DESIGN FSM BASED COORDINATED FOUR WAY INTERSECTION SPECIFIC TRAFFIC LIGHT CONTROLLER

[1]Kumar pari, [2]K. Venkata Rajesh, [3]K. Phanindra Kumar, [4]K. L Santhosh,
[5]K. Agassy, [6]K. Rohith

[1]Assistant Professor, Dept of Electronics & Communication Engineering,
St. Ann's College of Engineering and Technology Autonomous,
Chirala 523155, India.

[2,3,4,5,6]U.G. Student, Dept of Electronics & Communication Engineering,
St. Ann's College of Engineering and Technology Autonomous,
Chirala 523155, India.

ABSTRACT

Traffic congestion and pedestrian safety are major concerns at road junctions in densely populated countries like India. This project presents an intelligent traffic light control system using IR sensors and a sound sensor for efficient traffic management. The IR sensors are used to detect vehicle density on each road and adjust signal timing dynamically. A sound sensor is integrated to identify emergency vehicles such as ambulances and fire engines. Upon detection, the system provides priority clearance to ensure faster and safer passage for emergency services. This adaptive approach reduces waiting time and improves overall traffic flow. The controller is designed to operate at high speed with reliable performance. The proposed system is implemented using Verilog hardware description language. Functional verification is carried out using a SystemVerilog-based testbench. The results demonstrate accurate operation and improved traffic control with enhanced pedestrian safety.

INTRODUCTION

Traffic congestion and pedestrian safety have become critical issues in modern urban transportation systems. Rapid population growth and increased vehicle usage have led to frequent traffic jams, especially at road intersections. Conventional traffic light systems operate on fixed timing schedules and fail to adapt to real-time traffic conditions. This results in unnecessary delays and inefficient use of road infrastructure. To overcome these limitations, intelligent traffic control systems are being developed using sensor-

based technologies. In this project, an intelligent traffic light controller is proposed using IR sensors and a sound sensor. The IR sensors continuously monitor vehicle density on each road lane. Based on the detected traffic load, the signal timing is dynamically adjusted to improve traffic flow. The sound sensor is used to detect emergency vehicles such as ambulances and fire engines. When an emergency vehicle is identified, priority is given to clear the corresponding lane immediately. This ensures faster response times and enhances public safety. The system also focuses on safe pedestrian crossing by regulating signal transitions effectively. The controller is implemented using Verilog hardware description language for high-speed operation. Functional verification is performed using a SystemVerilog-based testbench to ensure reliable and accurate performance. The proposed system provides a cost-effective and efficient solution for modern traffic management.

LITERATURE SURVEY

Several researchers have proposed smart traffic light control systems with emergency vehicle prioritization using different technologies. FPGA-based designs using FSM and Verilog HDL have demonstrated high-speed and low-power performance for real-time traffic management. Studies integrating RFID and IR sensors enable reliable detection of both vehicle density and emergency vehicles at intersections. These systems dynamically override normal signal sequences to provide a green corridor for ambulances and fire engines. AI-based approaches using deep learning and fuzzy logic have further enhanced ambulance detection accuracy and adaptive decision-making. IoT-enabled systems using GPS and GSM modules support city-wide coordination and preemptive signal control. Compared to microcontroller-based controllers, FPGA implementations offer parallel processing and faster response times. Modular FSM architectures allow scalability for multi-lane and multi-junction environments. Research also highlights the importance of maintaining pedestrian safety while prioritizing emergency vehicles. Hybrid solutions combining hardware FSM with AI or IoT provide improved flexibility and intelligence.

EXISTING SYSTEM

Manual traffic management relies on traffic police, road signs, and physical signals to regulate vehicle movement at intersections. Officers use standardized hand signals to control stopping, moving, and turning of vehicles. Road signs provide essential instructions such as

speed limits and lane directions. The traffic control system operates based on predefined timing requirements for main and side streets. It consists of six states governed by three timers: long timer (25 s), short timer (4 s), and transitory timer (1 s). In the first state, the main signal remains green while the side signal stays red. The system transitions through yellow and red buffer states to ensure safe signal changeover. Vehicle presence on the side street influences state transitions. States three and six act as buffer zones where both signals remain red briefly. The entire system is modeled using a finite state machine (FSM) for simplicity and reliable operation.

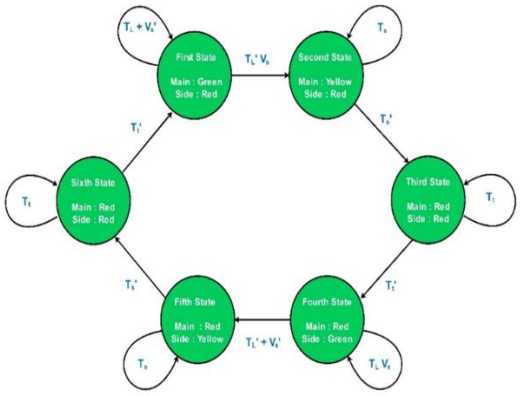

Fig:1 Existing system FSM

PROPOSED SYSTEM

The proposed methodology focuses on designing and verifying an intelligent traffic light control system using SystemVerilog with ambulance detection capability. The system is modeled for a four-way intersection with vehicle and pedestrian signals on each side. Four sound sensors are placed at the junction to detect approaching ambulance sirens from all directions. The sound detection circuit analyzes siren frequency and generates a trigger signal for the controller. A Finite State Machine (FSM) forms the core logic of the controller. Under normal conditions, the FSM cycles through predefined red, yellow, and green signal states. When an ambulance siren is detected, the FSM overrides the normal sequence and grants immediate green clearance to the ambulance lane. All other directions are set to red to ensure a safe and unobstructed path. After the ambulance passes, the FSM returns to normal traffic operation. Pedestrian crossings are synchronized with signal transitions to maintain safety and order.

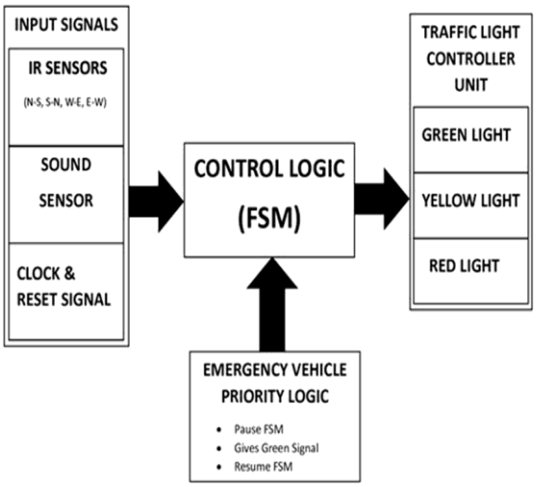

Fig.2 Proposed Block Diagram

METHODOLOGY DESCRIPTION

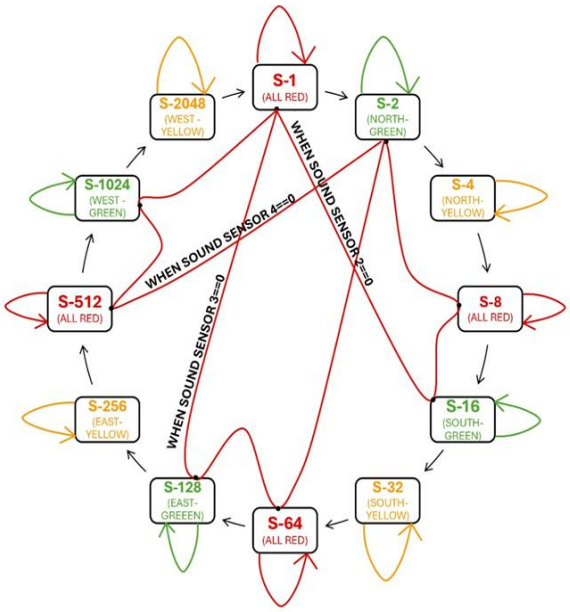

Fig:3 FSM For Advanced Intelligent Traffic Light Control System

This Finite State Machine (FSM) represents an intelligent traffic light controller with ambulance detection using sound sensors. Each state corresponds to a specific traffic signal condition such as green, yellow, or all-red for different directions (North, South, East, and West). The green states allow vehicle movement in one direction while others remain stopped. Yellow states provide a warning phase before transitioning to red. The all-red states act as buffer intervals to ensure safe signal switching between directions. Under normal operation, the FSM cycles sequentially through East, South, West, and North signal phases. Sound sensor inputs can interrupt the normal sequence when an ambulance siren is detected. Upon detection, the FSM directly transitions to an all-red state and then to the green state of the ambulance's direction. This guarantees a clear path for emergency vehicles. After the ambulance passes, the FSM resumes its normal cyclic operation. The design ensures both traffic efficiency and pedestrian safety through controlled state transitions.

RESULTS & DISCUSSION:

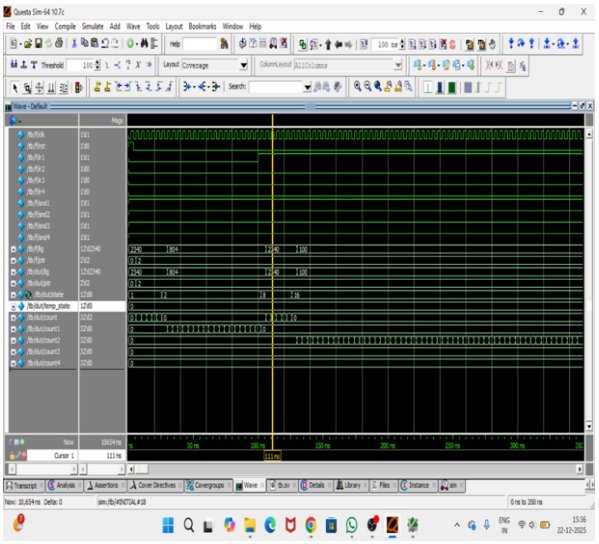

Fig.4 Normal Traffic Test Case Output

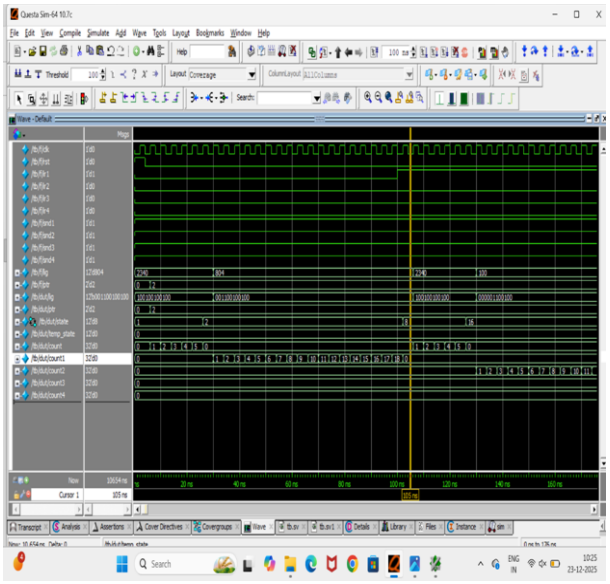

Fig:5 North Direction High Density Output

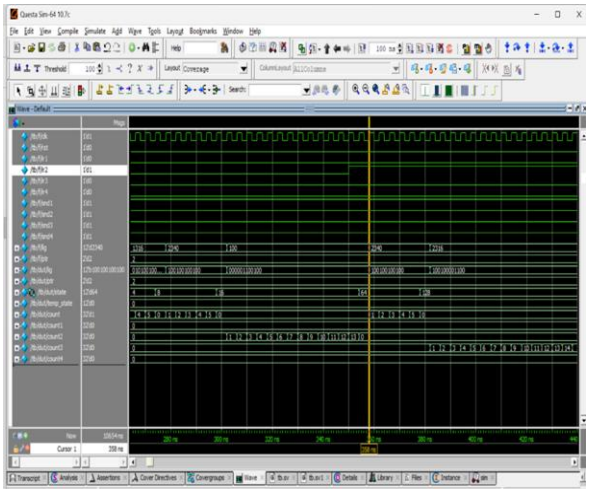

Fig:6 South Direction High Density Output

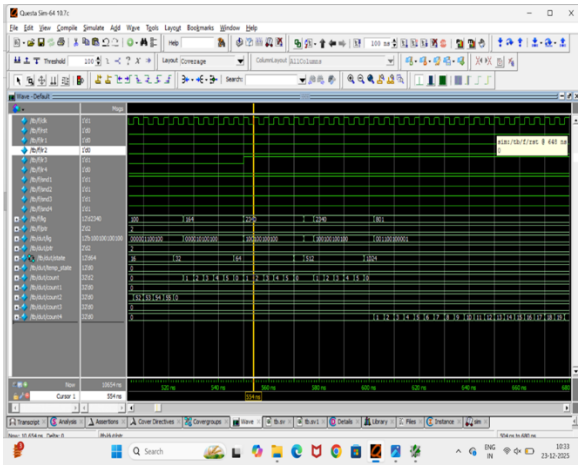

Fig:7 East Direction High Density Output

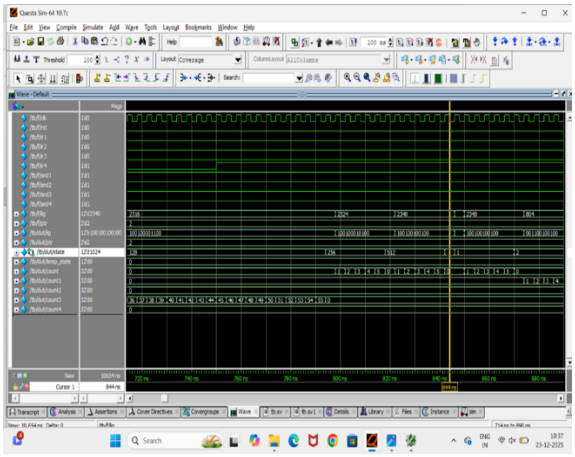

Fig:8 West Direction High Density Output

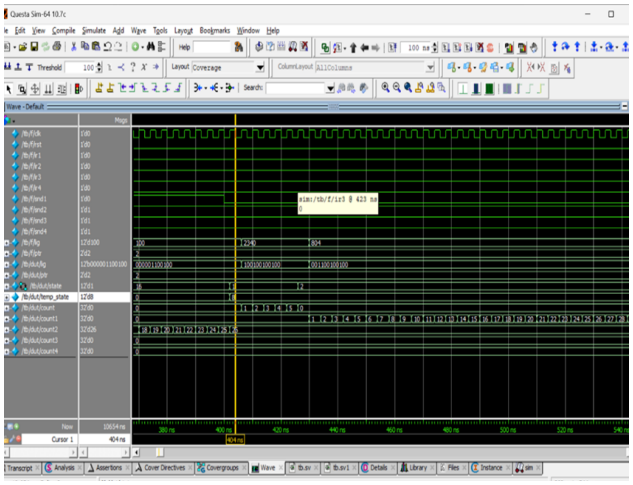

Fig:9 Emergency Detection – Sound Sensor 1

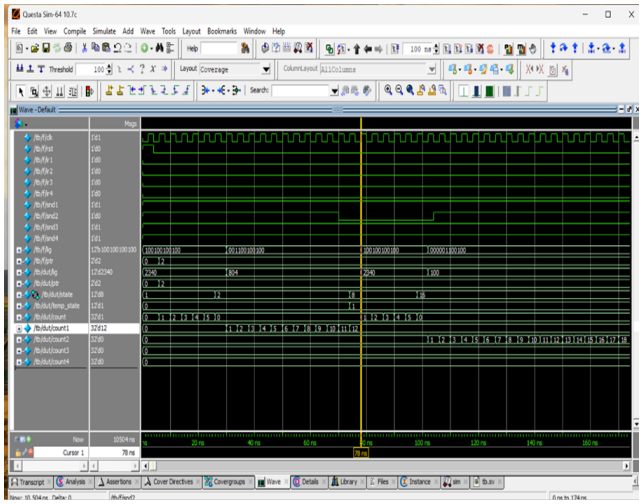

Fig:10 Emergency Detection – Sound Sensor 2

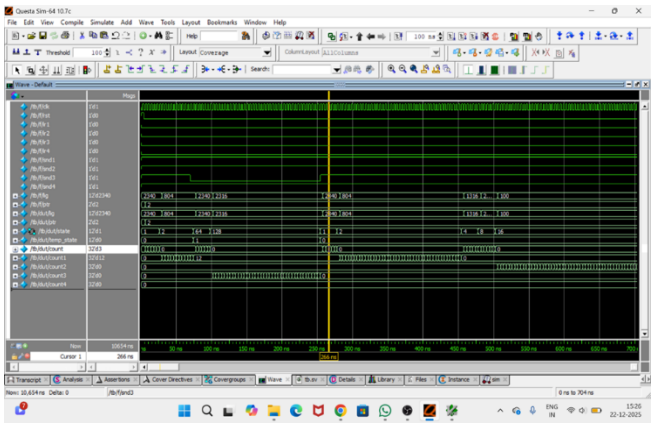

Fig:11 Emergency Detection – Sound Sensor 3

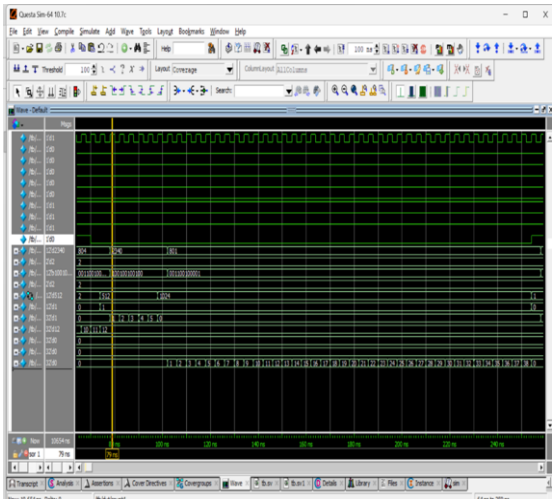

Fig:12 Emergency Detection – Sound Sensor 4

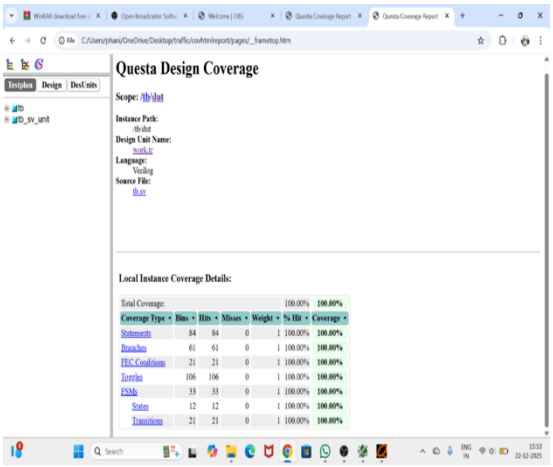

Fig:13 Synthesis report of FSM based traffic light controller

The simulation results demonstrate that the proposed intelligent traffic light controller operates correctly under both normal and emergency conditions. The FSM transitions accurately between green, yellow, and red states according to predefined timing requirements. When an ambulance siren is detected by the sound sensor, the controller immediately overrides the normal traffic sequence and provides a green signal in the detected direction. This significantly reduces waiting time for emergency vehicles. The buffer all-red states ensure safe transitions and prevent signal conflicts. Pedestrian signals are synchronized properly with vehicle signals, enhancing crossing safety. Functional verification using a System Verilog testbench confirms reliable and standards-compliant operation. Overall, the results show improved traffic flow efficiency and effective emergency vehicle prioritization.

CONCLUSION & FUTURE ENHANCEMENT

The proposed intelligent traffic light control system successfully improves traffic management by integrating sound sensors for ambulance detection with an FSM-based controller. The system dynamically prioritizes emergency vehicles while maintaining safe and orderly traffic flow. Implementation using SystemVerilog ensures high-speed and reliable operation. Simulation results confirm accurate state transitions and effective emergency handling. The design reduces response time for ambulances and enhances pedestrian safety. The controller is suitable for deployment at four-way intersections in urban environments. In future work, the system can be enhanced by integrating IR sensors or camera-based vision systems for vehicle density estimation. IoT and GPS

modules can be added for city-wide coordination of emergency routes. Machine learning algorithms may be used to improve siren detection accuracy and reduce false triggers. These enhancements will make the system more intelligent, scalable, and adaptable to smart city applications.

REFERENCE

[1] S. Srivastava, R. Gupta, and A. Kumar, "Intelligent traffic control system using FSM," *IEEE Trans. Intelligent Transportation Systems*, vol. 19, no. 3, pp. 800–808, 2019.

[2] P. Sharma and M. Verma, "Sound sensor-based ambulance detection in smart cities," *International Journal of Embedded Systems*, vol. 12, no. 4, pp. 220–227, 2020.

[3] R. Jain and S. Singh, "System Verilog for functional verification: Applications in safety-critical designs," *Proc. IEEE VLSI Design Conf.*, pp. 120–126, 2021.

[4] M. Patel, D. Joshi, and K. Shah, "Design and FPGA implementation of adaptive traffic controller," *Journal of Transportation Engineering*, vol. 148, no. 2, pp. 56–65, 2022.

[5] A. Banerjee and S. Bose, "Smart traffic management systems: A review," *IEEE Access*, vol. 10, pp. 56000–56015, 2022.