Bilkent University
CS223 Laboratory Project
Calculator

Groups: Each student will do the project individually. **Group size = 1**

Important dates:

Project submission and demo presentation day: Upload your **project code files** and **project report** to Unilica until **08:00** o'clock on **13/05/2019**. You will download your project code and **make your project demo** on your regular lab date and time.

Description:

The purpose of the project is to **build a simple calculator** using a keypad, seven-segment display, and FPGA on Basys 3 board. The calculator would be able to add, subtract, multiple, and divide 8 bit numbers. The project is an example of interfacing multiple components and performing computations on the FPGA.

Reset State: Calculator will display 0000 on seven segment display, calculator will check user switches on reset and drive corresponding LEDs if switch positions are ON.

Calculator Operations: Calculator will execute addition (covers also subtraction), multiplication and division operations with two operands (Figure 1).

$$\begin{array}{r} Operand\ 1 \\ +\ Operand\ 2 \\ \hline Result \end{array} \qquad \begin{array}{r} Operand\ 1 \\ \div\ Operand\ 2 \\ \hline Result \end{array} \qquad \begin{array}{r} Operand\ 1 \\ x\ Operand\ 2 \\ \hline Result \end{array}$$

***Figure 1**: Calculator Operations*

All the operations will be processed in a flow such that instructions will be taken from the push-buttons, operands will be taken from the user switches and datapath will be controlled with a FSM so that according to the operation requested, calculated result will be displayed through the seven-segment display (Figure 2).

Data Input interface: 16 user switches and their corresponding 16 user LEDs will be used in order to input two 8 bit numbers before operation execution. As shown in Figure 3, first 8 user switches will be used in order to input the first operand number for the calculator and second 8 user switches will be used in order to input the second operand number. 2's complement form will be used in both operands.

Calculator Operation: Once the operands before executing an operation is programmed by using the user switches 5 user push buttons of the Basys board will be used for executing an operation. The key-operation matching is given in Figure 4.

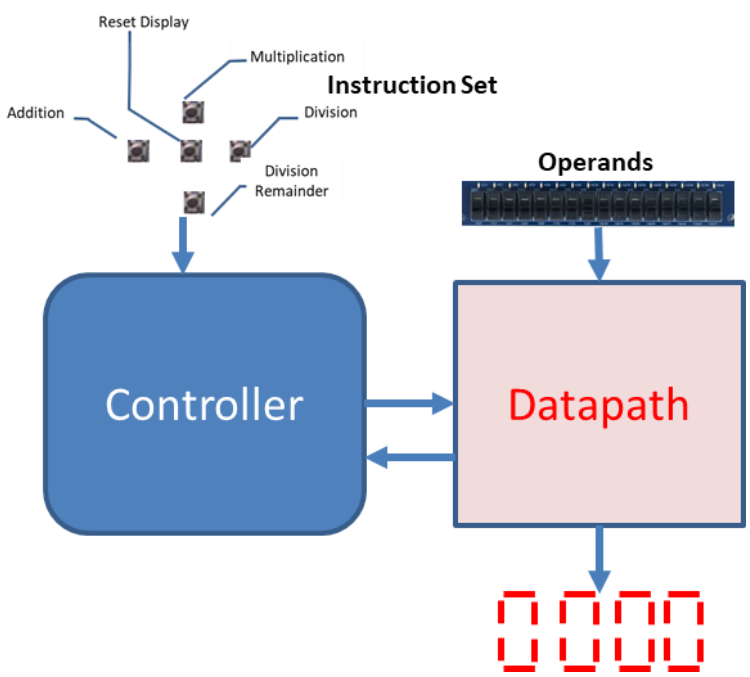

***Figure 2**: Operation Flow Architecture*

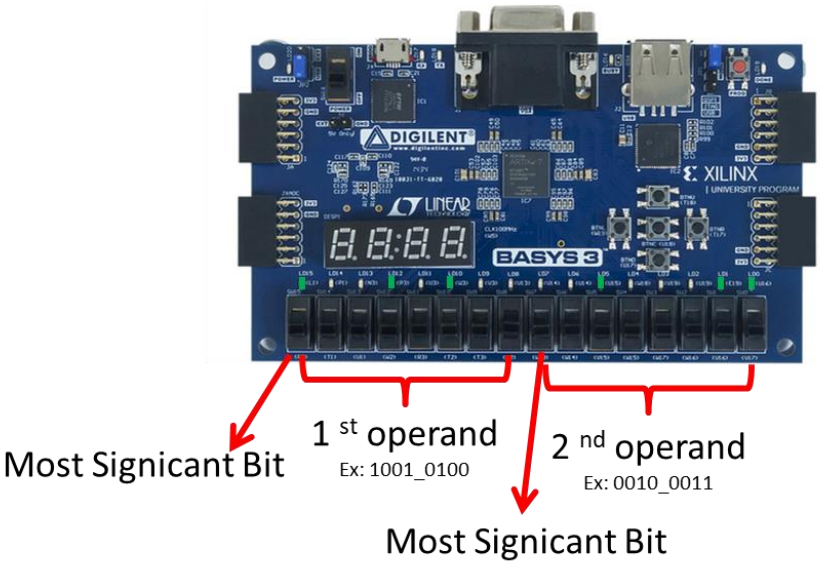

***Figure 3**: User-Switches, User-LEDs for Inputs*

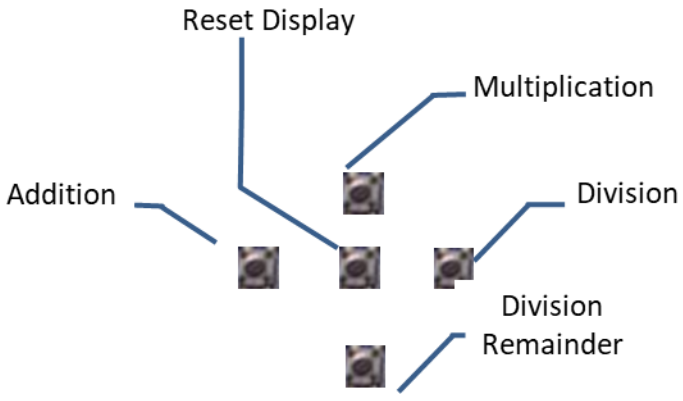

***Figure 4**: Push Button-Operation*

1. Addition Key:

The statuses of switches SW15-8 are registered to the first operand, and the status of switches SW7-0 to the second operand in 8-bit Signed 2's complement form. If the LEDs corresponding to the keys are ON than the bit that corresponds to the LED is 1, on the other hand if the LED if OFF than the bit corresponding to the switch is 0. The sign bits for the two operands are SW15 and SW7 respectively. (Figure 3)

The two operands are added and result is recorded **on addition key press**. When the result is calculated the result value will be displayed on the seven segment display. If the result is negative than the most significant display of the seven segment display will show a minus '-' sign. By using addition operation not only addition but also subtraction operation will be executed. The calculated result will blink on the seven segment display. For the blinking result display you are required to use a 500 millisecond timer. By using this timer the result will be displayed on the 7-segment display for 500 millisecond and during the next 500 millisecond the display will be OFF.

2. Multiplication Key:

The statuses of switches SW15-8 are registered to the first operand, and the status of switches SW7-0 to the second operand in 8-bit Signed 2's complement form. If the LEDs corresponding to the keys are ON than the bit that corresponds to the LED is 1, on the other hand if the LED if OFF than the bit corresponding to the switch is 0. and the bit corresponding to 0 is zero. The sign bits for the two operands are SW15 and SW7 respectively. (Figure 3)

The two operands are multiplied and result is recorded on multiplication key press. When the result is calculated the result value will be displayed on the seven segment display. If the result is negative than the most significant display of the seven segment display will show '-' sign. The calculated result will blink on the seven segment display. For the blinking result display you are required to use a 500 millisecond timer. By using this timer the result will be displayed on the 7-segment display for 500 millisecond and during the next 500 millisecond the display will be OFF.

3. Division Key:

The statuses of switches SW15-8 are registered to the first operand, and the status of switches SW7-0 to the second operand in 8-bit Signed 2's complement form. If the LEDs corresponding to the keys are ON than the bit that corresponds to the LED is 1, on the other hand if the LED if OFF than the bit corresponding to the switch is 0. and the bit corresponding to 0 is zero. The sign bits for the two operands are SW15 and SW7 respectively. (Figure 3)

The two operands are divided and result is recorded on division key press. When the result is calculated the result value will be displayed on the seven segment display. If the result is negative than the most significant display of the seven segment display will show '-' sign. The calculated result will blink on the seven segment display. For the blinking result display

you are required to use a 500 millisecond timer. By using this timer the result will be displayed on the 7-segment display for 500 millisecond and during the next 500 millisecond the display will be OFF.

4. Division-Remainder Key:

The statuses of switches SW15-8 are registered to the first operand, and the status of switches SW7-0 to the second operand in 8-bit Signed 2's complement form. If the LEDs corresponding to the keys are ON than the bit that corresponds to the LED is 1, on the other hand if the LED if OFF than the bit corresponding to the switch is 0. and the bit corresponding to 0 is zero. The sign bits for the two operands are SW15 and SW7 respectively. (Figure 3)

The two operands are divided and remainder is recorded on remainder key press. When remainder is calculated this value will be displayed on the seven segment display. The remainder will blink on the seven segment display. For the blinking remainder value you are required to use a 500 millisecond timer. By using this timer the result will be displayed on the 7-segment display for 500 millisecond and during the next 500 millisecond the display will be OFF.

5. Reset Display Key:

Regardless of the latest operation executed upon key reset display key press all seven segment display will reset to 0. (Figure 5)

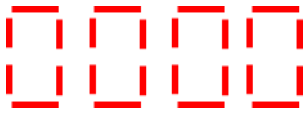

***Figure 5**: Seven Segment Display On Reset*

The calculated result will blink on the seven segment display. For the blinking result display you are required to use a 500 millisecond timer. By using this timer the result will be displayed on the 7-segment display for 500 millisecond and during the next 500 millisecond the display will be OFF. For a calculated result of -123 the display is shown in Figure 6.

***Figure 6**: Seven Segment Display (Calculated Result Display)*

Notes:

1. Study Basys3 and Beti board documents carefully to avoid connecting different wires to each other and damaging your Basys3. Specifically, read Basys3_converter_board.pdf file on Unilica.
2. You need to have a report for your project and show it to your TAs during demo. Report at least should include:
    - Give explanation about which physical modules you used on beti board/ Basys3, such as keypad or switches etc.
    - Describe your own design, Systemverilog modules and codes, timer, FSMs. (do not include your code in the report).
    - Give detailed diagram of the main FSM in your design, and clear explanation for each state's duty.
    - If you use any ready code from internet, mention it at the end of your report.