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Smart Traffic Light System using ESP32 and Infrared Sensors

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Abstract

This project presents the design and implementation of a smart traffic light system using the ESP32 microcontroller and infrared (IR) sensors. Unlike traditional traffic lights that operate on fixed timers, this system dynamically adjusts signals based on real-time vehicle detection. The prototype demonstrates how embedded systems and automation can reduce congestion, save energy, and improve road efficiency. The project also explores future enhancements such as IoT connectivity, solar power, and emergency vehicle priority.

Contents

Chapter 1

Introduction

Traffic congestion is a growing problem in urban areas, leading to wasted time, increased fuel consumption, and higher pollution levels. Conventional traffic lights operate on fixed cycles, which often fail to adapt to varying traffic conditions.

This project aims to develop a smart traffic light system that uses IR sensors to detect vehicles and an ESP32 microcontroller to control traffic lights dynamically. By responding to real-time traffic flow, the system ensures smoother movement and reduces unnecessary waiting time.

Chapter 2

Objectives

- To design a microcontroller-based traffic light system that adapts to vehicle presence.

- To integrate IR sensors for real-time detection of vehicles at intersections.

- To implement traffic control logic using ESP32 programming.

- To demonstrate the potential of IoT and automation in smart city applications.

- To explore future improvements such as AI-based adaptive timing and cloud monitoring.

Chapter 3

Components Used

- ESP32,PVC Board,Cross Wire

- Infrared Obstacle Sensors (8 units)

- LEDs (12 units: Red, Yellow, Green for each road)

- Busbar and jumper wires

- Glue Stick and zip ties

- Power Supply

Chapter 4

Methodology

4.1 Circuit Design

Each road (A, B, C, D) has three LEDs connected to ESP32 GPIO pins. Each road has two IR sensors connected to GPIO pins for vehicle detection. All sensors share common VCC and GND connections.

4.2 Programming

GPIO pins are defined for LEDs and sensors. Sensor values are read using `digitalRead()`. Traffic logic is implemented with `if-else` conditions. Delay functions simulate realistic traffic light transitions.

Chapter 5

Pin Mapping

Road	Green LED	Yellow LED	Red LED	IR Sensor 1	IR Sensor 2
A	GPIO4	GPIO2	GPIO15	GPIO34	GPIO35
B	GPIO13	GPIO12	GPIO14	GPIO21	GPIO19
C	GPIO27	GPIO26	GPIO25	GPIO18	GPIO5
D	GPIO33	GPIO32	GPIO22	GPIO17	GPIO16

Chapter 6

Working Principle

IR sensors detect vehicles at each road. ESP32 processes sensor signals and decides which road gets priority. Traffic lights operate as follows:

- Green – vehicles are allowed to move

- Yellow – transition warning

- Red – vehicles must stop

Chapter 7

Results

- The system successfully detected vehicles using IR sensors.

- Traffic lights responded dynamically, reducing idle waiting time.

- The prototype demonstrated automation in a small-scale model.

Chapter 8

Challenges Faced

- Problem faced during jumper wire extension using cross wire.

- Power fluctuations when multiple LEDs and sensors were active.

- Pin conflicts during initial coding.

- Loose jumper wires causing unstable connections.

- Complex logic requiring debugging to prevent multiple green signals.

Chapter 9

Innovative Ideas (Future Scope)

- Emergency vehicle priority using RFID or special sensors.
- Adaptive timing using AI and machine learning.
- Pedestrian crossing integration with push buttons.
- Solar-powered traffic lights for eco-friendly operation.
- IoT connectivity for cloud-based monitoring.
- Accident alert system for stalled vehicles.

Chapter 10

Conclusion

This project demonstrates how ESP32 and IR sensors can be combined to create an intelligent traffic light system. It highlights the role of embedded systems and IoT in addressing real-world traffic problems.

Chapter 11

Acknowledgements

We would like to express our sincere gratitude to our teachers for their guidance and support throughout the project.

Chapter 12

References

- ESP32 Technical Documentation

- IR Sensor Datasheet

- Arduino and ESP32 Programming Guides

- OpenAI

- Internet Resources.