Digital Logic and Circuit
Paper Code: CS-102

Outline

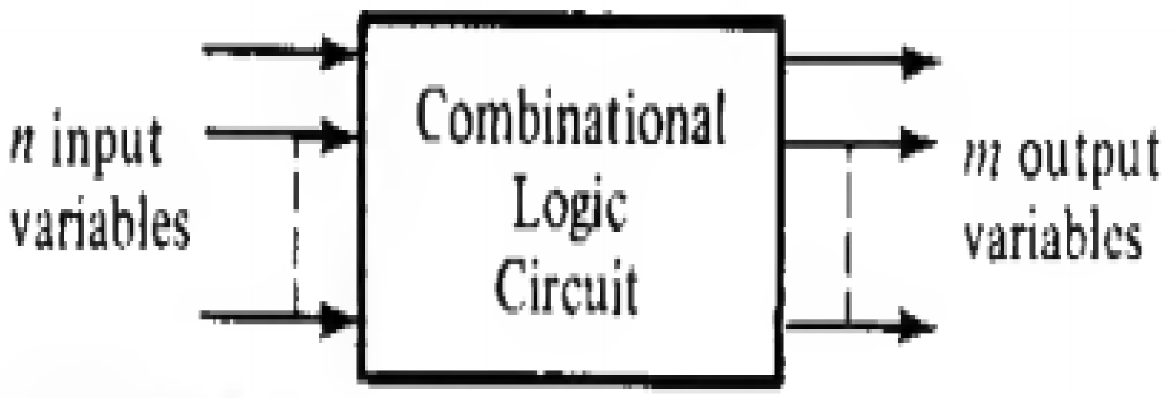
- Combinational Circuit
  - Adder
    - Half Adder
    - Full Adder

Combinational Circuit

- A combinational circuit consists of logic gates whose outputs at any time are determined directly from the present combination of inputs without regard to previous inputs.
- A combinational circuit performs a specific information-processing operation fully specified logically by a set of Boolean functions.
- A combinational circuit consists of input variables, logic gates, and output variables. The logic gates accept signals from the inputs and generate signals to the outputs.
- This process transforms binary information from the given input data to the required output data.
- Obviously, both input and output data are represented by binary signals, i.e., they exist in two possible values, one representing logic- 1 and the other logic-0.

Combinational Circuit

- For n input variables, there are 2^n possible combinations of binary input values.
- For each possible input combination, there is one and only one possible output combination.
- A combinational circuit can be described by m Boolean functions, one for each output variable. Each output function is expressed in terms of the n input variables.



Block diagram of a combinational circuit

Design Procedure of Combinational circuit

The design of combinational circuits starts from the verbal outline of the problem and ends in a logic circuit diagram or a set of Boolean functions from which the logic diagram can be easily obtained. The procedure involves the following steps:

1. The problem is stated.

2. The number of available input variables and required output variables is determined.

3 . The input and output variables are assigned letter symbols.

4 . The truth table that defines the required relationships between inputs and outputs is derived.

5 . The simplified Boolean function for each output is obtained.

6. The logic diagram is drawn.

- A truth table for a combinational circuit consists of input columns and output columns.
- The 1’s and 0’s in the input columns are obtained from the 2" binary combinations available for n input variables.
- The binary values for the outputs are determined from examination of the stated problem.
- An output can be equal to either 0 or 1 for every valid input combination. However, the specifications may indicate that some input combinations will not occur. These combinations become don’t-care conditions.

ADDERS

A combinational circuit that performs the addition of two bits is called a half-adder.

One that performs the addition of three bits (two significant bits and a previous carry) is a full-adder

Half-Adder

A half-adder needs two binary inputs and two binary outputs. The input variables designate the augend and addend bits; the output variables produce the sum and carry.

It is necessary to specify two output variables because the result may consist of two binary digits. We arbitrarily assign symbols x and y to the two inputs and S (for sum) and C (for carry) to the outputs.

This truth table is

x	y	C	S
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Half-Adder (Cont..)

This truth table is

x	y	C	S
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

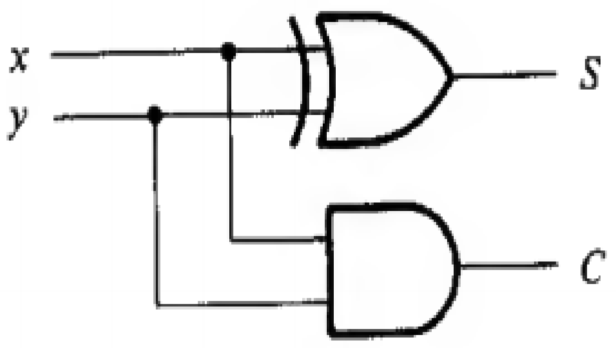
The carry output is 0 unless both inputs are 1. The S output represents the least significant bit of the sum. The simplified Boolean functions for the two outputs can be obtained directly from the truth table. The simplified sum of products expressions are

$S = x'y + xy'$

$C = xy$

Half-Adder (Cont..)

The logic diagram for this implementation



$S = x \oplus y$
$C = xy$

implementations of a half-adder

Full-Adder

- A full-adder is a combinational circuit that forms the arithmetic sum of three input bits.
- It consists of three inputs and two outputs. Two of the input variables, denoted by x and y, represent the two significant bits to be added. The third input, z, represents the carry from the previous lower significant position.
- The two outputs are designated by the symbols S for sum and C for carry.
- The binary variable S gives the value of the least significant bit of the sum.
- The binary variable C gives the output carry.

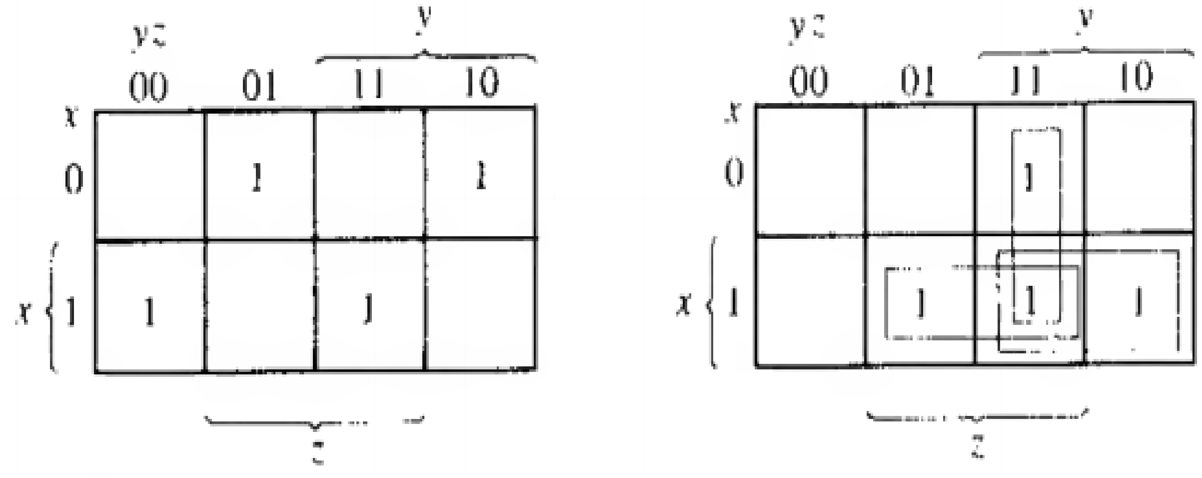
The truth table of the full-adder is

x	y	z	C	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

x	y	z	C	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

The input-output logical relationship of the full-adder circuit may be expressed in two Boolean functions, one for each output variable.

Each output Boolean function requires a unique map for its simplification as shown here:



$S = x'y'z + x'yz' + xy'z' + xyz$

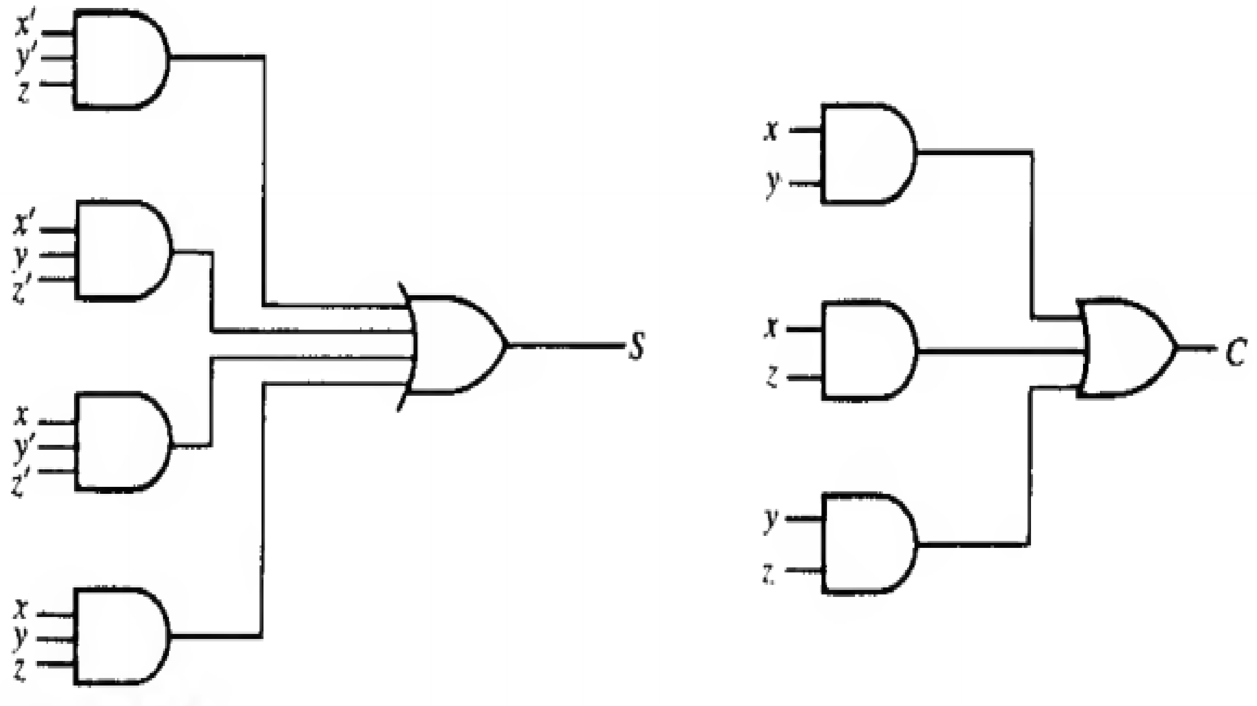
$C = xy + xz + yz$

The FA implementation uses the following Boolean expressions:

S=x'y'z + x'yz’ + xy'z’ + xyz

C = xy+ xz + yz

The logic diagram for the full-adder implemented in sum of products .



Implementation of a full-adder in sum of products

Suggested Reading

- M. Morris Mano, Digital Logic and Computer Design, PHI.

Thank you