



Звіт

З лабораторної роботи № 3

З дисципліни “Моделювання комп’ютерних систем”

На тему: “Поведінковий опис цифрового автомата. Перевірка роботи автомата
за допомогою стенда”

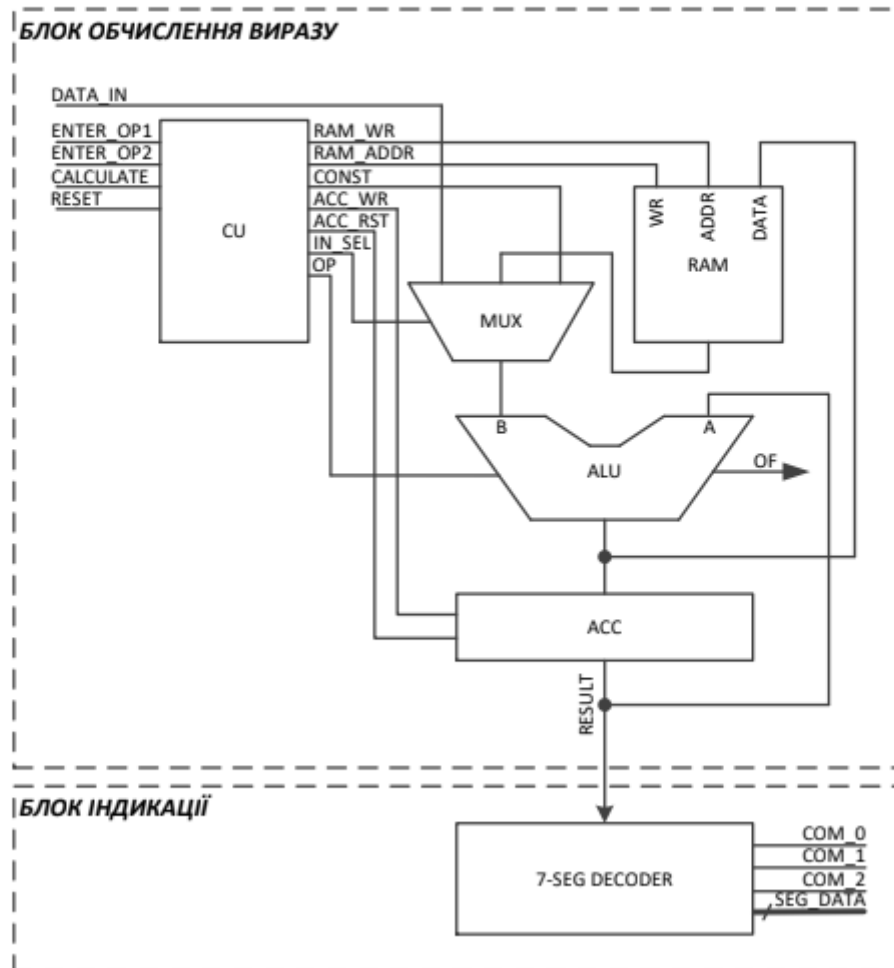
Варіант – 21

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Перевірив:
асистент
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Львів 2023

Мета роботи : На базі стенда Elbert V2 – Spartan 3A FPGA, реалізувати цифровий автомат для обчислення значення виразу дотримуючись наступних вимог:

1. Функціонал пристрою повинен бути реалізований згідно отриманого варіанту завдання. Дивись розділ ЗАВДАННЯ..
2. Пристрій повинен бути ітераційним (АЛП (ALU) повинен виконувати за один такт одну операцію), та реалізованим згідно наступної структурної схеми (Малюнок 1):



Малюнок 1 - Структурна схема автомата.

Завдання

6	$((OP1 + OP2) - 2) \ll OP2$
---	-----------------------------

Виконання роботи:

Файл CU.vhd:

```
-----  
-- Company:  
-- Engineer:  
--  
-- Create Date: 16:27:31 04/27/2023  
-- Design Name:  
-- Module Name: CU - Behavioral  
-- Project Name:  
-- Target Devices:  
-- Tool versions:  
-- Description:  
--  
-- Dependencies:  
--  
-- Revision:  
-- Revision 0.01 - File Created  
-- Additional Comments:  
--  
-----  
library IEEE;  
use IEEE.STD_LOGIC_1164.ALL;  
  
-- Uncomment the following library declaration if using  
-- arithmetic functions with Signed or Unsigned values  
use IEEE.NUMERIC_STD.ALL;  
use IEEE.STD_LOGIC_UNSIGNED.ALL;  
  
-- Uncomment the following library declaration if instantiating  
-- any Xilinx primitives in this code.  
--library UNISIM;  
--use UNISIM.VComponents.all;  
  
entity CU_intf is  
    port(CLOCK      : IN STD_LOGIC;  
         RESET       : IN STD_LOGIC;  
         ENTER_OP1   : IN STD_LOGIC;  
         ENTER_OP2   : IN STD_LOGIC;  
         CALCULATE    : IN STD_LOGIC;  
  
         RAM_WR       : OUT STD_LOGIC;  
         RAM_ADDR_BUS : OUT STD_LOGIC_VECTOR(1 downto 0);
```

```

        CONSTANT_BUS      : OUT STD_LOGIC_VECTOR(7 downto 0):=
"00000010";
        ACC_WR : OUT STD_LOGIC;
        ACC_RST : OUT STD_LOGIC;
        IN_SEL : OUT STD_LOGIC_VECTOR(1 downto 0);
        OP_CODE_BUS : OUT STD_LOGIC_VECTOR(1 downto 0)
    );
end CU_intf;

```

architecture CU_arch of CU_intf is

```

type cu_state_type is (cu_rst, cu_idle, cu_load_op1, cu_load_op2, cu_run_calc0,
cu_run_calc1, cu_run_calc2, cu_run_calc3, cu_finish);
signal cu_cur_state : cu_state_type;
signal cu_next_state : cu_state_type;

```

```

begin
CONSTANT_BUS      <= "00000010";
CU_SYNC_PROC: process (CLOCK)
begin
    if (rising_edge(CLOCK)) then
        if (RESET = '1') then
            cu_cur_state <= cu_rst;
        else
            cu_cur_state <= cu_next_state;
        end if;
    end if;
end process;

```

```

        CUNEXT_STATE_DECODE: process (cu_cur_state, ENTER_OP1,
ENTER_OP2, CALCULATE)

```

```

begin
    --declare default state for next_state to avoid latches
    cu_next_state <= cu_cur_state; --default is to stay in current state
    --insert statements to decode next_state
    --below is a simple example
    case(cu_cur_state) is
        when cu_rst =>
            cu_next_state <= cu_idle;
        when cu_idle =>
            if (ENTER_OP1 = '1') then
                cu_next_state <= cu_load_op1;
            elsif (ENTER_OP2 = '1') then
                cu_next_state <= cu_load_op2;
            elsif (CALCULATE = '1') then
                cu_next_state <= cu_run_calc0;
            else

```

```

        cu_next_state <= cu_idle;
    end if;
    when cu_load_op1      =>
        cu_next_state <= cu_idle;
    when cu_load_op2      =>
        cu_next_state <= cu_idle;
    when cu_run_calc0 =>
        cu_next_state <= cu_run_calc1;
    when cu_run_calc1 =>
        cu_next_state <= cu_run_calc2;
    when cu_run_calc2 =>
        cu_next_state <= cu_run_calc3;
    when cu_run_calc3 =>
        cu_next_state <= cu_finish;
    when cu_finish      =>
        cu_next_state <= cu_finish;
    when others          =>
        cu_next_state <= cu_idle;
end case;
end process;

```

CU_OUTPUT_DECODE: process (cu_cur_state)

begin

```

    case(cu_cur_state) is
        when cu_rst          =>
            IN_SEL              <= "00";
            OP_CODE_BUS <= "00";
            RAM_ADDR_BUS <= "00";
            RAM_WR              <= '0';
            ACC_RST             <= '1';
            ACC_WR              <= '0';
        when cu_idle          =>
            IN_SEL              <= "00";
            OP_CODE_BUS <= "00";
            RAM_ADDR_BUS <= "00";
            RAM_WR              <= '0';
            ACC_RST             <= '0';
            ACC_WR              <= '0';
        when cu_load_op1      =>
            IN_SEL              <= "00";
            OP_CODE_BUS <= "00";
            RAM_ADDR_BUS <= "00";
            RAM_WR              <= '1';
            ACC_RST             <= '0';
            ACC_WR              <= '1';
        when cu_load_op2      =>

```

```

        IN_SEL                <= "00";
        OP_CODE_BUS <= "00";
        RAM_ADDR_BUS <= "01";
        RAM_WR           <= '1';
        ACC_RST          <= '0';
        ACC_WR           <= '1';
    when cu_run_calc0 =>
        IN_SEL                <= "01";
        OP_CODE_BUS <= "00";
        RAM_ADDR_BUS <= "00";
        RAM_WR           <= '0';
        ACC_RST          <= '0';
        ACC_WR           <= '1';
    when cu_run_calc1 =>
        IN_SEL                <= "01";
        OP_CODE_BUS <= "01";
        RAM_ADDR_BUS <= "01";
        RAM_WR           <= '0';
        ACC_RST          <= '0';
        ACC_WR           <= '1';
    when cu_run_calc2 =>
        IN_SEL                <= "10";
        OP_CODE_BUS <= "10";
        RAM_ADDR_BUS <= "01";
        RAM_WR           <= '0';
        ACC_RST          <= '0';
        ACC_WR           <= '1';
    when cu_run_calc3 =>
        IN_SEL                <= "01";
        OP_CODE_BUS <= "11";
        RAM_ADDR_BUS <= "01";
        RAM_WR           <= '0';
        ACC_RST          <= '0';
        ACC_WR           <= '1';
    when cu_finish    =>
        IN_SEL                <= "00";
        OP_CODE_BUS <= "00";
        RAM_ADDR_BUS <= "00";
        RAM_WR           <= '0';
        ACC_RST          <= '0';
        ACC_WR           <= '0';
    when others        =>
        IN_SEL                <= "00";
        OP_CODE_BUS <= "00";
        RAM_ADDR_BUS <= "00";
        RAM_WR           <= '0';
        ACC_RST          <= '0';

```

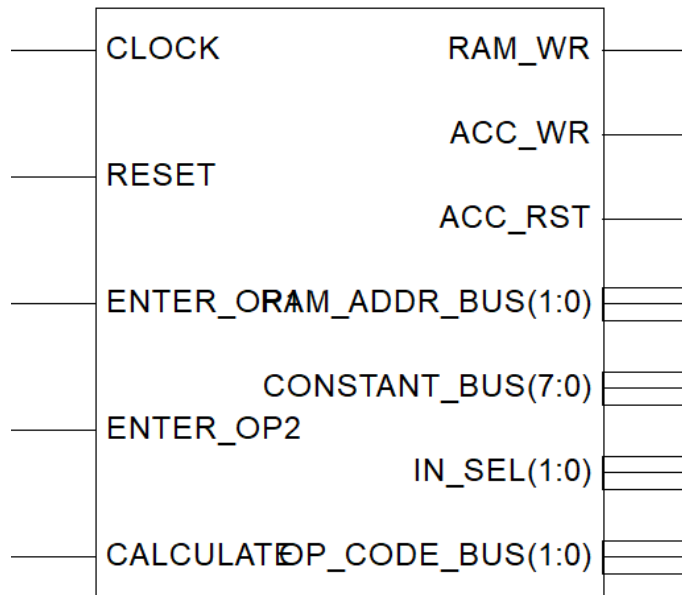
```

        ACC_WR                                     <= '0';
    end case;
end process;
end CU_arch;

```

Элемент CU:

CU_intf



Файл MUX.vhd:

```

-----
-- Company:
-- Engineer:
--
-- Create Date: 15:06:55 04/27/2023
-- Design Name:
-- Module Name: MUX - Behavioral
-- Project Name:
-- Target Devices:
-- Tool versions:
-- Description:
--
-- Dependencies:
--
-- Revision:
-- Revision 0.01 - File Created
-- Additional Comments:
--
-----

```

```

library IEEE;
use IEEE.STD_LOGIC_1164.ALL;

```

```

-- Uncomment the following library declaration if using
-- arithmetic functions with Signed or Unsigned values

```

```

use IEEE.NUMERIC_STD.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;

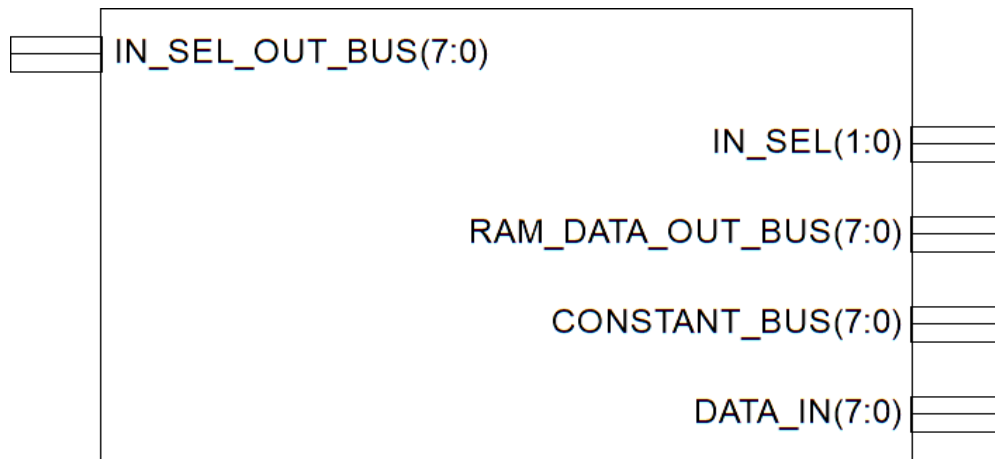
-- Uncomment the following library declaration if instantiating
-- any Xilinx primitives in this code.
--library UNISIM;
--use UNISIM.VComponents.all;

entity MUX_intf is
    port(
        DATA_IN          : IN STD_LOGIC_VECTOR(7 downto 0);
        CONSTANT_BUS : IN STD_LOGIC_VECTOR(7 downto 0);
        RAM_DATA_OUT_BUS: IN STD_LOGIC_VECTOR(7 downto 0);
        IN_SEL              : IN STD_LOGIC_VECTOR(1 downto
0);
        IN_SEL_OUT_BUS : OUT std_logic_vector(7 downto 0)
    );
end MUX_intf;

architecture MUX_arch of MUX_intf is

begin
    INSEL_A_MUX : process(DATA_IN, CONSTANT_BUS,
RAM_DATA_OUT_BUS, IN_SEL)
        begin
            if(IN_SEL = "00") then
                IN_SEL_OUT_BUS <= DATA_IN;
            elsif(IN_SEL = "01") then
                IN_SEL_OUT_BUS <= RAM_DATA_OUT_BUS;
            else
                IN_SEL_OUT_BUS <= CONSTANT_BUS;
            end if;
        end process INSEL_A_MUX;
    end MUX_arch;
Элемент MUX:

```

MUX_intf

Файл RAM.vhd:

```

-----
-- Company:
-- Engineer:
--
-- Create Date: 16:49:14 04/27/2023
-- Design Name:
-- Module Name: RAM - Behavioral
-- Project Name:
-- Target Devices:
-- Tool versions:
-- Description:
--
-- Dependencies:
--
-- Revision:
-- Revision 0.01 - File Created
-- Additional Comments:
--
-----

```

```

library IEEE;
use IEEE.STD_LOGIC_1164.ALL;

```

```

-- Uncomment the following library declaration if using
-- arithmetic functions with Signed or Unsigned values
use IEEE.NUMERIC_STD.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;

```

```

-- Uncomment the following library declaration if instantiating
-- any Xilinx primitives in this code.
--library UNISIM;
--use UNISIM.VComponents.all;

```

```

entity RAM_intf is
port(
    RAM_WR          : IN STD_LOGIC;
    RAM_ADDR_BUS    : IN STD_LOGIC_VECTOR(1 downto
0);
    ACC_DATA_IN_BUS : IN STD_LOGIC_VECTOR(7 downto 0);
    RAM_DATA_OUT_BUS: OUT STD_LOGIC_VECTOR(7 downto 0);
    CLOCK           : IN STD_LOGIC
    );
end RAM_intf;

architecture RAM_arch of RAM_intf is
type ram_type is array (3 downto 0) of STD_LOGIC_VECTOR(7 downto 0);
signal RAM_UNIT          : ram_type;
signal RAM_DATA_IN_BUS : STD_LOGIC_VECTOR(7 downto 0);

begin
    RAM_DATA_IN_BUS <= ACC_DATA_IN_BUS;

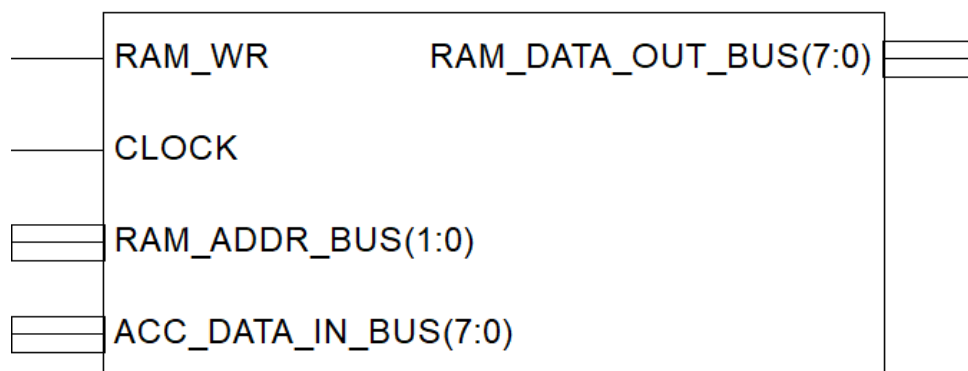
    RAM : process(CLOCK, RAM_ADDR_BUS, RAM_UNIT)
    begin
        if (rising_edge(CLOCK)) then
            if (RAM_WR = '1') then
                RAM_UNIT(conv_integer(RAM_ADDR_BUS)) <=
RAM_DATA_IN_BUS;
            end if;
        end if;
        RAM_DATA_OUT_BUS <=
RAM_UNIT(conv_integer(RAM_ADDR_BUS));
    end process RAM;
end RAM_arch;

```

end RAM_arch;

Элемент RAM:

RAM_intf



Файл ALU.vhd:

```
-----
-- Company:
-- Engineer:
--
-- Create Date: 16:13:46 04/27/2023
-- Design Name:
-- Module Name: ALU - Behavioral
-- Project Name:
-- Target Devices:
-- Tool versions:
-- Description:
--
-- Dependencies:
--
-- Revision:
-- Revision 0.01 - File Created
-- Additional Comments:
--
-----

library IEEE;
use IEEE.STD_LOGIC_1164.ALL;

-- Uncomment the following library declaration if using
-- arithmetic functions with Signed or Unsigned values
use IEEE.NUMERIC_STD.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;

-- Uncomment the following library declaration if instantiating
-- any Xilinx primitives in this code.
--library UNISIM;
--use UNISIM.VComponents.all;

entity ALU_intf is
port(
    IN_SEL_OUT_BUS : IN STD_LOGIC_VECTOR(7 downto 0);
    ACC_DATA_OUT_BUS : IN STD_LOGIC_VECTOR(7 downto 0);
    OP_CODE_BUS : IN STD_LOGIC_VECTOR(1 downto 0);
    ACC_DATA_IN_BUS : OUT STD_LOGIC_VECTOR(7 downto 0);
    OVER_FLOW : OUT STD_LOGIC
    --OF - overflow
);
end ALU_intf;

architecture ALU_arch of ALU_intf is
begin
```

```

ALU : process(OP_CODE_BUS, IN_SEL_OUT_BUS, ACC_DATA_OUT_BUS)
    variable A : unsigned(7 downto 0);
    variable B : unsigned(7 downto 0);
    variable temp : std_logic_vector(8 downto 0);
begin
    A := unsigned(ACC_DATA_OUT_BUS);
    B := unsigned(IN_SEL_OUT_BUS);

    if OP_CODE_BUS = "00" then
        ACC_DATA_IN_BUS <= STD_LOGIC_VECTOR(B);
    elsif OP_CODE_BUS = "01" then
        temp := STD_LOGIC_VECTOR('0' & A) +
STD_LOGIC_VECTOR('0' & B);
        if (temp(8) = '1') then
            OVER_FLOW <= '1';
        else
            OVER_FLOW <= '0';
        end if;
        ACC_DATA_IN_BUS <= temp(7 downto 0);
    elsif OP_CODE_BUS = "10" then
        temp := STD_LOGIC_VECTOR('0' & A) - STD_LOGIC_VECTOR('0'
& B);
        if (temp(8) = '1') then
            OVER_FLOW <= '1';
        else
            OVER_FLOW <= '0';
        end if;
        ACC_DATA_IN_BUS <= temp(7 downto 0);
    elsif OP_CODE_BUS = "11" then
        case(B) is --case(B) is
            when x"00"      => ACC_DATA_IN_BUS <=
STD_LOGIC_VECTOR(A sll 0);
            when x"01"      => ACC_DATA_IN_BUS <=
STD_LOGIC_VECTOR(A sll 1);
            when x"02"      => ACC_DATA_IN_BUS <=
STD_LOGIC_VECTOR(A sll 2);
            when x"03"      => ACC_DATA_IN_BUS <=
STD_LOGIC_VECTOR(A sll 3);
            when x"04"      => ACC_DATA_IN_BUS <=
STD_LOGIC_VECTOR(A sll 4);
            when x"05"      => ACC_DATA_IN_BUS <=
STD_LOGIC_VECTOR(A sll 5);
            when x"06"      => ACC_DATA_IN_BUS <=
STD_LOGIC_VECTOR(A sll 6);
            when x"07"      => ACC_DATA_IN_BUS <=
STD_LOGIC_VECTOR(A sll 7);

```

```

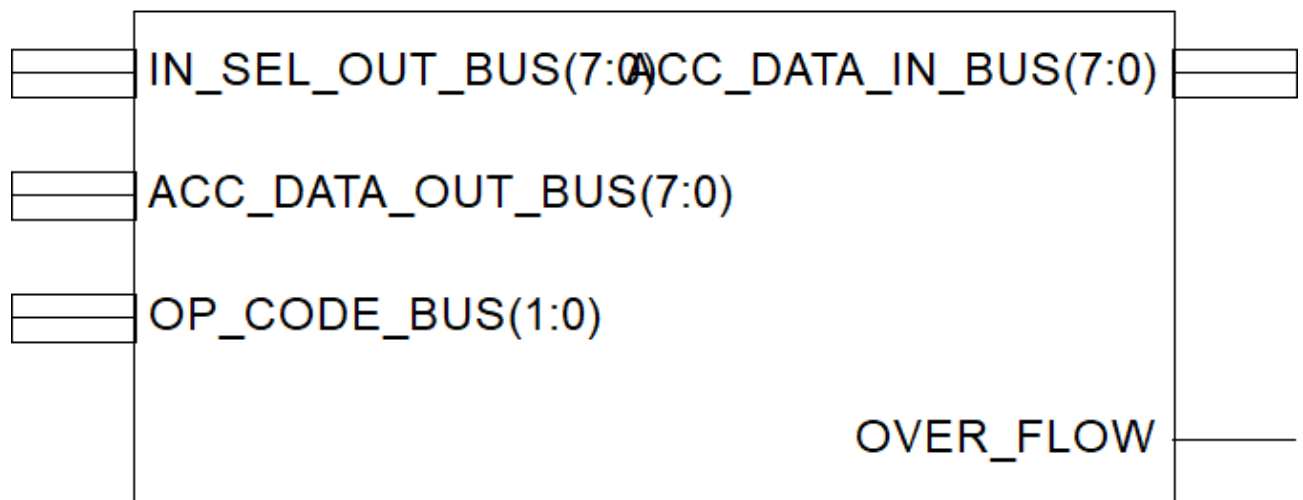
                                when others => ACC_DATA_IN_BUS <=
STD_LOGIC_VECTOR(A sll 0);
                                end case;
                                else
                                ACC_DATA_IN_BUS <= "00000000";
                                end if;
                                end process ALU;

                                end ALU_arch;

```

Элемент ALU:

ALU_intf



Файл ACC.vhd:

```

-----
-- Company:
-- Engineer:
--
-- Create Date: 15:27:57 04/27/2023
-- Design Name:
-- Module Name: ACC - Behavioral
-- Project Name:
-- Target Devices:
-- Tool versions:
-- Description:
--
-- Dependencies:
--
-- Revision:
-- Revision 0.01 - File Created
-- Additional Comments:
--
-----

```

```

library IEEE;
use IEEE.STD_LOGIC_1164.ALL;

-- Uncomment the following library declaration if using
-- arithmetic functions with Signed or Unsigned values
use IEEE.NUMERIC_STD.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;

-- Uncomment the following library declaration if instantiating
-- any Xilinx primitives in this code.
--library UNISIM;
--use UNISIM.VComponents.all;

entity ACC_intf is
port(
    CLOCK          : IN STD_LOGIC;
    ACC_RST        : IN STD_LOGIC;
    ACC_WR         : IN STD_LOGIC;
    ACC_DATA_IN_BUS : IN STD_LOGIC_VECTOR(7 downto 0);
    ACC_DATA_OUT_BUS : OUT STD_LOGIC_VECTOR(7 downto 0)
);
end ACC_intf;

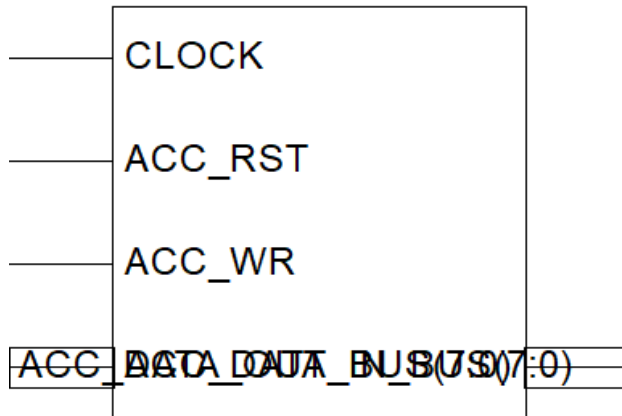
architecture ACC_arch of ACC_intf is

    signal ACC_DATA          : STD_LOGIC_VECTOR(7 downto 0);

begin
    ACC : process(CLOCK, ACC_DATA)
    begin
        if (rising_edge(CLOCK)) then
            if(ACC_RST = '1') then
                ACC_DATA <= "00000000";
            elsif (ACC_WR = '1') then
                ACC_DATA <= ACC_DATA_IN_BUS;
            end if;
        end if;
        ACC_DATA_OUT_BUS <= ACC_DATA;
    end process ACC;
end ACC_arch;
Элемент ACC:

```

ACC_intf



Файл SEGDEC.vhd:

```
-----
-----
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;

-- Uncomment the following library declaration if using
-- arithmetic functions with Signed or Unsigned values
use IEEE.NUMERIC_STD.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;

-- Uncomment the following library declaration if instantiating
-- any Xilinx primitives in this code.
--library UNISIM;
--use UNISIM.VComponents.all;

entity SEGDEC_intf is
port(
    CLOCK          : IN STD_LOGIC;
    ACC_DATA_OUT_BUS : IN STD_LOGIC_VECTOR(7 downto 0);
    RESET          : IN STD_LOGIC;
    OverFlow_IN    : IN STD_LOGIC;
    COMM_ONES      : OUT STD_LOGIC;
    COMM_DECS      : OUT STD_LOGIC;
    COMM_HUNDREDS  : OUT STD_LOGIC;
    SEG_A          : OUT STD_LOGIC;
    SEG_B          : OUT STD_LOGIC;
    SEG_C          : OUT STD_LOGIC;
    SEG_D          : OUT STD_LOGIC;
    SEG_E          : OUT STD_LOGIC;
    SEG_F          : OUT STD_LOGIC;
    SEG_G          : OUT STD_LOGIC;
    DP             : OUT STD_LOGIC;
    OverFlow_OUT   : OUT STD_LOGIC := '0'
```

```

    );
end SEGDEC_intf;

```

```

architecture SEGDEC_arch of SEGDEC_intf is
signal ONES_BUS : STD_LOGIC_VECTOR(3 downto 0) := "0000";
signal DECS_BUS : STD_LOGIC_VECTOR(3 downto 0) := "0000";
signal HONDREDS_BUS : STD_LOGIC_VECTOR(3 downto 0) := "0000";
begin

```

```

OVERFLOW_INDICATE : process(OverFlow_IN, RESET)
begin
    --if rising_edge(CLOCK) then
    if (RESET = '1') then
        OverFlow_OUT <= '0';
    elsif (RESET = '0' and OverFlow_IN = '1') then
        OverFlow_OUT <= '1';
    end if;
    --end if;
end process OVERFLOW_INDICATE;

```

```

BIN_TO_BCD : process (ACC_DATA_OUT_BUS)
variable hex_src : STD_LOGIC_VECTOR(7 downto 0) ;
variable bcd : STD_LOGIC_VECTOR(11 downto 0) ;
begin
    bcd := (others => '0') ;
    hex_src := ACC_DATA_OUT_BUS;

    for i in hex_src'range loop
        if bcd(3 downto 0) > "0100" then
            bcd(3 downto 0) := bcd(3 downto 0) + "0011" ;
        end if ;
        if bcd(7 downto 4) > "0100" then
            bcd(7 downto 4) := bcd(7 downto 4) + "0011" ;
        end if ;
        if bcd(11 downto 8) > "0100" then
            bcd(11 downto 8) := bcd(11 downto 8) + "0011" ;
        end if ;

        bcd := bcd(10 downto 0) & hex_src(hex_src'left) ; -- shift bcd + 1 new entry
        hex_src := hex_src(hex_src'left - 1 downto hex_src'right) & '0' ; -- shift src +
pad with 0
    end loop ;

    HONDREDS_BUS <= bcd (11 downto 8);
    DECS_BUS <= bcd (7 downto 4);
    ONES_BUS <= bcd (3 downto 0);

```



```

end process BIN_TO_BCD;

INDICATE : process(CLOCK)
    type DIGIT_TYPE is (ONES, DECS, HUNDREDS);

    variable CUR_DIGIT    : DIGIT_TYPE := ONES;
    variable DIGIT_VAL    : STD_LOGIC_VECTOR(3 downto 0) :=
"0000";
    variable DIGIT_CTRL   : STD_LOGIC_VECTOR(6 downto 0) :=
"0000000";
    variable COMMONS_CTRL : STD_LOGIC_VECTOR(2 downto 0) :=
"000";

    begin
        if (rising_edge(CLOCK)) then
            if(RESET = '0') then
                case CUR_DIGIT is
                    when ONES =>
                        DIGIT_VAL := ONES_BUS;
                        CUR_DIGIT := DECS;
                        COMMONS_CTRL := "001";
                    when DECS =>
                        DIGIT_VAL := DECS_BUS;
                        CUR_DIGIT := HUNDREDS;
                        COMMONS_CTRL := "010";
                    when HUNDREDS =>
                        DIGIT_VAL := HONDREDS_BUS;
                        CUR_DIGIT := ONES;
                        COMMONS_CTRL := "100";
                    when others =>
                        DIGIT_VAL := ONES_BUS;
                        CUR_DIGIT := ONES;
                        COMMONS_CTRL := "000";
                end case;

                case DIGIT_VAL is
                    --abcdefg
                    when "0000" => DIGIT_CTRL := "1111110";
                    when "0001" => DIGIT_CTRL := "0110000";
                    when "0010" => DIGIT_CTRL := "1101101";
                    when "0011" => DIGIT_CTRL := "1111001";
                    when "0100" => DIGIT_CTRL := "0110011";
                    when "0101" => DIGIT_CTRL := "1011011";
                    when "0110" => DIGIT_CTRL := "1011111";
                    when "0111" => DIGIT_CTRL := "1110000";
                    when "1000" => DIGIT_CTRL := "1111111";
                    when "1001" => DIGIT_CTRL := "1111011";
                end case;
            end if;
        end if;
    end process;

```

```

        when others => DIGIT_CTRL := "0000000";
    end case;
else
    DIGIT_VAL := ONES_BUS;
    CUR_DIGIT := ONES;
    COMMONS_CTRL := "000";
end if;

COMM_ONES    <= COMMONS_CTRL(0);
COMM_DECS    <= COMMONS_CTRL(1);
COMM_HUNDREDS <= COMMONS_CTRL(2);

SEG_A <= DIGIT_CTRL(6);
SEG_B <= DIGIT_CTRL(5);
SEG_C <= DIGIT_CTRL(4);
SEG_D <= DIGIT_CTRL(3);
SEG_E <= DIGIT_CTRL(2);
SEG_F <= DIGIT_CTRL(1);
SEG_G <= DIGIT_CTRL(0);
DP    <= '0';

    end if;
end process INDICATE;
end SEGDEC_arch;
Элемент SEGDEC:

```

SEGDEC_intf

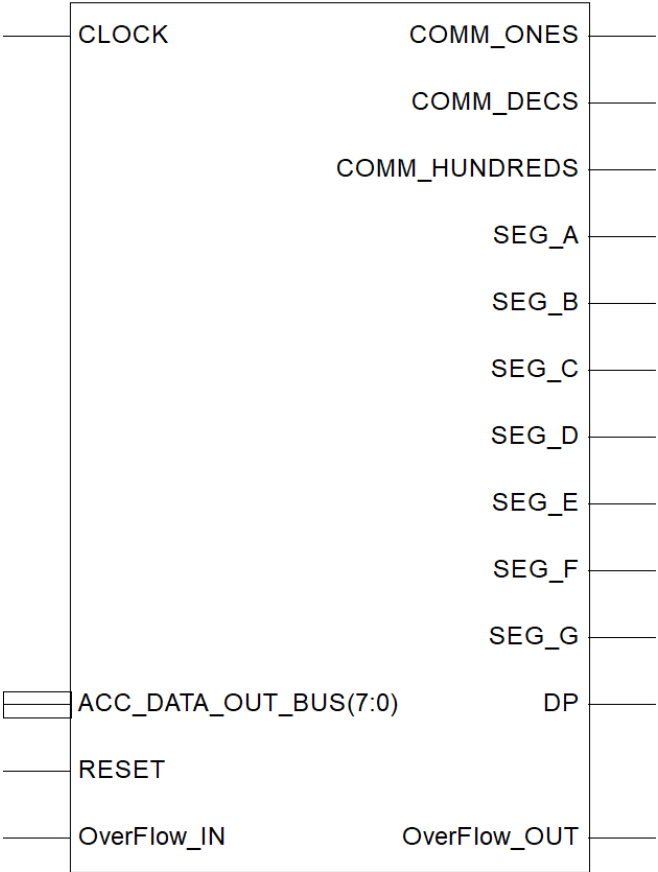
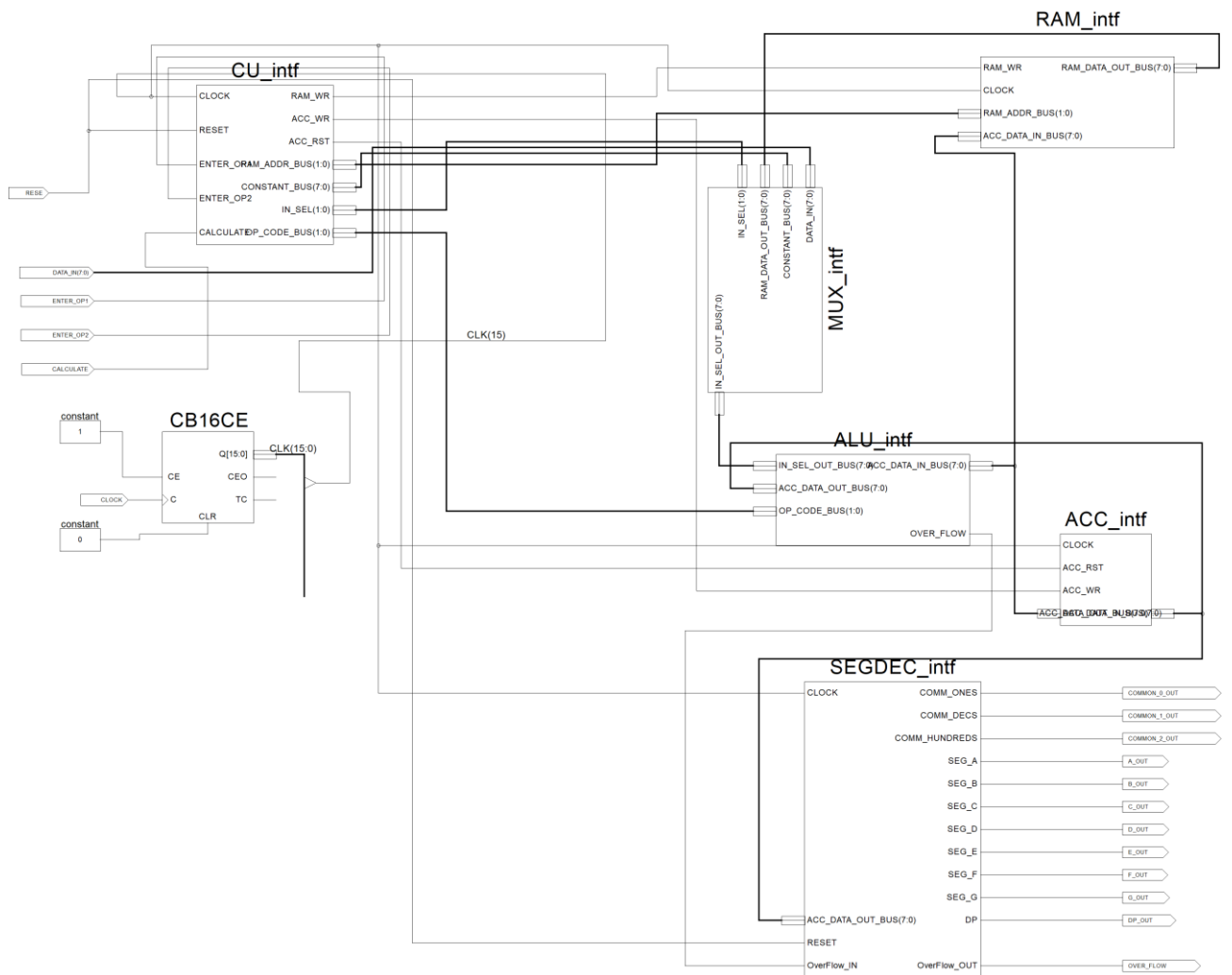


Схема для Top Level:



Файл Constraints.ucf:

```

*****
*****
*****#

```

UCF for ElbertV2 Development Board

```

#
#
#*****
*****
*****#

```

CONFIG VCCAUX = "3.3" ;

Clock 12 MHz

NET "CLOCK" LOC = P129 | IOSTANDARD = LVCMOS33 | PERIOD = 12MHz;

```

#####
#####

```

LED

```

#####
#####

```

```
NET "OVERFLOW"      LOC = P46  | IOSTANDARD = LVCMOS33 |
SLEW = SLOW | DRIVE = 12;
```

```
#####
#####
```

```
#              Seven Segment Display
```

```
#####
#####
```

```
NET "A_OUT"  LOC = P117 | IOSTANDARD = LVCMOS33 | SLEW = SLOW
| DRIVE = 12;
```

```
NET "B_OUT"  LOC = P116 | IOSTANDARD = LVCMOS33 | SLEW = SLOW
| DRIVE = 12;
```

```
NET "C_OUT"  LOC = P115 | IOSTANDARD = LVCMOS33 | SLEW = SLOW
| DRIVE = 12;
```

```
NET "D_OUT"  LOC = P113 | IOSTANDARD = LVCMOS33 | SLEW = SLOW
| DRIVE = 12;
```

```
NET "E_OUT"  LOC = P112 | IOSTANDARD = LVCMOS33 | SLEW = SLOW
| DRIVE = 12;
```

```
NET "F_OUT"  LOC = P111 | IOSTANDARD = LVCMOS33 | SLEW = SLOW
| DRIVE = 12;
```

```
NET "G_OUT"  LOC = P110 | IOSTANDARD = LVCMOS33 | SLEW = SLOW
| DRIVE = 12;
```

```
NET "DP_OUT"  LOC = P114 | IOSTANDARD = LVCMOS33 | SLEW =
SLOW | DRIVE = 12;
```

```
NET "COMMON_2_OUT"  LOC = P124 | IOSTANDARD = LVCMOS33 |
SLEW = SLOW | DRIVE = 12;
```

```
NET "COMMON_1_OUT"  LOC = P121 | IOSTANDARD = LVCMOS33 |
SLEW = SLOW | DRIVE = 12;
```

```
NET "COMMON_0_OUT"  LOC = P120 | IOSTANDARD = LVCMOS33 |
SLEW = SLOW | DRIVE = 12;
```

```
#####
#####
```

```
#              DP Switches
```

```
#####
#####
```

```
NET "DATA_IN(0)"    LOC = P70  | PULLUP | IOSTANDARD =
LVCMOS33 | SLEW = SLOW | DRIVE = 12;
```

```
NET "DATA_IN(1)"    LOC = P69  | PULLUP | IOSTANDARD =
LVCMOS33 | SLEW = SLOW | DRIVE = 12;
```

```
NET "DATA_IN(2)"    LOC = P68  | PULLUP | IOSTANDARD =
LVCMOS33 | SLEW = SLOW | DRIVE = 12;
```

```
NET "DATA_IN(3)"    LOC = P64  | PULLUP | IOSTANDARD =
LVCMOS33 | SLEW = SLOW | DRIVE = 12;
```

```

NET "DATA_IN(4)"      LOC = P63  | PULLUP | IOSTANDARD =
LVCMOS33 | SLEW = SLOW | DRIVE = 12;
NET "DATA_IN(5)"      LOC = P60  | PULLUP | IOSTANDARD =
LVCMOS33 | SLEW = SLOW | DRIVE = 12;
NET "DATA_IN(6)"      LOC = P59  | PULLUP | IOSTANDARD =
LVCMOS33 | SLEW = SLOW | DRIVE = 12;
NET "DATA_IN(7)"      LOC = P58  | PULLUP | IOSTANDARD =
LVCMOS33 | SLEW = SLOW | DRIVE = 12;

```

```

#####
#####
#                               Switches
#####
#####

```

```

NET "ENTER_OP1"      LOC = P80  | PULLUP | IOSTANDARD =
LVCMOS33 | SLEW = SLOW | DRIVE = 12;
NET "ENTER_OP2"      LOC = P79  | PULLUP | IOSTANDARD =
LVCMOS33 | SLEW = SLOW | DRIVE = 12;
NET "CALCULATE"      LOC = P78  | PULLUP | IOSTANDARD =
LVCMOS33 | SLEW = SLOW | DRIVE = 12;
NET "RESET"          LOC = P75  | PULLUP | IOSTANDARD = LVCMOS33 |
SLEW = SLOW | DRIVE = 12;

```

```

#####
#####

```

Файл TestTopLevel.vhd:

```

-- Vhdl test bench created from schematic D:\Lab_3_Example\TopLevel.sch - Mon
May 01 21:40:52 2023

```

```
--
```

```
-- Notes:
```

```

-- 1) This testbench template has been automatically generated using types
-- std_logic and std_logic_vector for the ports of the unit under test.
-- Xilinx recommends that these types always be used for the top-level
-- I/O of a design in order to guarantee that the testbench will bind
-- correctly to the timing (post-route) simulation model.
-- 2) To use this template as your testbench, change the filename to any
-- name of your choice with the extension .vhd, and use the "Source->Add"
-- menu in Project Navigator to import the testbench. Then
-- edit the user defined section below, adding code to generate the
-- stimulus for your design.

```

```
--
```

```

LIBRARY ieee;
USE ieee.std_logic_1164.ALL;
USE ieee.numeric_std.ALL;

```

```

LIBRARY UNISIM;
USE UNISIM.Vcomponents.ALL;
ENTITY TopLevel_TopLevel_sch_tb IS
END TopLevel_TopLevel_sch_tb;
ARCHITECTURE behavioral OF TopLevel_TopLevel_sch_tb IS

```

```

    COMPONENT TopLevel

```

```

    PORT( RESE      :    IN   STD_LOGIC;
          ENTER_OP1 :    IN   STD_LOGIC;
          ENTER_OP2 :    IN   STD_LOGIC;
          CALCULATE  :    IN   STD_LOGIC;
          COMMON_0_OUT :    OUT STD_LOGIC;
          COMMON_1_OUT :    OUT STD_LOGIC;
          COMMON_2_OUT :    OUT STD_LOGIC;
          A_OUT      :    OUT STD_LOGIC;
          B_OUT      :    OUT STD_LOGIC;
          C_OUT      :    OUT STD_LOGIC;
          D_OUT      :    OUT STD_LOGIC;
          E_OUT      :    OUT STD_LOGIC;
          F_OUT      :    OUT STD_LOGIC;
          G_OUT      :    OUT STD_LOGIC;
          DP_OUT     :    OUT STD_LOGIC;
          CLOCK      :    IN   STD_LOGIC;
          DATA_IN   :    IN   STD_LOGIC_VECTOR (7 DOWNT0 0);
          OVER_FLOW  :    OUT STD_LOGIC);
    END COMPONENT;

```

```

        signal op1 : STD_LOGIC_VECTOR(7 DOWNT0 0);
        signal op2 : STD_LOGIC_VECTOR(7 DOWNT0 0);
    SIGNAL RESE :    STD_LOGIC;
    SIGNAL ENTER_OP1 :    STD_LOGIC;
    SIGNAL ENTER_OP2 :    STD_LOGIC;
    SIGNAL CALCULATE :    STD_LOGIC;
    SIGNAL COMMON_0_OUT :    STD_LOGIC;
    SIGNAL COMMON_1_OUT :    STD_LOGIC;
    SIGNAL COMMON_2_OUT :    STD_LOGIC;
    SIGNAL A_OUT :    STD_LOGIC;
    SIGNAL B_OUT :    STD_LOGIC;
    SIGNAL C_OUT :    STD_LOGIC;
    SIGNAL D_OUT :    STD_LOGIC;
    SIGNAL E_OUT :    STD_LOGIC;
    SIGNAL F_OUT :    STD_LOGIC;
    SIGNAL G_OUT :    STD_LOGIC;
    SIGNAL DP_OUT :    STD_LOGIC;
    SIGNAL CLOCK :    STD_LOGIC;
    SIGNAL DATA_IN :    STD_LOGIC_VECTOR (7 DOWNT0 0);
    SIGNAL OVER_FLOW :    STD_LOGIC;

```

```
constant CLK_period: time := 1 us;  
constant TC_period: time := 65536 us;
```

```
BEGIN
```

```
UUT: TopLevel PORT MAP(  
    RESE => RESE,  
    ENTER_OP1 => ENTER_OP1,  
    ENTER_OP2 => ENTER_OP2,  
    CALCULATE => CALCULATE,  
    COMMON_0_OUT => COMMON_0_OUT,  
    COMMON_1_OUT => COMMON_1_OUT,  
    COMMON_2_OUT => COMMON_2_OUT,  
    A_OUT => A_OUT,  
    B_OUT => B_OUT,  
    C_OUT => C_OUT,  
    D_OUT => D_OUT,  
    E_OUT => E_OUT,  
    F_OUT => F_OUT,  
    G_OUT => G_OUT,  
    DP_OUT => DP_OUT,  
    CLOCK => CLOCK,  
    DATA_IN => DATA_IN,  
    OVER_FLOW => OVER_FLOW  
);
```

```
CLK_process : process  
begin  
    CLOCK <= '1';  
    wait for CLK_period/2;  
    CLOCK <= '0';  
    wait for CLK_period/2;  
end process CLK_process;
```

```
stim_proc: process  
begin  
    RESE <= '1';  
    ENTER_OP1 <= '0';  
    ENTER_OP2 <= '0';  
    CALCULATE <= '0';  
    DATA_IN <=(others => '0');  
  
    wait for 2*CLK_period;  
    RESE <='0';
```



```

wait for 4*TC_period;
ENTER_OP1 <='1';
DATA_IN  <= op1;

wait for 2*TC_period;
ENTER_OP1 <='0';

wait for 4*TC_period;
ENTER_OP2 <='1';
DATA_IN  <= op2;

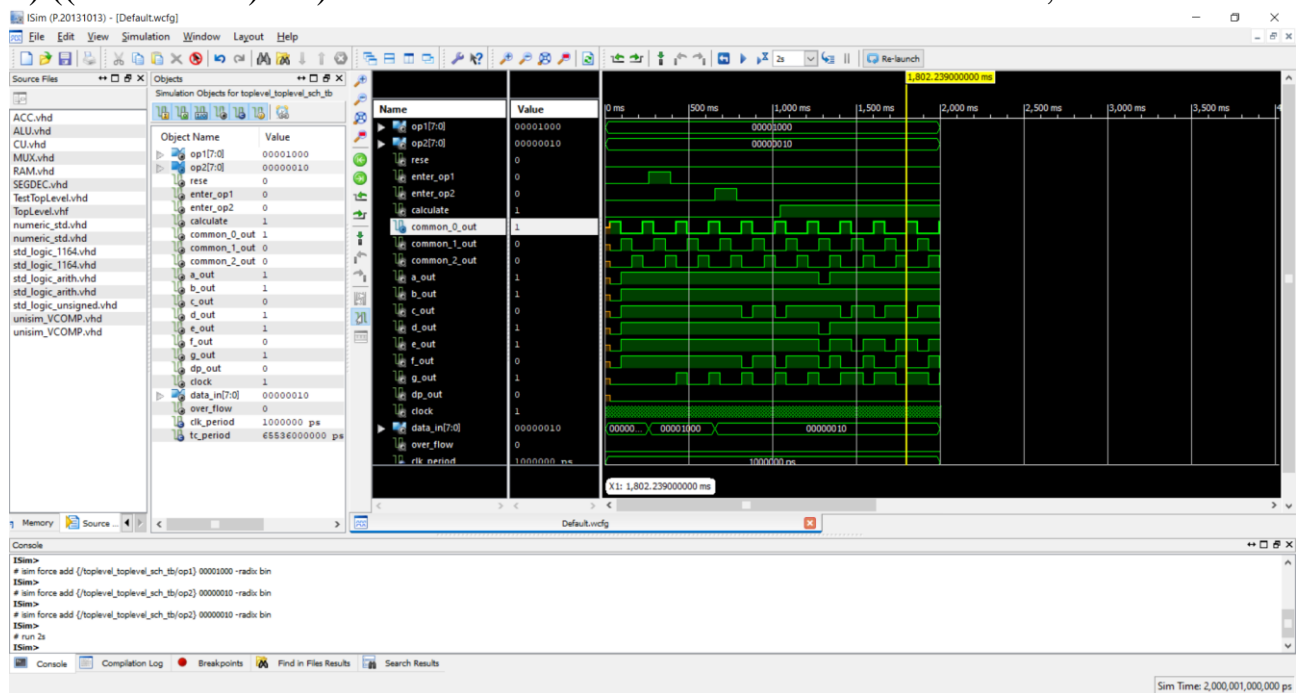
wait for 2*TC_period;
ENTER_OP2 <='0';
wait for 4*TC_period;

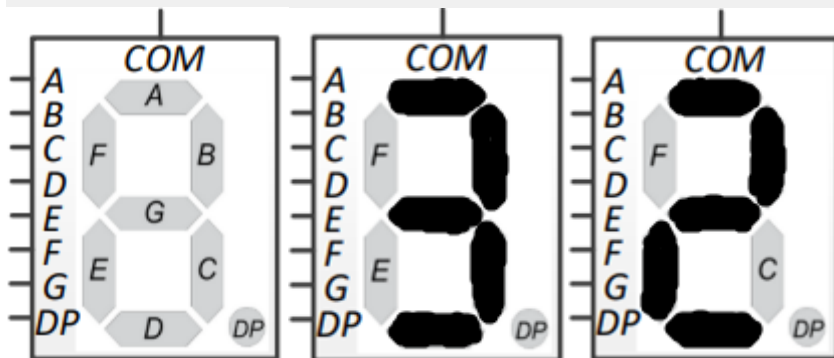
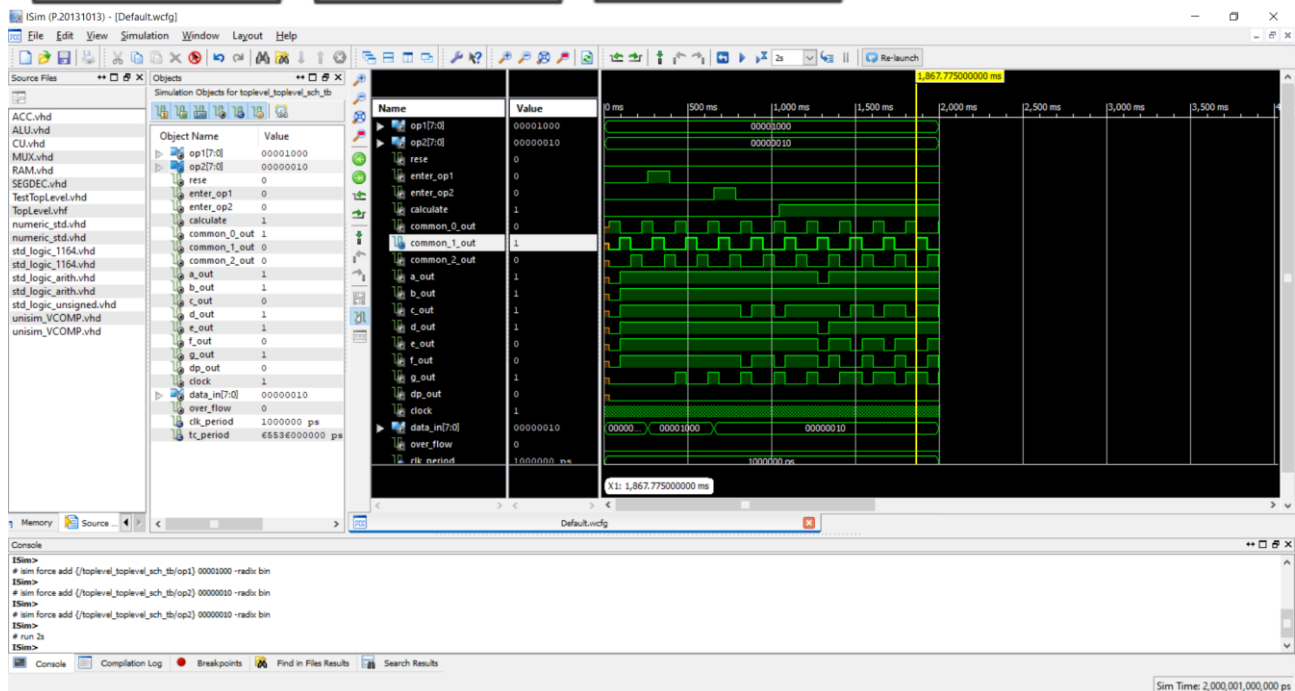
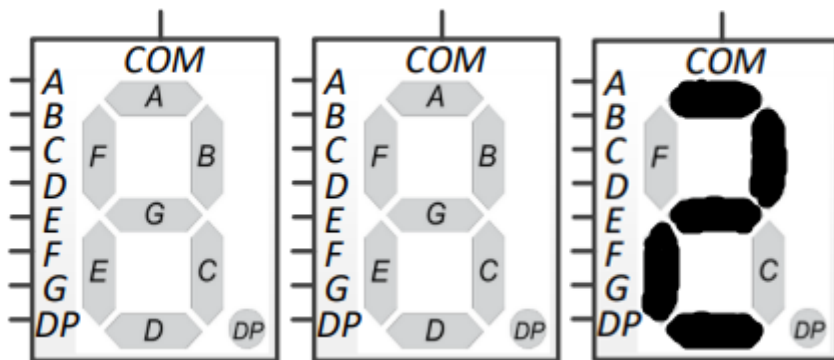
CALCULATE <= '1';
wait for 8*TC_period;
wait;
end process stim_proc; --1.835 s
END;

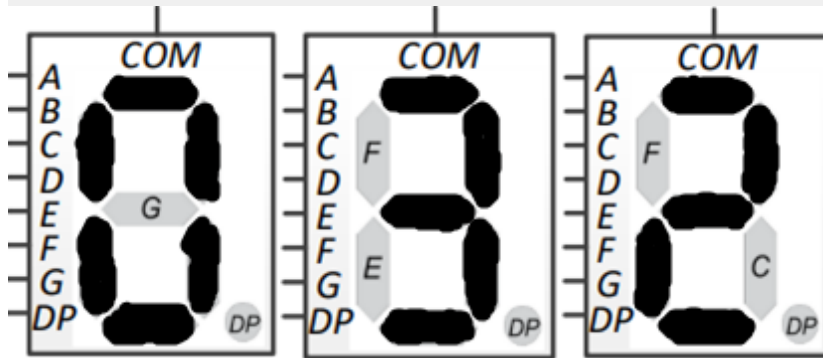
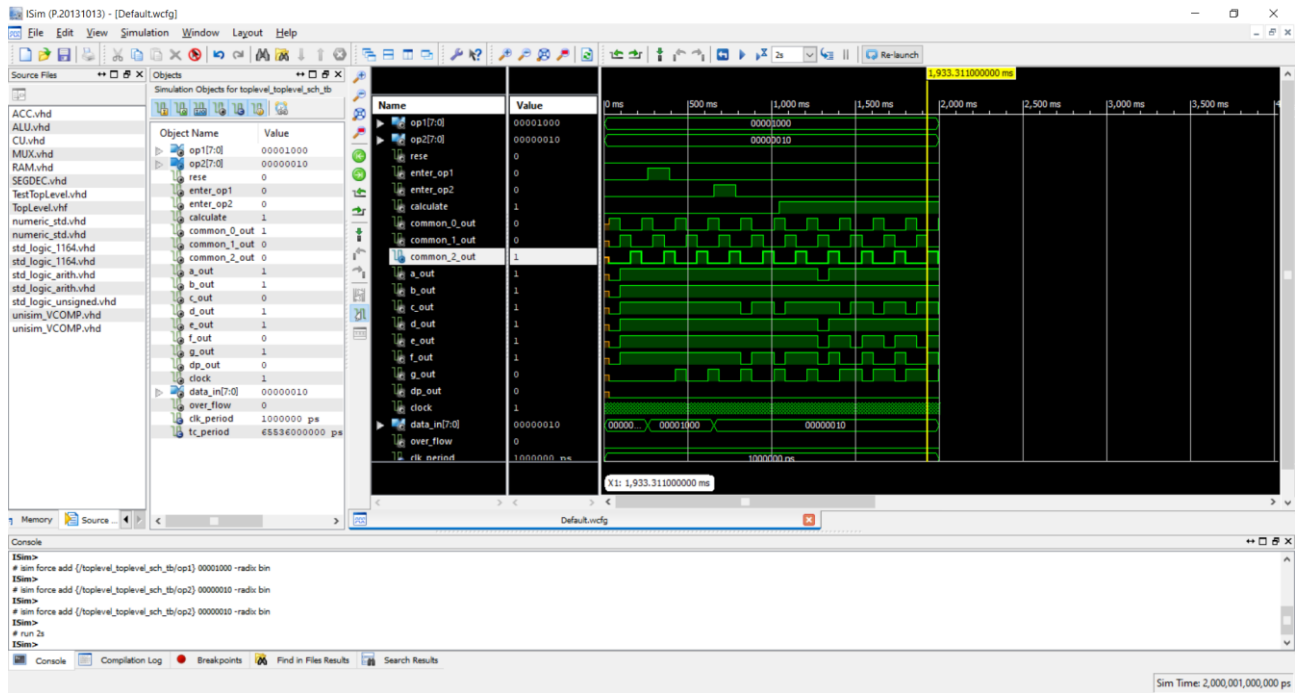
```

Перевірка результату

OP1=00001000;
 OP2=00000010;
 $((OP1 + OP2) - 2) \ll OP2 = 00100000$
 1) $(OP1 + OP2) = 00001000 + 00000010 = 00001010$;
 2) $(OP1 + OP2) - 2 = 00001010 - 00000010 = 00001000$;
 3) $((OP1 + OP2) - 2) \ll OP2 = 00001000 \ll 00000010 = 00100000$;







Висновок: Під час даної лабораторної роботи, я на базі стенда Elbert V2 – Spartan 3A FPGA, реалізував цифровий автомат для обчислення значення заданого виразу.