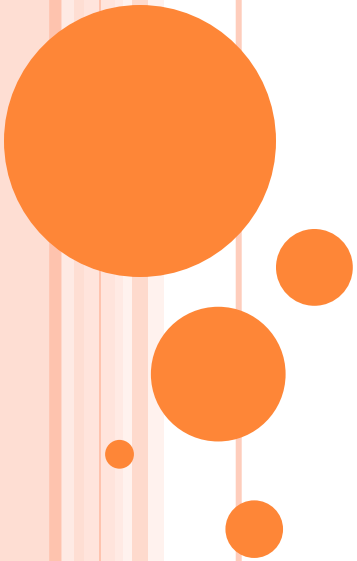


CSE 2105: Digital Logic Design

Combinational Logic

- **Logic Circuits:**

  - Logic circuits for digital systems may be combinational or sequential.

- **Combinational Circuits:**
  - 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 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.

Combinational Circuits

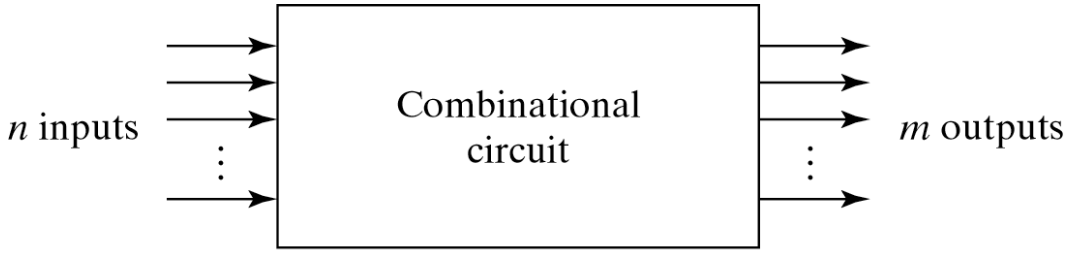


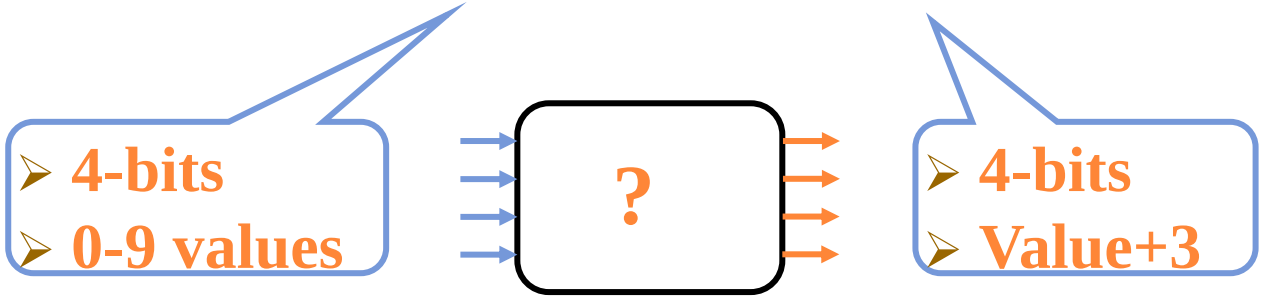
Fig. 4-1 Block Diagram of Combinational Circuit

- For n input variables, there are $\mathbf{2}^{n}$ 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.

Design Procedure of Combinational logic circuit

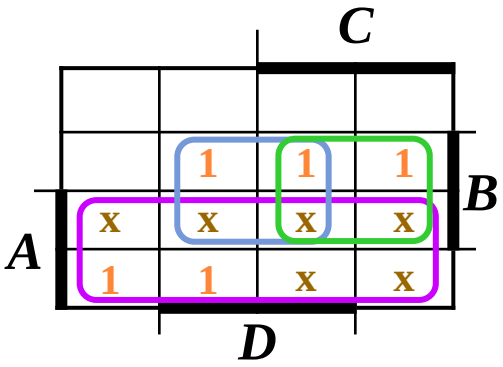
- Given a problem statement:
  - Determine the number of *input variables* and *output variables*. The input and output variables are assigned letter symbols.
  - Derive the truth table to define the required relationships between input and outputs.
  - Simplify the Boolean expression for each output.
  - Produce the required circuit and verify it.

Example: Design a circuit to convert a 4 bit "BCD" digit to "Excess 3" code converter.

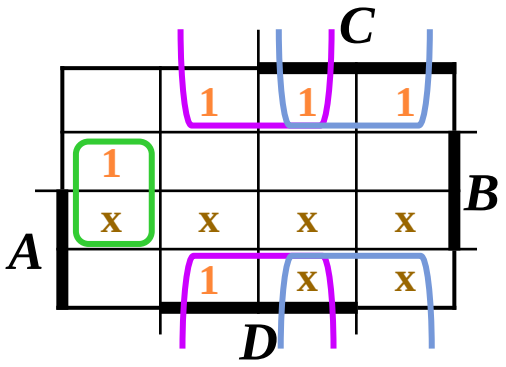


Design Procedure
BCD-to-Excess 3 Converter

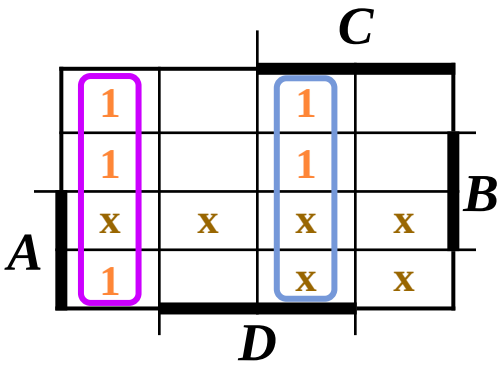
A B C D	w x y z
0 0 0 0	0 0 1 1
0 0 0 1	0 1 0 0
0 0 1 0	0 1 0 1
0 0 1 1	0 1 1 0
0 1 0 0	0 1 1 1
0 1 0 1	1 0 0 0
0 1 1 0	1 0 0 1
0 1 1 1	1 0 1 0
1 0 0 0	1 0 1 1
1 0 0 1	1 1 0 0
1 0 1 0	x x x x
1 0 1 1	x x x x
1 1 0 0	x x x x
1 1 0 1	x x x x
1 1 1 0	x x x x
1 1 1 1	x x x x



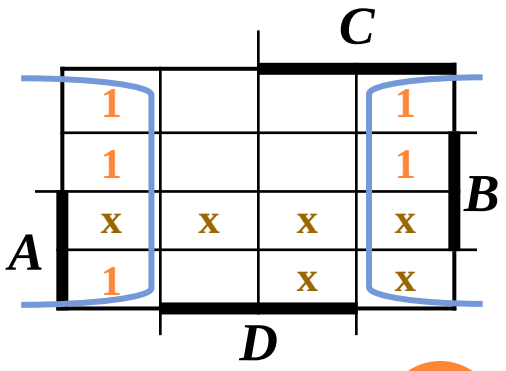
$w = A + BC + BD$



$x = B'C + B'D + BC'D'$



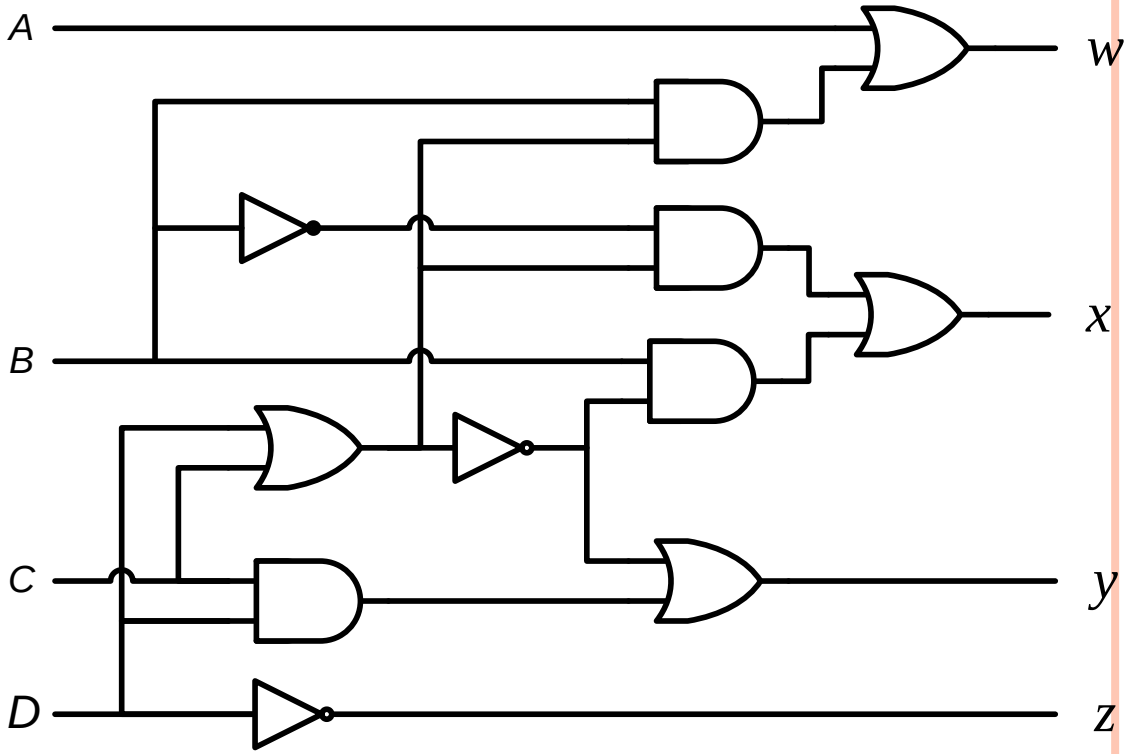
$y = C'D' + CD$



$z = D'$

Design Procedure
BCD-to-Excess 3 Converter

A	B	C	D	w	x	y	z
0	0	0	0	0	0	1	1
0	0	0	1	0	1	0	0
0	0	1	0	0	1	0	1
0	0	1	1	0	1	1	0
0	1	0	0	0	1	1	1
0	1	0	1	1	0	0	0
0	1	1	0	1	0	0	1
0	1	1	1	1	0	1	0
1	0	0	0	1	0	1	1
1	0	0	1	1	1	0	0
1	0	1	0	x	x	x	x
1	0	1	1	x	x	x	x
1	1	0	0	x	x	x	x
1	1	0	1	x	x	x	x
1	1	1	0	x	x	x	x
1	1	1	1	x	x	x	x



$w = A + B(C+D)$

$x = B'(C+D) + B(C+D)'$

$y = (C+D)' + CD$

$z = D'$

Verification

Check the functional correctness of the logic circuit:

- Apply all possible input combinations
- And check if the circuit generates the correct outputs for each input combinations
- For large circuits with many input combinations, this may not be feasible.
- Statistical techniques may be used to verify the correctness of large circuits with many input combinations.

Exercise

- Design a combinational circuit that converts a four bit Gray code to a four bit Binary number.
- Design a code converter that converts a decimal digit from the 8,4,-2,-1 code to BCD.
- Design a four bit 2's complementer circuit.
- Design a three bit square circuit.