Lab 3
The LightsOut Puzzle: Bonus Tasks

You can earn up to 30 bonus points (compared to 100 points for the required tasks) by extending the puzzle with the following additional features:

**Bonus Problem 1: Difficulty Levels and Time Enforcement**

Extend the puzzle with 7 difficulty levels. At each of the seven levels L (L=1..7), the user should have 8-L time units to complete the puzzle. The length of the time unit should be defined at the time of synthesis of the VHDL code. The default value should be 30 seconds. Thus, at level 1, the user should have 7 time units = 3.5 minutes to complete the puzzle. At level 7, this time should be reduced to 8-7=1 time unit = 30 seconds.

After reset, the level L=1 should be shown using the rightmost seven segment display. After correctly solving the puzzle at each level, the new level number should be shown at the same time as the winning display pattern.

When the start button is pressed, the rightmost display should be used to indicate the number of remaining time units.

With 7 time units remaining, all segments of the rightmost seven-segment display should be turned on. With 6 time units remaining, segment A should be off. With 5 time units remaining, segments A and B should be off, etc. Finally, with only 1 time unit remaining, only the segment G should remain on.

If the puzzle is solved at a given level, the winning display pattern should appear, and the rightmost seven-segment display should show the next level value. The game should resume after the user presses the start button.

If the puzzle is not solved at a given level, the losing display pattern should appear, and the rightmost seven-segment display should show the level value 1.
**Bonus Problem 2: Winning and Losing Display Patterns**

![Matrix Example]

Assuming the numbering of lights shown above,

a) The winning display pattern is defined as follows:
   - 1
   - 2, 4
   - 3, 5, 7
   - 6, 8
   - 9.

b) The losing display pattern is defined as follows:
   - 1, 4, 7
   - 2, 5, 8
   - 3, 6, 9.

Each combination of lights should be displayed for 0.5 seconds. The entire sequence should be repeated until either the start button or the reset button is pressed.

**Corresponding Tasks:**

1. Revise the block diagram describing the Datapath of the LightsOut Puzzle.
2. Revise the Algorithmic State Machine (ASM) chart or draw a new ASM chart describing the Controller of the extended LightsOut Puzzle. Please note that multiple state machines, working in parallel, can be used to achieve the required behavior.
3. Translate the block diagram and ASM charts to VHDL.
4. Develop a simple testbench with two versions of timing constants, one used for simulation, and the other used for the actual operation of the circuit on the board.
5. Perform functional simulation of your code
7. Prepare the correct XDC (Xilinx Design Constraint) file.
8. Implement your circuit using Xilinx Vivado.
9. Check thoroughly all implementation reports. Pay attention to timing, resource usage, and pin allocations.
11. Perform static timing analysis.
12. Check very carefully your pin allocations listed in the report files, and only if these pin allocations are correct, download your bitstream to the FPGA board.
13. Test the operation of your circuit experimentally using the Basys 3 FPGA Board.
Bonus Deliverables:

1. All block diagrams describing the extended Datapath of your circuit.
2. All ASM charts describing the extended Controller of your circuit.
3. All source files used for synthesis and implementation of your circuit.
4. A simple testbench.
5. User constraint files.
6. All synthesis and implementation report files.
7. RTL netlist.
8. Simulation waveforms from the functional and post-synthesis simulations, proving the correct operation of your circuit (in the PDF format).
10. Your own report containing at least the following additional information:
   - Resource utilization.
   - Minimum clock period and maximum clock frequency after synthesis and after implementation.
   - List of any deviations from the original specification.
   - Difficulties encountered and lessons learn

Important Dates

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<thead>
<tr>
<th>Deliverables Due</th>
<th>Tuesday Section</th>
<th>Wednesday Section</th>
<th>Friday Section</th>
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<td>02/25/2020</td>
<td>02/26/2020</td>
<td>02/28/2020</td>
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<tr>
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<td>8:30am</td>
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