EEL 3705L, Digital Logic Design Lab, Spring 2011

Lab Assignment #2: Black Box Investigation

Version history:
v1.0, 09/18/08: Re-write based on the previous lab named "Plane Crash". – H. Hoang
Spr. '11, v1.0, 1/20/11: Re-wrote previous lab #2 from Spring 2010 semester. –MPF

1. Document description:

This document describes the third full lab assignment for the Spring '11 semester of EEL 3705L, Digital Logic Design Lab. This assignment exercises students' ability to design & conduct lab experiments and to analyze & interpret data.

2. Assignment Synopsis:

In this assignment, students will come up with a procedure to reverse-engineer a given black-box combinational circuit. This is a problem that frequently arises in industry, *e.g.*, when taking apart and analyzing a pre-existing legacy system for which the original documentation has been lost or is unavailable, to figure out what it's doing, so that the same function can be reimplemented in a newer technology.

3. Educational Objectives:

This assignment is intended to:

1. Exercise students' understanding of K-maps and logic minimization.
2. Exercise students' ability to design & carry out experimental procedures suitable for reverse-engineering the design of a simple combinational logic circuit.

4. Design Objective:

When you arrive in lab, it will be pre-programmed with an unknown combinational circuit that uses the first four slider switches (SW0-SW3) to control the state of the first four red LEDs (LEDR0-LEDR3) in some unknown way. Your task in the pre-lab is to design and specify an experimental procedure that you will go through in lab to collect data that will be sufficient for you to fully determine the functionality of this circuit, and also design an analytical procedure that you will go through during lab to reverse-engineer the structure of another circuit that produces the same results. Then in lab, you will execute your experimental procedure, construct your reverse-engineered circuit, and verify that it works.

5. Pre-Lab Preparation:

Reminder: You MUST complete the pre-lab assignment BEFORE coming to lab, and turn in your pre-lab report at the start of lab.

5.1. Guiding Questions

Include answers to the following questions in your pre-lab report.

Question 1. Given the general description of the unknown circuit in section 4, what is a systematic procedure that you can go through in lab that will allow you to fully determine the function of the circuit? What detailed sequence of steps will you go through to

collect the data? Prepare an empty table (with appropriately labeled rows and columns) that you can fill in during lab to collect all of the data you will need.

Question 2. Once you have collected all the data, what is a systematic method you can use to analyze this data in such a way as to produce a design for an efficient logic circuit to re-implement the same function? Plan a general strategy for producing a design that uses the smallest number of basic 1- and 2-input gates that you can. Your goal should be to produce a design that is at least no worse than using the minimum product-of-sums or sum-of-products circuit for each output bit, although in some cases, you might do a little better than this by using some XOR gates, and/or by sharing subcircuits between output bits. Describe your analytical plan in your pre-lab report.

Question 3. To test the plan you came up with for question 2, try making up a random 3-input, 3-output Boolean function (you can do this by, say, flipping coins to fill in all 24 output entries in the truth table), and then designing a Boolean circuit to implement that same function. Include this as an example of your analysis method in your pre-lab report.

5.2 Pre-Lab Report Format

For this assignment, you may follow the generic pre-lab report format that is given in the *General Lab Requirements* document, modified as required to incorporate your answers to the questions above in a sensible way. Note that this format is a little bit simpler than the one you had to use for lab #1. (Some of the larger projects you will do later in the semester will return to a more detailed format.)

6. In-Lab Procedure:

1. As usual, turn in a copy of your pre-lab report as soon as you arrive in lab.
2. When you arrive in lab, the DE2 board at your team's station will have been pre-programmed with a secret black-box function.
3. Execute your experimental plan for testing this circuit and gathering data about its functionality. Record the data in your lab notebook.
4. Execute your plan for designing a new logic circuit (using 1-input and 2-input gates) that implements the same function. Input your design into a Quartus schematic and demonstrate its function to the TA. If you run out of time to complete your design during the lab period, demonstrate at least 2 working output bits for partial credit. (However, your lab report should include correct designs for all 4 output bits.)
5. The conclusion of your lab report should also include a "lessons learned" section. This section will explain how well your experimental and design procedures worked, and where these procedures could have been improved.

Before leaving the lab, demonstrate to the TA that your circuit indeed does do the correct thing in all input cases, and get the TA to sign off on your lab notebook.

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