

Laboratórna úloha číslo 7

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GitHub:

Link repozitára: <https://github.com/DaNNym99/Digital-electronics-1>

1. Pravdivostne tabulky

1.1. D-ff

D	Q _n	Q(n+1)	Comments
0	0	0	Zapis pri nabeznej hrane
0	1	0	Zapis pri nabeznej hrane
1	0	1	Zapis pri nabeznej hrane
1	1	1	Zapis pri nabeznej hrane

1.2. JK-ff

J	K	Q _n	Q(n+1)	Comments
0	0	0	0	No change
0	0	1	1	No change
0	1	0	0	Reset
0	1	1	0	Reset
1	0	0	1	Set
1	0	1	1	Set
1	1	0	1	Invertor
1	1	1	0	Invertor

1.2. T-ff

T	Q _n	Q(n+1)	Comments
0	0	0	Pamatanie
0	1	1	Pamatanie
1	0	1	Invertor
1	1	0	Invertor

2. D-latch

2.1. Proces p_d_latch

```
p_d_latch : process (d, arst, en)
begin
    if (arst = '1') then
        q <= '0';
        q_bar <= '0';
    elsif (en = '1') then
        q <= d;
        q_bar <= not d;
    end if;
end process p_d_latch;
```

2.2. Súbor tb_d_latch.vhdl

```
p_reset : process
begin
    s_arst <= '0';
    wait for 38 ns;
    s_arst <= '1';
    wait for 53 ns;
    -- Reset activated
    s_arst <= '0';
    wait for 660 ns;
    s_arst <= '1';
    wait;
end process;

p_stimulus : process
begin
    report "Stimulus process started" severity note;
    s_d <= '0';
    s_en <= '0';

    assert(s_q = '0')
    report "" severity error;

    wait for 10ns;
    s_d <= '0';
    wait for 10ns;
    s_d <= '1';
    wait for 10ns;
    s_d <= '0';
    wait for 10ns;
    s_d <= '1';
    wait for 10ns;
    s_d <= '0';
end process;
```

```
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';

s_en <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';

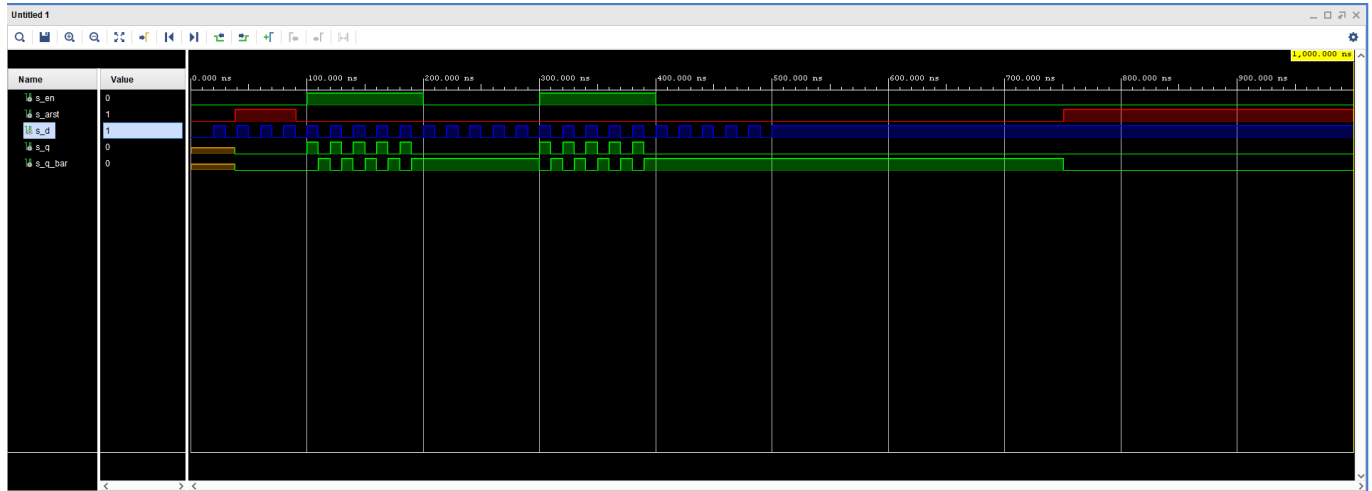
s_en <= '0';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
```

```
s_en <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';

s_en <= '0';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';

report "Stimulus process finished" severity note;
wait;
end process p_stimulus;
```

2.3. Vystup simulácie



3. Hradlá

3.1. Proces p_d_ff_arst

```
p_d_ff_arst : process (arst, clk)
begin
    if (arst = '1') then
        q <= '0';
        q_bar <= '1';
    elsif rising_edge(clk) then
        q <= d;
        q_bar <= not d;

    end if;
end process p_d_ff_arst;
```

3.2. Proces p_d_ff_rst

```
p_d_ff_rst : process (clk)
begin
    if rising_edge(clk) then
        if (rst = '1') then
            s_q <= '0';
        else
            if rising_edge(clk) then
                s_q <= d;
            end if;
        end if;
    end if;
end process p_d_ff_rst;
```

3.3. Proces p_jk_ff_rst

```
p_jk_ff_rst : process ( clk)
begin
    if rising_edge(clk) then
        if (rst = '1')then
            s_q <= '0';
        else
            if(j = '0' and k = '0')then
                s_q <= s_q;
            elsif(j = '0' and k = '1')then
                s_q <= '0';
            elsif(j = '1' and k = '0')then
                s_q <= '1';
            else
                s_q <= not s_q;
            end if;
        end if;
    end if;
end process p_jk_ff_rst;
```

3.4. Proces p_t_ff_rst

```
p_t_ff_rst : process (clk)
begin
    if rising_edge(clk) then
        if (rst = '1')then
            s_q <= '0';
        else
            if(t = '0')then
                s_q <= s_q;
            elsif(t = '1')then
                s_q <= not s_q;
            end if;
        end if;
    end if;
end process p_t_ff_rst;
```

3.5. Súbor tb_p_d_ff_arst

```
p_reset : process
begin
    s_arst <= '0';
    wait for 25 ns;
    s_arst <= '1';
    wait for 55 ns;
    -- Reset activated
    s_arst <= '0';
    wait for 108 ns;
    s_arst <= '1';
```

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```
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';

wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';

wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';

wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
```



```
wait for 10ns;  
s_d <= '1';  
wait for 10ns;  
s_d <= '0';  
wait for 10ns;  
s_d <= '1';  
wait for 10ns;  
s_d <= '0';  
wait for 10ns;  
s_d <= '1';  
wait for 10ns;  
s_d <= '0';  
wait for 10ns;  
s_d <= '1';
```

```
wait for 10ns;  
s_d <= '0';  
wait for 10ns;  
s_d <= '1';  
wait for 10ns;  
s_d <= '0';  
wait for 10ns;  
s_d <= '1';  
wait for 10ns;  
s_d <= '0';  
wait for 10ns;  
s_d <= '1';  
wait for 10ns;  
s_d <= '0';  
wait for 10ns;  
s_d <= '1';  
wait for 10ns;  
s_d <= '0';  
wait for 10ns;  
s_d <= '1';
```

```
wait for 10ns;  
s_d <= '0';  
wait for 10ns;  
s_d <= '1';  
wait for 10ns;  
s_d <= '0';  
wait for 10ns;  
s_d <= '1';  
wait for 10ns;  
s_d <= '0';  
wait for 10ns;  
s_d <= '1';  
wait for 10ns;  
s_d <= '0';  
wait for 10ns;  
s_d <= '1';  
wait for 10ns;  
s_d <= '0';
```

```
wait for 10ns;
s_d <= '1';

wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';

wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';

wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
```

```
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';

wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 10ns;
s_d <= '0';
wait for 10ns;
s_d <= '1';

report "Stimulus process finished" severity note;
wait;
end process p_stimulus;
```

3.6. Súbor tb_p_d_ff_rst

```
p_reset : process
begin
    s_rst <= '0';
    wait for 25 ns;
    s_rst <= '1';
    wait for 55 ns;
    -- Reset activated
    s_rst <= '0';
    wait for 660 ns;
    s_rst <= '1';
    wait;
end process p_reset;
```

```
p_stimulus : process
begin
    report "Stimulus process started" severity note;

    s_d <= '0';

    assert(s_q = '0')
    report "" severity error;

    s_d <= '0';
    wait for 10ns;
    s_d <= '1';
    wait for 15ns;
    s_d <= '0';
    wait for 15ns;
    s_d <= '1';
    wait for 5ns;
    s_d <= '0';
    wait for 15ns;
    s_d <= '1';
    wait for 20ns;
    s_d <= '0';
    wait for 10ns;

    s_d <= '0';
    wait for 10ns;
    s_d <= '1';
    wait for 15ns;
    s_d <= '0';
    wait for 15ns;
    s_d <= '1';
    wait for 5ns;
    s_d <= '0';
    wait for 15ns;
    s_d <= '1';
    wait for 20ns;
    s_d <= '0';
    wait for 10ns;

    s_d <= '0';
    wait for 10ns;
    s_d <= '1';
    wait for 15ns;
    s_d <= '0';
    wait for 15ns;
    s_d <= '1';
    wait for 5ns;
    s_d <= '0';
    wait for 15ns;
    s_d <= '1';
    wait for 20ns;
    s_d <= '0';
```

```
wait for 10ns;

s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 15ns;
s_d <= '0';
wait for 15ns;
s_d <= '1';
wait for 5ns;
s_d <= '0';
wait for 15ns;
s_d <= '1';
wait for 20ns;
s_d <= '0';
wait for 10ns;

s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 15ns;
s_d <= '0';
wait for 15ns;
s_d <= '1';
wait for 5ns;
s_d <= '0';
wait for 15ns;
s_d <= '1';
wait for 20ns;
s_d <= '0';
wait for 10ns;

s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 15ns;
s_d <= '0';
wait for 15ns;
s_d <= '1';
wait for 5ns;
s_d <= '0';
wait for 15ns;
s_d <= '1';
wait for 20ns;
s_d <= '0';
wait for 10ns;

s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 15ns;
s_d <= '0';
wait for 15ns;
s_d <= '1';
```

```
wait for 5ns;
s_d <= '0';
wait for 15ns;
s_d <= '1';
wait for 20ns;
s_d <= '0';
wait for 10ns;

s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 15ns;
s_d <= '0';
wait for 15ns;
s_d <= '1';
wait for 5ns;
s_d <= '0';
wait for 15ns;
s_d <= '1';
wait for 20ns;
s_d <= '0';
wait for 10ns;

s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 15ns;
s_d <= '0';
wait for 15ns;
s_d <= '1';
wait for 5ns;
s_d <= '0';
wait for 15ns;
s_d <= '1';
wait for 20ns;
s_d <= '0';
wait for 10ns;

s_d <= '0';
wait for 10ns;
s_d <= '1';
wait for 15ns;
s_d <= '0';
wait for 15ns;
s_d <= '1';
wait for 5ns;
s_d <= '0';
wait for 15ns;
s_d <= '1';
wait for 20ns;
s_d <= '0';
wait for 10ns;

s_d <= '0';
```

```
        wait for 10ns;
        s_d <= '1';
        wait for 15ns;
        s_d <= '0';
        wait for 15ns;
        s_d <= '1';
        wait for 5ns;
        s_d <= '0';
        wait for 15ns;
        s_d <= '1';
        wait for 20ns;
        s_d <= '0';
        wait for 10ns;

        report "Stimulus process finished" severity note;
        wait;
    end process p_stimulus;
```

3.7. Súbor tb_p_jk_ff_rst

```
p_reset : process
begin
    s_rst <= '0';
    wait for 25 ns;
    s_rst <= '1';
    wait for 55 ns;
    -- Reset activated
    s_rst <= '0';
    wait for 660 ns;
    s_rst <= '1';
    wait;

end process p_reset;

p_stimulus : process
begin
    report "Stimulus process started" severity note;

    s_j <= '0';
    s_k <= '0';

    assert(s_q='0')
    report "" severity error;

    s_j <= '0';
    s_k <= '0';
    wait for 10ns;
    s_j <= '1';
    s_k <= '0';
    wait for 15ns;
```

```
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '1';
wait for 5ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '1';
s_k <= '1';
wait for 20ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '1';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '1';
wait for 5ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '1';
s_k <= '1';
wait for 20ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '1';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '1';
wait for 5ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '1';
s_k <= '1';
wait for 20ns;
```



```
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '1';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '1';
wait for 5ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '1';
s_k <= '1';
wait for 20ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '1';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '1';
wait for 5ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '1';
s_k <= '1';
wait for 20ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '1';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
```

```
s_j <= '0';
s_k <= '1';
wait for 5ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '1';
s_k <= '1';
wait for 20ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '1';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '1';
wait for 5ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '1';
s_k <= '1';
wait for 20ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '1';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '1';
wait for 5ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '1';
s_k <= '1';
wait for 20ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
```

```
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '1';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '1';
wait for 5ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '1';
s_k <= '1';
wait for 20ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;
s_j <= '1';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '0';
s_k <= '1';
wait for 5ns;
s_j <= '0';
s_k <= '0';
wait for 15ns;
s_j <= '1';
s_k <= '1';
wait for 20ns;
s_j <= '0';
s_k <= '0';
wait for 10ns;

report "Stimulus process finished" severity note;
wait;
end process p_stimulus;
```

3.8. Súbor tb_p_t_ff_rst

```
p_reset : process
begin
```

```
s_rst <= '0';
wait for 25 ns;
s_rst <= '1';
wait for 55 ns;
-- Reset activated
s_rst <= '0';
wait for 660 ns;
s_rst <= '1';
wait;
end process p_reset;

p_stimulus : process
begin
    report "Stimulus process started" severity note;

    s_t <= '0';

    assert(s_q = '0')
    report "" severity error;

    s_t <= '0';
    wait for 10ns;
    s_t <= '1';
    wait for 15ns;
    s_t <= '0';
    wait for 15ns;
    s_t <= '1';
    wait for 5ns;
    s_t <= '0';
    wait for 15ns;
    s_t <= '1';
    wait for 20ns;
    s_t <= '0';
    wait for 10ns;

    s_t <= '0';
    wait for 10ns;
    s_t <= '1';
    wait for 15ns;
    s_t <= '0';
    wait for 15ns;
    s_t <= '1';
    wait for 5ns;
    s_t <= '0';
    wait for 15ns;
    s_t <= '1';
    wait for 20ns;
    s_t <= '0';
    wait for 10ns;

    s_t <= '0';
    wait for 10ns;
    s_t <= '1';
```

```
wait for 15ns;
s_t <= '0';
wait for 15ns;
s_t <= '1';
wait for 5ns;
s_t <= '0';
wait for 15ns;
s_t <= '1';
wait for 20ns;
s_t <= '0';
wait for 10ns;

s_t <= '0';
wait for 10ns;
s_t <= '1';
wait for 15ns;
s_t <= '0';
wait for 15ns;
s_t <= '1';
wait for 5ns;
s_t <= '0';
wait for 15ns;
s_t <= '1';
wait for 20ns;
s_t <= '0';
wait for 10ns;

s_t <= '0';
wait for 10ns;
s_t <= '1';
wait for 15ns;
s_t <= '0';
wait for 15ns;
s_t <= '1';
wait for 5ns;
s_t <= '0';
wait for 15ns;
s_t <= '1';
wait for 20ns;
s_t <= '0';
wait for 10ns;

s_t <= '0';
wait for 10ns;
s_t <= '1';
wait for 15ns;
s_t <= '0';
wait for 15ns;
s_t <= '1';
wait for 5ns;
s_t <= '0';
wait for 15ns;
s_t <= '1';
wait for 20ns;
```

```
s_t <= '0';  
wait for 10ns;
```

```
s_t <= '0';  
wait for 10ns;  
s_t <= '1';  
wait for 15ns;  
s_t <= '0';  
wait for 15ns;  
s_t <= '1';  
wait for 5ns;  
s_t <= '0';  
wait for 15ns;  
s_t <= '1';  
wait for 20ns;  
s_t <= '0';  
wait for 10ns;
```

```
s_t <= '0';  
wait for 10ns;  
s_t <= '1';  
wait for 15ns;  
s_t <= '0';  
wait for 15ns;  
s_t <= '1';  
wait for 5ns;  
s_t <= '0';  
wait for 15ns;  
s_t <= '1';  
wait for 20ns;  
s_t <= '0';  
wait for 10ns;
```

```
s_t <= '0';  
wait for 10ns;  
s_t <= '1';  
wait for 15ns;  
s_t <= '0';  
wait for 15ns;  
s_t <= '1';  
wait for 5ns;  
s_t <= '0';  
wait for 15ns;  
s_t <= '1';  
wait for 20ns;  
s_t <= '0';  
wait for 10ns;
```

```
s_t <= '0';  
wait for 10ns;  
s_t <= '1';  
wait for 15ns;  
s_t <= '0';  
wait for 15ns;
```

```

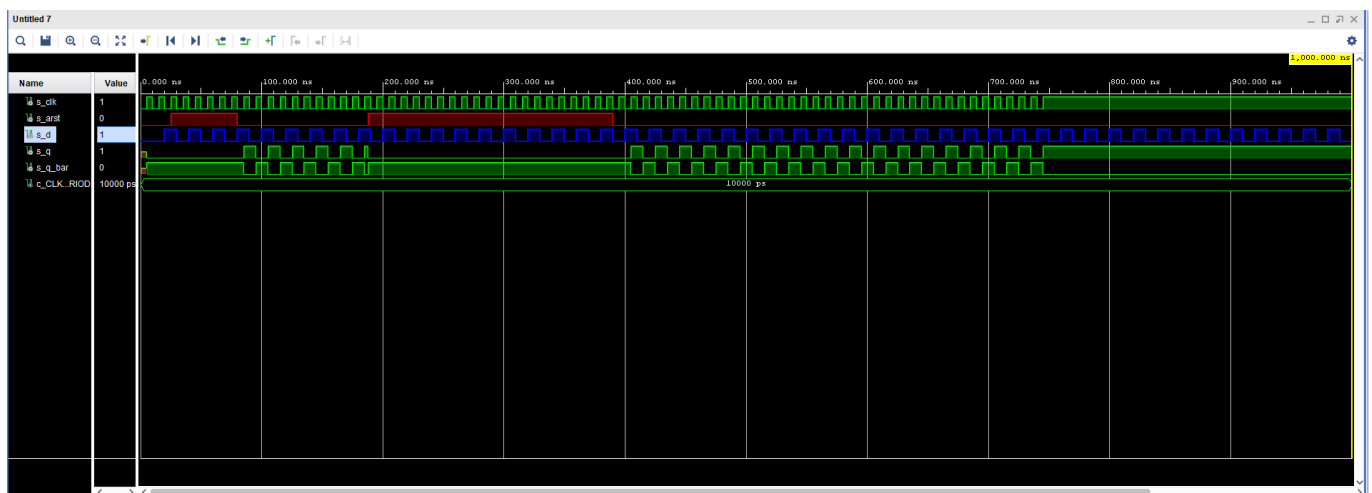
s_t <= '1';
wait for 5ns;
s_t <= '0';
wait for 15ns;
s_t <= '1';
wait for 20ns;
s_t <= '0';
wait for 10ns;

s_t <= '0';
wait for 10ns;
s_t <= '1';
wait for 15ns;
s_t <= '0';
wait for 15ns;
s_t <= '1';
wait for 5ns;
s_t <= '0';
wait for 15ns;
s_t <= '1';
wait for 20ns;
s_t <= '0';
wait for 10ns;

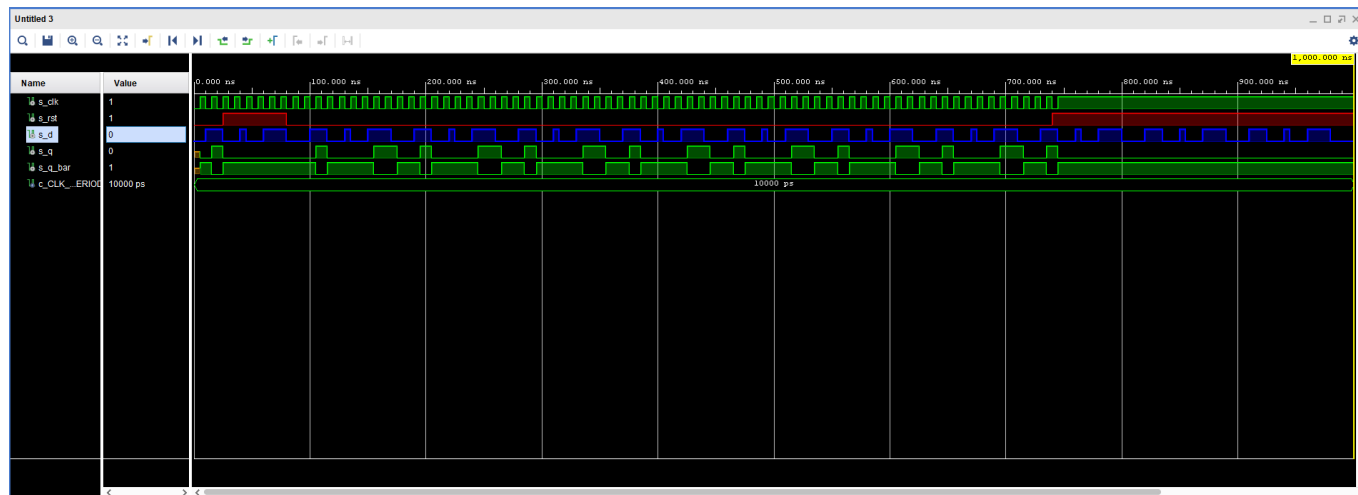
report "Stimulus process finished" severity note;
wait;
end process p_stimulus;

```

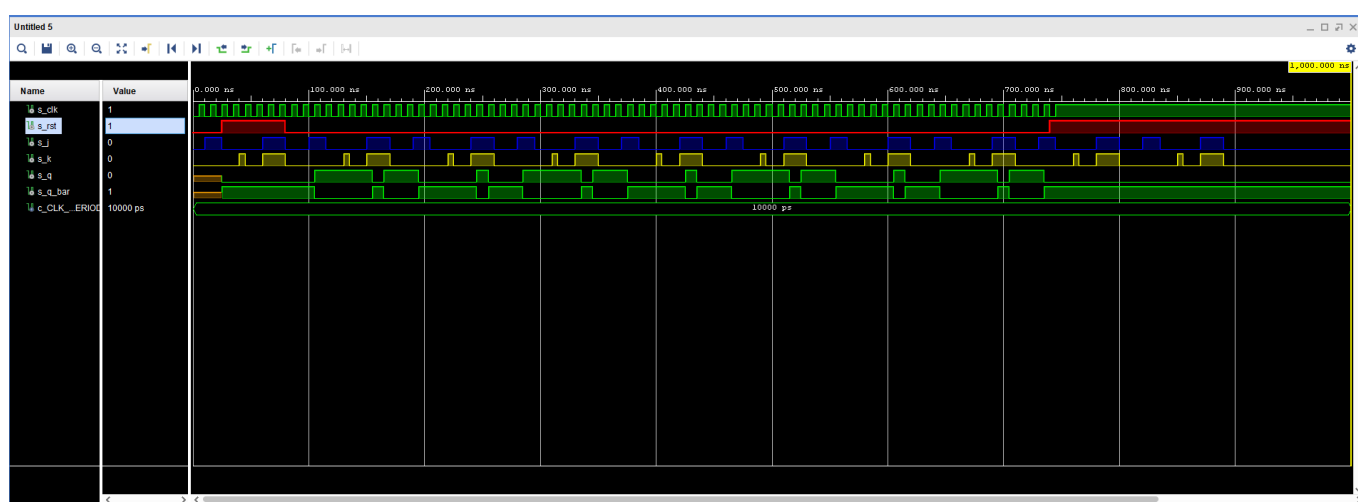
3.9. Vystup simulácie tb_p_d_ff_arst



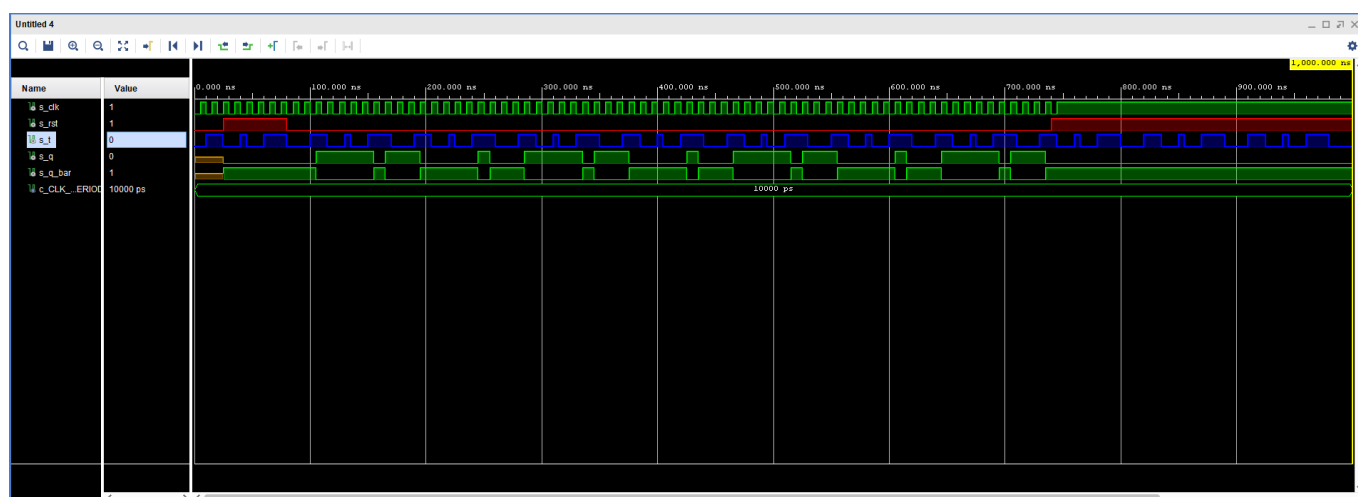
3.10. Vystup simulácie tb_p_d_ff_rst



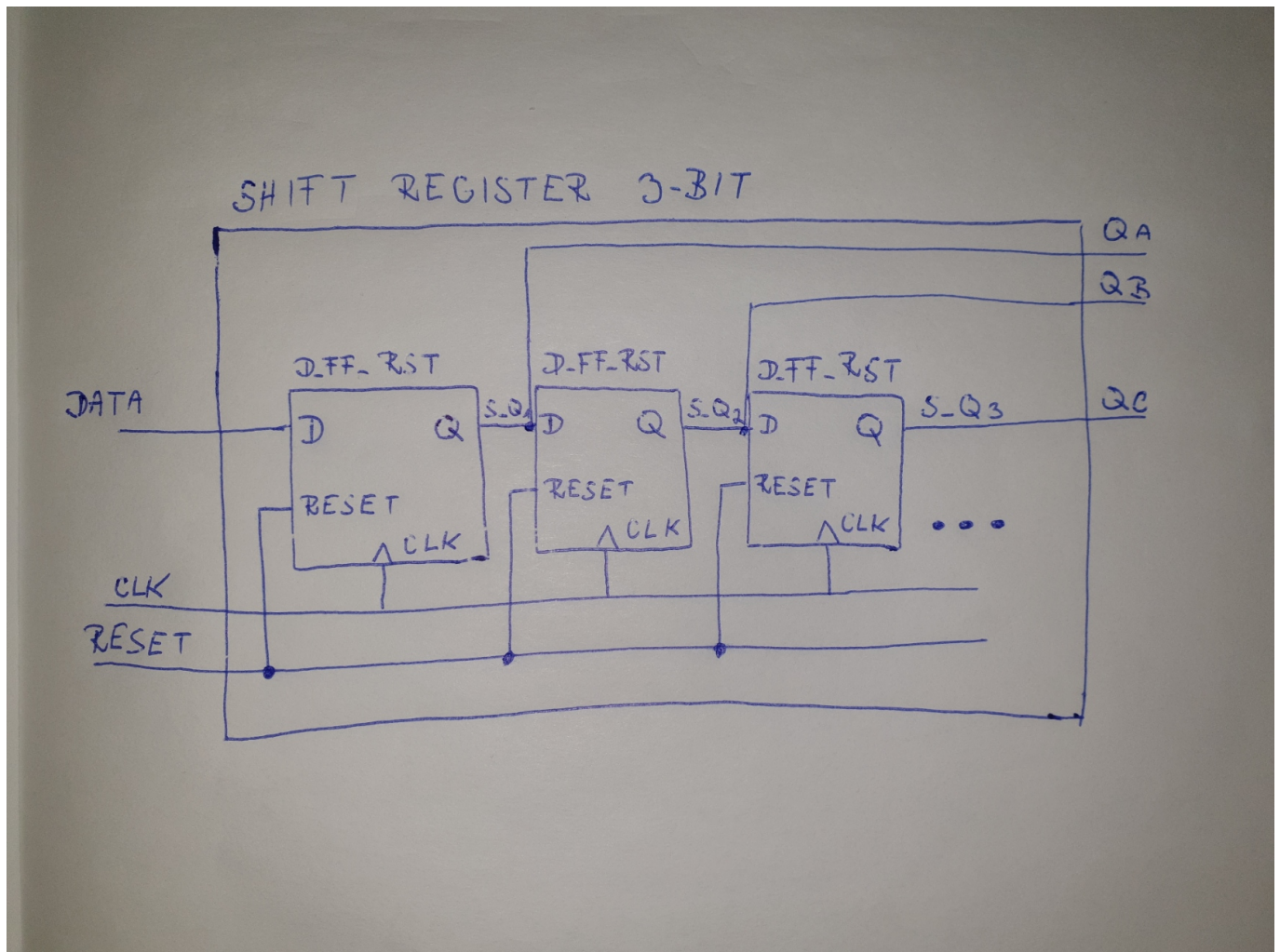
3.11. Výstup simulácie tb_p_jk_ff_rst



3.12. Výstup simulácie tb_p_t_ff_rst



4. Posuvný register pre 3-bit



- Naznačenými bodkami je možné pokračovať do požadovaného počtu bitov