Design and Implementation of a Low-Cost Logic-Based Traffic Light Controller with Pedestrian Integration

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***Abstract*—This paper presents the design and implementation of a low-cost, logic-based traffic light control system integrated with pedestrian crossing functionality for a four-way intersection. The proposed system utilizes basic digital logic components such as 555 timer ICs, CD4017 counters, and logic gates (AND, OR, NOR) to control vehicle flow and pedestrian movement through a well-defined finite state machine (FSM). Pedestrian input is managed via push-button switches acting as request signals for safe crossing. The system was developed using Verilog hardware description language (HDL) and simulated in Proteus before physical implementation on a breadboard. Experimental results demonstrate that the system operates as intended, coordinating vehicular and pedestrian signals efficiently. While the current prototype supports partial pedestrian routing due to hardware limitations, the design framework is extensible to include full-scale real-world applications. This project provides a practical and educational model for traffic signal control, with implications for urban traffic optimization and pedestrian safety.**

I. Introduction

Urban traffic congestion [1] remains one of the most pressing challenges in modern cities, especially in densely populated regions such as Dhaka, Bangladesh. Inefficient traffic signal management [2] not only leads to increased travel times but also contributes significantly to road accidents, environmental pollution [3], and economic losses. [4] Traditional fixed-time traffic light systems often fail to account for real-time variables such as pedestrian demand [5], emergency vehicles [6], or fluctuating traffic volumes [7], resulting in suboptimal traffic flow and increased safety risks for both drivers and pedestrians. The recent work by Ruijie Zhu proposed a Multi-Agent Broad Reinforcement Learning (MABRL) algorithm for Intelligent Traffic Light Control (ITLC), using a broad network architecture instead of deep neural networks to reduce training time. It introduces a Dynamic Interaction Mechanism (DIM) based on attention to enhance coordination among traffic signal agents. [8]Another study by Lucas Koch shows an adaptive traffic light control system using Proximal Policy Optimization (PPO), a deep reinforcement learning algorithm. [9]Ashish Tigga presents an intelligent Traffic Light Control System (TLCS) using Deep Q-Learning (DQL), a Deep Reinforcement Learning approach, to optimize traffic signal timing. [10]Ali Wided develops a simulator-based intelligent traffic light control system that mimics large city intersections using a grid of traffic lights. The system uses custom scheduling algorithms to dynamically adjust light signals based on real-time traffic presence and density. [11] However, these approaches rely heavily on high computational power, expensive sensors, and large-scale deployment infrastructure, which makes them less suitable for immediate implementation in developing countries or educational contexts. Moreover, many of these models prioritize vehicular flow optimization and often neglect or oversimplify pedestrian movement integration—an equally vital component in urban safety and mobility.

This paper addresses these gaps by proposing a low-cost, logic-based traffic light control system that explicitly incorporates pedestrian crossing functionality. Unlike AI-based systems, our approach leverages simple hardware components—logic gates, 555 timer ICs, CD4017 counters—and is designed using a finite state machine (FSM) framework. This makes the system both accessible and scalable for real-world prototyping, particularly in resource-constrained environments. Pedestrian movement is managed using push-button sensors, allowing for dynamic crossing requests while maintaining traffic safety through synchronized light transitions.

This design is not only educational but also serves as a practical prototype that can be further expanded with FPGA deployment, sensor-based inputs, and emergency lane integration, thus paving the way for smart yet affordable urban traffic solutions. The contribution from our work is as follows:

1) FSM and truth table designed from problem analysis
2) Logic synthesized using ICs and HDL
3) Simulation in Proteus and Verilog
4) Hardware implementation on breadboard
5) Validation through real-time testing and waveform analysis

II. Methodology

This section outlines the design, simulation, and hardware implementation of the traffic light control system with pedestrian movement. The methodology integrates finite state machine (FSM) modeling, truth table construction, hardware logic circuit design, and HDL-based digital simulation.

A. System Overview

The system controls a four-way intersection with vehicular and pedestrian signals. Each road has dual lanes and pedestrian pathways (P1–P8). The system is designed to ensure that only one direction has a green signal at a time, and pedestrian movement is allowed only when it is safe, based on synchronized states.

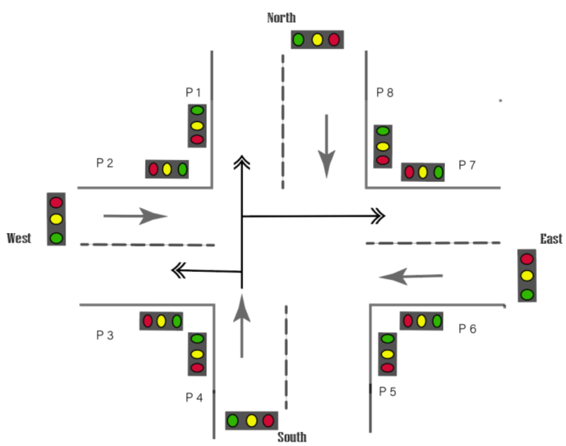

Fig. 1: Schematic of Traffic Light Control System with Pedestrian Crossings

B. Finite State Machine Design

We modeled the system as a Finite State Machine (FSM) with eight states, $S = \{A, B, C, D, E, F, G, H\}$. Each state corresponds to a specific configuration of vehicular and pedestrian lights. The transitions are governed by a clock signal generated using a 555 Timer and CD4017 Decade Counter.

State transitions are triggered on the clock signal w:

$$S_t \xrightarrow{w=1} S_{t+1}$$

Figure 2 represents the state diagram for the traffic light control system with pedestrian movement. It visually illustrates the Finite State Machine (FSM) used in the system's design.

C. Truth Table Design

In this subsection, we present the truth tables that define the behavior of the traffic light control system and pedestrian signal system. The states for both vehicle and pedestrian signals are determined based on the current system state and the traffic light transitions governed by an FSM. The system comprises eight states(A to H) that represent the different configurations of traffic lights for all four directions (North,

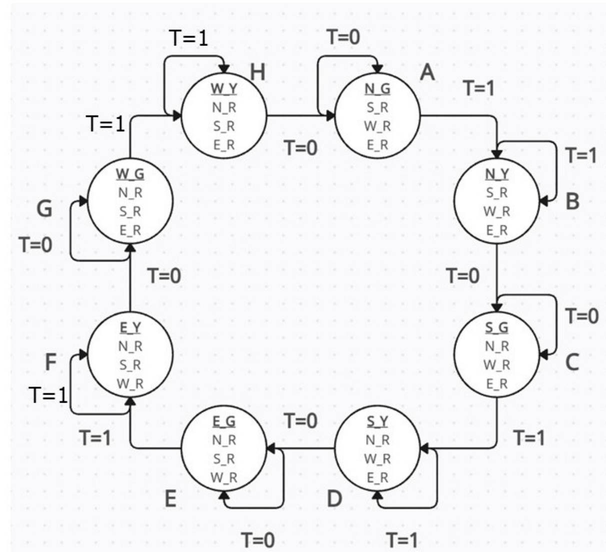

Fig. 2: State diagram for traffic light control system

TABLE I: Traffic Light Signal States

State	North			South			East			West		
	G	Y	R	G	Y	R	G	Y	R	G	Y	R
A	1	0	0	0	0	1	0	0	1	0	0	1
B	0	1	0	0	0	1	0	0	1	0	0	1
C	0	0	1	1	0	0	0	0	1	0	0	1
D	0	0	1	0	1	0	0	0	1	0	0	1
E	0	0	1	0	0	1	1	0	0	0	0	1
F	0	0	1	0	0	1	0	1	0	0	0	1
G	0	0	1	0	0	1	0	0	1	1	0	0
H	0	0	1	0	0	1	0	0	1	0	1	0

South, East, and West). The truth table for the traffic light signal states is given below.

The pedestrian signal system operates in tandem with the traffic lights, indicating when pedestrians can cross safely. There are eight pedestrian crossings, and their states are also modeled using an FSM. The truth table for pedestrian signal states is given below.

The pedestrian signals are controlled by the traffic lights and transition based on the current state of the system. The general transition function for the pedestrian signal system is:

$$\text{Next State}_{\text{Pedestrian}} = f(\text{Current State}_{\text{Pedestrian}}, \text{Traffic Light Status}, \text{Pedestrian Request}) \quad (1)$$

Where: - Current $\text{State}_{\text{Pedestrian}}$ is the current state of the pedestrian signal. - Traffic Light Status represents the status of the traffic lights (Green, Yellow, Red). - Pedestrian Request is the input from the pedestrian button press.

The transitions occur according to the logic in the table, where the pedestrian signals are synchronized with the vehicle traffic light signals to ensure safe crossings. The truth tables provided for both the traffic light and pedestrian signals define

TABLE II: Pedestrian Signal States with Color Encoding

State	P1			P2			P3			P4			P5			P6			P7			P8		
	G	Y	R	G	Y	R	G	Y	R	G	Y	R	G	Y	R	G	Y	R	G	Y	R	G	Y	R
N-G	1	0	0	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	0	0	1
N-Y	0	1	0	0	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	0	1
S-G	0	0	1	0	0	1	0	0	1	1	0	0	1	0	0	0	0	1	1	0	0	1	0	0
S-Y	0	0	1	0	0	1	0	0	1	0	1	0	0	1	0	0	0	1	0	1	0	0	1	0
E-G	1	0	0	0	0	1	0	0	1	0	0	1	1	0	0	1	0	0	1	0	0	0	0	1
E-Y	0	1	0	0	0	1	0	0	1	0	0	1	0	1	0	0	1	0	0	1	0	0	0	1
W-G	1	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	1	1	0	0	0	0	1
W-Y	0	1	0	0	0	1	0	1	0	0	1	0	0	0	1	0	0	1	0	1	0	0	0	1

the system's operation. The FSM and the truth table logic ensure that both vehicle and pedestrian signals are synchronized and follow the correct transition rules based on the inputs.

D. Circuit Implementation

The hardware circuit uses the following components:

- IC 7402 (NOR) for red light logic
- IC 7408 (AND), 7432 (OR) for control logic
- 555 Timer for pulse generation
- Capacitors and resistors
- CD4017 Decade Counter to manage FSM transitions
- LEDs to represent G, Y, R states

A simplified schematic is shown in Figure 3. Simulation was conducted in Proteus.

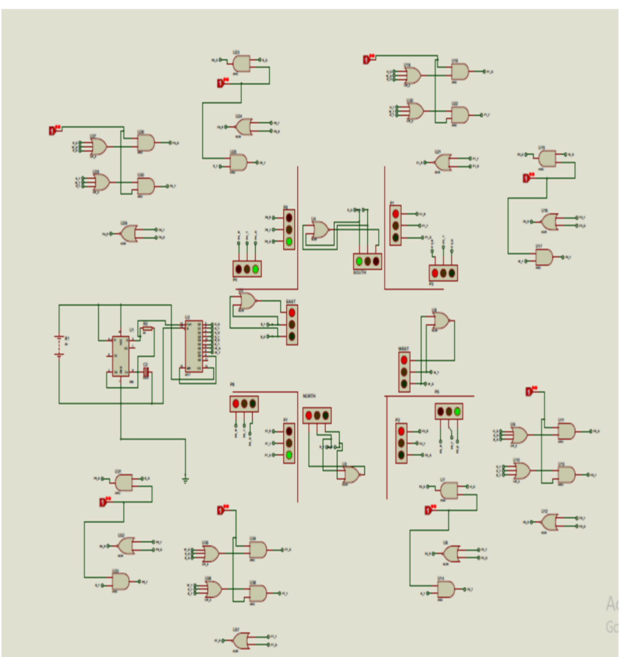

Fig. 3: Simplified Circuit Schematic for Traffic Control

E. Hardware Prototyping

The full system was implemented on a breadboard. Due to power limitations, only four pedestrian nodes were activated. The rest of the system functioned as per the truth table and FSM. Push buttons simulated pedestrian requests.

- Traffic signals responded correctly to FSM state changes.
- Pedestrian LEDs turned ON/OFF based on safe intervals.

III. Experimental Results and Discussion

To validate the design, an equivalent FSM model was implemented in Verilog. States were encoded as 3-bit values:

$$\text{State A} = 3'b000, \quad \text{State B} = 3'b001, \ldots, \text{State H} = 3'b111$$

State transitions and output logic were verified through simulation in ModelSim.

```
always @(posedge Clk or posedge Reset)
    if (Reset)
        y <= A;
    else
        y <= Y;
```

A sample timing diagram from the simulation is shown in Figure 4, 5 and 6.

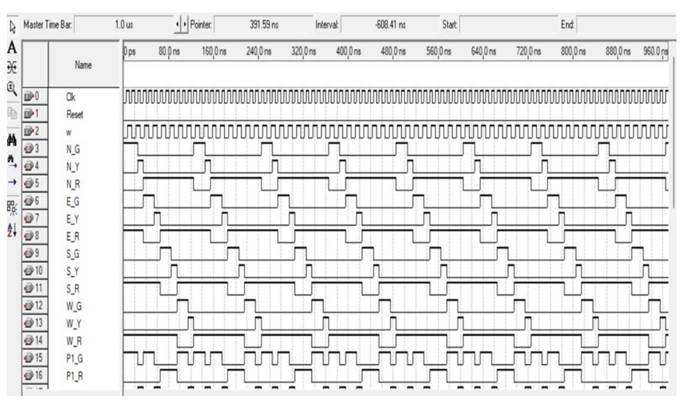

Fig. 4: First output from Verilog

To validate the simulation results, the project was also implemented practically using discrete logic ICs instead of an FPGA board. One of the key components in this hardware implementation was the 555 timer IC, which was configured to control timing operations such as LED blinking durations

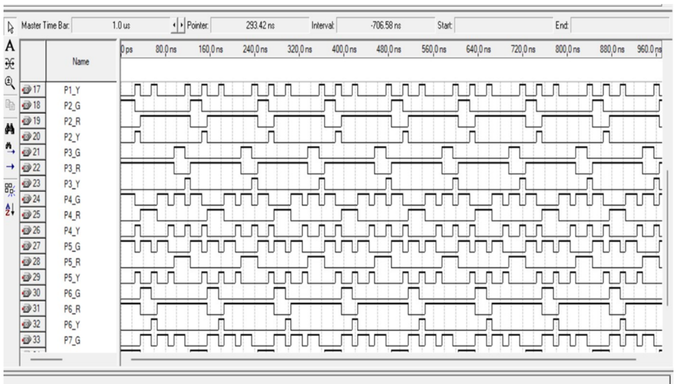

Fig. 5: Second output from Verilog

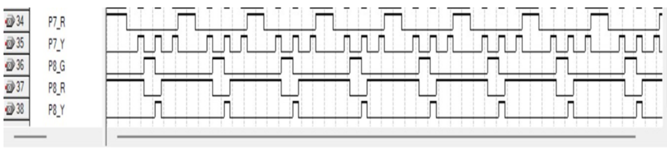

Fig. 6: Third output from Verilog

and signal transitions. The 555 timer was used in astable mode to generate a continuous square wave output.

During the hardware design phase, different combinations of resistor (R) and capacitor (C) values were tested to achieve an appropriate time period for the output signal. After several trial-and-error experiments, a resistor value of $4\,\mathrm{k}\Omega$ and a capacitor of $22\,\mu\mathrm{F}$ were selected as optimal for the desired timing behavior. The time period T for a 555 timer in astable mode is given by the formula:

$$T = 1.44 \times R \times C \tag{2}$$

Substituting the chosen values:

$$\begin{aligned} T &= 1.44 \times 4000\ \Omega \times 22 \times 10^{-6}\ \mathrm{F} \\ &= 0.1267 \text{ seconds} \approx 127\,\mathrm{ms} \end{aligned} \tag{3}$$

This indicates that the output from the timer toggles roughly every $127\,\mathrm{ms}$, which was suitable for the blinking and logic control requirements of the traffic light model.

The 555 timer circuit and other logic ICs were assembled on a breadboard, and corresponding LED indicators were connected to represent traffic signal outputs. A regulated DC power adapter was used to supply power to the entire circuit, ensuring stable operation.

Upon successful implementation of the hardware prototype, it was observed that the circuit behavior aligned closely with the simulation outputs obtained from software tools. The consistent results across both platforms demonstrated the accuracy of the design and validated the feasibility of the system in a real-world scenario.

IV. Conclusion and Future Work

A. Conclusion

In this work, a traffic light control system with pedestrian crossing using digital logic circuits was designed and implemented. The system integrates vehicle and pedestrian signal management through a finite state machine (FSM) and was verified both through Verilog-based simulation and hardware implementation using logic ICs. Despite limitations in hardware resources, the project successfully demonstrated synchronized signal control at a four-way intersection. The results show that the proposed system improves safety and efficiency by coordinating traffic and pedestrian flow, thus serving as a scalable prototype for real-world applications.

B. Future Work

While the project met its fundamental objectives, there remains scope for further improvement. Future enhancements may include:

- Implementation of all eight pedestrian movements with complete synchronization.
- Integration of real-time pedestrian detection using sensors (e.g., IR or pressure-based).
- Addition of emergency vehicle detection and dedicated priority signal control.
- Full deployment on an FPGA platform to improve timing accuracy, scalability, and power efficiency.

These advancements will make the system more intelligent, adaptive, and suitable for deployment in modern urban traffic infrastructures.

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