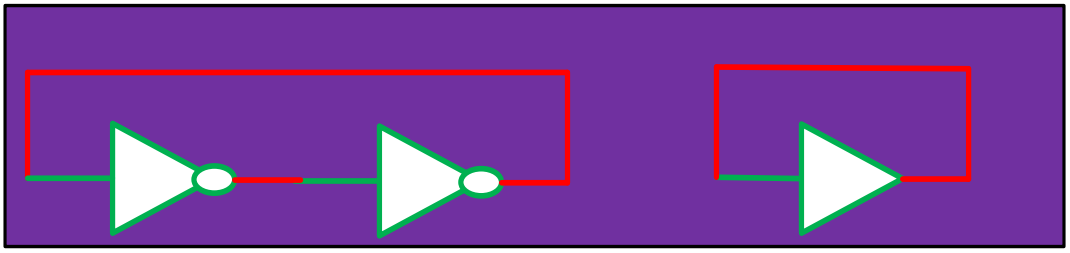


## *4. Latches and Flip-Flops (Introduction).*

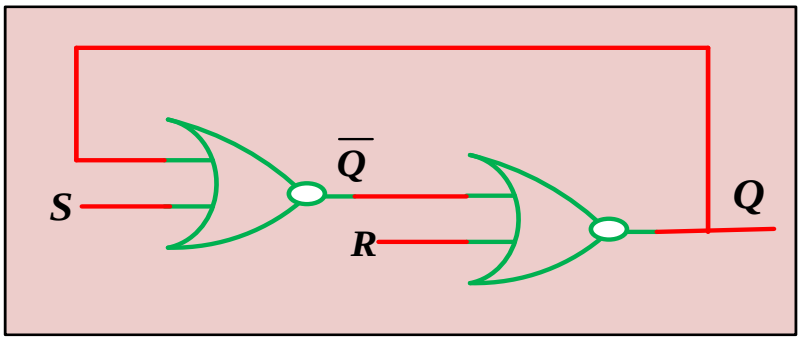
- Two common types of storage elements:
  - ***Latch.***
  - ***Flip-flop.***
- Latches and Flip-Flops can remember a bit.
- ***Latch***:
  - Level-sensitive device.
  - Cheap to implement.
  - Somewhat unwieldy to design with.
- ***Flip-flop:***
  - Edge-sensitive device.
  - More costly to implement.
  - Much easier to design with.
- ***Memory cell implementation:***
  - Simple ***NOT gate*** whose output is connected to its input. The effect is that output oscillates between ***HIGH*** and ***LOW*** (i.e. 1 and 0).



  - The basic idea of having the feedback is to store the value or hold the value, but in the above circuit, output keeps ***toggling*** (not stable).
  - To solve this problem, we can use ***two inverters*** connected in cascading scheme as the following :



  - This circuit equivalent ***the buffer*** with its output connected to its input.
  - The problem of the above circuit is that the buffer output cannot be known and we cannot ***set the value***.
  - To set the value, we can ***replace*** the inverters with ***NOR gate***.




- **S** is called ***set*** and **R** is called ***Reset***.