Design an Intelligent Traffic Light Controller

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Abstract

The aim of this research is to design an intelligent traffic light control system using Field Programmable Gate Array (FPGA) technology. And Very High Speed Hardware Description Language (VHDL). A structure of four road intersection (Al-Raiyah intersection) has been selected as reference site, which is located in Al-Nasiriyah city, Iraq. This intersection interconnects Bent-Al-Huda hospital, civil defense directory, the international high-way, the police office directory, and the railway station. In addition to utilizing a regular Traffic Light Controller (TLC), multiple level of functionality such as adding a standby control signal have been considered in this design. Moreover, the motion sensor handling part, special request implementation, and loaded traffic design have been taken into consideration. Its function was verified and simulated using ModelSim.

Keywords: Intelligent Traffic Light, FPGA, VHDL, Simulation, and ModelSim,

المستخلص

الهدف من هذا البحث هو تصميم منظومة سيطرة ذكية للتحكم بتقاطعات الطرق وحركة المركبات بالاعتماد على الجهاز القابل للبرمجة (FPGA). صممت هذه المنظومة باستخدام لغة ال (VHDL). تم اختيار نموذج متكون من تقاطع اربعة طرق لاختبار المنظومة بشكل عملي (تقاطع الراية)، والكائن في مدينة الناصرية، العراق.المثير للأهتمام في هذا التقاطع انه يربط بين مستشفى بنت الهدى، مديرية الدفاع المدني، الطريق الدولي السريع، مديرة الشرطة، ومحطة القطار. تم التنفيذ باتباع خطوتين رئيسيتين، الاولى هي تصميم المنظومة بشكلها المعتاد، والثانية تتضمن اضافة الافكار التي من شأنها رفع مستوى كفاءة منظومة السيطرة. هذه الافكار تتمثل بـ: اضافة خيار الذهاب الى وضع التشغيل الاحتياطي، اضافة متحسس الحركة في كل خط، اضافة خاصية الاستجابة لطلب خط معين، و ادارة اي خط يظهر فية عدد مركبات بشكل اكثر. تم التحقق و اختبار جميع اجزاء المنظومة باستخدام البرنامج (ModelSim).

1. Introduction

Traffic light controller (TLC) is used to lessen or eliminate conflicts at area shared among multiple traffic streams which is called intersections [1]. During the rush hours, an effective TLC is required to avoid the traffic jam. Which would lead to reduce fuel consuming, carts emissions, and accidents [2]. In this research work three functional concepts was targeted, namely, using a motion sensor, request for a special road, and loaded road request, to enhance the performance of the TLC system. The FPGA has been employed in this design due to its concurrency or the parallelism feature. The concurrency feature of the FPGA is a stark contrast to the traditional controller in which the control loop rate was the limiting factor. The processing performance of the FPGA is only limited by the sensors, actuators, and other I/O models which are connected to the FPGA. In this paper the VHDL language has been selected for programming the FPGA to fill two important needs in the design process. Firstly, it gives full description of the structure of a design that is how it is decomposed into sub-designs, and how those sub-designs are interconnected. Secondly, it allows to simulate the design before starting the manufacturing. Accordingly, the designers can quickly compare alternatives and test for correctness without the delay and expense of hardware prototyping [3], [4], [5].

Many studies have been achieved to design functional TLC using different approaches. In [1], the FPGA is used to design the controller of managing the access of areas shared among multiple intersections. The FPGA-based 24-hour TLC that manages traffic movement of four roads is implemented by [6]. In [7], the TLC has been designed using Programmable Logic Controller (PLC) to replace the relay wiring.

2. System Design

Figure 1 shows the schematic top view of the selected traffic light model, for four road intersection. As depicted in this figure, each lane has one traffic light signal, which has a set of signals (Red, Yellow, and Green). The conventional TLC is considered as Present Cycle Time system, in which, initially preset time for green, while yellow and red lights for each phase and cycle, respectively [8]. The aim of this work is to design a traffic light control system enhanced by some ideas, as mentioned above, to get fully functional final framework. The designing of the TLC is selected to be mapped into two main parts. In the first part, the normal TLC is designed without any functional concepts. In the second part, some smart ideas are added to enhance the functionality of the controller.

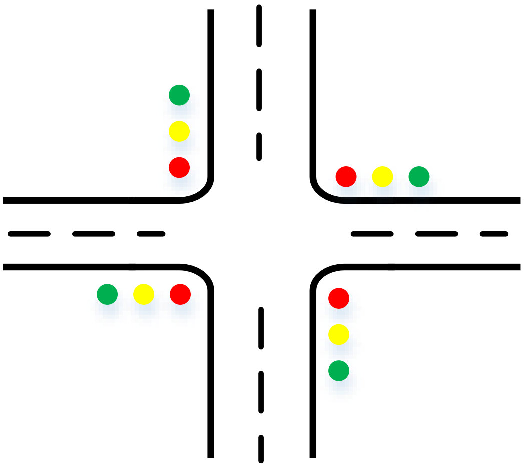

Figure 1: Schematic top view of the suggested roads intersection

2.1 Regular Traffic Light Controller Design

Designing with VHDL provides the ability to use state machine to implement complex algorithms.

Table 1: Regular design state machine and their outputs signals

state	State Code	Description	Traffic 1	Traffic 2	Traffic 3	Traffic 4
0	STANDBY	All Standby	Yellow	Yellow	Yellow	Yellow
1	ONE_G	Traffic 1 Green	Green	Red	Red	Red
2	ONE_Y	Traffic 1 Yellow	Yellow	Red	Red	Red
3	TWO_G	Traffic 2 Green	Red	Green	Red	Red
4	TWO_Y	Traffic2 Yellow	Red	Yellow	Red	Red
5	THREE_G	Traffic 3 Green	Red	Red	Green	Red
6	THREE_Y	Traffic 3 Yellow	Red	Red	Yellow	Red
7	FOUR_G	Traffic4 Green	Red	Red	Red	Green
8	FOUR_Y	Traffic 4 yellow	Red	Red	Red	Yellow

Within the state machine the design is executed by jumping from one state to another for finite number of states [9]. The regular controller has been designed with nine states as shown in Table 1. The three indication signals are appeared to implement different phase of operation.

Figure 2 shows stage machine diagram (bubble diagram), which illustrates the code.

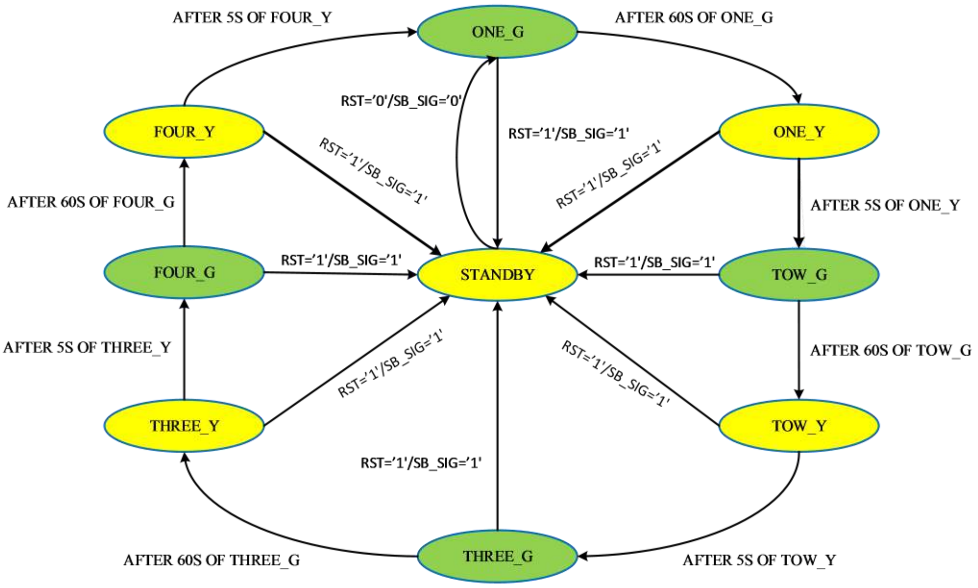

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Figure 2: State machine for traffic light "Regular Design".

three approaches have been chosen to enhance the functionality of the traffic light control system.

2.2.1 Using Motion Sensor

A motion sensor is a device that detects moving objects, hence, it can be used to sense the presence or absence of vehicles in the normal systems, some detectors are used on the road such as inductive loop detector, micro-loop probes, pneumatic road tubes, video, radar, ultrasonic sensors, and wireless sensor [10].

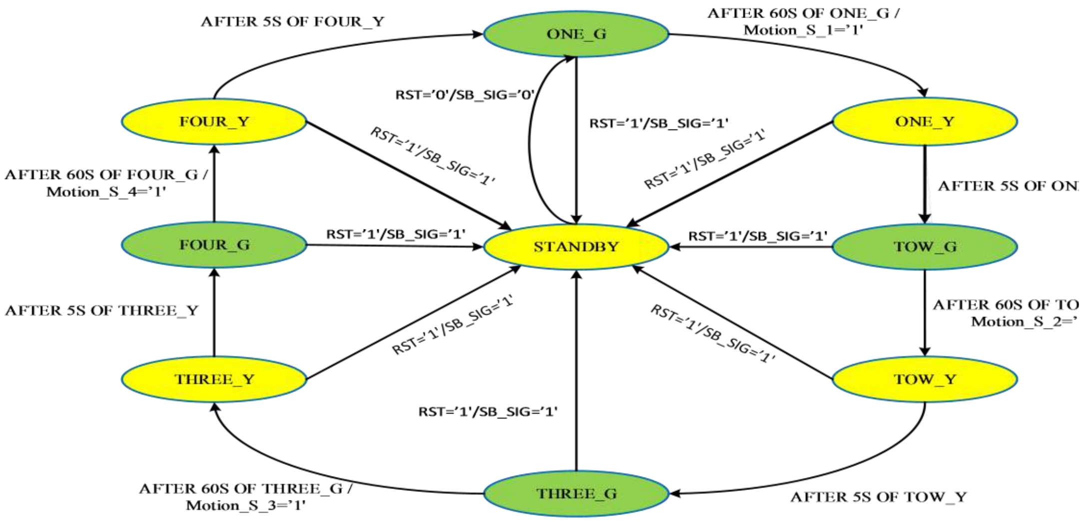

Figure 3: State machine for traffic light "motion sensor".

The motion sensor is functioning continuously by giving a logic '1' when there are no vehicles, and logic '0' when there are vehicles present. After the traffic light-1 became green and the cars start in moving the motion sensor checks whether the road is vacant or used by the vehicles. If there are no cars on the road, the sensor gives logic ‘0’ to indicate the light-1 to change from green to yellow which takes five seconds, then from yellow to traffic-2 green. The same sequence will be continued for other roads within endless loop. Figure 3 shows the using of motion sensor in traffic light.

2.2.2 Request for a Special Road

Considering Al-Raiyah road intersection, we have a hospital and director of civil defense on one side and a police office on another side. Accordingly, a special technique to deal with an immediate request for a police car, fire engine, or ambulance is necessary. In this case, a sensor system could be included a transmitter on the car and receiver in the TLC. When the traffic light at any road is green and the controller receives a special request from any other road, it will directly turning the current road light from green to yellow. Then it jumps to the requested line by turning the light to green. The state machine diagram in Figure 4 illustrates this concept in case of ONE_G is the current state. However, the same implementation is carried out for other roads.

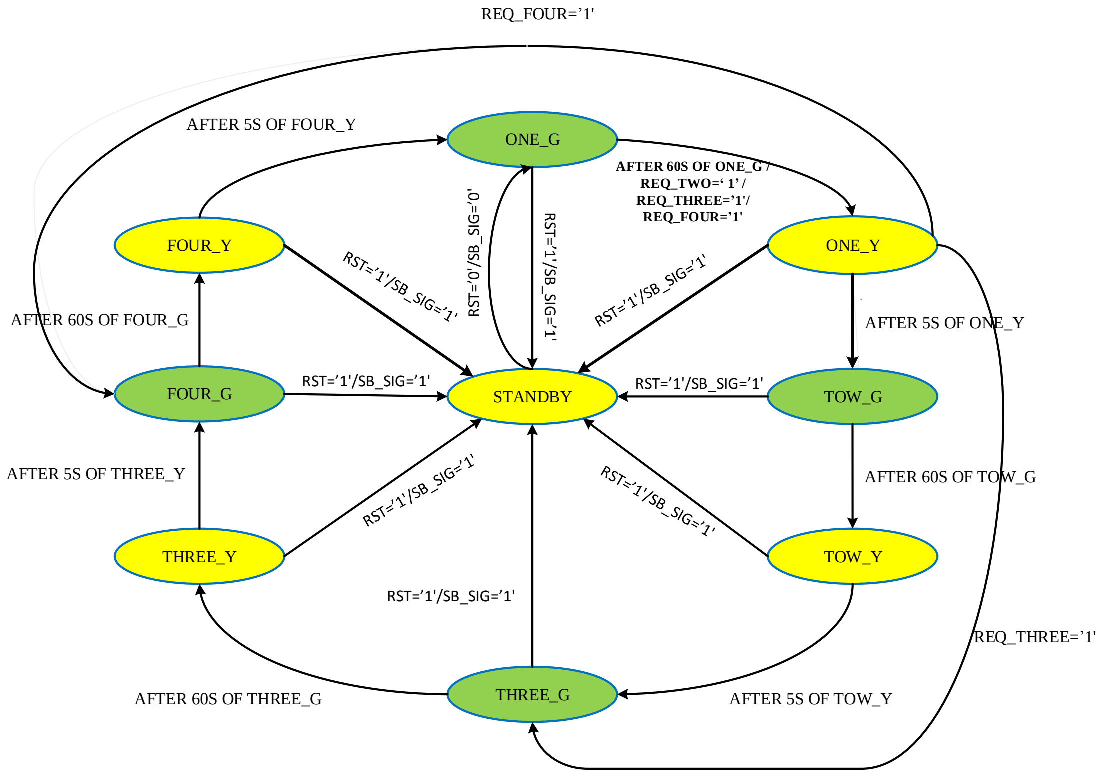

Figure 4: State machine for traffic light "request for special road"

2.2.3 Loaded Road Request

In this approach, a special sensor is places away from traffic light (let's say fifty meters away from the TLC on that road). If the time of the green phase in any road is end, but it is still loaded with so many cars, the sensor indicates that to the controller to display the green light for another time period. Consequently, the traffic light reduces the load on that road. After that the sequence of states continues by turning on the yellow light then green light to the next road as explained in Figure 5.

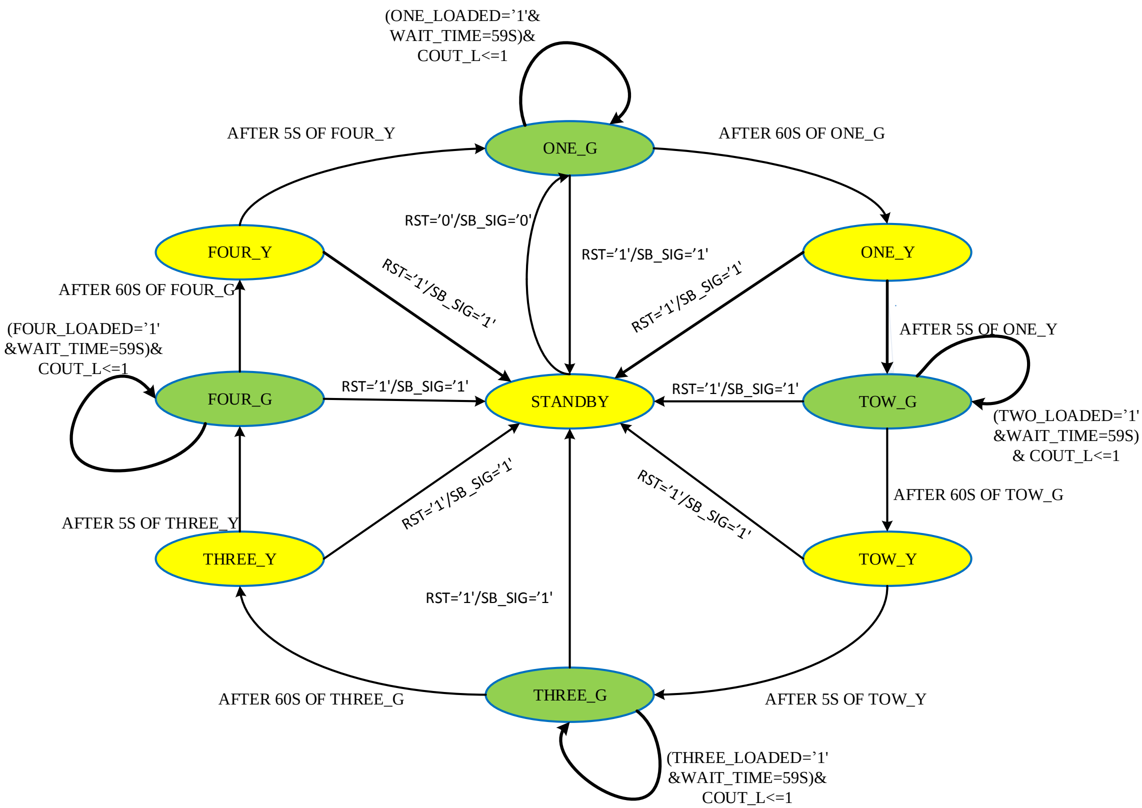

Figure 5: State machine for traffic light "loaded road request"

3. Design Simulation

The key advantage in using the VHDL in systems design is allowing the behavior of the required system to be described (modelled) and verified (simulated) before synthesis tools translate the design into real hardware (gates and wires) [9].

To start coding in VHDL, one needs a simulation tool such as the ModelSim to simulate the design. This section explains the design in different levels, namely; regular design, adding the standby control signal, and the motion sensor, special request implementation, and managing the loaded traffic design. Figure 6 demonstrates the controller entity which include all input and output signals that are connected to the designed controller. The validation of our design for regular TLC using VHDL is verified by simulation results as shown in Figure 7.

Figures 8, 9, 10 and 11 explain the simulation results of our design model by including the standby control signal, motion sensor controlled system, the special road request, and the overload traffic handling system, respectively.

```
ENTITY TRAFFIC_LIGHT_2 IS
  PORT (          CLK, RESET : IN STD_LOGIC ;
            ST_BY       : IN STD_LOGIC ;
            MOTION_S_1, MOTION_S_2, MOTION_S_3, MOTION_S_4        : IN STD_LOGIC ;
            REQ_ONE, REQ_TWO, REQ_THREE, REQ_FOUR                 : IN STD_LOGIC;
            ONE_LOADED, TWO_LOADED, THREE_LOADED, FOUR_LOADED  : IN STD_LOGIC;
            ONE_G,ONE_Y,ONE_R         : OUT STD_LOGIC;
            TWO_G,TWO_Y,TWO_R         : OUT STD_LOGIC;
            THREE_G,THREE_Y,THREE_R : OUT STD_LOGIC;
            FOUR_G,FOUR_Y,FOUR_R     : OUT STD_LOGIC );
END TRAFFIC_LIGHT_2;
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Figure 6: The controller design VHDL code entity

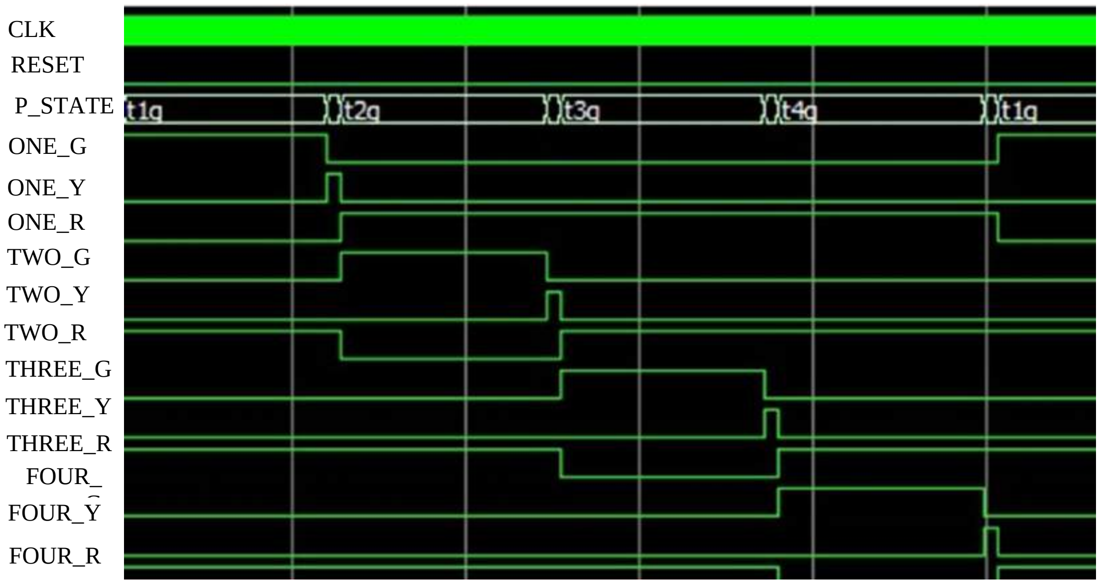

Figure 7: Simulation of the regular TLC design

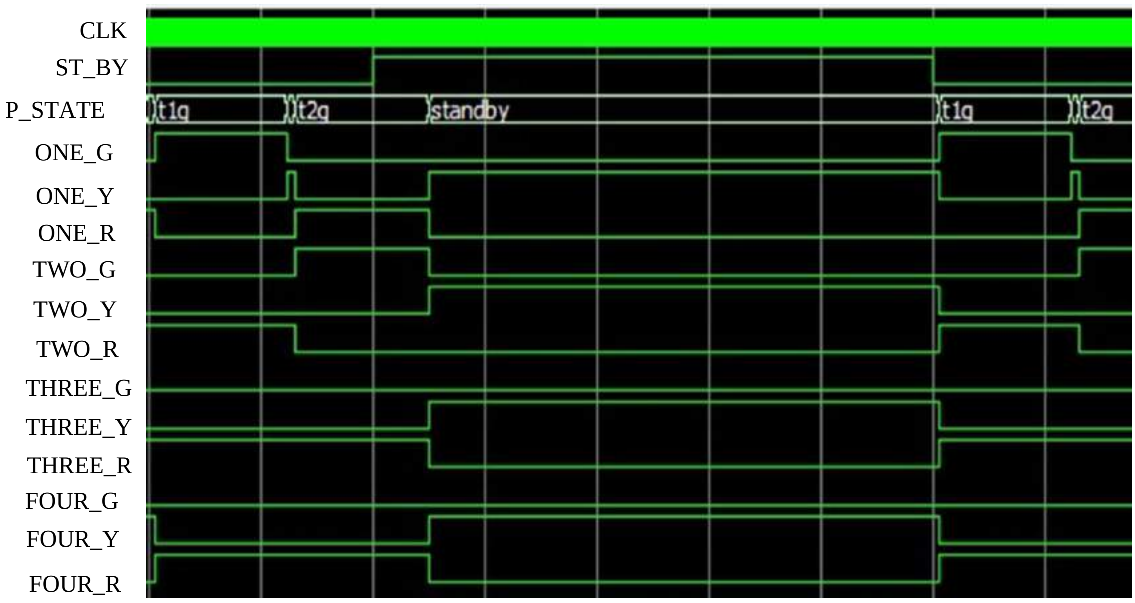

Figure 8: Simulation of the design including the standby control signal

Figure 9: Code simulation for motion sensor controlled traffic light

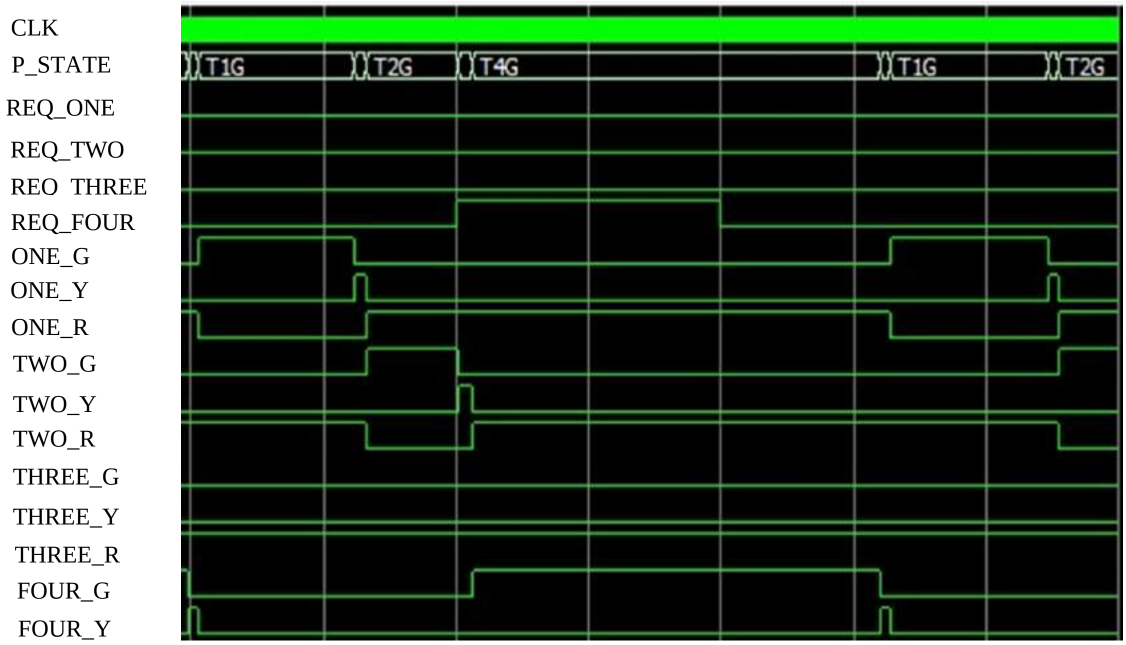

Figure 10: Code simulation after adding the request signals

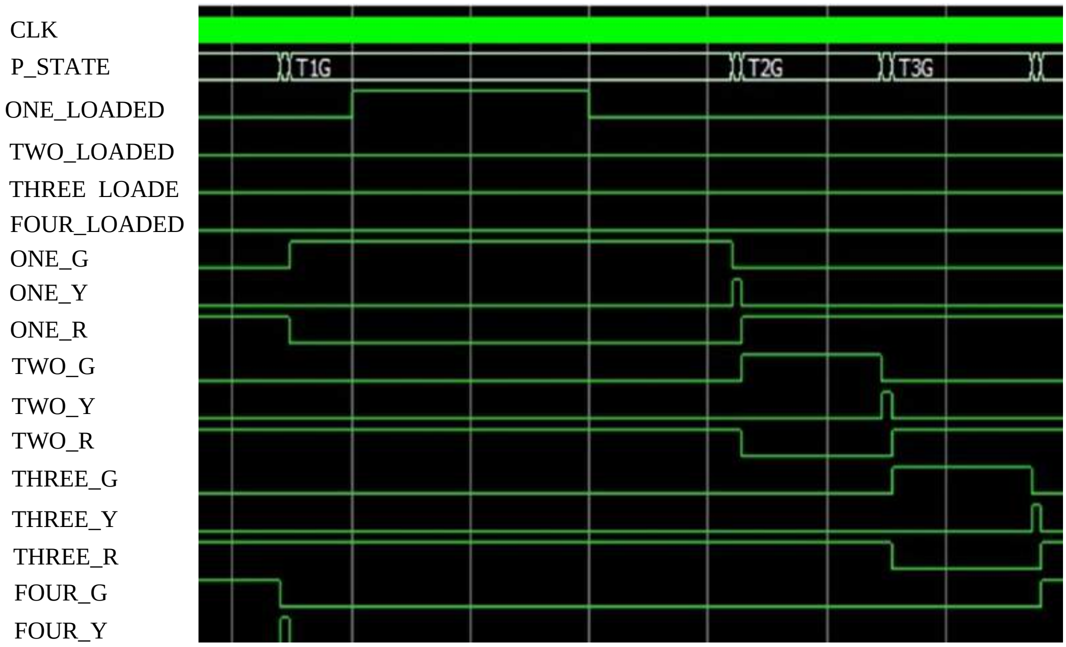

Figure 11: Code simulation considering the load sensors signals

4. Conclusions

The modern ways of intersection traffic management improve the traffic condition up to a large extent. Advanced signaling controllers contribute in improving of the urban traffic; which is proportional to the complexity of the controller. Al-Raiyah road intersection has been considered as a practical example to handle the traffic jam during the rush hours. The proposed final design with some functional concepts could positively impact on the performance of the TLC in this intersection.

The VHDL has been used as the FPGA programing language in our design. It has been concluded that more complex controllers can be well handled using states machines. Multi-design levels have been simulated using the ModelSim which is very suitable simulation tool to verify the design. In the first place the regular traffic light design has been designed and simulated. Then some functional approaches have been added to enhance the design. The project results show that the intelligent traffic control system can extremely meet the requirements of the modern traffic intersections, regardless the complexity of the suggested ideas that are used to enhance its functionality. All of that because of the flexibility of utilizing the FPGA.

5. References

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