AKTU B.Tech II-Year

GATEWAY CLASSES

EC & EC Allied

DSD : Digital System Design

Unit-2 Lec-1

Today's target

- Analysis and Design of combinational circuits
- Types of Adders
- PYQ
- DPP



Avinash Sir

Gateway Classes

AKTU : *DIGITAL SYSTEM DESIGN (BEC-302)* Syllabus

UNIT-2 : Combinational circuits:

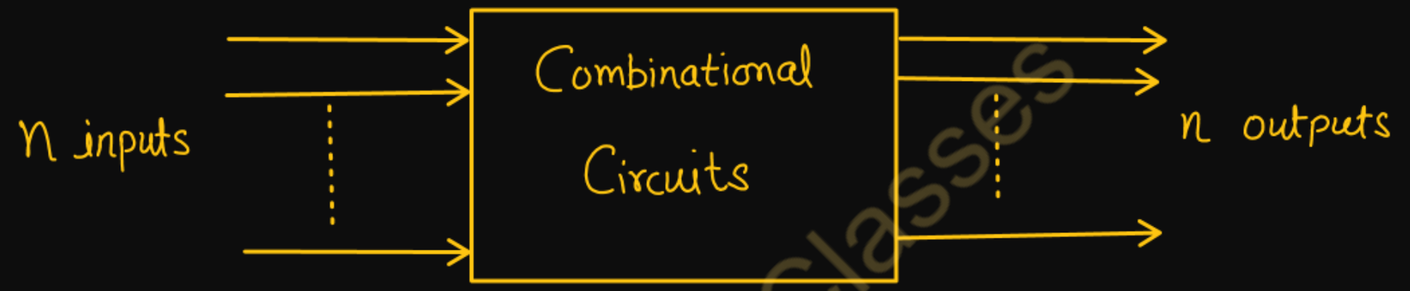
- Analysis and Design of combinational circuits
- MSI devices like comparators, multiplexers, demultiplexers, encoder, decoder,
- circuit realization using Multiplexers and decoders, half and full adders, subtractors, serial and parallel adders, BCD adder, barrel shifter and ALU.

Gateway Classes

Combinational Circuits

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A combinational circuit is formed by the interconnection of logic gates. The output of the circuit depends only on the present values of the input signals. These circuits process binary input data and generate the required binary output data.



The circuit takes n input variables from an external source and produces m output variables, which are delivered to an external destination through the internal logic network.

A combinational circuit can be fully defined in two ways:

- By a truth table listing all possible input combinations and their corresponding outputs.
- By m Boolean functions, one for each output, expressed in terms of the n input variables.

- Examples: Adders, Subtractors, Multiplexers, Demultiplexers, Encoders, Decoders, Comparators.

Gateway Classes

Analysis Procedure

(Used when the circuit is already given, and we need to determine how it works.)

- Identify inputs and outputs of the circuit.
- Determine the Boolean function for each output in terms of the inputs by tracing logic gates.
- Simplify the Boolean expressions (using Boolean algebra or Karnaugh maps).
- Construct the Truth Table to list outputs for all possible input combinations.
- Interpret results to understand the circuit's function (e.g., is it an adder, comparator, etc.?).

Gateway Classes

Design Procedure

(Used when the required function is given, and we need to build the circuit.)

- Problem statement: Define the circuit's required behavior.
- List input and output variables:

  Let the number of inputs = n & number of outputs = m

- Form the Truth Table that relates inputs to outputs.
- Derive Boolean functions for each output variable from the truth table.
- Simplify Boolean expressions (using Boolean algebra, Karnaugh maps, or Quine–McCluskey method).
- Draw the logic diagram using the simplified Boolean expressions and logic gates.
- Implement and verify the design.

Gateway Classes

Design Procedure

(Used when the required function is given, and we need to build the circuit.)

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- Draw the logic diagram using the simplified Boolean expressions and logic gates.
- Implement and verify the design.

Gateway Classes

Adder

- An Adder is a combinational circuit that performs binary addition. It is one of the basic building blocks of arithmetic circuits.
- There are mainly two basic types of adders:
  - Half Adder (HA)
  - Full Adder (FA)

Gateway Classes

Half -Adder

➤ A circuit that adds two 1-bit binary numbers (A and B). And has two outputs S(Sum) & Carry(C).

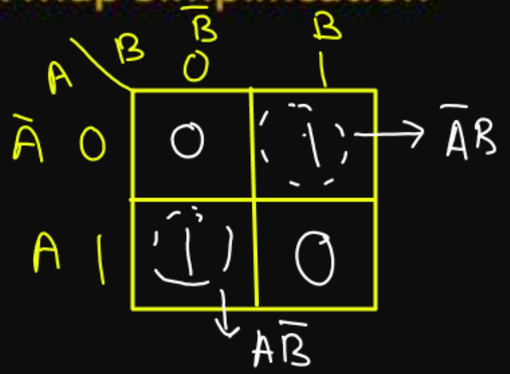


$Sum(s) = A \oplus B = A\bar{B} + \bar{A}B$

$Carry(C) = AB$

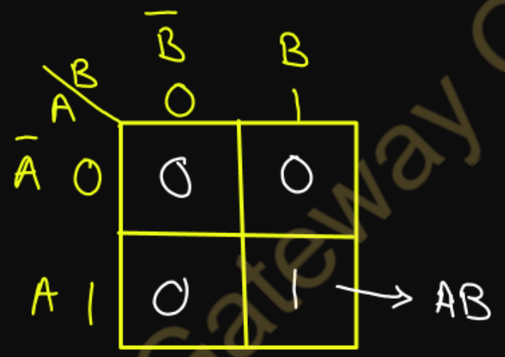
INPUTS		OUTPUTS	
A	B	Sum (S)	Carry (C)
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

➤ K Map Simplification



$S = \bar{A}B + A\bar{B}$

$= A \oplus B$



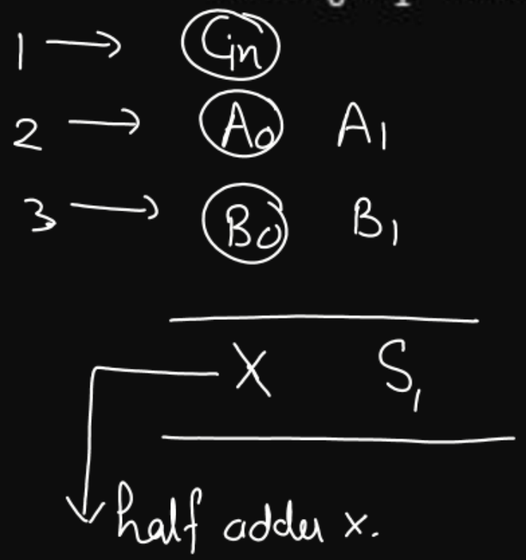
$C = A \cdot B$

Gateway Classes

Limitation of Half Adder

- Cannot add previous carry (works only for 2 inputs).
- Example Let we must ADD two 2- bit numbers

$A = A_0\ A_1$ and $B = B_0\ B_1$



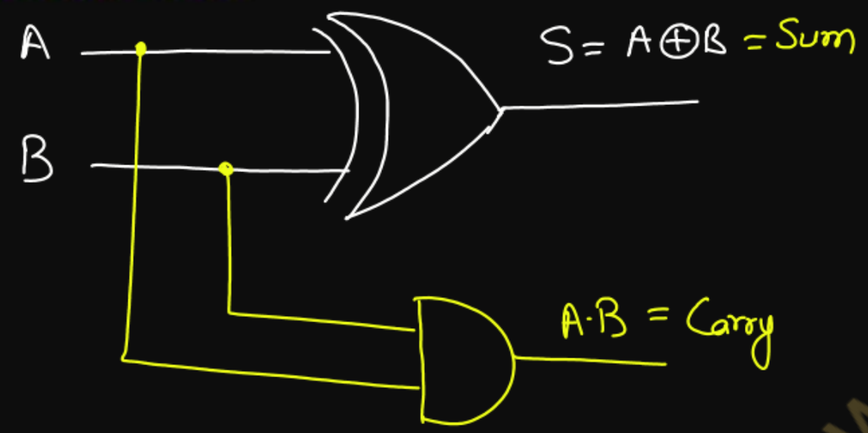
Gateway Classes

Logic Implementation

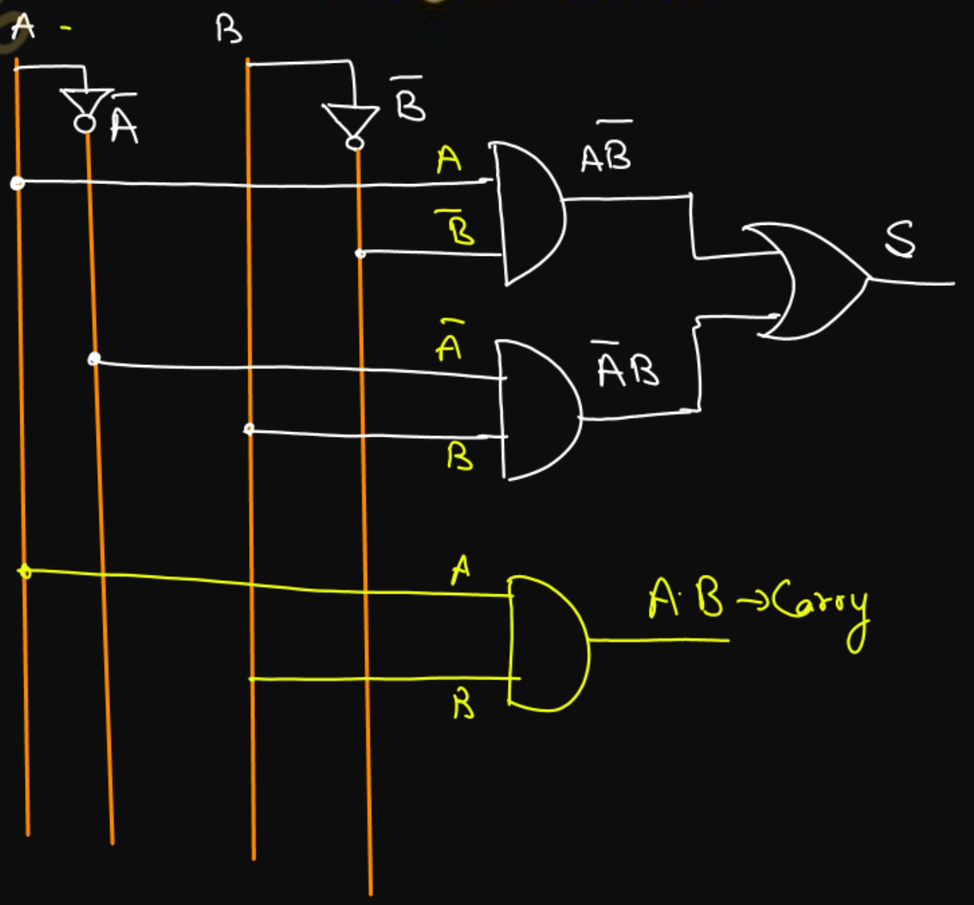
$S = A \oplus B = A\bar{B} + \bar{A}B$

$C = A \cdot B$

Using Ex-OR Gate



Using Basic Gates



Gateway Classes

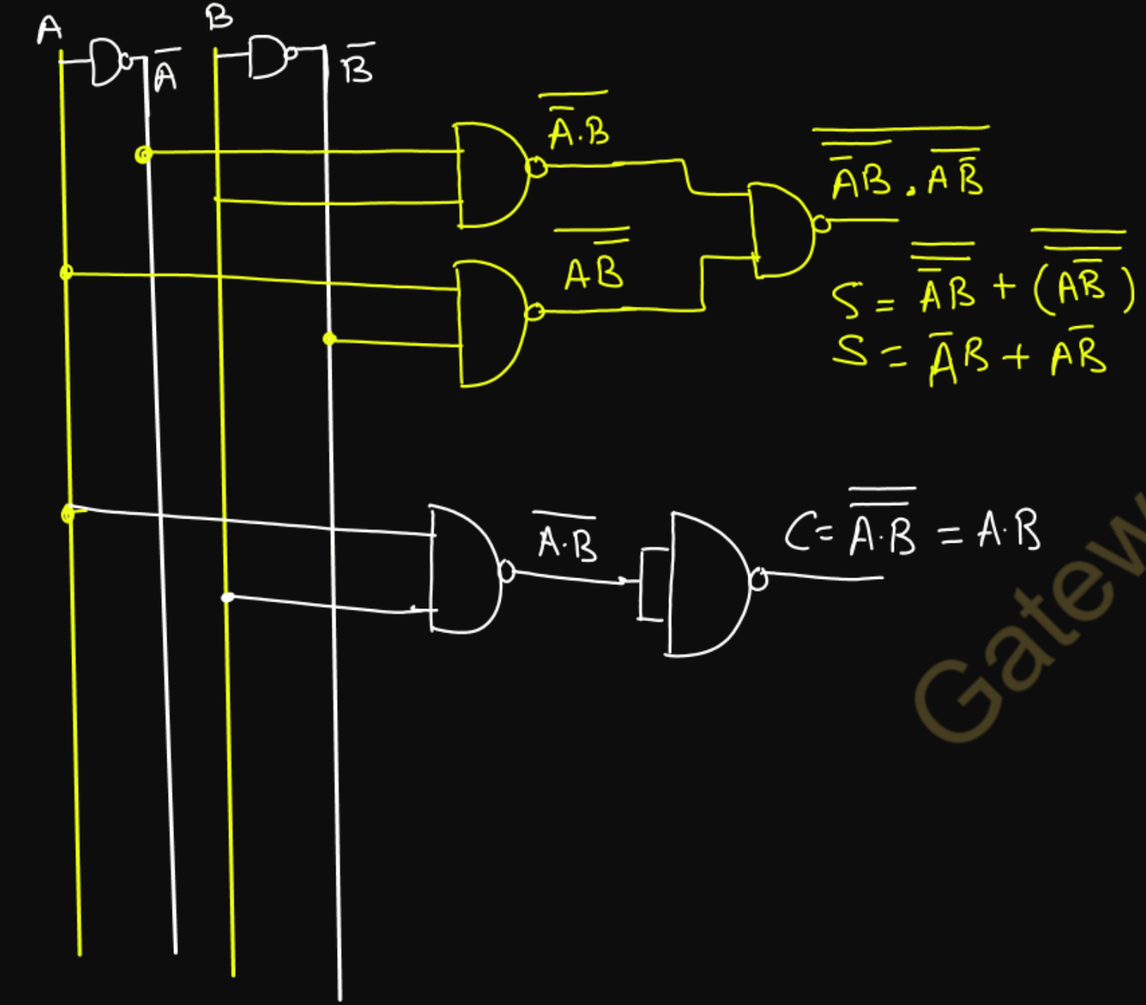
Logic Implementation

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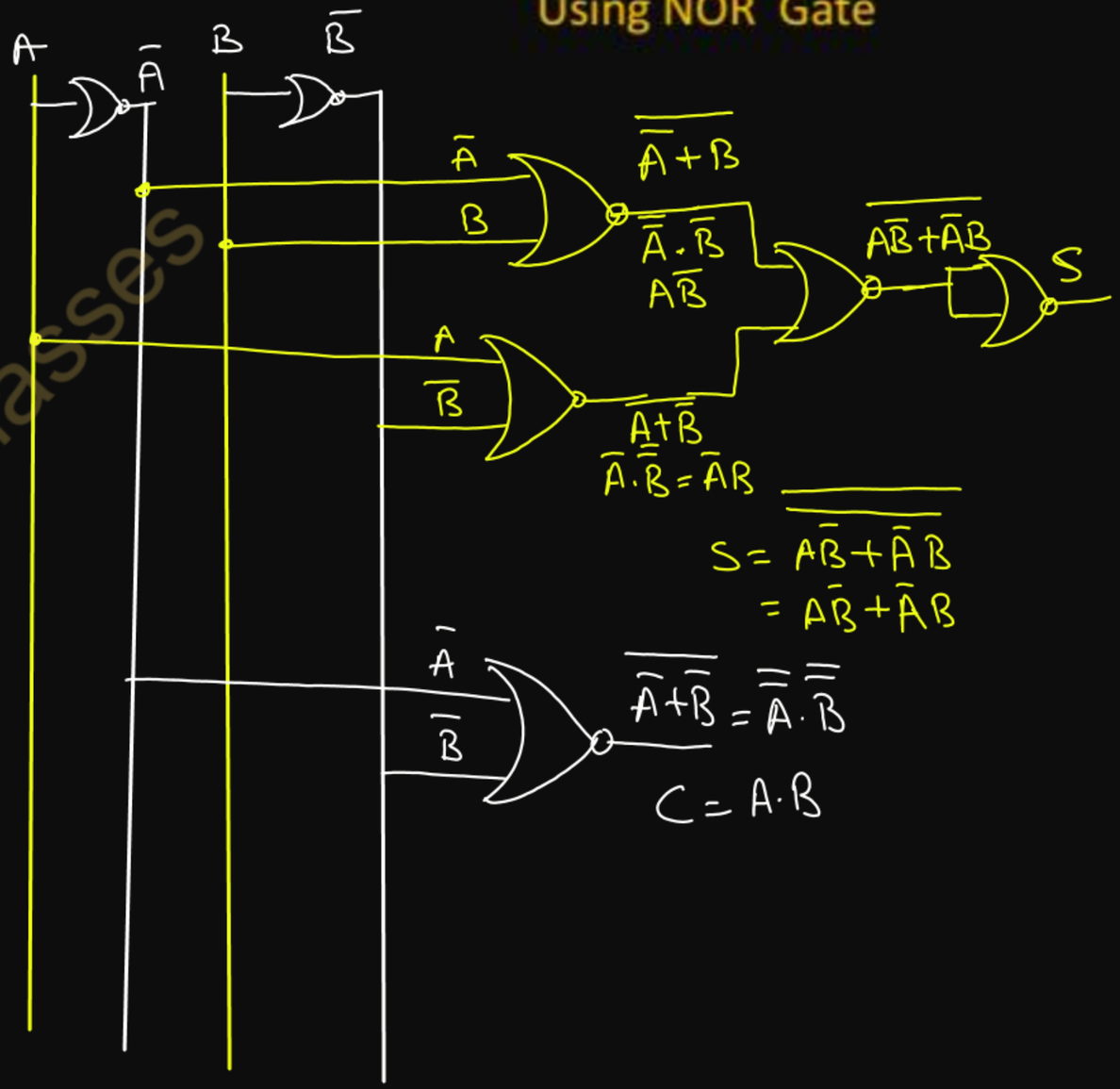
$C = A \cdot B$

Using NAND Gate

$S = \overline{\bar{A}B + A\bar{B}} = \overline{\bar{A}B} \cdot \overline{A\bar{B}}$



Using NOR Gate

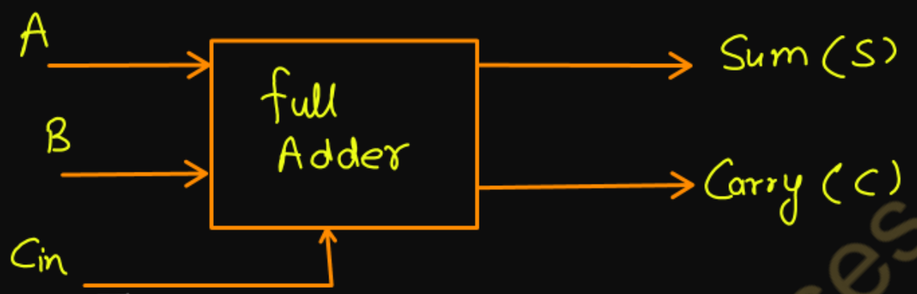


Gateway Classes

Full Adder

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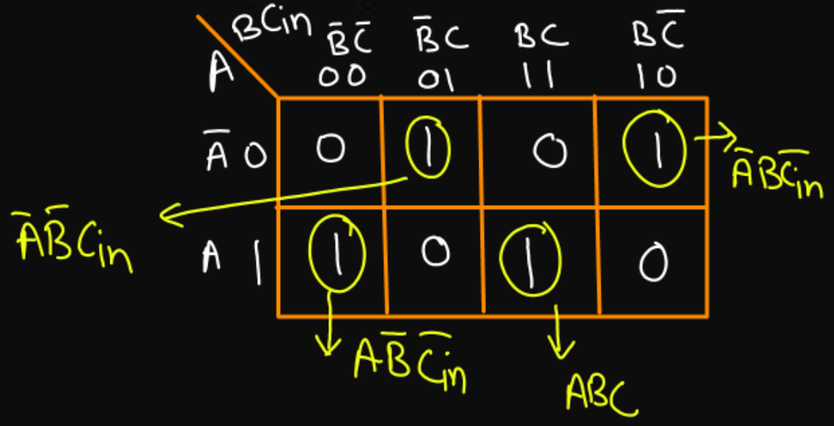
- A circuit that adds three 1-bit binary numbers (A, B, and Cin – previous carry) And has two outputs S(Sum) & Carry(C).

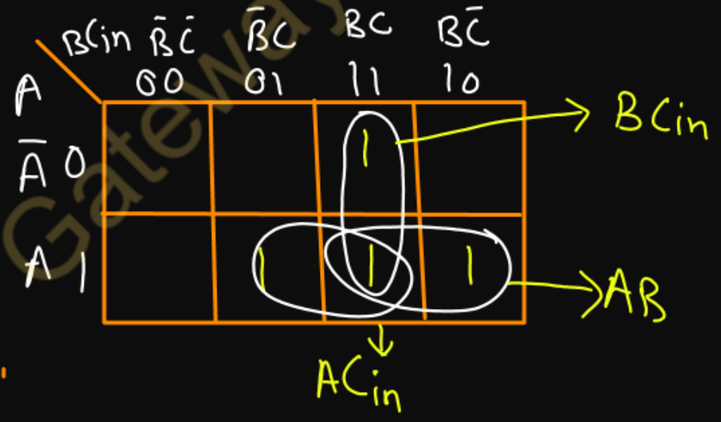


$$Sum(s) = \bar{A}\bar{B}C_{in} + \bar{A}B\bar{C}_{in} + A\bar{B}\bar{C}_{in} + ABC_{in} = A \oplus B \oplus C$$

$$Carry\ output\ (C) = AB + AC_{in} + BC_{in}$$

- K Map Simplification





INPUTS			OUTPUTS	
A	B	C_{in}	Sum (S)	Carry out (C)
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

Gateway Classes

$$S = \bar{A}\bar{B}C_{in} + \bar{A}B\bar{C}_{in} + A\bar{B}\bar{C}_{in} + AB\bar{C}_{in}$$

$$= C_{in}(\bar{A}\bar{B} + AB) + \bar{C}_{in}(\bar{A}B + A\bar{B})$$

$(\bar{A}\bar{B} + AB)$: x-NOR

$(\bar{A}B + A\bar{B})$: XOR $= (A \oplus B)$

$$S = C_{in}(\bar{X}) + \bar{C}_{in}(X)$$

where $X = \bar{A}B + A\bar{B}$

$$S = C_{in}\bar{X} + \bar{C}_{in}X$$

$$= X \oplus C_{in}$$

$$\boxed{S = A \oplus B \oplus C_{in}}$$

X-OR = $\overline{\text{X-NOR}}$

$A \oplus B = \overline{A \odot B}$

$\bar{A}B + A\bar{B} = \overline{AB + \bar{A}\bar{B}}$

$= \overline{A\bar{B}} \cdot \overline{\bar{A}\bar{B}}$

$= (\bar{A} + \bar{B}) \cdot (\bar{\bar{A}} + \bar{\bar{B}})$

$= (\bar{A} + \bar{B}) \cdot (A + B)$

$= A\bar{A} + \bar{A}B + \bar{B}A + \bar{B}B$ → 0

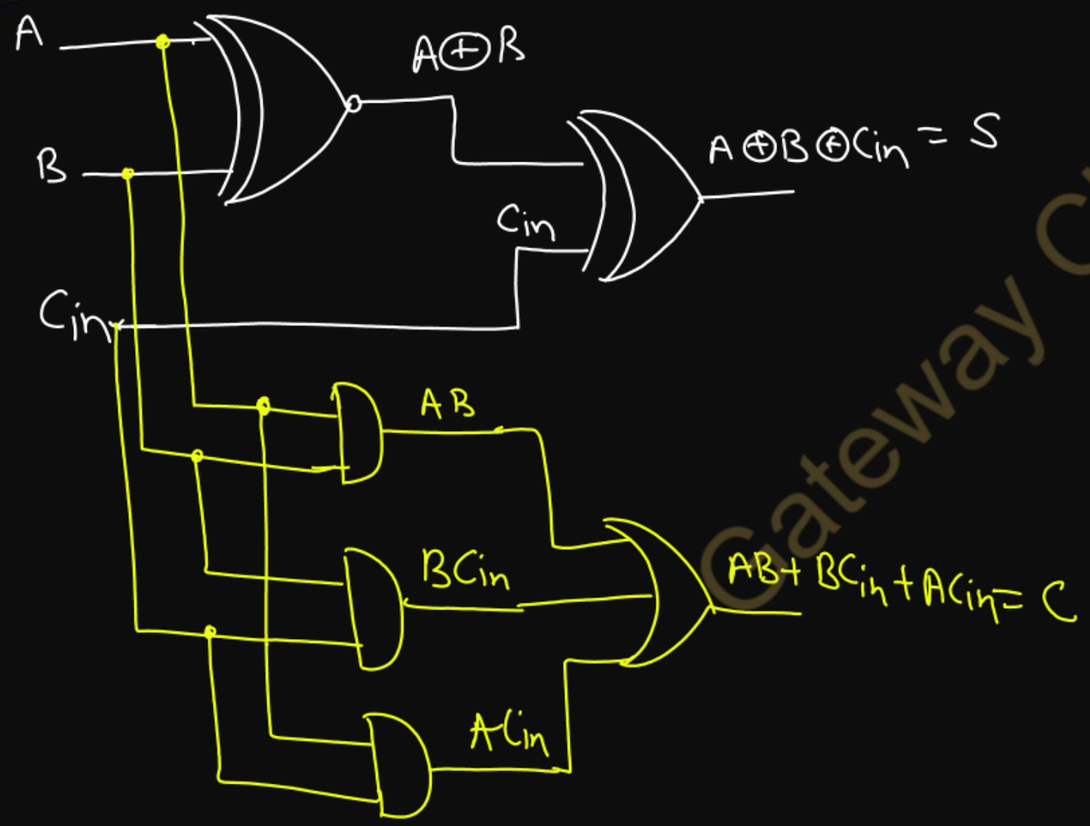
Gateway Classes

Logic Implementation

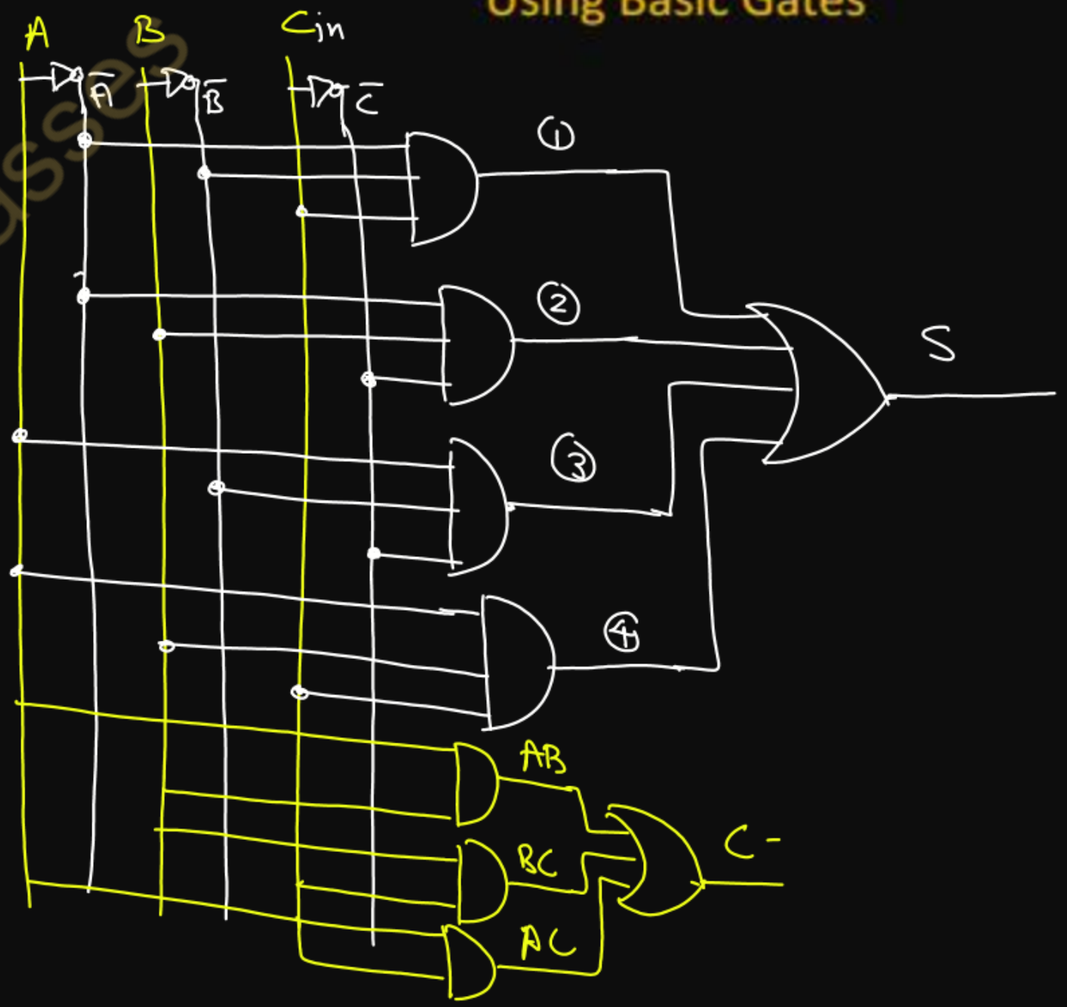
$$\text{Sum} = A \oplus B \oplus C_{in}$$
$$= \bar{A}\bar{B}C_{in} + \bar{A}B\bar{C}_{in} + A\bar{B}\bar{C}_{in} + ABC_{in}$$
$$\text{(1)} \qquad \text{(2)} \qquad \text{(3)} \qquad \text{(4)}$$

$$\text{Carry output } C = AB + BC_{in} + AC_{in}$$

Using Ex-OR Gate



Using Basic Gates



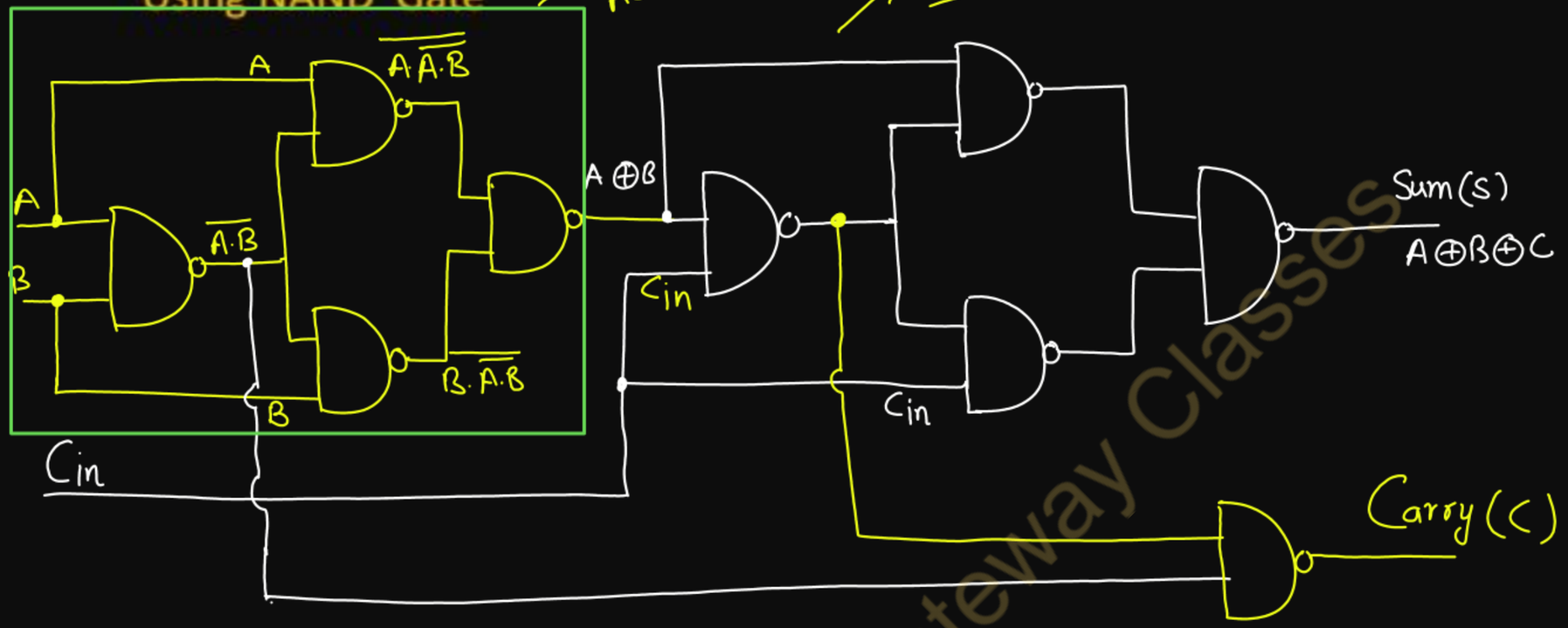
Gateway Classes

Logic Implementation

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$S = A \oplus B \oplus C$

Using NAND Gate



$C = \overline{(\overline{A \cdot B}) \cdot \overline{(A \oplus B) C_{in}}}$

$= AB + BC + AC$

Using NOR Gate

"Try yourself"

$S = \overline{(\overline{A \cdot \overline{A \cdot B}}) \cdot (\overline{B \cdot \overline{A \cdot B}})}$

$S = (\overline{A \cdot \overline{AB}}) + (\overline{B \cdot \overline{AB}})$

$= (A \cdot \overline{AB}) + (B \cdot \overline{AB})$

$= (A \cdot (\bar{A} + \bar{B})) + (B \cdot (\bar{A} + \bar{B}))$

$= (A\bar{A} + A\bar{B}) + (B\bar{A} + B\bar{B})$

$= A\bar{B} + B\bar{A}$

$A \oplus B$ ✗

Gateway Classes

Full Adder using NAND GATE

$$S = \bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$$

$$S = \overline{\bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC}$$

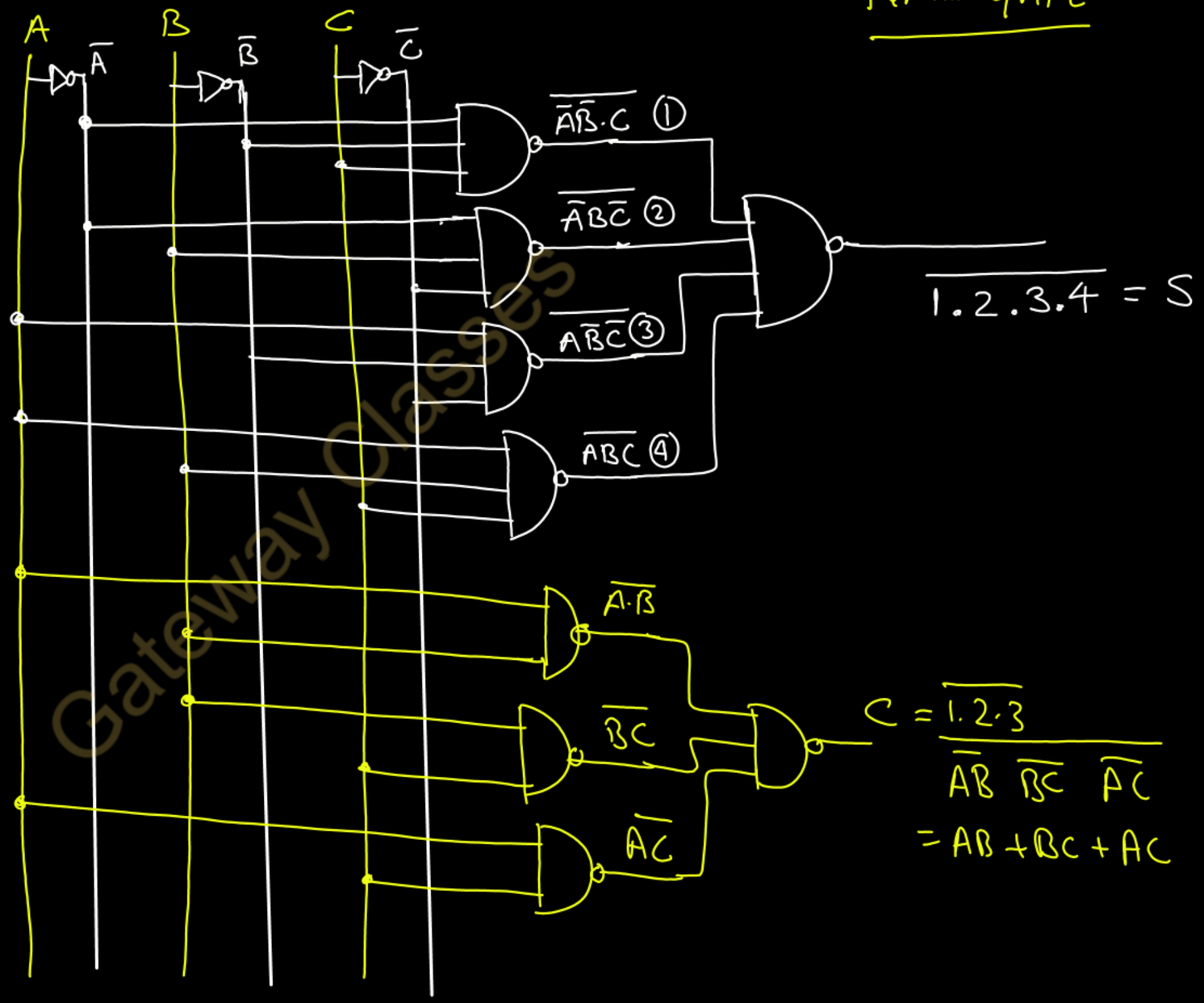
$$S = \overline{\bar{A}\bar{B}C} \cdot \overline{\bar{A}B\bar{C}} \cdot \overline{A\bar{B}\bar{C}} \cdot \overline{ABC}$$

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$$C = \overline{AB + BC + AC}$$

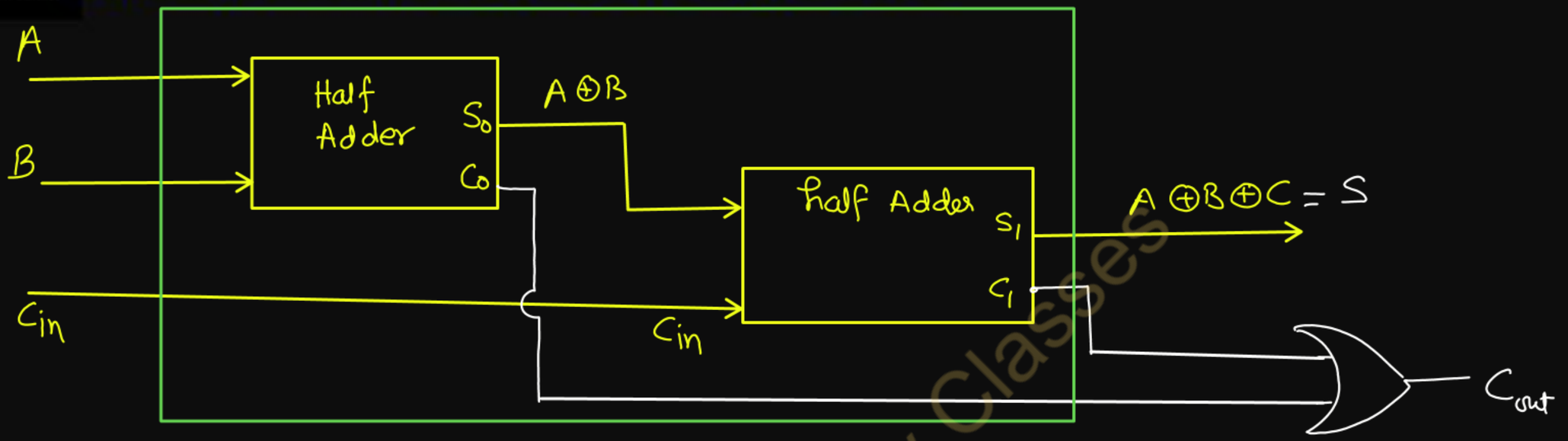
$$= \overline{AB} \cdot \overline{BC} \cdot \overline{AC}$$

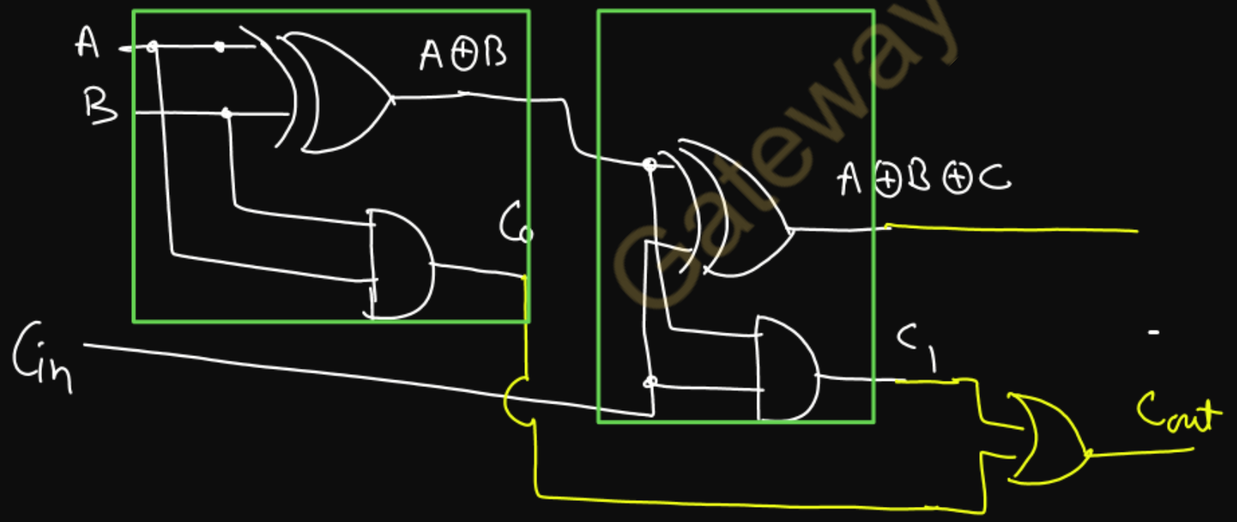
① ② ③



Gateway Classes

Logic Implementation for Full adder using half adder





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Thank You

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