Lecture 11
Combinational Circuits

Combinational Circuits

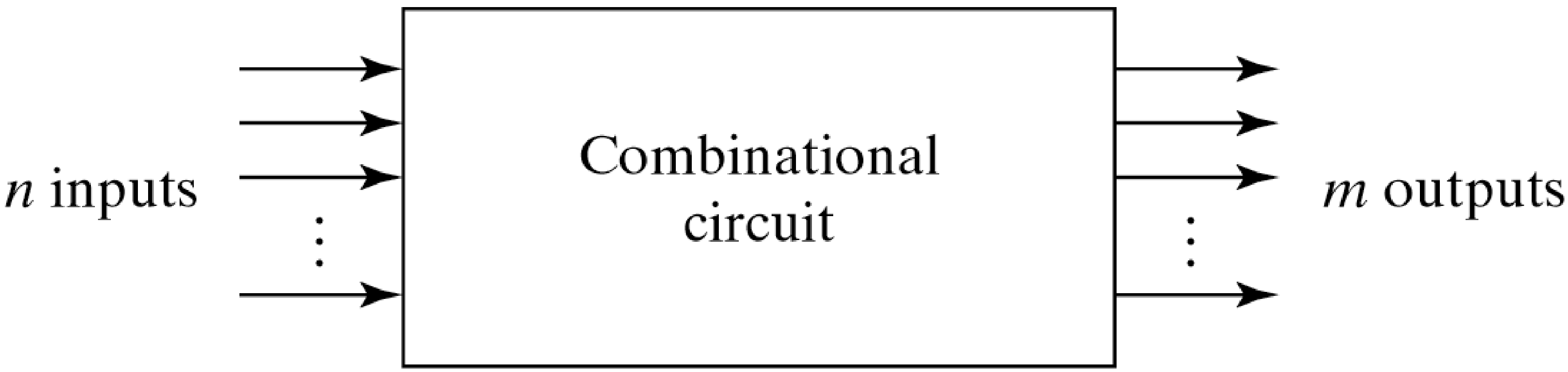


Fig. 4-1 Block Diagram of Combinational Circuit

What is Combinational Circuits?

- A Combinational Circuit is a combination of Logic gates, the output depends upon the current value of the inputs.

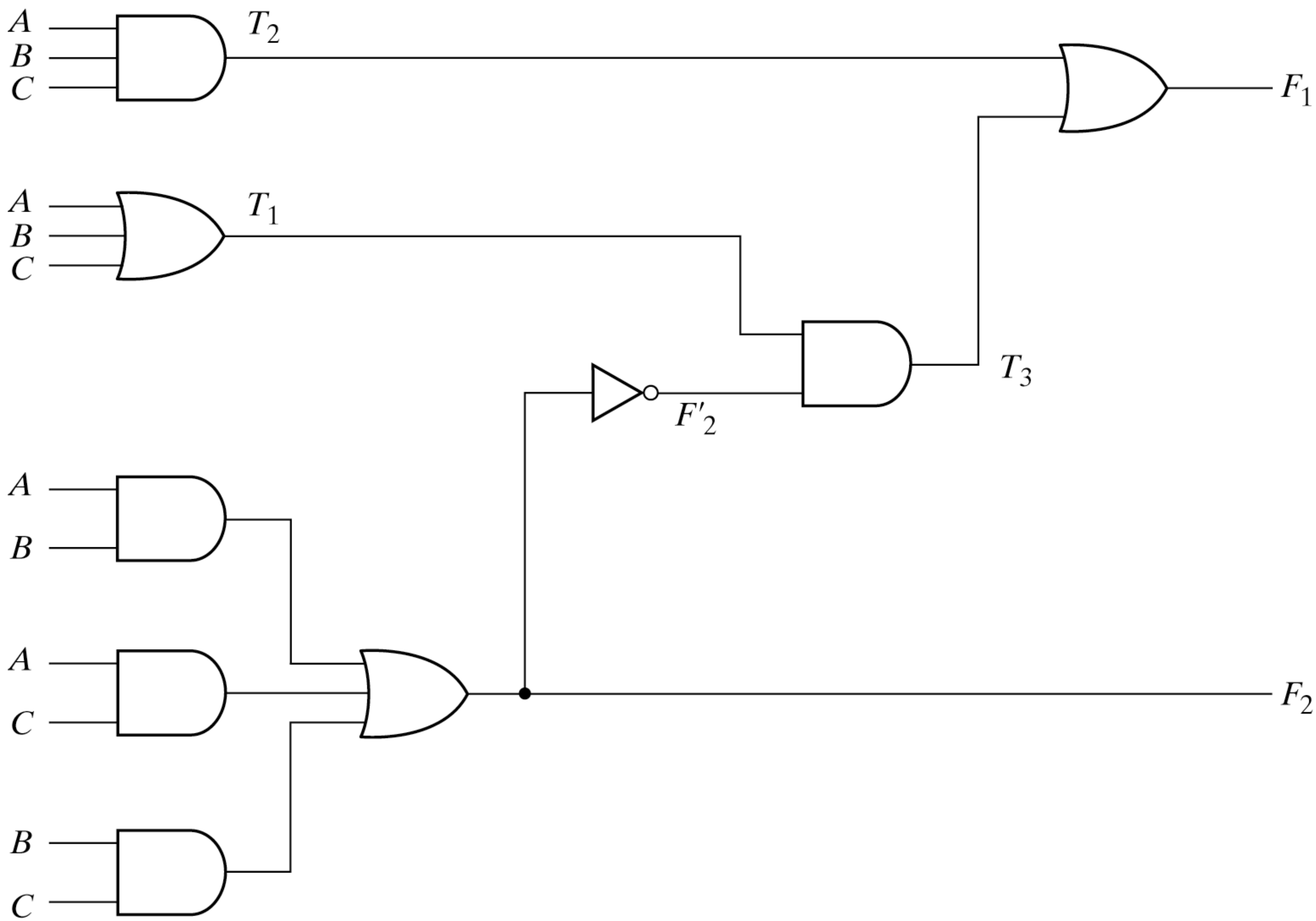


Fig. 4-2 Logic Diagram for Analysis Example

Examples of Combinational Circuits

- Addition:
  - **Half Adder (HA).**
  - **Full Adder (FA).**
  - **BCD(Decimal) Adder.**
- Subtraction:
  - **Half Subtractor.**
  - **Full Subtractor.**
- Multiplication:
  - **Binary Multipliers.**
- Comparator:
  - **Magnitude Comparator.**

Examples of Combinational Circuits

- Multiplexers
- Demultiplexers
- Encoders
- Decoders
- Converters
- Binary to Gray Code
- Gray to Binary Code
- Binary to BCD Code

Two types of questions come in the exam based on Combinational Circuit:

1. Designing of a combinational Circuit
2. Analysis of Combinational Circuit

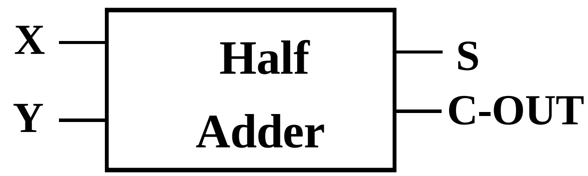
Designing Combinational Circuits

In general we have to do following steps:

1. Problem description
2. Input/output of the circuit
3. Define truth table
4. Simplification for each output
5. Draw the circuit

Half Adder

- Adding two single-bit binary values, X, Y produces a sum S bit and a carry out C-out bit.
- This operation is called half addition and the circuit to realize it is called a half adder.

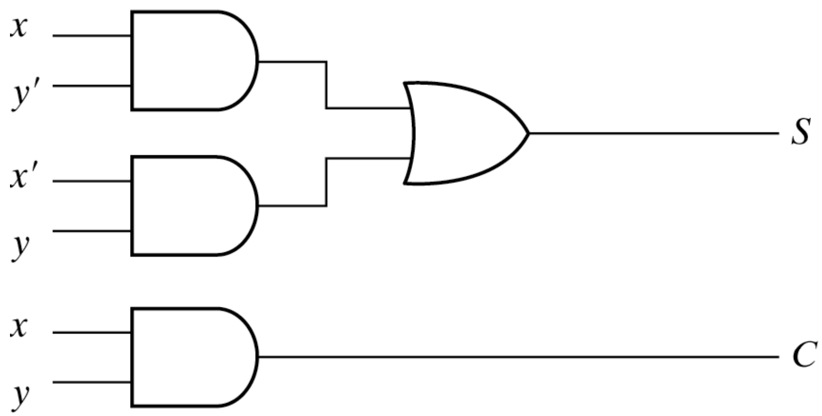


Half Adder Truth Table

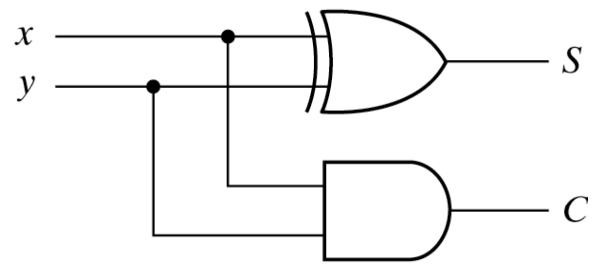
Inputs		Outputs	
X	**Y**	**S**	**C-out**
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

$S(X,Y) = \Sigma\ (1,2)$
$S = X'Y + XY'$
$S = X \oplus Y$

$C\text{-out}(x, y) = \Sigma\ (3)$
$C\text{-out} = XY$



(a) $S = xy' + x'y$
$C = xy$



(b) $S = x \oplus y$
$C = xy$

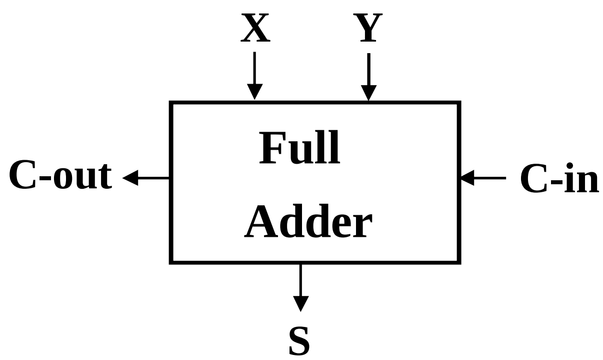
Fig. 4-5 Implementation of Half-Adder

Full Adder

- Adding two single-bit binary values, X, Y with a carry input bit C-in produces a sum bit S and a carry out C-out bit.

Full Adder Truth Table

Inputs			Outputs	
X	Y	C-in	S	C-out
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



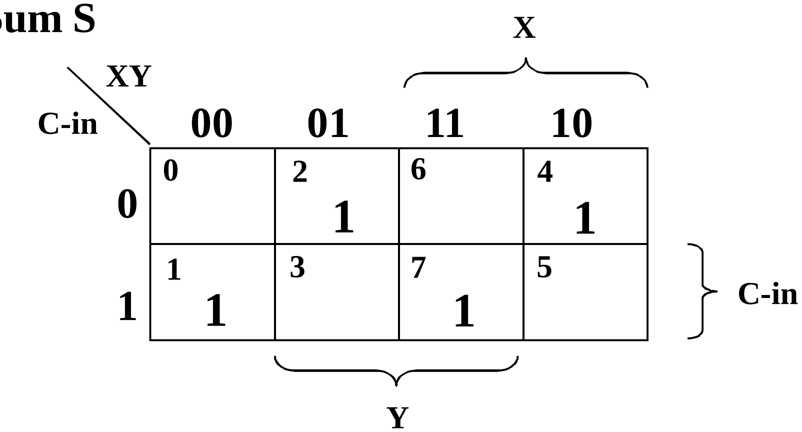
Full Adder

Inputs			Outputs	
X	Y	C-in	S	C-out
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

Full Adder Truth Table

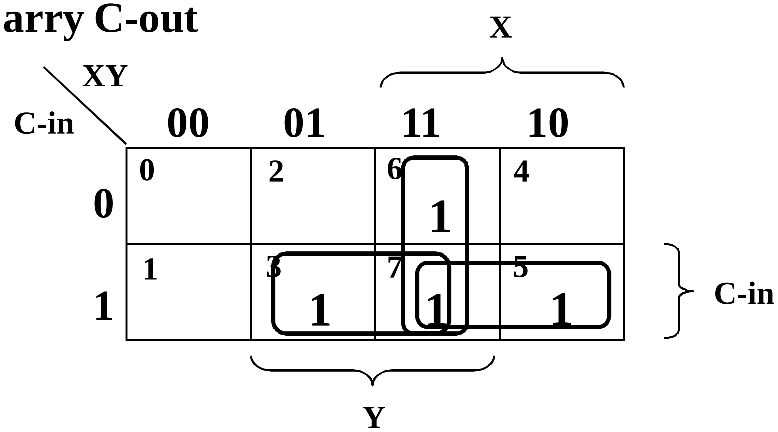
S(X,Y, C-in) = Σ (1,2,4,7)
C-out(x, y, C-in) = Σ (3,5,6,7)

Sum S



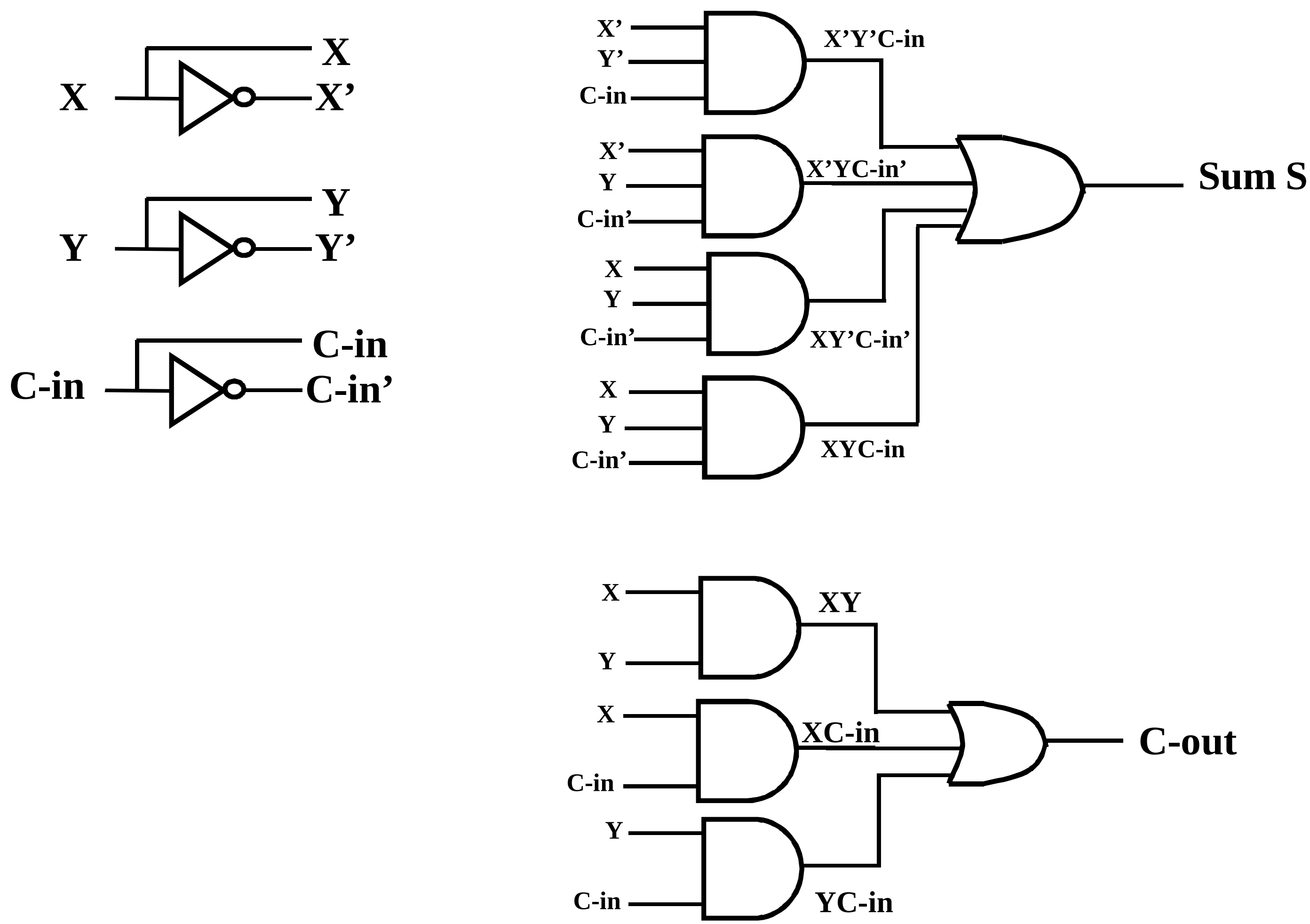
S = X'Y'(C-in) + XY'(C-in)' + XY'(C-in)' + XY(C-in)
S = X $\oplus$ Y $\oplus$ (C-in)

Carry C-out

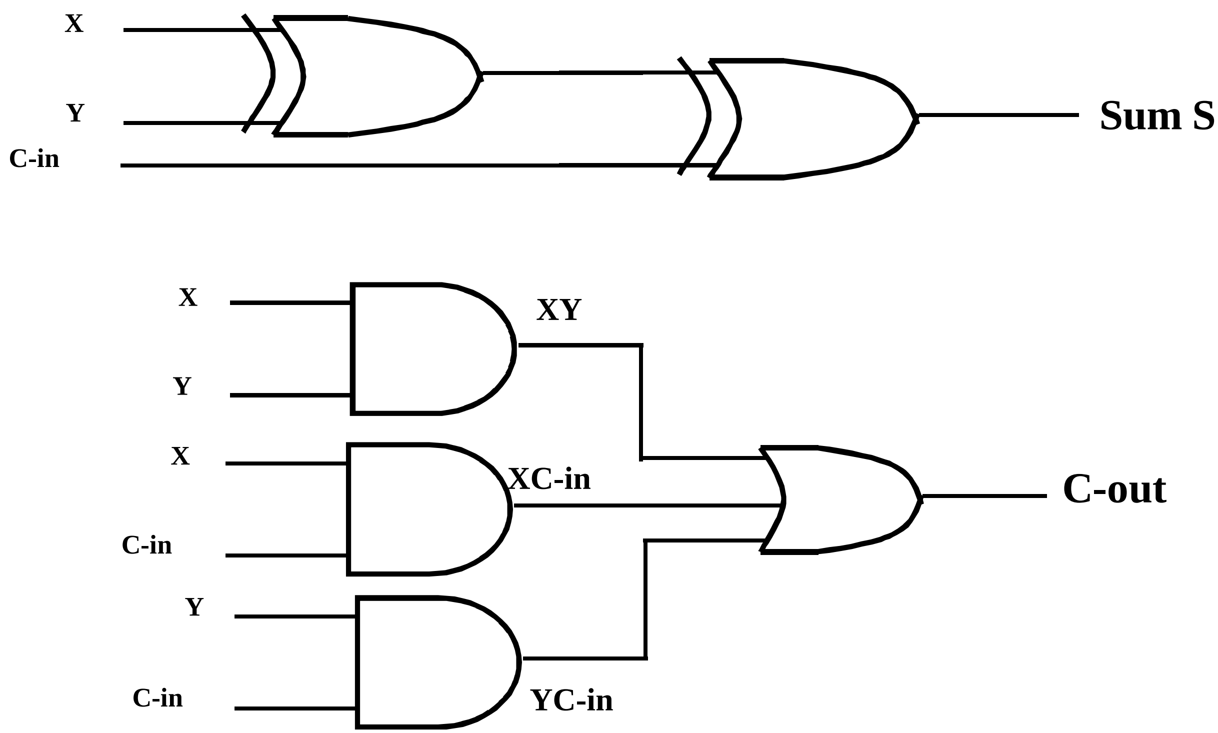


C-out = XY + X(C-in) + Y(C-in)

Full Adder Circuit Using AND-OR



Full Adder Circuit Using Ex-OR



Full Adder Circuit Using two half - Adders

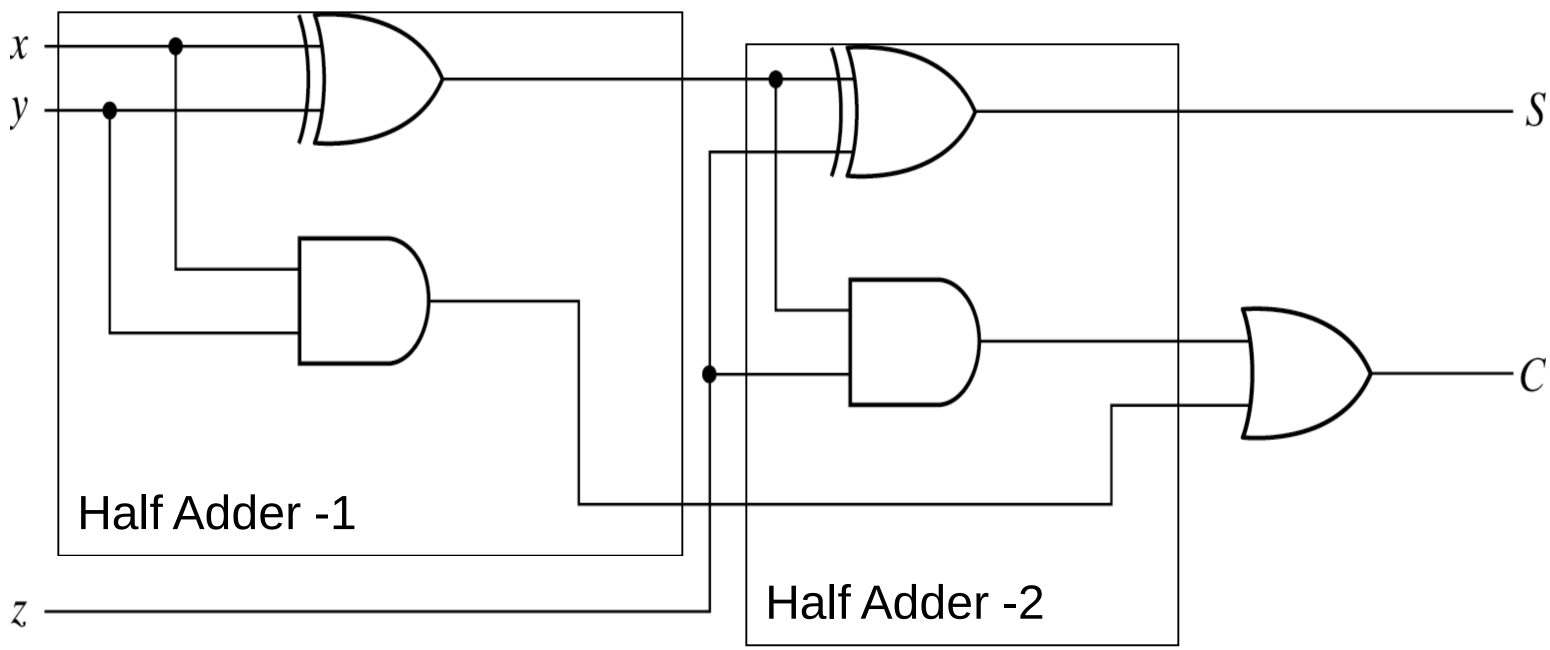


Fig. 4-8 Implementation of Full Adder with Two Half Adders and an OR Gate

Binary adder

- Binary adder that produces the arithmetic sum of binary numbers can be constructed with full adders connected in cascade, with the output carry from each full adder is connected to the input carry of the next full adder in the chain
- Note that the input carry C_0 in the least significant position must be 0.

Binary Adder

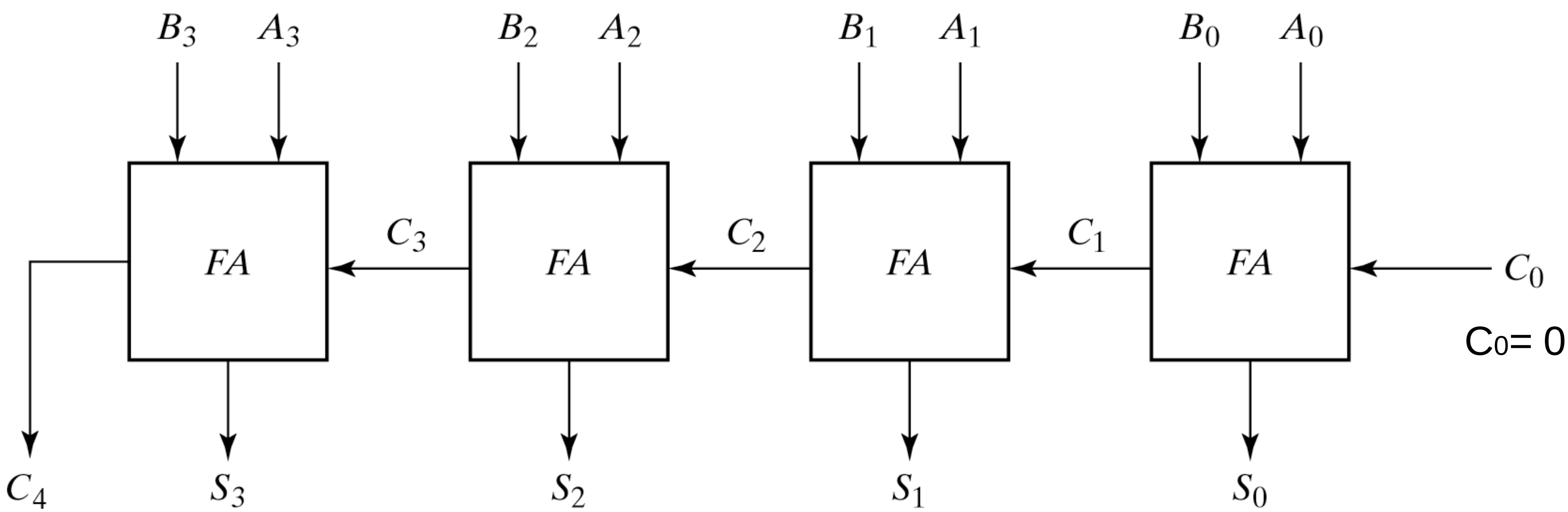


Fig. 4-9 4-Bit Adder

Binary Adder

- For example to add A= 1011 and B= 0011

subscript i:	3	2	1	0	
Input carry:	0	1	1	0	C_i
Augend:	1	0	1	1	A_i
Addend:	0	0	1	1	B_i
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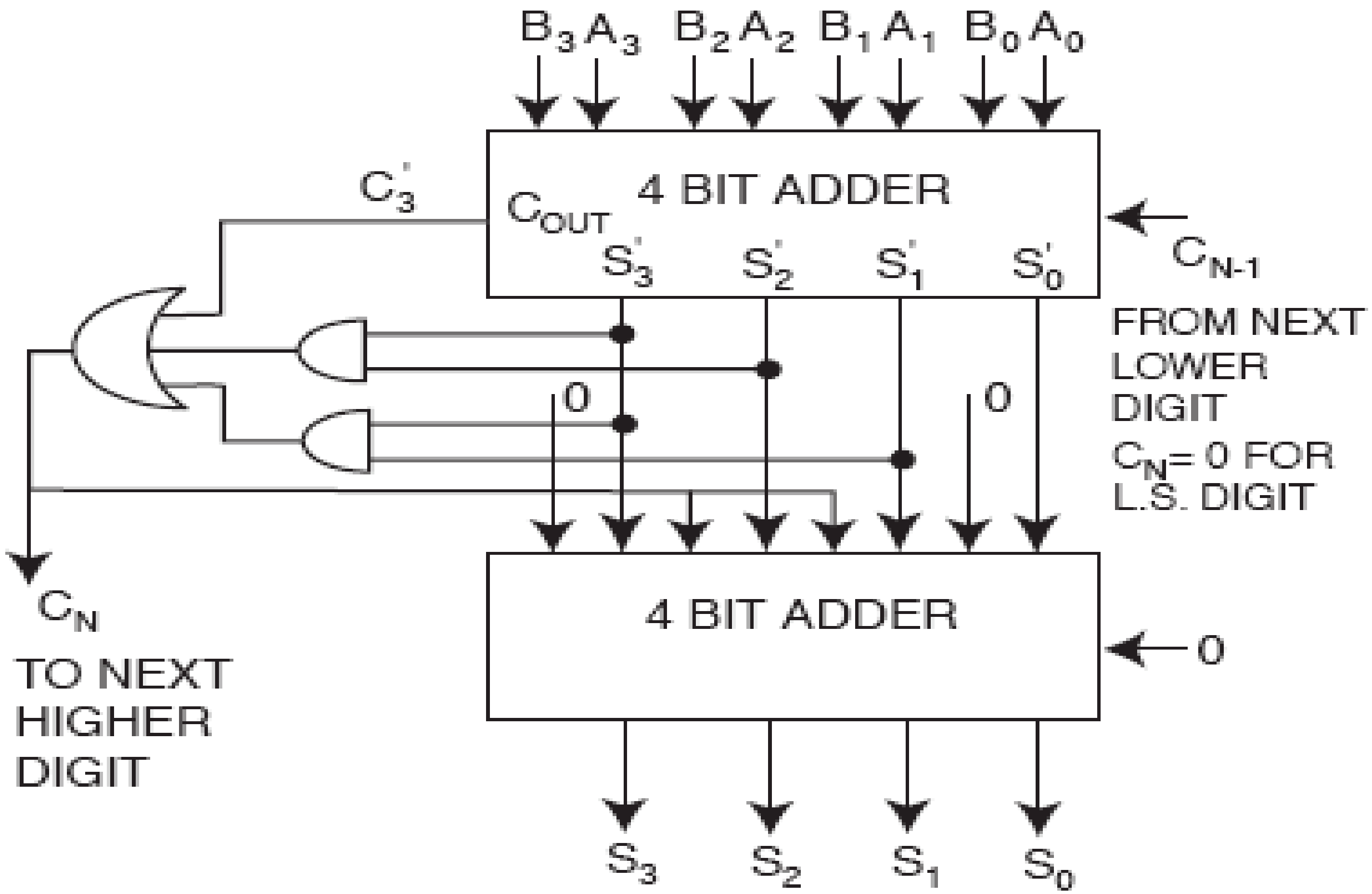
Sum:	1	1	1	0	S_i
Output carry:	0	0	1	1	C_{i+1}

DECIMAL/BCD ADDER



- ADD **0110 WHEN C_N=1**
- ADD **0000 WHEN C_N=0**