

Implementation of an Intelligent Traffic Control System: The use of FPGA and Verilog HDL

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The Intelligent Traffic Control system proposed in this paper goes for diminishing holding up times of the vehicles at traffic signals and providing easy and fast pathways for emergency vehicles such as ambulance. The proposed system is developed on FPGA DE1-SoC Board using Verilog HDL and implementing IR and RFID sensors. From the results of the simulation we have found that the system responses almost instantly to traffic density and switches the traffic lights according to the sensor readings. Moreover, when emergency vehicles are introduced in the simulation, the system adapts appropriately and clears the path for the emergency vehicle ensuring least waiting time.

Field of Research: Electrical Engineering

1. Introduction

In the present era, many researchers have been studied on intelligent traffic systems (Kaushik, Dahake & Mahalle 2015, Qureshi 2012, Jryian 2012, Dilip, Alekhya, Bharathi 2012, Mondloi & Rajnikant, Dash & Kumar, Jaiswal, Agarwal, Singh & Lakshita 2013, Belokar & Joshi 2014, Abdullah, Hashmi & Abd 2010, Albagul, Hrairi, Wahyudi & Hidayathullah 2006). Different technologies are being used for intelligent traffic systems (Qureshi 2012, Mondloi & Rajnikant, Dilip, Alekhya, Bharathi 2012, Albagul, Hrairi, Wahyudi & Hidayathullah 2006). The implementation of traffic Light Controller can be through a Microcontroller, Field Programmable Gate Array or Application Specific Integrated Circuit. In this paper, a FPGA model of intelligent traffic light system was build. FPGA technology is one of the prominent for intelligent traffic systems because FPGA offers greatly reduced cost, more prominent adaptability, and a shorter configuration cycle, decreasing the danger while still keeping up deterministic execution time and high power proficiency. (Kaushik, Dahake & Mahalle 2015, Qureshi 2012, Jryian & Khwarizmi 2012). Most traffic light controllers have confinements because it uses the pre-defined hardware, which is working according to the program that does not have the adaptability of alteration on real time basis. In which all alternative traffic light settings get a specific time-interim for being green. The fixed time traffic light control system can't give the ideal solution for the traffic blockage. In rush hours emergency vehicles need to hold up a long and results in human and money related misfortune. So, there is a need to develop a safe, quick and dependable traffic control system proficient to control the vehicular activity in rush hours without a need of traffic sergeant.

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An intelligent traffic light system senses the presence or absence of vehicles and responds appropriately. The thought behind the intelligent traffic system is to diminish unnecessary sitting tight time for drivers when the light is red and permit the emergency vehicles to pass at whatever point it's identified. The timings of Red, Green lights at every intersection of street will be intelligently chosen by determining the density of the vehicles on the streets. In this study, along with intelligent traffic management, emergency vehicles are given utmost priority by installation of RFID system. Such a system allows the emergency vehicles to cut through the traffic in the most optimized method. This feature sets this study apart from previous studies. Although there are many studies that focus on intelligent system, this study adds a revolutionary feature of identifying emergency vehicles with RFID tags. In all previous studies, emergency vehicles were treated as a regular vehicle, which is the primary reason behind the development of this paper. The implementation of this study would minimize the traffic in busy cities and at the same time allow optimized path and clear route for emergency vehicles which has the potential to save countless lives during emergency.

This paper is organized into 5 sections. Section 1, 'Introduction' introduces the key aspects of the paper and gives an overview of the study. Section 2, 'Literature Review' gives a brief comparison of this study to other similar studies conducted previously. Section 3, 'Methodology' details the construction of the system and the techniques which were used to find the results. Section 4, 'Findings' gives details of the data given by the system and their significance. Finally the paper is summarily concluded in Section 5, 'Conclusion'.

2. Literature Review

In previous studies, development of FPGA based intelligent Traffic control systems have been developed. Jryian (2015) developed a system based on FPGA Spartan-3A XC3S700A FPGA kit. The system claims to have a power saving mechanism. It also proposes the use of sensors to detect traffic but the methods suggested are not very feasible. Inductive Loop will have a large space requirement and errors will result from this method. Video density detection using video footage is not very cost effective as a separate mechanism for image processing will be required to identify the traffic density.

Another study shows the development of algorithms that will drive the intelligent system through FPGA. Despite sensors are a required element of this system, there is no comparison of sensors to determine the best choice. (Dilip, Alekhya & Bharathi 2012). Mandloi & Rajnikant (2012), proposes a finite state machine based Intelligent traffic control system. There is no practical design suggested in the study for practical implementation. Albagul, Hrairi, Wahyudi & Hidayathullah (2006) proposes an algorithm for traffic control. The system is developed and simulated using MATLAB. All of the studies assume emergency vehicles to be the same as other vehicles. Moreover, specific uses of sensors are not mentioned. In our study, we try to overcome these shortcomings. Traditional traffic control systems has two noteworthy drawbacks: First, due to lack of adjustments in timings of traffic signals, the traffic has to wait a long on the lane with few vehicles while on same lane, the traffic cannot pass through in short time due to rush on lane. Second, there is no provision of movement of emergency vehicles like ambulance and fire brigades etc. In rush hours these emergency vehicles have to wait a long and results in human and financial loss. In manual controlling system we need man power. As we have poor strength of traffic police we cannot

control the traffic manually in all area of a city or town. So, there is a need to develop a secure, fast and reliable traffic control system capable to control the vehicular traffic in rush hours without a need of traffic sergeant. An intelligent traffic light system senses the presence or absence of regular vehicles and emergency vehicles and reacts accordingly. The idea behind the intelligent traffic systems is to reduce unnecessary waiting time for drivers when the light is red and save the country from any potential human or financial loss by allowing emergency vehicles to pass whenever it's detected. This system operates according to the number of vehicles on each side of the intersection instead of using a fixed time for each traffic light (green, yellow, and red). So this system will work like a traffic cop when governing the passage of vehicles.

Advantages of Intelligent traffic System:

- Controlling traffic in a modern way without a need of a sergeant.
- Number of road accident can be reduced.
- Valuable time and life of people can be saved.
- Emergency services will no longer be affected due to traffic congestion.
- Cost effective

A. FPGA

The FPGA configuration is generally specified using a hardware description language (HDL). FPGAs can be used to implement any logical function. Traffic light control system has been implemented using microcontroller, FPGA, and ASIC design. FPGA has many advantages over microcontroller, some of these advantages are; the speed, number of input/output ports and performance, at the same time ASIC design is more expensive than FPGA. The main and the most significant difference between the microcontroller and the FPGA is that FPGA doesn't have a fixed hardware structure; on the contrary it is programmable according to user applications. FPGA is a programmable logic device, so the advantage is that hardware resources can be controlled by coding, while Micro-controller cannot do that because of its fixed in hardware. Micro-controller use C-programming, it means sequential processing, FPGA can do pipeline or parallel processing, the processing speed is much higher. Memory resources on FPGA are much higher than Micro-controller. Its great flexibility gives engineers the opportunity to control the hardware and modify and update whole design by only changing the code on FPGA, without any change on circuit board layout.

B. Radio Frequency Identification

RFID is wireless system that uses radio frequency electromagnetic field to transfer data from a RFID tag attached to the windscreen of an emergency vehicle, for automatic identification. The tags contain electronically stored information. The RFID windscreen tag uses passive RFID UHF technology. Two-way radio transmitter-recipients readers send a signal to the tag and read its reaction. Bangladesh government has already launched the Vehicle Retro-Reflective number plate from 31 October 2012. BRTA is setting digital number plates with radio frequency identification chip on every vehicle to enhance administrations in the transport area. Introducing this system Bangladesh has entered into the era of advanced technology. In this paper we will utilize this modern technology for the purpose of emergency vehicle identification. Currently every vehicle on the street has a RFID tag attached to its windscreen. For identifying an emergency vehicle, we will assign a special RFID version for all emergency vehicles which will have different electronic data from all other vehicles.

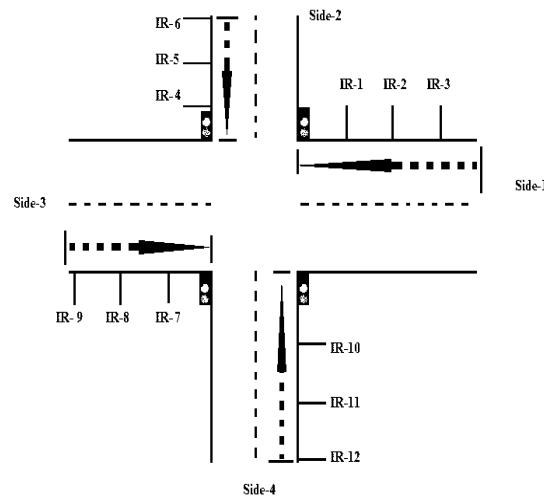
Benefits of RFID tag and readers:

- Long read range.
- Can read fast moving tags.
- Constant hands free operation.
- Low maintenance and repair cost.

3. Methodology

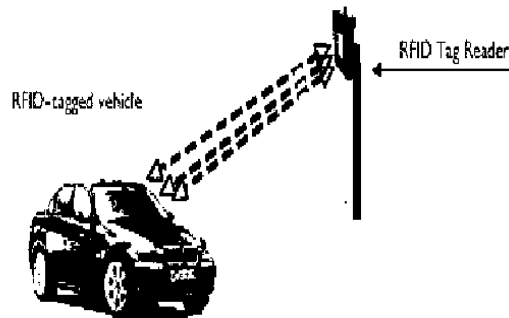
The main and the most significant difference between the microcontroller and the FPGA is that FPGA doesn't have a fixed hardware structure, on the contrary it is programmable according to user applications. Hardware structure in the FPGA is not fixed so it is defined by the user. Although logic cells are fixed in FPGA, functions they perform and the interconnections between them are determined by the user. So operations that FPGAs can do are not predefined. You can have the processes done according to the written HDL code. There are two ways to program FPGA, one is by using VHDL and the other is by using Verilog HDL. Verilog is easier to learn compared to VHDL. This is due, in part, to the popularity of the C programming language, making most programmers familiar with the conventions that are used in Verilog. Compared to VHDL, Verilog data types are very simple, easy to use and very much geared towards modeling hardware structure as opposed to abstract hardware modeling. Verilog was also preferred because of its simplicity. Starting with zero knowledge of either language, Verilog was the easiest to grasp and understand. Figure: 1 shows the structure of any intersection consisting of four streets. We are using four traffic signals on the roads. Traffic signals on each street have three lights red, yellow and green. The sensor used for the configuration of these traffic light systems is a passive infra-red sensor. There are three sensors on every street to detect vehicles. The sensor is set at a separation far from the intersection with the goal that it doesn't get bothered by the vehicles stopping at the signal. The three sensors are placed 30ft apart from each other on each lane and determining the number of sensors activated we can decide the traffic density of the cross-roads. The density of the vehicles is measured in three zones i.e., low, medium, high based on which timings are allotted as needs to be. These sensors are connected with the FPGA, which receives beats from the sensors. With no sensors active the green signal will last for only 10s. For low traffic density i.e. just one sensor is active the timing for green signal is set to 20s, for medium 40s and for high 60s. For any other condition the default timing for green signal is set to 25s. From this combination of sensors, we will know the expected time for green signal on when every path change to the green signal.

Figure1: Structure of Intersection Consisting of 4 Main Roads



For emergency vehicle, we have introduced the idea of RFID sensors and electronic tags. The high performance RFID reader mounted over the roadway will read data from the electronic tags attached to the windscreen of the vehicles. We will use a unique electronic tag for all the emergency vehicles (ambulance, fire service, etc) and whenever the sensor will detect that special tag, the signal for that path will automatically go green and will remain in that state until the vehicle passes. Fig: 2 shows a hypothetical situation where a RFID sensor is reading the tag attached to a vehicle approaching.

Figure 2: RFID Sensor Detecting the Tagged Vehicle Approaching



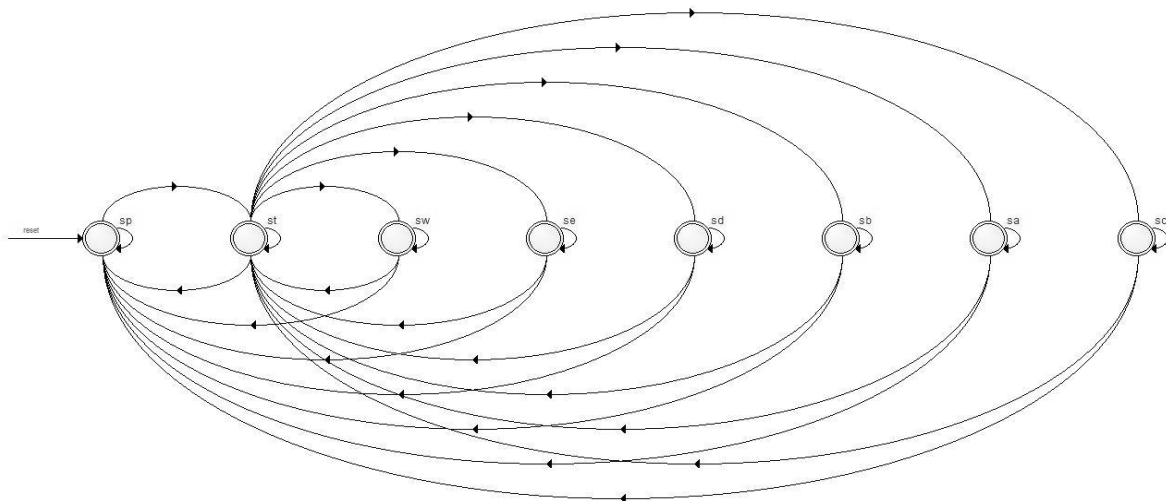
The FPGA model of intelligent traffic system is build using VERILOG HDL in Quartus II software version 15.0. Altera Quartus II is programmable logic device design software created by Altera. HDL designs can be analyzed and synthesized by Quartus II which assemble outlines, perform timing analysis, view RTL graphs, simulate a design's reaction to various stimuli, and configure the target device. Quartus incorporates an execution of VERILOG HDL and Verilog for equipment depiction, visual altering of logical circuits, and vector waveform simulation. After modeling the design, it was simulated using ModelSim-Altera Starter Edition 10.3d before executing. It is a custom Altera rendition of the ModelSim software by Mentor Graphics, which is a multi-dialect HDL simulation environment, for the simulation of hardware description languages, for example, VERILOG HDL, Verilog and SystemC, and has an in-build C debugger. Simulation can be done using the graphical user interface (GUI), or consequently utilizing scripts. We have used the ModelSim-Altera Starter Edition, which has the same

components as ModelSim-Altera Edition programming aside from two zones. ModelSim-Altera Starter Edition's simulation performance is lower than ModelSim-Altera Edition's, and has a line farthest point of 10,000 executable lines contrasted with the boundless number of lines permitted in the ModelSim-Altera Edition programming. The hardware system was implemented on FGPA DE1-SoC Board using IR and LEDS. The LED denotes the Traffic light sets on each road. IR sensors are placed on roads are used for vehicle detection.

4. Findings

The proposed system works with eight states as shown in Figure 3. In primary state (sp) allLights are switched off. The other states represent the normal operation of the traffic light system. Before going from one state to another the system always passes through a transition state (st) for 5 seconds. If one side of the intersection has many vehicles and too 60 seconds passed (including yellow light state), the system will go to the other state, to prevent a long wait on the other sides of the intersection. All these conditions lead to reduce waiting time at the intersection when the red light was on. Whenever there is emergency vehicle on the road (se), the traffic on that road is allowed to pass and the traffic on all the roads is forcibly stopped. After passing of emergency vehicle, the emergency switch will be disabled. And the sequence is allowed to continue from a position where it was stopped.

Figure 3: State Diagram



The complete coding has been done in VERILOG HDL and the result of the simulation is shown below.

Figure 4.1 shows the output waveform when the system first begins with primary state. At primary state the output on each side (A0, B0, C0, D0) is 0000. Before moving to the next state 001(side A) the system goes through a transition state where side A (A0) gets yellow light for 5s and after that green light for side A becomes activated and all other roads get red light. The output for side A is 1100. As the input for side A (A1) is 111 i.e. all three sensors are active, the system remains at this state for 55s before going to the

transition state. At transition state Side A and Side B gets yellow light for 5s and after that system moves to the next state which is 010.

Figure 4.1: Output Waveform

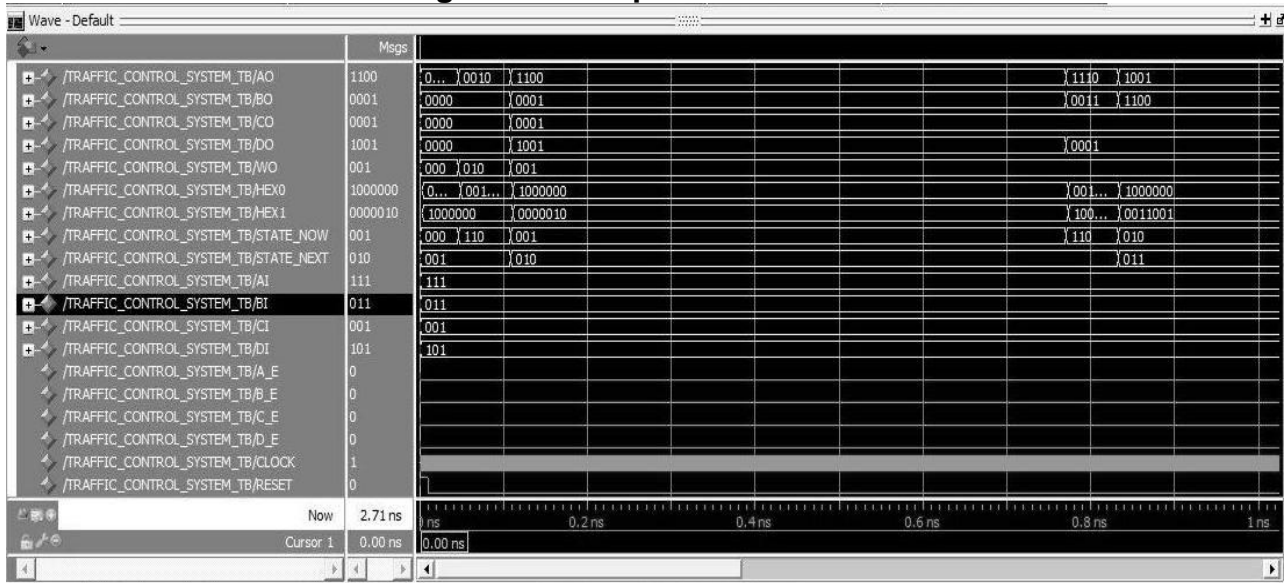


Figure 4.2: Output Waveform

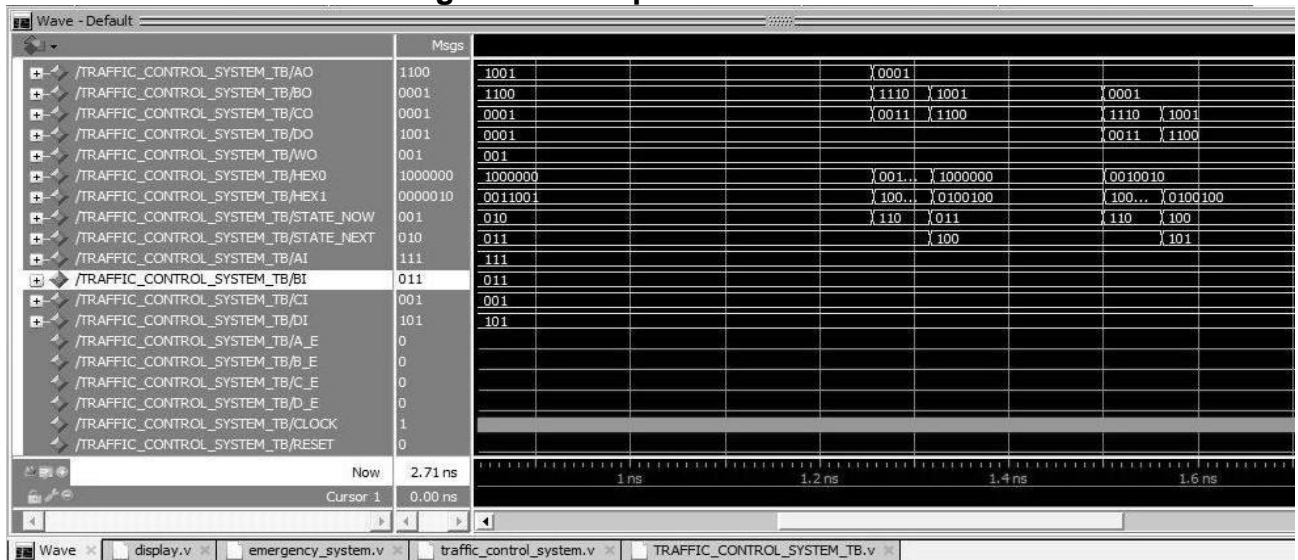
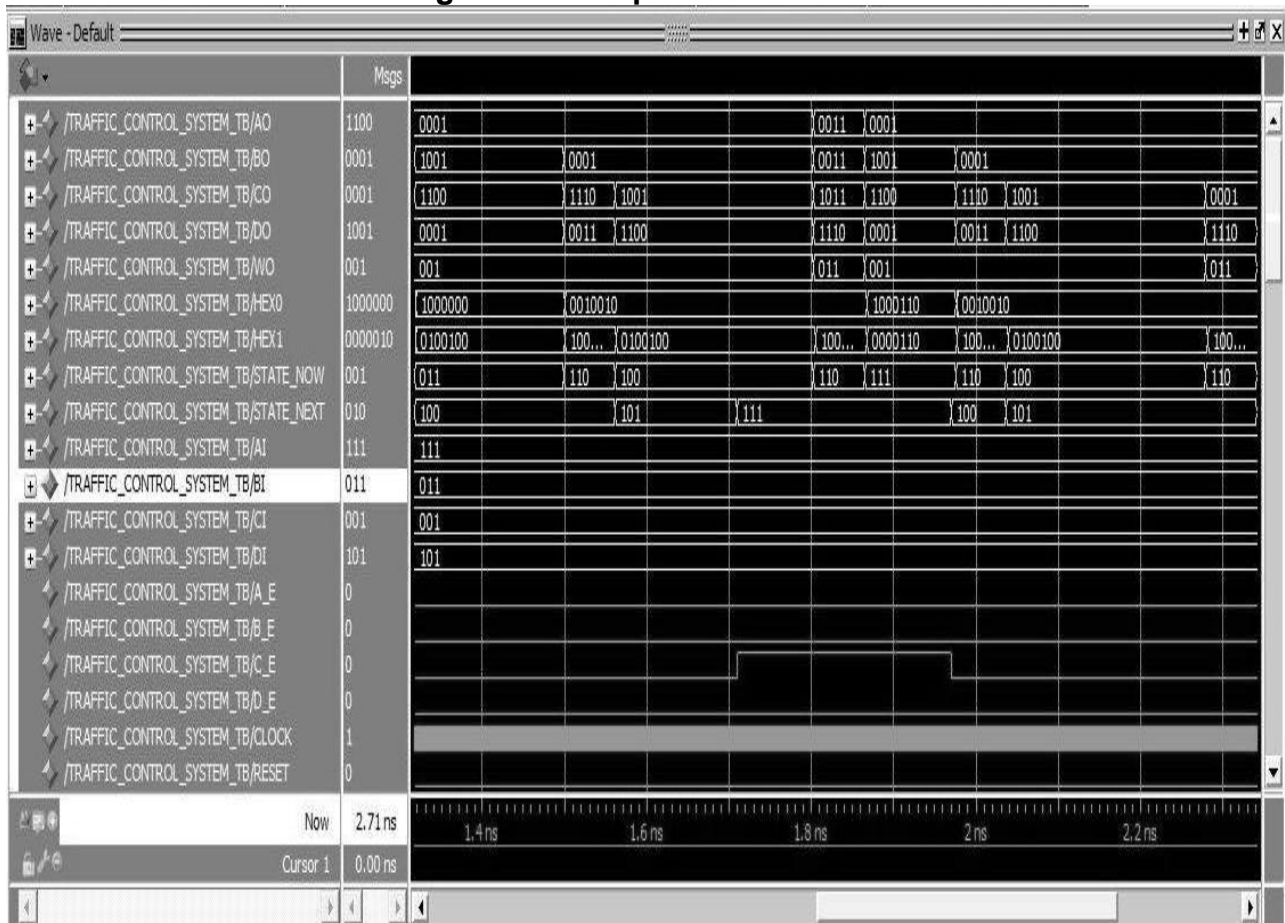


Figure 4.2 shows result when the system is at 010 state i.e. green light for side B and red light for all other sides. The output of side B (B0) shows 1100 which means green light is activated. As the input for side B is 011 that is only two sensors are active, the system remains at this state for 35s and again moves to transition state for 5s before going to next state 011 (side C). At transition state side B and side C gets yellow light for 5s and after that green light for side C becomes activated. The system remains at this state for 15s because only one sensor is shown to be active on that road and again moves to transition state.

Figure 4.3 shows the output waveform when side C gets an emergency input. The present state of the system is 100 i.e. the green light for side D is activated. After going through the transition state the system is supposed to move to the next state which is

101. But when an emergency pulse is encountered on side C the system immediately moves to 111 state i.e. green light for side C becomes activated. The system remains at this state as long as the emergency pulse remains active and after that the system goes to its regular operation.

Figure 4.3: Output Waveform



5. Conclusion

Intelligent traffic control system using FPGA has been studied in this paper. A hardware implementation has also been done using FPGA and Verilog HDL. The system changes state i.e. moves from A to B or B to C whenever 60s passes staying on one single state. This is a great achievement because any vehicle on a road will have to wait a maximum of only 3 minutes on traffic lights. Which is an improvement over previous studies. The 3 states 111, 011, 001 corresponding with the activation of different number of sensors giving a measure of the traffic density on each of the road also gives the system an adaptive edge over other similar systems due to the fact that it can change its output accordingly in response to the feedback from the sensors. The introduction of RFID tag for emergency vehicles is also a new feature of this system. It enables the system to react accordingly whenever an emergency arises, thereby making the path clear for emergency vehicles. However, the proposed system is limited by the fact that once the system responds to an emergency situation and clears the path for emergency vehicles, the system cannot fully revert back to the state the system was in before the emergency response. The system remains in the emergency state as long as the emergency pulse exists, and when the emergency road is being cleared, all the other roads are in the red

state which adds up to an unprecedented delay which the system cannot compensate for. Moreover, when the system reverts to a state after the emergency response, the timer of that state starts from $t=0s$, there is no memory to hold the expended time in a state, this would create a bias as some roads will have an extended period of delays in red state while some will have extended periods of green state. Despite the limitations, the proposed system has the potential to achieve the greatest use of the traffic system both amid surge hours and slug hours. To make this potential into real time performance, it is necessary to increase the handling capacity of the system, so that more than 4 sets of traffic lights can be controlled. Another improvement can be done by adding more sensors on each road. This would enable the command in the control room to allocate more time for a road in case the traffic density becomes too large on that road. This system can be expanded to other adjacent roads and streets and connected intelligently, the whole network of roads can be controlled with this intelligent system and thereby, minimizing traffic throughout the network and at the same time prioritize the traffic system to clear path for emergency vehicles.

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