Design and Construction of a Microcontroller-based Driver's Anti-Sleep Device with Multiple Alert Mechanisms

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Abstract

Introduction: Driver drowsiness is a critical causative factor in the alarming rate of road traffic accidents globally. This accounted for a significant portion of the 10,027 crashes and 5,081 fatalities recorded in 2023. Existing mitigation strategies are largely ineffective, and advanced technological solutions are often prohibitively expensive and ill-suited for the local vehicle and environmental conditions. This research addresses the pressing need by leveraging embedded systems engineering to design, implement, and test a cost-effective, real-time Driver Anti-Sleep System (DASS) prototype.

Methodology: The system is architected around an ESP32 microcontroller, which serves as the central processing unit. It employs an ESP32-CAM module for real-time visual monitoring, utilizing computer vision techniques and the Eye Aspect Ratio (EAR) algorithm to detect signs of drowsiness, such as prolonged eye closure. Upon detection, a multi-modal alert subsystem is activated, comprising a buzzer for audio alerts, a vibration motor for haptic feedback, and a SIM800L GSM module to send SMS alerts to pre-configured emergency contacts. A 16 by 2 Liquid Crystal Display (LCD) system status. The system was evaluated based on key engineering metrics, including detection accuracy and response latency.

Result(s): Results reveals 96.7%, and 91.3% detection accuracy and at 1.2s and 1.5s response time, for sleep and drowsiness, respectively.

Recommendation(s): This system provides a critical means for enhancing road safety and provides a foundational framework for future integration with Advanced Driver-Assistance Systems (ADAS) and IoT-based fleet management solutions. It is recommended for adoption by commercial transport operators. Future work should focus on further optimization and large-scale deployment.

1.0 Introduction

Shocking statistics revealed by World Health Organization (WHO) in a 2009 report showed that more than 1.2 million people die on roads around the world every year. Moreover, an additional 20 to 50 million individuals suffer non-fatal injuries. Despite progress, road traffic deaths continue to rise, with an annual 1.35 million fatalities. Road traffic injuries are now the leading killer of children and young people aged 05-29 years. Globally, of all road traffic deaths, pedestrians and cyclists account for 26% and motorcycle riders and passengers account for 28%. The risk of a road traffic death remains three times higher in low-income countries than in high-income countries, with rates highest in Africa (26.6 per 100,000 populations) and lowest in Europe (9.3 per 100,000 populations). Every year, over 39,000 Nigerians die from road crashes. In the 2018 Global Status Report on Road Safety, the World Health Organization (WHO) estimated road traffic fatalities in Nigeria at 39,802, while the estimated rate per 100,000 deaths stood at 21.4.%. US National Sleep Foundation (NSF) reported that 54% of adult drivers have driven a vehicle while feeling drowsy and 28% of them actually fell asleep on the wheel. Powell et al. concluded that sleepiness can impair driving performance as much or more than alcohol. A more recent report from The American Automobile Association (AAA) estimates that one out of every six (16.5%) deadly accidents, and one out of eight (12.5%) crashes requiring hospitalization of car drivers or passengers is due to drowsy driving.

In summary, there is a substantial amount of evidence that suggests that drowsiness is one of the big factors in road accidents. Recent studies indicate that fatigue is a major contributing factor of serious accidents, with about 20% of fatal road accidents attributable to driver fatigue. In 2013, drowsy driving was responsible for an estimated 72,000 crashes, 44,000 injuries, and 800 deaths globally (WHO, 2019). These statistics are not surprising when you consider that according to a recent report, 60% of adults admitted to driving while tired, while 37% admitted to have fallen asleep behind the wheel. Currently available driver drowsiness detection systems usually fall into two categories: very expensive systems, limited to specific high-end car models; affordable solutions that lack robustness while some drivers have the device neither on them nor in the car which they drive. The research is to detect the state of sleep/sleepiness and alert not only the driver but also passengers and family friends of the driver of the car.

2.0 Literature Review

Drowsiness in driving accounts for 30-40% accidents that occurs (Mrudula et al., 2013). There are four ways to determine drowsiness in drivers. The use of biological signals and electrodes to measure sleeping tendencies/drowsiness in drivers. Meanwhile, biological means of determining drowsiness is the best but the need to attach electrodes on to the body of the driver is the main limitation. Second mode of determining drowsiness is by the drivers' performance on the road which is measured by the velocity, the steering wheel angle and the Controller-Area Network (CAN) signals. These are affected by vehicle type, driver's experience, condition of the road, geometric characteristics, etc. The third means of drowsiness determination is by using visual assessment of the driver's face and eye appearances. The fourth means is based on measurement of the eye blinking of the driver. Irregular increase in blinking pattern is an indication of drowsiness. The driver needs to wear a glass (spectacle) which can amount to additional weight on the driver.

There are software developed to help driver to be awake. Among them are: Attention Assist, Anti-Sleep Pilot, Drive Awake, and Anti-Sleep Alarm (Suryaprasad et. al., 2005) are programs which were developed to guide against drowsiness while driving. There had been some designs which were developed to identify drowsiness in drivers. Mrudula et al. (2013) developed an algorithm for a prototype based in "Minimum Intrusion" approach for monitoring driver drowsiness, based on computer vision technique. Once drowsiness is detected, a signal is sent to engine to slow down the car. Limitation of this approach include, dependence on ambient light, optimum range required, face orientation, poor detection with the use of spectacle and the problem of multiple faces. Suganya et al., (2017) developed a computer vision-based drowsiness of driver detection algorithm which raises an alarm to alert the driver of drowsiness if discovered with the driver. It employed Raspberry Pi as its processing unit, a DC power source, a buzzer to raise alarm, camera as sensor. Delimitation factors are: time for decision making because of algorithm execution for image processing, illumination, camera hardware.

Dincer *et al.*, (2018) designed an image processing technique based embedded system that used a raspberry pi 3 module to detect driver's eyes and decide whether the driver is sleeping or not. Once sleepiness or drowsiness is identified, an alarm system is activated. The system's decision is based on Eye opening ratio. If the eye-opening ratio is below the set threshold, the alarm was activated. Subbarao and Sahithya (2019) designed a system which operates based on eye blinking frequency of the driver to determine drowsiness. Once drowsiness is detected, alarm system will be activated to alert the driver.

Existing products and designs

Devices in the market are Anti-Fatigue Alarm 1080p camera which uses camera system to monitor driver's awakeness. It rotates between 30^{o} -70^{o}, uses 3D image processing for night detection, it is

USB compatible and driven by a 12vlt battery. Another product is Vibration Anti-sleep car alarm that alerts the driver with beeps and vibration(s). it works within a range of 60º view of the user. It is without mercury and weighs 2.39 ounces and it 6”x 4.7”x2” in dimension. Third product is Anti-Sleep device for drivers with cigarette lighter which works real-time, using face recognition procedure, having 1~2s response time. It works within the range of 40~60cm distance and weight of 358g/12.6ounces.

In many of the existing design, prototypes were developed by researchers which were mostly non-invasive. Such includes eyeglasses (Soumen *et al.,* 2019, Deshmikh Iet al., 2024, Kumar *et al.,* 2023, Subbarao and Sahithya 2019). Catayag developed a wrist wearable prototype (Catayag et al., 2021) while Pathak employed a DC motor (Pathak *et al.,* 2025). Many of these designs employed eyeblink sensors for data acquisition (Kalaiani *et al.,* 2025, Ayus *et al.,* 2025, Soumen *et al.,* 2024, Deshmukh *et al.,* 2023, Kumar *et al.,* 2023, Subbarao *et al.,* Sathithya, 2019). Catayag employed pulse sensor (Catayag *et al.*, 2021) while Pathak employed Web camera with card reader (Pathak *et al.,* 2025) as sensors for capturing drowsiness. All the existing designs were DC driven.

Outputs from these devices were either as buzzer reaction (Kalaiani *et al.,* 2025, Ayus *et al.,* 2025, Pathak *et al.,* 2025, Soumen *et al.,* 2024, Deshmukh *et al.,* 2023, Kumar *et al.,* 2023), display on the Liquid Cystal Display (LCD) (Sabbarao and Sathiya, 2019). Vibrator (Ayus *et al.,* 2025, Catayag *et al.,* 2021), tactile feedbac and remote notification (*Soumen et al.*, 2024). Pathank presented the accuracy of the prototype as 99.18% (Pathak *et al.,* 2025) while other designs didn’t reflect results.

3.0 Design Methodology

The Driver Anti-Sleep System was implemented using the ESP32-CAM microcontroller with WiFi capability, IR light, LED display, buzzer, and SIM module. Each component played a specific role in the system.

ESP32-CAM: captures images of the driver’s eyes, processed them, and determined whether the driver was alert, drowsy, or asleep. The *IR Light* enables the camera to capture clear images of the eyes during nighttime or low-light driving conditions. LED Display displays real-time system feedback “Awake,” and “Drowsy”. Buzzer provides an immediate audio alert to warn the driver when drowsiness or sleep was detected. SIM Module sends SMS alerts to pre-registered emergency contacts if the driver remained unresponsive for a prolonged period.

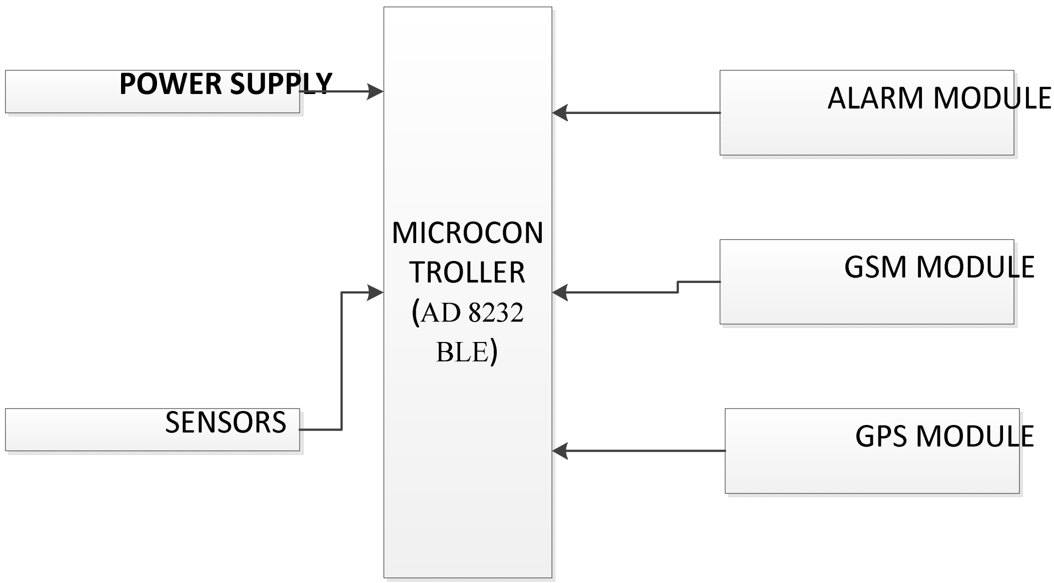


Figure 1. System Architecture

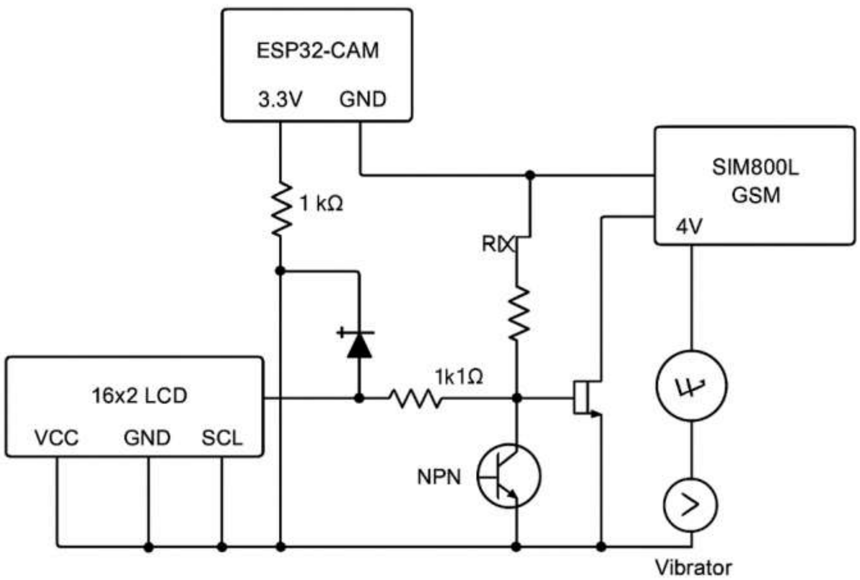
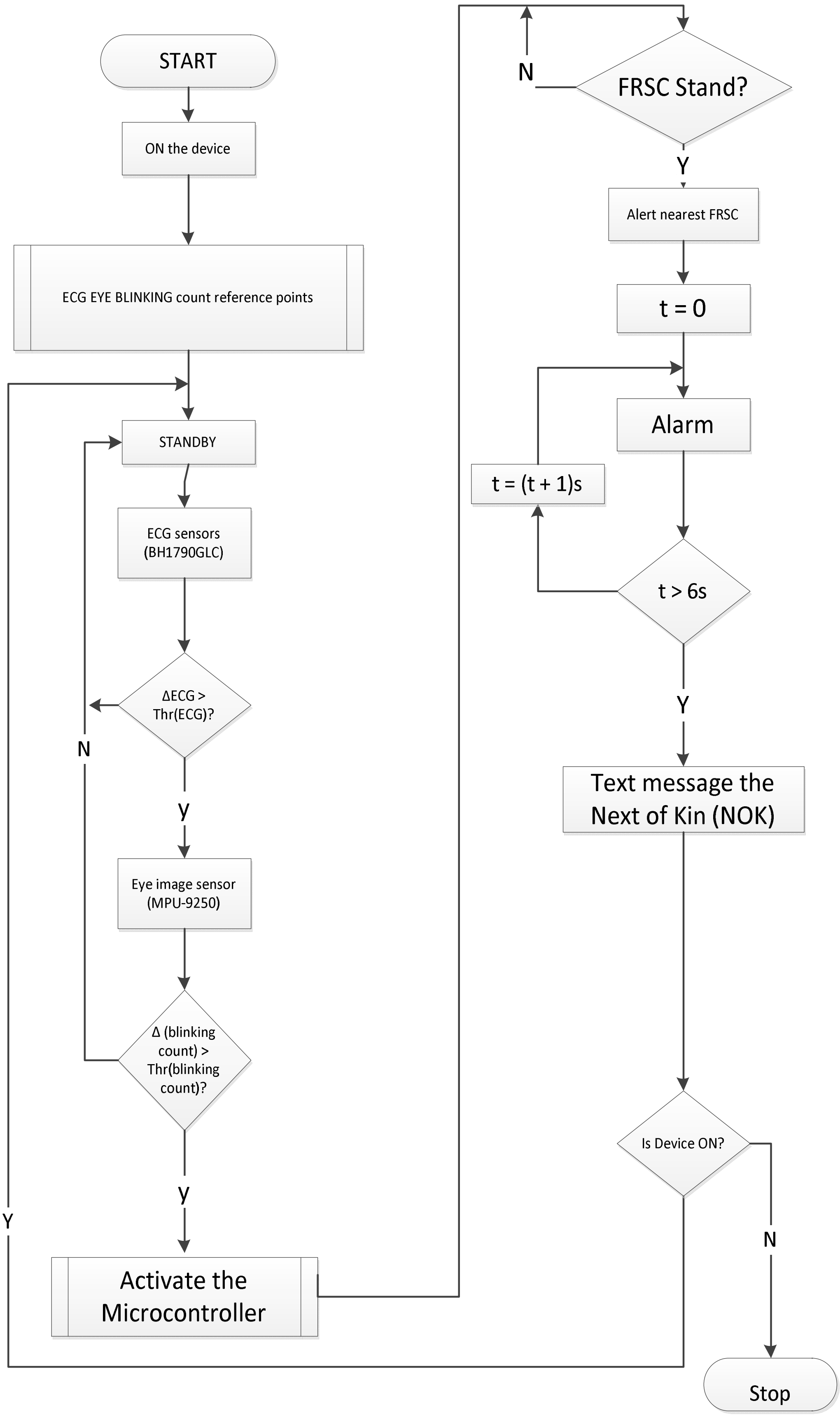


Figure 2. Circuit diagram of the device


START
ON the device
ECG EYE BLINKING count reference points
STANDBY
ECG sensors (BH1790GLC)
ΔECG > Thr(ECG)?
N
y
Eye image sensor (MPU-9250)
Δ (blinking count) > Thr(blinking count)?
y
Y
Activate the Microcontroller
N
FRSC Stand?
Y
Alert nearest FRSC
t = 0
Alarm
t = (t + 1)s
t > 6s
Y
Text message the Next of Kin (NOK)
Is Device ON?
N
Stop

4.0 Results and Discussions

Ten participants (5 male, 5 female) between the ages of 20–45 years were tested under different simulated driving conditions. Each participant was subjected to 15 trials in each condition (alert, drowsy, sleep).

Table 1. Results

Condition	Total Trials	**Detection**		Alarm	
		Correct	Missed	False	Accuracy (%)
Awake	150	144	0	6	96.00
Drowsy	150	137	13	0	91.30
Sleep	150	145	5	0	96.70
Total	**450**	**426**	**18**	**6**	**94.70**

Table 2: Response Time and SMS Alerts

Condition	Ave. Response Time(s)	SMS Triggered (%)
Alert		
Drowsy	1.5	10
Sleep	1.2	100

5.0 Conclusion and Recommendations

The developed system was able to recognize drowsy driving and sleep conditions, capturing the view of users within 60cm distance and 75^0 range view.

The system can be improved upon through 3D manufactured enclosure for portability and aesthetic. The response time can be improved upon and the remote feedback capabilities should be improved

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Appendix I

***Awake Condition Performance:** Binary Table of Awake Test (1 = Correct, 0 = Missed)*

Trial	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10
1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1
3	1	1	0	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	0	1
5	1	1	1	1	0	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	0
7	1	1	1	1	1	1	1	0	1	1
8	0	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1
10	1	1	0	1	1	1	1	1	0	1
11	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	0	1	1	1
14	1	0	1	1	1	1	1	1	1	1
15	0	1	1	0	1	1	1	1	1	1

Summary of Awake Test (15 Trials)

Person	Correct (1)	Missed (0)	Accuracy (%)
p1	13	2	86.7
p2	14	1	93.3
p3	13	2	86.7
p4	14	1	93.3
p5	14	1	93.3
p6	14	1	93.3
p7	14	1	93.3
p8	14	1	93.3
p9	13	2	86.7
p10	14	1	93.3
Total	**137**	**13**	**91.3**

Drowsy Condition Performance: ***Binary Table of Drowsy Test (1 = Correct, 0 = Missed)***

Trial	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10
1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1
6	1	1	1	0	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	0	1
8	0	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	0	1	1	1
11	1	1	1	1	1	1	1	1	1	0
12	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1

Summary of Drowsy Test (150 Trials)

Person	Correct (1)	Missed (0)	Accuracy (%)
p1	14	1	93.3
p2	15	0	100
p3	15	0	100
p4	14	1	93.3
p5	15	0	100
p6	15	0	100
p7	14	1	93.3
p8	15	0	100
p9	14	1	93.3
p10	14	1	93.3
Total	**145**	**5**	**96.7**