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This assignment is due on 28 Feb 2020

Please remember to write your name and student number.

Please submit a single PDF for each assignment. Handwritten submissions and proprietary formats (e.g. Pages or MS Word) will not be accepted. The Lab portion must be submitted separately.

Assignment 3

1. Design a combinational circuit that accept a 3-bit number and generates a 6-bit binary number output equal to the square of the input number.
   A. Write down the specification (input, output variables, and their relation).
   B. Formulation write down the relations in boolean algebra or truth table.
   C. Perform optimisation to simplify the design.
   D. Perform technology mapping using AND, OR, NOT gates, draw the logical diagram.
2. Design a 4-input AND gate using 2-input NOR gates and NOT gates, and draw the circuit diagram.
3. A traffic metering system for controlling the release of traffic from an entrance ramp onto a superhighway has the following specifications for a part of its controller. There are three parallel metering lanes, each with its own stop (red)–go (green) light. One of these lanes, the car pool lane, is given priority for a green light over the other two lanes. Otherwise, a "round robin" scheme in which the green lights alternate is used for the other two (left and right) lanes. The part of the controller that determines which light is to be green (rather than red) is to be designed. The specifications for the controller follow:

Inputs

PS Car pool lane sensor (car present—1; car absent—0)
LS Left lane sensor (car present—1; car absent—0)
RS Right lane sensor (car present—1; car absent—0)
RR Round robin signal (select left—1; select right—0)

Outputs

PL Car pool lane light (green—1; red—0)
LL Left lane light (green—1; red—0)
RL Right lane light (green—1; red—0)

Operation

1. If there is a car in the car pool lane, PL is 1.
2. If there are no cars in the car pool lane and the right lane, and there is a car in the left lane, LL is 1.
3. If there are no cars in the car pool lane and in the left lane, and there is a car in the right lane, RL is 1.
4. If there is no car in the car pool lane, there are cars in both the left and right lanes, and RR is 1, then LL = 1.

5. If there is no car in the car pool lane, there are cars in both the left and right lanes, and RR is 0, then RL = 1.
6. If any PL, LL, or RL is not specified to be 1 above, then it has value 0.

A. Find the truth table for the controller part.

B. (Draw the circuit only) Find a minimum multiple-level gate implementation using AND gates, OR gates, and inverters.

4. (Draw the circuit only) Design a circuit to implement the following pair of Boolean equations:

$$F = A(C\overline{E} + DE) + \overline{A}D$$
$$G = B(C\overline{E} + DE) + \overline{B}C$$

To simplify drawing the schematic, the circuit is to use a hierarchy based on the factoring shown in the equation. Three instances (copies) of a single hierarchical circuit component made up of two AND gates, an OR gate, and an inverter are to be used. Draw the logic diagram for the hierarchical component and for the overall circuit diagram using a symbol for the hierarchical component.

5. (Draw the circuit only) A hierarchical component with the function $H = \overline{X}Y + XZ$ is to be used along with inverters to implement the following equation:

$$G = \overline{A}\,\overline{B}C + \overline{A}BD + A\overline{B}\,\overline{C} + AB\overline{D}$$

The overall circuit can be obtained by using Shannon's expansion theorem,

$$F = \overline{X} \cdot F_0(X) + X \cdot F_1(X)$$

where $F_0(X)$ is F evaluated with variable $X = 0$ and $F_1(X)$ is F evaluated with variable $X = 1$. This expansion F can be implemented with function H by letting $Y = F_0$ and $Z = F_1$. The expansion theorem can then be applied to each of F_0 and F_1 using a variable in each, preferably one that appears in both true and complemented form. The process can then be repeated until all F_i's are single literals or constants. For G, use $X = A$ to find G_0 and G_1 and then use $X = B$ for G_0 and G_1. Draw the top-level diagram for G using H as a hierarchical component.

6. (Draw the circuit only) Design a 16-to-1 multiplexer using 4-to-16 decoder and a 16 2-input AND gate and a 16-input OR gate.

Lab 2

You must complete the following assignment and submit a PDF of instructions enough to replicate your results, and required documentation. You will also need to upload LogicWork circuit design files as specified, and your own library file. Then upload a single ZIP file to Moodle.

1. Save the library and circuit files we created in class containing the following designs in the final ZIP file:
    1. 2-to-4 Decoder (`circuit1-1.cct`);
    2. 3-to-8 Decoder implemented using the 2-to-4 Decoder (`circuit1-2.cct`);
    3. 8-to-3 priority encoder with validity bit (`circuit1-3.cct`);
    4. 4bit 4-to-1 Multiplexer implemented using the 3-to-8 Decoder (`circuit1-4.cct`).

2. Implement the following Boolean function with an 8-to-1 (or 16-to-1)multiplexer and a single inverter with variable D as its input:

   $$F(A, B, C, D) = \Sigma m(2,4,6,9,10,11,15)$$

   Implement the digital circuit in LogicWorks. Use the 8-to-1 multiplexer we implemented in class (from your own library). Save the file as `circuit2.cct` .

3. A home security system has a master switch that is used to enable an alarm, lights, video cameras, and a call to local police in the event one or more of six sets of sensors detects an intrusion. In addition there are separate switches to enable and disable the alarm, lights, and the call to local police. The inputs, outputs, and operation of the enabling logic are specified as follows:

   Inputs

   S_i, $i = 0,1,2,3,4,5$: signals from six sensor sets (0 = intrusion detected, 1 = no intrusion detected)
   M: master switch (0 = security system enabled, 1 = security system disabled)
   A: alarm switch (0 = alarm disabled, 1= alarm enabled)
   L: light switch (0 = lights disabled, 1= lights enabled)
   P: police switch (0 = police call disabled, 1 = police call enabled)

   Outputs

   A: alarm (0 = alarm on, 1 = alarm off)
   L: lights (0 = lights on, 1 = lights off)
   V: video cameras (0 = video cameras off, 1 = video cameras on) C: call to police (0 = call off, 1 = call on)

   Operation

   If one or more of the sets of sensors detects an intrusion and the security system is enabled, then outputs activate based on the outputs of the remaining switches. Otherwise, all outputs are disabled.

   Find a realisation of the enabling logic using AND and OR gates and inverters. Save the file as `circuit3.cct` .