Synchronous & Asynchronous Circuits

Digital Logic Design (CC131)

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Synchronous & Asynchronous Circuits

- Synchronous and Asynchronous Circuits are two fundamental categories of sequential logic circuits in.

- Sequential circuits have memory elements (like flip-flops or latches) whose outputs depend on both current inputs and previous states, unlike combinational circuits.

Synchronous Circuits

- A **synchronous circuit** is a digital circuit in which all state changes occur at specific instants controlled by a **common clock signal**.
- The clock acts like a timing reference shared by all storage elements.

Basic Idea

- Inputs may change anytime.
- But outputs/state update only on the active edge of the clock:
  - Rising edge (0 → 1)
  - Falling edge (1 → 0)
- Most modern digital systems are synchronous because they are easier to design and test.

Main Parts of a Synchronous Circuit

A synchronous system mainly contains:

A. Clock Signal

- The **clock** is a periodic square wave used for synchronization.

Functions

- Coordinates operations
- Determines when data is stored
- Keeps all components operating together

Main Parts of a Synchronous Circuit

Clock Parameters

i. Clock Period (T)

Time required for one complete cycle.

$$T=1/f$$

where:

T = period

f = frequency

ii. Clock Frequency

Number of cycles per second.

Measured in:

- Hz
- MHz
- GHz

iii. Duty Cycle

- Percentage of time clock remains HIGH.
- For a perfect square wave:

Duty cycle = 50%

Main Parts of a Synchronous Circuit

B. Memory Elements (Storage Elements)

These store binary information.

Types

i. Latches

- Level-triggered
- Active while enable signal is active

ii. Flip-Flops

- Edge-triggered
- Change only at clock edge
- Common flip-flops:
- SR Flip-Flop
- JK Flip-Flop
- D Flip-Flop
- T Flip-Flop

Main Parts of a Synchronous Circuit

C. Combinational Logic

Logic gates that compute outputs from present inputs and stored states.

- Examples:
  - AND
  - OR
  - NOT
  - NAND
  - XOR
- These blocks determine the **next state**.

D. Interconnection/Wiring

- Connects:
- Inputs
- Flip-flops
- Logic gates
- Outputs

Characteristics of Synchronous Circuits

Advantages

1. Predictable Timing

Operations happen only at clock edges.

2. Easier Design

Timing analysis becomes systematic.

3. Reliable Operation

Less sensitive to propagation delays.

4. Simpler Testing and Debugging

Characteristics of Synchronous Circuits

Disadvantages

1. **Clock Distribution Problem**

   Clock must reach all parts simultaneously.

2. **Higher Power Consumption**

   Clock continuously toggles.

3. **Speed Limited by Worst-Case Delay**

   Clock period must be long enough for slowest path.

Examples of Synchronous Circuits

- Counters
- Registers
- CPUs
- Microprocessors
- Memory systems
- Examples include processors from Intel and AMD.

Asynchronous Circuits

- An **asynchronous circuit** is a digital circuit that operates **without a global clock**.
- State changes occur immediately whenever inputs change.

Basic Idea

- No common timing signal
- Operations depend on propagation delays
- Components communicate through signal changes

Main Parts of an Asynchronous Circuit

A. Combinational Logic

Performs logical operations based on current inputs and states.

B. Memory Elements

Usually implemented using:

Latches

Feedback paths

Unlike synchronous circuits, no clock controls updates.

C. Feedback Paths

Outputs are often fed back as inputs to maintain states.

This feedback creates sequential behavior.

Operation of Asynchronous Circuits

- When an input changes:
  - Logic responds immediately
  - Signals propagate through gates
  - State updates automatically
  - No waiting for clock edge

Characteristics of Asynchronous Circuits

Advantages

1. Faster Potential Speed

No need to wait for clock.

2. Lower Power Consumption

Circuit operates only when needed.

3. No Clock Skew Problem

No global clock distribution.

Characteristics of Asynchronous Circuits

Disadvantages

1. Difficult Design

Timing behavior is complex.

2. Race Conditions

Outputs may depend on signal arrival order.

3. Hazard Problems

Temporary unwanted output changes can occur.

4. Harder Testing and Verification

Examples of Asynchronous Circuits

- Asynchronous FIFOs
- Some pipeline stages in high-performance processors
- Muller pipelines
- Asynchronous microprocessors (rare)
- Arbiters
- Clock domain crossing synchronizers (mixed designs).

Thank You