Lab 3: Combinational Logic Design

A. Objectives

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

B. Theory

Minterms and Maxterms:

A binary variable may appear either in its normal form (x) or in its complement form (x'). Now consider two binary variables x and y combined with an AND operation. Since each variable may appear in either form, there are four possible combinations: x'y', x'y, xy', and xy. Each of these four AND terms is called a minterm, or a standard product. If we have n variables, they can be combined to form 2^n minterms.

In a similar fashion, n variables forming an OR term, with each variable being primed or unprimed, provide 2^n possible combinations, called maxterms, or standard sums.

The four minterms and maxterms for 2 variables, together with symbolic designations, are listed in **Table 1**.

		Minterms		Maxterms	
x	**y**	**Term**	**Designation**	**Term**	**Designation**
0	0	x'y'	m_0	x + y	M_0
0	1	x'y	m_1	x + y'	M_1
1	0	xy'	m_2	x' + y	M_2
1	1	xy	m_3	x' + y'	M_3

Table 1

It is important to note that the maxterm with subscript *j* is a complement of the minterm with the same subscript *j* and vice versa.

That is, $\mathbf{m'_j = M_j}$

Canonical Forms:

Boolean functions expressed as a sum of minterms or product of maxterms are said to be in **1st Canonical Form** and **2nd Canonical Form** respectively**.** Functions in their canonical form can also be expressed in a brief notation. For example, the function **F = x'y' + xy'** (1st canonical form) can be expressed as **F(x,y) = Σ(0,2)** and the function **X = (A+B)(A+B')** (2nd canonical form) can be expressed as **X(A,B) = Π(0,1)**. The numbers following the sum and product symbols are the indices of the minterms and maxterms of the respective functions.

New Apparatus

1) IC 4073 Triple 3-input AND gate
2) IC 4075 Triple 3-input OR gate

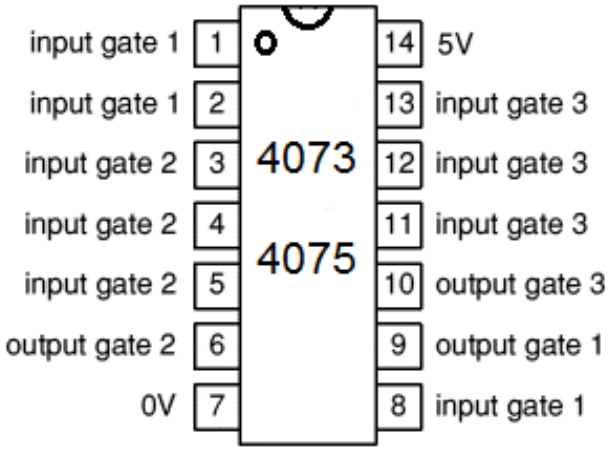

Figure 1: Pinout diagam for IC 4073 and IC 4075

C. Apparatus

- Trainer Board
- 1 x IC 4073 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. Use the given truth table to express the function F in 1st and 2nd Canonical Forms in in Table F.2. Write down both the brief and full expressions of the sum of minterms and product of maxterms expressions of the function.
3. Draw the circuits for the 1st and 2nd canonical forms of the 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.

Questions

1. What is a minterm? What is meant by 'sum-of-products (or first) canonical form'? Is the following expression in the first canonical form? Explain your answer.
   - **F = AB′ + ABC′**
2. If a Boolean expression is in canonical form, can we also say that it is in its minimal form? Use an example to illustrate your answer.
3. You have been given 4 binary variables: A, B, C and D. List all of the minterms and maxterms of the variables in order. Now, use your list to convert the following product of maxterms expression into sum of minterms:
   - **Z = (A+B′+C+D′)(A′+B′+C′+D)(A′+B+C+D)(A′+B′+C′+D′)(A+B+C+D′)(A+B′+C′+D)**
4. In this experiment, you used the 4073, 3-input AND IC. There's another 3-input AND IC named 7411. Draw the internal gates of the 7411 IC.
5. Draw the IC diagram for the 1st canonical form of the circuit in Figure F.1

E. Experimental Data

Instructor's Signature: .....

Group:	Date:	Section

Input Reference	*A B C*	*F*	Min term	Max term
0	0 0 0	0		
1	0 0 1	1		
2	0 1 0	1		
3	0 1 1	0		
4	1 0 0	0		
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