<SmartTrack system for Vehicles>

B.Tech in Computer Science and Engineering **(CSE)**, **Winter** Semester **2024-25**

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Abstract :

The proposed project introduces a novel ESP32-based vehicle diagnostics and tracking system that integrates real-time health monitoring, GPS tracking, and IoT capabilities to address limitations in traditional fleet management solutions. Unlike existing GPS/GSM-based systems that focus solely on location tracking, this system combines onboard diagnostics (OBD-II) with predictive maintenance features, enabling proactive detection of critical issues such as engine overheating (P0118) or low battery voltage (P0562). The system utilizes an ESP32 microcontroller for efficient data processing and communication, along with sensors like DS18B20 for temperature monitoring and a potentiometer to simulate battery voltage. Diagnostic Trouble Codes (DTCs) are dynamically generated and displayed on a 16×2 LCD screen alongside real-time metrics such as RPM, speed, and voltage. Alerts are delivered locally through LEDs and buzzers, and remotely via SMS using a GSM module.

Scalability is achieved through IoT integration, allowing fleet managers to monitor multiple vehicles via cloud platforms for predictive analytics and operational optimization. This unified approach enhances fleet safety, reduces downtime, and minimizes maintenance costs. By merging diagnostics, tracking, and IoT features into a cost-effective solution, the project addresses modern challenges in automotive systems while paving the way for future enhancements like AI-driven analytics and advanced sensor integration.

Problem Statement & Analysis

Problem Statement :

Traditional vehicle tracking systems focus mainly on monitoring the location of the vehicle using GPS and GSM modules but they fail to incorporate real-time vehicle health diagnostics.Due to lack of suitable system for vehicle diagnostics, there occur many undetected mechanical failures, reactive repairs and increase in operational costs.

Fleet operators often face challenges such as unexpected breakdowns, inefficiency in route planning, and safety risks due to engine or battery issues that were left unaddressed.

The proposed project aims to integrate GPS tracking with On-Board Diagnostics(OBD-II) into a unified IoT-based system.In this project,we leverage ESP32 microcontrollers, TinyGPSPlus libraries for GPS parsing, and GSM modules for communication,the system will provide real-time location tracking alongside monitoring key vehicle parameters such as engine RPM,coolant temperature and diagnostic trouble codes(DTC's). Predictive maintenance algorithms will analyse this data to forecast potential failures,which helps in reducing the downtime and repair costs.In a situation with critical issues, alerts will be sent via SMS or displayed on an IOT dashboard.

This solution addresses the gaps in existing systems by combining location tracking with health diagnostics, this enables proactive maintenance and improves fleet safety.It also optimizes operational efficiency.

Problem Analysis : Integrated vehicle diagnostics and GPS Tracking system.
The transportation industry faces significant challenges with the fleet management due to the disconnected nature of the existing fleet monitoring systems.Present systems and solutions mainly operate in isolated domains, ie; GPS tracking focuses solely on location data,while OBD-II diagnostics remain confined to maintenance areas rather than a real time monitoring environment. This isolated approach creates gaps in fleet operational awareness.
Statistical analysis reveals that 60% of fleet breakdowns occur due to an undiagnosed engine and failures in components that could have been detected through a proactive OBD-II parameter monitoring system.These undetected mechanical issues lead to problems; unexpected vehicle downtime increases by 45%,maintenance costs escalate by 3x when repairs are reactive, and efficiency decreases by 28% due to unplanned route disruptions.
Currently existing GPS tracking systems provide location based insights but they lack the integration with the vehicle’s health metrics.This seperation prevents fleet operators from finding correlation between driving behaviors with vehicle wear patterns which if related, could be helpful in operational decision making.
For example : Imagine a vehicle’s engine temperature is rising above normal levels due to prolonged waiting in traffic.Without a unified system that combines OBD-II diagnostics(such as monitoring coolant temperature) and GPS tracking(which shows that the vehicle is stationary),the fleet manager cannot detect that the overheating is due to idling of vehicle.This lack of insight could lead to engine damage is the issue is not addressed promptly.
By combining OBD-II data with GPS data,the system can generate an alert: “Engine overheating due to prolonged idling at [location].”
This allows proactive action, such as instructing the driver to turn off the engine or move to a cooler area.

Objectives of the project :

- ➢ To monitor key On-Board Diagnostics(OBD-II) parameters,such as engine RPM,coolant temperature,battery voltage, and diagnostic trouble codes(DTCs),in real-time.
- ➢ To track the vehicle’s geographical location using GPS modules and transmit real-time data to fleet managers or owners.
- ➢ To create a centralised dashboard that combines the OBD-II diagnostics and GPS tracking data for fleet monitoring
- ➢ Predictive maintenance by using machine learning algorithms to analyze historical OBD-II data and forecast potential failures.
- ➢ To enable driver alerts which notify drivers of critical health issues via

SMS or visual indicators.

- ➢ To optimize costs through better route planning, and predictive maintenance schedules.
- ➢ To design a system that can be scaled across multiple vehicles with minimal hardware modifications.

Outcomes of the project :

- ➢ Early detection of mechanical issues such as overheating or battery degradation.This helps in preventing unexpected breakdowns and reduces maintenance costs.
- ➢ Live updates on vehicle location which enables route optimisation, prevents any thefts and improves operational efficiency.
- ➢ Visualisation of vehicle location data alongside engine health-metrics,which allows better decision making and operational control.
- ➢ Predictive maintenance helps reduce downtime and extends vehicle lifespan while lowering repair costs.
- ➢ Driver alerts enhance safety by ensuring immediate corrective action during emergency situations.
- ➢ Cost optimization minimizes unnecessary expenses related to fuel usage and reactive repairs.
- ➢ Efficient management of large fleets without any additional investment.

Existing System

Paper on existing system : GPS_and_GSM_Based_Vehicle_Tracking_System.pdf

1. Introduction :

Vehicle Tracking systems are mainly used for fleet management, logistics and personal vehicle security.The existing GPS and GSM based vehicle tracking system is a practical solution to monitor the location of vehicles in real time using the available technologies.This system combines a GPS module, a GSM modem, and Arduino UNO to provide efficient tracking of the vehicle. The GPS in the system is used to retrieve the geographical coordinates of the vehicle(latitude and longitude).The GSM in the system is used to transmit the data via SMS to the user or a centralised database.The integration of these technologies ensures that the users can monitor their vehicles anytime,anywhere and under any kind of weather conditions.

The system operates by embedding the hardware components inside the vehicle securely.When a user sends a request via SMS, the GSM module communicates with the Arduino to retrieve the location of the vehicle from the GPS module.This information is then sent back to the user as an SMS containing the geographical coordinates.Additionally the data retrieved is displayed on a LCD screen that is installed in the vehicle or is visualised on google maps through a smartphone.

2. Objective of Existing Systems

- Real time tracking and instant updates on the vehicle location and movements using GPS
- Tracking driving habits like speeding, harsh braking and excessive idling
- Define virtual boundaries on maps and receive notifications when vehicles enter or exit these zones.
- Plan efficient routes based on traffic conditions and other factors such as terrains etc..
- Enable recovery of stolen vehicles by tracking their precise location.
- Review past movements and location history to identify tends

3. Illustration

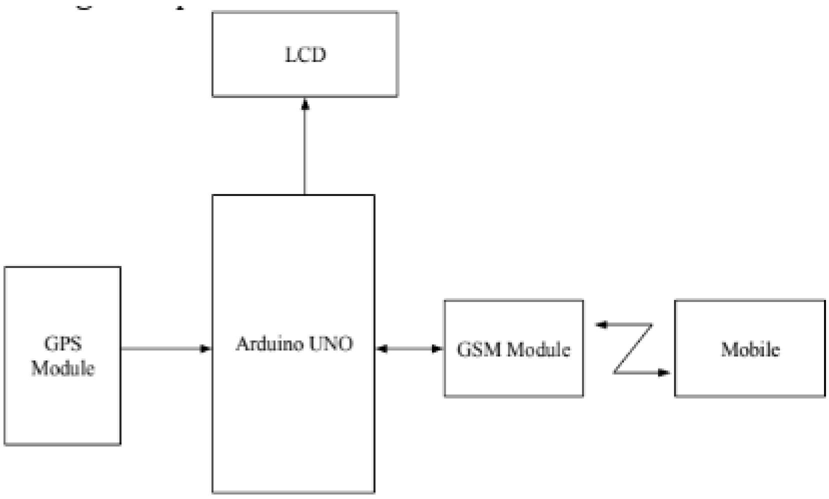


Fig1: Block Diagram of GPS and GSM Based Vehicle Tracking System

The block diagram of the existing GPS and GSM based vehicle tracking system illustrates the core components. In the center is the Arduino UNO microcontroller that serves as the control unit.It interfaces both the GPS receiver and GSM modem.The GPS module retrieves location data in NMEA format which includes the latitude and longitude and other parameters.This data is processed by the Arduino and is displayed on an 16x2 LCD screen for monitoring.
Simultaneously, the GSM modem transmits location data through SMS to the user’s mobile phone on request.The user sends a predefined command to the GSM module to which it triggers the Arduino to fetch the coordinated from the GPS module.If no GPS signal is available then default values(latitude 00.00 and longitude 00.00) will be sent instead.

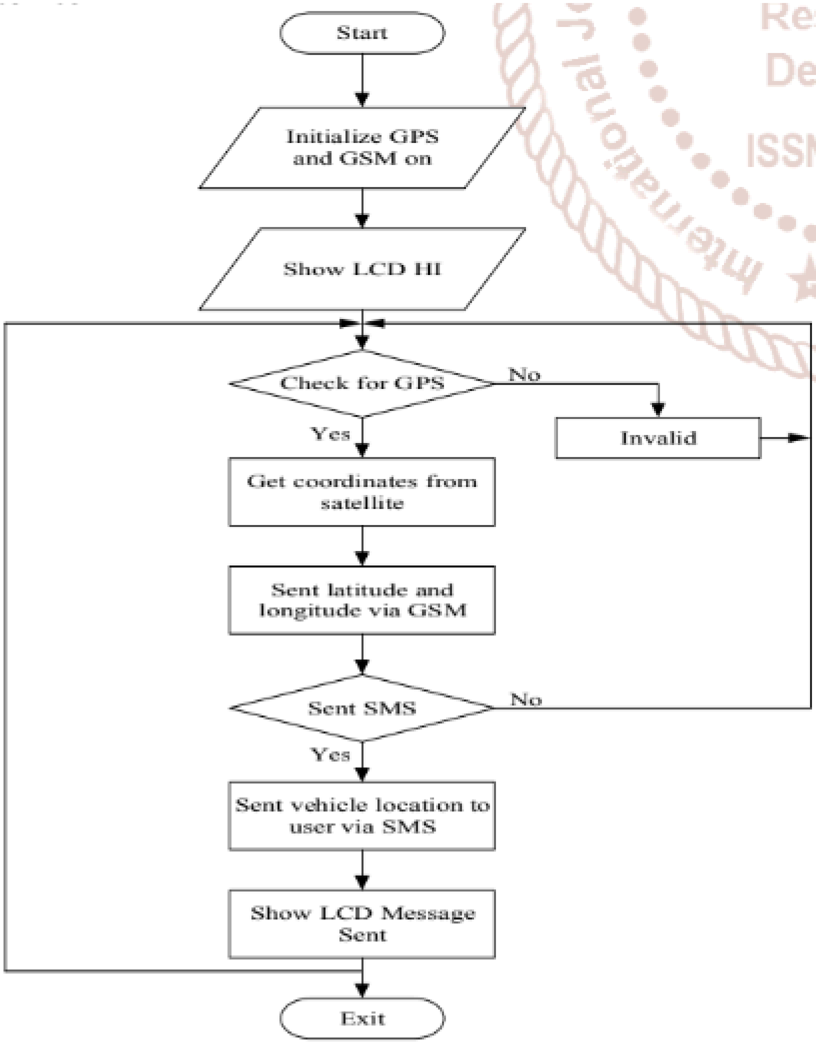


Fig 2: Flowchart of Vehicle Tracking System

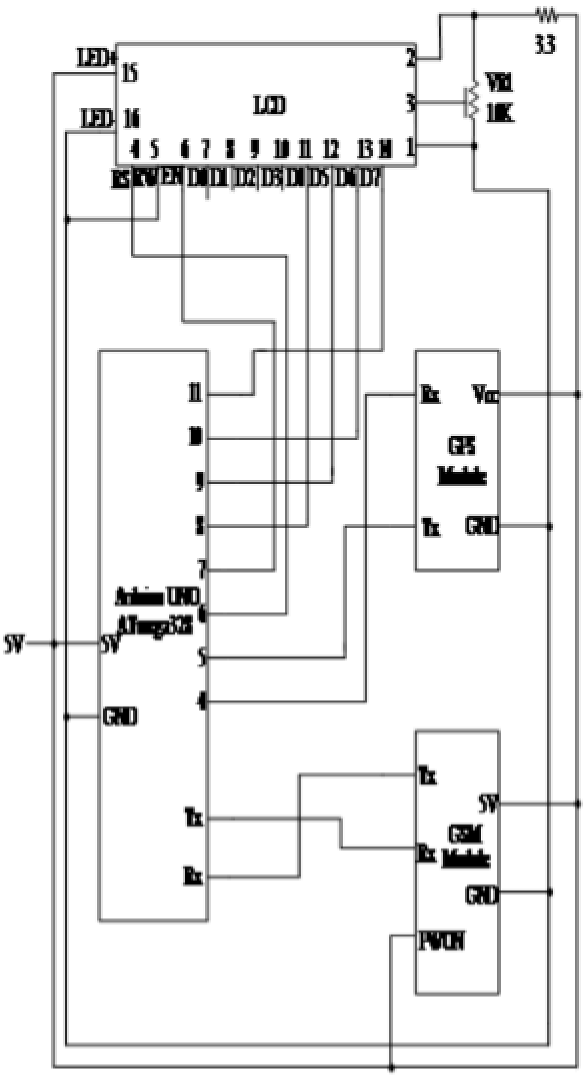


FIG 3 : Overall circuit diagram of the system

4. Issues & Constraints

While GPS and GSM based vehicle tracking systems offer significant advantages such as theft prevention and real-time monitoring, they face critical issues and concerns related to privacy,cost and technical limitations such as:

- ➢ Lack of vehicle health monitoring.The existing system focuses only on GPS-based location tracking and does not monitor critical vehicle health parameters, such as engine temperature and battery voltage.
- ➢ The existing system provides no insights into vehicle wear and tear, leading to reactive maintenance after failures occur.
- ➢ The existing system lacks machine learning or analytics capabilities to forecast potential issues.
- ➢ Alerts in the existing system are limited to SMS-based transmission of location data without actionable insights.
- ➢ GPS data and vehicle diagnostics are not integrated, preventing fleet managers from correlating location with driving patterns or

mechanical stress.

- The existing system provides no insights into vehicle wear and tear leading to reactive maintenance after failures occur.

5. Gap Analysis

The existing vehicle tracking system using GPS and GSM and the proposed system share foundational concepts in vehicle diagnostics and tracking but they differ significantly in scope,implementation and functionality.

1.The existing system uses Arduino UNO as the microcontroller that is interfaces with GPS(GY-NEO6MV2) and GSM(SIM900A) modules. The system also includes an optional 16x2 LCD for displaying the coordinates and status messages locally. Meanwhile the proposed system uses ESP32 which is more advanced than arduino UNO and it also offers built-in WiFi/Bluetooth capabilities.

2.Proposed system detects engine overheating (P0118) and low battery voltage (P0562) before breakdowns occur, unlike existing trackers that only report location.

3.Cost and Scalability:

- 50% cheaper (ESP32 replaces Arduino + multiple modules).
- Scalable for predictive analytics, fleet management, and OBD-II integration

Proposed System

1. Introduction

The proposed ESP-32 based vehicle diagnostics and tracking system is an advanced solution that integrates real-time diagnostics,tracking and alert mechanisms.

Traditional systems rely solely on GPS and GSM for the tracking of vehicle location whereas the proposed system combines onboard diagnostics with location monitoring.This makes SmartTrack a comprehensive tool for vehicle management.The system uses an ESP32 microcontroller which offers superior processing power,built-in WiFi/Bluetooth capabilities, and cost efficiency compared to Arduino-based systems.

The proposed system incorporates a DS18B20 temperature sensor for monitoring engine temperature and a potentiometer for simulating battery voltage. It generates Diagnostic Trouble Codes (DTCs) like overheating (P0118) or low voltage (P0562) to provide actionable insights into vehicle health. A 16x2 LCD display shows real-time diagnostics such as RPM, coolant temperature, battery voltage, and speed, along with active DTC warnings. Alerts are delivered via LEDs, buzzers, and optional GSM-based SMS notifications.

The system’s scalability allows integration with IoT platforms for cloud-based monitoring. It also supports Wokwi simulation for cost-effective testing before deployment. By combining real-time diagnostics with preventive maintenance features, this system addresses both security (tracking) and operational efficiency (health monitoring), making it ideal for modern vehicles and fleet management applications.

2. Conceptual Architecture

This architecture integrates real-time vehicle diagnostics, tracking, and IoT capabilities using the ESP32 microcontroller. It addresses limitations of existing systems by combining onboard diagnostics (OBD-II) with predictive maintenance and multi-channel alerts.

1. Hardware Layer

Components:

- ESP32 Microcontroller: Dual-core processing for simultaneous data collection, analysis, and communication.
- OBD-II Interface: Direct CAN bus communication via ELM327 chip to read ECU data (RPM, coolant temp, DTCs).
- Sensors:
  - DS18B20: Monitors engine temperature.
  - Potentiometer: Simulates battery voltage for testing.
  - GPS Module: Provides real-time location tracking.
- Alert System:
  - LCD Display (16x2): Shows diagnostics (e.g., RPM: 2500, Batt: 12.6V) and shortened DTC alerts (e.g., P0118: Overheat).
  - LED + Buzzer: Local alerts for critical conditions.

2. Communication Layer

- GSM Module: Sends SMS alerts (e.g., "Engine Overheating: 105°C") to users (search result 1, 4).
- WiFi/Bluetooth: Transmits data to:
  - Cloud Platform (AWS IoT/ThingSpeak): Stores historical data for predictive analytics.
- CAN Bus: Direct ECU communication for OBD-II diagnostics

3. Data Processing Layer

- DTC Management:
  - Detects faults (e.g., P0118 for overheating) using thresholds.
  - Auto-clears DTCs when parameters normalize (e.g., temp < 40°C).

4. User Interface Layer

- LCD Dashboard: Displays real-time diagnostics (RPM, voltage, speed) and active DTCs.

- Mobile App: Shows GPS location, engine health, and cloud analytics.

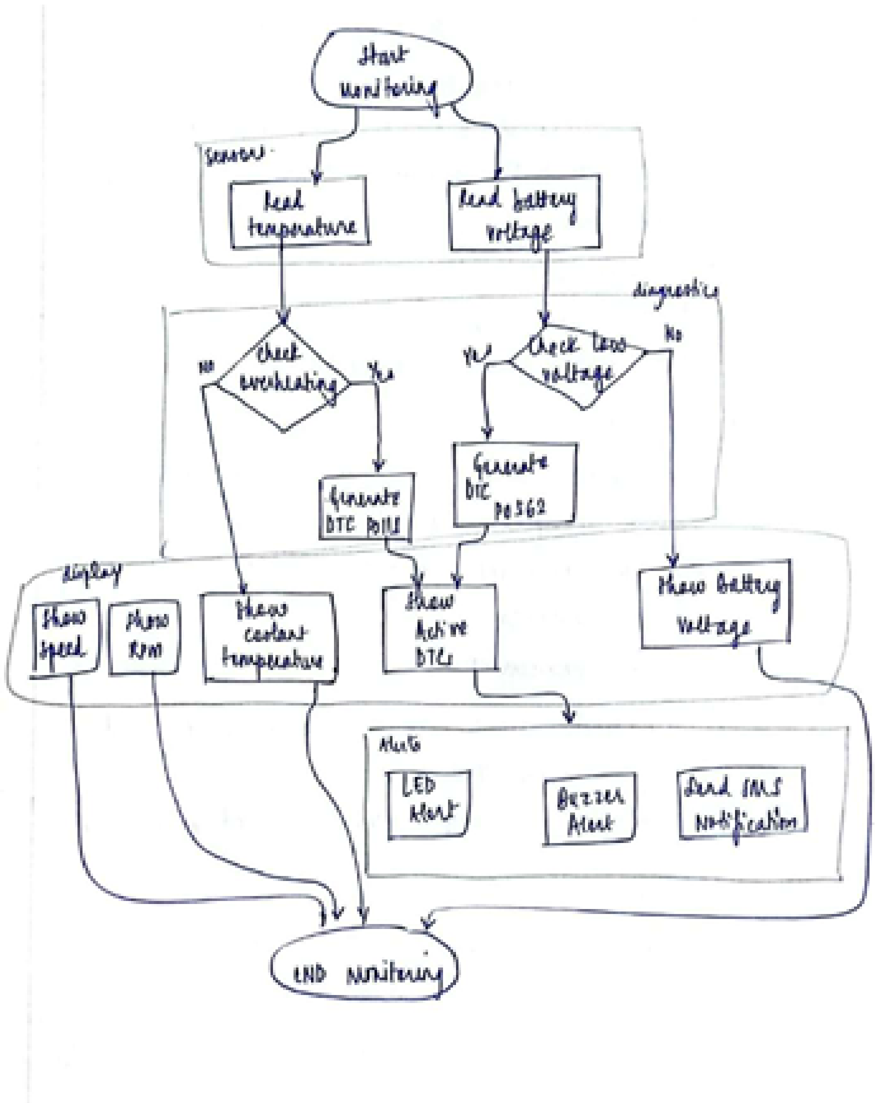
5. Security & Power Management

- Secure Protocols: MQTT with TLS for encrypted cloud communication (search result 8).
- Power Optimization:
    - Sleep modes to prevent battery drain.

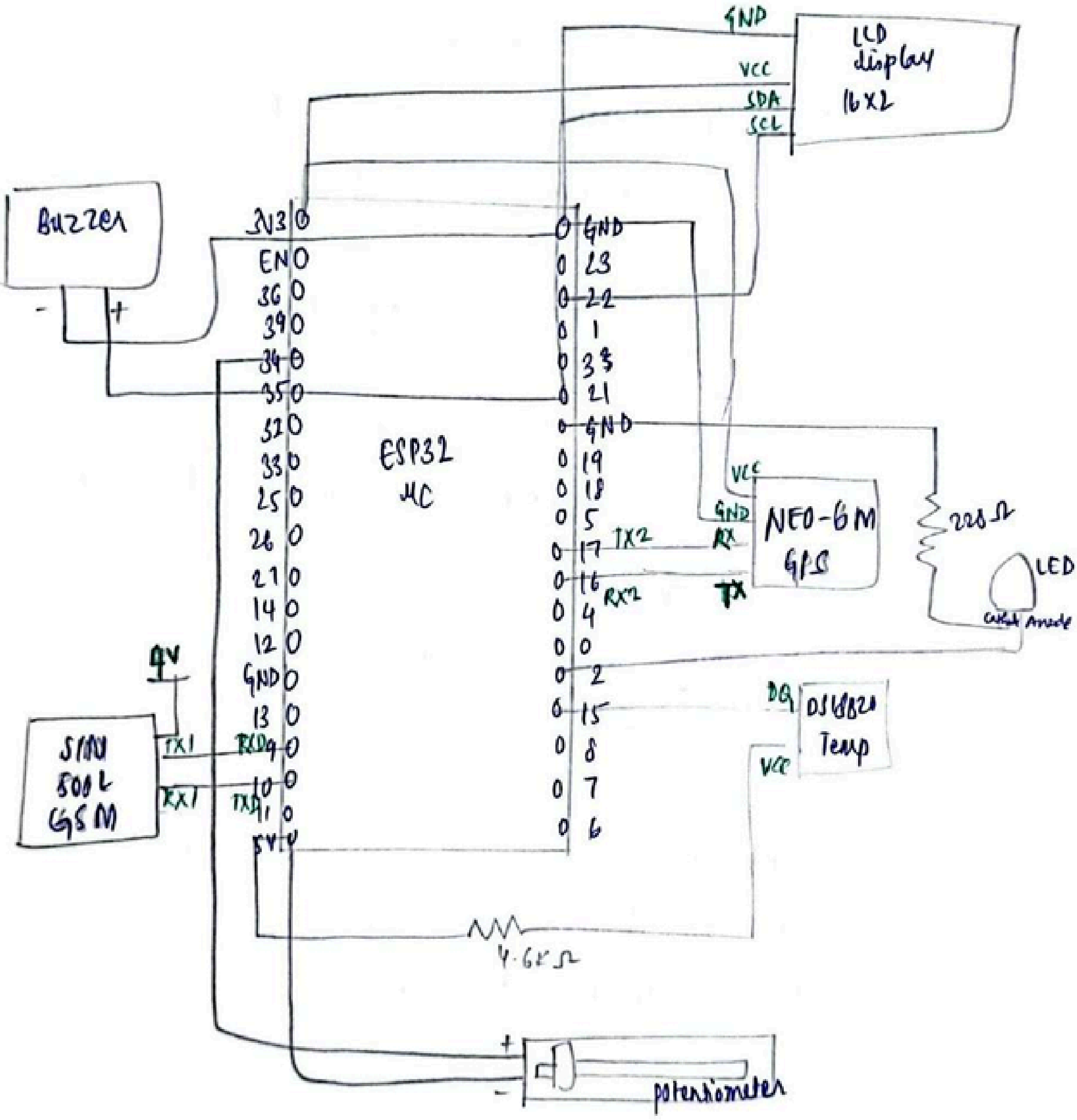
Key Innovations

1. Hybrid Alerts: Combines local (LED/buzzer) and remote (SMS/cloud) notifications.
2. Modular Design: Add/remove sensors (e.g., accelerometer for theft detection) without hardware changes.
3. Cost Efficiency: ESP32 replaces Arduino + multiple modules

<u>BLOCK DIAGRAM :</u>



<u>HARDWARE CONNECTIONS:</u>



TESTCASES :

Test Case	Component	Input Condition	Expected Behavior
TC1	DS18B20 Sensor	Temp = [20°C–40°C]	Normal operation; no DTC; LED OFF
TC2	DS18B20 Sensor	Temp >40°C	Overheating; DTC P0118; LED ON; buzzer sounds
TC3	Potentiometer	Voltage = [11.8V–13.0V]	Normal operation; no DTC; LED OFF
TC4	Potentiometer	Voltage <11.8V	Low voltage; DTC P0562; LED ON; buzzer sounds
TC5	GPS Module	Valid GPS data	Serial monitor shows coordinates; SMS includes location
TC6	GPS Module	Invalid GPS data	Serial monitor shows "INVALID"; SMS warns of GPS signal loss
TC7	GSM Module	Temp >40°C	Sends SMS alert for overheating
TC8	GSM Module	Voltage <11.8V	Sends SMS alert for low battery voltage
TC9	LCD Display	Normal diagnostics	Displays RPM, temp, voltage, speed
TC10	LCD Display	Active DTCs	Alternates between diagnostics and DTC codes
TC11	LED	Active DTCs	LED turns ON
TC12	LED	No active DTCs	LED turns OFF
TC13	Buzzer	Critical conditions	Buzzer sounds during alerts

Testing Procedure

1. Connect all components as per the pin configuration provided earlier.
2. Upload the code to your ESP32 using Arduino IDE.

3. Perform each test case by simulating inputs (e.g., adjusting potentiometer or modifying DS18B20 readings).

4. Observe outputs on the LCD, serial monitor, GSM module (SMS), LED, and buzzer.

Future Enhancements
- Add CAN bus integration for EVs.
- Implement driver scoring using accelerometer data.

Conclusion

The proposed ESP32-based vehicle diagnostics and tracking system addresses key limitations of existing GPS/GSM-based tracking systems by integrating real-time diagnostics, predictive maintenance, and IoT capabilities. Traditional systems primarily focus on location tracking using GPS modules and GSM for SMS alerts, but they lack the ability to monitor vehicle health, detect critical conditions, or provide actionable insights for preventive maintenance. This project bridges these gaps by combining onboard diagnostics with tracking functionality, making it a comprehensive solution for modern vehicles.

The system leverages the advanced capabilities of the ESP32 microcontroller, which offers built-in WiFi/Bluetooth for IoT integration, faster processing, and lower power consumption compared to Arduino-based systems. It incorporates a DS18B20 temperature sensor for monitoring engine coolant temperature and a potentiometer for simulating battery voltage. Diagnostic Trouble Codes (DTCs), such as overheating (P0118) or low battery voltage (P0562), are generated dynamically and displayed on a 16x2 LCD screen alongside real-time diagnostics like RPM, speed, and voltage. Alerts are delivered locally via LEDs and buzzers and remotely via SMS notifications using the GSM module.

The proposed system also introduces scalability by enabling cloud connectivity for remote monitoring and predictive analytics. Fleet managers can leverage IoT dashboards to monitor multiple vehicles simultaneously, analyze historical data, and optimize operations. Additional features like geofencing, accident detection, and driver behavior analysis can further enhance security and efficiency.

By merging diagnostics, tracking, and IoT into a unified solution, this system outperforms existing solutions in terms of functionality, cost-effectiveness, and scalability. It is ideal for applications such as fleet management, theft prevention, and proactive vehicle maintenance. The project demonstrates how emerging technologies can be effectively utilized to address modern challenges in automotive systems while paving the way for future enhancements like AI-driven analytics and advanced sensor integration.