Traffic Light Controller

Requirements for the exercise (issues and skills necessary to complete the task):

- **representation of numbers in decimal, binary and hexadecimal systems;**
- **setting up a new project in Quartus Prime;**
- **creating a hardware module (symbol) in Quartus Prime based on a schematic file (*.bdf);**
- **creating a hardware module (symbol) in Quartus Prime based on a source code file (eg. *.vhd);**
- **ability to simplify a logical expressions using the Karnaugh Map method;**
- **ability to implement a scheme with logic gates based on an algebraic equation.**

FREQUENCY DIVIDER (Toggle Mode)

Each kind of Flip-Flop can be configured to work in switching mode called Toggle Mode, works as a binary, frequency divider. In this mode, a rectangular wave is generated at the outputs Q and ~Q with the frequency equal to half of the clock frequency given to the flip-flop. The figure below shows several flip-flops configured in toggle mode.

Moreover, by connecting several flip-flops in series, you can obtain a mod 2^N counter (eg. counter mod 4, mod 8, mod 16, mod 32, ….).

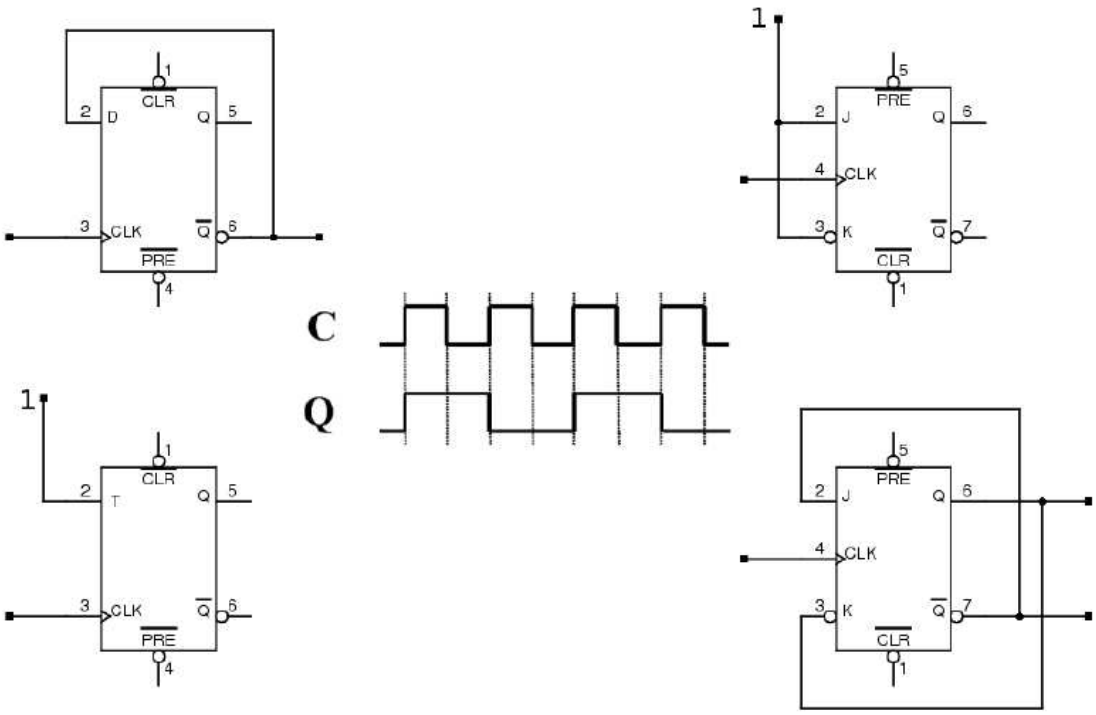

Fig. 1: D, T and JK Flip-flops configured to work in switching mode.

TRAFFIC LIGHT CONTROLLER

Design and implement the up-counter (mod 16) by connecting in series toggle mode configured flip-flops. Next, design combinational logic circuit to control the led traffic to get the sequence, as on the figure below. The inputs of the combinational circuit should be the counter outputs..

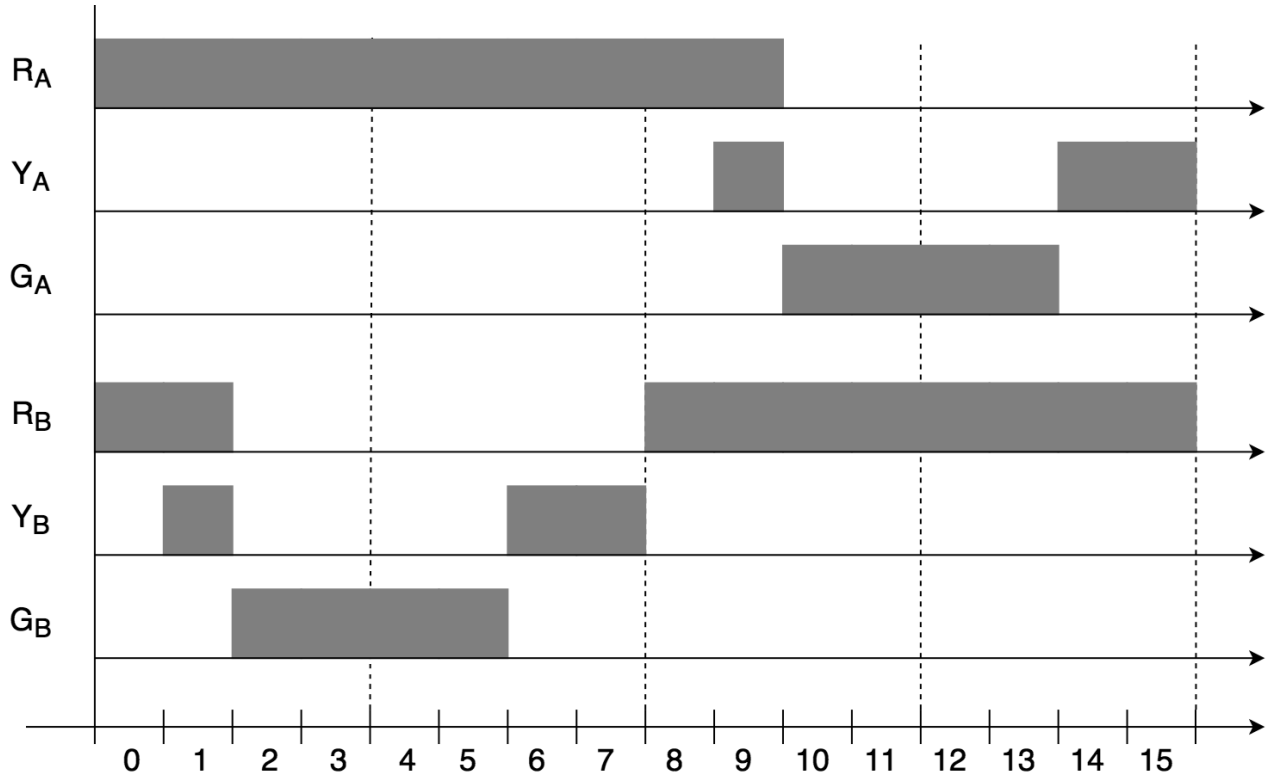

Fig. 2: Traffic light sequence at the intersection of roads A and B

Use the 1Hz signal from the Multiprescaler block as the clock signal for the counter. An example of the mod 16 up-counter, based on flip-flops configured as toggle mode, is shown in Fig. 3. Table 1 shows the Karnaugh map for the red light signal, for road A (R_A signal). Based on such maps, combinational circuits should be implemented for all traffic light signals (R_A, Y_A, G_A, R_B, Y_B, G_B). Implement the logic for controlling the lights (combination circuits) in the form of a hardware module (in the form of a symbol).

As a street light simulator on the DE10-Lite board, use the 7-segment displays HEX0 and HEX1, as shown in Fig. 4. Connect the unused display bars to the high state - VCC (HEX0[1], HEX0[2], HEX0[4], HEX0 [5], HEX1[1], HEX1[2], HEX1[4], HEX1[5]). Figure 5 shows the final circuit diagram of the Traffic Light Controller.

$X_3 X_2$ \ $X_1 X_0$	00	01	11	10
00	1	1	1	1
01	1	1	1	1
11	0	0	0	0
10	1	1	0	0

Tab. 1: Karnaugh map for R_A signal

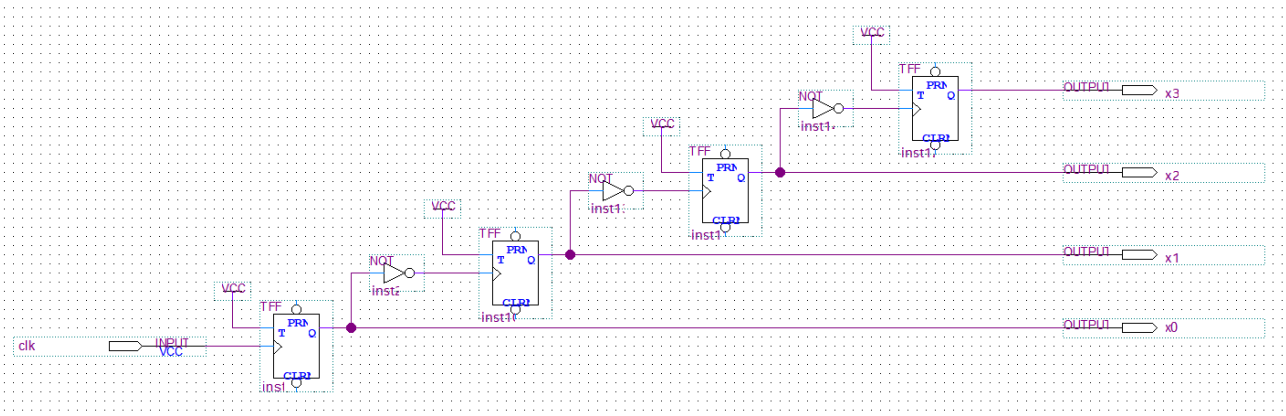

Fig. 3: Up counter mod 16

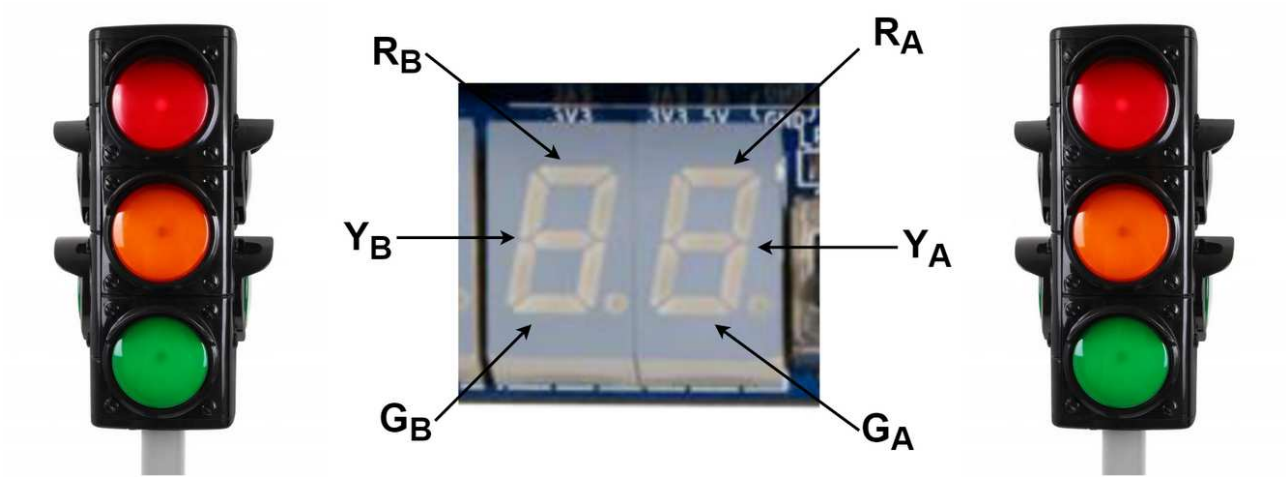

Fig. 4: Using 7-segment displays as a traffic light simulator

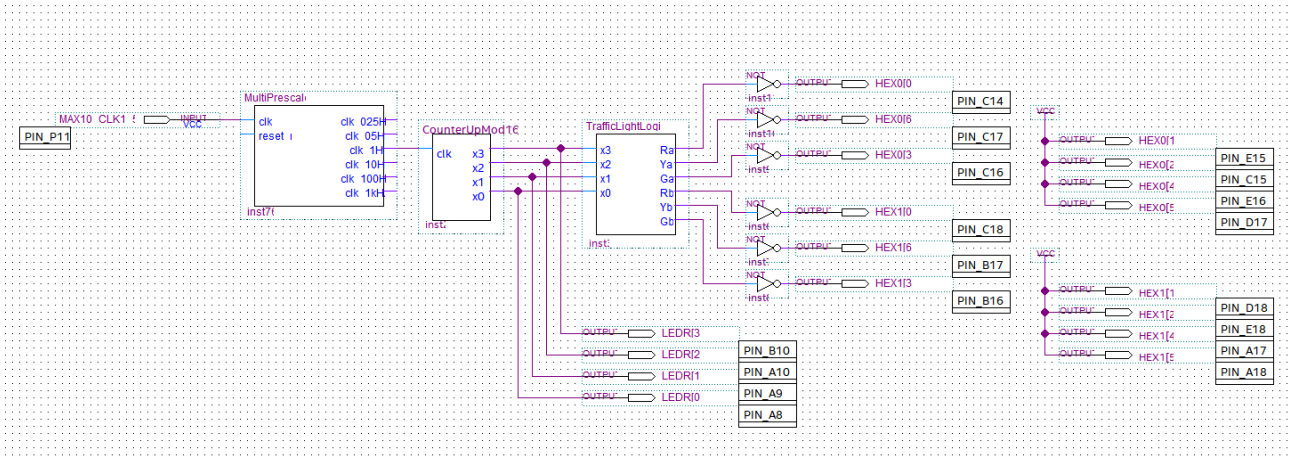

Fig. 5: Diagram of the traffic light controller system

Questions

1) Draw a frequency divider by 2 circuit based on a T / D / JK flip-flop.
2) Draw a schematic of a mod-4 up/down counter based on a binary counter using T / D / JK flip-flops.
3) How can the counting direction be changed in a mod-2^N counter that uses flip-flops in binary counter mode?
4) What will happen if the inversion is removed from the circuit shown in Fig. 3?
5) Which bit in the circuit from Fig. 3 is the most significant and which is the least significant? What does “most significant bit” / “least significant bit” mean?
6) How many flip-flops are needed to build a mod-32 / mod-64 / mod-128 / mod-256 / etc. counter?