# Combinational Circuits (Part 1)

**1. What is a combinational circuit? Give examples.**

A combinational circuit is a logic circuit whose output depends only on the current inputs, not on any past input (no memory). Examples: adders, multiplexers, encoders, decoders, comparators.

**2. How does a multiplexer work? Explain with truth table and logic diagram.**

A multiplexer selects one input from multiple data lines and forwards it to the output based on select lines.  
Example: A 2:1 MUX

* Inputs: I0, I1, Select (S)
* Output: Y = S̅I0 + SI1  
  Truth Table:  
  | S | Y |  
  |---|---|  
  | 0 | I0 |  
  | 1 | I1 |

**3. Design a 4-to-1 multiplexer using basic gates.**

* Inputs: I0–I3, Select lines: S1, S0
* Output: Y = I0·S1̅·S0̅ + I1·S1̅·S0 + I2·S1·S0̅ + I3·S1·S0  
  Use AND gates for product terms and an OR gate to combine them.

**4. What is the difference between decoder and demultiplexer?**

* **Decoder**: Converts n-bit input into 2ⁿ outputs. One output line is high for each input combination.
* **Demultiplexer**: Routes a single input to one of many outputs based on select lines.

**5. Explain the working of a full adder circuit.**

A full adder adds three inputs: A, B, and Cin.

* Sum = A ⊕ B ⊕ Cin
* Carry = AB + BCin + ACin

**6. Design a 2-bit comparator circuit.**

Compares two 2-bit numbers A1A0 and B1B0.

* A = B: (A1 ⊕ B1)' · (A0 ⊕ B0)'
* A > B: A1·B1' + (A1 ⊕ B1)'·A0·B0'
* A < B: B1·A1' + (A1 ⊕ B1)'·B0·A0'

**7. How does a priority encoder function?**

It outputs the binary code of the highest-priority active input. If multiple inputs are high, only the highest priority one is encoded.

**8. What are the applications of combinational logic circuits?**

* Arithmetic logic (adders, subtractors)
* Data routing (MUX, DEMUX)
* Code conversion (encoders, decoders)
* Display systems (BCD to 7-segment)

**9. Describe the working of a BCD to 7-segment decoder.**

It takes a 4-bit BCD input and activates segments a–g of a 7-segment display to represent decimal digits 0–9 using logic expressions for each segment.

**10. How can you implement Boolean functions using multiplexers?**

Use the select lines to represent the function variables and connect data inputs according to the truth table values. Each output line implements a Boolean function.

**11. What are the limitations of combinational circuits?**

* No memory of past inputs
* Sensitive to noise and glitches
* Not suitable for sequential operations

**12. Explain the concept of logic minimization using Karnaugh Maps.**

K-Maps help group adjacent 1s (minterms) to simplify Boolean expressions. It reduces logic gate count and improves circuit efficiency.

**13. Design a binary to Gray code converter.**

Gray Code = Binary XOR (Binary shifted right by 1)

* G3 = B3
* G2 = B3 ⊕ B2
* G1 = B2 ⊕ B1
* G0 = B1 ⊕ B0

**14. What is the use of encoders in digital systems?**

Encoders convert active inputs into a binary code. Applications include keyboards, digital systems for compression and address generation.

**15. Explain the design procedure of combinational circuits.**

1. Define the problem
2. List inputs and outputs
3. Create a truth table
4. Derive Boolean expressions
5. Simplify using K-map
6. Draw the logic diagram

**16. What is the role of adders in digital systems?**

Adders perform binary arithmetic in ALUs, processors, and digital calculators. They are essential in performing arithmetic operations.

**17. How does a look-ahead carry adder improve performance?**

It calculates carry outputs in advance using logic, reducing delay from carry propagation seen in ripple carry adders.

**18. Describe how you can design a parity generator and checker.**

* **Parity Generator**: Produces an extra parity bit to make the number of 1s even or odd.
* **Checker**: Recomputes parity and compares with the received bit to detect errors.

**19. Explain the concept of bit-slice architecture in ALUs.**

Modular ALU design using identical slices for each bit (e.g., 1-bit ALU). Multiple slices are combined to build multi-bit processors.

**20. What are hazards in combinational logic and how are they avoided?**

Hazards are unwanted changes (glitches) in output due to different path delays.

* Types: static, dynamic
* Avoided using redundant logic or synchronized delays.

**21. How does a ROM-based combinational circuit work?**

ROM stores truth table of a function. Inputs act as address lines, outputs are pre-programmed values. Useful for implementing fixed logic.

**22. What is a PLA and how does it differ from PAL?**

* **PLA (Programmable Logic Array)**: Programmable AND and OR arrays.
* **PAL (Programmable Array Logic)**: Programmable AND array, fixed OR array. PLA is more flexible.

**23. Describe a real-world application where a multiplexer is used.**

Used in processors to select between different data sources (e.g., selecting between ALU output and memory in a register file).

**24. What is a tri-state buffer and where is it used?**

A buffer with 3 states: 0, 1, high impedance (Z). Used in bus systems to allow multiple devices to share the same data line without interference.

**25. Explain Shannon's expansion theorem and its application.**

Shannon's theorem:  
**F = x·F(x=1) + x̅·F(x=0)**  
It breaks complex functions into smaller ones using a variable. Used in MUX implementation and recursive logic design.