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Please remember to write your name and student number.

You must complete the following assignment and submit a PDF of relevant questions. Handwritten submissions and proprietary formats (e.g. Pages or MS Word) will not be accepted. You will also need to upload LogicWork circuit design file. Then upload a single ZIP file to Moodle.

Submission File structure:

The files circuit1-1, circuit1-2, circuit3 are 1pt each, circuit2 2pt, circuit3 3pt, answer.pdf 2pt.

Lab 4

1. (PDF) Datapath conceptual question: assume a datapath with a 4-bit register array (4 GPRs inside) that can perform certain functions. The datapath takes input Func_{2:0} from the control unit for function selection, reg_{1:0} and reg 2_{1:0} for register selection, Func in_{3:0} for value input.

Func2:0	Register Operation
000	No change
001	Clear a single register to 0, selected by $reg_{1:0}$
010	Perform register transferring, assign the value of register at address $reg_{1:0}^2$ to register at $reg_{1:0}$.
011	Load value from $Func_{in_{3:0}}$ into a single register, selected by $reg_{1:0}$
110	Perform addition of 2 register values, selected by $reg_{1:0}$ and $reg_{2:0}$, store the output to register with address $reg_{1:0}$. (Use the adder-subtractor functional block)
111	Perform subtraction of 2 register values, selected by $reg_{1:0}$ and $reg_{2:0}$, store the output to register with address $reg_{1:0}$. (Use the adder-subtractor functional block)

Write down the sequence for all necessary inputs for computing 4 + 5 - 7. You will need to load number 4, 5, 7 into the datapath, then perform the necessary calculation, and finally store the result in register number 0. (2pt)

Hint: here's a sample for loading value 4 into register number 0, and 5 into register 1 (one line per):

$$Func_{2:0} = 011, reg_{1:0} = 01, Func_{in_{3:0}} = 0101$$

- 2. Register design:
 - A. Draw the circuit diagram of a D Flip-Flop with EN, using the D flip-flop wo/SQ component in the system library. Save it as a component in your library, as well as in a circuit file (circuit1-1.cct).
 - B. Draw the circuit diagram of a 4bit Register using the above D Flip-Flop with EN, your register must have $D_3D_2D_1D_0$, *EN*, *C*, and *R* as input ports, and $Q_3Q_2Q_1Q_0$ as output (circuit1-2.cct).
- 3. Register array: draw the circuit diagram of a Register array with 4 registers, that meets the following specification (circuit2.cct):
 - A. the register array will have one 4bit data_in bus providing new values to be stored, 2bit reg_in bus specifying the register to take in new values;
 - B. one 4bit data out bus outputting values from the register array, selected by the 2bit reg out bus;
 - C. a single ${\tt Clear}$ switch that can clear all registers to 0; and
 - D. a single ${\tt CLK}$ switch simulating the clock unit.
 - E. you should use your own register in Q1, 2-to-4 decoder, 4channel 4bit multiplexer. I also recommend using the HEX display and keyboards to help run simulations.
- 4. Datapath functional block: implement a 4bit Bitwise NOT component (circuit3.cct).
- 5. Final assembly:
 - A. Copy your design from circuit2.cct, name it circuit4.cct.
 - B. Overall Inputs:
 - I. func_in, a hex keyboard
 - II. mode, a switch for functional block mode
 - III. func, a hex keyboard, using least significant 2bits for function selection
 - IV. reg in, a hex keyboard, using least significant 2bits
 - V. reg_out, a hex keyboard, using least significant 2bits
 - VI. reg_out_2, a hex keyboard, using least significant 2bits
 - $\ensuremath{\mathsf{VII}}\xspace.\ensuremath{\mathsf{CLK}}\xspace, a switch for simulating clock$
 - VIII. Clear, a switch for clearing all registers

- C. You should have 4 functional blocks, selected by 2bit input bus func:
 - I. Function 0: register assignment, takes input from a HEX keyboard (func_in);
 - II. Function 1: register transferring, takes input from the register output bus (data_out);
 - III. Function 2: Bitwise NOT, takes input from the register output bus (data_out), outputs its bitwise complement.
 - IV. Function 3: Adder-Subtract, takes input from the register output bus (data_out), and another register (data_out_2), specified by 2bit reg_out_2 bus. There should also be a mode switch input, selecting between performing addition and subtraction.
- D. The output from the functional block selected by func will be fed back into the register array on data_in, replacing the keyboard in circuit2.cct.