1. Half Adder

A Half Adder is a combinational circuit that performs binary addition of two bits.
It produces two outputs: a sum (S) and a carry (C).

Logic Equations:

- Sum (S) = A XOR B
- Carry (C) = A * B

Truth Table:

A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Applications:

- Basic binary addition circuits
- Building blocks for full adders

Diagram: XOR gate for Sum, AND gate for Carry

2. Full Adder

A Full Adder adds three binary bits: A, B, and Carry-in (Cin).
It produces two outputs: a sum (S) and a carry-out (Cout).

Logic Equations:

- Sum = A XOR B XOR Cin
- Carry = AB + BCin + ACin

Truth Table:

A	B	Cin	Sum	Carry
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Applications:

- Used in arithmetic logic units for multi-bit addition

Diagram: Two XORs, two ANDs, one OR gate

3. Half Subtractor

A Half Subtractor subtracts binary digit B from A.
It produces two outputs: Difference (D) and Borrow (B).

Logic Equations:

- Difference = A XOR B
- Borrow = NOT A AND B

Truth Table:

A	B	Diff	Borrow
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

Applications:

- Simple binary subtraction logic

Diagram: XOR gate for difference, NOT + AND for borrow

4. Full Subtractor

A Full Subtractor performs subtraction of A - B - Bin (borrow-in).
It has three inputs and produces a Difference and Borrow output.

Logic Equations:

- Difference = A XOR B XOR Bin
- Borrow = NOT A * B + Bin * NOT (A XOR B)

Truth Table:

A	B	Bin	Diff	Borrow
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

Applications:

- Binary subtraction with borrow management

Diagram: Logic blocks with XOR, NOT, AND, OR gates

5. Multiplexer (MUX)

A Multiplexer selects one input from multiple and sends it to the output, based on select lines.

Example: 4-to-1 MUX

Inputs: I0, I1, I2, I3
Select Lines: S1, S0
Output Equation:
Y = I0·S1'·S0' + I1·S1'·S0 + I2·S1·S0' + I3·S1·S0

Truth Table:

S1	S0	Y
0	0	I0
0	1	I1
1	0	I2
1	1	I3

Applications:

- Data routing
- CPU control logic

Diagram: MUX block with data lines and selectors

6. Demultiplexer (DEMUX)

A Demultiplexer takes one input and distributes it to one of several outputs.

Example: 1-to-4 DEMUX

Input: D
Select Lines: S1, S0
Outputs:

- Y0 = D·S1'·S0'
- Y1 = D·S1'·S0
- Y2 = D·S1·S0'
- Y3 = D·S1·S0

Applications:

- Memory writing control
- Data line switching

Diagram: DEMUX block with one input and multiple outputs

7. Encoder

An Encoder converts multiple input lines into a smaller number of output lines (binary code).

Example: 4-to-2 Encoder

D3	D2	D1	D0	A1	A0
1	0	0	0	1	1
0	1	0	0	1	0
0	0	1	0	0	1
0	0	0	1	0	0

Applications:

- Keyboard scanners
- Data compression

Diagram: Block diagram with 4 inputs and 2 outputs

8. Decoder

A Decoder performs the reverse of an encoder. It converts n binary inputs into 2^n outputs.

Example: 2-to-4 Decoder

A	B	Y0	Y1	Y2	Y3
0	0	1	0	0	0
0	1	0	1	0	0
1	0	0	0	1	0
1	1	0	0	0	1

Applications:

- Memory address decoding
- Instruction decoding

Diagram: Block with 2 inputs and 4 outputs