

## An FPGA Based Vehicles Density Dependent Intelligent Traffic Light System

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### ABSTRACT

In this paper, a vehicles density dependent intelligent traffic light system based on FPGA has been built. The intelligent traffic light system counts the number of available vehicles in the sides of the traffic intersection via the sensors placed on the ends of the road. Subsequently, it determines passage time required for each side, depending on the density of existing vehicles in it, in order to pass the largest number of vehicles in the intersection during a certain time. The proposed system is built using VHDL, simulated using Xilinx ISE 9.2i package, and implemented using Spartan-3A XC3S700A FPGA kit. Implementation and Simulation behavioral model results show that proposed system fits the specified functional requirements, and finds a solution to overcome the problem of traffic jam at intersections.

**Keywords:** Intelligent traffic light system, vehicles density intelligent traffic light system, FPGA, VHDL, Xilinx ISE 9.2i.

اعتماد مصفوفة البوابات القابلة للبرمجة موقِعياً في نظام الإشارات  
المرورية الذكي المعتمد على كثافة المركبات

### الخلاصة

تم بناء نظام الإشارات المرورية الذكية بالاعتماد على كثافة المركبات باستخدام FPGA. يقوم نظام الإشارات المرورية الذكي بحساب عدد المركبات المتوفرة في جوانب التقاطع المروري من خلال المتحسسات التي توضع على أطراف الطريق. بعد ذلك، سوف يتم حساب وقت المرور اللازم لكل جانب بالاعتماد على كثافة المركبات فيه لجعل أكبر عدد من المركبات تمر في التقاطع خلال وقت معين. تم بناء النظام المقترح في هذا البحث باستخدام لغة الـ VHDL وتم محاكاته باستخدام Xilinx ISE 9.2i package وتم تنفيذه باستخدام Spartan-3A XC3S700A FPGA kit. أظهرت نتائج تنفيذ و محاكاة هذا النموذج بان النظام المقترح قد طابق المتطلبات التشغيلية المحددة، وقد اوجد حلا لعلاج مشكلة الاختناق في التقاطعات المرورية.

## INTRODUCTION

Recently, the traffic congestion became a major obstacle to the global economy, due to fuel and time consumption. The long delay for access to work in the specified time is led to the relative loss in the duty. Since this problem around the world, it is necessary to think hard to find a scientific way to reduce this suffering. One of the manners to solve this difficulty is to use new technologies for traffic light system.

The trends of traffic lights technology is growing rapidly due to its usefulness in controlling traffic on the road. Conventional traffic light works based on configurations that has been set. These techniques found to be not practical nowadays due to the increasing high number of vehicles and lack of consideration for emergency vehicles to bypass especially during peak hours [1].

There are typically several light control phases for each intersection, depending on the given time of the day. It is equally important to notice that the fixed-time strategy cannot respond to any change in traffic condition since their settings are based on historical data rather than real-time data [2-3]. Most traffic light controllers are fixed-cycle controllers, in which all alternative traffic light settings get a particular time-interval for being green [4].

Approaches to reduce traffic jams have been proposed in several disciplines like transportation engineering, physics, and artificial intelligence, among others [5]. In the fixed time traffic light control system, cannot get the optimal solution for the traffic congestion. This leads to use other systems. One of these systems is an intelligent traffic light system [6].

The traffic signal system consists of three important parts. The first part is the controller, which represents the brain of the traffic system. It consists of a computer that controls the selection and timing of traffic movements in accordance to the varying demands of traffic signal as registered to the controller unit by sensors [7]. The second part is the signal visualization or in simple words is signal face. Signal faces are part of a signal head provided for controlling traffic in a single direction and consist of one or more signal sections. These usually comprise of solid red, yellow, and green lights. The third part is the detector or sensor. The sensor or detector is a device to indicate the presence of vehicles [8].

Various sensors have been employed to estimate traffic parameters for updating traffic information [9]. Magnetic loop detectors have been the most used technologies, but their installation and maintenance are inconvenient and might become incompatible with future ITS infrastructure. It is well recognized that vision-based camera system is more versatile for traffic parameter estimation [10].

This paper presents a proposed design for a new approach of an intelligent traffic light system based on FPGA. This system operates according to the density of vehicles present in the sides of the traffic intersection. Therefore, it evaluates the time required for the passage of vehicles in each side depending on its vehicle density, in order to make more vehicles passing during the specified period of time.

**THE PROPOSED SYSTEM**

The vehicles density on the sides of traffic intersection is the principal performance of the proposed intelligent traffic light system. The counting of existing vehicles in the sides is performed by placing sensors on the ends of the road. These sensors calculate the number of vehicles of each road by computing the number of vehicles entering to and leaving from the side. If the ( $V_{in}$ ) represents the number of vehicles entering the side and ( $V_{out}$ ) is the number of vehicles outside from it. Hence, the number of vehicles in the side is equal to the difference between ( $V_{in}$ ) and ( $V_{out}$ ) as cleared in equation (1).

$$V_n = Vin_n - Vout_n \quad \dots(1)$$

where  $V_n$  is the number of vehicles in side  $n$ .

Thus, the total number of vehicles available at the traffic intersection is equal to the total number of vehicles in each side as shown in equation (2).

$$V_{total} = \sum_{n=1}^{n=4} V_n \quad \dots( 2)$$

On the assumption that each side has a specific time for the passage of vehicles, which is assigned by ( $T_n$ ), as a result, the total time for the traffic intersection per cycle is equal to the sum of the times of the four sides.

$$T_{total} = \sum_{n=1}^{n=4} T_n \quad \dots( 3)$$

The passage time is constant for each side in fixed-time traffic lights system, but the proposed system will be adaptive the passage time required for each side, depending on the density of the vehicles with enduring the total time per cycle. The vehicles density percentage of one side with respect to other sides of the intersection can be calculated by equation (4).

$$Vd_n = \frac{V_n}{V_{total}} \quad \dots( 4)$$

where  $Vd_n$  is the vehicles density percentage for side  $n$ .

Accordingly, it is possible to calculate the adaptive passage time required for one side via equation (5).

$$T_n = Vd_n * T_{total} \quad \dots(5)$$

These computations are occurring when the yellow light of one side is illuminating in order to determine the passage time (green light time) required for the next side. In other words, all the computations are calculated for three sides only, since the first side has completed the passage of vehicles, and so on. That means the ( $n$ ) will take three values when implemented in the previous equations.

### FPGA MODEL OF THE PROPOSED SYSTEM

The FPGA model of the intelligent traffic light system which is dependent on the vehicles density is built using VHDL (Very high speed Hardware Description Language), and implemented and simulated using Xilinx ISE 9.2i package. Figure (1) shows the control signals of the proposed intelligent traffic light system. As it is clear, the signal  $V_{in}$  is used to indicate that a vehicle has entered the side, while the signal  $V_{out}$  is responsible for providing the indication at the exit of a vehicle from the side. The signals (TL1, TL2, TL3, and TL4) are used to control the traffic light signals of the intersection as described in the table (1).

Figure (2) illustrates the method of development of sensors on both ends of each side of the intersection.

This traffic light system counts the number of vehicles in each side, depending on equation (1) when the yellow light is lit in one of the sides. Moreover, the system calculates the vehicles density of next side by equation (4). Then it determines the time required for the passage of vehicles for the next side based on equation (5).

This system performs all these operations on each side at the end of the time taken by yellow light. Therefore, passage time of each side will be appropriate with the number of vehicles in it. Subsequently, there will be less traffic jam and less time spent at the intersection. Figure (3) shows the operations flowchart of this system.

The simulation behavioral model test results of the intelligent traffic light system using Xilinx ISE 9.2i package shown in Figures (4-6). As demonstrated in Figure (4) the system works like the fixed-time system in the absence of vehicles on the sides of the intersection, while Figures (5-6) show the system action to adapt the time when the number of vehicles is different from one side to other. As illustrated in Figure (5), the green light of side 1 taking a half cycle time, because it contains a number of vehicles equal to 50% of the total number of vehicles. In Figure (6), it is observed that the green light of traffics 3 and 4 will take longer time than other sides because they contain more vehicles.

Figure (7) shows the number of vehicles that can pass in a specific side through a one cycle compared to the available vehicles in other sides. As observed, it is possible to pass 180 vehicles on one side, if the vehicles are absent in other sides in case of using the proposed system, while not exceeding 60 vehicles in the event of using the fixed-time system. Implementation of the proposed system is illustrated Figure (8); a prototype of traffic lights system had been used. The entry and exit vehicles are detected by push-bottom sensors, which are placed at the ends of intersection sides. The signals of the sensors are received by the Spartan-3A XC3S700A FPGA kit. This kit will count the number of vehicles in each side according to equation (1). Therefore, it adapts the passage time required for each

side and send signals to illuminate the traffic lights depending on the evaluated passage time.

The proposed system has many advantages over other traffic lights systems. It can use any type of sensors in comparison with other system where specific types of sensors, like RF [2] or camera [2, 10], have to be used. Also, this system estimates the passage time required for each side while other system duplicates the passage time independent on the number of vehicles [4]. Moreover, most of other systems use computer to control the traffic lights and this make it more liable to be exposed to hacking and system errors, while the proposed system is not.

### **CONCLUSIONS**

In this paper, the vehicles passage time of the intersection sides has been adapted, by calculating the vehicles density in the side which is intended to determine the passage time in it. Therefore, evaluate the time required to illuminate the green light according to the number of vehicles in this side. The previous actions are done by implementing the proposed vehicles density dependent intelligent traffic light system. This system reduces congestion and waiting time at traffic intersections by passing the largest number of vehicles per cycle. This system increases the number of passing vehicles three folds than fixed time system in one side if other sides empty.

It is hopeful that the proposed system will offer a simple and suitable solution for the roads and intersection sides in the city of Baghdad due to the significant variations of number of vehicles there.

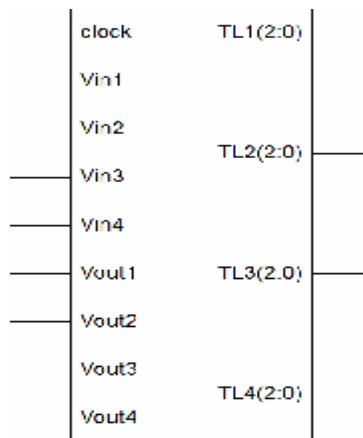
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**Table (1) Operation of the four traffics according to the control signals of the proposed system.**

| TL1 | TL2 | TL3 | TL4 | Traffic1 | Traffic2 | Traffic3 | Traffic4 |
|-----|-----|-----|-----|----------|----------|----------|----------|
| 1   | 4   | 4   | 4   | Green    | Red      | Red      | Red      |
| 2   | 4   | 4   | 4   | yellow   | Red      | Red      | Red      |
| 4   | 1   | 4   | 4   | Red      | Green    | Red      | Red      |
| 4   | 2   | 4   | 4   | Red      | yellow   | Red      | Red      |
| 4   | 4   | 1   | 4   | Red      | Red      | Green    | Red      |
| 4   | 4   | 2   | 4   | Red      | Red      | yellow   | Red      |
| 4   | 4   | 4   | 1   | Red      | Red      | Red      | Green    |
| 4   | 4   | 4   | 2   | Red      | Red      | Red      | yellow   |



**Figure (1) The intelligent traffic light control signals.**

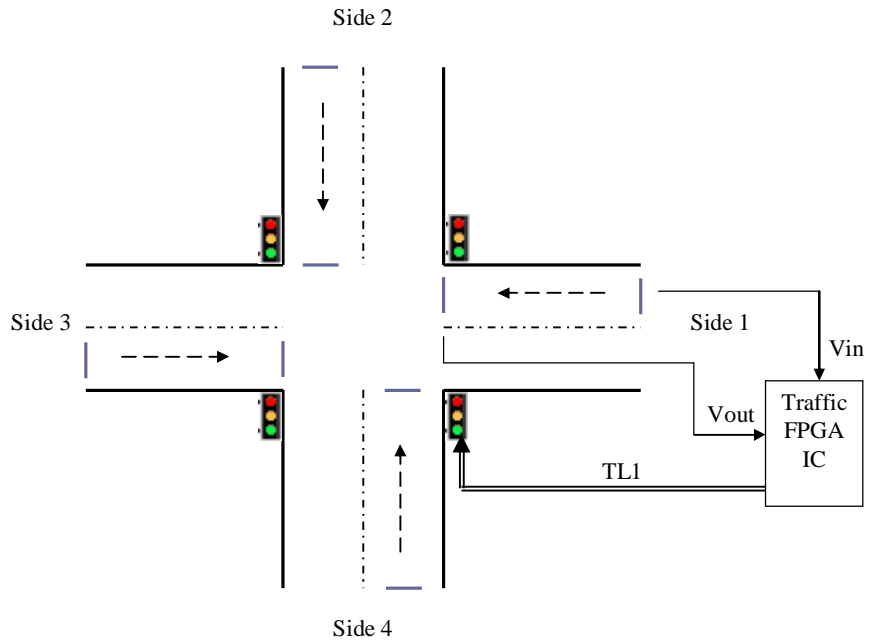


Figure (2) The manner of development of sensors on the intersection.

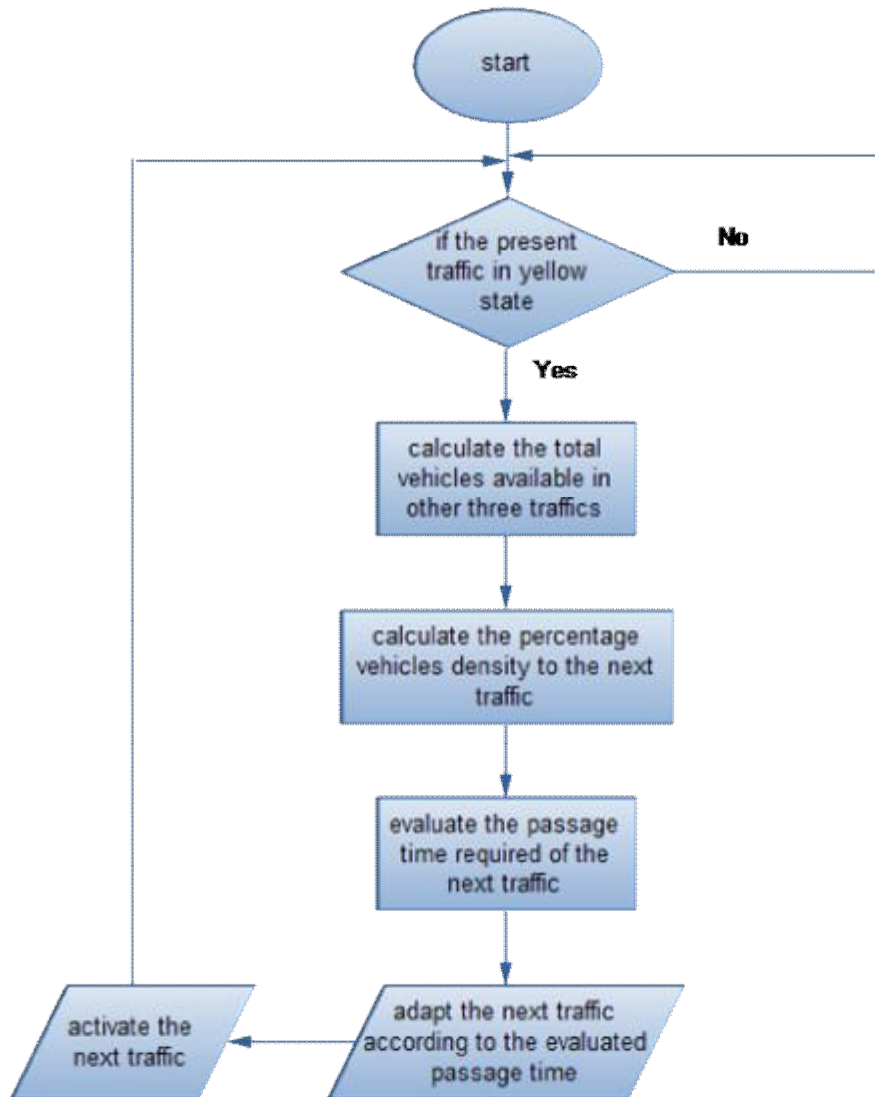


Figure (3) The operation flowchart of the proposed system.



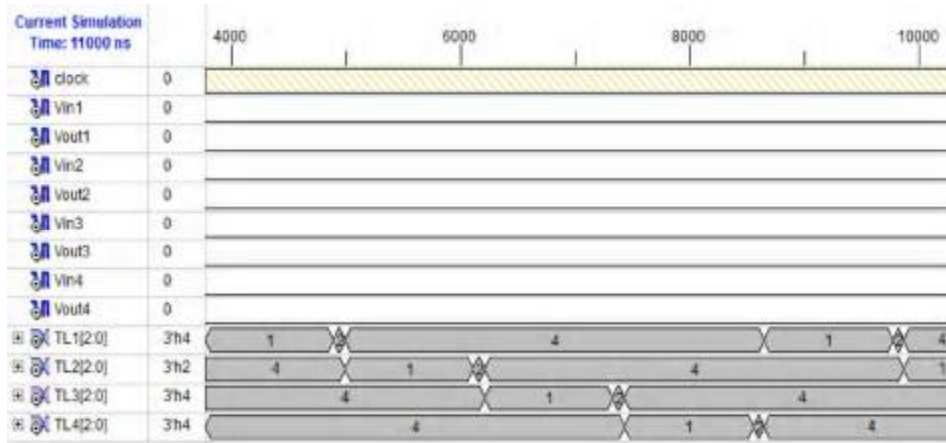


Figure (4) System simulation results when the vehicles are not available at the sides of the intersection.

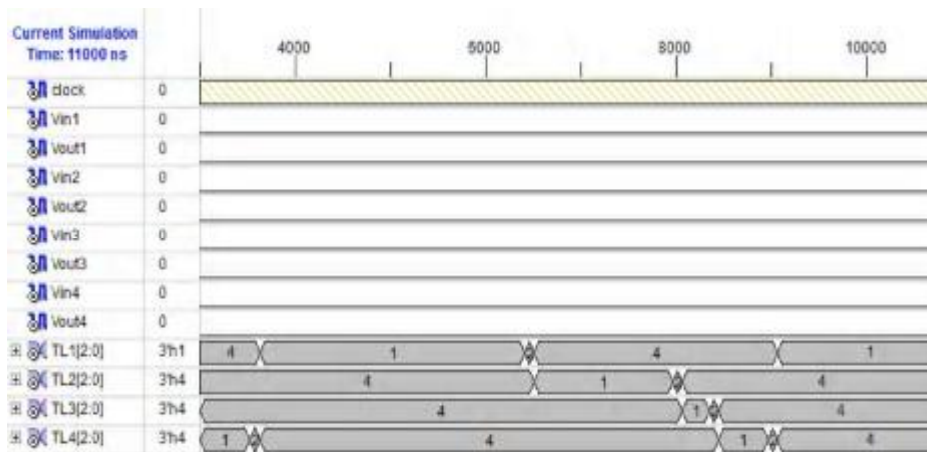


Figure (5) System simulation results when side 1 has 50% of the total vehicles on the intersection.

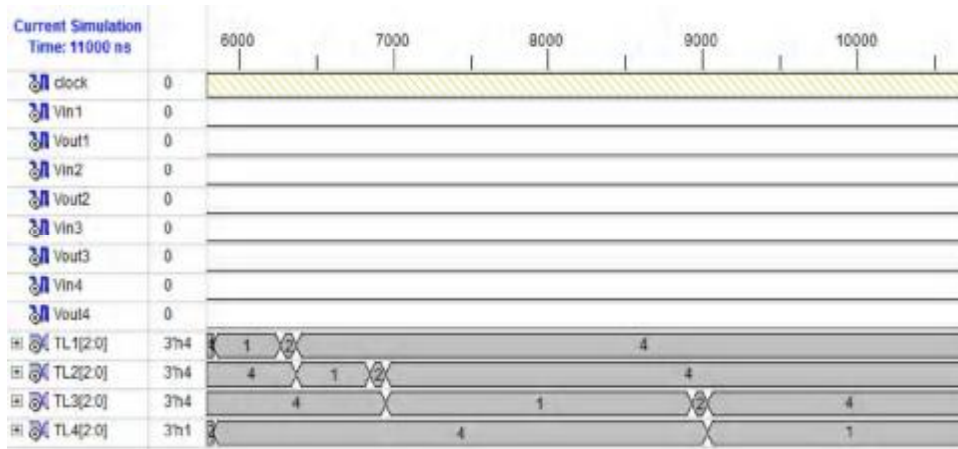


Figure (6) System simulation results when sides 3 and 4 have vehicles more than others sides on the intersection.

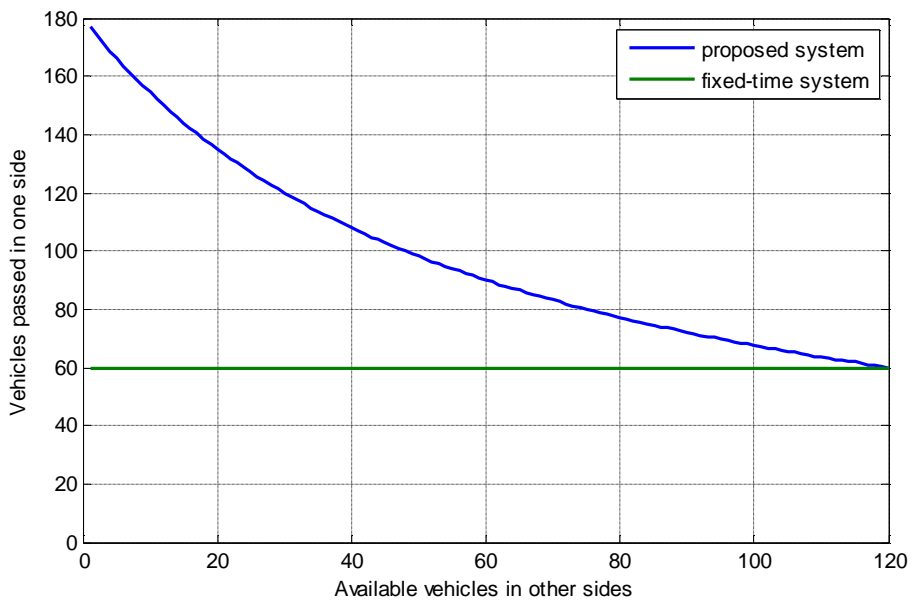


Figure (7) Number of vehicles passed in one side through one cycle compared to those in other sides, for the proposed system and the fixed time system.



**Figure (8) Implementation of the proposed traffic system using the Spartan-3A XC3S700A FPGA kit.**