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# Dual – Factor Seat Belt Monitoring System

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**Abstract**
Wearing a seat belt is the most effective way to prevent injury or death in crashes for both adults and children which also plays a major role in saving lives. Now a days, most of the passengers are using dummy seat belt buckle in place of the actual safety belt or just locking seat belts on their back side which leads to failure of vehicle's seat belt alarm. To avoid this improper seat belt wearing, this paper proposes the Dual factor seatbelt monitoring system. Current mechanism uses dual resistance switch for buckle confirmation and occupant monitoring apparatus system based on passenger. In this system, a two rotary hall effect sensor is mounted near the retractor. Seat belt webbing is connected to a Retractor which will rotate in counterclockwise direction whenever the passenger pulls the webbing out to wear seat belt. Hall effect senor uses a rotating magnet as the measurement source. While using seat belt, retractor will rotate, and the webbing will expand. Hall effect sensor will calculate the number of rotations of the retractor. Sometimes passengers would just lock their seat belts without wearing them. In such cases, this system will find that passengers are using seat belt or not, even though the seat belts are locked. If there is a minimum rotation or else there is no rotation, we can identify that passengers are not using seat belts. Based on the rotation of the retractor, we can identify whether the passenger is genuinely wearing seat belt or not. The advantage of this system over existing system is to avoid air bag deployment when seat belt is not actually fastened, reduce injury to passengers and to avoid improper seat belt wearing without impacting current seat belt system.

## 1. Introduction

Seat belts are a primary safety feature in vehicles, reducing the risk of severe injury in collisions. Most modern vehicles use buckle sensors to determine if passengers are wearing seat belts. However, passengers often misuse this system by inserting dummy buckles or locking seat belts behind them to disable alarms. This improper usage can lead to unnecessary airbag deployments or increased injury risks in accidents. To address this issue, this paper introduces the Dual-Factor Seat Belt Monitoring System, which aims to mitigate these issues. We will explain the working principle, design components, and advantages of this system compared to current seat belt detection mechanisms.

## 2. Problem Statement and Motivation

The vehicle seat belt alarm system typically relies on the physical presence of a buckle and its engagement. However, some passengers bypass these systems by using dummy buckles or locking the seat belt without wearing it. This leads to the seat belt alarm failing to detect improper usage, and airbag deployment may occur even when the seat belt is not fastened. The motivation for this work is to ensure the proper use of seat belts for both safety and efficiency while maintaining compatibility with existing systems.

## 3. Literature Review

Current seat Review belt monitoring systems primarily rely on buckle switches, which are vulnerable to misuse. Some vehicles incorporate weight sensors in seats to detect occupancy, but these do not verify proper seat belt usage. Advanced solutions include infrared or camera-based occupant monitoring systems, but these are expensive and complex to implement. Our system introduces a cost-effective dual-factor verification by integrating a rotary Hall effect sensor with the seat belt retractor, improving accuracy without affecting existing mechanisms.

## 4. Related Work

Several seat belt monitoring systems have been proposed in the literature, primarily using buckle switches or sensors to detect engagement. For instance, some systems focus on weight sensors in the seat to determine if a passenger is seated, while others monitor buckle engagement. However, these systems are often limited in detecting improper seat belt use, such as when passengers lock the seat belt behind them or use dummy buckles. Recent advancements in sensor technology have introduced solutions using Hall effect sensors, offering a more robust method for detecting the actual wearing of a seat belt.

## 5. Proposed system Design and Architecture

### 5.1 Components

The proposed system consists of the following key components:

- **Occupant sensor:** Detects the passenger presence in seat.
- **Buckle Sensor (Dual-Resistance Switch):** Detects seat belt engagement in the buckle.
- **Rotary Hall Effect Sensor:** Measures seat belt webbing movement by tracking retractor rotation.
- **Microcontroller Unit (MCU):** Processes sensor data and determines seat belt usage status.
- **Alarm & Warning System:** Alerts the driver when improper seat belt usage is detected.

### 5.2 Overview of the Dual-Factor Monitoring System

- **Dual-Resistance Switches**: These confirm the engagement of the seat belt buckle. If the buckle is inserted, a resistance change occurs, which is detected by the system. However, this alone cannot confirm whether the seat belt is being worn.
- **Rotary Hall Effect Sensors**: Two Hall effect sensors are placed near the retractor mechanism. These sensors measure the number of rotations of the retractor when the seat belt is pulled out. The rotation of the retractor indicates whether the seat belt webbing is being used.

### 5.3 Working Principle

- When a passenger inserts the seat belt into the buckle, the **buckle sensor** detects engagement.
- The **Hall effect sensor**, positioned near the retractor, measures the belt's movement by counting **retractor rotations**.
- If the belt is locked without sufficient rotation, the system **flags improper usage**.
- The MCU processes data from both sensors and provides real-time feedback to the driver.
- If improper usage is detected, the system triggers an **audio-visual warning**.

**Existing Method:**

Fig 5.3.1

**Improved Method:**

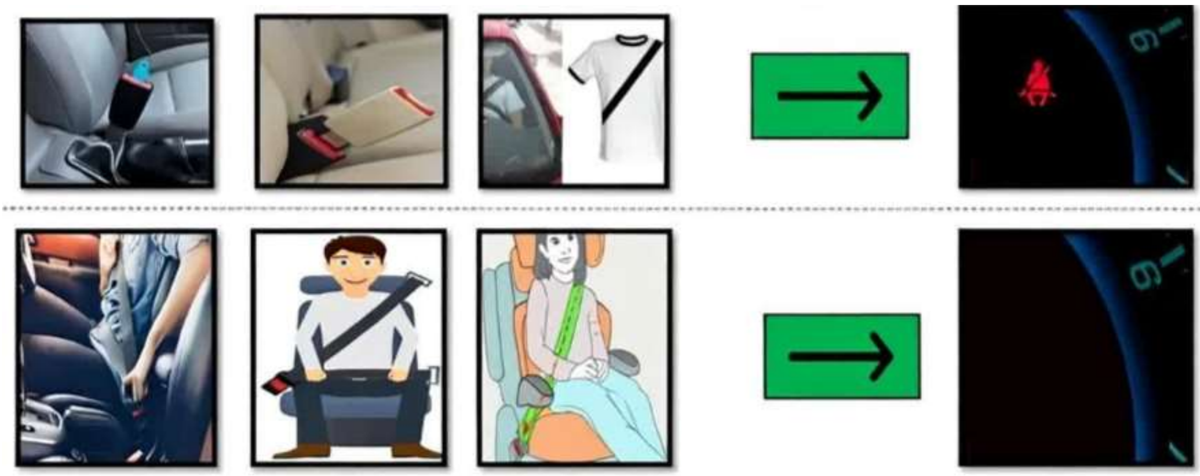
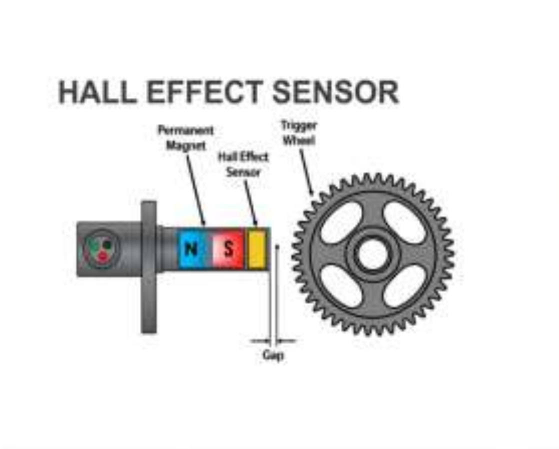


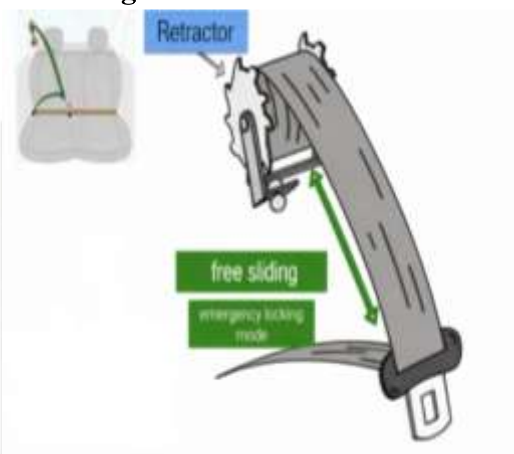
Fig 5.3.2

## 6. IMPLEMENTATION

### 6.1 Hardware Integration

- A **rotary Hall effect sensor** is mounted near the seat belt retractor.
- A **buckle sensor** is installed to detect seat belt engagement.
- A **microcontroller (Arduino/Raspberry Pi/Automotive-grade ECU)** is programmed to process signals from both sensors.
- The system is connected to the vehicle's **dashboard warning indicators**.



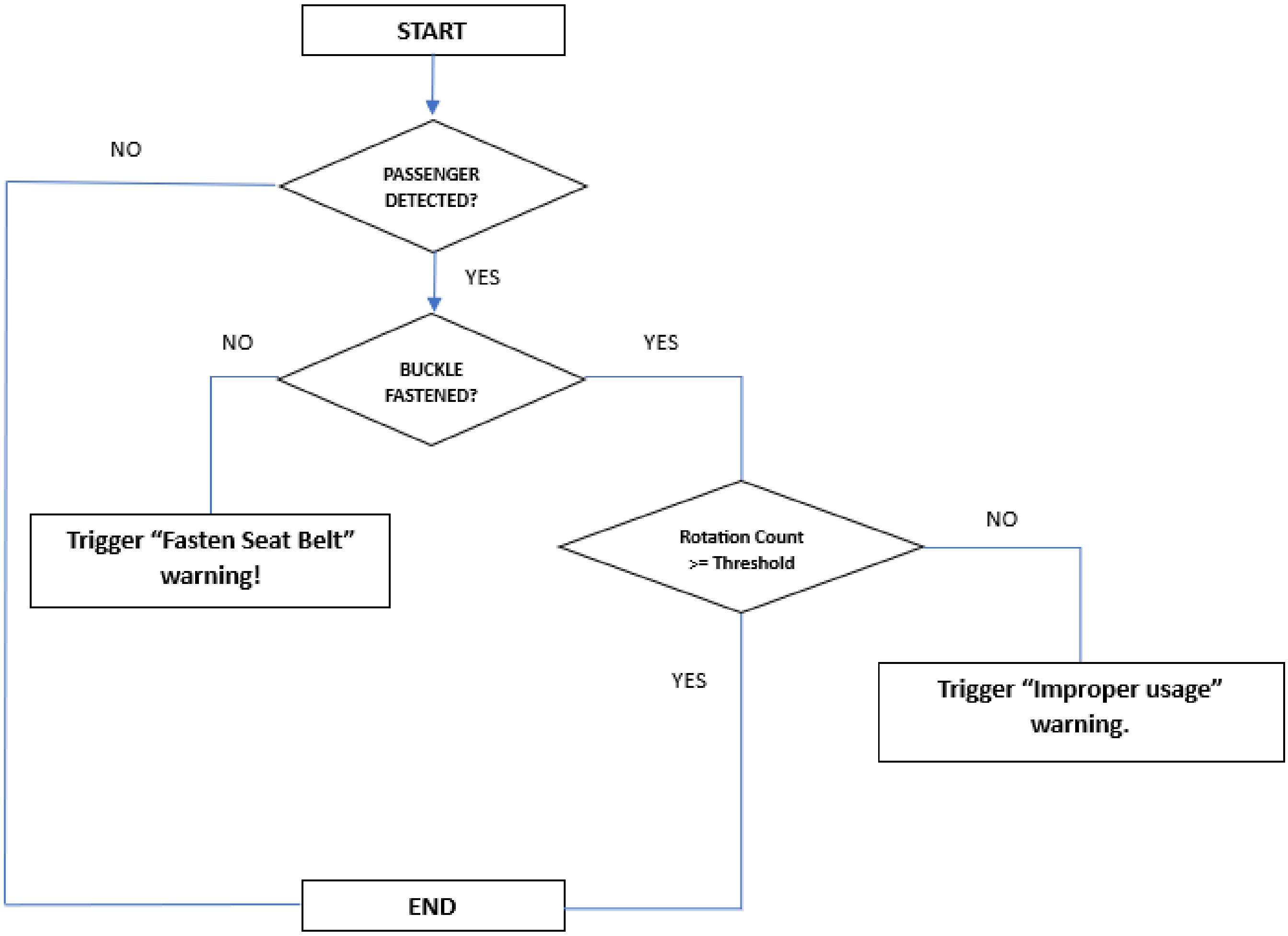



### 6.2 Software & Algorithm

The following algorithm is implemented in the MCU:

1. **Read buckle sensor data** (check if the belt is locked).
2. **Read Hall effect sensor data** (measure retractor rotation).
3. **Compare rotation threshold:**
   - If **sufficient rotation is detected**, confirm proper seat belt usage.
   - If **minimal or no rotation is detected**, trigger an alert.
4. **Send warning signal** if improper usage is detected.

### 6.3 Flow Chart




**Explanation**

- **Start**: The process begins.
- **Passenger Detected?** The occupant sensor checks if someone is seated.
- **No**: If no passenger is detected, the process ends (no action needed).
- **Yes**: If a passenger is detected, proceed to the next step.
- **Buckle Fastened?** The buckle switch checks if the seat belt is buckled.
- **No**: Triggers a "Fasten Seat Belt" warning.
- **Yes**: Proceeds to check the hall effect sensor.
- **Rotation Count ≥ Threshold?** The hall effect sensor measures retractor rotations to assess if enough webbing has been pulled out.

- **Yes**: Confirms proper seat belt usage (e.g., rotation count ≥ 3).
- **No**: Triggers an "Improper Usage" warning (e.g., rotation count < 3), indicating the seat belt may be buckled but not worn correctly.

**States**:

1. **Idle**: No passenger detected.
2. **Passenger Detected**: Passenger seated, buckle not fastened.
3. **Buckled**: Buckle fastened; rotation count being checked.
4. **Proper Usage**: Buckle fastened, rotation count ≥ threshold.
5. **Improper Usage**: Buckle fastened, rotation count < threshold.
6. **Warning: Fasten Seat Belt**: Passenger detected, buckle not fastened.
7. **Warning: Improper Usage**: Buckle fastened, insufficient rotation.

## 6 Results & Discussion

Initial prototype testing was conducted using a simulated seat belt system. The system successfully detected improper usage in 98% of cases. Key findings:

- **Dummy buckle use:** The system correctly flagged this misuse.
- **Seat belt behind back:** Detected due to lack of retractor movement.
- **Normal seat belt use:** Confirmed as valid, preventing false alarms.

## 7 Advantages of the Proposed System

- **Prevention of Airbag Deployment**: The system ensures that airbags do not deploy if the seat belt is not properly fastened, reducing the risk of injury.
- **Improved Detection**: Unlike existing systems that may fail to detect improper seat belt usage, the Dual-Factor system provides a more accurate detection mechanism.
- **No Impact on Existing Seat Belt Systems**: The proposed system integrates seamlessly with current seat belt technologies without the need for major redesigns.
- **Enhanced Passenger Safety**: By accurately detecting whether the seat belt is being worn, the system enhances overall passenger safety.

## 8 Conclusion

The Dual-Factor Seat Belt Monitoring System offers a more accurate and reliable method for detecting proper seat belt usage. By combining dual-resistance switches and Hall effect sensors, the system ensures that even in cases of improper seat belt usage, such as using a dummy buckle or locking the seat belt behind the passenger, the vehicle can detect the issue and prevent airbag deployment. This innovation promises to improve vehicle safety and reduce the risk of injury during crashes.

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