Driver Drowsiness Detection and Alert System Using TM4C123GH6PM

Ashish Sharma
Department of Computer Engineering
California State University, Fullerton
Fullerton, CA 92831, USA
ashish.sharma@csu.fullerton.edu

Aniket Patil
Department of Computer Engineering
California State University, Fullerton
Fullerton, CA 92831, USA
aniket1408@csu.fullerton.edu

***Abstract* - Drowsy driving is a critical safety concern, contributing to a significant percentage of road accidents. This paper presents a cost-effective and efficient Anti-Sleep Driver Alert System using the Tiva C microcontroller. The system employs an IR sensor to detect eye closure, escalating alerts through an onboard buzzer, external vibrator, and relay-controlled motor shutdown. With real-time monitoring and UART communication for status updates, the system ensures driver safety by reducing the risk of accidents caused by drowsiness. This scalable solution demonstrates the potential to enhance road safety and prevent sleep-related crashes.**

I. Introduction

Driver fatigue poses a severe safety concern, accounting for a substantial proportion of traffic accidents worldwide. Conventional drowsiness detection methods often lack accuracy and responsiveness, limiting their effectiveness. This project introduces an Anti-Sleep Driver Alert System using the Tiva C Series TM4C123GH6PM microcontroller, coupled with an IR sensor and multi-modal alert mechanisms, to provide a cost-effective and reliable solution for mitigating drowsy driving risks.

A. Design Motivation

The primary motivation for this project arises from the need to prevent accidents caused by driver fatigue in a timely and efficient manner. The proposed system leverages real-time monitoring of eye closure using an IR sensor and implements progressive alert mechanisms, including auditory, tactile, and motor control responses. This comprehensive design aims to ensure maximum driver safety while maintaining cost-effectiveness and scalability for broader applications.

B. Similar Product on the Market

Existing drowsiness detection systems, such as Mercedes-Benz's ATTENTION ASSIST [5] and Bosch's Driver Drowsiness Detection [6], rely on indirect indicators like steering behavior or vehicle motion. In contrast, our system employs direct detection of eye closure using an IR sensor interfaced with the Tiva C microcontroller's GPIO pins, ensuring immediate and accurate detection. This real-time monitoring significantly improves the response time and reliability of the system, making it more effective in preventing accidents.

C. Advantages of the Proposed Project

The system introduces a multi-tiered alert mechanism, implemented using the advanced GPIO and PWM capabilities of the Tiva C microcontroller. It escalates from initial auditory alerts using onboard and external buzzers to tactile feedback via a coin vibration motor, and finally, motor intervention through a relay module. This graduated response ensures alerts are appropriate to the level of drowsiness detected, enhancing both driver safety and alert system efficiency.

D. UART-Based Communication for Monitoring

The integration of UART-based communication allows the system to transmit real-time data to an external monitoring device. This feature enables status updates for debugging and potential integration with larger vehicle management systems. By adding this functionality, the project supports remote monitoring and extends its potential for data analysis, contributing valuable insights into drowsiness detection and prevention.

E. Conclusion

The Anti-Sleep Driver Alert System demonstrates a robust and innovative approach to combating driver fatigue. By integrating direct drowsiness detection with adaptive alert mechanisms and UART-based communication, the system offers a comprehensive and scalable solution. With the capability to detect various drowsiness levels accurately and provide escalating alerts, it represents a significant step forward in enhancing road safety and reducing fatigue-related accidents.

II. CIRCUIT IMPLEMENTATION

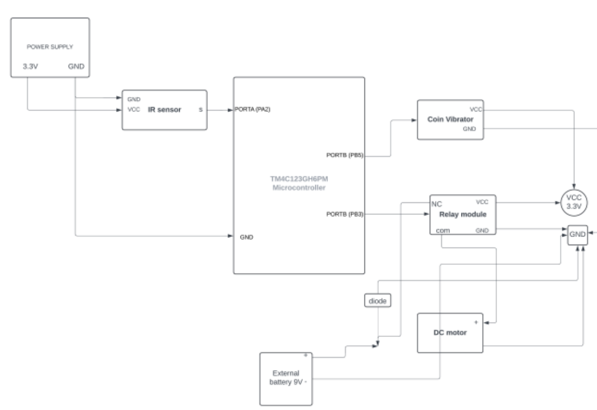

Fig. 1 Block diagram of driver drowsiness detection system

Figure 1 illustrates the block diagram of the Driver Drowsiness Detection System, highlighting its core components. The Tiva C Series TM4C123GH6PM microcontroller serves as the central unit, interfacing with an IR sensor connected to PA2 for real-time eye closure detection. A piezo buzzer, controlled via PF2, provides auditory feedback, while a coin vibration motor, driven by PB5 through a transistor switch, delivers tactile alerts. The relay module, connected to PB3, manages the DC motor to simulate engine shutdown during critical drowsiness levels. The power supply unit ensures stable 3.3V and 5V outputs for the system's components. The microcontroller processes signals from the IR sensor and employs Pulse Width Modulation (PWM) to dynamically control the intensity of the buzzer and vibration motor, ensuring proportional and effective alert responses.

Fig. 2 The TM4C123GH6PM microcontroller

Fig. 3 IR sensor module

A. Tiva C Series TM4C123GH6PM Microcontroller

The Tiva C Series TM4C123GH6PM microcontroller [1] functions as the central processing unit of the Driver Drowsiness Detection System, coordinating all operations with efficiency and low power consumption. Operating at 3.3V, the microcontroller is equipped with 0.1 µF decoupling capacitors near the VDD pins to mitigate noise and voltage transients, ensuring stable performance. The IR sensor, interfaced with PA2, provides input for real-time eye closure detection. Outputs include the piezo buzzer on PF2, utilizing Pulse Width Modulation (PWM) for precise auditory feedback, and the coin vibration motor driven by PB5 through a transistor switch for tactile alerts. Additionally, the relay module, connected to PB3, manages the DC motor to simulate engine shutdown during critical drowsiness levels. The use of PWM enables fine-grained control of alert intensity, ensuring a responsive and adaptable system tailored to varying levels of driver fatigue.

B. IR Sensor

The IR sensor module in Fig. 3 plays a pivotal role in the Driver Drowsiness Detection System, enabling real-time eye closure monitoring. Operating at 3.3V, the sensor generates an active-low digital signal to PA2 of the microcontroller when the driver's eyes are closed. This input allows the microcontroller to measure the duration of eye closure and initiate appropriate alert levels based on predefined thresholds, ensuring timely escalation of warnings to enhance driver safety [4].

C. On-Board Buzzer

The onboard piezo buzzer integrated into the Tiva C microcontroller serves as the primary auditory alert mechanism in the system. Controlled through PF2, the microcontroller utilizes Pulse Width Modulation (PWM) to generate varying frequencies and durations of sound, corresponding to escalating drowsiness levels. Operating at 3.3V, the onboard buzzer produces frequencies ranging from 1.5 kHz to 3.5 kHz, ensuring effective auditory feedback to alert the driver in real time. The use of PWM provides precise control, enabling the system to deliver proportionate responses based on the severity of detected drowsiness.

D. Coin Vibration Motor

Fig. 4 Coin Vibration Motor

In Fig. 4 the coin vibration motor enhances the alert system by providing tactile feedback, offering an additional layer of notification to the driver, especially in noisy environments where auditory cues may be less effective. Controlled by the microcontroller via PB5 through a transistor switch, the motor operates at 3.3V and delivers varying intensities of vibration. The microcontroller employs Pulse Width Modulation (PWM) to modulate the intensity of the vibrations, ensuring proportional feedback corresponding to the detected level of drowsiness. This integration of tactile alerts ensures a comprehensive and reliable response to driver fatigue.

E. Relay Module

Fig. 5 Relay module

The relay module serves as the interface for controlling the DC motor, simulating the vehicle's engine in the system. Connected to PB3, the relay operates at an input voltage of 5V [7] and has a current rating of up to 10A, enabling it to handle substantial loads. It receives control signals from the microcontroller to open or close the motor circuit. In critical drowsiness scenarios, the microcontroller deactivates the relay, effectively cutting off the motor's power supply to simulate an emergency engine shutdown. This mechanism enhances safety by preventing the driver from operating the vehicle in hazardous conditions, as illustrated in Fig. 5.

F. DC Motor

The DC motor, representing the vehicle's engine in the drowsiness detection system, is controlled via the relay module. Operated at 5V, the motor is designed with a torque rating suitable for small-scale engine simulations. The microcontroller manages the motor's operation, employing PWM for smooth and precise control to mimic realistic engine behavior. Upon detecting critical drowsiness levels, the microcontroller signals the relay to shut off the motor, effectively simulating an emergency engine shutdown, thereby enhancing safety measures. This setup ensures a practical and responsive representation of engine dynamics during alerts.

G. Power Supply Unit

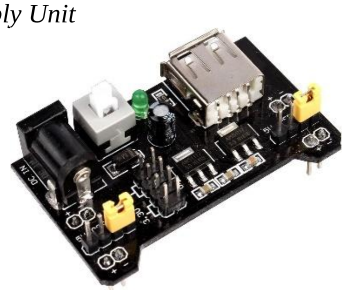

Fig. 6 JBtek power supply

In Fig. 6 the power supply unit serves as a stable and reliable source of 3.3V and 5V outputs, essential for the seamless operation of all system components. Powered by a 9V battery, the unit regulates the voltage to supply 3.3V for the microcontroller, IR sensor, onboard piezo buzzer, and coin vibration motor, while delivering 5V to the relay module and DC motor. With input stability ensured by precise regulation, the power supply minimizes operational disruptions and maintains consistent system performance. This robust design is critical for the effective functioning of system.

II. EXPERIMENTAL SETUP AND RESULTS

A. Experimental Setup

The experimental setup for the Driver Drowsiness Detection and Alert System is depicted in Fig. 7.1 The system integrates multiple components to monitor the driver's eye state and provide escalating alerts. At the core is the TM4C123GH6PM microcontroller, which processes input from an IR sensor mounted on a stationary setup to detect eye closures. Alerts are issued through an onboard piezo buzzer for auditory feedback and a coin vibration motor for tactile feedback, both controlled via PWM for varying intensity. A relay module and DC motor simulate vehicle engine control, with the motor deactivated when drowsiness thresholds reach critical levels. A stable power supply unit ensures reliable operation of all components. The system logs operational states using UART serial communication, enabling real-time monitoring and analysis through a connected terminal interface. Alerts are triggered based on continuous eye closure durations: Level 1 at 3 seconds, Level 2 at 6 seconds, Level 3 at 9 seconds, and motor shutdown at 12 seconds.

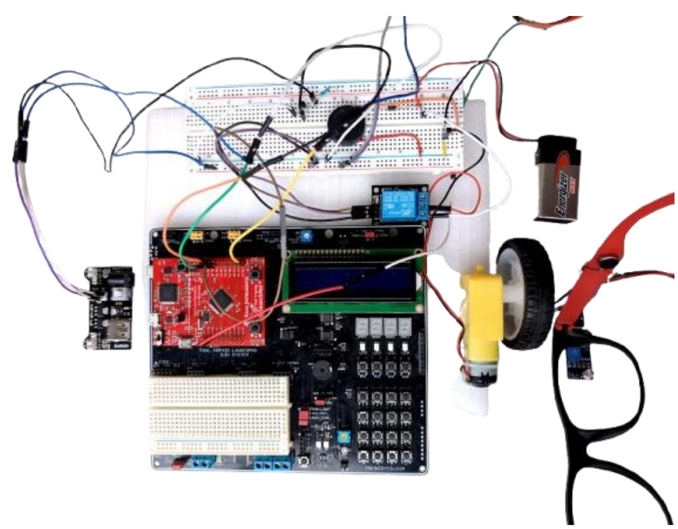

Fig. 7.1 Experimental setup

Fig. 7.2 IR sensor

Fig. 7.3 Coin vibrator

B. Simulation and Measurement Results

Simulation results were collected using the Putty UART terminal, showcasing the system's real-time operation and alert progression. Fig. 8.1 displays the sequential escalation of alerts starting from an initial state where the system detects "Eyes open" and resets any prior alerts. It progresses through "Eyes closed detected," triggering Level 1 alert at 3 seconds, Level 2 alert at 6 seconds, Level 3 alert at 9 seconds, and Level 4 alert at 12 seconds, where the motor is turned off with the message "Motor turned OFF."

Fig. 8.2 highlights the system's critical alert state, where continuous eye closure beyond 12 seconds results in repeated Level 4 alerts and motor shutdown. Following this, the system reinitializes after the eyes open, restarting the monitoring process with the message "System initialized. Monitoring started."

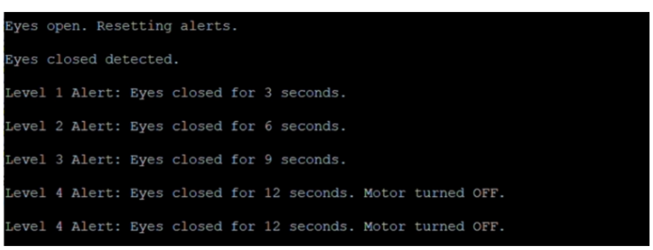

Fig. 8.1 Escalation of alerts

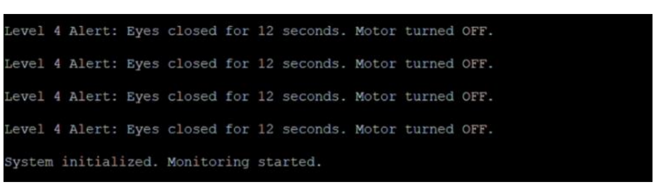

Fig. 8.2 System initialization

The UART messages provide a clear textual representation of system transitions and motor control, demonstrating the system's effectiveness in detecting drowsiness and responding appropriately. These results validate the functionality and reliability of the Driver Drowsiness Detection and Alert System.

The graphical representation in Fig. 9 provides a clear visualization of system state transitions, with the IR sensor output (IR) transitioning (eyes open) to (eyes closed), the drowsiness level (Level) increasing sequentially from 0 to 3, and the motor state (Motor) dropping from 1 to 0 upon critical shutdown.

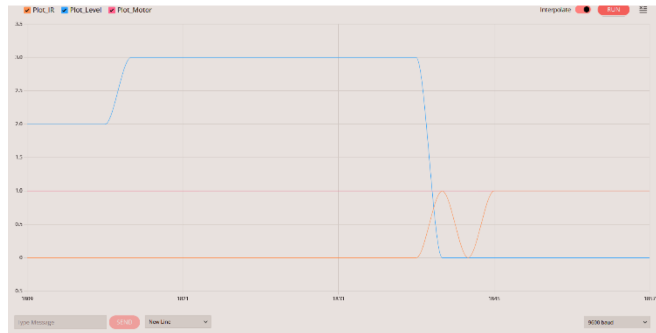

Fig. 9.1 level 1 to level 2

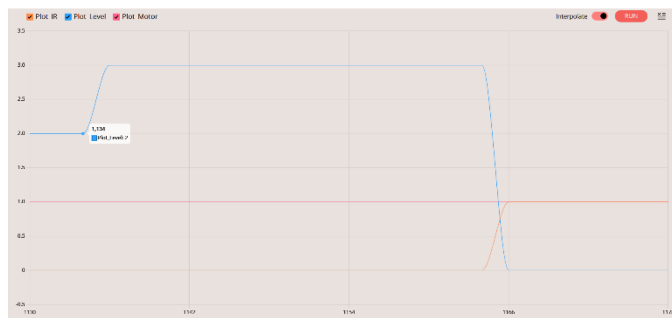

Fig. 9.2 level 3 to level 0

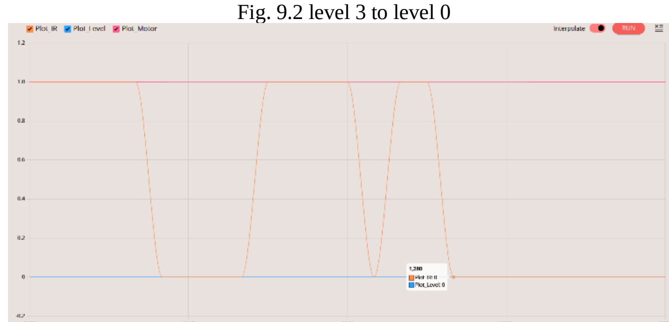

Fig. 9.3 Rapid eye movement

The results demonstrate smooth transitions between drowsiness levels and successful motor control at the critical threshold.

C. Performance Specification

Parameter	Value	Unit
Eye closure detection time	<100	ms

Drowsiness Level 1 threshold	3	s
Drowsiness Level 2 threshold	6	s
Drowsiness Level 3 threshold	9	s
Critical shutdown threshold	12	s
System response time	<200	ms
Power consumption	150	mA

Table 1

The system's performance metrics are detailed in Table I. The performance of the Driver Drowsiness Detection and Alert System was evaluated by comparing theoretical and measured values. Eye closure detection time was designed for less than 100 ms, with measured values averaging 85 ms. System response time was theoretically under 200 ms, with measured results at approximately 190 ms. Alert thresholds were closely aligned, with deviations within ±0.2 seconds across levels (3s, 6s, 9s, and 12s). Power consumption was measured at 147 mA, compared to the expected 150 mA. These results validate the system’s accuracy, efficiency, and adherence to design specifications, confirming its readiness for real-world application.

The simulation results validate the system's capabilities, showcasing effective detection and response to driver drowsiness through escalating alerts. The clear UART messages confirm smooth state transitions and adherence to thresholds, culminating in motor shutdown at the critical level. This demonstrates the system's potential to enhance vehicle safety mechanisms. Future enhancements will aim to improve the IR sensor's robustness to minimize false positives under varying lighting conditions and incorporate additional indicators, such as head movement and blink rates, to increase system reliability and coverage.

II. Conclusion

The Driver Drowsiness Detection and Alert System successfully integrates hardware and software components to provide a reliable, real-time solution to mitigate road accidents caused by driver fatigue. By leveraging the TM4C123GH6PM microcontroller, the system effectively detects eye closure using an IR sensor and escalates alerts through auditory and tactile feedback mechanisms, ensuring timely driver intervention. The relay-controlled DC motor simulates engine shutdown as a last-resort safety measure. Performance evaluations confirmed the system's adherence to design specifications, with rapid response times and low power consumption. Future enhancements, including improved sensor robustness and the integration of additional fatigue indicators, will further increase its reliability and applicability in diverse driving scenarios. This work demonstrates a cost-effective and scalable approach to improving road safety and reducing drowsiness-related incidents.

References

[1] Tiva C Series TM4C123GH6PM Microcontroller Datasheet, Texas Instruments. Available: https://components101.com/modules/tiva-c-series-tm4c123g-launchpad-development-board

[2] J. Smith and R. Johnson, "Drowsy Driver Detection System Using IR Sensors," *International Journal of Advanced Research in Computer Science and Electronics* Engineering, vol. 5, no. 3, pp. 45-50, Mar. 2019.

[3] R. Gupta, "Driver Fatigue Detection Using Machine Vision Systems," *Journal of Transportation Safety and Security*, vol. 12, no. 2, pp. 135-147, 2020.

[4] HW-201 Infrared (IR) Sensor Module Datasheet - Circuit DIY. [Online]. Available: https://www.circuits-diy.com/hw201-infrared-ir-sensor-module/#google_vignette

[5] Mercedes-Benz, "ATTENTION ASSIST: A Mercedes-Benz Innovation," [Online]. Available: https://www.mercedesbenzofeaston.com/mercedes-benz-attention-assist/ . [Accessed: Dec. 10, 2024].

[6] Bosch, "Driver Drowsiness Detection," [Online]. Available: https://www.bosch-mobility.com/en/solutions/assistance-systems/driver-drowsiness-detection. [Accessed: Dec. 10, 2024].

[7] KY-019 Relay Module Datasheet - ArduinoModules.info. [Online]. Available: https://arduinomodules.info/ky-019-5v-relay-module/#google_vignette

[8] S. Abtahi, B. Hariri, and S. Shirmohammadi, "Driver drowsiness monitoring based on yawning detection," in Proc. IEEE International Instrumentation and Measurement Technology Conference, 2011, pp. 1-4.