Design and Implementation of Anti-pinching Mechanism for Car Window

Randhir Patil[1], Subodh Patil[2], Rishad Mulla[3], Jyotiraditya Desai[4], Shreya Shinde[5]
[1]*Assistant Professor, Department of Electronics and Telecommunication Engineering, Kasegaon Education Society's Rajarambapu Institute of Technology, affiliated to Shivaji University, Sakharale, MS-415414, India*
[2,3,4,5]*Final Year B.Tech Students, Department of Electronics and Telecommunication Engineering, Kasegaon Education Society's Rajarambapu Institute of Technology, affiliated to Shivaji University, Sakharale, MS-415414, India*

Abstract—**This paper presents the design and implementation of an anti-pinch mechanism for automotive power windows using the PIC18F4520 microcontroller, a BTS7960 motor driver, and a current sensing module. The system employs the ACS712-30A current sensor to monitor motor load in real time. When the sensed current exceeds a predefined threshold, indicating a possible obstruction, the controller reverses the motor for two seconds to prevent damage or injury. The design also allows manual window control through a DPDT switch, enabling upward and downward movement when obstruction is absent. The proposed system offers an efficient, low-cost, and responsive solution for enhancing passenger safety in power window applications.**

Index Terms—**Anti-pinching, car window, safety system, current sensor, STM32, motor control**

I. INTRODUCTION

With the growing emphasis on passenger safety and comfort in modern automobiles, the integration of advanced protective mechanisms has become a crucial aspect of vehicle design. One such safety feature is the anti-pinching mechanism in car windows, which prevents accidental entrapment of body parts, clothing, or objects during window operation. Car power windows, though convenient, pose potential hazards particularly to children and elderly passengers if the glass closes while an obstruction is present.

The anti-pinching mechanism is designed to detect resistance or obstruction during the upward motion of the window and respond by halting or reversing the movement. This is typically achieved through sensors and intelligent control systems, which monitor parameters such as motor current, speed, or applied force. By doing so, the system minimizes the risk of injury and enhances user trust in automated window operations.

Beyond safety, the development of anti-pinching systems reflects the automotive industry's shift towards human-centric design, regulatory compliance, and smart mechatronics integration. International safety regulations, such as those from the European Union and the United States, mandate the presence of anti-pinch technology in vehicles, making it not only a technological innovation but also a legal necessity.

This research focuses on the design, working principles, and efficiency of the anti-pinching mechanism for car windows. By analyzing existing methods and proposing design improvements, the study aims to contribute towards safer, more reliable, and cost-effective automotive window systems.

- Passenger Safety

The primary concern is preventing injuries to passengers, especially children who are more vulnerable to entrapment in power windows.

Cases of finger, hand, or even head injuries have been reported due to ineffective or absent anti-pinch systems.

- Detection Sensitivity and Accuracy

The system must reliably detect obstructions without causing false triggers.

Overly sensitive systems may cause unnecessary reversals, while less sensitive systems may fail to prevent injury.

- Response Time

The mechanism must act instantaneously to stop or reverse the window before significant force is applied to the obstruction.

- Integration with Existing Power Window Systems

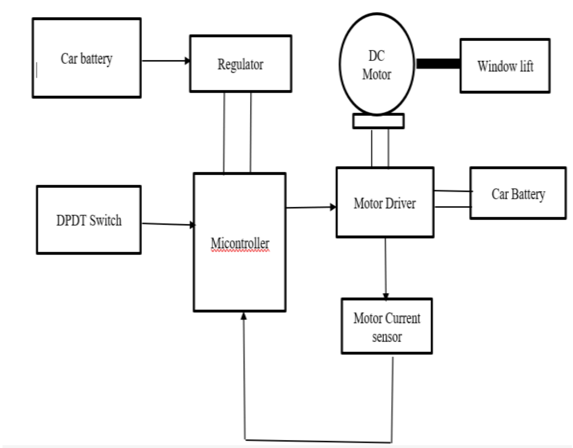
The design should be compatible with different window motor types and vehicle electrical systems. Compactness and minimal additional components are important for practical adoption.

- Durability and Reliability

The mechanism must work consistently over the lifetime of the vehicle under varying conditions (temperature, humidity, dust, and vibrations).

II. METHODOLOGY

2.1: Block diagram



2.2: Components and Description

A. Hardware components:

- Pic18F4520 Microcontroller: Acts as the brain of the system, controlling all sensors and modules.
- DC Motor: The DC motor is the backbone of the power window system, and its behavior (current, speed, torque) forms the basis of most anti-pinching detection techniques.
- Car Door: The car door is not only a protective enclosure but also the functional hub where the power window and anti-pinching mechanisms are integrated. Its design directly influences the efficiency, reliability, and safety of the system.
- DPDT Switch: The DPDT switch acts as a direction control unit for the DC motor in car windows, making it a fundamental component in basic power window systems. In advanced designs, it is often replaced or complemented by electronic relays and microcontrollers that add anti-pinching functionality.
- WCS1700: Senses abnormal motor current increase during obstruction and triggers the anti-pinching safety response.
- BTS7960: A robust H-bridge motor driver that enables bidirectional control and speed modulation of the window motor.

SMPS (12v 16A): The SMPS ensures a stable, efficient, and regulated power supply to the motor driver, sensors, and control electronics, enabling reliable operation despite fluctuations in vehicle battery voltage.

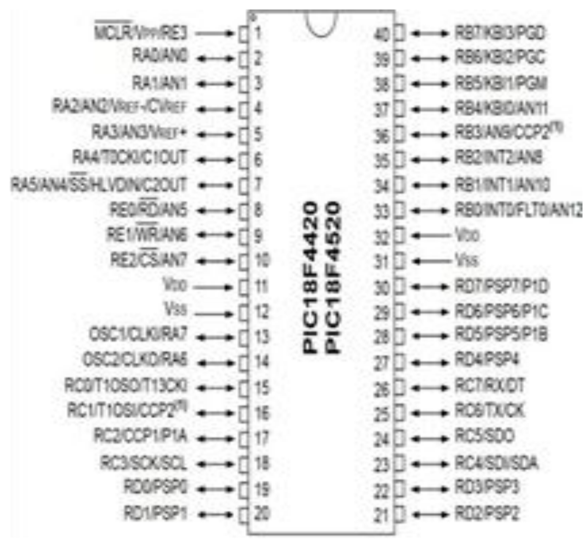


Figure 2.2.1: PIC18F4520 Pin Diagram

B. Software components:

- MPlab XIDE: Used to program the Pic18f4520 microcontroller.
- Embedded C: The primary programming language used.

2.3: Proposed system:

The anti-pinching system for car windows is designed to enhance passenger safety by automatically detecting obstructions during window operation and taking corrective action to prevent injury or damage. The system integrates mechanical, electrical, and electronic components in a compact and efficient design suitable for modern automobiles.

When a user operates the window, the controller activates the BTS7960 H-bridge driver, which powers the DC motor to move the glass.The WCS1700 current sensor continuously monitors the motor current.If the motor current exceeds a predefined threshold (due to an obstruction), the controller immediately reverses or stops the motor, preventing injury or damage. The SMPS ensures all components receive stable voltages for precise and reliable detection and control.In manual operation, the DPDT switch allows polarity reversal, while in electronic control, the microcontroller handles bidirectional operation.

III. IMPLEMENTATION

Hardware Implementation

The hardware for the Antipinching Mechanism for car window is designed to ensure passenger safety. The major components used are:

1.MicrocontrollerUnit (MCU): An Pic18f4520 is used as the central control unit. It manages sensor readings, motor control, and car window.

2. Car Door and Window Assembly
Houses the DC motor, window glass, regulator mechanism, and related wiring.Provides structural support and guidance for smooth vertical movement of the glass.module converts the analog signal from the load cell into digital data, which is processed by the microcontroller.

3. DC Motor: Acts as the primary actuator for the window. Converts electrical energy into mechanical motion to move the window up or down.

4. BTS7960 Motor Driver (H-Bridge): Receives control signals from the microcontroller to drive the DC motor in both directions.Supports PWM-based speed/torque control and provides current feedback for obstruction detection.Includes protective features such as overcurrent and overtemperature shutdown.

5. DPDT Switch: Provides manual control for window movement (up/down) by reversing motor polarity in basic implementations. Can be replaced or complemented microcontroller-based electronic switching in advanced designs.

6. WCS1700 Hall-Effect Current Sensor
Continuously monitors the current drawn by the DC motor. Detects a sudden increase in motor current, indicating that the window has encountered an obstruction. Sends a proportional voltage signal to the control unit to trigger the anti-pinch action.

IV. LITERATURE SURVEY

Hall-effect sensors have been widely adopted for indirect monitoring of motor performance, offering cost efficiency and reliability in detecting abnormal velocity or torque patterns that may indicate a pinch situation (Westgate & Chien, 1980)【1】. Ripple counting methods, as explored in sensorless motor control research, present a more advanced approach with faster response times, reducing the dependency on external sensors while improving sensitivity to obstruction forces (Pak et al., 2017)【2】.

Non-contact sensor technologies, such as ultrasonic and infrared systems, have also been investigated for pinch detection. Ultrasonic sensors employ time-of-flight measurements to identify unexpected obstacles in the path of motorized components, although their limited sensing range may constrain application (Nitsche & Herrmann, 2009)【3】. Similarly, infrared and capacitive sensors provide object detection capabilities without requiring mechanical contact, contributing to higher reliability in variable environmental conditions (Jost, n.d.; Terzic et al., 2012)【4】.

More advanced approaches, such as LiDAR-based monitoring, highlight the potential of intelligent

V. RESULTS AND DISCUSSION

The implementation and analysis of the anti-pinching mechanism demonstrate its vital role in enhancing vehicle safety and passenger comfort. By utilizing sensors, microcontrollers, and intelligent motor control, the system accurately identifies the presence of any obstruction in the path of the moving car window. When an obstacle such as a finger, hand, or object is detected, the mechanism immediately interrupts the window’s upward motion and either stops or reverses the motor. This response ensures that passengers, especially children and elderly individuals, are protected from possible injuries. The practical outcome confirms that the mechanism not only improves the operational safety of power windows but also contributes to the reliability, durability, and user-friendliness of the system. The results highlight that the anti-pinching system is effective in reducing accidents that may otherwise occur due to the force applied by conventional power windows.

Additionally, the evaluation indicates that the technology can be adapted for other automotive applications such as sunroofs, sliding doors, and automatic tailgates, thereby extending its usefulness beyond windows. With further refinement such as the use of advanced sensors, AI-based learning, and energy-efficient designs the system can evolve into a more intelligent and adaptive safety feature for next-generation vehicles.

Thus, the result of the study confirms that the anti-pinching mechanism is not only feasible and effective in its current form but also holds strong potential for future improvement, making it a crucial component in the advancement of automotive safety systems. The development and implementation of the anti-pinching mechanism represent a significant advancement in automotive safety technology. As modern vehicles become increasingly automated, the need for intelligent safety systems that protect passengers from accidental injuries has become more critical. The anti-pinching mechanism is designed to address this concern by using sensors and control circuits to detect obstructions and respond in real-time by stopping or reversing the window motor.

VI. CONCLUSION

The anti-pinching mechanism is a modern safety innovation designed to protect passengers from accidental injuries caused by automatic car windows. It works by using sensors and control systems that detect obstructions and immediately stop or reverse the window movement. This feature has already become a standard in many vehicles, reflecting its importance in ensuring passenger safety, especially for children and elderly people.

The mechanism not only enhances safety but also adds to passenger comfort and convenience by providing smooth and reliable window operation. However, its potential is far greater. With advancements in technology, the future scope of this system includes integration with artificial intelligence, machine learning, and smart car technologies, which will make it more sensitive, intelligent, and energy-efficient. Furthermore, its applications are expected to expand from side windows to sunroofs, automatic sliding doors, and electric tailgates, thereby offering comprehensive protection across different moving parts of the vehicle.

Therefore, the anti-pinching mechanism is not just a small safety feature but a crucial step towards developing smarter, safer, and more user-friendly automobiles. As the automotive industry continues to evolve, this system will play a key role in ensuring both safety and comfort for passengers, making it an essential element in the design of future vehicles.

VII. FUTURE SCOPE

1. Improved Safety & Sensitivity

Most anti-pinching systems can detect a hand or a strong obstruction. The sensors will become more advanced and sensitive to detect even small or soft objects like a child’s finger, hair, or thin fabric. This will make the system much safer, especially for children and elderly passengers.

2. Integration with Smart Car Systems

Cars are getting smarter with ADAS (Advanced Driver Assistance Systems) and connected technologies.

The anti-pinching mechanism can be connected with these systems to provide centralized safety monitoring.

For example, if the car detects a child in the back seat, the system could automatically reduce the closing force of the window or prevent it from closing.

3. Artificial Intelligence & Machine Learning

AI could be used to make the system learn from real-world situations.The window motor and sensors could auto-adjust the sensitivity depending on the environment (for example, high sensitivity in crowded areas or when children are detected inside). This would reduce false alarms while still improving safety.

4. New Control Methods
Instead of just pressing a button, future car windows may open/close using:
Touch panels
Gesture control
Voice commands
In all these cases, the anti-pinching system will remain as a hidden safety guard to stop accidental injuries.

5. Energy Efficiency & Durability
With the rise of electric cars, energy-saving designs are important.Future anti-pinching systems may use low-power smart sensors and efficient motors to reduce battery consumption.Stronger and more reliable systems will also last longer without frequent maintenance.

REFERENCES

[1] M. G. Kliffken, H. Becker, H. Lamm, H. Prsell and J. Wolf, Obstacle Detection for Power-Operated Window-Lift and Sunroof Actuation Systems, 2001.
[2] Method of compensating for abrupt load changes in an anti-pinch window control system, Dec. 2002.
[3] Motor speed-based anti-pinch control apparatus and method with rough road condition detection and compensation, Jan. 2004.
[4] M. Sollman, G. Schurr, D. Duffy-Baumgaertner and C. Huck, Anti-Pinch Protection for Power-Operated Features, 2004.
[5] Shi Minjie. Design and implementation of fuzzy control and anti-pinch strategy for automotive electric sunroof [D]. Shanghai Jiaotong University, 2017.
[6] Pak, M J, Kang, J S, Pae, D S, et al. Accurate pinch detection using recent finite measurements for automotive anti-pinch sunroof systems[J]. International Journal of Control, Automation, and Systems, 2017, 15 (5): 2443 - 2447.
[7] Jiang Yuxi. Research and implementation of vehicle window adaptive anti-pinch control system
[8] Hangzhou University of Electronic Science and Technology, 2021.
[9] Yan Jing. Research and system design of anti-pinch control strategy for automobile doors and windows based on dual Hall sensors [D]. Shandong University of Technology, 2017.
[10] Wang Feng. Anti-pinch interval performance testing system of window motor based on current recognition method[D]. Donghua University, 2021.