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Design and Construction of Vehicle Speed Detector Using IR Sensor and ARDUINO Microprocessor

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Abstract

This project focuses on the design and construction of a vehicle speed detection system using infrared (IR) sensors and an Arduino-based microcontroller (Atmega328). The system aims to enhance road safety by monitoring and reporting vehicle speeds on highways, particularly in areas prone to accidents due to over-speeding. With the increasing rate of road traffic accidents caused by reckless driving, especially on highways, this system serves as a preventive measure by alerting drivers when they exceed the designated speed limit. The proposed system utilizes two IR sensors placed at a fixed distance to calculate the speed of a passing vehicle based on the time taken to move between the sensors. The Atmega328 microcontroller processes this data and displays the calculated speed on an LCD screen. A preset button allows users or traffic personnel to set the maximum allowable speed. When the detected speed exceeds this set limit, an audible alarm is triggered to alert the driver or the monitoring authority. This system is particularly beneficial for use by highway traffic enforcement agencies, as it provides real-time feedback and can help in monitoring traffic compliance. The simplicity, affordability, and accuracy of the design make it suitable for deployment in rural and urban highways alike. Overall, the project demonstrates a practical application of embedded systems and sensor technology in promoting safer driving habits and reducing road traffic accidents

Keywords: *Atmega328, highways, traffic, deployment, sensors*

1. Introduction

The Vehicle Speed Detector System is a modern electronic solution designed to monitor and measure the speed of moving vehicles. With increasing concerns over road safety, traffic regulation enforcement, and the need to reduce accidents caused by speeding, this system provides an efficient and reliable method for detecting vehicle speed in real-time. It is particularly useful in both urban and highway settings where constant monitoring is essential to ensure compliance with speed limits.

At the core of the system are sensors, a microcontroller, and display/output components that work together to detect motion, calculate speed, and respond accordingly. Infrared (IR) sensors are used to detect the presence and movement of a vehicle, while a microcontroller processes the signals received from the sensors and calculates the speed based on the time taken to cover a known distance. The calculated speed is then displayed on an LCD and can be compared to a predefined speed limit to trigger alerts or control actions.

This system can be implemented in both prototype testing environments and real-world scenarios. In academic and research settings, it helps demonstrate principles of motion detection, automation, and embedded systems. In practical applications, it serves as a cost-effective tool for improving traffic management and enforcing speed limits. The vehicle speed detector is a step forward in integrating technology with road safety initiatives, offering accuracy, reliability, and scalability.

The growing demand for transportation has made road safety a crucial global concern, particularly with the increase in vehicles and the resulting rise in road accidents. Speeding remains one of the primary causes of these accidents, highlighting the urgent need for advanced speed monitoring and enforcement systems. Various researchers have explored different technological approaches to address this challenge.

Chandorkar *et al.* (2021) proposed an innovative system that integrates connected-vehicle infrastructure with Haar cascade classifiers, a machine learning approach that uses trained data to detect vehicles in images or videosoffering potential for intelligent speed detection applications. Similarly, Sriram *et al.* (2020) introduced an automatic speed warning and penalty collection system that minimizes human involvement by automating the detection of over-speeding and issuing penalties, thereby improving compliance and reducing enforcement costs. Esco *et al.* (2020) investigated the influence of speed warning systems on driver behaviour, finding that such systems led to more frequent speedometer checks, suggesting improved speed awareness. Vishal Pande *et al.* (2015) designed an RFID-based autonomous speed management solution focused on area-specific speed regulation through embedded systems, supporting automated and localized speed monitoring. Monika Jain (2015) developed a system capable of identifying and reporting reckless driving, including over-speeding, with features for real-time data storage and authority notification, enhancing proactive traffic control. Setiyono and Wicaksono (2019) applied video processing with Gaussian Mixture Models and the Euclidean distance formula to non-invasively estimate vehicle speed across multiple lanes by analysing displacement across video frames. Nihanth *et al.* (2021) created an Arduino-based speed detection setup using IR sensors, displaying real-time speed on an LCD and triggering a buzzer when a speed limit is exceededoffering a simple, cost-effective method for immediate driver feedback. Adebisi *et al.* (2023) identified a critical flaw in earlier systems that depended on in-vehicle installations, which could be tampered with or removed by drivers. They underscored the need for external, tamper-resistant solutions to ensure more reliable and secure enforcement.

Building upon insights from these studies, the system proposed in this study utilizes two IR sensors and an Arduino UNO to measure vehicle speed externally, without requiring any components inside the vehicle. This approach mitigates tampering risks by positioning the sensors independently. Additionally, an audible buzzer and a digital LCD display provide instant alerts to drivers who exceed the speed limit, fostering safer driving practices.

2. DESIGN AND METHODOLOGY

This section covers the design considerations, methodology, and component selection for the vehicle speed detector and control system. It outlines the specifications and operational principles of the components used in the system. The block diagram of the vehicle speed detection and control system is presented in Fig 1.

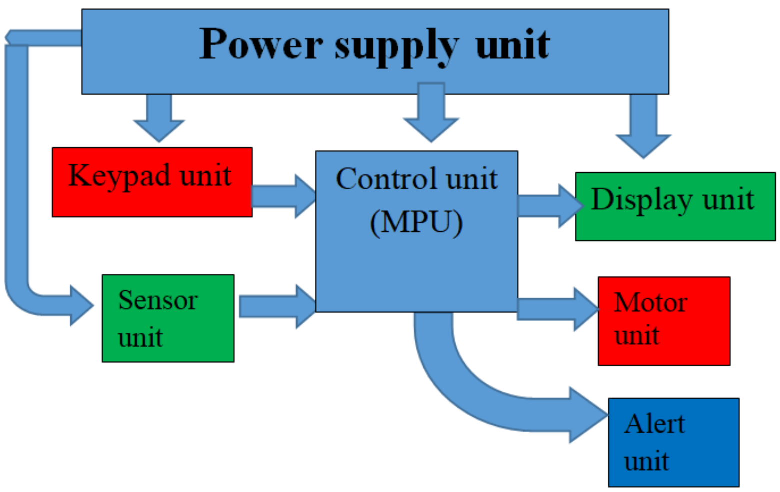

Fig 1: **System block diagram**

It is divided into six major functional units: the Power Supply Unit, the Microcontroller Unit, the IR Sensor Unit, the Display Unit, the Alert/Buzzer Unit, and the Keypad Unit. Each of these units has a specific role and interacts with the others to ensure the overall functionality of the system.

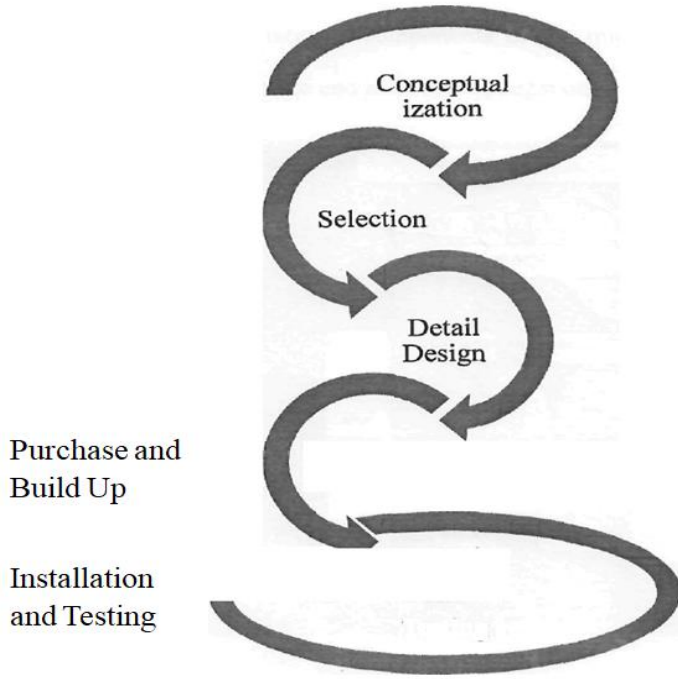

Fig. 2 Methodology

2.1 Conceptualization Stage

In response to increasing demand for effective speed control systems due to traffic regulations and safety considerations, various speed automation system models were reviewed. The final design approach was selected after careful analysis of different concepts, weighing their advantages and disadvantages.

2.2 Selection Stage

At this stage, different hardware and software options were compared and evaluated to identify the most suitable choices for the system. The comparisons involved occupancy sensor types, microcontroller options, and programming languages. Among the sensors considered were infrared sensors, Hall Effect sensors, and ultrasonic sensors. The Passive Infrared (PIR) sensor was ultimately selected due to its reliability, affordability, and broad detection range.

Between the two primary microcontrollers reviewed, namely the PIC and the ATmega328p, the ATmega328p was chosen. Its selection was based on its compatibility, wide application in embedded systems, and rich feature set. For programming, the C language was selected due to its powerful capabilities in hardware-level control, simplicity, and popularity in embedded system development.

2.3 Design Details and Requirements

The system is designed to prioritize efficiency, reliability, and energy conservation. It is expected to function effectively with an input voltage of 220 V AC, a maximum load current of 5A, and sensor operation limited to ranges of 5 cm for occupancy detection and 4 cm for infrared signal reception. The operating temperature range spans from -40°C to 85°C.

2.3.1 Power Supply Section

The power supply unit, as illustrated in Fig3, delivers a stable 5V DC to power the microcontroller and other system components. It includes a 220V to 12V step-down transformer, an IN4007 diode bridge for full-wave rectification, a 100µF/35V electrolytic capacitor for filtering, and an LM7805 voltage regulator for voltage stabilization. A 2.2kΩ resistor and an LED are included as an indicator to show system power status. Three 3.2V lithium batteries are connected in series to produce 9.6V, which is regulated to 5V using the LM7805.

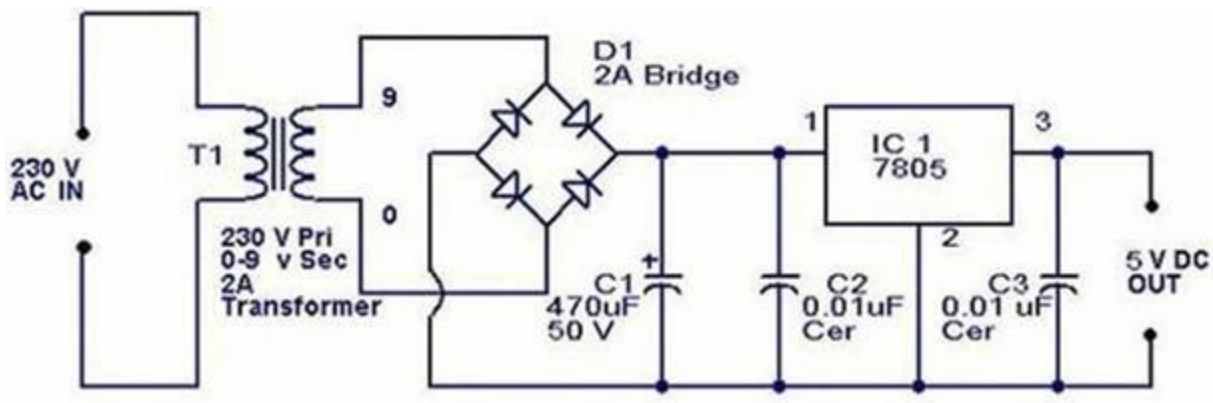

Fig. 3 Power Supply Unit

2.3.1.1 Power Supply Evaluation

The system receives an AC input voltage of 220V. The secondary maximum voltage from the transformer is 12V. The RMS voltage (VRMS) is calculated as 12/√2, which is approximately 8.49V. The total secondary resistance R_o, which includes the diode and transformer resistances, is 0.3Ω (0.1Ω + 0.2Ω). With a load current (I_L) of 0.76A, the secondary voltage drop (VSD) is 0.228V. The resulting DC voltage (VDC) is computed by subtracting both the diode forward voltage drop (0.6V) and VSD from VRMS, giving 7.662V. Under no load, the voltage (V_{NL}) is 7.89V. The voltage regulation (V_R) is then (7.89 - 7.662)/7.662 × 100, yielding approximately 2.98%. The load resistance (R_L) is 7.662V divided by 0.76A, resulting in 10.08Ω. The ripple factor (γ) is estimated using the formula $\gamma = ½ \times \sqrt{3} \times F \times C \times R_L$, with frequency F = 50Hz and capacitance C = 1000µF, yielding a ripple factor of approximately 0.436.

2.3.3 Microcontroller Unit

The microcontroller unit, is built around the ATmega328p microcontroller and includes a 16x2 LCD display, crystal oscillator, resistors, capacitors, a potentiometer, and a push button. The ATmega328p is a versatile 32-bit microcontroller featuring 1KB of EEPROM, eight 10-bit analog-to-digital converter channels, PWM functionality, USART, and comparators. It operates at a maximum clock speed of 20MHz and offers 23 general-purpose I/O pins. The 16x2 LCD can display up to 32 characters, split across two lines with each character rendered in a 5x7 pixel matrix.

2.3.3.1 CPU Utilization

CPU utilization helps assess whether the microcontroller is running near capacity. For this project, RAM and ROM usage were evaluated. With 2048 bytes of RAM available, 904 bytes were used, resulting in a 45% utilization. For ROM, 210 bytes were used out of an available 1024 bytes, resulting in 21% utilization.

2.3.3 Sensor Unit

The IR sensor unit consists of two infrared sensors used to detect motion over a distance of 7 cm. These sensors output signals when an object moves between them. Each sensor includes an amplifier to maintain signal strength. Although inexpensive and capable of functioning in both day and night conditions, the sensors are limited to a maximum detection distance of 5 cm. The velocity is calculated by dividing the sensor distance (0.07 m) by the time taken and converting the result to km/hr using the conversion factor (1 m/s = 3.6 km/hr).

2.3.4 Keypad Unit

As shown in Fig 4, the keypad unit includes three soft-touch buttons. These buttons are used to send input signals to the microcontroller for setting reference speed and controlling the DC motor speed. The buttons include a setup button, a decrement button, and an increment button.

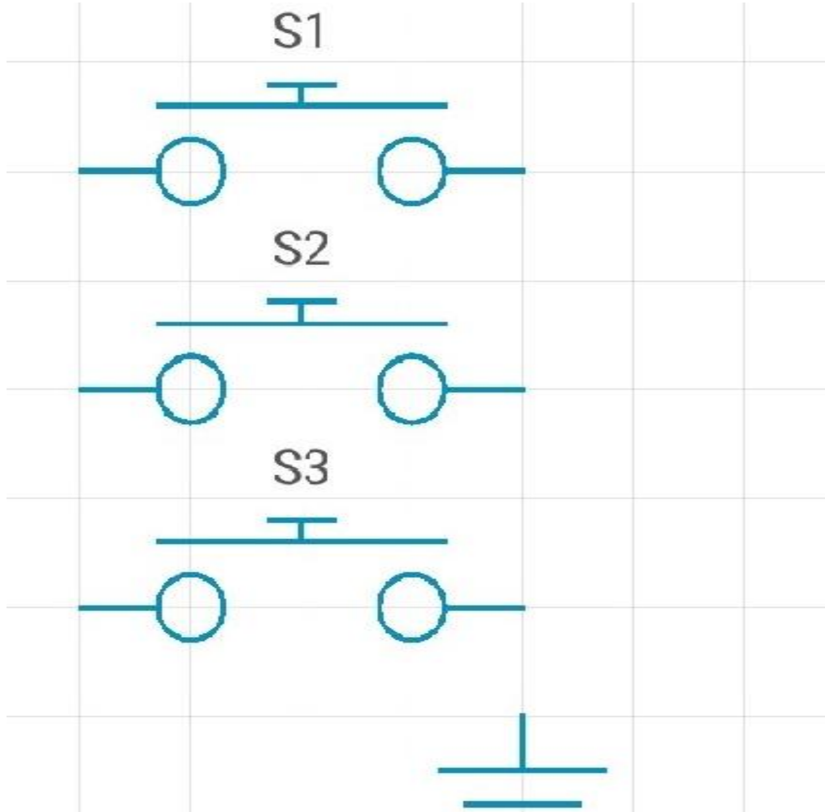

Fig 4: Keypad Unit

2.3.5 DC Motor Unit

The DC motor simulates vehicle movement in a lab environment, compensating for the limited 5 cm detection range of the IR sensors. Operating at 5V, the motor converts electrical energy into mechanical motion. This setup allows the system to measure speed accurately in a controlled environment by replicating vehicle motion. The motor also supports the conversion of rotational motion to linear (straight-line) motion, making it suitable for speed testing applications where real-world driving conditions are not feasible.

2.3.6 Complete Circuit Diagram

The complete circuit diagram of the system is presented in Fig 5. It integrates all functional units into a cohesive design.

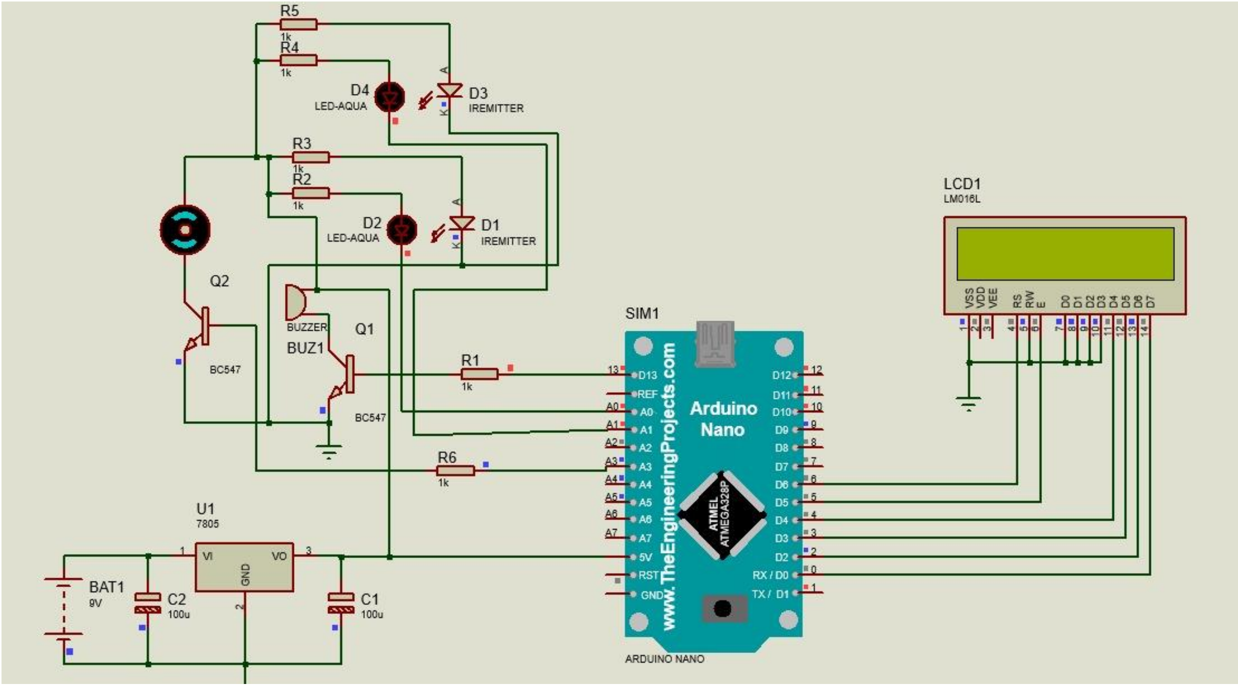

Fig. 5: A complete circuit diagram of the system

The operational sequence of the vehicle speed detection and control system begins with the IR sensor unit, which plays a crucial role in motion detection. Two infrared sensors are strategically placed at a fixed distance (7 cm) to detect the passage of a moving object, such as a miniature vehicle or rotating wheel driven by a DC motor. As the object interrupts each sensor's infrared beam in succession, the sensors generate digital output signals. The microcontroller records the time interval between these signals, then calculates the object's speed using the formula:

$$\text{Speed (km/h)} = \frac{\text{Distance (m)}}{\text{Time (s)}} \times 3.6 \qquad (1)$$

This calculated speed is then displayed on a 16x2 LCD screen connected to the ATmega328p microcontroller.

The keypad unit enables user interaction with the system by allowing manual input of a reference speed value. The keypad consists of three soft-touch buttons: setup, increment, and decrement. The user begins by pressing the setup button, which puts the system into configuration mode. The increment and decrement buttons are then used to adjust the desired speed threshold. Once the reference speed is set, the microcontroller continuously compares real-time speed measurements from the IR sensor unit with the stored threshold. If the measured speed exceeds the set reference, the system initiates a control response.

The DC motor unit, powered by a stable 5V supply regulated through the LM7805, simulates vehicle movement for testing purposes. If the speed of the simulated vehicle surpasses the configured limit, the microcontroller responds by either slowing down or stopping the motor to replicate speed control. This might involve deactivating the motor or reducing its power through PWM control. The system is designed to provide feedback through visual indicators or messages on the LCD. Altogether, the coordinated operation of sensors, microcontroller logic, user input, and output control ensure a reliable and responsive speed monitoring and control system suitable for educational demonstrations and prototype development

3.0 RESULTS AND DISCUSSION

This section presents the results obtained from the construction and testing of the vehicle speed detector and control unit, as well as an in-depth discussion of the observations. The construction process followed several sequential steps as illustrated in Fig 6 starting from circuit simulation to soldering, microcontroller programming, and final casing and packaging of the system.

3.1 Simulation

The system was initially simulated using the Proteus 8 Professional software, a versatile simulation platform that supports various microcontroller models. The simulation phase was essential for testing the logical flow and verifying the functionality of the circuit before physical implementation. By using the Proteus environment, the designed program for the ATmega328P microcontroller was compiled, debugged, and executed virtually, ensuring that the expected output behavior was achieved under different input conditions.

3.2 Soldering and Build-Up

After simulation, the soldering and hardware assembly were carried out on a continuous printed circuit board (PCB), as shown in Fig 6. All electronic components were carefully arranged and soldered according to the schematic diagram. This ensured a permanent and stable electrical connection among components to minimize contact failures during operation.

Fig. 6 Soldering and build up

3.3 Microcontroller Programming

The system's control logic was programmed using a suitable compiler within the Proteus 8 environment. This compiler enabled the writing, testing, and compilation of C language code into a hexadecimal (Hex) file that could be interpreted by the microcontroller. The compiler interface is displayed in Fig 7.

To upload the compiled Hex file into the microcontroller, a PICkit 2 programmer was used. The programmer served as the interface between the PC and the microcontroller, enabling the transfer of data via USB and ICSP (In-Circuit Serial Programming) connections. The essential pins used for the programming process included VppMCLR, Vdd target, Vss (ground), ICSPDAT/PGD, and ICSPCLK/PGC.

Fig. 7 Proteus 7 Professional Compiler

3.4 Casing and Packaging

After successful assembly and programming, the final system units were enclosed in protective casings to ensure durability and safety. The vehicle speed detector unit was enclosed in a plastic thermosetting box with high electrical resistance and low thermal conductivity, as seen in Fig8. The dimensions were 15.5 cm in length, 5 cm in breadth, and 23 cm in height, with a wall thickness of 0.4 cm. The white casing provided both aesthetic appeal and adequate insulation for the internal circuits.

Fig. 8: Vehicle Speed Detector Unit Casing

3.5 Testing and Result Analysis

Following the successful construction of the vehicle speed detector and control system, three major tests were conducted to validate the functionality and performance of the vehicle speed detector: the sensitivity test, accuracy test, and speed test. The results are discussed below.

3.5.1 Sensitivity Test

To assess the effectiveness of the IR sensor in detecting objects at varying distances, a sensitivity test was performed. The test involved placing an object at incremental distances from the IR sensor starting from 1 cm up to 7 cm, and recording whether the sensor detected the presence or not. As shown in Table 1 the test showed a consistent response from the sensor at distances between 1 cm and 5 cm, beyond which the sensor failed to register the object. This confirms that the reliable detection range of the IR sensor used in this project is limited to a maximum of 5 cm. The results are also graphically represented in Fig 9, the graphical plot of distance against response showed a clear threshold, indicating a drop in sensitivity after the 5 cm mark. This limitation should be considered in any practical deployment, as it defines the boundaries for accurate object detection.

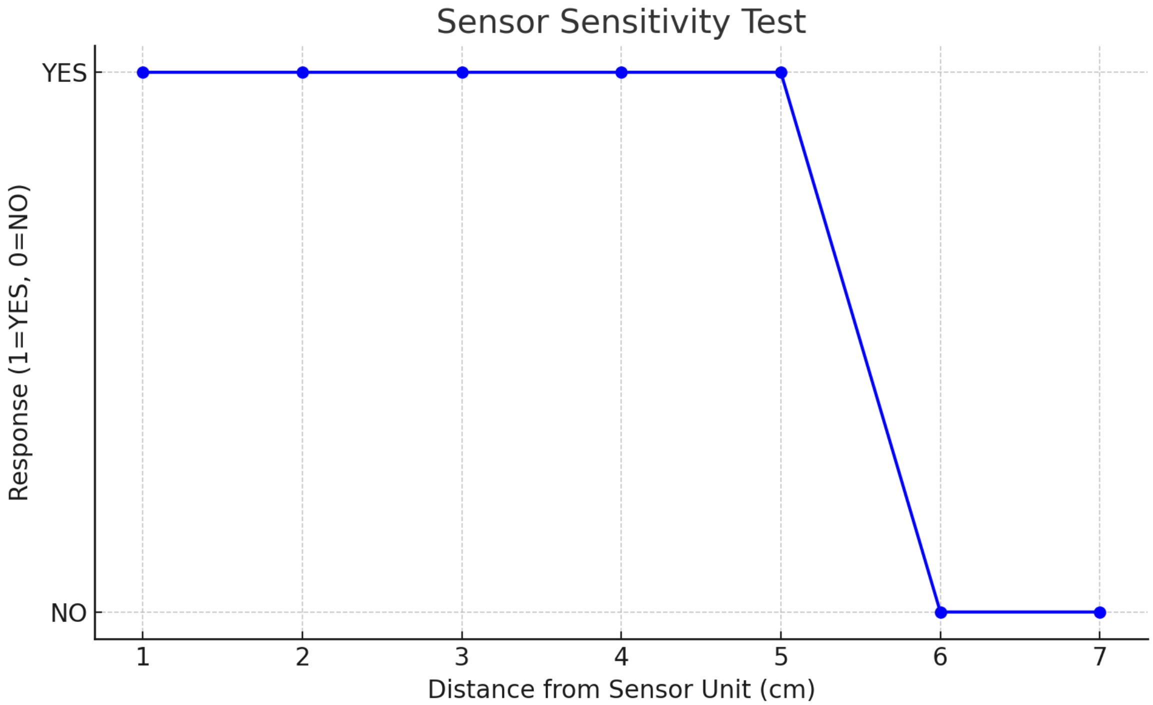

Fig 9: Sensor Sensitivity Test

Table 1: Sensitivity Test Results

Distance from Sensor Unit (cm)	Response
1	YES
2	YES
3	YES
4	YES
5	YES
6	NO
7	NO

3.5.2 Accuracy Test

The accuracy test was aimed at verifying the system's capability to measure and respond to the speed of an object, in this case, a toy car or DC motor, based on predefined distances between sensors. In this experiment, the sensors were spaced at distances of 7 cm, 13 cm, and 20 cm respectively. As shown in Table 2, the calculated speed readings for these distances were 23.6 km/hr, 6.1 km/hr, and 5.1 km/hr, and the device successfully responded to each scenario. However, it was observed that as the distance between the sensors increased, the accuracy of the speed measurement decreased slightly. This indicates that while the system functions reliably within short detection ranges, optimal results are obtained when the sensors are placed within 7 cm of each other as visually demonstrated in Fig 10. The trend also supports the initial sensitivity findings and reinforces the importance of close sensor placement for precise operation.

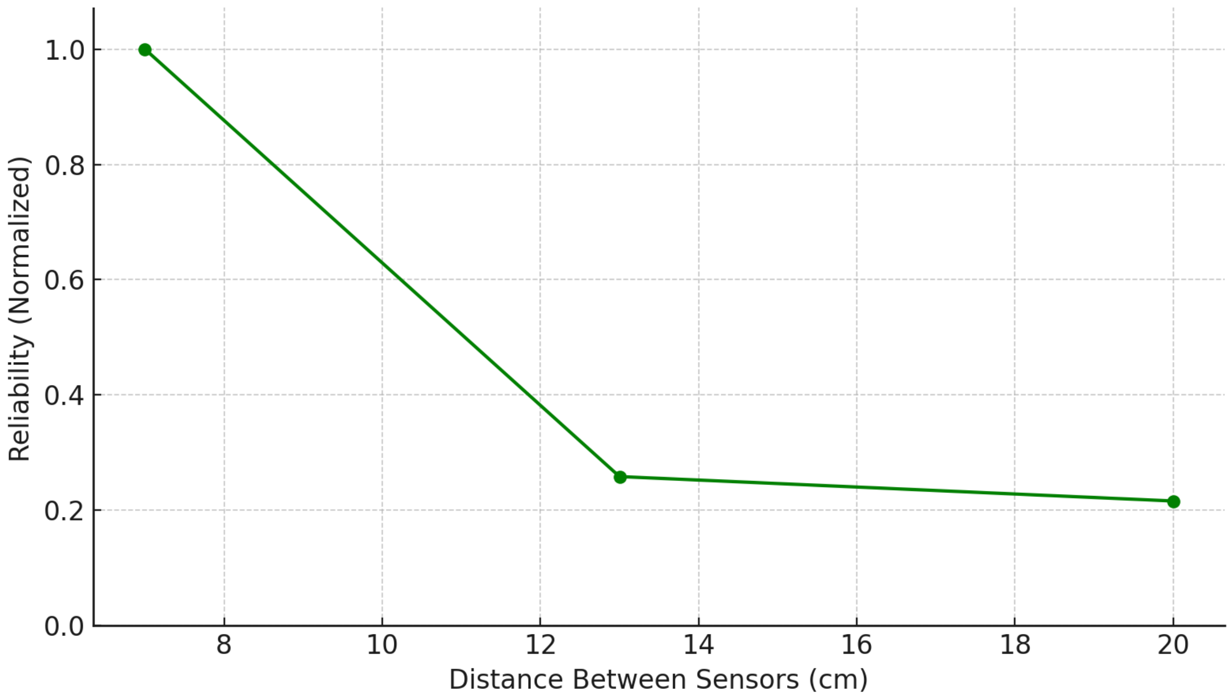

Fig 10: Speed Accuracy Test

Table 2: Accuracy Test Results

Distance Between Sensors (cm)	Speed Read (km/hr)	Accurate Response
7	23.6	YES
13	6.1	YES
20	5.1	YES

3.5.3 Speed Test

The speed test focused on determining the system's capacity to detect and process a wide range of speeds accurately. The car or DC motor was operated at increasing speeds, ranging from low (10 km/hr) to high speeds up to 500 km/hr. The recorded speeds and system performance are presented in Table 3.The readings obtained by the system were 0.5 km/hr, 6.1 km/hr, 23.6 km/hr, 46 km/hr, 310.3 km/hr, and 428.6 km/hr respectively. All performance results at these varying speeds were satisfactory, indicating that the system is capable of handling both low-speed and high-speed detection scenarios effectively thereby confirming the robustness of the design. This wide detection capability suggests the system can be applied not only in basic educational setups but also scaled for more complex real-world applications with proper modifications to sensor range and component power ratings.

Table 3: Vehicle Speed Test Results

Maximum Rated Speed	Measured Speed	Performance
10 km/hr	0.5 km/hr	Satisfactory
10 km/hr	6.1 km/hr	Satisfactory
50 km/hr	23.6 km/hr	Satisfactory
50 km/hr	46 km/hr	Satisfactory
500 km/hr	310.3 km/hr	Satisfactory
500 km/hr	428.6 km/hr	Satisfactory

Overall, the results confirm that the vehicle speed detector and control system performs satisfactorily in key operational areas. The IR sensor reliably detects objects within a 5 cm range, and the system can accurately calculate speeds when sensors are optimally spaced. The speed detection mechanism remains accurate across a broad spectrum of velocities, demonstrating both the robustness and reliability of the system. While the performance meets expectations for prototype and lab-scale implementation, real-world applications may benefit from enhancements such as extended-range sensors, environmental shielding, and calibration features to adapt to varying lighting and motion conditions. Overall, the system design and implementation have proven to be effective and promising for future development.

4.0 CONCLUSION

The project titled "Design and Construction of Vehicle Speed Detector and Control System Using IR Sensors and ATmega328P Microcontroller" was successfully conceptualized, designed, implemented, and tested to meet its objectives. The system utilizes IR sensors to detect vehicle speed and an ATmega328P microcontroller to process data and provide visual and control feedback. Simulation in Proteus 8 confirmed proper functionality across various scenarios, verifying logical and physical component interactions. Sensitivity tests revealed optimal sensor performance within 5 cm, while accuracy tests indicated reliable speed measurements when sensor spacing was 7 cm or less. Additionally, the system effectively detected a wide range of speeds—from 0.5 km/hr to 428.6 km/hr—demonstrating scalability and robustness.

The system's design proved to be energy-efficient, low-cost, and adaptable, thanks to widely compatible and programmable components such as the ATmega328P, IR sensors, LCD, buzzers, and DC motors. The protective casing and insulation also contributed to its safety and durability. Overall, the project successfully achieved its goals, delivering a functional and reliable embedded speed detection and control system. With enhancements like extended sensor range or wireless communication, the system holds potential for real-world applications in traffic control, smart zones, and vehicle monitoring in public or private spaces.

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