Smart Window System in Automobiles for Obstruction Detection.

Mr.VAIBHAV B PATIL
Dept.of Electrical and Electronics
BNM Institute Of Technology
Bengaluru, India
Vaibhav1234pala@gmail.com

Mr.PARAAG V
Dept.of Electrical and Electronics
BNM Institute Of Technology
Bengaluru, India
paraagvilas1978@gmail.com

Mr.PRATHEEK J
Dept.of Electrical and Electronics
BNM Institute Of Technology
Bengaluru, India
pratheekjgowda@gmail.com

Mrs.Champa P.N.
Dept.of Electrical and Electronics
BNM Institute Of Technology
Bengaluru, India
champa.pn@gmail.com

***Abstract*—Child safety is a paramount concern when it comes to power windows in vehicles. The act of obstructions being detected near closing windows poses a significant risk, resulting in a considerable number of emergency room visits and, tragically, even fatalities. This proposal aims to address this critical issue by proposing the design and development of an advanced system that can detect obstructions near power windows. The system's primary objective is to identify the potential entanglement risk and automatically activate a relay mechanism to reverse the window's direction, thus mitigating the risk of pinch or trapping incidents. Based on a National Highway Traffic Safety Administration (NHTSA) study, it has been estimated that power windows contribute to approximately 2,000 emergency room visits annually. The force exerted by power windows is capable of causing severe injuries, including bone fractures, crushing injuries, and the potential for strangulation. While most power window-related injuries typically result in damage to a child's finger or arm, the NHTSA has reported five tragic deaths within a one-year period caused by power window accidents. To address this urgent issue, a comprehensive system is proposed that utilizes advanced sensing technologies to detect obstructions in close proximity to power windows. Once a potential entanglement risk is detected, the system activates a relay to swiftly reverse the window's direction. This proposed system can be seamlessly integrated with existing power window mechanisms in vehicles, ensuring an efficient and user-friendly implementation. Implementing this innovative system has the potential to significantly reduce the occurrence of power window-related injuries, emergency room visits, and fatalities. By proactively detecting and automatically reversing window movements, the proposed solution aims to prioritize the safety of individuals, particularly children, in vehicular environments. In conclusion, the development and implementation of a sophisticated system to detect and prevent power window-related injuries is necessary. By addressing the risks associated with obstruction detection, this system offers the potential to save lives, minimize emergency room visits, and mitigate the physical and emotional toll inflicted by power window accidents.**

Keywords*— Power windows, Child safety, Obstruction detection, Entanglement, Safety mechanisms, Emergency visits, Fatalities, Sensing technology, Window reversal, Injury prevention

I. INTRODUCTION

What is Power Window? A power window is a car window that is raised and lowered by a motor that is controlled by a switch. Many power windows have a variety of added features such as one-touch opening, lockout switches, and "courtesy power on.

Working of Power Window The power window is operated by means of Lifting mechanism. The window lift on most of cars uses a really neat linkage lift the window glass while keeping it level. A small electric motor is attached to a worm gear and several other spur gears to create a large gear reduction giving it enough torque to lift the window. An important feature of power window is that it cannot be forced open. The worm gear in the drive, mechanism takes care of this. Many worm gears have a self -locking feature because of the angle of contact between the worm and the gear. The worm can spin the gear, but the gear cannot spin the worm, friction between the teeth causes the gears to bin.

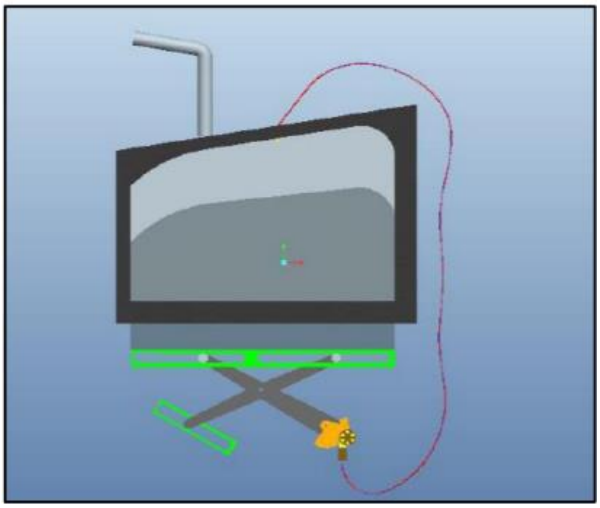

Fig 1.1: Power Window

II. LITERATURE SURVEY

A. "Federal Motor Vehicle Safety Standards; Power-Operated Window, Partition, and Roof Panel Systems

Agency: National Highway Traffic Safety Administration, Agency/Docket Number: Docket No. NHTSA 2004-19032,Date :15/09/2004 This final rule mandates that power-operated windows, partitions, and roof panel systems in new vehicles must have switches resistant to accidental actuation. It aims to prevent injuries by avoiding unintentional closure. Manufacturers meeting automatic reversal requirements are exempt from this rule, which denies petitions for mandatory automatic reversal systems in power windows and roof panel systems.

B. "Design of intelligent window opening system based on multi-sensor fusion.

Wenhao Zhou1 , Yong Huang1 , Xianbo Sun1 , Jingqiao Yi1 , Lin Gao1 , Shuxian Liang2 and Jiancong Ye2 , International Conference on advanced mechanical, electronic and electrical engineering (ICAMEE 2022) 26/08/2022 - 28/08/2022 Qingdao, Volume 2396, China, Citation Wenhao

Zhou et al 2022 J. Phys.: Conf. Ser. 2396 012039,DOI 10.1088/1742-6596/2396/1/012039.

This project aimed to develop an intelligent car window integrated with multiple sensors. The outcome was a reliable and stable electric window opener control system, incorporating sensor fusion and PID control for accurate window opening. The integration of IoT and sensor technology allowed for automatic control and remote operation, enhancing the versatility and market appeal of the electric window opener.

C. Design and Fabrication of Automated Child Safety Power Windows

S. Gopinath1 , K Kandasamy2 and R. Prabhu3 , International Journal of Production Technology and Management (IJPTM), 08(1), 2017, pp. 28–32.

"Automated Child Safety Power Windows" project focuses on addressing breathing difficulties caused by locked car windows, especially for children. By utilizing oxygen sensors, the system automatically opens the windows slightly when oxygen levels decrease, ensuring passenger safety. The concept of using oxygen sensors to control the windows inspired the incorporation of an ultrasonic sensor for obstruction detection in our project.

D. Ultra-Sonic Sensor based Object Detection for Autonomous Vehicles

Tommaso Nesti1 , Santhosh Boddana2 , Burhaneddin Yaman3, 1Bosch Centre for Artificial Intelligence, USA 2Bosch Centre for Artificial Intelligence, India, CVPR (Conference on Computer Vision and Pattern Recognition) workshop paper,2023, pp. 210-218.

In this project, a pioneering ultrasonic sensor-based object detection system is presented. The system demonstrates exceptional accuracy in detecting objects in low-speed scenarios. Due to the aforementioned advantages, we opted for the selection of the ultrasonic sensor in our obstruction detection project. The sensor's cost-effectiveness, durability, and resilience in detecting nearby objects even in challenging weather conditions were key factors in our decision.

III. METHODOLOGY

The implementation was initiated by fabricating an accurate representation of an actual car window. To achieve this, a frame was meticulously constructed using a composite material comprising fibre and glass, accurately mimicking the appearance and dimensions of a car window pane.

Subsequently, the project advanced to orchestrating the dynamic movement of the glass within the fabricated frame. This necessitated the strategic placement of high-torque DC motors, meticulously aligned with a precisely-calibrated rack and pinion gear mechanism. The precise positioning of these components was instrumental in achieving the desired window movement.

In the subsequent phase, the project required the procurement of essential electronic components to enable the functional implementation. The decision was made to leverage the capabilities of an Arduino microcontroller for intelligent control. Furthermore, an ultrasonic sensor was chosen as the means to detect nearby objects. A portable power bank was enlisted as the primary power source, ensuring operational autonomy. To facilitate the requisite forward and reverse actions of the motors, relay modules were integrated. A notable challenge encountered was the inherent high speed of the selected motors. To address this challenge and ensure controlled motion, a Pulse Width Modulation (PWM) module was ingeniously integrated to govern and regulate the motor speed effectively.

In essence, the project methodology meticulously encompassed the stages of conceptualization, physical realization, component selection, and technical integration. Each phase was executed with meticulous precision, aligning with professional standards, and culminating in the creation of an advanced and automated car window system.

IV. SYSTEM DESIGN/ARCHITECTURE

A. Block Diagram

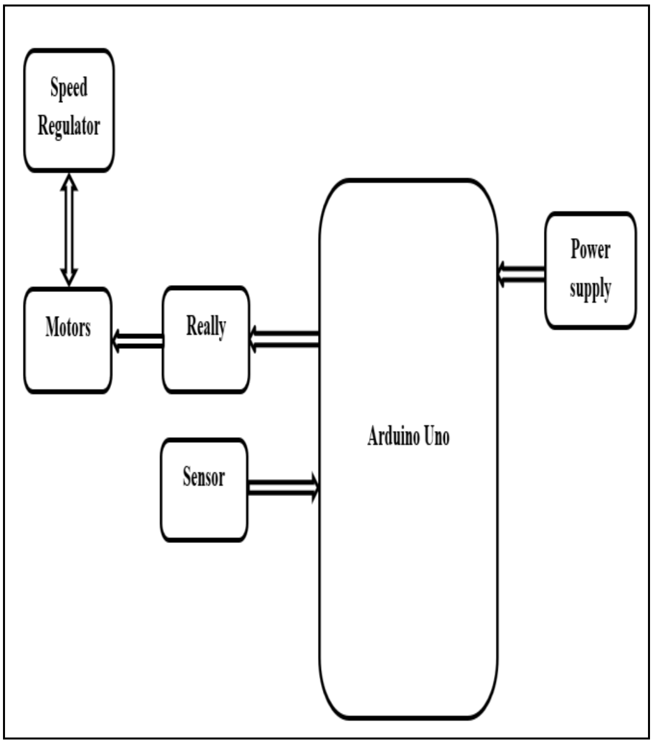

Fig 4.1: Block Diagram

The block diagram presented below in Fig 4.1 illustrates how the project will be built. The Li-ion battery supplies power to all components. The Arduino Uno functions as the project's central processing unit. It receives input from the ultrasonic sensor (HC-SR04). The output voltage of the battery is 12V, which is sufficient to power the 1203B PWM module, 2-channel 5V relay module,2- (3-12V) dual-shaft BO motor which is used to forwarding and reversing action of the glass window.

B. Hardware

1. Microcontroller (Arduino Uno):

The Arduino Uno was a remarkable choice for our Object detection project, offering exceptional capabilities and performance. Its versatility and ease of integration enabled seamless incorporation into our device, while operating with low power consumption. We were able to program the Arduino Uno effortlessly to effectively acquire and analyse sensor data for object detection and calculating the distance at which the object is present, ensuring precise and dependable results. With the Arduino Uno at the core of our project, we achieved a cost-effective and highly efficient Object detection model. Fig 4.2 visually represents the implementation of the Arduino Uno, and the accompanying table provides detailed specifications.

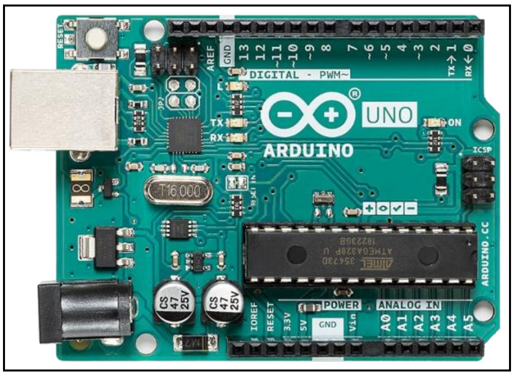

Fig 4.2: Arduino Uno

Table 1: Technical Specifications of Arduino Uno

Board	Name	Arduino UNO R3
	SKU	A000066
Microcontroller	ATmega328PT	
USB connector	USB-B	
Pins	Built-in LED Pin	13
	Digital I/O Pins	14
	Analog input pins	6
	PWM pins	6
Communication	UART	Yes
	I2C	Yes
	SPI	Yes
Power	I/O Voltage	5V
	Input voltage (nominal)	7-12V
	DC Current per I/O Pin	20 mA
	Power Supply Connector	Barrel Plug
Clock speed	Main Processor	ATmega328P 16 MHz
	USB-Serial Processor	ATmega16U2 16 MHz
Memory	ATmega328P	ATmega328P
Dimensions	Weight	25 g
	Width	53.4 mm
	Length	68.6 mm

2. 5V Dual-Channel Relay Module:

The 5V Dual-Channel Relay Module played a pivotal role in the aforementioned project. With its capability to control two independent circuits, it provided a reliable and efficient solution for reversing the direction of the motor when a hand or object was detected during the power window closing process. By receiving signals from the Arduino microcontroller, the relay module effectively switched the motor's rotation to prevent any potential accidents or injuries. Its compact design and compatibility with a 5V power supply made it easily integrated into the system. The use of the 5V Dual-Channel Relay Module added an extra layer of safety and control, ensuring the smooth and secure operation of the power window.

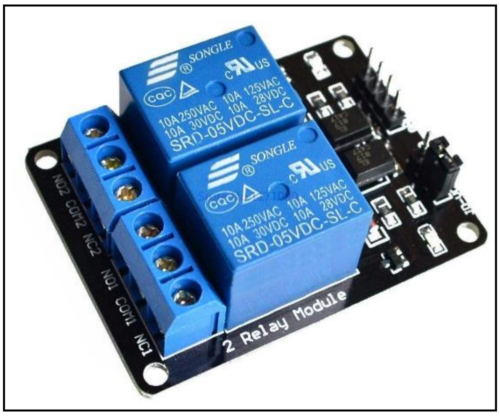

Fig 4.3: Relay Module

Table 2: Technical Specifications of Relay Module

Parameters	Technical Specs
Supply voltage	3.75V to 6V
Trigger current	5mA
Current when relay is active	~70mA (single), ~140mA (both)
Relay maximum contact voltage	250VAC, 30VDC
Relay maximum current	10A

3. DC Motor Speed Regulator

The 1203B PWM Motor Speed Regulator played a vital role in the project described above. With its ability to regulate the speed of DC motors, it offered precise control over the motor's rotation during the power window closing process. By connecting the PWM module to the motor, it allowed for smooth and controlled movement, ensuring the window closed at an optimal speed. The module's compatibility with various voltage ranges (6V, 12V, 24V, and 28V) made it suitable for different motor configurations used in the project. The 3A current rating provided ample power for driving the motor efficiently. Incorporating the 1203B PWM Motor Speed Regulator enhanced the overall functionality of the system, enabling accurate and customizable control over the motor's speed for a safer and more controlled power window operation.

PWM, or Pulse Width Modulation, is a modulation technique commonly used in electronics and control systems. It involves varying the width of pulses in a signal while keeping the frequency constant. By adjusting the pulse width, PWM can control the average power delivered to a device, such as a motor or LED, allowing precise control over its behaviour. PWM finds applications in motor speed control, dimming LEDs, and energy-efficient power delivery. It's a fundamental technique for achieving analog-like control using digital signals.

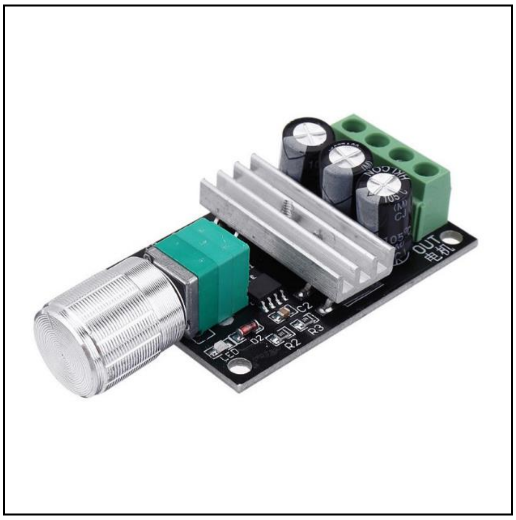

Fig 4.4: Speed Regulator

Table 3: Technical Specifications of PWM module

Parameters	Technical Specs
Voltage range	DC6V – 28V
Current range	Within 3A
Switch function	None
Speed range	0-100%
Dimension	65 x 30 x 15mm
Weight	25 g

4. 200 RPM Dual Shaft BO Motor -Straight

The 200 RPM Dual Shaft BO Motor played a crucial role in the aforementioned project. Its straight configuration allowed for direct and efficient power window operation. With a rotation speed of 200 RPM, it provided an optimal balance between speed and torque for the closing process. The dual shaft design offered versatility and flexibility for connecting other components, such as the relay module and PWM regulator, enabling smooth integration into the system. The motor's reliable performance ensured the power window closed effectively and safely. Overall, the 200 RPM Dual Shaft BO Motor proved to be an essential component in achieving the desired functionality of the power window system.

Fig 4.5: Dc motor

Table 4: Technical Specifications of Dc Motor

Parameters	Technical Specs
Operating Voltage (VDC)	3~12
Shaft Length (mm)	8.5
Shaft Diameter (mm)	(Double D-type) 5.5
No Load Current	40-180mA.
Rated Speed (After Reduction)	200 RPM
Rated Torque	0.55 Kgcm
Weight (gm)	30
Dimensions in mm (LxWxH)	70 x 23 x 19
Gearbox Shape	Straight (Dual Shaft)

5. Ultrasonic sensor-HC-SR04

The HC-SR04 Ultrasonic Sensor played a critical role in the mentioned project. It served as a key component for detecting hands or objects during the power window closing process. The sensor utilized ultrasonic waves to measure the distance between the sensor and any obstruction, enabling the system to determine if there was a potential safety hazard. With its accurate distance measurement capabilities and reliable performance, the HC-SR04 Ultrasonic Sensor ensured the timely detection of obstructions, triggering the necessary actions to reverse the motor's direction and prevent accidents. Its integration into the project enhanced the overall safety and functionality of the power window system.

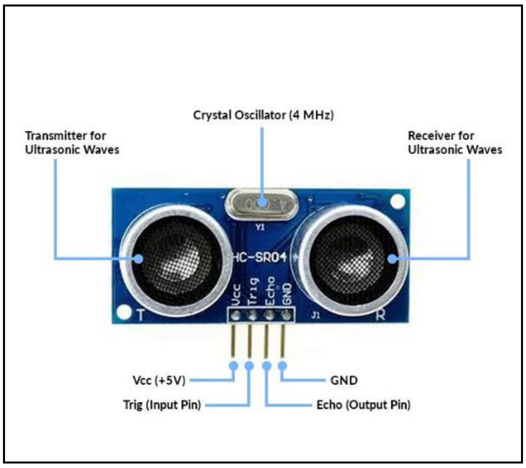

Fig 4.6: Ultrasonic Sensor

Table 5: Technical Specifications of Ultrasonic Sensor

Parameters	Technical Specs
Power Supply	3.3V – 5V
Operating Current	8mA
Working Frequency	40Hz
Ranging Distance	3cm – 350cm/3.5m
Resolution	1 cm
Measuring Angle	15°
Trigger Input Pulse width	10uS TTL
Dimension	50mm x 25mm x 16mm

6. Rack and Pinion gear

The Rack and Pinion gear mechanism played a significant role in the aforementioned project. It provided a reliable and efficient means of converting rotational motion into linear motion for the power window system. The rack, a straight gear-like component, was attached to the moving window, while the pinion, a small gear, engaged with the rack. As the pinion rotated, it caused the rack to move in a linear direction, resulting in the opening or closing of the power window. The Rack and Pinion gear mechanism offered precise and controlled movement, ensuring smooth operation of the power window. Its durability and effectiveness made it an essential component in achieving the desired functionality of the system.

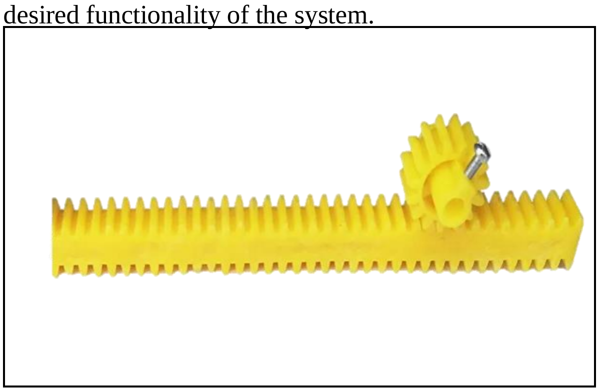

Fig 4.7: Rack and Pinion gear

7. Li-ion battery

The Li-ion battery 18650-2000mAh 7.4Wh as shown in Fig 4.8 and specifications are given in table 5 is used in this device is a rechargeable and lightweight power source that provides extended power to the device's components. A TP4056 charging module is used for safe and efficient charging, ensuring the battery's long lifespan.

Fig 4.8: Li-ion battery

Table 5: Technical Specifications of Li-ion Battery

Parameters	Technical Specs
Parameters	Technical Specs
Model Number	18650 Li-ion Cell 3.7V 2000mAh 7.4WH Rechargeable
Type	Lithium
Voltage	3.7 V
Capacity Rating	800
Capacity	2000 Ah

8. 3S x 18650 three-series lithium battery holder

The 18650 three-series lithium battery holder as shown in Fig 4.9 is a device that securely holds a single 18650 lithium-ion battery. It is commonly used in portable electronic devices due to its convenience and compatibility with popular batteries.

Fig 4.9: Lithium battery holder

C. *Software*

1. Arduino IDE:

Arduino IDE (Integrated Development Environment) is a programming prototype which can let the user draft various kinds of programs and load them into the Arduino microcontroller. We can also be programmed by using other IDEs too, like Eclipse. Arduino IDE is more versatile. This Arduino IDE needs no special drivers or additional components. This is available for Windows, Linux and Mac. Cross compiler-compiles for a different target platform than the one being programmed. The logo of Arduino IDE is shown below in Fig 4.10. Arduino IDE is required to write the program into the Arduino Uno.

ARDUINO

Fig 4.10: Logo of Arduino IDE

V. Implementation:

A. *Work flow of System :*

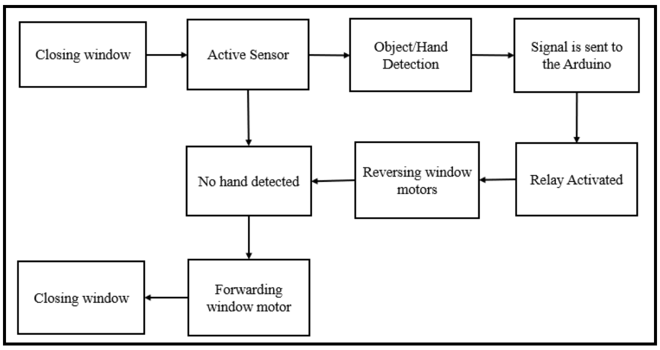

Fig 5.1 Work flow of the System

The workflow of the system is illustrated through a comprehensive block diagram, depicting the processes involved in both normal and abnormal conditions during window operation.

1. Normal Condition:

In a typical scenario, when the window operation is initiated, the process commences with the activation of the ultrasonic sensor. The sensor sends out an ultrasonic pulse which travels toward the closing window. Upon encountering an unobstructed path, the ultrasonic pulse reflects back to the sensor. This absence of an obstruction is detected, leading to the initiation of the forwarding process of the window motors. The window motors receive the signal and engage to drive the window in the desired direction, allowing it to close seamlessly.

2. Abnormal Condition - Obstruction Detection:

During abnormal situations, such as an obstruction within the window's path, the workflow adjusts accordingly. Once the ultrasonic sensor is activated, it sends out the ultrasonic pulse toward the closing window. However, in the presence of an obstruction, the ultrasonic pulse reflects back prematurely. The sensor detects this obstruction and promptly signals the Arduino microcontroller. Subsequently, the relay module is activated, causing the window motors to reverse their direction. This reversal allows the window to retract and clear the obstruction.

3. Resuming Normal Operation - Obstruction Clearance:

Following the reversal of the window motors, the ultrasonic sensor continues its operation, sending out pulses toward the now-retracting window. Once the obstruction is cleared, the ultrasonic pulse reflects back without interruption. The sensor detects this absence of an obstruction and triggers the resumption of the normal window operation. The relay module responds by forwarding the window motors, which proceed to close the window as initially intended.

B. Algorithm

1. Define constants for pin assignments and distance thresholds.
2. Set up pin modes and initial states for relay control.
3. Enter the main loop.
4. Trigger the ultrasonic sensor by sending a high pulse to the trigger pin.
5. Measure the duration of the echo pulse and calculate the distance.
6. Control the motor based on the distance measured:
   a. If distance is less than distance Threshold(20cm), reverse the motor by activating relay1Pin and deactivating relay2Pin.
   b. If distance is between distance Threshold(20cm) and stop Threshold(45cm), close the window in the normal direction by deactivating relay1Pin and activating relay2Pin.
   c. If distance is greater than or equal to stop Threshold(45cm), stop the motor by deactivating both relays.
7. Print the measured distance on the serial monitor.
8. Add a delay before the next iteration of the loop.
9. Repeat the loop indefinitely.

C. Code Snippets

1. Pin Definitions and Variable Initialization:

This section defines the pins used for the ultrasonic sensor's trigger and echo signals, as well as the relay control pins. It also sets distance thresholds for object detection and motor stopping.

```
// Pin Definitions
const int trigPin = 2; // Trigger pin of ultrasonic sensor
const int echoPin = 3; // Echo pin of ultrasonic sensor
const int relay1Pin = 4; // IN1 pin of relay module
const int relay2Pin = 5; // IN2 pin of relay module
// Variables
const int distanceThreshold = 20; /* Distance threshold for
object detection range (in centimeters)
const int stopThreshold = 45; // Distance threshold
to stop the motor (in centimeters)

```

2. Setup Function:

In the setup function, serial communication is initialized, and pin modes are configured for the various components. The relay modules are initially turned off to ensure a safe start.

```
void setup() {
  // Initialize Serial communication
  Serial.begin(9600);
  // Configure pin modes
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode(relay1Pin, OUTPUT);
  pinMode(relay2Pin, OUTPUT);
  // Turn off both relays initially
  digitalWrite(relay1Pin, LOW);
  digitalWrite(relay2Pin, LOW);
}
```

3. Loop Function (with Object Detection and Motor Control):
   a. This loop continuously triggers the ultrasonic sensor, measures the echo time to calculate the distance to an object, and checks if the object is within a specific range.
   b. If the object is within the range, the appropriate relay is activated to control the motor's direction based on the detected distance. If the distance is below a threshold, the motor is stopped and rotated backward; otherwise, it's rotated forward.
   c. If an object is detected beyond the range, both relays are used to stop the motor's motion. The distance is then printed to the Serial monitor, and a short delay is added before the next iteration.

```
void loop() {
  // Trigger the ultrasonic sensor
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  // Measure the echo time to calculate the distance
  long duration = pulseIn(echoPin, HIGH);
  int distance = duration * 0.034 / 2;
```

```
    // Check if an object is detected within the threshold distance
    if (distance < stopThreshold) {
      // Activate the relay based on the detected distance
      if (distance <= distanceThreshold) {
        digitalWrite(relay1Pin, HIGH);
         // Activate IN1 to stop rotating the motor backward
        digitalWrite(relay2Pin, LOW);
         // Activate IN2 to rotate the motor backward
      } else {
        digitalWrite(relay1Pin, LOW);
         // Activate IN1 to rotate the motor forward
        digitalWrite(relay2Pin, HIGH);
        // Activate IN2 to stop rotating the motor forward
      }
    } else {
      // Stop the motor if an object is detected
      //beyond the stop threshold distance
      digitalWrite(relay1Pin, LOW);
       // Activate IN1 to stop rotating the motor backward
      digitalWrite(relay2Pin, LOW);
       // Activate IN2 to stop rotating the motor forward
    }
    // Print the distance to the Serial monitor
    Serial.print("Distance: ");
    Serial.print(distance);
    Serial.println(" cm");
    // Delay before the next iteration
    delay(100);
```

VI. RESULT

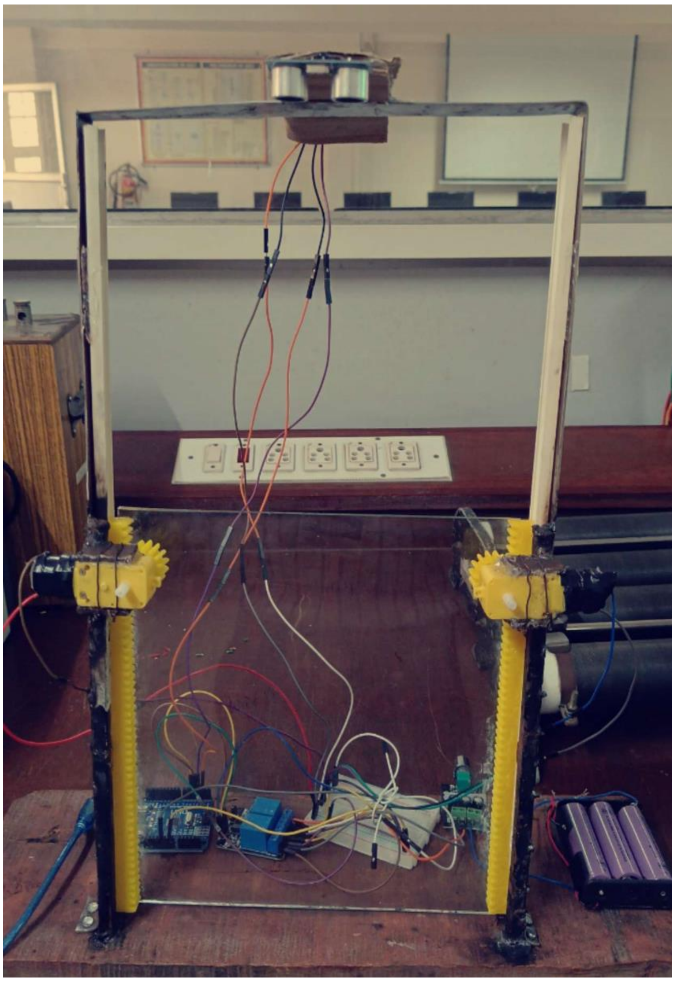

Fig 6.1: Final Implementation of Hardware

VII. CONCLUSION

As the authors in the referenced papers have highlighted, the development and implementation of advanced window control systems have led to significant strides in enhancing vehicle safety, particularly in the context of child safety and power windows [1] [2]. These systems employ various technologies, including ultrasonic sensors [1], multi-sensor fusion [6], and relay mechanisms [2], to detect obstructions, prevent accidents, and safeguard passengers, especially children. Such innovations are paramount in addressing the inherent risks associated with power windows and hold great promise in reducing accidents and their resulting consequences.

In conclusion, the concern for child safety in vehicles, particularly related to power windows, cannot be overstated. The proposed advanced obstruction detection system is a major contribution to tackling this issue. By identifying the potential entanglement risk near power windows and activating a relay mechanism to reverse the window's direction, the system effectively mitigates the danger of trapping incidents. The system's integration with existing power window mechanics ensures seamless operation and user-friendly implementation. This innovation is poised to significantly diminish the number of power window-induced injuries, decrease visits to the emergency room, and ultimately, save lives [1] [2]. More than a technological advancement, it addresses a real and pressing problem with tangible implications on public safety, particularly child safety, within vehicular environments. The reduction of physical and emotional harm caused by such accidents is a goal within our reach, thanks to the proposed solution. Ultimately, this work emphasizes the necessity and potential life-saving impact of further advancements in this area [1] [2].

In accordance with the references cited [1] [2], this research underscores the pivotal role of innovative technology in ensuring the well-being of vehicle occupants, especially children. It highlights the continued importance of research and development efforts in this field to further enhance vehicle safety and reduce the risks associated with power windows.

VIII. FUTURE SCOPE:

There are several potential advancements that can be explored in the future to enhance the power window system. One possibility is incorporating additional sensors, such as light sensors or rain sensors, to enable automatic window opening and closing based on environmental conditions. Implementing wireless communication protocols could enable remote control and monitoring of the power windows. Furthermore, integrating the system with a central control unit or home automation platform could allow for seamless integration with other smart devices in a building or vehicle. These advancements would further improve user convenience, comfort, and safety in power window operations.

REFERENCES

[1] S. Gopinath, K Kandasamy and R. Prabhu, " Design and Fabrication of Automated Child Safety Power Windows", International Journal of Production Technology and Management (IJPTM), 08(1), 2017, pp. 28–32.

[2] Gordon G. Giesbrecht, Michael Percher, Pierre Brunet, Yanik Richard, Marion Alexander, Alixandra Bellemare, Yash Rawal, Aram Amassian & Gerren Mcdonald | (2017) An automatic window opening system to prevent drowning in vehicles sinking in water, Cogent Engineering, 4:1, 1347990, DOI: 10.1080/23311916.2017.1347990.

[3] Hyde, Justin (15 April 2006). "Power Window Evolves: Cars will get pullswitches for safety".Detroit Free Press. Retrieved 5 July 2010.

[4] "Q&As: Power windows and child safety". Insurance Institute for Highway Safety. November 2009. Retrieved 5 July 2010.

[5] Ultra-Sonic Sensor Based Object Detection for Autonomous Vehicles Tommaso Nesti, Santhosh Boddana, Burhaneddin Yaman; Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) Workshops, 2023, pp. 210-218.

[6] Design of intelligent window opening system based on multi-sensor fusion Wenhao Zhou1, Yong Huang1, Xianbo Sun1, Jingqiao Yi1, Lin Gao1, Shuxian Liang2 and Jiancong Ye2 Conf. Ser. 2396 012039,DOI 10.1088/1742-6596/2396/1/012039

[7] Federal Motor Vehicle Safety Standards; Power-Operated Window, Partition,and Roof Panel Systems.