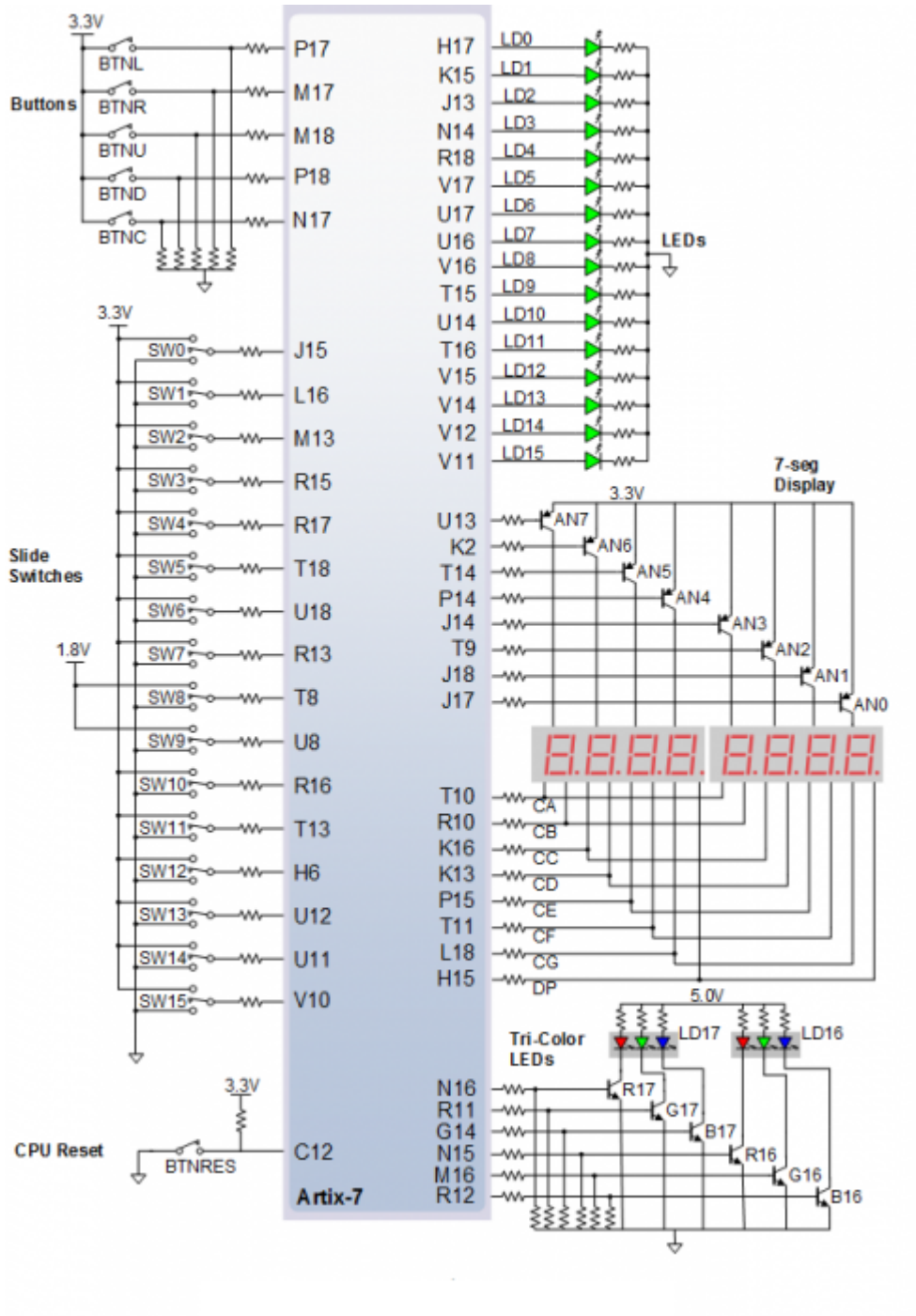
Lab 8: Traffic light controller

Preparation tasks

State table

Input P	0	0	1	1	0	1	0	1	1	1	1	0	0	1	1	1
Clock	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
State	A	A	A	B	C	C	D	A	B	C	D	B	B	B	C	D
Output R	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1

Nexys A7 board leds



RGB LED	Artix-7 pin names	Red	Yellow	Green
LD16	N15, M16, R12	`1,0,0`	`1,1,0`	`0,1,0`
LD17	N16, R11, G14	`1,0,0`	`1,1,0`	`0,1,0`

Traffic lights controller

Process `p_traffic_fsm` code

```
p_traffic_fsm : process(clk)
    begin
        if rising_edge(clk) then
            if (reset = '1') then       -- Synchronous reset
```

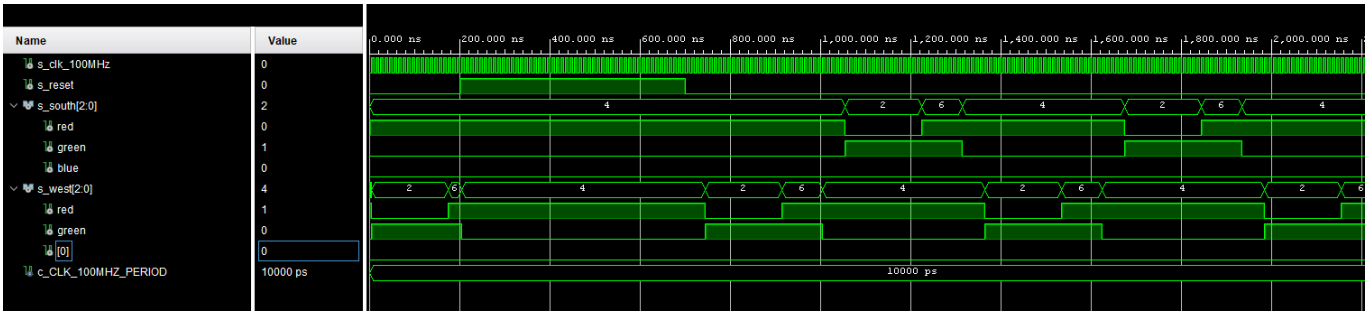
```
            s_state <= STOP1 ;      -- Set initial state
            s_cnt   <= c_ZERO;      -- Clear all bits

        elsif (s_en = '1') then
            -- Every 250 ms, CASE checks the value of the s_state
            -- variable and changes to the next state according
            -- to the delay value.
            case s_state is

                -- If the current state is STOP1, then wait 1 sec
                -- and move to the next GO_WAIT state.
                when STOP1 =>
                    -- Count up to c_DELAY_1SEC
                    if (s_cnt < c_DELAY_1SEC) then
                        s_cnt <= s_cnt + 1;
                    else
                        -- Move to the next state
                        s_state <= WEST_GO;
                        -- Reset local counter value
                        s_cnt   <= c_ZERO;
                    end if;

                when WEST_GO =>
                    --  red, green, 4s
                    if (s_cnt < 4 * c_DELAY_1SEC ) then
                        s_cnt <= s_cnt + 1;
                    else
                        s_state <= WEST_WAIT;
                        s_cnt <= c_ZERO;
                    end if;

                when WEST_WAIT =>
                    -- red, yellow, 2s
                    if (s_cnt < 2 * c_DELAY_1SEC ) then
                        s_cnt <= s_cnt + 1;
                    else
                        s_state <= STOP2;
                        s_cnt <= c_ZERO;
                    end if;

                when STOP2 =>
                    -- red, red, 1s
                    if (s_cnt < c_DELAY_1SEC ) then
                        s_cnt <= s_cnt + 1;
                    else
                        s_state <= SOUTH_GO;
                        s_cnt <= c_ZERO;
                    end if;

                when SOUTH_GO =>
                    -- green, red, 4s
                    if (s_cnt < 4 * c_DELAY_1SEC ) then
                        s_cnt <= s_cnt + 1;
                    else
```

```
                            s_state <= SOUTH_WAIT;
                            s_cnt <= c_ZERO;
                        end if;

                    when SOUTH_WAIT =>
                        -- yellow, red, 2s
                        if (s_cnt < 2 * c_DELAY_1SEC ) then
                            s_cnt <= s_cnt + 1;
                        else
                            s_state <= STOP1;
                            s_cnt <= c_ZERO;
                        end if;


                    when others =>
                        s_state <= STOP1;

                end case;
            end if; -- Synchronous reset
        end if; -- Rising edge
    end process p_traffic_fsm;
```

Process `p_output_fsm` code

```
p_output_fsm : process(s_state)
    begin
        case s_state is
            when STOP1 =>
                south_o <= "100";   -- Red (RGB = 100)
                west_o  <= "100";   -- Red (RGB = 100)
            when WEST_GO =>
                south_o <= "100";   -- Red (RGB = 100)
                west_o  <= "010";   -- Green (RGB = 010)
            when WEST_WAIT =>
                south_o <= "100";   -- Red (RGB = 100)
                west_o  <= "110";   -- Yellow (RGB = 110)
            when STOP2 =>
                south_o <= "100";   -- Red (RGB = 100)
                west_o  <= "100";   -- Red (RGB = 100)
            when SOUTH_GO =>
                south_o <= "010";   -- Green (RGB = 010)
                west_o  <= "100";   -- Red (RGB = 100)
            when SOUTH_WAIT =>
                south_o <= "110";   -- Yellow (RGB = 110)
                west_o  <= "100";   -- Red (RGB = 100)

            when others =>
                south_o <= "100";   -- Red
                west_o  <= "100";   -- Red
        end case;
    end process p_output_fsm;
```

Simulated waveforms



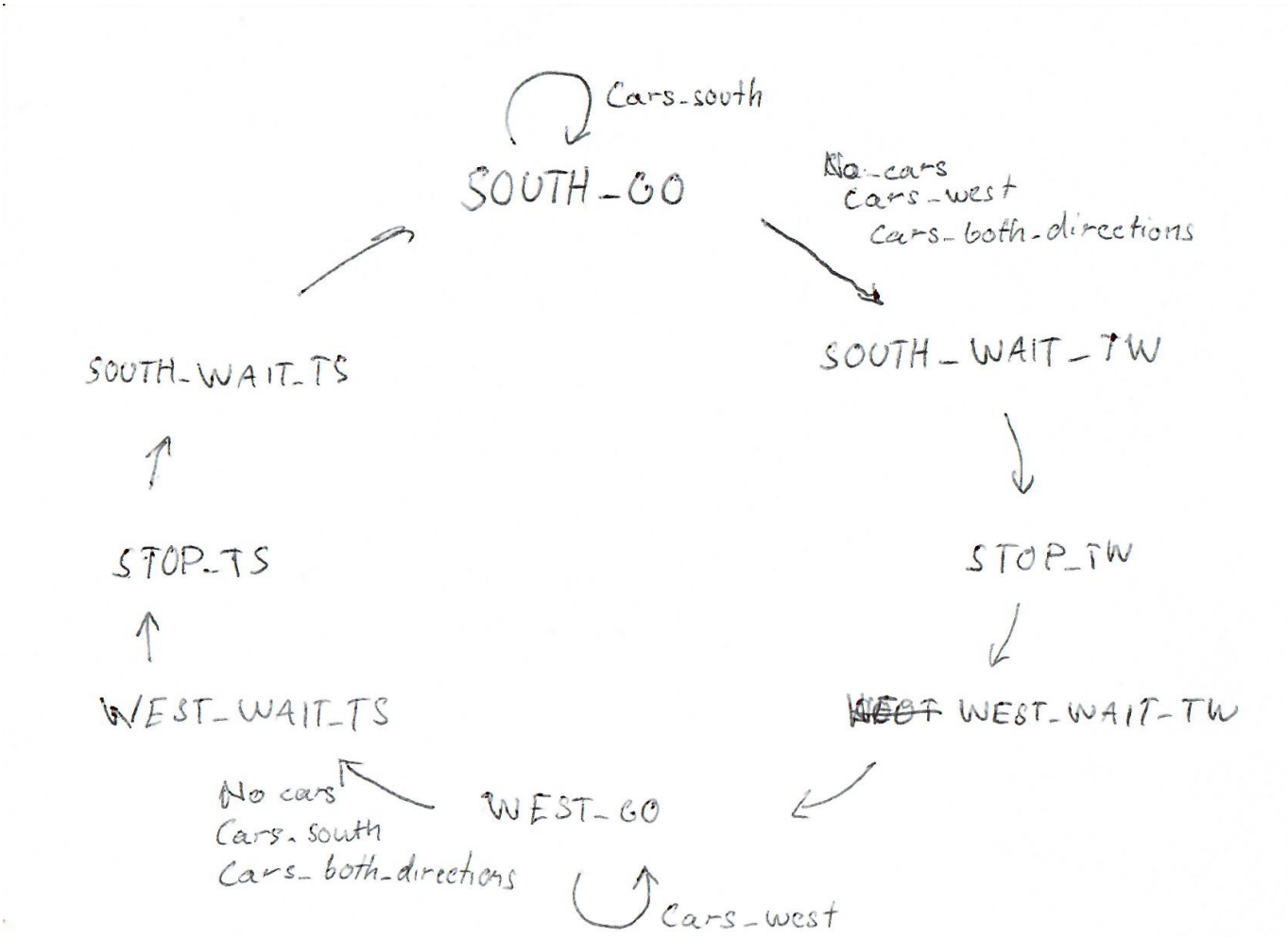
Smart controller

State table

State	State name	South lights	West lights	`No cars	Cars to west	Cars to south	Cars both ways
0	SOUTH_GO	Green	Red	1	1	0	1
1	SOUTH_WAIT_TW	Yellow	Red	2	2	2	2
2	STOP_TW	Red	Red	3	3	3	3
3	WEST_WAIT_TW	Red	Yellow	4	4	4	4
4	WEST_GO	Red	Green	5	4	5	5
5	SOUTH_WAIT_TS	Yellow	Red	6	6	6	6
6	STOP_TS	Red	Red	7	7	7	7
7	WEST_WAIT_TS	Red	Yellow	0	0	0	0

- TS stands for to south and vice versa for TW

State diagram



Listing of sequential process p_smart_traffic_fsm

```
p_smart_traffic_fsm : process(clk)
    begin
        if rising_edge(clk) then
            if (reset = '1') then       -- Synchronous reset
                s_state <= STOP_TS ;      -- Set initial state
                s_cnt   <= c_ZERO;      -- Clear all bits

            elsif (s_en = '1') then
                case s_state is

                    when SOUTH_GO =>
                        if (s_cnt < c_DELAY_4SEC) then
                            s_cnt <= s_cnt + 1;
                        else
                            if (cars_to_south = '1') and (cars_to_west = '0') then
                                s_state <= SOUTH_GO;
                                s_cnt <= c_DELAY_4SEC - c_DELAY_1SEC;
                                -- This will cause 1s checks both values changed.
                                -- In case of real crossroad, intervals are much
longer.
                                -- Setting smaller countdown time between checks
```

```
                    -- after long time in one state the reaction to
                    -- change would be faster.
                else
                    s_state <= SOUTH_WAIT_TW;
                    s_cnt   <= c_ZERO;
                end if;
            end if;

        when SOUTH_WAIT_TW =>
            if (s_cnt < c_DELAY_1SEC ) then
                s_cnt <= s_cnt + 1;
            else
                s_state <= STOP_TW;
                s_cnt <= c_ZERO;
            end if;

        when STOP_TW =>
            if (s_cnt < c_DELAY_2SEC ) then
                s_cnt <= s_cnt + 1;
            else
                s_state <= WEST_WAIT_TW;
                s_cnt <= c_ZERO;
            end if;

        when WEST_WAIT_TW =>
            if (s_cnt < c_DELAY_1SEC ) then
                s_cnt <= s_cnt + 1;
            else
                s_state <= WEST_GO;
                s_cnt <= c_ZERO;
            end if;

        when WEST_GO =>
            if (s_cnt <  c_DELAY_4SEC ) then
                s_cnt <= s_cnt + 1;
            else
                if (cars_to_south = '0') and (cars_to_west = '1') then
                    s_state <= WEST_GO;
                    s_cnt <= c_DELAY_4SEC - c_DELAY_1SEC;
                else
                    s_state <= WEST_WAIT_TS;
                    s_cnt <= c_ZERO;
                end if;
            end if;

        when WEST_WAIT_TS =>
            if (s_cnt < c_DELAY_1SEC ) then
                s_cnt <= s_cnt + 1;
            else
                s_state <= STOP_TS;
                s_cnt <= c_ZERO;
            end if;

        when STOP_TS =>
```

```
                        if (s_cnt < c_DELAY_2SEC ) then
                            s_cnt <= s_cnt + 1;
                        else
                            s_state <= SOUTH_WAIT_TS;
                            s_cnt <= c_ZERO;
                        end if;

                    when SOUTH_WAIT_TS =>
                        if (s_cnt < c_DELAY_1SEC ) then
                            s_cnt <= s_cnt + 1;
                        else
                            s_state <= SOUTH_GO;
                            s_cnt <= c_ZERO;
                        end if;


                    when others =>
                        s_state <= STOP_TS;

                end case;
            end if; -- Synchronous reset
        end if; -- Rising edge
    end process p_smart_traffic_fsm;
```