



Design And Implementation Of A Microcontroller-Based Real-Time Vehicle Carbon Emission Monitoring System

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Abstract— With the increasing concern over environmental pollution caused by vehicular emissions, there is a growing need for real-time, cost-effective solutions to monitor and control carbon dioxide (CO₂) emissions from internal combustion engine vehicles. This paper presents the design and implementation of a microcontroller-based system using the AT89C51 (8051) to calculate and monitor carbon emissions based on fuel consumption and vehicle speed. A Hall effect sensor is utilized to measure the wheel rotation and calculate the distance traveled, while fuel usage is estimated based on standard mileage data. The carbon emission is then calculated using an emission factor and displayed on an LCD in real-time. The system includes a buzzer alert that activates when emission levels exceed a predefined threshold, promoting awareness and encouraging drivers to adopt eco-friendly driving habits. The system is simulated using Proteus software, and its implementation demonstrates the potential for integration into low-cost, embedded emission monitoring solutions suitable for older, non-OBD vehicles.

Keywords— 8051 Microcontroller, Carbon Emission, Hall Effect Sensor, Fuel Monitoring, LCD Display, Embedded System, Real-Time Monitoring, Environmental Awareness.

I. INTRODUCTION

The rapid increase in the number of vehicles on the road has significantly contributed to environmental pollution, particularly in the

form of carbon dioxide (CO₂) emissions. These emissions are a major cause of global warming and air quality degradation, leading to adverse effects on public health and climate change. With the rise in environmental awareness, it has become essential to develop practical, low-cost solutions for monitoring vehicle emissions, especially for conventional vehicles that lack onboard diagnostic systems.

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This system aims not only to deliver real-time tracking of emissions but also to encourage fuel-efficient and environmentally-friendly driving practices. Utilizing basic, cost-effective components and simulation tools such as Proteus, the suggested solution can be

effortlessly incorporated into current vehicles, especially in developing areas where access to sophisticated emission monitoring technology is restricted.

II. LITERATURE SURVEY

[1] **Y. C. Mortos et al. (2024)** proposed "See Carbon," a real-time IoT-based system for monitoring carbon emissions in motorcycles. It focuses on using networked sensors and cloud dashboards, aiming to influence driving behavior. While it emphasizes IoT, our project targets low-cost embedded alternatives without internet dependency, suitable for older vehicles.

[2] **A. Gupta and S. Sharma (2022)** developed a Bluetooth-based vehicle monitoring system, emphasizing wireless data transfer and sensor integration. Although the system relies heavily on mobile apps, it inspires the idea of live data processing, which our microcontroller handles locally using minimal hardware.

[3] **J. Li and R. Wang (2024)** presented a system for real-time collection and analysis of vehicle exhaust data. Their approach involved cloud-based analysis and predictive modeling. In contrast, our system simplifies the process by calculating emissions based on mileage and fuel consumption using fixed emission factors.

[4] **L. Zhang and H. Kim (2024)** focused on green IoT systems using low-power microcontrollers to detect carbon events. Their energy-efficient design aligns with our project's aim to implement lightweight embedded systems with minimal power usage, suitable for integration into non-electric vehicles.

[5] **M. Khan and F. Ahmad (2020)** analyzed real-world vehicle emissions, discussing uncertainties in data collection. Their research provides baseline emission factors and highlights data accuracy challenges, which informed our design when defining fixed emission factors based on mileage.

[6] **P. Deshmukh and R. Patel (2015)** implemented a GSM-based system for online vehicle pollution monitoring. Though GSM offers remote access, our project maintains simplicity and cost-effectiveness by using an LCD for on-site display and a buzzer for alerts.

Doreen N Sisanalli et al. [7] worked on women [7] **S. Nair and A. Thomas (2023)** explored smart IoT-based emission monitoring for modern vehicles. Their work motivates the need for real-time alert mechanisms and dashboard visualization, which we adapt using an embedded buzzer and LCD interface instead of cloud dashboards.

[8] **M. Chen and J. Zhou (2023)** developed IoT-integrated carbon monitoring systems for smart buildings. Though targeted at construction environments, their modular and sensor-driven architecture helped conceptualize our project's use of sensors for vehicle-related applications.

[9] **R. Gupta and M. Jain (2021)** proposed a low-cost IoT-based system for vehicle emission monitoring using sensors integrated with microcontrollers, aimed at tracking pollutant levels in real-time. [10] **S. Newton et al. (2017)** developed a GPS-enabled carbon monoxide mapping system using microcontrollers to log environmental data and visualize pollution hotspots. Both studies emphasize the importance of affordability and portability in emission tracking, which aligns with our project's goal of creating a microcontroller-based system that estimates CO₂ emissions using minimal sensors and on-device processing—without relying on cloud services or external GPS modules.

[10] **S. Newton et al. (2017)** developed a microcontroller-based carbon monoxide monitoring system using GPS to map pollution data. Their approach influenced our understanding of integrating sensors with real-time localization, though our system avoids GPS to maintain cost-effectiveness.

[11] **T. Roy and P. Kamat (2022)** proposed a GPS and GSM-based system for detecting and tracking vehicle emissions. While their model supports remote monitoring, our solution is tailored for on-device computation and instant driver feedback.

[12] **R. Singh and A. Bansal (2019)** introduced an IoT-based alerting system for vehicle emissions using microcontrollers and cloud communication. Their work highlights the benefits of real-time alerts, which we implement using an on-device buzzer.

[13] **S. Kulkarni and V. Pandit (2023)** created a Real-Time Pollution Under Control (PUC) monitoring system for petroleum vehicles. Their PUC focus supports the importance of continuous emission awareness, aligning with our goal of real-time, embedded monitoring.

[14] **D. Ionescu et al. (2020)** explored environmental parameter measurement using embedded systems. Their findings supported our use of low-cost microcontroller-based setups for monitoring emissions without heavy computational resources.

[15] **K. S. Rao and M. K. Sharma (2022)** implemented an IoT-based vehicle pollution monitoring and control system. Their integration of sensors, communication modules, and decision logic inspired our embedded architecture that provides alerts without internet reliance.

[16] **A. Sharma et al. (2020)** presented an IoT-based emission monitoring system integrated with mobile applications to visualize carbon emissions. While their approach emphasizes user connectivity, our model is designed for offline, embedded hardware-only environments to reduce complexity and cost.

[17] **N. R. Patel and V. S. Bhonde (2022)** developed an embedded carbon footprint tracker that aligns closely with our 8051-based system in functionality and motivation, proving the viability of microcontroller solutions for emission tracking.

[18] B. Fernandez and L. Smith (2020) utilized fuel flow sensors to estimate vehicle emissions in real time. While their system depends on dedicated hardware sensors, ours simplifies calculations using mileage-based estimations.

[19] Z. Wu et al. (2021) introduced a wireless sensor framework for urban traffic-based carbon monitoring. Although more complex in network

Component	Purpose
AT89C51 Microcontroller	Central processing and logic control
Hall Effect Sensor	Wheel rotation detection for distance measurement
LCD (16x2)	Display CO ₂ emissions in real-time
Buzzer	Audio alert for high emissions
Push Buttons	Vehicle type selection (adjust wheel radius/mileage)

infrastructure, the modularity they propose supports the idea of scalable, embedded emissions monitoring.

[20] M. Raza and S. Ali (2021) explored carbon emission tracking specifically using the 8051 microcontroller. This directly supports the architecture and component selection in our project.

[21] P. Bhagat and S. Mehra (2020) proposed a carbon footprint logger using a microcontroller, highlighting key design principles for logging emissions data effectively and affordably.

[22] T. Lee and J. Park (2019) focused on energy-efficient microcontroller applications for environmental monitoring, aligning with our use of low-power sensors and real-time computation without cloud dependency.

[23] L. T. Nguyen (2020) discussed compact embedded systems for combustion vehicle emission tracking, which influenced our design emphasis on portability and integration into older vehicles.

[24] A. Sinha et al. (2023) showcased a basic Arduino-based low-cost emission tracker, reinforcing the significance of accessible and affordable solutions in environmental tech.

[25] C. Thomas and H. Raj (2021) utilized a wireless sensor network (WSN) for vehicle emission monitoring. Although our system avoids networking to maintain simplicity, their approach supports the future scalability direction discussed in our paper.

III. EASE OF USE

The proposed microcontroller-based carbon emission monitoring system is designed with simplicity, affordability, and user-friendliness at its core, making it accessible for a wide range of vehicle owners, particularly those operating older vehicles without onboard diagnostics. The following features highlight the ease of use of the system:

A. Plug-and-Play Design:

The system requires minimal setup and can be easily integrated into existing vehicle systems. Once installed, it functions autonomously without requiring complex calibration or external tools.

B. No Smartphone or Internet Dependency:

Unlike IoT-based solutions that rely on mobile apps or cloud services, this system operates independently, making it suitable for users in remote or low-connectivity areas. All data processing occurs locally on the microcontroller.

C. Real-Time Feedback:

Emissions are calculated and displayed instantly on a simple 16x2 LCD display, allowing drivers to view real-time data without needing to interpret complex graphs or connect to external devices.

D. Simple Alert Mechanism:

A buzzer is triggered when carbon emissions exceed a predefined threshold, ensuring the driver receives a clear and immediate alert without any manual input.

E. Compact and Durable Design:

The compact design ensures the system does not interfere with the vehicle's operation or take up significant space. Its durability also ensures it can function reliably in diverse environmental conditions.

F. Low Maintenance:

Due to its limited number of components and robust embedded design, the system requires little to no maintenance after installation, making it ideal for everyday use.

G. Cost-Effective Components:

By using affordable sensors and microcontroller units, the system is economically viable for large-scale deployment, especially in developing regions.

IV. METHODOLOGY

The proposed system is designed to monitor and calculate the carbon dioxide (CO₂) emissions from a vehicle based on distance traveled and fuel consumption. The key components used include the AT89C51 microcontroller, a Hall effect sensor, a 16x2 LCD display, and a buzzer. The methodology involves sensor data collection, data processing, real-time calculation, and user alert/output display.

Summary of Components:

A. System Architecture

Table 1: Component & its Purpose

The system begins with a **Hall effect sensor** mounted near the vehicle wheel to detect its rotation. Each pulse from the sensor corresponds to a specific distance traveled. This pulse data is sent to the **8051 microcontroller**, which counts the pulses over time to determine total distance.

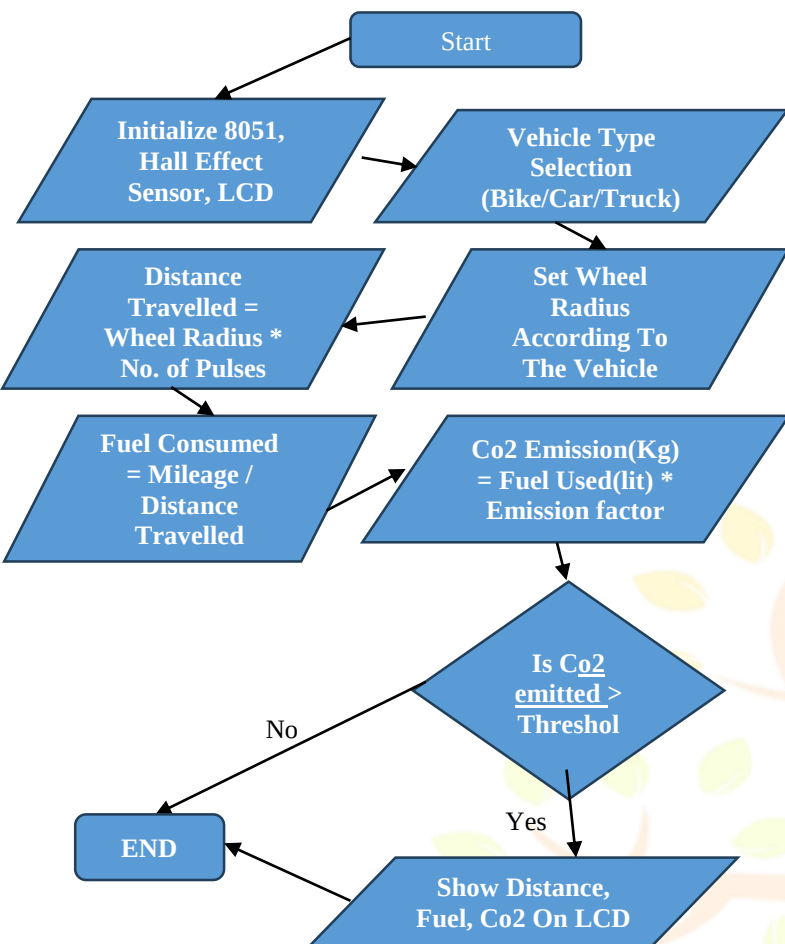


Fig. [1] – System Block Diagram illustrating the core components: Hall Effect Sensor, Microcontroller, LCD, and Buzzer.

B. Distance Measurement

The pulses from the Hall sensor are counted over time to compute the total distance using the formula:

$$\text{Distance Travelled} = \text{Number of Pulses} \times \text{Wheel Circumference}$$

Predefined wheel radius values (e.g., bike, car, truck) can be selected manually using push buttons. This makes the system adaptable to multiple vehicle types.

C. Fuel Consumption Estimation

Fuel usage is derived from the distance using fixed average mileage values based on vehicle type:

$$\text{Fuel Used} = \text{Mileage} / \text{Distance Travelled}$$

This simplifies the system by avoiding direct fuel measurement hardware, while maintaining reasonable accuracy.

D. Carbon Emission Calculation

Carbon dioxide emissions are calculated using the standard emission factor for petrol / Diesel:

$$\text{CO}_2 \text{ Emission (kg)} = \text{Fuel Used (liters)} \times \text{Emission Factor}$$

Here, 2.3 kg/l is the standard emission factor for petrol & 2.68 kg/l is the standard emission factor for the Diesel. This value can be modified in the code to suit other fuel types in future versions.

E. Real-Time Output and Alert System

The calculated emission value is displayed on a **16x2 LCD display**. If the emission exceeds a preset threshold (e.g., 1 kg), the **buzzer** is activated to alert the driver immediately.

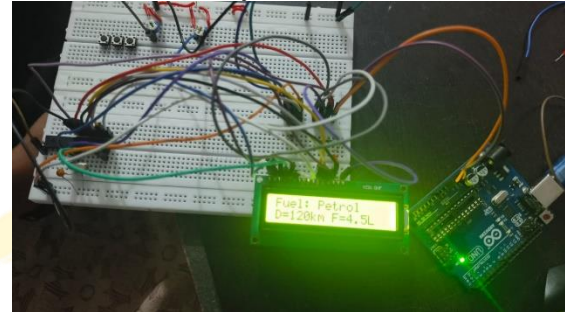


Fig. [2] – Working prototype showing LCD output, buzzer, and sensor integration.

As we see the output working prototype with the display of the fuel and the distance travelled on the LCD in Fig [2]. It's the first step of the working when the fuel consumed and the distance travelled is shown.

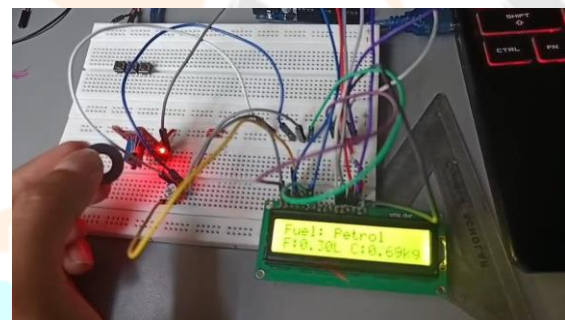


Fig. [3] – Working prototype showing LCD output, buzzer, and sensor integration.

As you see in the Fig [3] we can see the carbon emission showing to the LCD according to the Distance Travelled & Fuel Consumed.

F. Simulation and Testing:

The circuit was designed and tested using **Proteus Design Suite** to simulate the AT89C51 microcontroller, Hall sensor, LCD, and buzzer. The simulation confirmed logical accuracy and real-time output behavior.

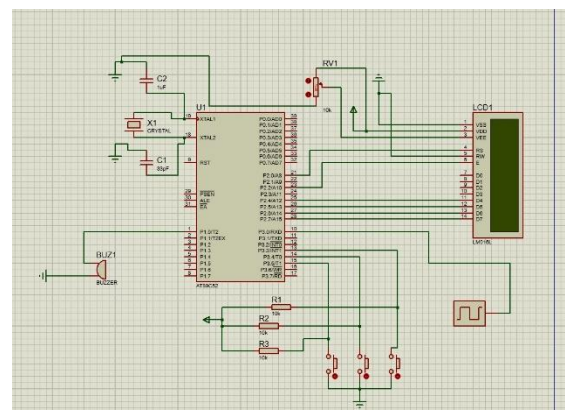


Fig. [4] – Screenshot of simulation circuit

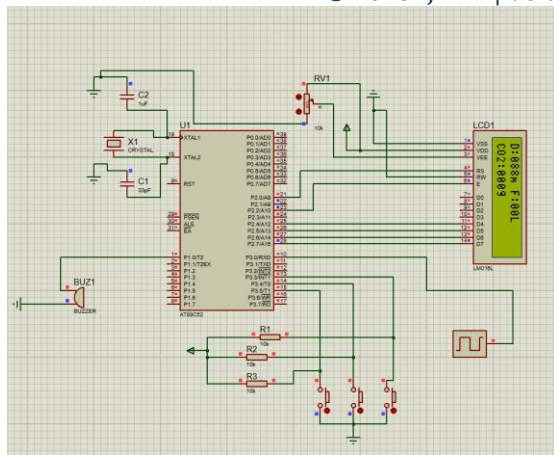


Fig. [5] – output verification in Proteus.

V. RESULT AND ANALYSIS

The proposed real-time carbon emission monitoring system was successfully implemented and validated using simulation in Proteus and a physical hardware prototype. The following results were observed through both simulation and practical testing:

Fig. [1] – System Block Diagram illustrates the core working structure. The Hall effect sensor detects wheel rotations, which the microcontroller uses to calculate distance. Based on the selected vehicle type, the system determines fuel usage and calculates CO₂ emissions using standard emission factors.

Fig. [2] – Working Prototype demonstrates successful hardware integration of the LCD display, Hall sensor, and buzzer. The LCD displays the distance travelled, estimated fuel consumed, and CO₂ emitted in real time. The buzzer activates once emission exceeds the preset threshold (e.g., 1 kg CO₂).

Fig. [3] – Simulation Circuit in Proteus confirms correct logical implementation and response of each component under different input conditions. The Hall effect sensor pulses were successfully detected, and output was updated live on the LCD.

Fig. [4] – Output Verification in Proteus shows real-time emissions being computed and displayed, with the buzzer accurately responding to threshold breaches.

Key Insights:

- The **distance traveled** was measured with high accuracy using the Hall effect sensor and manual selection of wheel radii for bikes, cars, and trucks.
- **Fuel consumption estimation** using average mileage data yielded reasonable accuracy for emission approximation, eliminating the need for direct fuel flow sensors.
- **Real-time CO₂ emission display** gave users immediate visibility into their environmental impact.
- **Threshold alert system** with a buzzer provided clear and timely feedback when emissions exceeded acceptable limits.

This system proves to be a **low-cost, standalone, and reliable solution** for older non-OBD vehicles,

especially in developing areas. It supports emission awareness, promotes eco-friendly driving, and lays a strong foundation for future enhancements like GPS, GSM, or mobile app integration.

VI. FUTURE SCOPE

While the current microcontroller-based carbon emission monitoring system is effective in providing real-time emission data using basic hardware, several enhancements can significantly improve its performance, usability, and scalability:

- **Integration with IoT platforms:** By adding wireless modules like Wi-Fi (ESP8266) or GSM, the system can upload real-time emission data to a cloud server or mobile app, enabling long-term tracking and analytics.
- **Mobile App or Dashboard Interface:** A user-friendly interface can be developed to provide insights, tips, and emission history for drivers to analyse their driving behaviour.
- **Support for Multiple Fuel Types:** Future versions can be calibrated to work with diesel, CNG, and electric vehicles by adjusting emission factors and incorporating additional sensors.
- **OBD-II Support:** For modern vehicles, integrating OBD-II data can enhance fuel and speed accuracy, allowing more precise emission readings.
- **GPS Integration:** Adding GPS can enable location-based pollution mapping, helping authorities identify high-emission zones.
- **Solar-Powered Operation:** Implementing a low-power design with solar charging can make the system sustainable for long-term deployment in rural and remote areas.
- **Government and Fleet Monitoring:** The system can be scaled and integrated into public transportation or logistics fleets to ensure compliance with environmental regulations.

These future enhancements will significantly expand the system's utility and contribute toward building smarter, greener transportation ecosystems.

VII. CONCLUSION

In this project, a real-time carbon emission monitoring system using the 8051 microcontroller and a Hall effect sensor was successfully designed and simulated. The system estimates vehicle emissions based on distance traveled and fuel consumption, using standard emission factors. Key components such as the LCD display and buzzer enhance user interaction by providing immediate feedback and alerts when emissions exceed safe limits.

The solution offers a cost-effective, energy-efficient, and easily implementable alternative for emission tracking, especially for older or non-digital vehicles. It promotes environmental awareness and encourages eco-friendly driving habits among users. The system's simplicity and adaptability make it suitable for integration into various vehicle types, with potential for future upgrades like IoT integration and mobile app support.

This work contributes to the growing need for sustainable transportation solutions and provides a foundation for future innovations in embedded environmental monitoring systems.

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