Laboratory 1

(Due date: **011**: September 17th, **005**: September 18th, **007**: September 19th)

Objectives

- ✓ Introduce VHDL Coding for FPGAs.
- ✓ Learn to write testbenches in VHDL.
- ✓ Learn the Xilinx FPGA Design Flow with the Vivado HL: Synthesis, Simulation, and Bitstream Generation.
- ✓ Learn how to assign FPGA I/O pins and download the bitstream on the Nexys™ A7-50T Board (or A7-100T).

VHDL Coding

- ✓ Refer to the Tutorial: VHDL for FPGAs for a list of examples.

Nexys™ A7-50T FPGA Trainer Board Setup

- The Nexys A7-50T Board can receive power from the Digilent USB-JTAG Port (J6). Connect your Board to a computer via the USB cable. If it does not turn on, connect the power supply of the Board.
- Nexys A7-50T documentation: Available in class website.

First Activity (100/100)

Design Problem

- **Majority function**: An LED is lit (f=1) if any three or all four of the switches (represented by Boolean variables a, b, c, d) are in the same position, where '1' represents the ON position of a switch, and '0' the OFF position.
  The Boolean variable f is represented by an LED ('1': LED is ON, '0': LED is OFF).
  For example: if abcd=1010 →- f=0. If abcd=0010 → f=1.

  - ✓ Complete the truth table for this circuit: (5 pts)

  - ✓ Derive (simplify if possible) the Boolean expression: (10 pts)

    f =

a	b	c	d	f
0	0	0	0	
0	0	0	1	
0	0	1	0	
0	0	1	1	
0	1	0	0	
0	1	0	1	
0	1	1	0	
0	1	1	1	
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	
1	1	0	0	
1	1	0	1	
1	1	1	0	
1	1	1	1	

Procedure

- **Vivado Design Flow for FPGAs: complete the following steps (follow the order strictly)**: (85 pts)

  - ✓ Create a new Vivado Project. Select the corresponding Artix-7 FPGA device as per the table:

Kit	Artix-7 FPGA Device	Master XDC File	Comments
Nexys A7-50T	XC7A50T-1CSG324I	`Nexys-A7-50T-Master.xdc`	Recommended board.
Nexys A7-100T	XC7A100T-1CSG324C	`Nexys-A7-100T-Master.xdc`	
Basys 3	XC7A35T-1CPG236C	`Basys-3-Master.xdc`	Suggested if you only take ECE2700
Nexys 4 Nexys 4 DDR	XC7A100T-1CSG324C	`Nexys4_Master.xdc` `Nexys4DDR_Master.xdc`	Discontinued

  - ✓ Write the VHDL code that implements the simplified Boolean expression. Synthesize your circuit (Run Synthesis).

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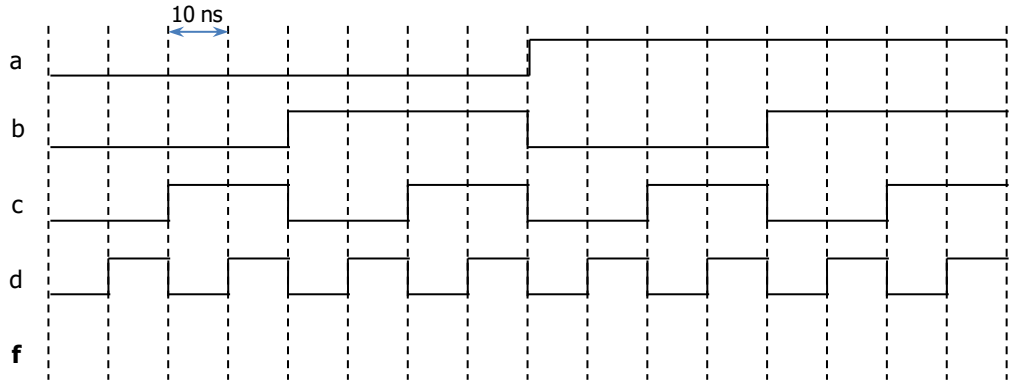
- ✓ Write the VHDL testbench to test every possible combination of the inputs.
  - The figure below provides a suggestion of what the input waveform described by your testbench should look like. Complete the output f so that you can compare it with the output generated by the simulator (next step).



- ✓ Perform Functional Simulation (Run Simulation → Run Behavioral Simulation). Verify that the output f generated by the simulator matches the one you manually completed. **Demonstrate this to your TA.**

- ✓ I/O Assignment: Generate the XDC file. Download the corresponding constraints file (XDC) of your board and edit it.
  - Use `SW3, SW2, SW1, SW0` as inputs a, b, c, d respectively. Use `LED0` as the output f.

Board pin names	SW3	SW2	SW1	SW0	LED0
Signal names in code	a	b	c	d	f

  - The board pin names (`SW3-SW0, LED0`) are used by all the listed boards (Nexys A7-50T/A7-100T, Basys 3, Nexys 4/DDR). The I/Os listed here are all active high.

- ✓ Implement your design (Run Implementation).

- ✓ Do Timing Simulation (Run Simulation → Run Post-Implementation Timing Simulation). **Demonstrate this to your TA.**

- ✓ Generate the bitstream file (Generate Bitstream).

- ✓ Download the bitstream on the FPGA (Open Hardware Manager) and test. **Demonstrate this to your TA.**

- Submit (as a .pdf) this lab sheet completed and signed off by the TA (or instructor)

- Submit (as a .zip file) the generated files: VHDL code, VHDL testbench, and XDC file to Moodle (an assignment will be created). DO NOT submit the whole Vivado Project.
  - ✓ Your .zip file should only include one folder. Do not include subdirectories.
    - It is strongly recommended that all your design files, testbench, and constraints file be located in a single directory. This will allow for a smooth experience with Vivado.
  - ✓ You should only submit your source files AFTER you have demoed your work. Submission of work files without demo will get NO CREDIT.

lab1
- `top.vhd` — Design file
- `top_tb.vhd` — Testbench file
- `lab1.xdc` — Constraints file

TA signature: _____ **Date:** _____

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