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Traffic Light Control Using Nexys A7

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Abstract:

A traffic light controller is an electronic device that controls the sequence of traffic signals at an intersection, ensuring smooth and safe traffic flow. In modern traffic light controllers, digital logic circuits are used to control the sequence of traffic signals. The traffic light controller uses a state machine to determine the sequence of traffic signals. The state machine has a set of states, each of which corresponds to a particular sequence of traffic signals. The state machine changes state based on a set of input signals, such as a clock signal or a pedestrian signal. Here we are implementing a 4-way traffic light controller which is designed to manage the flow of vehicular and pedestrian traffic at an intersection with four directions: North, South, West, and East. Each direction is represented by a different label or abbreviation, such as m1 for North, m2 for South, m3 for West, and m4 for East. The purpose of a 4-way traffic light controller is to regulate and optimize the flow of traffic at intersections. It ensures safe and efficient movement of vehicles by assigning right-of-way to different directions in a coordinated manner. By alternating the signal lights, it reduces the chances of accidents and congestion, improving overall traffic management.

Keywords: Nexys A7, Traffic Congestion, Traffic Management, Traffic light controller.

1. Introduction

Traffic signals, a creation dating back to 1912, serve as signaling apparatus designed to regulate the movement of vehicles and pedestrians at various points such as road intersections, crosswalks, railway crossings, and similar locations. These traffic signals typically incorporate three standard colors: the green light grants permission for traffic to move in the specified direction, the yellow light serves as a cautionary signal for vehicles to prepare for a brief stop, and the red signal unequivocally prohibits any further movement of traffic [1].

In contemporary times, numerous nations grapple with the challenges of traffic congestion, which significantly impact urban transportation systems, presenting a substantial dilemma. Despite the transition from human traffic officers and flagmen to automated traffic systems, effectively mitigating heavy traffic congestion remains a paramount challenge, particularly at complex intersection points [2]. The exponential growth in the volume of automobiles and the continual rise in the number of road users has not been met with a corresponding expansion of infrastructure and resources. To address this issue, partial solutions have been proposed, including the construction of new roadways, the implementation of overpasses and bypass routes, the creation of ring roads, and the rehabilitation of existing road networks.

In a variety of traffic management systems, infrared (IR) sensors find extensive application [3-7]. These systems typically involve the installation of both an IR transmitter and an IR receiver on opposite sides of a road. When a vehicle passes through the space between these IR sensors, the system activates, and the vehicle count is increased. This collected data regarding traffic density on different road segments within an intersection is then analyzed to dynamically adjust the green light timings for lanes with significant traffic loads. The entire system can be controlled using a PIC microcontroller [1-2, 4-5] or alternatively, through the use of a PLC [8-9].

In order to alert the traffic system to the approach of emergency vehicles at intersections, RF emitters are deployed [10-12]. These emitters transmit cautionary signals to RF transceivers strategically positioned at each traffic light intersection. Subsequently, the sequencing of the traffic lights is adjusted to facilitate a dedicated path for the emergency vehicles. In a separate approach, some researchers [13] utilize the Global Positioning System (GPS) for communication with traffic light controllers, enabling the transmission of preemptive signals. Additionally, ambulances are equipped with both RF communication capabilities for interacting with traffic light controllers and GSM modules for reporting the patient's condition to hospital personnel. This allows for the reception of instructions pertaining to the necessary medical interventions or initial aid required for the injured patient [14].

Numerous studies [15-16] anticipate traffic density using image processing methodologies. However, these approaches necessitate the capture of high-quality images, the reliability of which can be influenced by weather conditions, particularly in cases of rain and fog. In contrast, some researchers employ advanced algorithms to represent diverse traffic conditions, such as fuzzy logic [17] and genetic algorithms [18].

2. **High level proposed system view**

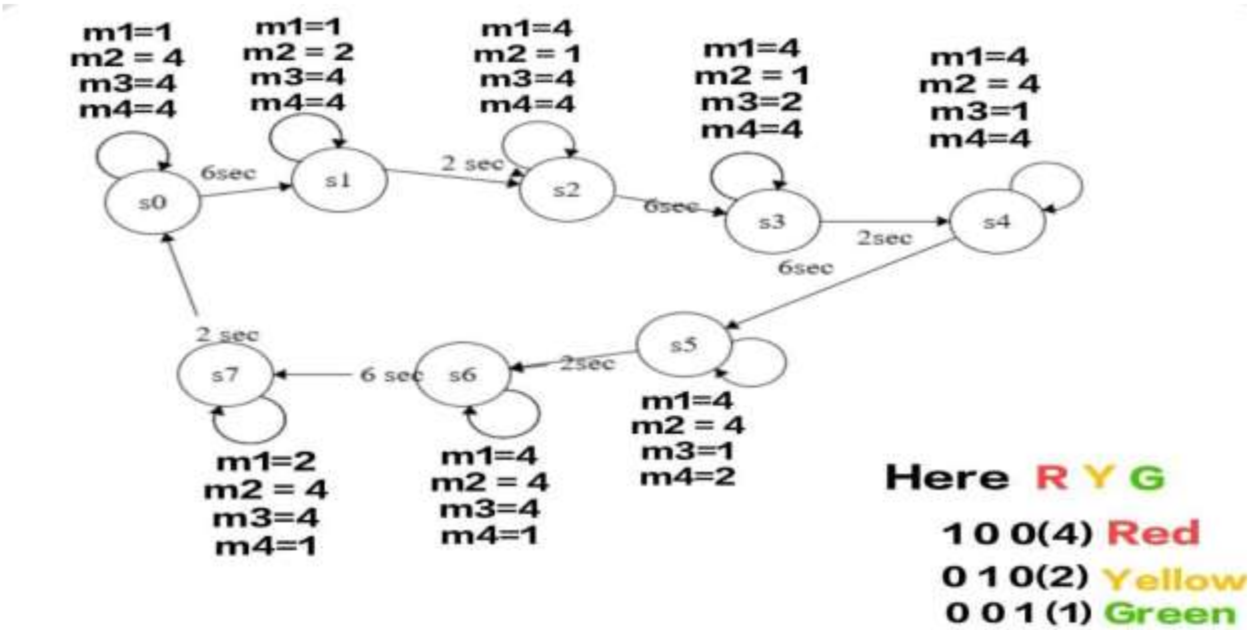

Fig1: State machine for Traffic Light Controller

In this particular FSM, there are eight states: s0, s1, s2, s3, s4, s5, s6, and s7. Each state represents a different stage of the traffic signal cycle.

s0 is the initial state, representing the start of the traffic signal cycle. From s0, the FSM transitions to s1, which represents the green signal for the North-South direction. The green signal lasts for a predefined period of time, and after this period, the FSM transitions to s2, which represents the yellow signal for the North-South direction. The yellow signal serves as a warning that the green signal is about to end, and it typically lasts for a few seconds.

After the yellow signal in s2, the FSM transitions to s3, which represents the green signal for the West-East direction. This green signal also lasts for a predefined period of time, and after this period, the FSM transitions to s4, which represents the yellow signal for the East-West direction.

The cycle then repeats, with the FSM transitioning back to s1 for another green signal for the North-South direction. This cycle continues until the traffic signal controller is turned off or reset.

In this particular FSM, there is a delay of 6 seconds between the green signal for one direction and the green signal for the other direction. Additionally, there is a 2-second delay between the yellow signal and the green signal change.

Overall, this FSM represents a simple but effective traffic light controller that cycles through the different signal stages with a predefined timing sequence, helping to regulate the flow of traffic and ensure safety on the road.

3. **Uniqueness of the Project**

The uniqueness of a 4-way traffic light controller can be attributed to its specific design, functionality, or features that differentiate it from other types of traffic light controllers. Here are a few aspects that may contribute to the uniqueness of a 4-way traffic light controller:

1. Intersection Management: A 4-way traffic light controller is designed to manage traffic flow at a complex intersection where four roads intersect. Its uniqueness lies in its ability to regulate the movement of vehicles from all four directions effectively, ensuring safe and efficient traffic management.

2. Timing and Sequencing: The timing and sequencing of the traffic lights are crucial for maintaining traffic flow and reducing congestion. A unique 4-way traffic light controller may incorporate intelligent algorithms or adaptive timing mechanisms that optimize signal timing based on real-time traffic conditions, thereby improving traffic efficiency.

3. Sensors and Detection Systems: Uniqueness can also arise from the incorporation of advanced sensors and detection systems in the traffic light controller. These sensors can detect the presence of vehicles, pedestrians, or cyclists, allowing the controller to adjust signal timings dynamically based on the actual traffic demand at any given moment.

4. Communication and Coordination: In some cases, a 4-way traffic light controller may offer unique communication capabilities to facilitate coordination with other nearby traffic lights or intelligent transportation systems. This enables the controller to synchronize traffic signals across multiple intersections, creating green corridors or optimizing traffic flow across a larger network.

4. Simulation results

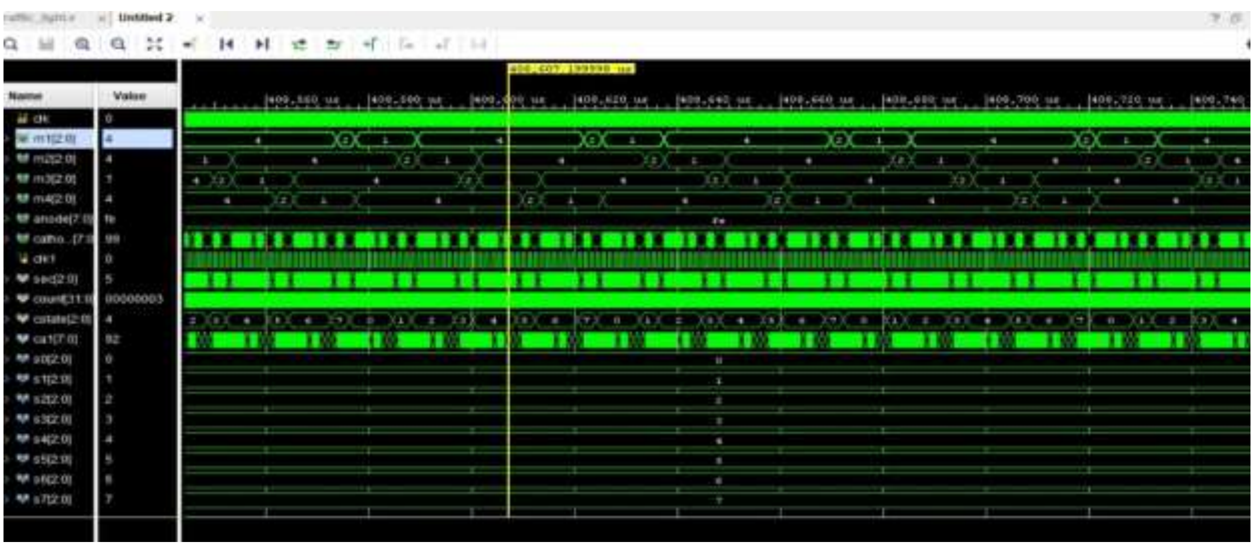

Fig. 2. Simulation results

The given sequence of binary numbers represents the traffic signals for the four different directions at an intersection. The four directions are denoted by m1, m2, m3, and m4, where m1 represents North, m2 represents South, m3 represents West, and m4 represents East.

The binary code 100 indicates a red signal, 001 indicates a green signal, and 010 indicates a yellow signal. Therefore, the given sequence of binary numbers translates to the following traffic signal states:

- m1: red
- m2: red
- m3: green
- m4: red

This indicates that the traffic signal for the West direction (m3) is green, while the signals for the other three directions are red. Therefore, vehicles traveling in the West direction would have the right of way, while those in the other directions would have to stop.

Overall, the sequence of binary numbers represents a snapshot of the traffic signal states at a given point in time, and the colours of the signals indicate which direction of traffic has the right of way. By following these signals, drivers and pedestrians can safely navigate through the intersection.

4.1 RTL Diagram

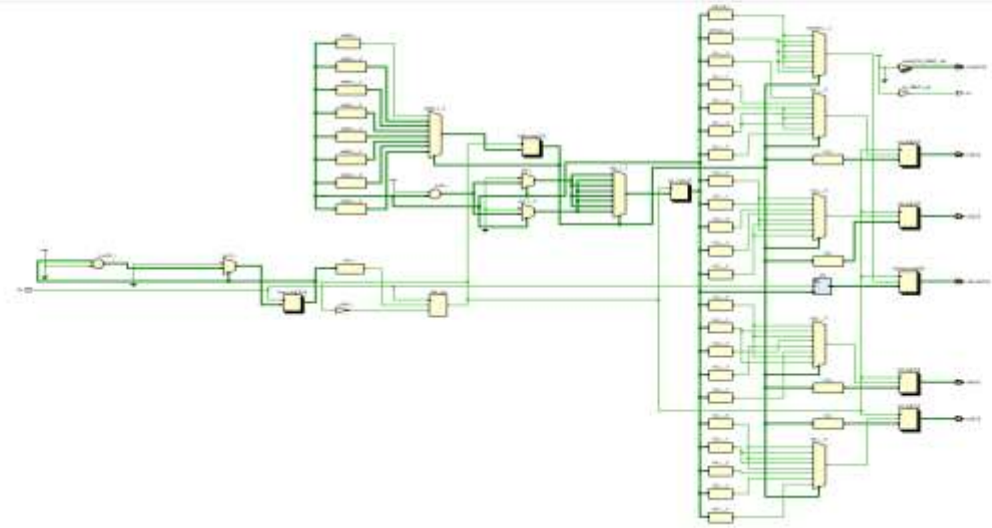

Fig3: RTL Diagram

4.2 Synthesis

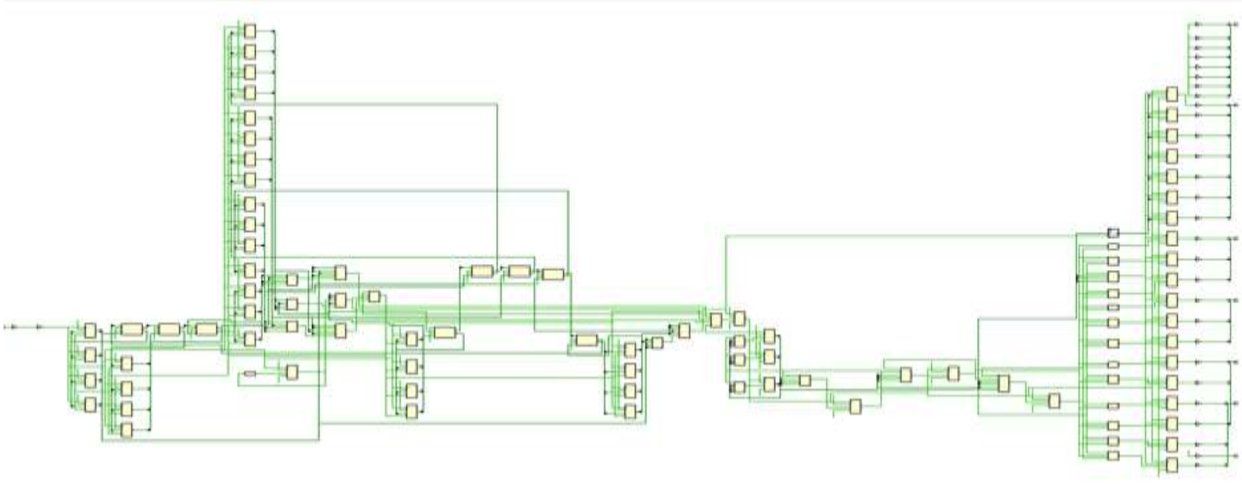

Fig4: Synthesis for Traffic Light Controller

5. Hardware prototype

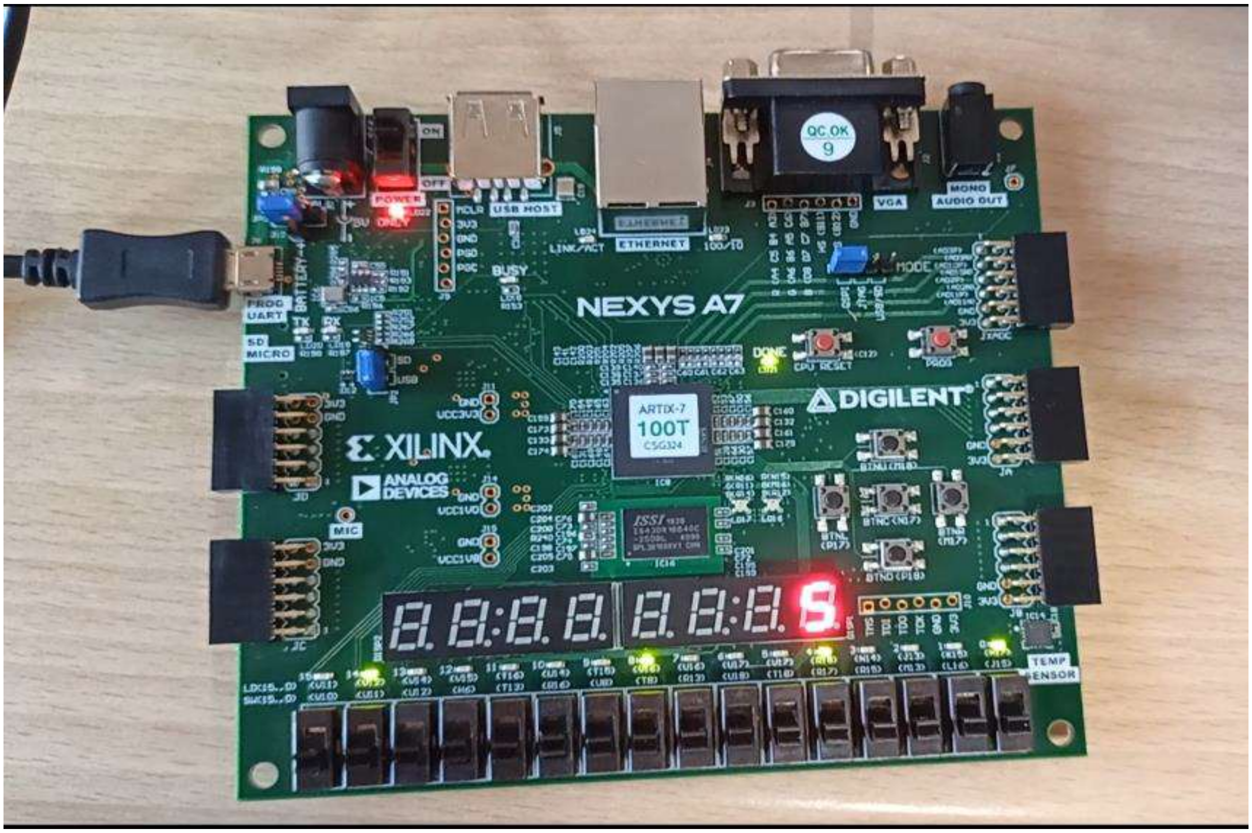

Fig5: Hardware Prototype (FPGA) for Traffic Light Controller

6. Performance metric

When evaluating the performance of a four-way traffic light controller, several performance metrics can be considered. These metrics can help assess the efficiency, safety, and effectiveness of the traffic control system. Here are some performance metrics that can be used:

1. Traffic Flow: Measure the average number of vehicles passing through the intersection per unit of time. This metric can indicate the system's ability to handle traffic efficiently and maintain smooth traffic flow.

2. Queue Length: Determine the length of vehicle queues at each approach of the intersection. Long queues may indicate congestion and delays, highlighting areas that require optimization.

3. Delay: Calculate the average delay experienced by vehicles at the intersection. Delay can be measured as the waiting time for vehicles before they can proceed through the intersection. Lower delays indicate better traffic management.

4. Intersection Capacity: Assess the maximum capacity of the intersection to handle vehicle flows without significant congestion or delays. This metric helps determine the system's ability to accommodate peak traffic demands.

7. Conclusion

A 4-way traffic light controller is an important piece of infrastructure that helps to manage the flow of traffic at intersections. It consists of a system of traffic signals that use different colours and patterns to indicate which direction of traffic has the right of way. The implementation of a 4-way traffic light controller typically involves the use of a Finite State Machine (FSM) model, which provides a structured approach to managing the timing and sequencing of the traffic signals. The FSM defines different states for each direction of traffic, and transitions between these states based on predefined timing sequences and triggers. By regulating the flow of traffic through the intersection, a 4-way traffic light controller helps to reduce the risk of accidents and minimize traffic congestion. It is an essential piece of infrastructure for ensuring the safety and efficiency of transportation networks, and is an important consideration for urban planners and traffic engineers.

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