CSE231 Digital Logic Design

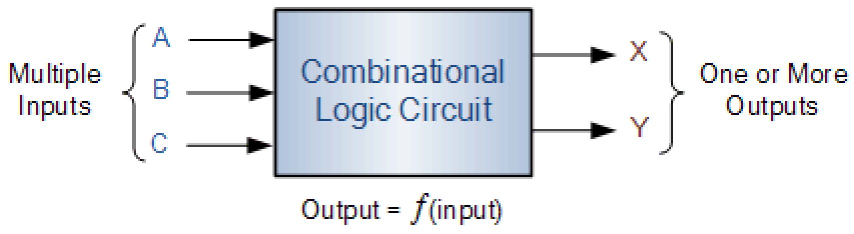
Experiment 3: Combinational Logic Design (Canonical Form)

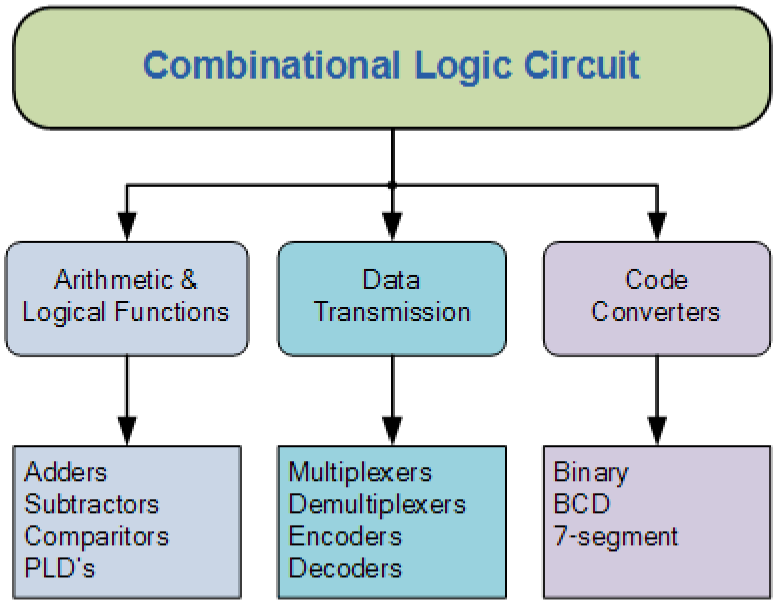
A. Objectives

- Become familiarized with the analysis of combinational logic networks.
- Learn the implementation of networks using the two canonical forms.

B. Theory

❖ Combinational logic Circuit





❖ Min terms and max terms

Variables			Min terms	Max terms
A	B	C	m_i	M_i
0	0	0	A' B' C' = m 0	A + B + C = M 0
0	0	1	A' B' C = m 1	A + B + C' = M 1
0	1	0	A' B C' = m 2	A + B' + C = M 2
0	1	1	A' B C = m 3	A + B' + C' = M 3
1	0	0	A B' C' = m 4	A' + B + C = M 4
1	0	1	A B' C = m 5	A' + B + C' = M 5
1	1	0	A B C' = m 6	A' + B' + C = M 6
1	1	1	A B C = m 7	A' + B' + C' = M 7

❖ Analysis of combinational logic design

The design procedure for combinational logic circuits starts with the problem specification and comprises the following steps:

1. Determine required number of inputs and outputs from the specifications.
2. Derive the truth table for each of the outputs based on their relationships to the input.
3. Simplify the boolean expression for each output. Use Karnaugh Maps or Boolean algebra.
4. Draw a logic diagram that represents the simplified Boolean expression. Verify the design by analysing or simulating the circuit.

For Example, let's say that you are working as an engineer in Ruppur Nuclear Power Plant. It has 3 primary water pumps and a secondary-pump for cooling purposes. You have been asked to design a system which will automatically turn on the secondary –pump in case of the following:
i. Pump 1 (A) is off **and** Pump 3 (C) is on **OR**
ii. Pump 1 (A) is on **and** Pump 2 (B) is off **OR**
iii. Pump 2 (B) is on **and** Pump 3 (C) is on
As we have 3 primary pumps, we can say that we have 3 input variables with 2 possible options (On/Off).
So, we will have $2^3 = 8$ possible INPUT combinations. They will be,

Pump-1 (A)	**Pump-2 (B)**	**Pump-3 (C)**	**Output at Secondary pump (F)**
OFF (0)	OFF (0)	OFF (0)	OFF (0)
OFF (0)	OFF (0)	ON (1)	ON (1)
OFF (0)	ON (1)	OFF (0)	OFF (0)
OFF (0)	ON (1)	ON (1)	ON (1)
ON (1)	OFF (0)	OFF (0)	ON (1)
ON (1)	OFF (0)	ON (1)	ON (1)
ON (1)	ON (1)	OFF (0)	OFF (0)
ON (1)	ON (1)	ON (1)	ON (1)

❖ Canonical Forms

In Boolean algebra, Boolean function can be expressed as Canonical Disjunctive Normal Form known as **minterm** and some are expressed as Canonical Conjunctive Normal Form known as **maxterm.**
In Minterm, we look for the functions where the output results in "1" while in Maxterm we look for function where the output results in "0".
We perform Sum of minterm also known as Sum of products (SOP).
We perform Product of Maxterm also known as Product of sum (POS).
Boolean functions expressed as a sum of minterms or product of maxterms are said to be in canonical form.

C. Apparatus

- Trainer Board
- 2 x IC 7411 Triple 3-input AND gates
- 2 x IC 4075 Triple 3-input OR gates
- 1 x IC 7404 Hex Inverters (NOT gates)

D. Procedure

1. Write down all the min terms and max terms of three inputs ABC in Table F.1.
2. Write down the function F in 1st and 2nd Canonical Forms in in Table F.2
3. Draw the circuits for the 1st and 2nd canonical forms of function in Figure F.1, clearly indicating the pin numbers corresponding to the relevant ICs.
4. Construct the 1st canonical form of the circuit and test it with the truth table.
   i. Connect one min term at a time and check its output.
   ii. Once all min terms have been connected and verified, OR the min terms for the function output.
5. Construct the 2nd canonical form of the circuit and test it with the truth table.
   i. Connect one max term at a time and check its output.
   ii. Once all max terms have been connected and verified, AND the max terms for the function output.

E. Report

Simulation:

1. Draw the IC diagram for the 1st canonical form of the circuit in Figure F.1

IC diagram:

2. Simulate the circuit for the 2nd canonical form in Figure F.1 in Logisim. Provide a screenshot of the Logisim circuit schematic and truth table with your report.

Questions:

1. Convert Boolean expression in standard form F=y'+xz'+xyz
2. Using Canonical forms, given two input bits A and B, produce three outputs X, Y, and Z so that

X is 1 only when only when A > B,

Y is 1 only when A < B, and

Z is 1 only when A = B

F. Experimental Data

Input Reference	$A\ B\ C$	F	Min term	Max term
0	0 0 0	0		
1	0 0 1	1		
2	0 1 0	0		
3	0 1 1	1		
4	1 0 0	1		
5	1 0 1	0		
6	1 1 0	1		
7	1 1 1	0		

Table F.1 Truth table to a combinational circuit

	Shorthand Notation	Function
1st Canonical Form	$F = \Sigma$	$F =$
2nd Canonical Form	$F = \Pi$	$F =$

Table F.2 1st and 2nd canonical forms of the combinational circuit of Table F.1

1st Canonical Form
2nd Canonical Form

Figure F.1 1st and 2nd canonical circuit diagrams of the combinational circuit of Table F.1