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Design and Implementation of a Low-Cost Microcontroller-Based Vehicle Speed Detection and Overspeed Alert System Using Dual IR Sensors

Anirudh Deshpande
Department of electronics engineering
MS.Bidve Engineering College Latur

Arjun Suryawanshi
Department of electronics engineering
MS.Bidve Engineering College Latur

Vaibhav gurme
Department of electronics engineering
MS.Bidve Engineering College Latur

***Abstract*—Overspeeding is a leading cause of road accidents, yet commercial speed-enforcement equipment such as radar guns and speed cameras is costly and opaque for educational use. This paper presents the design and implementation of a low-cost vehicle speed detection and overspeed alert system built around an AT89C51 (8051) microcontroller and two infrared (IR) sensor modules placed 12 cm apart. When a vehicle is detected by the first sensor, Timer0 is started; when it reaches the second sensor, the timer is stopped and the elapsed count is converted to speed using the distance–time relation. The result is shown on a 16×2 LCD, and a transistor-driven buzzer raises an audible alarm whenever the measured speed exceeds a programmed limit. An 11.0592 MHz crystal gives a machine-cycle time of 1.085 µs, so timer resolution is not the limiting factor of the design. The paper describes the architecture, circuit connections, timing analysis and control algorithm, and estimates a bill of materials of about ₹1,830. The prototype shows that automatic speed measurement and overspeed indication can be achieved with inexpensive, widely available components, which makes it well suited to embedded-systems teaching and small-scale road-safety demonstrations.**

***Index Terms*—AT89C51, 8051 microcontroller, infrared sensor, vehicle speed detection, overspeed alert, embedded system, road safety.**

I. INTRODUCTION

The number of vehicles on the road is growing steadily, and with it the importance of traffic safety. Excessive speed is among the main contributors to road accidents, increasing both the likelihood of a collision and the severity of injuries and property damage. Monitoring vehicle speed is therefore a basic requirement for encouraging safe driving. Radar speed guns, laser devices and camera-based enforcement systems are effective, but they depend on specialised hardware and are expensive and complex for small institutions and student laboratories.

Microcontrollers combined with simple electronic sensors offer a practical alternative. A pair of IR sensors placed a known distance apart can act as a "start" and "stop" gate: the time a vehicle takes to travel between them, measured by a hardware timer, directly yields its speed. This paper develops that idea on the classic 8051 architecture, which remains a standard teaching platform for embedded systems [3], [4].

The main contributions of this work are:

- a dual-IR, timer-based speed measurement scheme implemented on an AT89C51 microcontroller;
- a timing analysis giving the measurement resolution and the minimum measurable speed for the chosen sensor spacing and clock frequency;
- a complete hardware description with pin connections and an estimated bill of materials; and
- an overspeed alert mechanism combining an LCD status display with a transistor-driven buzzer.

The remainder of the paper is organised as follows. Section II reviews related work, Section III presents the system architecture, Section IV describes the hardware, Section V explains the measurement principle and control algorithm, Section VI discusses the results, and Sections VII–IX cover advantages and applications, limitations with future work, and conclusions.

II. RELATED WORK

Conventional vehicle speed measurement relies on mechanical devices, radar and laser systems. These technologies are widely deployed for identifying overspeeding vehicles and provide reliable measurements, but they generally require specialised equipment and carry high implementation costs. The availability of inexpensive microcontrollers and electronic sensors has made low-cost alternatives feasible for educational and small-scale use.

Several microcontroller-based approaches use infrared, ultrasonic or other sensing techniques to detect a moving object and compute its speed. Nafiza [1] discusses vehicle speed detection with two IR sensors, an Arduino controller, an LCD and a buzzer. Vu et al. [2] estimate vehicle speed using two roadside passive infrared sensors. The present work follows the same two-sensor principle but is built on an 8051 microcontroller, uses its hardware timer directly, and explicitly analyses timing resolution and measurable speed range, which are often left implicit in student-level implementations.

III. SYSTEM ARCHITECTURE

The block diagram of the proposed system is shown in Fig. 1. The system comprises a power supply, the AT89C51 microcontroller, an oscillator and reset circuit, two IR sensors, a 16×2 LCD and a buzzer driver.

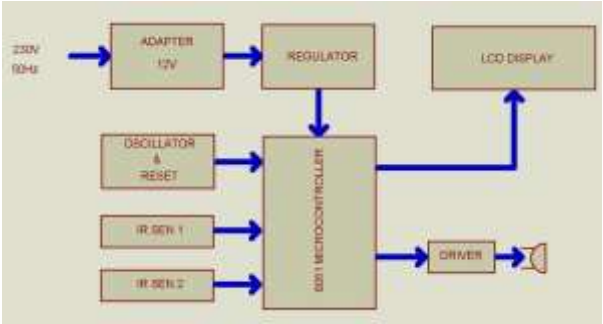


Fig. 1. Block diagram of the vehicle speed detection and overspeed alert system.

A. Power Supply

A 12 V DC adapter converts the 230 V AC mains to 12 V DC, which feeds a 7805 linear regulator. The regulator delivers a stable 5 V supply to the microcontroller, the IR sensors and the LCD. A filter capacitor suppresses supply fluctuations, and a red LED with a series resistor indicates that power is present.

B. Microcontroller

The AT89C51 is the central controller. It reads the digital outputs of both IR sensors, starts and stops Timer0 accordingly, computes the speed from the timer count, drives the LCD, and controls the buzzer according to the comparison between the measured speed and the programmed limit.

C. IR Sensing Unit

Each IR sensor module contains an infrared transmitter–receiver pair. When a vehicle interrupts or reflects the infrared beam, the module produces a digital output transition. The first sensor marks the entry of the vehicle and starts the measurement; the second sensor, mounted 12 cm from the first, marks the exit and stops it.

D. Clock and Reset

An 11.0592 MHz crystal with two 33 pF capacitors connected to XTAL1 and XTAL2 provides the system clock. A 10 kfi resistor, a 10 µF capacitor and a push button form the power-on and manual reset circuit.

E. Display and Alert

A 16×2 character LCD, interfaced through an 8-bit data connection, shows the calculated speed together with a status message (normal or overspeed). When the limit is exceeded, the microcontroller switches an NPN transistor through a base resistor; the transistor drives the buzzer, which stays off while the speed is within the limit.

IV. HARDWARE IMPLEMENTATION

A. Circuit Connections

Table I summarises the principal connections of the circuit.

TABLE I

PRINCIPAL CIRCUIT CONNECTIONS

Signal / pin	Connection
7805 pin 1 / 2 / 3	12 V input / GND / regulated 5 V output
VCC (pin 40)	+5 V
GND (pin 20)	Ground
XTAL1, XTAL2 (pins 19, 18)	11.0592 MHz crystal; 33 pF capacitor from each pin to ground
RST (pin 9)	10 kfi resistor, 10 µF capacitor and push button
EA (pin 31)	+5 V (internal program memory enabled)
P3.2 (INT0)	Output of IR sensor 1 (start)
P3.3 (INT1)	Output of IR sensor 2 (stop)
Alert output	NPN transistor via base resistor, driving buzzer
Display	16×2 LCD, 8-bit data interface
Supply filter / indicator	1000 µF capacitor; red LED with 330 fi resistor

B. Component List and Cost

The components used and their estimated cost are listed in Table II. The estimated total of about ₹1,830 confirms the low-cost nature of the design.

TABLE II

COMPONENTS AND ESTIMATED COST

No.	Component	Qty	Rate (₹)
1	AT89C51 microcontroller	1	300
2	16×2 LCD display	1	300
3	IR sensor module	2	160
4	7805 voltage regulator IC	1	30
5	12 V DC adapter	1	300
6	11.0592 MHz crystal	1	30
7	33 pF capacitor	2	10
8	1000 µF capacitor	1	30
9	10 µF capacitor	1	10
10	10 kfi resistor	1	4
11	330 fi resistor	2	8
12	4.7 kfi potentiometer	1	20
13	NPN transistor	1	20
14	Buzzer	1	40
15	Red LED	1	10
16	Push-button switch	1	10
17	Port 0 pull-up resistor network	1	20
18	Connecting wires and PCB	1 lot	350
	Estimated total (₹)		**1,830**

V. MEASUREMENT PRINCIPLE AND ALGORITHM

A. Speed Computation

If the two sensors are separated by a distance d and a vehicle takes a time t to travel between them, its average speed is

$$v = d / t \quad (1)$$

where d = 0.12 m in the prototype and t is measured with Timer0.

The 8051 executes one machine cycle every 12 oscillator periods. With the 11.0592 MHz crystal, the machine-cycle time is

$$T_{mc} = 12 / f_{osc} = 1.085\ \mu s \quad (2)$$

If Timer0 holds a count N when stopped, the elapsed time is $t = N \cdot T_{mc}$, and the speed in km/h becomes

$$v = 3.6\ d / (N \cdot T_{mc}) \quad (3)$$

B. Resolution and Measurable Range

The counting resolution of the timer is one machine cycle (1.085 µs). Table III lists the theoretical time interval and timer count for several speeds over the 12 cm baseline, together with the relative quantisation error of ±1 count. Even at 80 km/h the timer contributes an error of only about 0.02 %, so the overall accuracy is determined mainly by sensor response time and mechanical alignment rather than by the timer.

TABLE III

THEORETICAL TIMING FOR A 12 cm SENSOR SPACING

Speed (km/h)	Time t (ms)	Count N	±1 count (%)
10	43.20	39813	0.003
20	21.60	19907	0.005
40	10.80	9953	0.010
60	7.20	6636	0.015
80	5.40	4977	0.020

In 16-bit mode Timer0 overflows after 65 536 machine cycles, i.e. 71.1 ms. For d = 12 cm this corresponds to a minimum measurable speed of about 6.1 km/h, as illustrated in Fig. 2; slower vehicles would require overflow handling in software or a larger timing range.

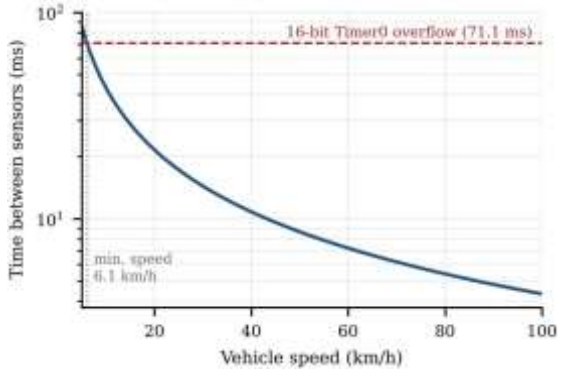


Fig. 2. Time between the two sensors versus vehicle speed for d = 12 cm, with the 16-bit Timer0 overflow limit.

C. Control Algorithm

The control flow is shown in Fig. 3. After initialising the LCD, Timer0 and port pins, the program displays a ready message and waits for the first sensor. A detection on P3.2 starts Timer0; a detection on P3.3 stops it. The speed is computed from the count, displayed on the LCD, and compared with the speed limit stored in the program. If the limit is exceeded, an overspeed warning is displayed and the buzzer is switched on; otherwise a normal-speed message is shown and the buzzer remains off. The system then returns to its initial state and waits for the next vehicle.

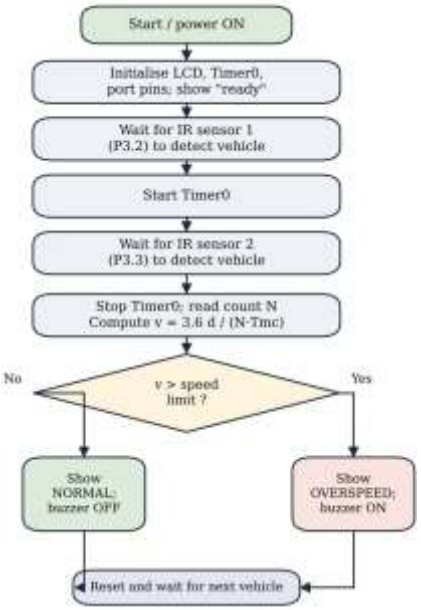


Fig. 3. Flowchart of the speed measurement and overspeed alert program.

VI. RESULTS AND DISCUSSION

The system was designed and implemented as a working prototype on a custom PCB. On power-up it initialises the LCD and timer and displays a message indicating that the system is ready. When a vehicle passes the first sensor, Timer0 starts; when the same vehicle reaches the second sensor, the timer stops and the speed is calculated and displayed. For a speed above the programmed limit, the LCD shows an overspeed warning and the buzzer sounds through the transistor driver; for a speed within the limit, the LCD shows a normal-speed message and the buzzer stays off. After each measurement the system resets and waits for the next vehicle, so successive vehicles are handled without manual intervention.

The timing analysis in Section V shows that the 11.0592 MHz clock provides far more resolution than the application needs, so measurement quality depends chiefly on the IR sensors: their response time, the sharpness of the detection edge, and the alignment of the two modules at the specified 12 cm spacing. Because the speed is an average over the 12 cm baseline, it represents the vehicle's speed between the sensors rather than an instantaneous value, which is appropriate for the short, near-constant-speed interval considered.

VII. ADVANTAGES AND APPLICATIONS

The principal advantages of the system are its low cost, owing to the use of common components; fully automatic measurement without manual timing; immediate overspeed warning through the buzzer; and ease of monitoring on the LCD. Potential applications include basic demonstrations of traffic and highway speed monitoring, teaching laboratories in polytechnic and engineering institutions for microcontroller programming and sensor interfacing, and road-safety awareness projects that illustrate the importance of observing speed limits.

VIII. LIMITATIONS AND FUTURE WORK

The 12 cm spacing suits a scaled demonstration; a roadside installation would need a larger baseline, weather-

resistant sensors and protection against ambient infrared interference. The speed limit is fixed in the program, and the prototype measures one vehicle at a time. Future work could add a keypad for an adjustable limit, interrupt-driven edge capture with software overflow handling for low speeds, data logging or GSM/IoT reporting of violations, camera-based number-plate capture, and a quantitative calibration against a reference speed source to report measurement error statistically.

IX. CONCLUSION

A low-cost vehicle speed detection and overspeed alert system based on the AT89C51 microcontroller and two IR sensors has been designed and implemented. The system measures the travel time between two sensors 12 cm apart with Timer0, computes the speed from the distance–time relation, displays it on a 16×2 LCD and triggers a buzzer through a transistor driver when the programmed limit is exceeded. The analysis shows a timing resolution of 1.085 µs and a minimum measurable speed of about 6.1 km/h in 16-bit mode, and the estimated cost is about ₹1,830. The design is simple, economical and extensible, and offers a practical platform for embedded-systems education and road-safety demonstration.

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