ECPE 71L -- Laboratory 3
Design and Debugging of Combinational Circuits

PRE-LAB required. Make sure you label all figures in your pre-lab so that you can reference by figure number in your notes.

Datasheets needed: 7400, 7410, 7420

No worksheet is provided for this lab. You are required to take notes on engineering paper. Be sure to answer all of the items in the lab, noting the section and item number (e.g. B-7 – Truth table).

Objectives:
Upon completion of this lab, you should be able to:
1. Translate a problem statement into a circuit function
2. Implement a multi-function combinational circuit
3. Debug a circuit that is not working properly

Experiment descriptions

Before building or changing any circuit, be sure the power switch of the Cadet II is turned off. Never add or remove chips from the breadboard area while the power is on. This is not so much for your safety as for the safety of the chips!

The design process

Up to this point in lab, we have been examining individual gate operation. We have not started from a problem description and followed a design process through to implementation. Be sure to follow these design steps:

1. Read through the entire problem statement.
2. Write a description of the expected behavior of the circuit. For example, when signal A and B (representing the dog barking and the cat meowing) are active, then activate signal C (representing the water sprinklers).
3. Define the circuit as a structure of primitive logic gates.
4. Implement the design on the breadboard
5. Test the design
6. Debug each module, if necessary
A) An Experiment

You are designing a 1’s bit counter. In other words, the system takes as input one 3–bit value, \( X \), counts the number of bits which are logic 1, and displays the decimal representation on the 7–segment LED display. For example, if the input \( X \) is 101, the output will display 2 on the 7–segment LED.

1. Follow the design process:
   - Clearly state the problem (objective)
   - Identify and label the inputs
   - Identify and label the outputs
2. Derive the truth table for how you expect the circuit to act.
3. Derive the functions in canonical SOP form (sum–of–minterms).
4. Implement the design using only NAND gates. This means you should use NANDs as inverters, if necessary. You have 2–input, 3–input and 4–input NANDs available to you. (Show connections to all unused inputs.) NOTE: You are limited to four chips (integrated circuit packages) on the board. Be sure to label all inputs and outputs. Remember that no input should be left unconnected, including to the 7–segment LED. Write pin numbers on all inputs and outputs. If you use two or more of the same type chip, also label each gate to indicate the specific chip containing that gate.
5. (Optional): Derive truth tables table for each individual gate; in other words, determine what the output of each NAND gate should be for the three inputs. This could be useful later when implementing and debugging your circuit later.
6. Provide a parts list of what will be needed to implement the design. Include the logic device number, name and the number of the devices you will need.
7. Once in the lab you will implement your design. A strongly suggested approach is:
   - Check each chip to make sure it works (i.e., test each gate).
   - Implement the inverted values. Test to make sure they work.
   - Implement one term at a time, test to make sure it works.
   - Combine all the terms to generated the function(s).
8. Record in your notes any surprises that you experience while implementing your design. Be sure to note if you had to change your original design and, if so, how it changed.
9. Record a truth table for the final implementation of your circuit.
10. Describe debugging procedure used.
11. Now that your design works, it is time to practice some debugging techniques. Swap benches with another group (or two) and completely remove one signal wire from their design (don’t remove power or ground wires). Don’t let them watch, and don’t watch while they do the same to your circuit!
12. Try to predict what will happen to the other group’s circuit. Where will the first "failure" happen? What would be the symptom or result of removing that wire? Test their modified circuit and record what symptoms the circuit actually shows; compare to your predictions.
13. Very carefully note the steps you take to debug the circuit. For example, step 1 may be to confirm that power and ground are being provided to all your chips. You then may want to work your way through the circuit, checking the output of each NAND gate and noting if you get what you expect.
14. When you locate the problem, verify with the other group that you have found the correct problem.
15. Do not forget to thank your fellow student for providing you with this challenging experience.