LAB NOTE

Subject: Digital Design Principles

Topic: Seven Segment Display

Student: Minh Quan Tran

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1. Objectives

- Design a parking indicator using Quartus software.
- Write a VHDL and Verilog code from the design.
- Push the code and run to the SCEMA5F31C6N board.

2. Design

2.1 Requirement

- Use VHDL to implement a binary to 7 Segment decoder.
- Introduction to the VHDL Case statement.
- **Above and beyond:** Create a calculator that can perform basic addition up to 2 digit.

2.2 Solution

To design this system, first need to identify input and output:

- Input will be from SW0 to SW3.
- Output will be the 7 LED from Seven Segment Led.

Then identify what the output will be from the 4 Switches, because the LED is active high so the code for 7 segment code will be:

Nº	Input	Output
0	0000	100 0000
1	0001	111 1001
2	0010	010 0100
3	0011	011 0000
4	0100	001 1001
5	0101	001 0010
6	0110	000 0010
7	0111	111 1000
8	1000	000 0000
9	1001	001 0000
10	1010	000 1000
11	1011	000 0011
12	1100	100 0110
13	1101	010 0001
14	1110	000 0110
15	1111	000 1110

3. VHDL and Verilog

3.1 VHDL code

```
library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;
-- Declaring input and output
entity MTran_Lab4_VHDL_7SegmentLed is
    port
     (
        SW :  in  std_logic_vector (9 downto 0);
          BT :  in  std_logic_vector (3 downto 0);
        LED:  out std_logic_vector (7 downto 0);
          HEX0: out std_logic_vector (6 downto 0);
          HEX1: out std_logic_vector (6 downto 0);
          HEX2: out std_logic_vector (6 downto 0);
          HEX3: out std_logic_vector (6 downto 0)

        );
end MTran_Lab4_VHDL_7SegmentLed;

-- Describing the relationship between output and input
architecture behavioral of MTran_Lab4_VHDL_7SegmentLed is
shared variable num1_flag, num2_flag, add_flag, err_num1, err_num2: Boolean := false;
shared variable hundred, tenth, unit: integer := 0;
shared variable err, digit0, digit1, digit2, digit3, num1, num2, result: integer := 0;

-- Function declaration

-- Assignment
function SevenSegmentDisplay(Switch : std_logic_vector (3 downto 0)) return
std_logic_vector is
begin
    case (Switch) is
    when "0000" => return "1000000";
    when "0001" => return "1111001";
    when "0010" => return "0100100";
    when "0011" => return "0110000";
    when "0100" => return "0011001";
    when "0101" => return "0010010";
    when "0110" => return "0000010";
    when "0111" => return "1111000";
    when "1000" => return "0000000";
    when "1001" => return "0010000";
    when "1010" => return "0001000";
    when "1011" => return "0000011";
    when "1100" => return "1000110";
    when "1101" => return "0100001";
    when "1110" => return "0000110";
    when "1111" => return "0001110";
    when others => return "1111111";
    end case;
end SevenSegmentDisplay;

-- Displaying Digit
function DigitDisplay(Switch : std_logic_vector (3 downto 0);dig : integer) return
std_logic_vector is
begin
    if (dig <= 9) then return SevenSegmentDisplay(Switch);
    else
    return SevenSegmentDisplay("1111");
    end if;

end DigitDisplay;

-- Check Digit
function DigitCheck(dig0 : integer; dig1 : integer) return Boolean is
begin
    if (dig0 > 9 or dig1 > 9) then
    return true;
    else return false;
    end if;

end DigitCheck;

-- End of Function Declaration

-- Main code
begin

    -- Check SW
    Control_Number: process(SW,BT(3))
    begin

    -- Reset
    err := 0;
    if (BT(3) = '0') then
        HEX3 <= "1111111";
        HEX2 <= "1111111";
        HEX1 <= "1111111";
        HEX0 <= "1111111";
        err_num1 := false;
        err_num2 := false;
    end if;

    -- SW9 to change different assignment
    if (SW(9) = '0') then
        HEX3 <= "1111111";
        HEX2 <= "1111111";
        HEX1 <= "1111111";
        HEX0 <= SevenSegmentDisplay(SW(3 downto 0));
    else

    -- Displaying number 1 and number 2
        if (add_flag = false) then
            if (num1_flag = false) then
                digit0 := to_integer(unsigned(SW(3 downto 0)));
                HEX0 <= DigitDisplay(SW(3 downto 0),digit0);

                digit1 := to_integer(unsigned(SW(7 downto 4)));
                HEX1 <= DigitDisplay(SW(7 downto 4),digit1);

                -- Check num1
                err_num1 := DigitCheck(digit0, digit1);

                -- Turn off HEX2 and
                HEX2 <= "1111111";
                HEX3 <= "1111111";
            elsif (num2_flag = false) then
                digit2 := to_integer(unsigned(SW(3 downto 0)));
                HEX2 <= DigitDisplay(SW(3 downto 0),digit2);
                digit3 := to_integer(unsigned(SW(7 downto 4)));
                HEX3 <= DigitDisplay(SW(7 downto 4),digit3);

                -- Check num2
                err_num2 := DigitCheck(digit3, digit2);

                -- Turn off HEX0 and
                HEX1 <= "1111111";
                HEX0 <= "1111111";
            end if;
        else

            -- Add up 2 number then display
            result := num1 + num2;
            hundred := result / 100;
            tenth   := (result / 10) mod 10;
            unit    := result mod 10;
            if (result >= 100) then
                HEX3 <= "1111111";
                HEX2 <= SevenSegmentDisplay(std_logic_vector(to_unsigned(hundred,4)));
                HEX1 <= SevenSegmentDisplay(std_logic_vector(to_unsigned(tenth,4)));
                HEX0 <= SevenSegmentDisplay(std_logic_vector(to_unsigned(unit,4)));
            elsif result >= 10 then
                HEX3 <= "1111111";
                HEX2 <= "1111111";
                HEX1 <= SevenSegmentDisplay(std_logic_vector(to_unsigned(tenth,4)));
                HEX0 <= SevenSegmentDisplay(std_logic_vector(to_unsigned(unit,4)));
            else
                HEX3 <= "1111111";
                HEX2 <= "1111111";
                HEX1 <= "1111111";
                HEX0 <= SevenSegmentDisplay(std_logic_vector(to_unsigned(unit,4)));
            end if;

            -- Check if error
            if (err_num1 or err_num2) then
                HEX3 <= "1111111";
                HEX2 <= "0000110"; --E
                HEX1 <= "0101111"; --r
                HEX0 <= "0101111"; --r
            end if;
        end if;
    end if;
    end process Control_Number;

    -- BT0 to confirm number
    Check_BT0: process (BT(0),BT(3))
    begin
        if (BT(3) = '0') then
            LED (3 downto 0) <= "0000";
            num1_flag := false;
        end if;

        if (BT(0) = '0') then
            if (num1_flag = false) then
                num1_flag := true;
                if not err_num1 then
                    num1 := digit1 * 10 + digit0;
                else
                    LED (3 downto 0) <= "1111";
                end if;
            end if;
        end if;
    end process Check_BT0;

    -- BT1 to confirm number 2
    Check_BT1: process (BT(1),BT(3))
    begin
        if (BT(3) = '0') then
            LED (7 downto 4) <= "0000";
            num2_flag := false;
        end if;

        if (BT(1) = '0') then
            if (num2_flag = false) then
                num2_flag := true;
                if not err_num2 then
                    num2 := digit3 * 10 + digit2;
                else
                    LED (7 downto 4) <= "1111";
                end if;
            end if;
        end if;
    end process Check_BT1;

    -- Check BT2
    Calculate_BT2: process (BT(2), BT(3))
    begin
        if BT(3) = '0' then
            add_flag := false;
        end if;
        if BT(2) = '0' then
            add_flag := true;
        end if;
    end process Calculate_BT2;

end behavioral;
```

3.2 Verilog code

```
module MTran_Lab4_Verilog_7SegmentLed (
    input [9:0] SW,
    input [3:0] BT,
    output reg [7:0] LED,
    output reg [6:0] HEX0,
    output reg [6:0] HEX1,
    output reg [6:0] HEX2,
    output reg [6:0] HEX3
);

    // Variable declaration
    reg add_flag, num1_flag, num2_flag;
    integer hundred, tenth, unit;
    integer err, err_num1, err_num2, digit0, digit1, digit2, digit3, num1, num2,
result;

    initial
     begin
        add_flag = 0;
          num1_flag = 0;
          num2_flag = 0;
        hundred = 0;
        tenth = 0;
        unit = 0;
        err = 0;
        err_num1 = 0;
          err_num2 = 0;
        digit0 = 0;
        digit1 = 0;
        digit2 = 0;
        digit3 = 0;
        num1 = 0;
        num2 = 0;
        result = 0;
    end

    // Function Declaration

     // Displaying 7 segment function
    function [6:0] SevenSegmentDisplay;
        input [3:0] Switch;
        begin
            case (Switch)
                4'b0000: SevenSegmentDisplay = 7'b1000000;
                4'b0001: SevenSegmentDisplay = 7'b1111001;
                4'b0010: SevenSegmentDisplay = 7'b0100100;
                4'b0011: SevenSegmentDisplay = 7'b0110000;
                4'b0100: SevenSegmentDisplay = 7'b0011001;
                4'b0101: SevenSegmentDisplay = 7'b0010010;
                4'b0110: SevenSegmentDisplay = 7'b0000010;
                4'b0111: SevenSegmentDisplay = 7'b1111000;
                4'b1000: SevenSegmentDisplay = 7'b0000000;
                4'b1001: SevenSegmentDisplay = 7'b0010000;
                4'b1010: SevenSegmentDisplay = 7'b0001000;
                4'b1011: SevenSegmentDisplay = 7'b0000011;
                4'b1100: SevenSegmentDisplay = 7'b1000110;
                4'b1101: SevenSegmentDisplay = 7'b0100001;
                4'b1110: SevenSegmentDisplay = 7'b0000110;
                4'b1111: SevenSegmentDisplay = 7'b0001110;
                default: SevenSegmentDisplay = 7'b1111111;
            endcase
        end
    endfunction

    // Function to display a digit on 7-segment display
    function [6:0] DigitDisplay;
        input [3:0] Switch;
        input integer dig;
        begin
            if (dig <= 9)
                    begin
                         DigitDisplay = SevenSegmentDisplay(Switch);
                    end
                else
                    begin
                         err = err + 1;
                         DigitDisplay = SevenSegmentDisplay(4'b1111);
                    end
        end
    endfunction

    // Main code

     //
    always @(SW)
```

```
begin
   // Reset
   err = 0;

   // SW9 to change different assignment
   if (SW[9] == 1'b0)
     begin
       HEX3 = 7'b1111111;
       HEX2 = 7'b1111111;
       HEX1 = 7'b1111111;
       HEX0 = SevenSegmentDisplay(SW[3:0]);
   end

     else
     begin
       // Displaying number 1 and number 2
       if (!add_flag)
           begin
           if (!num1_flag)
                begin
               digit0 = SW[3:0];
               HEX0 = DigitDisplay(SW[3:0], digit0);

               digit1 = SW[7:4];
               HEX1 = DigitDisplay(SW[7:4], digit1);

               // Turn off HEX2 and HEX3
               HEX2 = 7'b1111111;
               HEX3 = 7'b1111111;
           end
                else
                begin
               digit2 = SW[3:0];
               HEX2 = DigitDisplay(SW[3:0], digit2);

               digit3 = SW[7:4];
               HEX3 = DigitDisplay(SW[7:4], digit3);

               // Turn off HEX0 and HEX1
               HEX1 = 7'b1111111;
               HEX0 = 7'b1111111;
           end
       end
           else

           // Add up 2 number then display
          begin
               result = num1 + num2;
               hundred = result / 100;
               tenth   = (result / 10) % 10;
               unit    = result % 10;
               if (result >= 100)
               begin
                    HEX3 = 7'b1111111;
                    HEX2 = SevenSegmentDisplay(hundred);
                    HEX1 = SevenSegmentDisplay(tenth);
                    HEX0 = SevenSegmentDisplay(unit);
               end
               else if (result >= 10)
               begin
                    HEX3 = 7'b1111111;
```

```
                     HEX2 = 7'b1111111;
                     HEX1 = SevenSegmentDisplay(tenth);
                     HEX0 = SevenSegmentDisplay(unit);
                end
                else
                begin
                     HEX3 = 7'b1111111;
                     HEX2 = 7'b1111111;
                     HEX1 = 7'b1111111;
                     HEX0 = SevenSegmentDisplay(unit);
                end

                // Check if error
                if (err_num1 || err_num2)
                begin
                     HEX3 = 7'b1111111;
                     HEX2 = 7'b0000110; //E
                     HEX1 = 7'b0101111; //r
                     HEX0 = 7'b0101111; //r
                end
          end
    end
 end

// Check BT0
 always@ (negedge(BT[0]) or negedge(BT[3]))
 begin
    // Reset
    if (!BT[3])
    begin
        num1_flag = 0;
        err_num1 = 0;
        LED[3:0] = 4'b0000;
    end

    // Assigning num1
    if (~BT[0])
    begin
        num1_flag = 1;
     if (err == 0)
            begin
            num1 = digit1 * 10 + digit0;
            end
        else
            begin
            LED[3:0] = 4'b1111;
            err_num1 = 1;
            end
  end
 end

 // Check BT1
 always@ (negedge(BT[1]) or negedge(BT[3]))
 begin
    // Reset
    if (!BT[3])
    begin
        num2_flag = 0;
        err_num2 = 0;
        LED[7:4] = 4'b0000;
    end
```

```
        // Assigning num2
        if (!BT[1])
        begin
            num2_flag = 1;
         if (err == 0)
                begin
                num2 = digit3 * 10 + digit2;
                end
            else
                begin
                LED[7:4] = 4'b1111;
                err_num2 = 1;
                end
      end
     end

    always@ (negedge(BT[2]) or negedge(BT[3]))
    begin
      if (!BT[3])
        begin
        add_flag = 0;
        end
        else
        begin
        add_flag = 1;
        end
   end

endmodule
```

4. Pin Planner

4.1 Input and Output

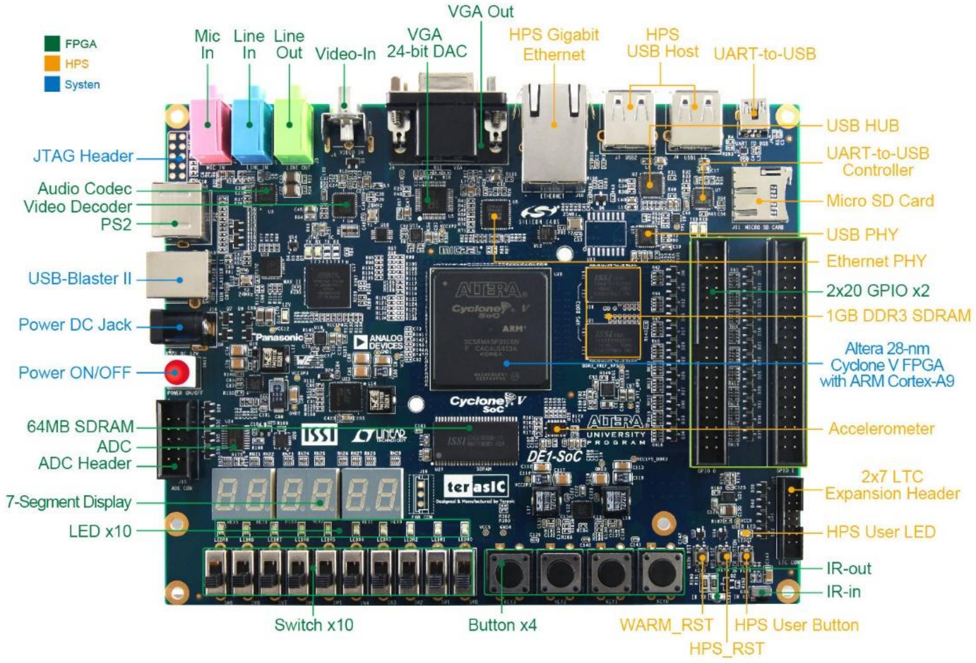


Figure 4-1: SCEMA5F31C6N board

Assigning:

BT[0]:	KEY0
BT[1]:	KEY1
BT[2]:	KEY2

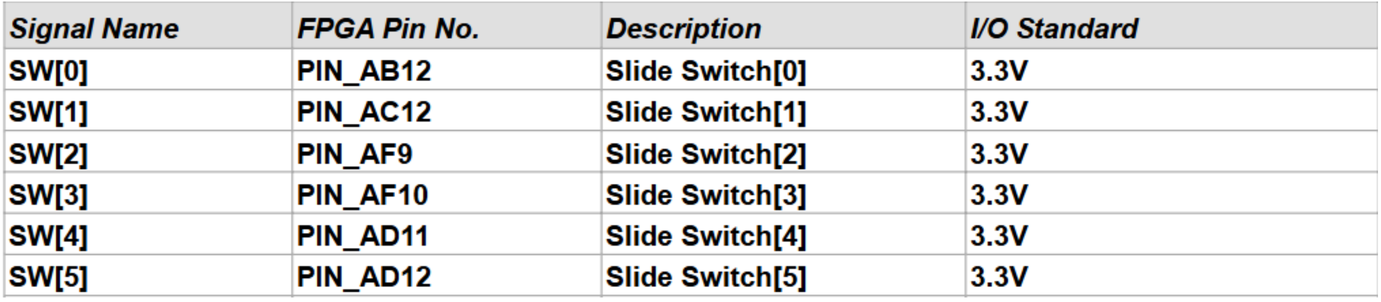
SW[0]:	SW0
SW[1]:	SW1
SW[2]:	SW2
SW[3]:	SW3
SW[4]:	SW4
SW[5]:	SW5
SW[6]:	SW6
SW[7]:	SW7
SW[8]:	SW8
SW[9]:	SW9

LED[0]:	LEDR0
LED[1]:	LEDR1
LED[2]:	LEDR2
LED[3]:	LEDR3
LED[4]:	LEDR4
LED[5]:	LEDR5
LED[6]:	LEDR6
LED[7]:	LEDR7

4. Pin Planner

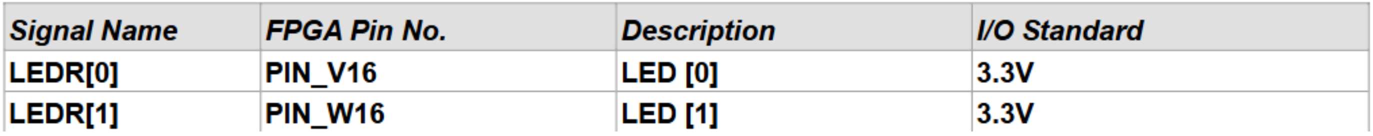
HEX0[0]:	HEX0[0]	HEX1[0]:	HEX1[0]	HEX2[0]:	HEX2[0]	HEX3[0]:	HEX3[0]
HEX0[1]:	HEX0[1]	HEX1[1]:	HEX1[1]	HEX2[1]:	HEX2[1]	HEX3[1]:	HEX3[1]
HEX0[2]:	HEX0[2]	HEX1[2]:	HEX1[2]	HEX2[2]:	HEX2[2]	HEX3[2]:	HEX3[2]
HEX0[3]:	HEX0[3]	HEX1[3]:	HEX1[3]	HEX2[3]:	HEX2[3]	HEX3[3]:	HEX3[3]
HEX0[4]:	HEX0[4]	HEX1[4]:	HEX1[4]	HEX2[4]:	HEX2[4]	HEX3[4]:	HEX3[4]
HEX0[5]:	HEX0[5]	HEX1[5]:	HEX1[5]	HEX2[5]:	HEX2[5]	HEX3[5]:	HEX3[5]
HEX0[6]:	HEX0[6]	HEX1[6]:	HEX1[6]	HEX2[6]:	HEX2[6]	HEX3[6]:	HEX3[6]

From the DE1_SoC_User_Manual,



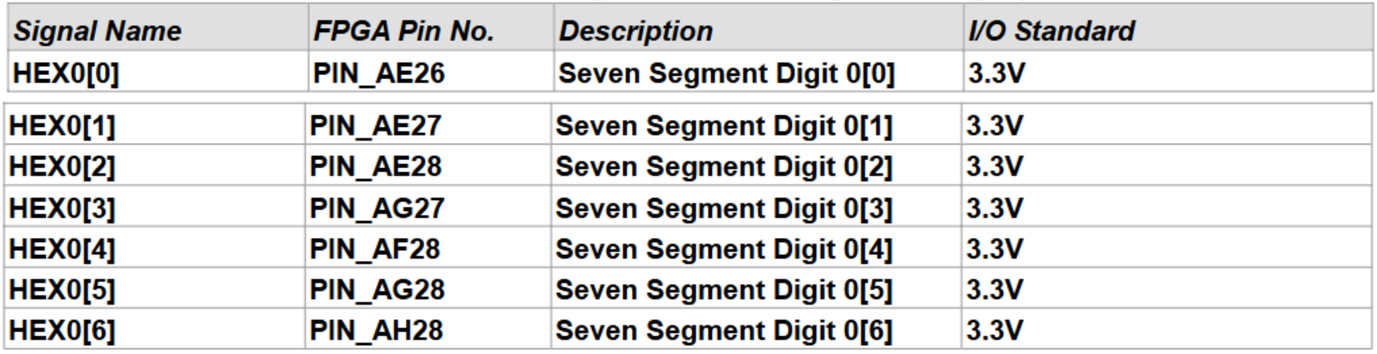
Signal Name	FPGA Pin No.	Description	I/O Standard
SW[0]	PIN_AB12	Slide Switch[0]	3.3V
SW[1]	PIN_AC12	Slide Switch[1]	3.3V
SW[2]	PIN_AF9	Slide Switch[2]	3.3V
SW[3]	PIN_AF10	Slide Switch[3]	3.3V
SW[4]	PIN_AD11	Slide Switch[4]	3.3V
SW[5]	PIN_AD12	Slide Switch[5]	3.3V

Figure 4-2: SW0 and SW1 Pin No



Signal Name	FPGA Pin No.	Description	I/O Standard
LEDR[0]	PIN_V16	LED [0]	3.3V
LEDR[1]	PIN_W16	LED [1]	3.3V

Figure 4-3: LEDR0's Pin No



Signal Name	FPGA Pin No.	Description	I/O Standard
HEX0[0]	PIN_AE26	Seven Segment Digit 0[0]	3.3V
HEX0[1]	PIN_AE27	Seven Segment Digit 0[1]	3.3V
HEX0[2]	PIN_AE28	Seven Segment Digit 0[2]	3.3V
HEX0[3]	PIN_AG27	Seven Segment Digit 0[3]	3.3V
HEX0[4]	PIN_AF28	Seven Segment Digit 0[4]	3.3V
HEX0[5]	PIN_AG28	Seven Segment Digit 0[5]	3.3V
HEX0[6]	PIN_AH28	Seven Segment Digit 0[6]	3.3V

Figure 4-4: HEX's Pin No

5. Result

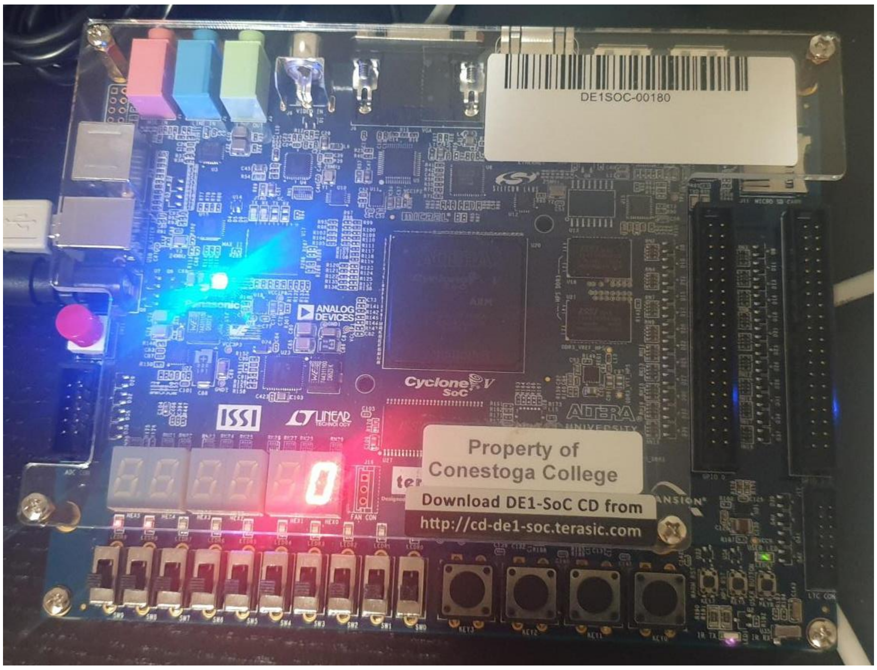


Figure 5-1: When all 6 levels are available.

SW[3:0] all equal to 0 in which displaying 0.

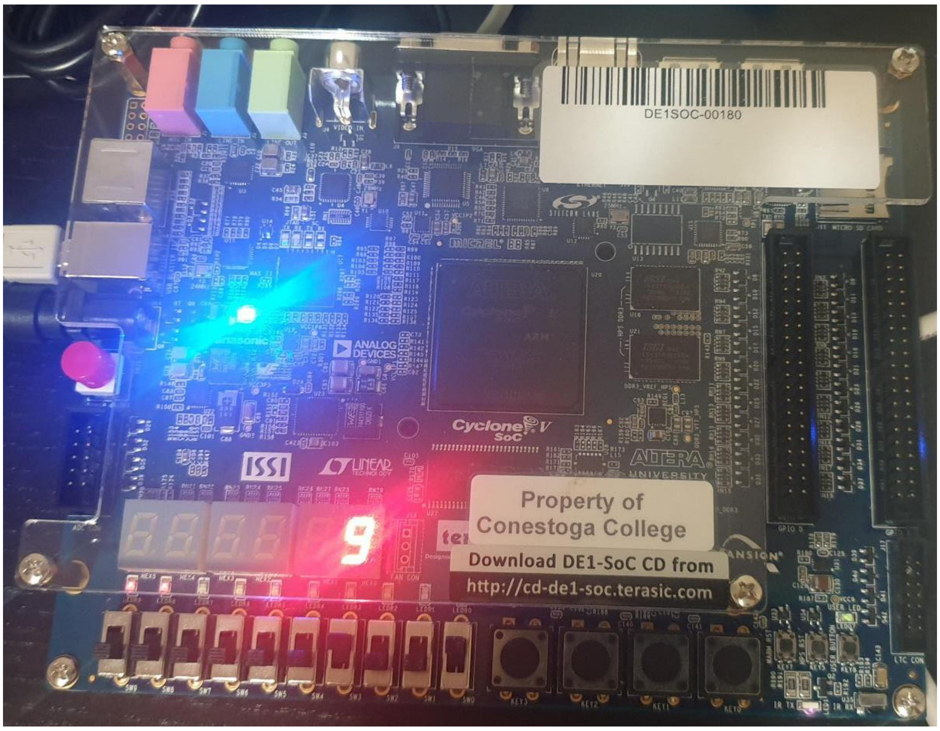


Figure 5-2: When 1 level is full

SW3 = 1, SW2 = 0, SW1 = 0, SW0 = 1 which should be 9 and the 7 segment LED displaying 9.

5. Result

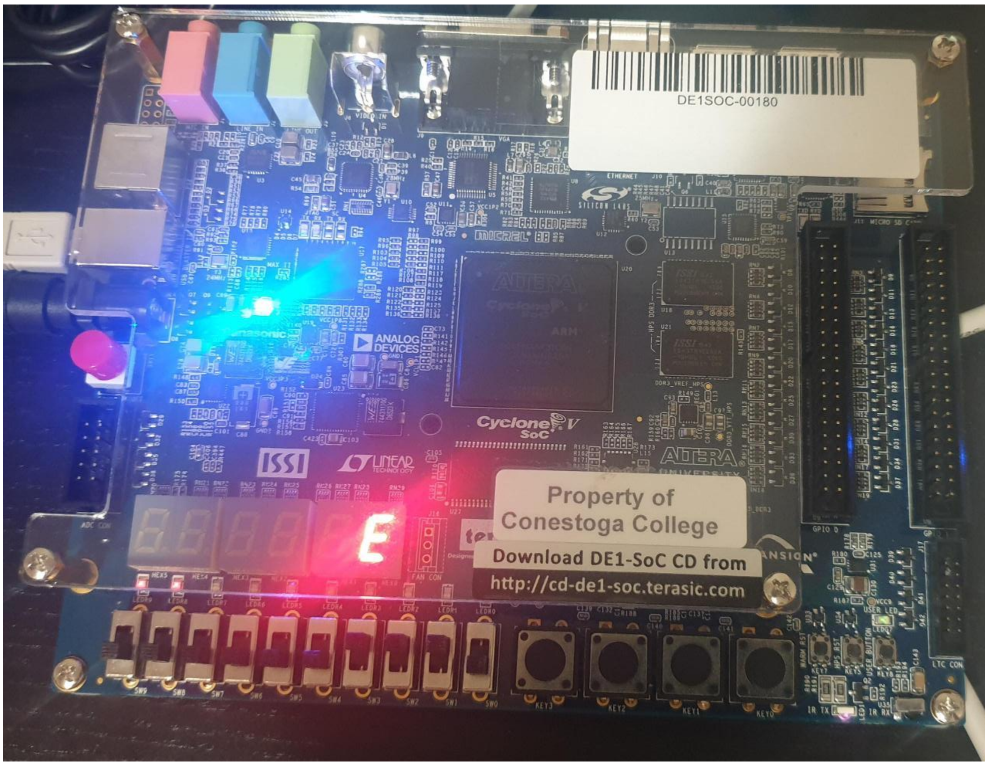


Figure 5-3: When all levels are full

SW3 = 1, SW2 = 1, SW1 = 1, SW0 = 0 which should be 14 and the 7 segment LED displaying ‘E’.

Calculator:

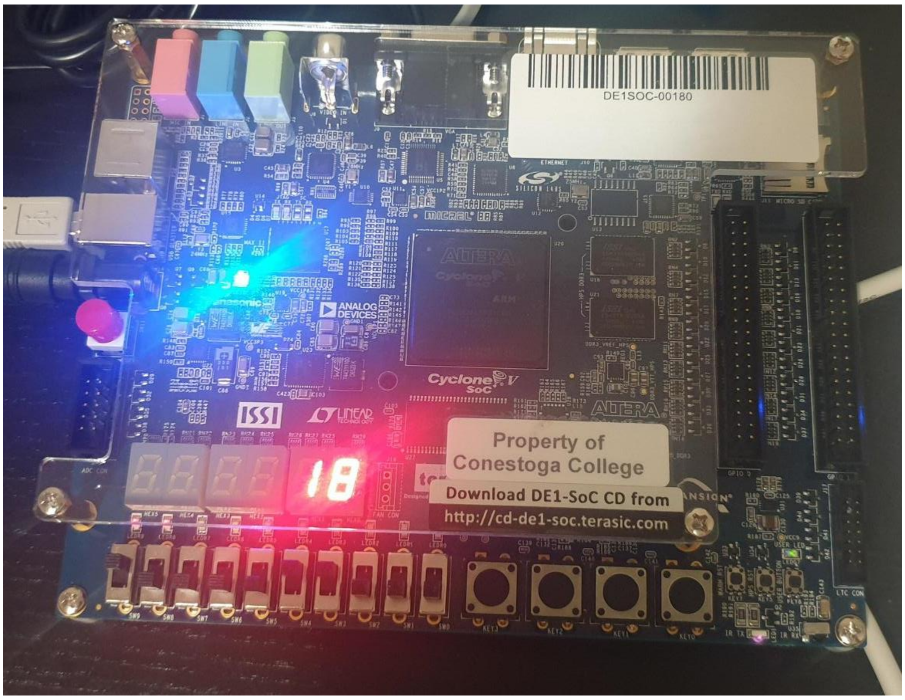


Figure 5-4: Choosing number 1

Input are SW[7:0] to choose number 1. SW[7:4] controlled HEX1 and SW[3:0] controlled HEX0. Input BT0 is used to confirm the first number.

5. Result

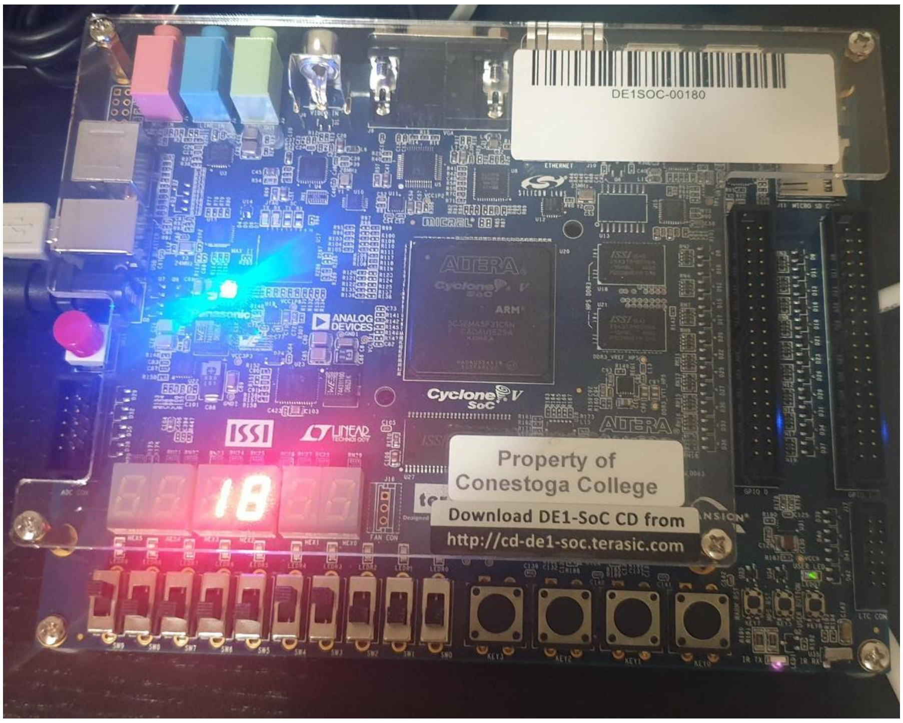


Figure 5-5: Choosing number 2

Also input are SW[7:0] to choose number 2. SW[7:4] controlled HEX3 and SW[3:0] controlled HEX2. Input BT1 is used to confirm the number.

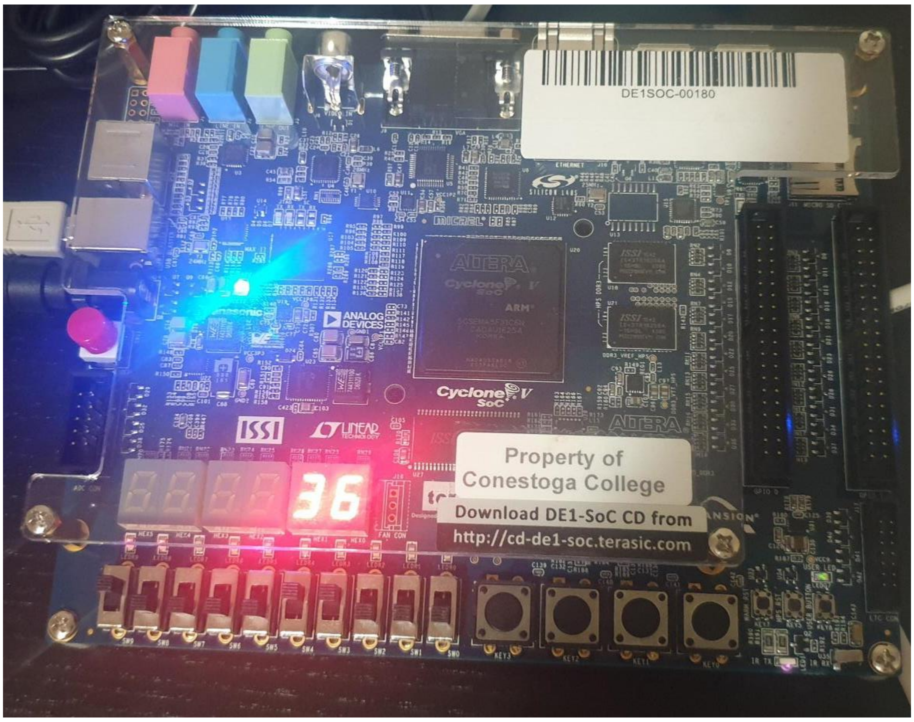


Figure 5-6: Result for adding them up

After confirming both number, press button 2 to add both number and HEX[2:0] will display the result.

REFERENCES