People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research

Business Incubator of Ghardaia's University
Faculty of Science and Technology
Department of Automatics and Electromechanics

N° d'enregistrement
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Thesis for a Master's Degree in Renewable Energy in Mechanics, in Accordance with the Ministerial decision 1275

MASTER & START-UP

Domain: Sciences and Technologies

Branch: Automation and Electromechanics

Major: Renewable Energy in Mechanics

Theme:

Automated Emergency System for Lowering Vehicle Windows and Opening Doors in case of Fire and Collision

Presented by:

MESSATFA Cheikh
SIRADJ Mohamed Abdelwahed

In front of the jury:

BAKAR Belkacem	MCA	**Univ.Ghardaia**	**Président(e)**
MEDOUKALI Hemza	MCA	**Univ.Ghardaia**	**Encadreur**
BELKHIR Fatima	MCA	**Univ.Ghardaia**	**Co-encadreur**
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Academic year 2024/2025

الجمهورية الجزائرية الديمقراطية الشعبية
People's Democratic Republic of Algeria
وزارة التعليم العالي والبحث العلمي
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Department of Mechanical and Electromechanical Engineering

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Thesis of final Study for the requirement of obtaining an Academic master's Degree

Master/Start-up Project

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Presented By :

SIRADJ Mohamed Abdelwahed / MESSATFA Cheikh
Publicly defended on June 25, 2025

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ملخص:

تُعتبر سلامة الركاب داخل المركبات من الأولويات القصوى التي تسعى التكنولوجيات الحديثة إلى تحقيقها، خاصة في ظل تزايد نسبة الاصابات و الوفيات الناجمة عن هذه الحوادث مثل الحريق أو الحوادث المرورية الخطيرة وهذا ما دفعنا إلى فكرة معالجة هذه المشكلة بحلول تكنولوجية مبتكرة. يهدف مشروع "نظام الطوارئ لإنزال النوافذ وفتح الأبواب تلقائيًا في حالة الحريق والاصطدام" كحل تقني مبتكر يُساهم في حماية الأرواح وتقليل الأضرارالناتجة عن هذه الحوادث. يعمل النظام على استشعار الظروف الخطيرة داخل السيارة مثل ظهور لهب أو انبعاث الدخان أو قوة الاصطدام ليقوم تلقائيًا بفتح الأبواب وإنزال النوافذ، مما يسمح بتهوئة المركبة و بخروج سريع وآمن للركاب أو تسهيل مهمة فرق الإنقاذ. يعتمد هذا النظام على مجموعة من المستشعرات، وحدة تحكم الكترونية مثلٌ Raspberry Pi , Arduino Uno موجودة داخل السيارة. هذا المشروع يندرج وفق القرار المعدل **008** و المتمم للقرار **1275** مؤسسة اقتصادية ناشئة.

الكلمات المفتاحية : فتح تلقائيً، مركبة، تكنولوجية، حريق، استشعار، اصطدام.

Abstract

The safety of passengers inside vehicles is one of the top priorities that modern technologies looking to achieve, especially in light of the increasing rate of injuries and deaths resulting from incidents, such as fire or serious traffic accidents, and this is what prompted us to the idea of processing this problem with innovative technological solutions. The "Emergency System for Automatically Lowering Windows and Opening Doors in Case of Fire and Collision" project aims to provide an innovative technical solution that contributes to protecting lives and reducing damage resulting from such accidents. The system works to sense dangerous conditions inside the car, such as high flame, smoke emission, or the force of the collision, to automatically open the doors and lower the windows, allowing the vehicle to be ventilated and for a quick and safe exit for passengers, or facilitating the task of rescue teams. This system relies on a set of sensors, an electronic control unit such as the Raspberry Pi, Arduino Uno located inside the car. This project came according to the decision amending **008** and supplementing the decision **1275** startup economic projects.

Keywords: Automatic open, Vehicle, Technology, Fire, sensing, collision.

Résumer

La sécurité des passagers à l'intérieur des véhicules est l'une des priorités majeures que les technologies modernes cherchent à atteindre, notamment face à l'augmentation du nombre de blessures et de décès causés par des incidents tels que les incendies ou les accidents de la route graves. Cela nous a conduits à envisager une solution technologique innovante pour traiter ce problème. Le projet intitulé « Système d'urgence pour l'abaissement automatique des vitres et l'ouverture des portes en cas d'incendie et de collision » vise à proposer une solution technique innovante contribuant à la protection des vies humaines et à la réduction des dommages résultant de tels accidents. Le système détecte les situations dangereuses à l'intérieur du véhicule, telles que l'apparition de flammes, l'émission de fumée ou la force d'un impact, pour ouvrir automatiquement les portes et abaisser les vitres, permettant ainsi d'aérer le véhicule et de faciliter une évacuation rapide et sécurisée des passagers, ou encore l'intervention des équipes de secours et de sauvetage. Ce système repose sur un ensemble des capteurs et une unité de contrôle électronique telle que le Raspberry Pi ou l'Arduino Uno, intégrée dans le véhicule.
Ce projet s'inscrit dans le cadre du décret modifié n° 008 et complétant le décret n° 1275 relatif aux start-ups.

Mots-clés : ouverture automatique, véhicule, technologie, incendie, détection, collision.

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List of abbreviations

NFPA: National Fire Protection Association

USA: united states of America

O2: Oxygen

ABS: Anti-lock Braking System

ECU: Controller unit

ESC: Electronic Stability Control

FCW: Forward Collision Warning

AEB: Automatic Emergency Braking

LKA: Lane Keeping Assist

BSM: Blind Spot Monitoring

AI: Artificial Intelligence

DC: Direct Current

V: Volt

mW: milliwatt

ppm: Parts Per Million

GND: Ground

DO: Digital Out

AO: Analog Out

VCC: Voltage Collector-Collector

CPU: Micro Controller Unit

A: Ampere

FIG: Figure

IOT: Internet of Things

TPMS: Tire Pressure Monitoring System

ADC: Analog to Digital Converter

RAM: Random Access Memory

GSM: Global System for Mobile Communications

LCD: Liquid Crystal Display

Fig : Figure

MQ: Metal Oxide Semiconductor

CPU : Micro Controller Unite

ASD: Aspirating Smoke Detection

°C: degree Celsius

EGR: Exhaust Gas Recirculation

UV: UltraViolet

IR: InfraRed

CO2: Carbon Dioxide

NDIR: Non-Dispersive InfraRed

MHZ: MegaHertz

URTA: Universal Asynchronous Receiver Transmitter

IDE: Integrated Development Environment

Uno: One In Italian Language

RPM: Revolutions Per Minute

GPL: Liquefied Petroleum Gas

KB: kilobyte

GPS: Global Positioning System

ERT: Emergency Response Team

MRT: Medical Response Team

ASR: AutoSafeRide

General Introduction

General Introduction .

In light of rapid technological progress and development seen by the automotive sector, especially in the field of control systems and safety technologies, where designers and manufacturing companies seek of finding a new safety systems help to reduce the rate of injuries and deaths resulting of traffic accidents, notably fires and hard collisions that pose a great danger to the lives of passengers, particularly in case of doors and windows of cars can't be opened in real-time.

If we compare the death rates in fire-related accidents in recent years, we find that these accidents rates may be high in some countries due to the absence of safety systems in the vehicles, which used in such a developing countries. Conversely, other countries such a European countries that rely on a high technology in their vehicle safety systems that uses and adhere to international safety standards uses in vehicles. That’s why the rate of accidents is very lower.

According to the National Fire Protection Association (NFPA), that in USA in the period of 2018 and 2022, there were approximately 195927 car fires /year. [1]

These accidents resulted in approximately of 579 deaths and 1336 injuries, in addition to a real damages valued at 2.2billion dollar annually.

These statistics underscore the importance of improving safety and prevention systems in vehicles.

From this spirit, the needed show up for smart innovation systems that automatically work when there is a risk. This is what this study looking for processing through a design of an emergency system for opening doors and lowering Windows automatically, without any human action, it is also noted that work is underway in accordance with the ministerial decision 1275 of the start-up master’s gradation.

Through all of the above we can pose the following **main problematic:**

"Is it possible for the automated emergency system effectively reduce the number of injuries and fatalities resulting from fires and collision as expected?"

The main hypothesis: If a vehicle's emergency system is designed by a quick and automatic, and the response time which will be less than three minutes according to international safety standards where mentioned that in case of shortage of oxygen(O2) or suffocation of passengers. The response time of rescue in these cases must be less the three minutes, because brain cells start stop working in the range of [3 to 5] minutes. This will significantly increase the possibility of passengers' survival in noticeably way in traffic accidents, by enabling them to quickly out of the car before the danger is getting worse.

Project Objectives:

- ✓ Contributing for reducing the mortality and injuries rate caused by vehicles fires.
- ✓ Assisting volunteers and rescue teams in rescue operations
- ✓ Creation of a new company for producing a local product which contributes to diversifying the national economy. The Project's importance is that it's aims to:
- ✓ Increasing Safety and Security in cars.
- ✓ Reducing the choking hazards and increasing the chances of survival.
- ✓ New topic, has not been touched, and also the scientific value lies in developing innovative solutions over human-machine interaction.
- ✓ Could also be used as a research model for developing future studies.
- ✓ Reducing human and material loses which leads to reduce economic encumbrance resulting from it such a health treatment, financial compensation, and Healthcare.

Motives of choosing this topic, which include Self-motivations:

- ✓ Lack of topics and studies in the field of vehicles Safety and Security.
- ✓ Personal tendencies for such a topic.

There are also Objective motives, one of the most important motivations that prompted us to think about this project is increasing of traffic accidents, especially those in which passengers are burned in cars due to unlocked of its doors or non-existence of other Escape ways out, without giving a solution for this issue from the car manufactures.

Also, lake of presence or rather the absence of this safety device at the local or international level, being not commonly known. Since we see this project or product as a great opportunity to provide an innovation solution that meets market needs and also contributes for improving safety and security standards in the vehicles as well as contributing to diversification of the national economy through this product.

Chapter I:

General Comprehensive of Automotive Safety Systems in cars

I.1 Introduction

Traffic safety is considered as one of the fundamental aspects of modern transportation systems, especially in smart cars. In recent years, vehicle safety technologies have seen significant development, with the integration of advanced systems such as airbags, automatic braking systems, front and rear-view cameras, lane departure warning sensors, forward collision alerts...etc.

However, there remains an urgent need for additional safety systems that can reduce the probability of passengers being exposed to danger. These systems should be capable of responding automatically to sudden dangers, such as a collision or setting fire, by providing mechanisms that enhance the safety and protection of vehicle users, especially in situations where they may face difficulties evacuating the vehicle, for example.

With the rapid advancement in automotive technology, safety systems have become an important consideration for vehicle manufacturers when designing modern cars.

These systems aim to reduce the risk of injuries and fatalities resulting from various types of road accidents, which continue to be one of the leading causes of death worldwide.

Despite the presence of several protective systems like airbags and automatic braking systems, and other systems, there are still cases in which passengers become trapped inside the vehicle, especially in severe collisions, fires, or in cases of vehicle rollovers.

I.2 Overview of vehicle safety systems:

Over the past years, vehicle safety systems have evolved significantly, shifting from basic mechanical features to highly intelligent and automated technologies.

These systems are designed not only to prevent accidents but also to protect occupants during and after a collision. Modern cars are now equipped with a wide range of safety features, which can be classify into Active Safety Systems and Passive Safety Systems.

I.2.1 Active Safety Systems:

These systems are designed to prevent accidents before they occur by helping the driver maintain control of the vehicle.

The most important of these systems are [2]:

a- Anti-lock Braking System (ABS);

The Anti-Lock Braking System, or ABS, is a safety mechanism in cars designed to stop the wheels from locking up when you brake hard. This system helps the driver to steer better and shortens the distance needed to stop on wet roads or in urgent situations.

When the ABS activates, it quickly varies the brake pressure, which may feel like a shaking sensation in the brake pedal.

This action lets the wheel continue to turn slightly, helping to preserve stabilization on the road.

This System Consist of:

- ✓ **Sensors:** Each wheel has a speed sensor that check how fast it's spinning.
- ✓ **Controller unit (ECU):** Receives signals from the sensors.
  - If a wheel is about to lock, the ECU steps in.
- ✓ **Valves:** For roll of control the brake pressure of each wheel.
- ✓ **Pump:** Restores pressure to the brakes after it's released by the valves.

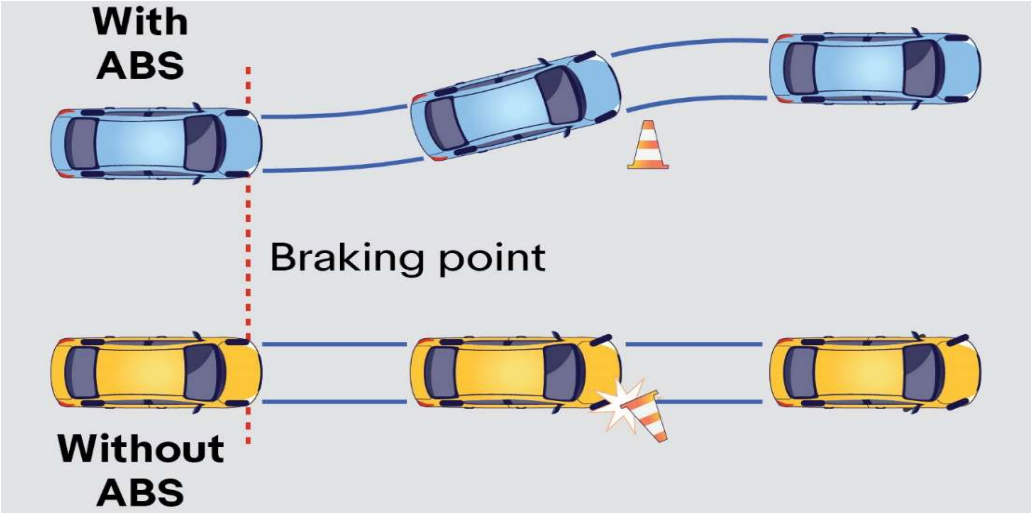

Fig. 1.1. Anti- Lock Braking System (ABS). [1]

❖ **ABS Benefits:**

✓ Prevent skidding.

✓ Embrace vehicle control.

✓ Reduces stopping distance (on dry and wet roads).

✓ Help avoid collisions.

b- Electronic Stability Control (ESC):

ESC is a vehicle safety system that designed to help driver maintain control of his car during extreme steering maneuvers, especially in slippery or emergency conditions.

If the system detects that the car is not going where the driver is steering like the case of skidding or spinning out, it automatically applies the brakes to individual wheels and may reduce engine power to help bring the car back on track.

The system consists of sensors to control: Steering angle, Wheel speed and Vehicle rotation [3].

❖ **ESC Advantages:**

✓ Prevents oversteering and understeering.

✓ Reduces the risk of skidding and rollovers.

✓ Helps maintain control in emergency situations, especially useful on wet, icy, or loose road.

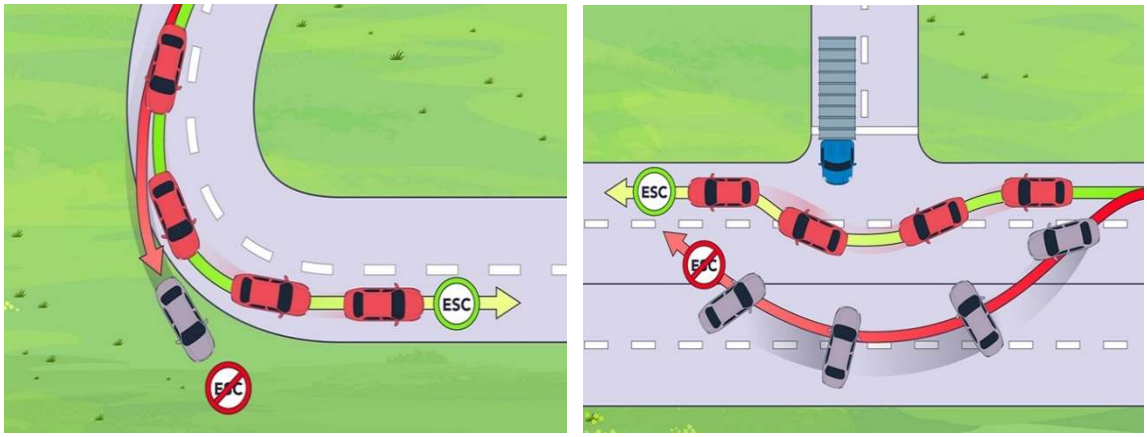

Fig. 1.2. ESC Electronic Stability Control. [2]

c- Forward Collision Warning (FCW):

Forward Collision Warning is a driver assistance system that warns the driver of a potential frontal collision with a vehicle or another object in front of the car.

The FCW system function as follow:

- Uses a radar, cameras or sensors to Control traffic ahead.
- Continuously tracks the distance and relative speed between the vehicle and the one in front.

If the system detects a risk of bumping, it gives a visual, audible alert (like a warning light, a horn beep).

❖ **Advantages of FCW system**:

- Helps to avoid rear-end collisions.
- Gives drivers more time to respond.
- Works in city and highway driving conditions.

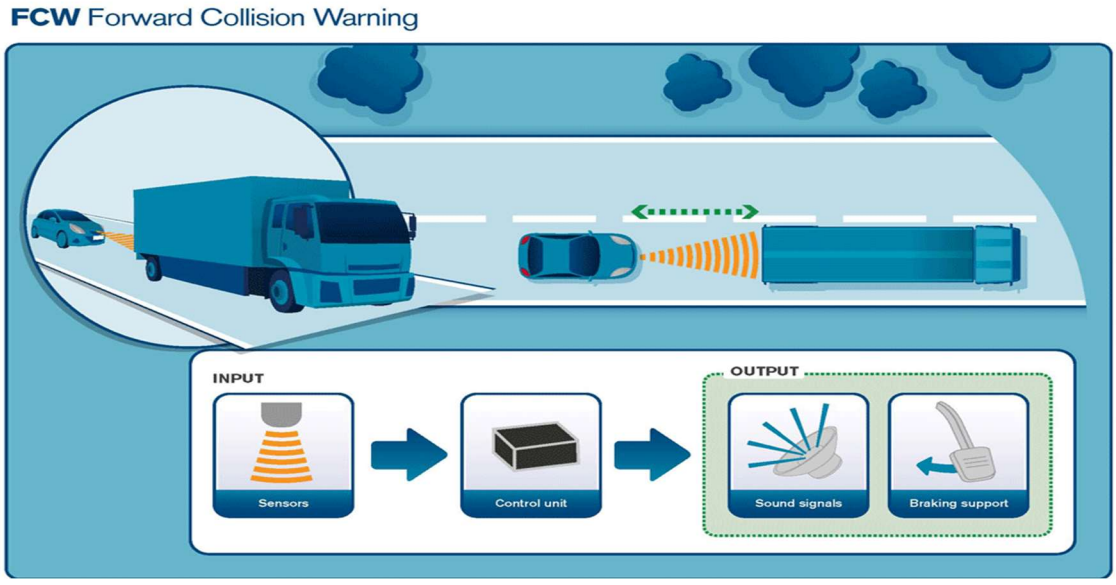

Fig. 1.3. FCW forward Collision Warning. [3]

d- Automatic Emergency Braking (AEB):

Automatic Emergency Braking (AEB) is the safety system that automatically applies the brakes when the vehicle detects an Impending collision and driver does not react in time.

❖ **AEB System function**:

Use cameras, radars or Laser Beams to scan the road in front of the car.

If a potential crash is detected, and the driver doesn't respond to Forward Collision Warning the system automatically applies the brakes to either reduce speed or avoid the crash.

The Relation between FCW and AEB: that FCW in the first step giving a driver a chance to react but AEB taken act directly.

❖ **Advantages of ABE system:**

✓ Help prevent or reduce the severity of frontal collisions.

✓ Protects both riders and vulnerable road users.

✓ Support driver reaction time in sudden situations.

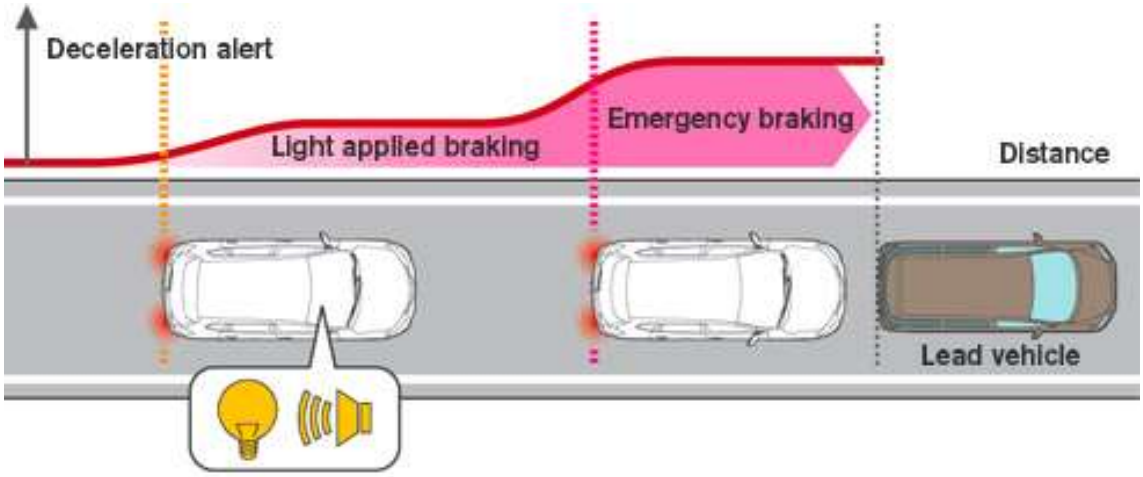

Fig. 1.4. AEB Automatic Emergency Braking. [4]

e- Lane Keeping Assist (LKA):

Lane Keeping Assist (LKA) is an advanced driver-assistance system (ADAS) designed to help driver stay within their lane on the way.

It uses camera (typically placed near the rearview mirror) to detect lane markings and provides automatic steering, if the vehicle begins to drift out of its lane without the use of turn signals [4].

❖ **Advantages of LKA System:**

✓ Reduce the risk of accidents which caused by driver distraction or Sleepiness.

✓ Improves overall driving safety.

✓ Support safe driving through encouraging lane discipline.

Fig. 1.5. LKA Lane Keeping Assist. [5]

f- Blind Spot Monitoring (BSM):

Blind Spot Monitoring (BSM) is a driver assistance system, designed to discover vehicles or objects located in the driver's blind spots, the areas that are not easily visible through the rearview or side mirrors.

The system alerts the driver when another vehicle is nearby, especially when the driver intends to change his lanes [5].

❖ **BSM System Function:**

Radar sensors or cameras usually mounted on the rear bumper or side panels monitor adjacent lanes. When a vehicle enters the blind spot, a visual warning appears on the side mirror. If the driver signals to change lanes while a vehicle is in the blind spot, the system issues an audible alert, or flashing light.

❖ Advantages of BSM System:

- ✓ Reduce the danger of collisions when changing lanes.
- ✓ Improve driver's awareness of surrounding traffic.
- ✓ Useful on highways and in heavy traffic conditions.

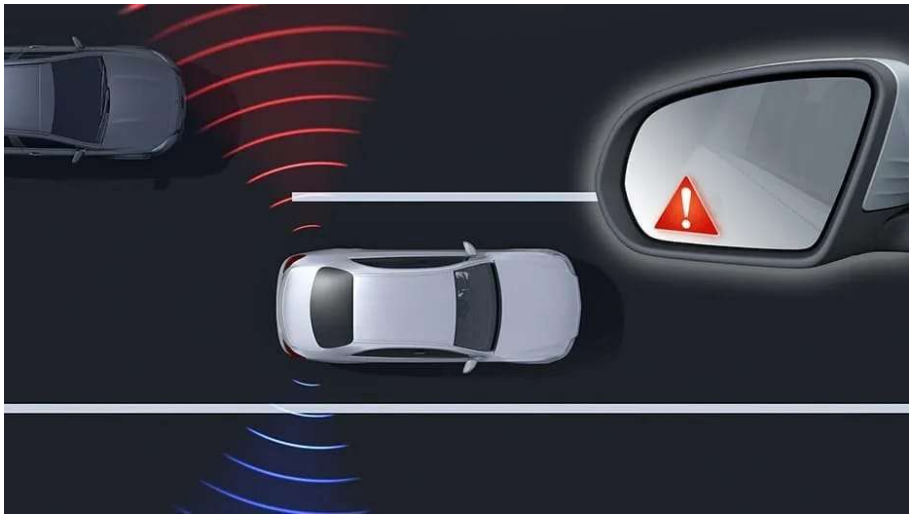

Fig. 1.6. Blind Spot Monitoring (BSM). [6]

I.2.2 Passive Safety Systems:

Passive safety systems are activated during a collision to protect cars users [6]:

a- Airbags System:

An airbag is one of the vehicle safety device designed to Blown up rapidly during a collision to protect riders from hitting the interior parts of the car, like the steering wheel, dashboard, or windows.

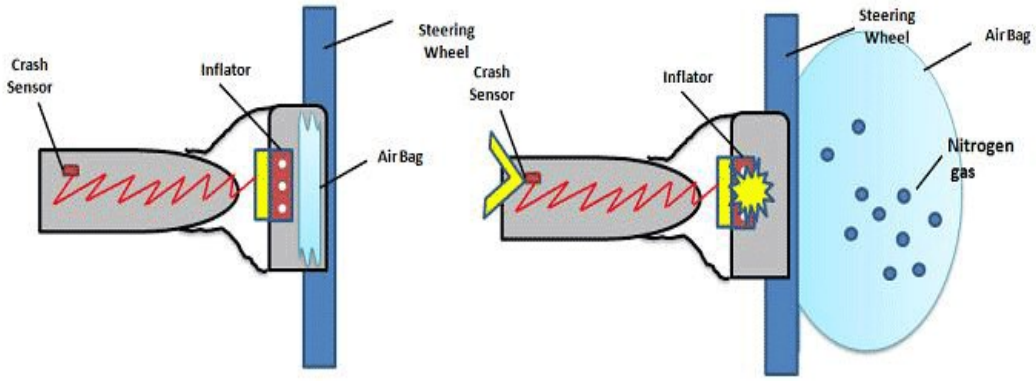

Fig. 1.7. Airbag Deployment System. [7]

b- Smart Seatbelt:

A smart seatbelt is a developed safety belt system that use sensors, sometimes AI to automatically modify or increase protection based on the riders' size, position, and movement, as well as driving conditions.

Fig. 1.8. Working of seat belt. [8]

c- Reinforced Safety Cages: A reinforced safety cage is a strong, strong frame built into car's body to protect riders during a collision.

Fig. 1.9. Inside safety Device.

Fig. 1.10. Outside reinforced safety.

d- Future Systems and AI Integration:

This system uses advanced technologies to interpret how vehicles operate, particularly in terms of safety.

The integration of AI into Automobile systems enables smarter, faster, and more correct responses for the normal driving conditions and emergency situations.

I.3 Existing Fire Detection Systems:

Fire detection systems in vehicles are safety technologies designed to detect signs of fire or overheating rapidly and notify the owner, and sometimes even activate

suppression systems automatically if exist [7].

popular Types of Fire Detection Systems in Cars are:

I.3.1 Heat Detectors:

Detect the elevation of the abnormal temperature, usually installed nearby of engine compartments, batteries or fuel zone.

Fig. 1.11. Temperature sensor. [9]

I.3.2 Smoke Detector: A smoke sensor module MQ-2 is an electronic sensing device designed to detect the presence of smoke, as an indicator of fire. It gives an early warning signal usually through an audible alarm to warn riders for evacuate or take action before the fire spreads.

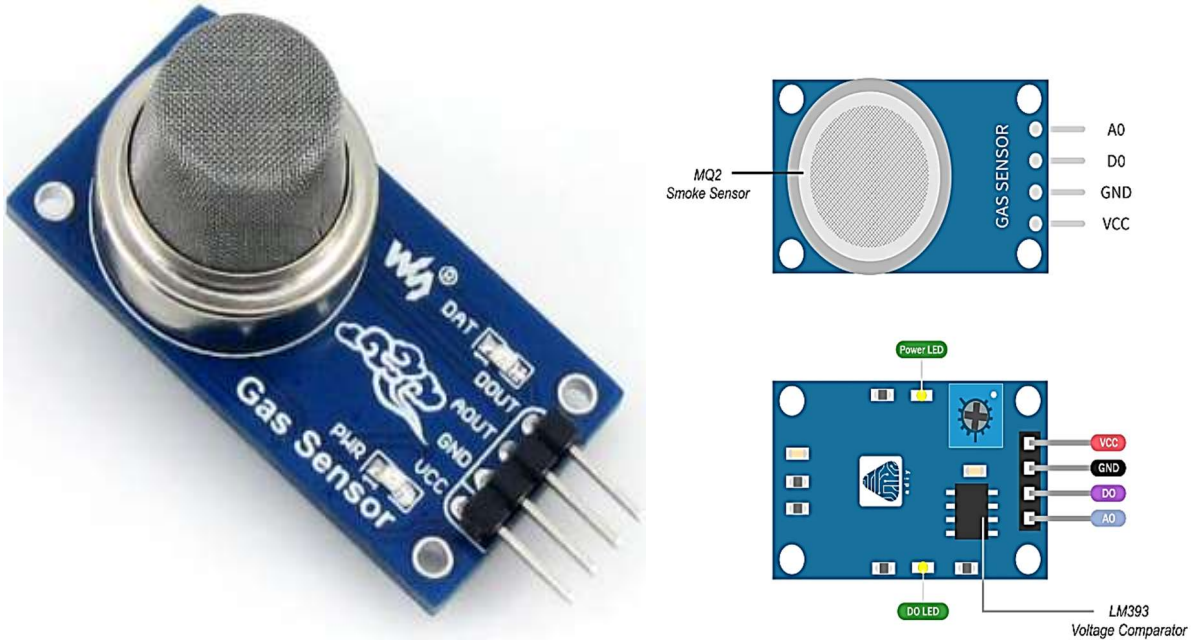

Fig.1.12. Smoke Sensor Module MQ-2. [10]

I.3.3 Flame Detector:

The KY-026 Flame Sensor module detects infrared light emitted by fire. This module has digital and analog outputs and have also potentiometer to adjust the sensitivity. Used in fire detection systems.

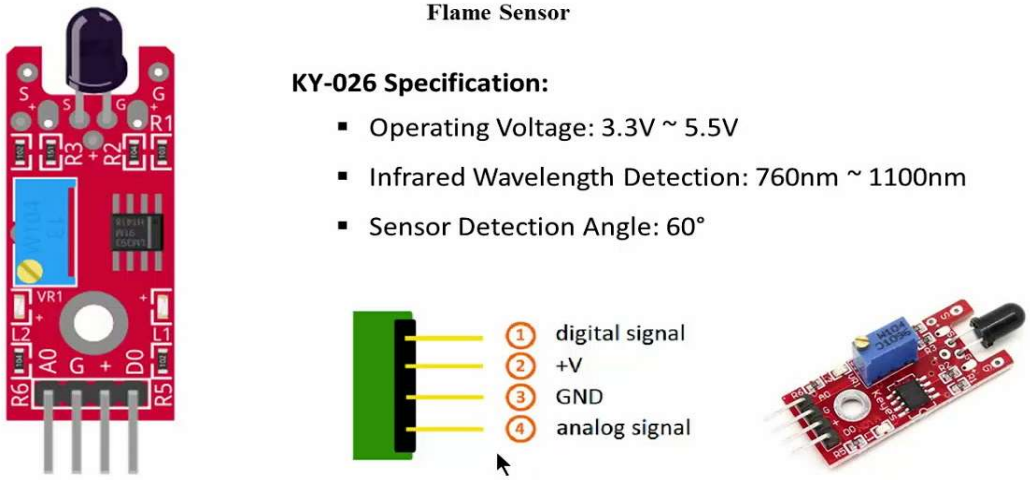

Fig. 1.13. Flame Detector KY-026. [11]

I.3.4 MQ-3 Gas Sensor:

The MQ-3 sensor module is a semiconductor-based gas sensor designed to detect alcohol vapors in the air, operates on 5V DC and consumes approximately 800mW.

It is widely used for breath alcohol detection; it can detect alcohol concentrations ranging from 25 to 500 ppm.

However, we observed that the smoke detection system is not included in regular utilitarian vehicles. This is where we got the idea of using a fire detection system to protect passengers, our project aims to add this type of system into these typical cars, although may found in those that are specially requested [8].

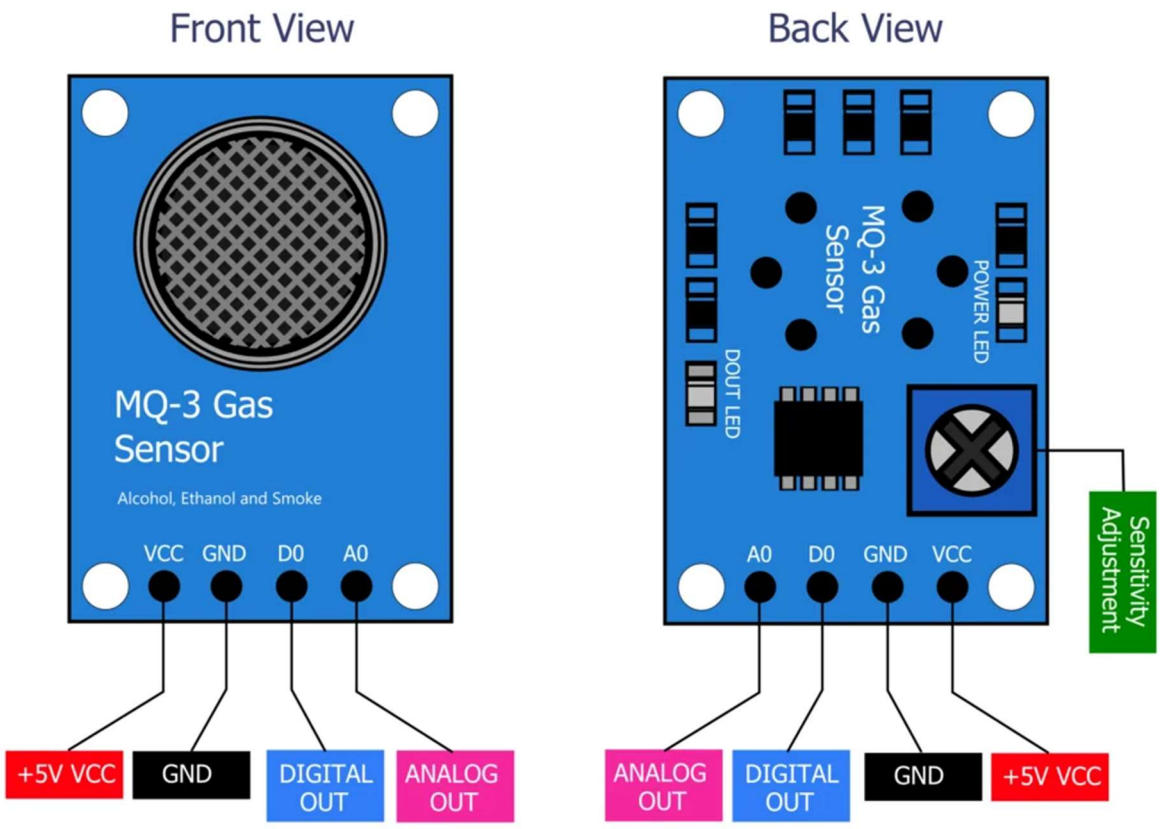

Fig. 1.14. MQ-3 Gas Sensor. [12]

I.4 Automated Windows and Doors Control Mechanisms:

Automated control systems for vehicle windows and doors are new technologies designed to boost users comfort and safety, especially during emergency situations such a fire or accidents. These systems depend on electronic detectors and Micro Controller Unit (CPU) that operate D.C motors to automatically open or close both windows and doors for a specific condition is detected. These systems play a pivotal role in enabling quick evacuation and providing immediate ventilation inside the car.

I.4.1 Automated car window control mechanism:

Automated window control mechanism is an electromechanical system in almost of vehicles that allow windows opened or closed automatically by using switches or sensor (like Rain Sensor) instead of using manual cranks.

a- Principal Components system:

Table.I.1. Principal Components system [1]

Component	Function
Power Window Motor	Operate the mechanism to move the window up and down.
Window Regulator (linkage)	Guides the window's vertical motion (scissor, cable, or rail type).
Switch/Button	Used by the driver or passengers to control window movement.
Electronic Control Unit (ECU) or Microcontroller	Manages inputs from switches or sensors and control motor behavior.
Detectors	control position and Detect barriers and stop/back the window to prevent injury especially for children.
Motor Driver Circuit	moderator between the ECU and motor, controlling motor power and direction.

b- How Automated Window Mechanisms Work?

The car window system uses a DC motor to operate the windows. This motor operates on DC current with a range of 2 to 5 A. The basic principle of motor operation is based on the reverse polarity of the power supply and ground input. Although window motors come in various sizes, their current range can be as high as 6 amps, with a peak voltage of up to 12 A in the presence of high resistance. The relays can deliver up to 40 A of power, which make it the best choice [9].

The window motor circuit works as follows. (Fig:15).

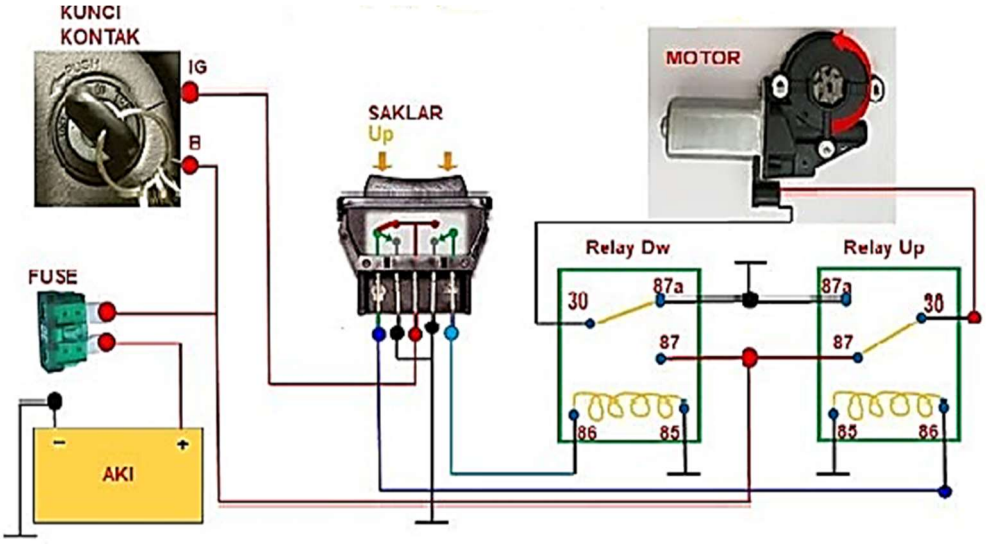

Fig.1.15. Power window circuit. [13]

2 V power is fed from the fuse to pin 87 of the relay.

This terminal then becomes the power input.

Power is also supplied to the relay coils in both stages at pin 85.

Terminal 87 A is connected directly to ground, so this terminal becomes the chassis ground input.

Then, the terminal 30 is wired directly to the window motor relay.

Each relay feeds one of the motor inputs. The end result is that each relay controls one side of the motor to wires.

Terminal 86 at each of the relays is connected to the window switch.

The window button acts like an up and down selector, which lead to the motor DC running completely.

The motor switch is also ground at the chassis.

The circuit works by keeping both relays grounded through terminal 87 A attached to terminal 30.

So, the motor D.C stays grounded at all times without turning the key.

Then, once the switch is activated one of the relays provides a power pulse to the motor.

Since the other side of the motor is already grounded, the end result is that the polarity is flipped.

Moving the button, the other direction also changes the polarity of the motor D.C, because then the other relay provides a power pulse.

This polarity reversal is what makes the motor move the glass up and down.

I.4.2 Types of the window Control systems.

a- Open-Loop Control system:

This control system not contain on feedback sensor to detect whether the window if fully up or down, where the output is not fed back to the controller.

It is a simple system that relies solely on user input. It functions as follow: When the window button is pressed, either up or down, the DC motor moves until the button is manually released. this system doesn’t know if window is fully closed or not, and this situation may many issues. this is one of its negative points. his features are that it's easy and simple to use, as well as inexpensive, we can find it in old cars.

b- Closed-Loop Control System:

A closed-loop control system uses detectors to give a feedback to control the output and automatically adjust the system to give best result.

This system Uses sensors to provide feedback to the system for automatic adjustment.

principal of works: The resistance or movement of the glass is measured, and if any obstacle is detected (like a hand, arm, anybody), the window is stopped or reversed. his advantages are safe system, Supports the automation system (Position Sensors, Limit Switches, Anti-Pinch
Sensors…etc.), the below figure show us the different between Open-Loop System and Closed-Loop System Fig I.16.

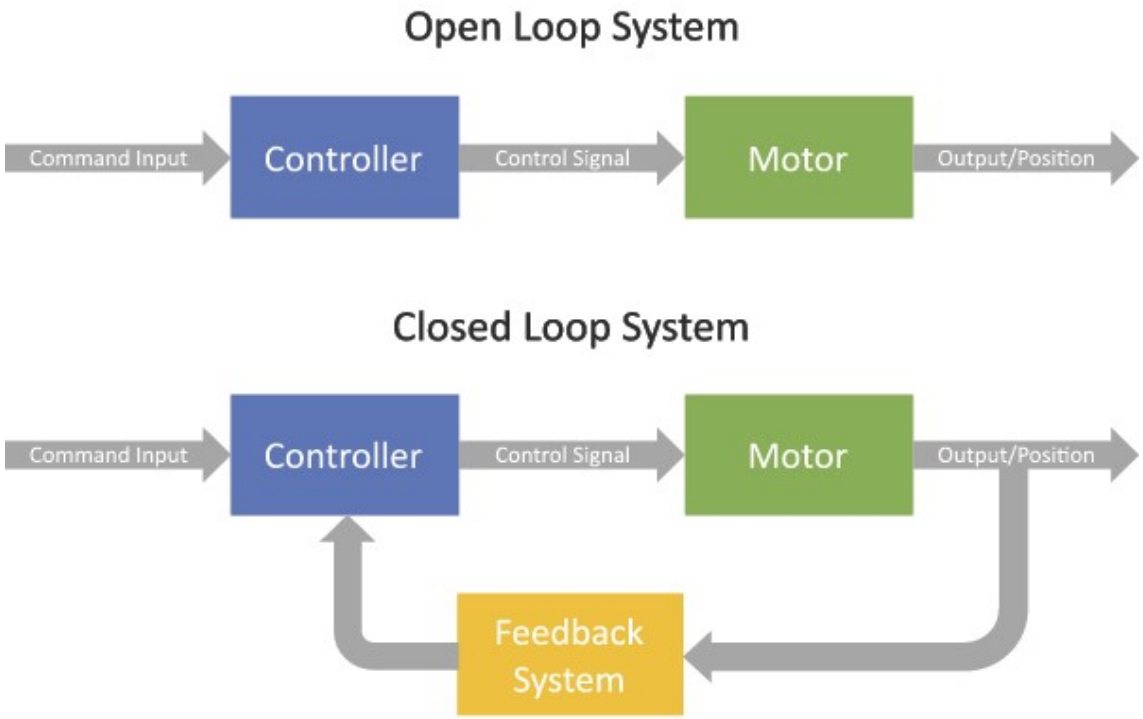

Fig I.16: Open and Closed-Loop System [14]

c- Semi –Automatic System:

This system merge between the manual and Semi-automatic control. Its principle of work is:

- A short press can move the glass halfway, while a long press can close or open the glass completely.
- This system is easy to use, but it doesn't provide intelligent protection and doesn't operate automatically in emergency situations.

d- One-Touch Automatic system:

One-touch automatic up/down system is a modern power window control feature that enables to be fully opened or closed of a vehicle window with a single, momentary

actuation of the window button. When the switch is pressed (for open) or pulled (for close) beyond a predetermined position, the system engages a continuous motor operation that drives the window to its fully open or closed position without the requiring

for sustained user input [10].

This function is typically integrated with an electronic control unit (ECU), which monitors window position and may include anti-pinch protection, which detects any obstructions during the closing cycle and automatically re-adjusts the window movement to prevent injury or deterioration. The advantages of this system being comfortable and easy to use and supports smart systems.

e-Automatic Sensing System (control based on detectors):

An automatic sensing system is an automated control mechanism that relies on set of sensors to detect operational conditions, changes in the environment or system status, and then react by automatically activate actions without the required of direct human input.

The system collects data through sensors, from surrounding environment, and analyzes it via an electronic control unit (ECU) or microcontroller, and then sends a new command to actuators like (motors, valves, or switches) based on in response to that data.

One of the most important features of this system we found that very useful in emergency situations as well as prompting safety [11].

Also, we can note some disadvantages like that requires precise sensors and needs for backup power in case of outage.

f- Smart System (AI or Smart IoT):

It is an intelligent system based on artificial intelligence, or the Internet of Things (IoT), which is an advanced technical framework that combines artificial intelligence and the connection of things to the Internet like sensors, appliances, vehicles, wearables, and machines that are connected to the internet and can collect, send, and receive data.to enable data-driven autonomous decision-making and intelligent control of devices and systems. The Internet of Things (IoT) is a concept that refers to a network of devices such as sensors, home appliances, cars, and smart watches that are connected to the internet and can collect, send, and receive data; and sometimes make decisions automatically based on this data. These devices are equipped with electronics, software, sensors, and communication tools that allow them to interact with their surrounding environment, with central systems, or even with each other.

One of the important features of this system are being developed system, Supports remote control and smart alerts, however, this system has some disadvantages like more expensive, complicated and need internet connection to work in good conditions.

I.5 Integration of Sensors and Actuators in Automotive Safety:

Integration refers to the linking and integration of key components sensors and controllers, and actuators into a unified system.

In this system, each technology doesn't operate independently, but rather exchanges data and interacts with each other to achieve a desired performance and achieve the highest levels of safety in the vehicle.

I.5.1 Mechanism of integrating sensors and actuators into a vehicle's safety system:

The safety, comfort, and performance systems found in modern cars depend on the integrated operation of the various components within the system.

a- Basic Components of the Integration System:

❖ **Sensors:**

Sensor is an electronic device that detects physical and chemical changes in the surrounding environment. Placed in strategic locations in the vehicle to monitor changes such as (Temperature, Pressure, Smoke and motion). For example: A temperature Detector is placed in the engine to measure its temperature …etc.

These sensors convert physical variables into electrical signals, which are then sent to the vehicle's Electronic Control Unit (ECU) to be processed.

Based on the incoming data, the system makes real-time decisions and leads to taking necessary actions [12].

Other examples:

- TPMS (Tire Pressure Monitoring System): Sensors placed inside each wheel to measure air pressure and transmit data wirelessly to the Control Unit.
- GPS sensors for location tracking.
- Accelerometers to detect vehicle movement.

❖ **ECU (Electronic Control Unit):**

The ECU is the central brain of all vehicle systems. It's an electronic circuit equipped with a processor microcontroller. It is programmed to:

- Receive signals from various sensors.

- Process these signals using predefined algorithms.
- Make decisions and send signals to actuators to perform the required actions.

Some systems controlled by the ECU include:

- Fuel system
- Engine ignition system
- Airbag system
- Brake system
- Safety systems and all connected sensors

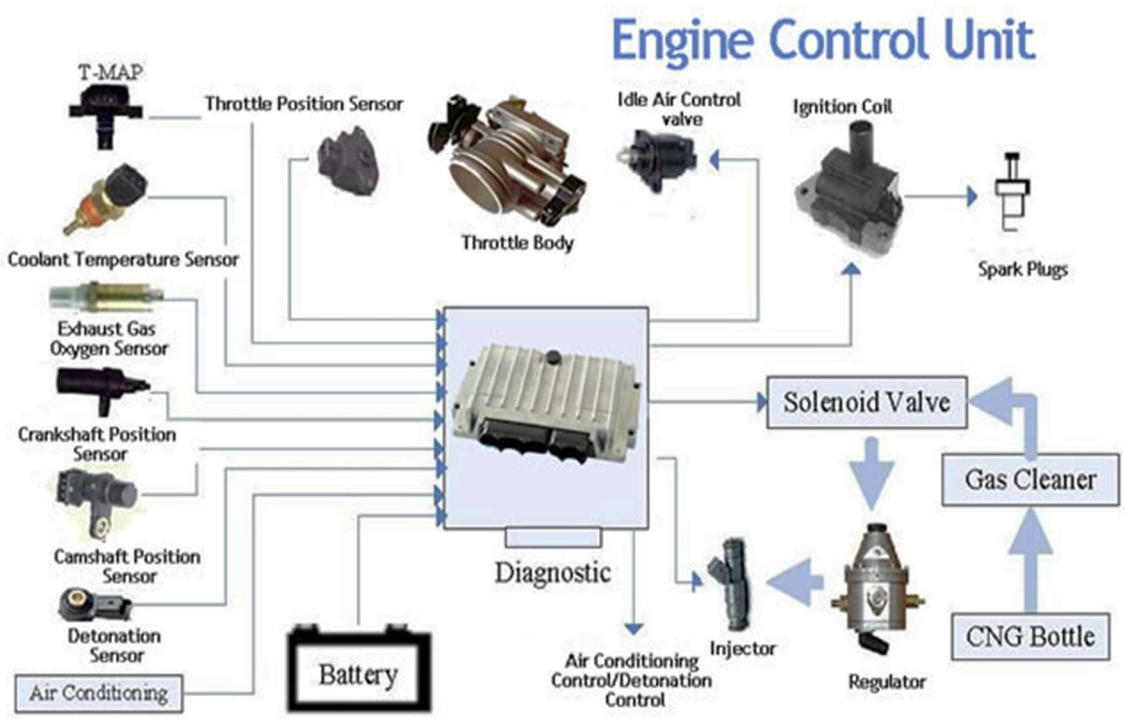

Fig.1.17. ECU Electronic Control Unit. [15]

❖ **Actuators:**

Actuators are electromechanical components that convert electrical signals from the ECU into mechanical actions. Examples include:

- Motors for opening/closing windows and doors
- Fuel pumps
- Warning systems
- Lighting indicators
- Smart braking systems (ABS & ESP)

b- Stages of System Integration

❖ **Data Collection:**

The process begins with sensors measuring specific variables and sending the data as an electrical signal usually (voltage or current).

The signal is often Analog then converted to digital signal using an Analog to Digital Converter (ADC). Readings are collected continuously, at a specific time interval.

These readings are organized and prepared for processing and analyzing.

❖ **Data Processing:**

The ECU receives the digital data from the sensors, and analyzes it based on pre-installed software. And makes decisions according to the pre-programmed information.

The analog signals are first converted by using ADC (Analog to Digital Converter).

The ECU reads the input data.

Data is instantly (Short and immediate) stored in RAM (Random Access Memory) for quick access and processing.

❖ **Data Analysis and Comparison with Reference Values:**

The ECU analyzes incoming data by comparing sensor readings with pre-defined reference values.

If the readings exceed the reference limits within a short period, the situation is classified as critical or urgent. Once a decision is made, the ECU sends a digital signal to the actuators to automatically execute the required action.

I.5.2 Importance of integration in improving car safety systems.

The importance of integration in components of a vehicle's safety systems is a fundamental step toward achieving safer driving [13].

Proper integration between the components of safety systems enables early detect potential hazards situations early and send warning signals to drivers to respond rapidly, and effectively and avoid any danger. The most important aspects of safety improvement output of this merger we can find:

- Comprehensive and accurate monitoring of the most important aspects of the vehicle.
- Making quick decisions in critical moments.
- Automated response to protect passengers in cases of loss of consciousness or inability to act
- Developing the system to integrate with smart technologies such as

"autonomous driving systems "and "intelligent rescue system".

I.6 Previous case studies of fire-related vehicle incidents:

A. <u>Case Number 01:</u>

"AUTOMATIC CAR WINDOW OPENING SYSTEM BY USING OXYGEN AND SOUND SENSOR."

Abstract:

Most vehicles today are equipped with air conditioning, which can lead to low oxygen levels in the air inside it, even in a fully enclosed system. An oxygen sensor detects low oxygen levels inside the vehicle's cabin, automatically opening the windows to provide fresh air for its passengers.

This invention includes a system and method for automatically opening and closing the windows in a vehicle. This system includes sound detection sensors and other low oxygen sensors, contributing to passenger safety. When the vehicle is left unattended with the windows open or down, the system automatically activates the power windows without driver action.

The system estimates the presence of passengers inside the vehicle, and if no human activity is detected, it automatically closes the windows. This system aims to improve passenger comfort and ensure their health and safety under all circumstances [14].

BLOCK DIAGRAM

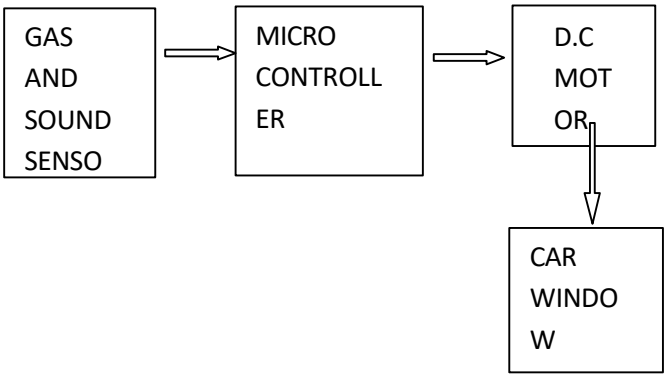

Fig .1. 18. Block Diagram of Automatic Car Window Opening System by Using Sound and Oxygen Sensor. [16]

DETAILED DRAWING

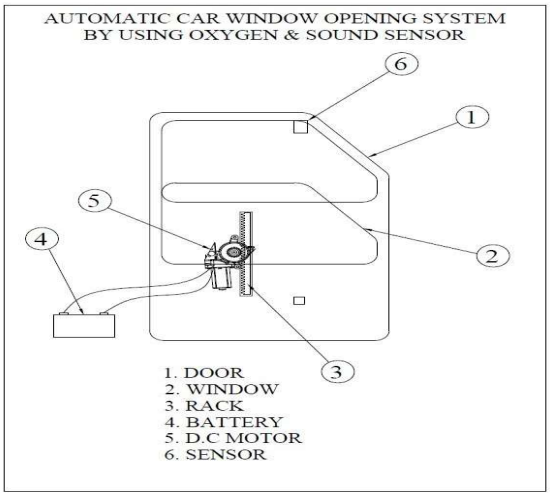

Fig .1.19. Attachment Diagram of Automatic Car Window Opening System by Using Sound and Oxygen Sensor. [17]

B. Case Number 02:

"**CAR EMERGENCY RESPONSE SYSTEM"**. [15]

Abstract:

This Emergency Response System is an Internet of Things-based system used in vehicles that responds to emergencies as soon as they occur. This proposed system works with sensors, which send information to a database after activation. The database then automatically connects to pre-

registered hotline numbers, which are then put on speed dial using the GSM module.

This system will come with an application that allows anyone to report any accident will encounter. This application will also allow people to take photos of an accident and the scene location, which will help provide directions to the accident site.

The primary aim of this proposed system is to reduce response time for emergency teams, such as rescue and medical teams, thereby reducing the number of injuries and deaths resulting from accidents [15].

Keywords: IoT, Sensors, Application, GSM.

Fig.1.20: Screenshots of various modules. [18]

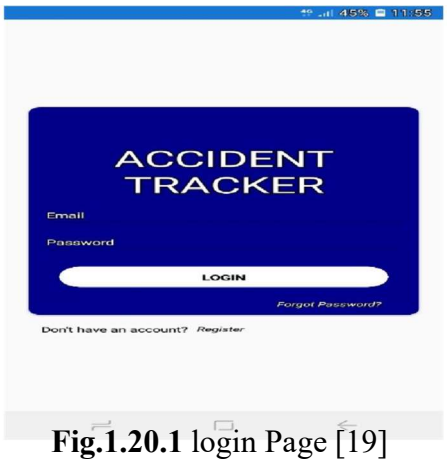

Fig.1.20.1 login Page [19]

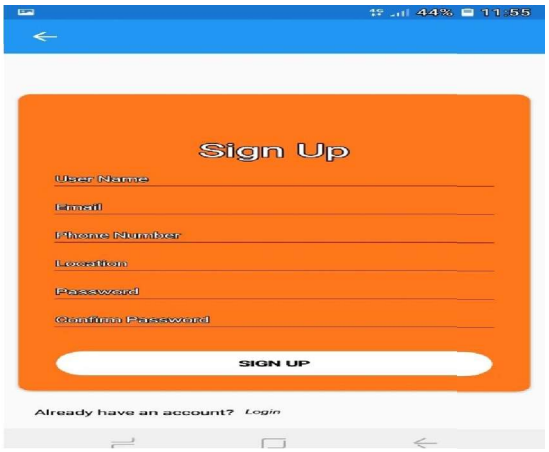

Fig.1.20.2 Sign Up Page [20]

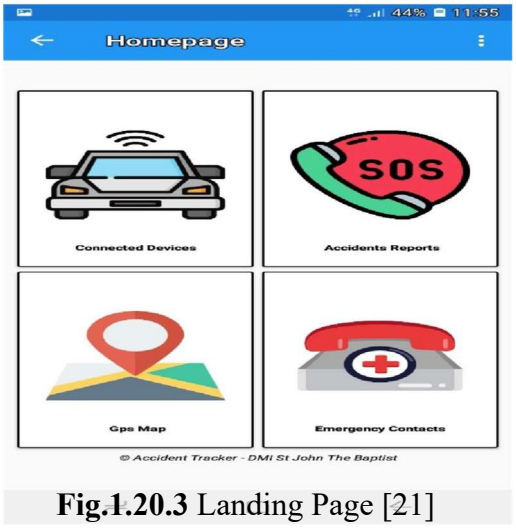

Fig.1.20.3 Landing Page [21]

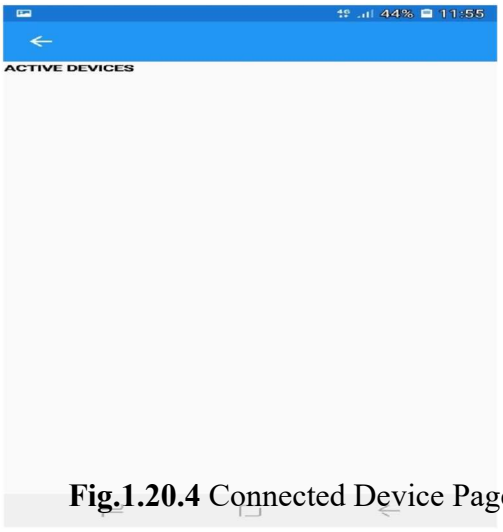

Fig.1.20.4 Connected Device Page [22]

C. Case Number 03:

Abstract:

This proposed prototype in this study is designed to detect fire incidents and how extinguish it remotely by the user, thus reducing the risks of my expose injury for volunteers or firefighters. The main idea of this proposed prototype, which focuses on the design and implementation of an automated fire extinguishing system especially for electric vehicles at a reasonable cost, is that the

fire extinguisher, in this system is activated when flames/smoke are detected in the vehicle's fire zone and automatically extinguishing the fire. There are many reasons of electric vehicle fires, the main one being the lithium batteries used in it. many cases of fires in such vehicles have been recorded due to this reason mentioned, resulting in the vehicles completely turning into ashes. Using this automated emergency system for extinguishing fires remotely in order to reduce the number of injuries caused by fires and increases the safety of vehicles and their passengers [16].

Keywords: Fire Situation, Controller, Emergency Alert, Accident Prevention, IoT Technology etc.

COMPONENTS

- Arduino Uno Controller
- LCD Display
- Buzzer
- Power supply unit
- Battery
- DC Pump
- Smoke sensor
- Water Tabj
- Photoelectric sensor
- Nozzle
- Development Board
- Relay Board
- IOT Module
- Others

DESIGN OF SYSTEM

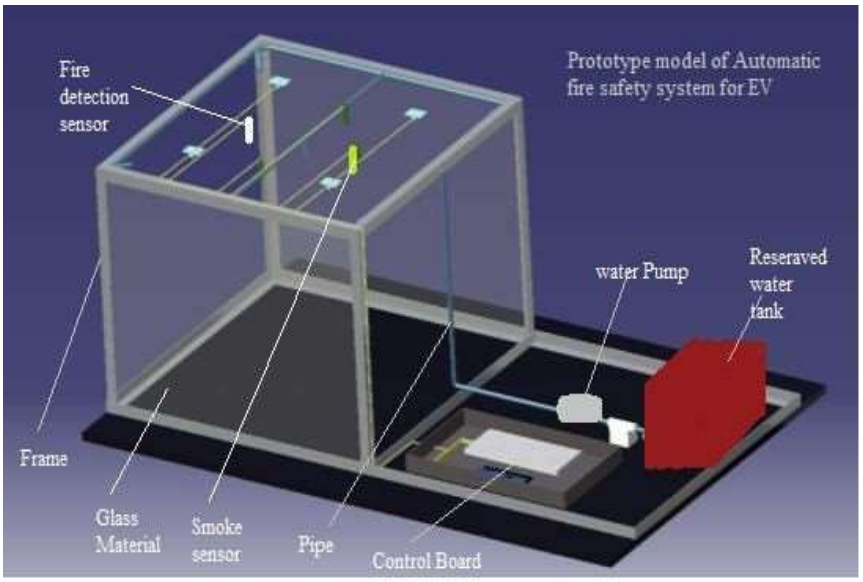

Fig.1.21 Design of structure.

[23]

I.7 Gaps in Current Research:

Table I-2: Positives and negatives of previous studies

Study	Positive Points	Negative Points

First Case Study	- An innovative idea that protects passengers from suffocation or oxygen deprivation inside a closed vehicle. - Very useful in hot or cold conditions. - Utilize of smart technologies in cars such oxygen and sound sensor.	- Opening windows by mistake or in hard weather conditions while driving. - Opening windows by fault when hearing a harmless sound.
Second Case Study	- An idea that aims to save lives with low-cost technology. - An emergency response system using the Internet of Things (IoT). aim to reduce deaths resulting from delayed response after accidents. - This System uses applications to send text messages with the ability to share photos and geographic location to multiple parties (police, civil defense, etc.).	- The technical analysis of the sensor is not sufficient to detect all types of accidents (such a side or rear collision, or fire accident). - System failure in case of network connection is lost.
Third Case Study	- Using the Internet of Things (IoT) permit sending quick messages to the driver, which prompt the response speed and reduces damage. - The system operates automatically, which gives more protection for drivers, passengers, and it reduces the risk of injury during a fire.	- In case of internet outage or network loss, the system becomes ineffective. - The System out of service if the main battery fails, due to the lack of a backup battery to support the system.

	- The ability to control the Vehicle and set off the fire extinguishing system remotely.	

I.7.1 Comparison between our study and previous studies:

Table I-3: Comparison of previous studies with our Study.

Comparison Side	Study 01	Study 02	Study 03	Our System
Fire Detection System			✓	✓
Fire Extinguishing System			✓	
Automated Unlock Doors In Emergency				✓
Lowering Windows in case of Smoke Or Collision			**Low O2**	✓
Using Smart Technologies	✓	✓	✓	✓
Protection passengers from Suffocation	✓			✓
Using a backup power source				✓
Using applications		✓		**Can developed**
Accidents alert	✓			
Ability to exit car without human help in emergency	✓			✓

I.8 Conclusion.

Safety and security systems are considered as an important part of modern cars, as they play a vital role in protecting lives and reducing victims, especially in traffic accidents.

These systems have developed significantly due to technological progress.

Among the most important of these systems, have Active Safety Systems, which include Anti-Lock Braking Systems (ABS) and Electronic Stability Control (ESC).

And have also another, passive safety system included airbags, seat belts, shock-absorbing structures, etc.

Over time, new types of accidents that were previously uncommon have emerged, such as car fires, whether resulting from electrical faults, hard collisions, or overheating of batteries in electric cars.

These have often caused an increase in the number of deaths and injuries, due to the development of cars, the complexity of their systems, and the integration of new technology.

Faced in these new challenges, it has become necessary to find additional systems that provide greater protection. That what has prompted researchers, engineers, and designers to develop highly innovative emergency systems, as the ones mentioned in our previous studies, to reduce these accidents and help save lives. Current automotive safety systems require a comprehensive vision that combines innovative detection, automatic response, facilitating evacuation, and activating smart rescue systems. This is what inspired us to think of an innovative solution that could help save lives and reduce injuries. This is achieved by creating an automatic emergency system that lowers car windows and opens doors in the event of a fire or collision.

Chapter II:

Overview of Project's features and Components

II.1 Introduction:

Fire poses one of the most severe hazards, especially within enclosed spaces like vehicles where ventilation is limited and escape paths are restricted. Cars contain a high concentration of flammable materials such as upholstered seats, plastic components, and fuel creating an environment ripe for rapid fire ignition and spread.

When a fire breaks out in a moving vehicle, it not only fills the cabin with toxic smoke but can also trigger catastrophic traffic incidents. Smoke quickly fills the interior, exposing occupants to dangerous gases, making escape incredibly difficult within minutes.

Because of these dynamics, any delay in detecting a fire can have devastating consequences for both human lives and property. Rapid detection and response are critical to preventing injury or death.

This project proposes the development of an intelligent, automated emergency system designed to detect vehicle fires and immediately respond by lowering the windows and unlocking the doors. By enabling rapid evacuation, the system reduces the risk of suffocation and entrapment, thus reducing the number of injuries and deaths.

II.2 Principles of Fire Detection:

II.2.1 Definition of Fire:

Fire is an exothermic chemical reaction accompanied by a rise in temperature, resulting from the quick combustion of a flammable material in the presence of an oxidizing elements, most often the Oxygen.

The occurrence of fire depends on the availability of the following elements: Heat (as the ignition source), Oxygen, and fuel (the flammable material) [17]. For appearance of flames, a fourth element must be existing, this element called the Chemical Chain Reaction which is known as the Fire Pyramid.

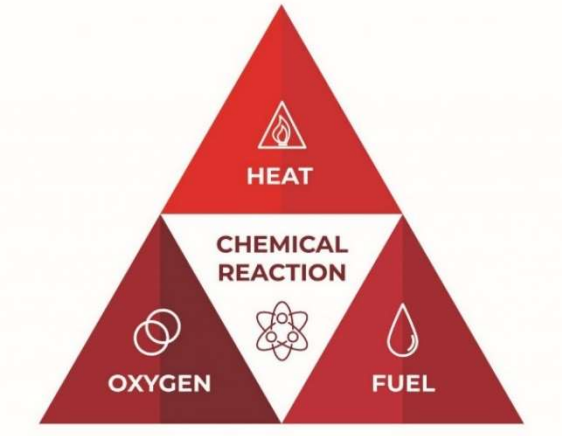

Fig. 2.1. Fire Pyramid. [24]

Important characteristics of fire are.

- Quick spread: especially in enclosed spaces.
- High temperatures and the production of toxic gases such as carbon monoxide (CO).
- Explosion risk, especially when fuel or lithium batteries are present.

II.2.2 The Fire Steps:

II.2.2.a) The Primary Step Ignition step:

This step begins when the necessary conditions for ignition are attending, as the presence of an energy source (such as a spark or flame) and flammable materials, such conditions the fire begins to burn.

II.2.2.b) Growth Step:

In this step, the fire develops rapidly, the temperature increases and the flames spread due to the presence of oxygen and flammable materials. Heavy smoke can be produced during this step.

II.2.2.c) Entirely Developed Step:

In this step, the fire reaches its maximum strength. The flames are at their peak and can spread significantly. which can cause significant property damage.

II.2.2.d) Decay Step:

The fire in this step begins when oxygen is lower or flammable materials are exhausted. The flames begin to die down, and the temperature begins to drop.

II.2.3 The Fire Classes:

II.2.3.a) Class A fires:

Are those which involve carbonaceous solids. A carbonaceous solid is one which contains the chemical element carbon as the basic fuel. Example: Wood, paper, cloth, rubber, plastics…

II.2.3.b) Class B fires:

Involve flammable and combustible liquids. Example: Petrol, Kerosene, oil, tar, paint, wax….

II.2.3.c) Electrical fires:

Electricity is not a fuel; it doesn't burn like a fuel. However, it is a dangerous complication at a fire, because it is a source of heat and potential**.**

II.2.3.d) Class D fires:

Involve combustible metals. Example Sodium, potassium, magnesium**….**

II.3 Sensor Technologies for Fire Detection:

Regarding the Sensors used in fire detection we can distinguish four detectors, will mention them as follow:

II.3.1 Smoke detector:

II.3.1.1 Types of Smoke defectors

In this type we are going to refer for the types commonly used with a brief description of each one:

II.3.1.1.a) Ionization Sensor:

An ionization sensor is a device used to detect and measure the presence of ionizing particles or gases by observe the flow of ions in area controlled.

Operate based on the principle of ionizing radiation or some gases can ionize the air in the sensing room, creating a particles or ions with positive and negative charges.

The function of this detector is to detect the smoke of fire by using a small amount of radioactive substance such Americium-241. Which can ionize air in room or in confined spaces.

When the smoke entre the room will distrust the ion's flow, which lead to reducing the current. This will act the alarm [18].

II.3.1.1.b) A photoelectric detector:

It is a type of sensor mainly used to detect smoke and sometimes particulate, depend on light. This light used to detect the presence of airborne particles.
It works on the principle of light scattering resulting of smoke entry a sensing area. This Detector work over two main configurations.

b.1 Light Scattering system:

This type is most common in smoke sensors. Inside the sensor chamber is a light source, usually LED, and a photodetector such as a photodiode or phototransistor. Under normal conditions, no light falls on the sensor. When smoke enters the chamber, it focuses light toward the photodetector. Once a sufficient amount of intense light reaches the sensor, it triggers the alarm.

b.2 Light Obscuration System:

In this system the beam moves form transmitter to receiver, when the smoke pass over the path of the beam reduces the light intensity arriving at the receiver.

II.3.1.1.c) Aspirating Smoke Detectors:

Smoke Detection System (ASD) it is a highly sensitive system, usually used in the area where required, pre-alarming or where we can't use the traditional smoke detectors, or it's not suitable.
How does it work?

First, we take air sampling throughout the protection area. These samples are taken to the central of detection unit.

This air passes over a laser-based or a highly sensitive smoke sensor. Then analysis the air for attaining the smoke particles. In case of smoke detected over pre-fined threshold, release an alarm. Examples of Smoke Detectors: MQ-2 or MQ-135.

II.3.1.2 Advantages of Smoke Detector:

- This type of detector can detect fires early even can detect smouldering or slow fires, before flame appear or intents heat.

- Can gives early alert, that's means give occupants and operators more time to evacuate the risk area.

- Has multiple types of detections, in various technologies, ionization, photoelectric and dual-sensor which can detect different types of fires.
- The consumption of power is lower and suitable for continuous control.
- Easy to install in various places due to lightweight and small size (compact), such in vehicle cabins, electrical boxes, or control panels.
- widely used, meets fire safety standards, and easy to integrate with alarm systems.

II.3.1.3 Disadvantages of Smoke Detector:

- Sensitive to dust, exhaust gases and humidity, which results of false alarms.
- Low performance in open and windy zones because of smoke disperses quickly which result in delaying or stopping detection process.
- Not suitable for quick flame fires.
- Required a frequent cleaning to prevent the issue of get clogged due to dust and dirt accumulation, humidity, water physical shocks or vibrations.
- Smoke detector components may degrade by the time which may require recalibration or replacement.

II.3.2 Heat Detector.

In this type we can distinguish two configurations.

a. Fixed Temperature System:

It’s a device that activates alarm when the temperature of the chamber reaches the preset level, generally around (57°C or 90°C) depending on the system model.

b. Rate-of-Rise System:

Is designed to trigger an alarm when the temperature up rapidly, usually at a rate between [6.7–8.3°C] / minute.

The device monitors the rate of change in the ambient air temperature. Examples of Heat Sensors: **DS18B20 , LM35 ، DHT22. [19]**

II.3.2.1 Advantages of Heat Detector.

- Less prone to false alarms compared to smoke or flame detectors, ideal in smoke, dusty or humid environments.

- heat sensor has a Simple technology, Easy to install and operate and not required regular maintenance.
- Low Cost, generally more affordable than others, flame, heat or smoke detectors.
- good effective for enclosed spaces or incloset like battery enclosure, where heat may up rapidly.
- Heat Sensor not effected by Dust or smoke or oily environment where the other detectors would fail due to sight problems.

II.3.2.2 Disadvantages of Heat Detector:

- Slow in response time due to detect fire after a significant rise in temperature, which may delay the suppression control.
- Not give an early alert, it can't detect a slow burning fire hat produce smoke but little or when materials burn at a low temperature.
- This sensor isn't useful in open and ventilated areas because heat dissipate quickly.
- The heat sensor may fail to detect fast flames, it might not responds or detect quick ignition sources like fuel or electrical fires.

II.3.3 Flame Detector:

A flame Sensor is a device used to detect the presence of a flame or fire. It ensures that a burner is operating correctly and prevents unburned fuel from accumulating, which could cause an explosion or fire hazard. A flame detector is a device used to detect the presence of a flame or fire. These detectors are commonly used in various domain like chemical plants, power plants and safety systems, to ensure fire safety and to initiate appropriate responses, such as activating fire suppression systems, activate an alarm, or shut down of the system ...

The flame detector operates based on optic, ionization, or thermal detection principles, depend on the detector choses. This detector is continent from Sensor Stick or Optical Detector (depend on the type), Wiring, Amplifier Circuit, Burner control board or flame

signal input (Usually, the flame signal is around 0.5 to 5 µA when flame detected), Control Interface for (relays or microcontrollers), System common ground, and Cover (heat resistant and tightly closed). Energy Source which be indirectly via control board [20].

II.3.3.1 Advantages of Flame Detectors:

- Can detects fire in milliseconds by sensing the radiation emitted by flame of both (UV) or (IR).
- Flame detectors are detecting the presence of an actual flame by reducing false positives of Non-Fire Heat Origin not like heat detectors, so direct detect the flame. Its reliable for open areas or open spaces like engine etc.
- Flame detectors can work in hard conditions like high temperatures where other sensors might fail due to heat.
- Very effective to detecting fast-flame fires especially rapid combustion such as fuel fires or electrical arcs.

II.3.3.2 Disadvantages of Flame Detectors:

- Flame sensor must have a clear and good line of sight of fire sources, Smoke, Dust may block detection process.
- The welding, sunlight sources or hot surfaces can cause false alarms if not
- properly protected or good calibrate.
- The coverage angle is limited: A single unit covers a specific angle usually between 90 - 120°, multiple units may be desired for the full coverage.
- Flame sensor is higher cost, more expensive comparing with a heat sensor or smoke sensor due to of hardware and installation systems.
- Flame detector needs a regular maintenance and inspections.

II.3.4 Gas Detector:

Gas sensors are chemical sensors that are of paramount importance. A chemical sensor comprises of a transducer and an active layer for converting the chemical information into another form of electronic signal like frequency change, current change or voltage change.

As the air surrounding us contains different amount of gases which could be hazardous to human health, atmospheric pollutants or of significance to an industrial or medical process, It becomes therefore very imperative to detect the presence of these gases since the environment we dwell in consists of humans, plants and animals as its main inhabitants, so the safety of their lives is of topmost priority [21].

In this type, there are many types of Gas sensors, in order to choose the suitable one, we need to know the various sensor characteristics. The important types are:

II.3.4.1.a) Electrochemical Gas Sensors:

Electrochemical sensors react with the measured gas and generate an electrical signal proportional to the gas concentration. Most electrochemical gas sensors are current sensors, producing a current that is linearly proportional to the gas concentration [22].

II.3.4.1.b) NDIR (Non-dispersive Infrared) Gas Sensors:

Is a specific of infrared gas sensor because IR Gas Sensor is a broad term which refer to any gas detector use IR light to discover gases. NDIR Gas Sensor uses a non-dispersive technique to discover gases such a CO_2, CO, CH_4 etc.

II.3.4.1.c) Catalytic Gas Sensors:

This sensor is a gas detector based on a platinum resistance temperature sensor. A high temperature resistant catalyst layer is prepared on the surface of the platinum resistor, and at a certain temperature, the combustible gas is catalytically burned on the surface. Therefore, the platinum resistance temperature increases, resulting in a change in the resistance value. Common Gases Detected we find: CH_4, Propane, Hydrogen.

II.3.4.2 Advantages of Gas Sensor:

- Strong resistance to hard climate and poisonous gas.
- Long life span.
- Can detect all flammable gases
- Oxygen is not required.
- Low maintenance cost.

II.3.4.3 Disadvantages of Gas Sensor:

- Work in the dark.
- Easy to explode or catch fire.
- Components are susceptible to poisoning by sulfide and halogen compounds, which shorten their service life.
- In a hypoxic environment, the error is larger.

II.4 Automotive Electronics and Control Systems:

II.4.1 General Overview of over Control Systems of vehicle.

Modern cars contain a set of electronics and mechanical systems that known as control systems. These systems are in charge of monitoring and regulating the performance of the vehicle's various components to improve the safety, comfort and efficiency of its own.

We will refer below to the most types commonly used:

II.4.1.1 Engine Control System (ECU):

The engine control system, typically managed by a system called Electronic Control Unit (ECU), is an electronic system responsible for monitoring and controlling of engine performance, the main functions of this system include:

- Controlling the timing and quantity of fuel injection.
- Regulating ignition timing.
- Managing the air-fuel ratio.
- Monitoring emissions systems (such as the oxygen sensor and EGR valve).
- Adjusting idle speed and throttle control.

Communicating with other vehicle systems (such as the transmission and ABS), the ECU relies on data from multiple sensors (such as the crankshaft position sensor,

air flow sensor, and engine temperature) and sends orders to actuators to adjust engine performance in real time [23].

II.4.1.2 Transmission Control System (TCU):

TCU is an electronic unit in charge of managing and optimizing the working of a vehicle's automatic transmission. It analyzes various inputs to define the optimal timing and ways of shifting gears [24].

Main Functions of TCU:

- Set the optimal shift timing based on data, such a vehicle speed - engine load - throttle position and transmission oil temperature.
- Controls the valves of actuators electrical/hydraulic, which execute the shifting process.
- Guarantee smooth shifting.
- Improved fuel efficiency and driving performance.
- Protects the transmission by preventing overloads, overheating, or incorrect shifting.

II.4.1.3 Electronic Stability Control (ESC), Electronic Stability Program (ESP):

Both of them refer to the same system, but the difference lies only in the manufactured company.

Electronic Stability Control (ESC) is an active safety system in the car that helps the drivers maintain control and stability, especially when turning quickly or on slick roads.

The main function:

Continuously monitors the vehicle's movement and upon detecting a sliding risk (loss of wheel control), the system automatically intervenes by selectively applying the brakes of one or more wheels.

Tentatively reducing engine power to back the vehicle to the correct path.

This system contains of - Wheel speed sensors - Steering angle sensor - side and rotary acceleration sensors [25].

II.4.1.4 Cruise Control and Adaptive Cruise Control:

Cruise Control is a system that maintains a constant speed without push the accelerator pedal.

As for Adaptive Cruise Control maintains a safe distance between the car in front and adjusts the speed automatically [26].

II.4.1.5 Safety and Assistance Control Systems:

The more important systems are:

- The Parking assistance system.
- Rear Camira.
- Blinding spot monitoring.
- Lane keeping assist.
- Forward Collision Warning.

II.4.1.6 Doors, Window and Comfort Control System: which includes

- Control of Central Locks.
- Raising and lowering the power windows.
- Side Mirror Control.
- Remote Operating systems.

II.4.2 Role of Microcontroller Arduinos' or Raspberry PI.

The Role of Microcontrollers Like Arduino and Raspberry Pi, consider as a Practical Applications, widely used in embedded systems, such as safety emergency systems, vehicle control and smart projects. And also reading data of sensors (such as smoke, gas, flame and temperature sensors). Controlling motors, lights, windows, doors, etc. Executing commands quickly and in real time [27].

II.4.2.1 Arduino Board:

Arduino boards are physical programmable board that are used for flexible programming, customizable signal types and easy adaptation to the existing installations can offer many benefits to world. A variety of boards are available in the market as shown in Fig.1. [4]

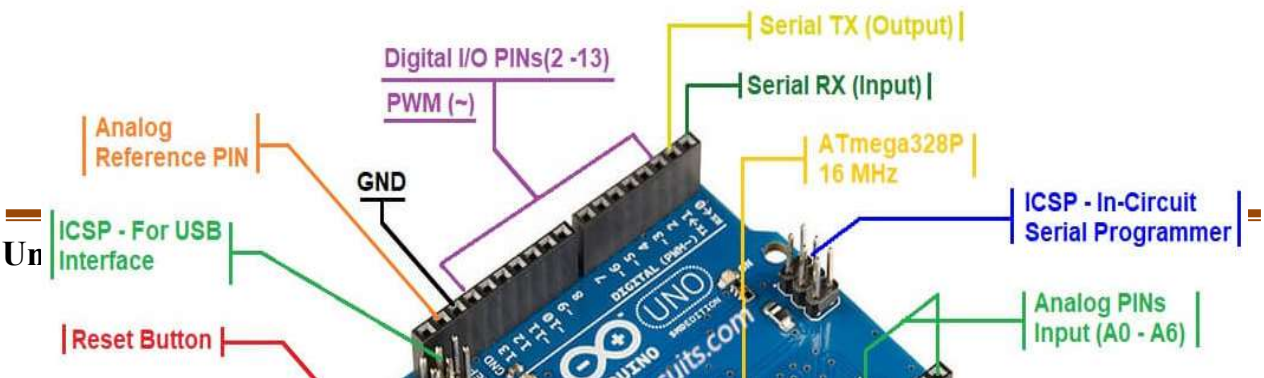

Fig.2.2. Electronic Circuits Arduino Uno [25]

Here are some applications of the Arduino Board as mentioned on the below table:

Table. II.3. Summary of Arduino Uno Application Areas [2].

Area	Applications
Smart Homes	**Motion sensors, Outlet Control, Temperature Sensors, Blower Control, Garage Door Control, Air Flow Control, Sprinkler Control and Bill of Materials**
Defense	**Arduino-based Ultrasonic Radar System**
Aero Space	**Airplane Flap Model, Integration of RC Vehicles in a Robotic Arena**
Automated Vehicle Control	**Control-System Experimentation, Strategies, and Sensors**
Traffic Signal Control	**Traffic Light Controller System**
Medical	**Cancer Detection, Heart Beat Rate Measurement, Open source EEG/ECG/EMG,Breathalyzer, Thermometer, Wifi Body Scale with Arduino Board, Lilypad Slipper Automatic Foot Massager**
Data Mining	**Health Care, Industries, Defense and Other Automation Sectors**
Laboratory	**Digital Microscope with Automated Slide Movement, EEG/ECG, Sample Collectors**
Body Control	**HandSight, Heart Rate Monitor, Muscle activity, Temperature, Respiration, Electrodermal Activity,Facial Expression, Eye Tracking**

II.4.2.2 Raspberry Pi:

The Raspberry Pi is a smaller version of a modern-day computer capable of performing task effectively. The module utilizes various kinds of the processor; therefore, it can only install open source operating systems and apps on it. Pi also enables the user to browse the internet, send emails, write documents using a word processor, and much more. Raspberry Pi support various programming languages such as Python, C, C++, BASIC, Perl and Ruby. [6]

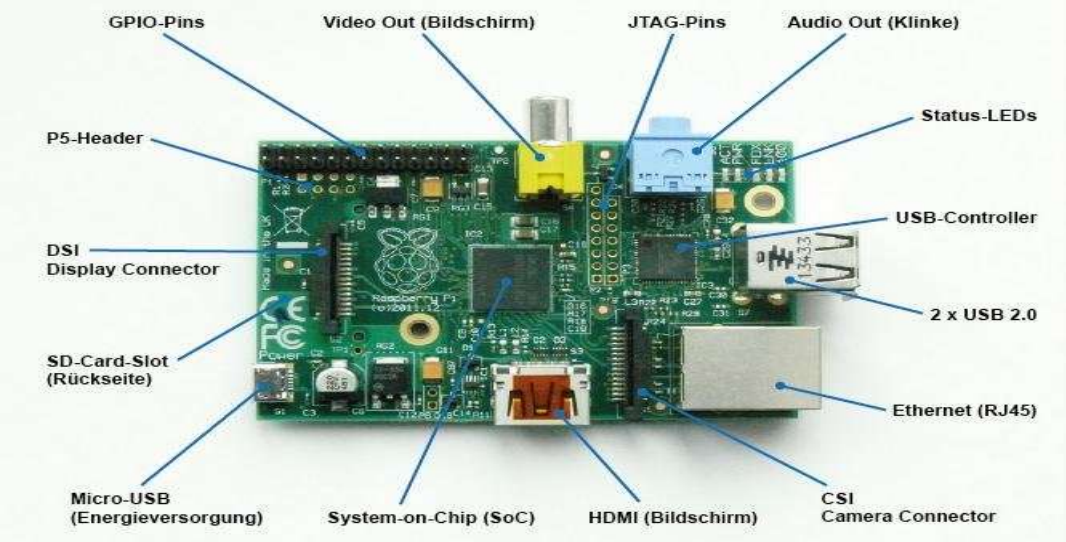

Fig.2.3. Raspberry Pi (Components Explanation) [26]

Its role in electronics projects:

- Complex data processing (such as image or video analysis).
- Running advanced software (artificial intelligence, databases, Internet of Things applications)
- Sending notifications, remote control, like analyzing an image or video from a camera to detect smoke or fire then send a notification to alert the owner on the phone for example.

Here are some applications of the Arduino Board as mentioned on the below table:

Table.II.4. THE APPLICATIONS OF Raspberry Pi [3]

Application Area	Purpose
Education	Teach programming and electronics Sach as circuit experiments, student projects.
Home Automation system	Control and automate smart home devices. Ex Smart lighting, voice assistants.
Internet of Things (IoT)	Act as a gateway or node for sensor networks. Ex: Weather stations, remote data logging, security systems.
Robotics	Control movement and behavior of robots. Ex: robotic arms, autonomous vehicles.
Web Server/Networking	Host lightweight servers and network tools. Ex: Personal blog, VPN server.
Agriculture	Automate and monitor farming systems. Ex: Smart irrigation, soil moisture

	monitoring, greenhouse control.
Environmental Monitoring	Collect and analyze environmental data. Ex: Air quality sensors, temperature logging, noise level detection.
Industrial Automation	Control and monitor factory equipment. Ex: Machine monitoring, predictive maintenance, remote dashboards.
Security & Surveillance	Provide monitoring and alert systems. Ex: CCTV systems, motion detection, facial recognition.
Scientific Research	Support data collection and experiment control. Ex: Lab automation, time-lapse imaging, sensor integration.

II.4.3 Connecting Sensors to an Electronic System in the Car:

Sensors in the car, such as the engine temperature sensor or Air Flow Sensor, are connected to the electronic systems ECUs like (TCU, BCM.....), to enable the vehicle to automat detection for danger and responds to it automatically without human action .

which are built-in computers that command certain functions by processing these data signals (Analog or Digital), which received from the sensors and provide commands.

will applying an example about Heat Temperature Sensor of the engine, the operation of treatment will pass over four steps will mention below as follow:

II.4.3.1 Read the signal of sensor:

The heat sensor continuously measures the temperature of the coolant. When the coolant temperature rises, the sensor sends an analog signal to the SCU (Smart Control Unit) for monitoring the changes of the temperature.

II.4.3.2 Converting the Inputs signals in SCU:

The SCU converts this analog signal to digital signals through the ADC (Analog to Digital Converter). The SCU then reads the value and compares it with the pre-programmed values or threshold (used as a reference), to determine whether the value is high or not.

II.4.3.3 Take Orders:

Once the SCU handles the input values, if the temperature is elevated, the SCU will turn on the engine fan to cool the coolant liquid.

Following this, the SCU will transmit a warning signal to the internal display (Infotainment screen) to inform the driver of the situation.

II.4.3.4 Connect with other Program Units:

In this step the SC Unit send these data to other Control units such (ECU, BCM…..) by CAN Bus (Control Area Network Bus) to displayed on the internal dashboard or take other preventive measurement.

II.5 System Design and Architecture:

The design of an automated emergency system for opening and lowering car doors in case of accident of a fire or collision include a combination of embedded hardware systems, sensor integration, software intelligence, and fault-protection mechanisms. A comprehensive explanation of this system's design and architecture is given below.

II.5.1 General System Operation:

In this section we are going to provide a general overview of our system of how is working. The system's operation is divided into three Steps:

II.5.1.1 First Step: Detection Phase:

At this stage, a smoke or fire sensor is placed inside the vehicle's cabin, specifically in the roof. In case of smoke or flames, the sensors send signals directly to the control unit.

The same thing applying for the collision sensor, which is usually placed in the front of or rear bumper of the vehicle. In case of a collision, this sensor immediately sends a signal to the Electronic Control Unit.

II.5.1.2 Second Step: Processing Phase:

Once the sensors transmit a signal to the electronic control unit, the information is quickly assessed to find out if the vehicle is at risk. This assessment involves matching the new data with information that has been stored earlier. If the risk is confirmed, the ECU send orders to applying a safety system.

II.5.1.3 Third Step: Action Phase.

Once the threat is confirmed, an electrical signal is send to the motors of the windows to bring down the glasses. Simultaneously, the motors for the locks are triggered to unlock the doors automatically, helping in the exit and escape for occupants. Additionally, the alarm system is

turned on, and the warning lights are activated.

The system also includes a backup battery that supplies electricity to the system if the vehicle's main battery fails due to a power loss.

This backup battery runs on solar power, which is generated by a mini solar panel placed behind the rear window of the vehicle.

This panel changes solar energy into electrical energy. Additionally, there is a voltage regulator included, that controls the voltage going into the battery to defend it against overcharging.

A backup lithium battery is part of this system, which holds the energy produced by the solar panel.

II.6. Components selection and justification:

The effectiveness and the reliability of our system depend on the right selection of its components.

Each element must be carefully chosen based on several key criteria to ensure accurate and responsiveness. will mention some of them.

- Type of hazard to be detected.
- Response Time.
- Reliability and precision.
- Compatibility of signals.

- Size and installation ease.
- power consumption.....

The Nature of our system requires the availability of a set of essential components, which we are going to attempt to detail below:

II.6.1 Sensing Devices:

We have chosen for our System; two sensors have been selected:

- Smoke and Gas sensor MQ-2.
- Crash Sensor S230.
- Flame Sensor.

II.6.1.1 Smoke and Gas sensor MQ-2.

This sensor is chosen due to its good technical specifications, its abilities to discover the smoke and flammable gases such Hydrogen (H2), Propane (C3H8), Methane (CH4), and CO2. And also, suitability to use in-car applications.

Regarding the gases founded in the smoke of fire, we are going to mentioned them in the below

table with their risk on human body.

Table.II.5. Smoke Gases and Its Danger [4]

GAS	Source	Danger Level
CO	Incomplete combustion	Killer
CO_2	Complete Reaction	Choke Causes
NCN	Plastic Combustion	Highly Toxic
NOX	Organic Combustion	Irritant for lung
SO_2	Rubber Combustion	Respiratory Irritant
Smoke and particles	Incomplete reaction	Causes chock and complications

Technical Specification of Crash Sensor MQ-2 is mentioned in the below table:

Table.II.6: Technical characteristics of Smoke and gas sensor MQ-2 [5].

Feature	Field of Work
Field Measure	From 300 to 10000 PPM
Operating Voltage	5V - DC
Output Signals	Analog + Digital
Response Time	10 – 30 second
Warm-up Time	About 20 – 60 second
Lifespan	From 2 – 3 years
Principal Use	Detection of Smoke and Flammable Gases

II.6.1.1.a) Causes of Chosen:

- ❖ Have a highly sensitive to smoke and flammable gases, making it suitable for fire detection.
- ❖ commercially available and easy to use with any microcontroller, such as an Arduino.
- ❖ Inexpensive and widely used.
- ❖ The perfect choice for detecting the fires resulting of fuel ignition or leaking of gases inside car.

II.6.1.2 Crash Sensor S230.

The S230 collision sensor was chosen due to its technical characteristics that meet the requirements of the emergency system project for lowering windows and opening doors in the event of a fire or collision, making it a suitable choice in terms of efficiency and rapid response. Technical Specifications of Crash Sensor S230 is mentioned in the below Table:

Table.II.7. Technical characteristics of Collison sensor S230 [6].

Feature	Field of Work
Principal Use	Detects surprised vibration or shock (such as a acollision)
Operating Voltage	3.3 to 5V - DC

Output Signals	Digital
Response Time	1 – 3 milliseconds
Warm-up Time	About 20 – 60 second
Lifespan	From 100,000 to 500,000 shock

II.6.1.2.a) Causes of Chosen:

- ☑ Simple and easy to install.
- ☑ Immediate collision detection.
- ☑ inexpensive and widely available.

II.6.2 Microcontroller and Processors:

For our system we are chosen an Arduino Uno as a controller unit. Arduino Uno is a Microcontroller, it's a board or slice based on Atmega 328P, uses for reading sensors, and control outputs such relays and motors.

Technical Specifications of Arduino Uno is mentioned in the below Table:

Table.II.8. Technical characteristics of Arduino Uno [7].

Feature	Value
Processor	Atmega328P
Operating Voltage	5V - DC
Processing Speed	16MHZ
Output/Input Digital Pins	14 Digital Inputs, and 6 Analog Inputs
ADC Resolution	10- bit (0 -1023)
Flash Memory	32KB
Interfaces	USB / UART
Power Consumption	Low, Suitable for combining systems
Measurement Range	0V - 5V

II.6.2.1 Causes of Chosen:

- ☑ Easy to program (Simple language, rapid prototyping using Arduino IDE.
- ☑ Wide sensor compatibility (Works with MQ-2, SW-420, S230, flame sensors, accelerometers, etc.)
- ☑ Executes commands in real time, ideal for safety systems.

- ✅ Inexpensive and cost-effective for prototypes.
- ✅ Sufficient of Inputs /Outputs ports.

II.6.3 Relay Module:

A low level a 5V Single Channel Relay Module is a circuit board containing a single relay, which requiring a 15-20mA driver current, used to control the on or off of a high voltage electrical appliance (such as 220V) using a low voltage to control signal from a microcontroller such as Arduino UNO or ESP32 [28].

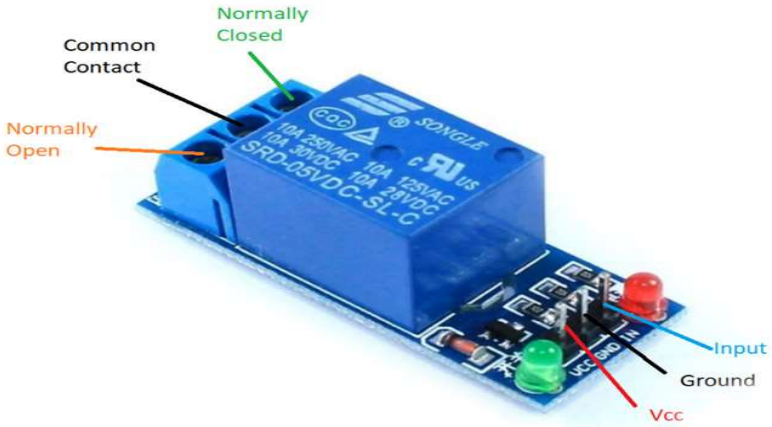

Fig.2.4. Channel Relay Module Components [27]

II.6.4 Actuators of Windows and Doors:

An Actuators are devices that convert an electrical signal from Arduino Uno into mechanical movement, for opening doors and lowering windows automatically.

II.6.4.1 Actuators of Windows:

A window actuator is an electromechanical device in charge of moving the car window glass up/down, in response to driver or passenger input via a switch. This device consists of [29]:

1- Window Motor.
2- Geared Arm.
3- Gear Driver.
4- Rail.
5- Plate.
6- Glass Holding Bracket.

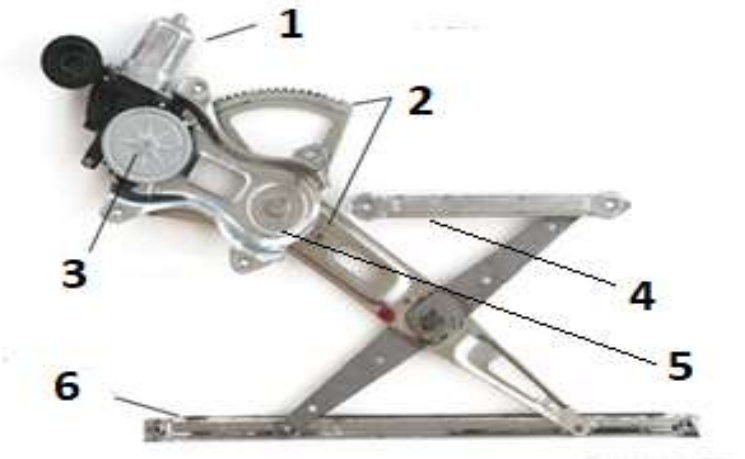

Fig.2.5. Window Actuator components [28]

- **Sequential Control Unit:**

Receives the information to raise or lower the window by simply pressing the switch.

The Control Unit then controls the geared motor until the window reaches the end of its path.

Its role is:

- Interpreting Commands.
- Control motor direction.
- Automation.
- Anti-pinch system safety function.

Fig.2.6. Smart Control Unit of windows [29]

II.6.4.1.a) Technical Specifications:

TABLE II.9. Actuators Windows Technical Specification [8].

Caractéristique	Value
Voltage Range	6V – 12V
Force Output	50 – 1500 N depend on choice model
Speed	5 – 300 RPM (Rotary)
Control Signal	ON / OFF Via Relay
Accuracy	±1 mm Rotational

II.6.4.1.b) Causes of Chosen:

☑ Simple to use and easy to install.

✅ inexpensive and widely available.

II.6.4.1.c) Mechanism of Work:

Main steps of the window mechanism actuators are:

- **Input signal**: first press the button of raise or the glass down inside the vehicle.
- **Send a signal to CU**: the switch sends an electrical signal to the window CU or directly to drive motor for act. Rotates in one direction to up or down the window.
- **Glass motion via mechanical regulator**: the window motor move the regulator mechanism which up or down the window glass, this mechanism could be Scissor type or a cable and track system.
- **Auto Stop:** The motor stops automatically when the glass window reaches the limits, this stop may be triggered by using limit switches or by detecting resistance.

II.6.4.2 Actuators of Doors (Central Door Lock):

Central Door lock is an electromechanical device used to lock or unlock a car door automatically. whenever by switch button or remote control [30].

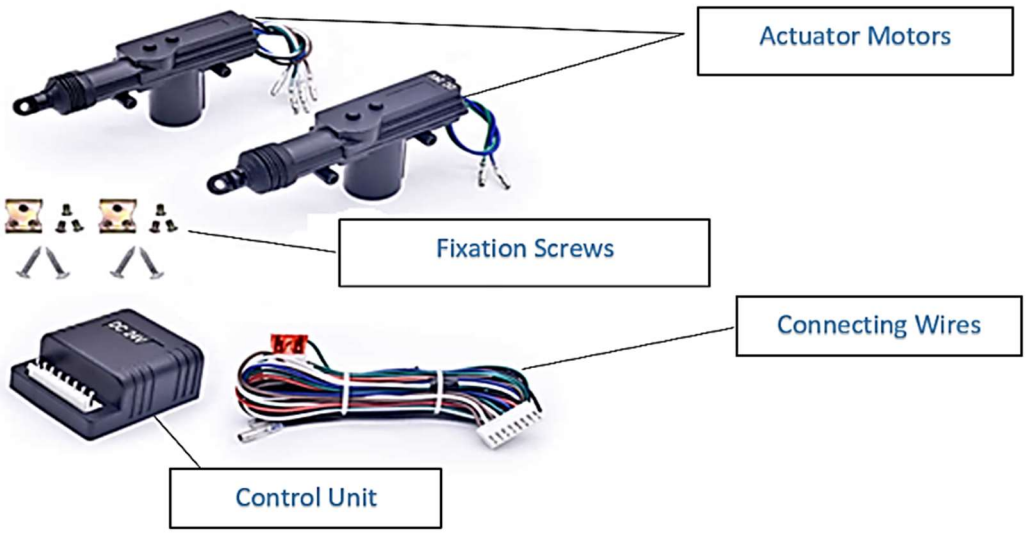

Fig.2.7. Centre lock Components. [30]

a- Controle Unit (System Brain).

- Receives input from buttons, remote control, or sensors.
- Send signals to actuators for locking or unlocking doors.

b- Door Lock Actuators.

- He is a small electric motor located in all doors of car, mechanically move the lock based on signal from the Central Unit.

c- Wiring and Connectors.

- An electrical connection between the CU, Actuators, switches, and Battery.

II.6.4.2.a) Mechanism of Work:

- **Input Signal**: When the driver presses the switch of lock or unblock or using remote control.
- **Signal reception:** the control unit receives the input signal comes from switching button.
- **Control Unit:** Take a decision and processing whether the doors will lock or unlock, by sending an electrical signal to the actuators**.**
- **Actuation:** Each actuator contains over a small electrical motor, when the motor receives an electrical signal, do a mechanical movement for locking the mechanism inside the door, if the signal for locking, it engages the lock. If the signal for unlocking, it disengages the lock.

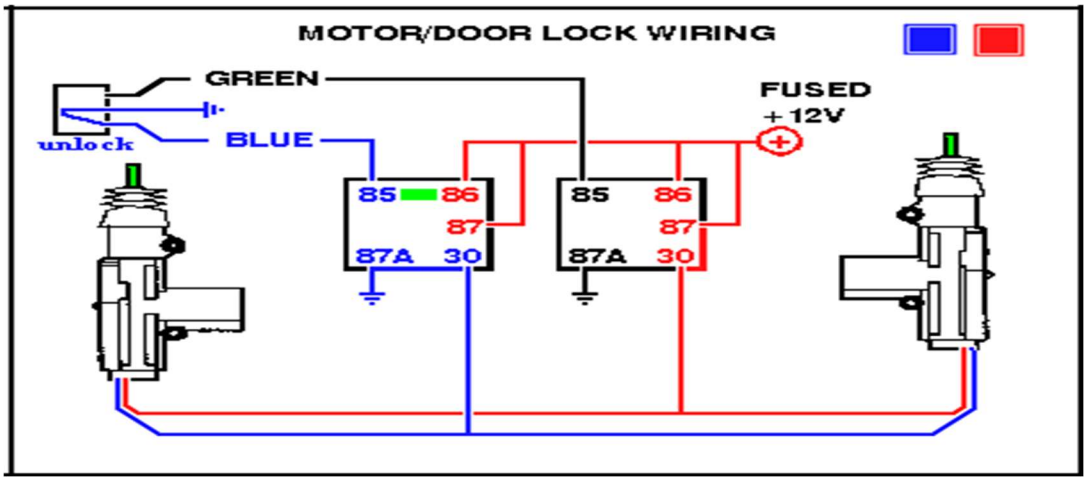

Fig.2.8. wiring connection during lock and unlock [31]

II.6.5 Power Supply Considerations:

The system is powered by the vehicle's main 12-volt battery. To ensure the system operates during a power outage or emergency, it uses a solar backup battery as the primary charging source.

II.6.5.1 Main Vehicle Battery:

Voltage typically 12 V-DC. Powering the entire system. During the normal operation, all commands are executed via this source. Placed in front of vehicle behind the engine.

II.6.5.2 Backup Battery:

His role to insure the working of system in case of the outage of the main battery supply or the emergency cases (fire, loss of power).

Usually be a small battery rechargeable, Placed inside of driver door. Mechanism of rechargeable of the backup battery working system.

- **Solar Panel**, usually placed behind the rear glass of the car, which converting the sun light to the electrical power DC current, the voltage uses is 12V or less as per the design chosen.

Fig.2.10. Solar Powered Trickle Charger [32]

- **Solar charge Controller**, which regulate the current and the voltage entry to the backup battery. His role is to prevent the overcharging and Over-discharge of battery.

II.7. System Integration:

In the following figure the interpretation of the method of how connect the elements mentioned above.

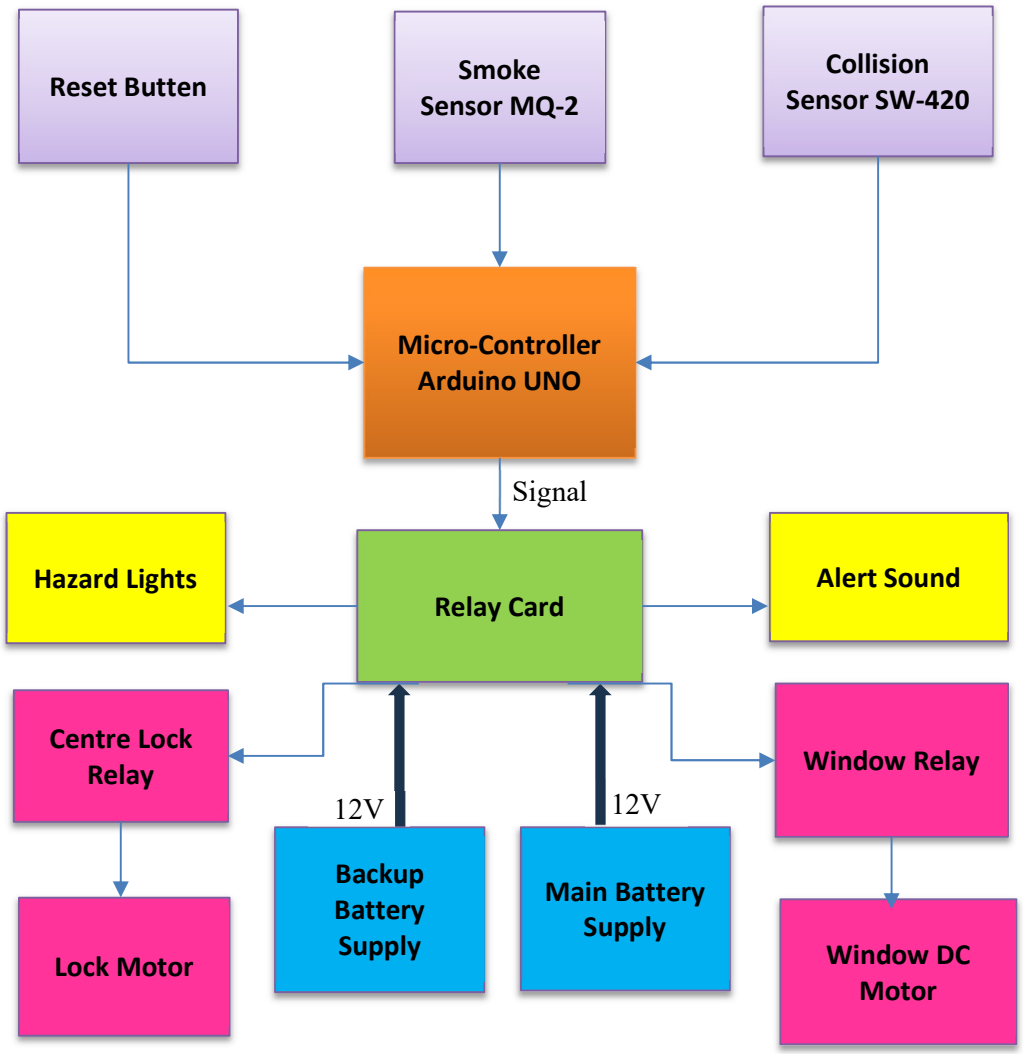

Fig.2.11. General Diagram of the Emergency System.

II.7.1 Interpretation of the Diagram:

In the first stage, the system is in a normal state (no risk detects), knowing that the process of detection be each one second. If there is a risk, such as smoke detection or a collision, which means that the value of the smoke sensor is more than 300 PPM and the collision sensor is higher than 30 Newton, these signals will send to the ECU (Arduino UNO) to analyze them at a high speed and compares them with the previously stored values. If the danger is confirmed. The ECU immediately sends an order (signal) to the relay card to close the circuit and send an electrical signal of 12V, to operate the window DC motor to lower the window and the actuator lock to unlocking the door. in addition, the Hazard lights and the Alert sound.

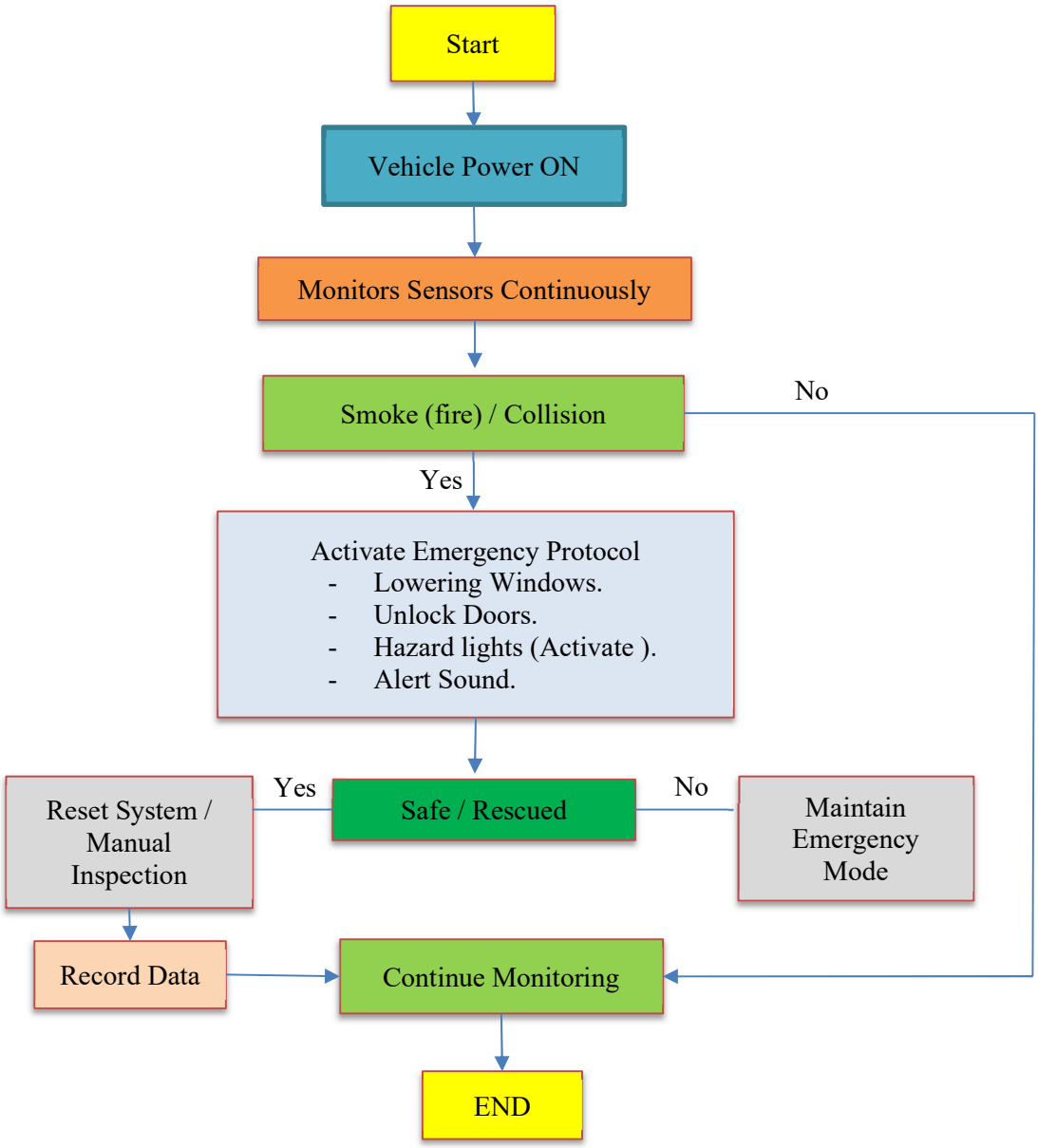

Fig.2.12. Flowchart Diagram Automated Emergency System [32]

II.8. Safety and redundancy features:

To avoid any potential system failures and for insuring proper and efficient operation, the most potential failures must be identified, along with knowledge of how to prevent and deal with them when they occur. in order to minimize any possible system malfunctions and ensure that the system operates effectively and efficiently. First, we must identify all significant failures.

II.8.1 Types of Faults:

In the below table the most important failures may face I our system.

Table.II.10. The main possible faults

Failure Type	Cause Issue
Electrical Failure	▪ Electrical outage due to battery not producing electricity. ▪ One of the connection wires is broken. ▪ One of fuses is broken down.
Sensor fault	▪ Expired. ▪ Need maintenance. ▪ Down due to dust. ▪ One of its components is damaged.
Mechanical Failure	▪ One of the motors has malfunction. ▪ Due to the window being stuck. ▪ Doors malfunction in case of crash..
Software error	▪ Delay in Response

II.8.2 Self-Diagnostic System:

The control unit is programmed to continuously control the performance of the system.

In the event of any malfunction or system failure, the ECU (Electronic Control Unit) sends a signal to a warning LED, which installed next the ON/OFF switch system on the dashboard to serve as a real-time system status indicator.

This LED light has three distinct states:

✓ When LED light is completely off, this indicate that the system is not operational.

✓ When the LED light is blinking (turning on and off repeatedly), it indicates that the system is functioning properly.

✓ When the LED is constantly on, it indicates that there is an issue or fault in the system.

II.8.3 The Protection methods:

To protect our system from the faults we should to take in our consideration the following points:

- Power Backup System.
- Send Notifications in case of an issue.
- High reliability components.
- Isolated the emergency system from the rest of car systems.
- Respect the periodic maintenance which should be from 2 to 5 years.

II.9 Conclusion:

Developing a smart system that contributes to save and safety of vehicle occupants is an advanced step toward enhancing safety in modern vehicles, by taking advantage of the integration of accurate sensors, electronic control units, and smart operating systems. Based on our in-depth understanding of fire characteristics and our identification of modern fire detection methods, we selected two appropriate sensors for our project: a smoke/flame sensor and a collision sensor.

We studied their characteristics, contexts of each, and the reasons for their selection, as explained in this chapter.

This resulted in the construction of an integrated system that combines all of these selected components in one system capable of detecting risk and taking automatic and immediate actions to meet safety needs by lowering vehicle windows, unlocking doors, and activating alarms.

This system also coincides with the safety standards, in terms of efficiency, system response speed, accuracy, and ease of use.

Therefore, this proposed system (presented in third Chapter), serves as a practical model that combines technological innovation with required safety requirements, with the possibility of further development and addition of additional features in the future.

Chapter III:

General Practical Implementation of ARS Emergency System

III.1. Introduction

In this chapter, we will present a practical prototype of our suggestion solution, which precise mechanisms in saving lives, in addition to highlighting the various obstacles and future prospects, designed to the project automatically unlocks car doors and lowers windows in the event of a traffic accident: vehicle collides or catches fire. We will present the circuitry, showing the connection of various components, including sensors, Arduino, and window-lowering and door-opening motors, as well as the programming that guides us in coordinating these components. Then we will review the development stages and tests that confirm the effectiveness of this system and its results.

III.2. Implementation:

In the car and while driving, emergency situations may occur, such as the risk of a traffic accident, a leaking of gasoline or explosion gas cylinder (GPL), or an electrical spark. In such cases comes the role of our automated system as an alert or as a smart assistant system who takes action to open the doors and lower the windows when needed.

This system has become available for almost of cars.

III.2.1 Components Used:

This system is designed with a variety of hardware components and electronic systems, each of performs a specific function.

III.2.1.1. Smoke / Gas Sensor (MQ-2):

MQ-2 sensor is a gas and smoke sensor able of detecting Smoke, Hydrogen, GPL, Methane, and other flammable gases. His role In this system for detecting the presence of smoke or other gas inside the vehicle cabin.

a) Specifications:

- Sensitive for hazardous gases.
- Operating Voltage on 5 Volts.
- Detection Range is between [300 – 10000] ppm.
- Quick response.
- Sensitivity is adjustable via on board potentiometer.

b) Function in our emergency System:

In case of smoke detected, the detector will send a voltage signal to Arduino Uno to indicating that possibility of fire.

III.2.1.2. Collision Sensor module (S230):

The S230 collision sensor is a digital sensor used to detect vibrations or mechanical shocks resulting from impacts. This unit is commonly used in intelligent systems, and vehicle safety, as it sends a digital signal at the threshold of a sudden collision or vibration.

a) Specifications:

- Output type: Digital (HIGH / LOW)
- Operating Voltage: 3.3V to 5V DC
- Current consumption: 5 mA
- Interface: 3 pins; VCC, GND, OUT

b) Function in our System:

When the sensor experiences a mechanical shock or bump action, this generate a digital signal (typically LOW) will send it to Arduino Uno to activates emergency protocols.

III.2.1.3 Flame Sensor:

This is an electronic device used to detect any presence of flame or source of heat resulting of fire. This his role in our system.

a) Specifications:

- Sensor type: IR (Infrared) or UV (Ultraviolet) light sensor
- Detection range is: 0 to 80 cm
- Detection angel: 60 °C.
- Output type: Digital.
- Response time: very fast < 1second.

b) Function in our System:

This detector will detect Infrared or Ultraviolet radiation emitted by light or flame inside the car cabin.

III.2.1.4 Arduino Uno:

The Arduino Uno is an open source platform use to easily build or create interactive electronic projects**.**

- Operating Voltage: 5V
- Digital In /Out Pins: 14
- Analog Input Pins: 6 (A0 to A5)
- Flash Memory: 32 KB (05 KB used by bootloader)

- DC Current Per In / Out pin: 20 mA.
- USB Interface: USB Type-B

a) Function in System:

Continuously reads input from detectors and triggers the relay card and actuators based on logic programmed in it. The Codes are written in simplified C++ Language using the program Arduino IDE.

III.2.1.5 Relay Card (5V Single Channel Relay Module):

Relays act as electrically controlled switches. The 5V relay module allows the Arduino to control high-current devices like motors.

a) Specifications:

- Trigger Voltage: 5V DC
- Switching Voltage (DC): Up to 30V DC at 10 Ampere
- Input Pins: VCC, GND, IN
- Current consumption: 70 mA.

b) Function in System:

Relays are used to amplify the voltage from 5 Volts to 12 Volts to operate a DC motor for window lowering and the actuator for door unlocking.

III.2.1.6 Windows Regulator (DC Motor):

The Part who is responsible for up and down the windows. We use the electrical type (automatic). Worked by DC motor controlled over a switch which placed on the car door.

a) His Components:

- **Electric Motor:** converts electrical energy in to mechanical motion.
- **Gear or cable System:** transfer the motion from DC motor to the glass.
- **Ruler or metal arm:** fixes the glass and moves it in vertically way.
- **Direction Control Switch:** give the signal for DC Motor to up or Down

b) Specifications:

- Operating Voltage: 12V DC
- Torque (rated): 1.5 – 30Nm
- Speed: 60 RPM (typical)
- No-load Speed 150-300 RPM

c) Function in System:

When activated by Relay Card, the motor will lower the window by driving the regulator mechanism.

d) Common Faults:

- Motor damage: loses the ability to up or lower the window.
- Cables break or damaging: prevent the transfer of movement.
- Broken of metal arm: due to frequent use.
- Control Switch default: the window not respond to the orders.

e) Maintenance and Reparation:

- Periodic lubrication of rulers and arms to avoid wear operation.
- Check cables, if there the moving slowly or make noise.
- replace the damaged DC motor or the cable if there is a serious fault.

III.2.1.7 Door Lock Actuator (Central Locking system):

Central lock is the responsible system for locking and unlocking the car doors remotely, either using smart key (Remote central looking) or operated by a physical switch from inside the car.

a) Specifications:

- Operating Voltage: 12V DC.
- Current actuation: 3 to 5 A.
- Current Draw: 5 to 15 mA depend on the actuator.
- Actuator Capacity: 15 to 25 Watts.
- Auto lock at certain speeds more than 20km/h.

b) Function in System:

When a fire is detected actuator is powered to unlock vehicle doors.

c) Common Faults:

- ✓ Power supply issue (dead of battery)
- ✓ Blown fuse
- ✓ Actuator damaging

d) Suggested Repair:

- ✓ Replace the battery.
- ✓ Check fuses.
- ✓ Check connection wires.

III.2.1.8 Power Supply:

a) Vehicle main Battery:

The primary source of energy for our system is the car's own battery 12V

b) Backup Battery 9V, 12V (optional):

If the main battery fails during an emergency situation, a secondary battery ensures the system operation, this battery will be placed inside the car door and charged via small solar panel. We couldn't use the solar powered backup battery, due to lack of financial resources.

c) Function in our Emergency System:

Its Role to ensure the continuous operation of the fire safety system even when the power loss due to an event.

III.2.1.9 Additional Components

a) Buzzer.

We use an audible Buzzer as an alert system to attract the attention or system activation

b) LED Indicators.

Give visual feedback on system state like Power On, Fire Detected.

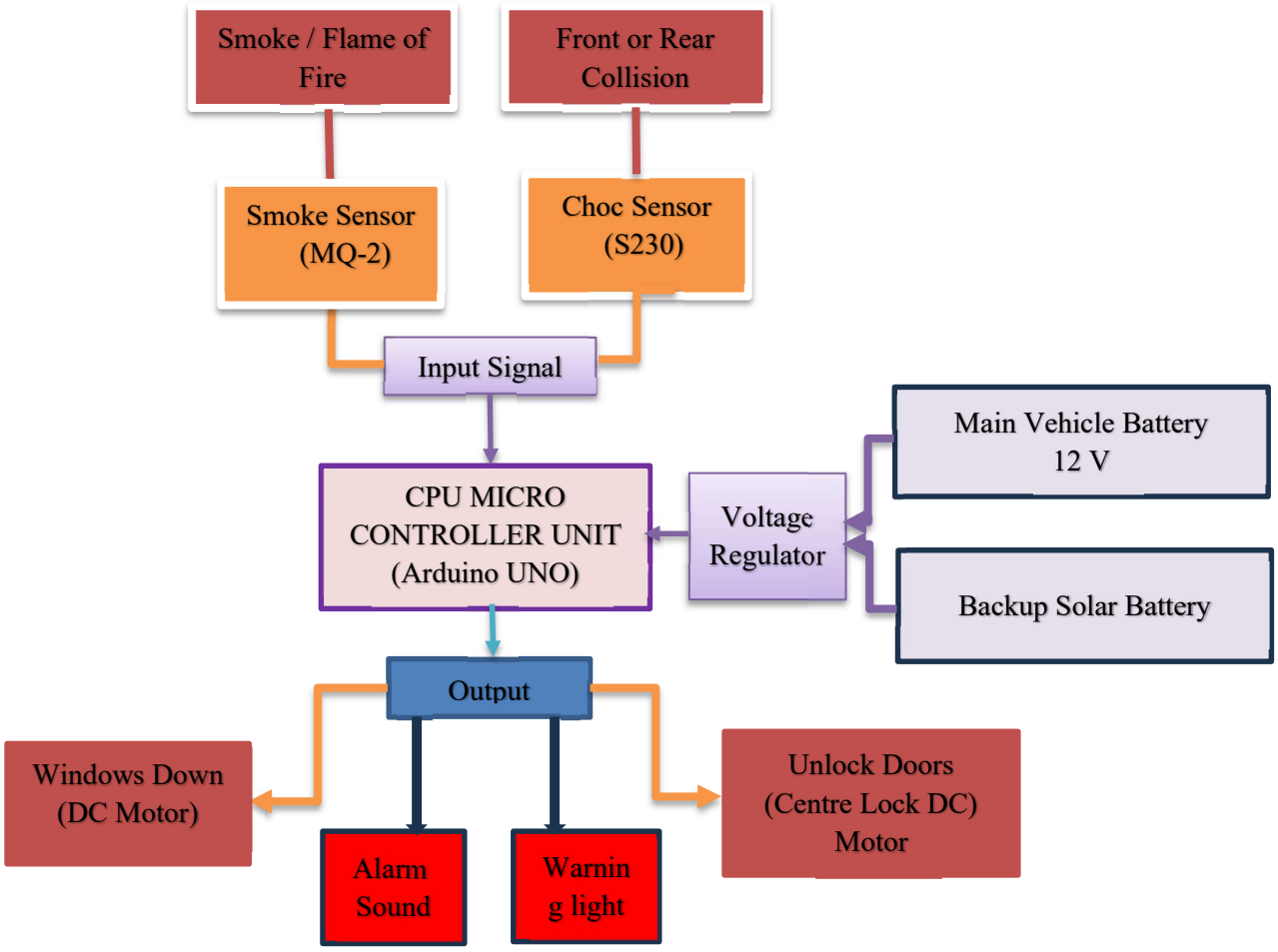

Fig.3.1. Diagram Operating System

c): System Components Work:

We install the sensors, LED light and Buzzer on the DC Board connected to the Arduino Uno Via wires to Supply power and data transfer at the same time.

We program the Arduino Uno by put codes in to it, by using the ARDUINO IDE program installed on the computer.

We connect the Arduino Uno to the relay Card, as the relay is an electrical switch that controls high-current circuits using a small electrical signal. This allows the Arduino Uno, which operates on a 5-volt voltage and low current, to control high-voltage devices (12V), such as the window DC motor and door lock central located in the car.

III.2.1.10 Wiring Diagram:

The wiring diagram includes the following details.

- MQ-2 and Collision (S230) sensors are connected to analog and digital pins on Arduino.
- Relay Input pin connected to digital output pin of Arduino Uno.
- Relays connected to DC motor and actuator powered via 12V.
- Power positive wire with fuse protection.

This section will include a diagram schematic as shown below.

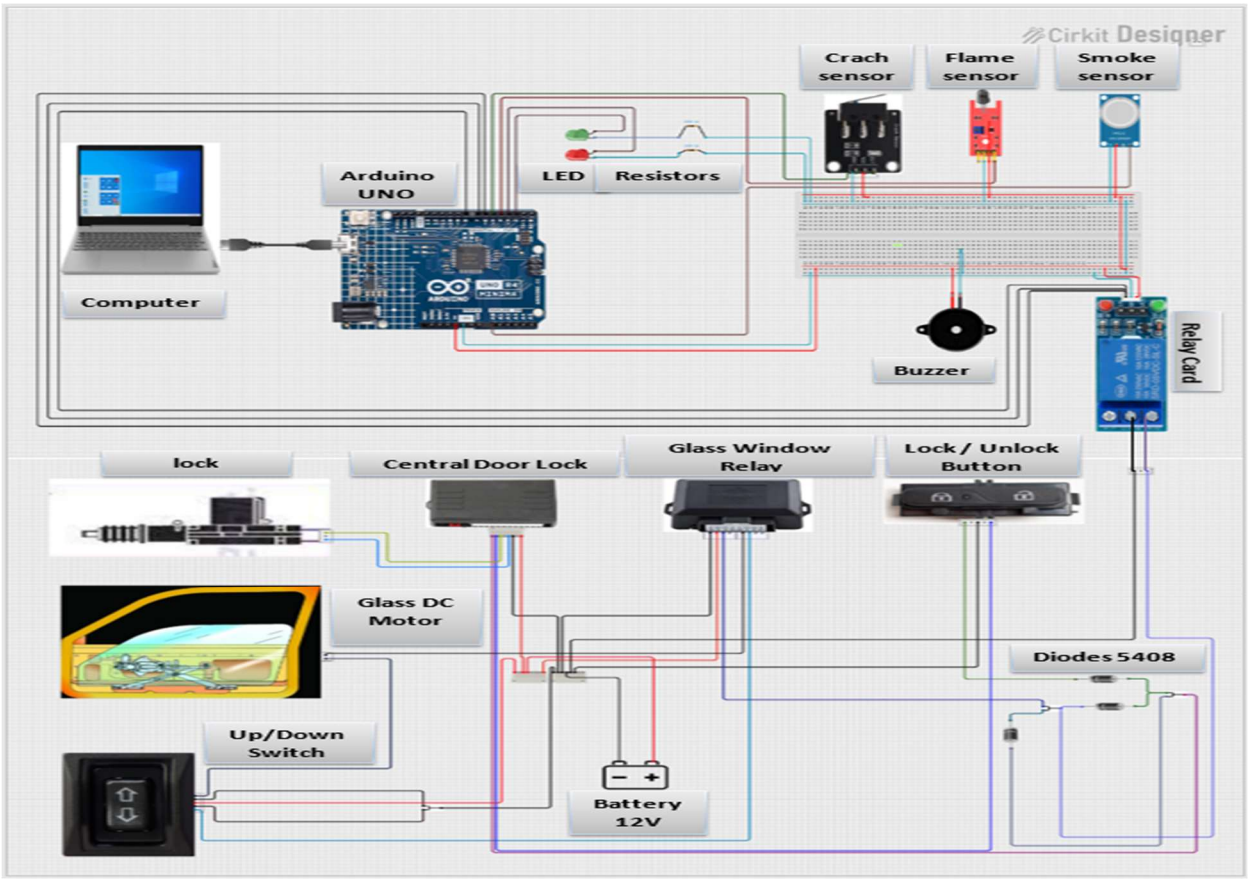

Fig.3.2. Wiring Diagram of Our Emergency System

III.2.2 System Logic and Software development

The Arduino Uno is programmed to:

- Continuously read value of light degrees and smoke levels.
- If smoke is detected or collision exceeds threshold:
  - ❖ Activate buzzer and LEDs.
  - ❖ Trigger relays to down windows and unlock car doors.

Maintain the system status till reset or conditions return to safe situation.

Code Snippet (Simplified): Entre software codes

```
void loop() {


 int flameValue = analogRead(flameSensorPin);
 int collisionState = digitalRead(collisionPin);
 int smokeValue = analogRead(smokeSensorPin);

 if(flameValue < flameThreshold) {
   triggerAlert("flame detected!"); // activate motor// unlock door
 }
 if(collisionState == LOW) {
   triggerAlert("Collision detected!"); // activate motor// unlock door
 }

 if(smokeValue > smokeThreshold) {
   triggerAlert("Smoke detected!"); // activate motor// unlock door
 }
 if(millis() - lastAlertTime > alertDuration && lastAlertTime !=
0) {
   resetSystem();
 }
else {
        // Normal operation
      }
```

An algorithm codes determine to lower the windows and open car doors if one of sensors send a signal follow of fire inside the car or the vehicle is involved in an accident.

III.2.2.1 Challenges and solutions

The following table will show almost challenges that we faced and their solutions.

Table III.11. The problems Faced and their Solutions

Issues	Solutions	Notes
1- The hardware does not respond to software commands.	➢ Check electrical connections : Make sure that the wires are correctly connected to the outlets. ➢ Checking the voltage: Use a multimeter to measure the supply voltage, 5 V or 3.3 V. ➢ Test with Simple Program: Execute basic code, such as an LED light, to isolate the problem. ➢ Using a multimeter. ➢ Pay attention for Arduino IDE instructions and read the hardware catalogs (datasheet) carefully.	➢ If the problem persists, try testing the hardware over another device. ➢ Check that there is no disagree in ports.
2- Delay in data processing.	➢ Improving algorithms: Using algorithms with lower time complexity and smaller data volume.	

III.3. Testing and Results:

III.3.1 Tests:

a) Work Place: Electronics laboratory and on a worktable (with a stable power supply).

b) Safety devices: Electrical resistors, protection fuses.

c) Measuring tools:

- **Multimeter**: For measuring voltage and current in ports.

d) Hardware and software:

- Local Computer.
- Linux (for better performance) or Windows.

III.3.1.1 Prototype in normal situation (Before an event)

Ensure that the prototype does not react or activate automatically in an normal conditions, ensuring that there are no false alarms or undesired activation.

- Operate the prototype as shown below.
- There is no Flame, Smoke or shock.
- Window not rolling down.
- Don’t unlock central lock.

Fig.3.3. Prototype in Normal Case

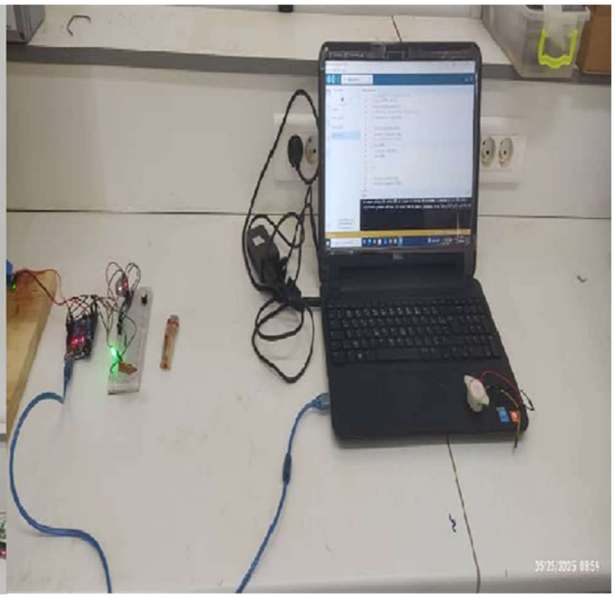

Fig.3.4. Software and Hardware in Normal Case

III.3.1.2 Prototype in emergency situation (after an event)

Test the reaction of our prototype in danger situation.

a) Smoke Test:

- ✓ Catch up a real smoke,
- ✓ Response time is 3 second.
- ✓ The Windows down
- ✓ Unlock doors

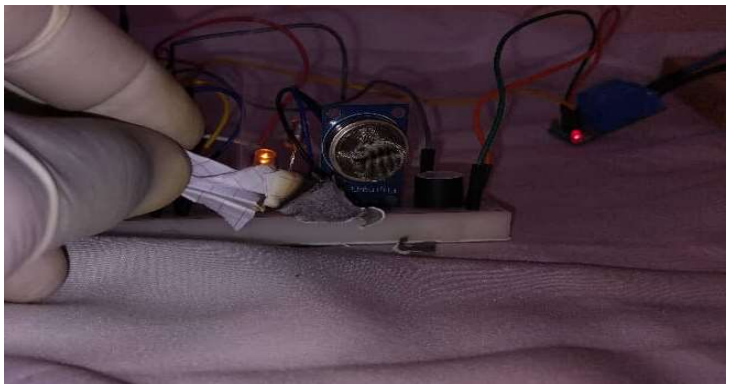

Fig.3.5. Smoke Test

b) Collision Test:

- ✓ Hit the Collision Detector
- ✓ Immediately responded.
- ✓ The Windows down.
- ✓ Unlock doors.

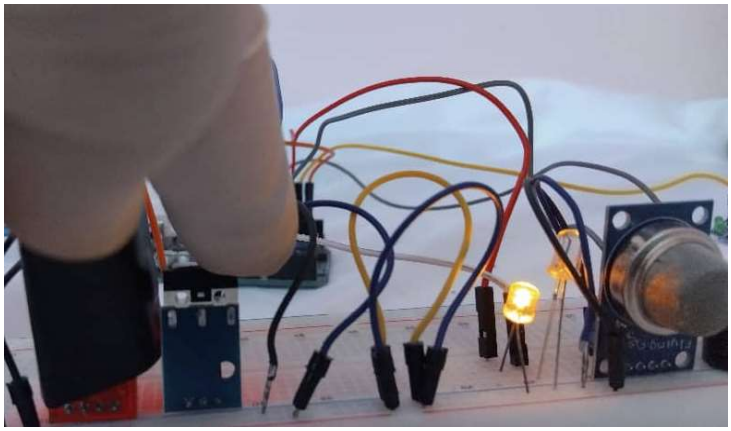

Fig.3.6. Collision Test

2.c) Flame Test:

- ✓ Catch up a real flame (Fig III.4)
- ✓ Response time was 1 second.
- ✓ The Windows down. (Fig III.5)
- ✓ Unlock doors.

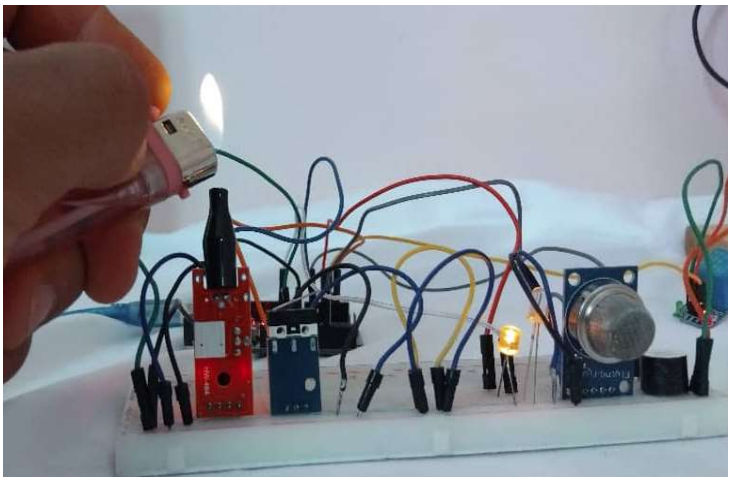

Fig.3.7. Flame Test

Fig.3.8. Reaction of the doors and Windows during an emergency.

III.3.2 Results.

III.3.2.1 Performance measures.

a) Observations in normal case (before accident)

- The emergency system maintained inactive in standby mode.
- Detectors didn't falsely act.
- Threshold calibration was confirmed that is accurate.

b) Observations in emergency cases

Testing was performed in simulated fire and collision conditions:

a- A smoke and gas source was placed near MQ-2.

b- A simulation was performed by hitting the collision sensor.

c- System responded by:

- Activating alarms
- Unlocking doors
- Lowering windows

Each component was tested independently and then in combination. The system successfully demonstrated the intended behavior.

The average response time, which is the time taken between sending a signal from the sensors and receiving a response from the devices in the range [3 to 5] second, is very good. This means that the model's fit with the data is excellent. Therefore, its accuracy is excellent.

III.3.3 Safety and Design Considerations

- All components were fused and isolated to prevent short circuits.
- Wires rated for automotive use were used.
- Delay and hysteresis logic added to avoid false triggering.

III.3.4 Comparison between Some emergencies systems.

In the below table comparison between open doors emergencies systems used currently in vehicles.

Table III.12. Technical Comparison of open doors emergencies systems.

System	Principle of work	Features	Disadvantages	Common use
The reserve spring	**-Work manualy without electrcity**	**-Reliable in collisions**	**-It may Corrode by the time. -Need a periodic maintenance.**	**Sedans and Luxury cars.**
Automatic Battery Cut-off	**-Cut the power after accident**	**- Prevents fire. -Quick response.**	**-Don't open doors**	**Exist in modern cars**
Backup electronic opening system	**-Small backup battery**	**-work when main battery fails**	**-May fail at extreme temperature**	**Smart and electric cars**
Our emergency system	**-Work with the main and backup battery**	**- work in all cases,**	**-work with extreme temperature**	**Can use in all car types**

III.3.5 Limitations of the Study:

III.3.5.1 Technical Limitations:

a) Testing in limited environment:

Study were simulated in a laboratory by using simulation software and prototype model, rather than in realistic scenarios or on real car, which may affect the accuracy of the results.

b) Using sensors that may be unoriginal in some cases (imitated devices)

The effectiveness of the system depends on the sensitivity of the sensors (such as a smoke, flame or collision sensor), which may issue false signals or delay the response in these cases.

c) Limited availability of electronic components locally

Which lead to waste more time, that's lead to buy them from abroad.

There are few qualified people in this field, can be recourse upon to solve issues.

III.3.5.2 Time Limitations:

Delay in purchasing equipment, and There is no enough time to perform more tests.

III.3.5.3 Financial limitations:

Lack of sufficient budget to purchase advanced equipment that helps in implementing the system better than that.

III.3.6 Future Recommendations:

1- Lectuers and training courses of start-ups must be held at the beginning of the academic year.
2- There should be agreements between university and Vocational Training Centers in field of electronics to help students develop their projects.
3- Integrating This system into vehicle's central Unit to enable direct interaction with others safety system into modern cars.
4- Add GSM and GPS wireless communication unit to send immediate notifications to the car owner or to rescue teams.
5- Conducting experiments on real cars in this field.

III.3.7 Conclusion.

At the end of this chapter, we say that our idea has succeeded as we expected as we shown through achieved experiments, and the good time for act. And the problem of passengers gotten stuck into the vehicle in case of either both cut of power or couldn't open it form inside the car due to fainting or inability to move.

here will come the role of our system, with this safety we can save lives of passengers with 60 or 70 %. this system can give people a new life.

as we can say also that we are going to developed it in the future by adding a new features, such as the feature of calling ER Team or MR Team, or by sending notifications for car owners also the feature of giving the location of event.

Chapter IV:

BMC Part

IV.1 Introduction:

The project of inventing an automated system for opening vehicle doors and windows in the case of fire or collision: it's a pioneering, new project and innovative idea. It offers a solution to say the least that can be said about it as a very serious problem that affects a large segment of society, which are the vehicles owners.

This project provides a solution to the consequences of car fires resulting from traffic accidents, which have increasingly become claimed many lives and caused significant material losses fall on the state responsibility.

Therefore, our project aims to develop a system that automatically opens doors and lowers windows in case of fire inside the vehicle, whether the fire is caused by a collision or any other reason, thereby increasing the chances of passenger survival.

However, like any economic activity, the success of this project depends on fulfilling all the necessary economic aspects, whether in terms of human resources, the legal and regulatory framework, and financial support, this is what we will attempt to fulfill it in the following points.

IV.2 Legal and Regulatory framework :

This project will be established as Société a Responsabilité Limitée (SARL), this legal structure has been chosen for many key reasons:

- The project is a collaborative idea between two students, hence, a partnership between them.
- This format is most suitable for future expansion of the project through non traditional financing methods, based on offering a portion of the capital for public subscription.

To comply with all legal and regulatory requirements, it is necessary to provide some foundational aspects of the company which we are summarized in the following.

Table.IV.13. Name and Brand of our Company

Trade name	**AutoSafeRide**
Brand (Logo)	ASR AutoSafeRide
Slogan of Company	**Drive safely with AutoSafeRide**

IV.3 Target Audience :

This project pertains to a safety device that can be installed in the car. Therefore, the target audience are:

IV.3.1. Middle income segment: This category consists of:

- Individuals who own tourist cars and are interested in increasing their vehicle's safety features.
- Taxi operators, especially those providing intercity transportation services, for whom this safety device is consider very important for them.

IV.3.2. High Incoming segment: This category includes.

- Owners of public transport vehicles, whether the medium and big mass transit that operate intercity ways, particularly those
- covering long distances.
- Truck operators engaged in intercity transportation, especially those transporting flammable liquids, hazardous materials, in addition to transport of goods intercity.
- companies heavily reliant on vehicle, such as tourism agencies and private transportation companies like " Yassir".

IV.4 Customer relationship:

Our relationship with customers will be through all means available, encompassing traditional methods such as direct engagement with shop owner, either through in person visits or via telephone calls. Also, by utilizing various electronic communications tools currently available, such as Facebook, WhatsApp, Viber and E-mail.

IV.5 Distribution Channels (Ways):

Initially, our distribution strategy will involve direct sales from the producer to the customer. This approach is due to the product's limited market and the high costs (product life cycle theory), as the product gains market acceptance and production increased, leading to reduced cost (economics of scale). Distributors are relied upon to cover customers' needs.

IV.6 Value Proposition:

I light of the increasing number of road accidents and so-called road terrorism and the large number of accidents associated risks of vehicle fires. This project will be an effective contribution for providing an additional safety measure for various cars. It is expendable to other modes of transportation, including ships, trains. It will also contribute to create of new product that may lead to increased economic diversification in Algeria as a first step, and then increased exports outside of hydrocarbons as a second step.

IV.7 Core Activities (Basic activities):

The primary activity of the company is the production of an emergency safety system (ASR), but the company may carry out some other

activities such:

- Maintenance of sold devices,
- After sales services,
- Training of personal (staff) to facilitate the operation of activity's expansion over various provinces within the country.

IV.8 Main Partners:

Our project requires certain partners to ensure its success, will mention them as follow:

- Electronics and smart components companies.
- Spare parts manufacturing companies.
- Companies that manufacture batteries used in the field of solar energy.

IV.9 Income sources:

No project can be launched without sufficient funding, which is defined as having the necessary funds available at the right time. According to our vision, income sources will first rely on external funding in the initial phase, specifically through a state financing. In later phases, the project will depend on other sources such as self-financing or offering a portion of the company's capital for public subscription in the capital market (stock exchange).

IV.10 Cost Structure:

We know that any project or product involves both fixed and variable costs.

- Fixed Costs: These include expenses such as shop rental, insurance fees, internal security, and employee salaries and wages, etc.

- Variable Costs: These include the primary materials used in the product assembly, such as sensors, relay cards, power switches, connecting wires, microcontrollers, and backup batteries, etc**.**

IV.10.1 Estimated Cost of Project Implementation:

This is presented in a table that calculates the cost of one device, followed by the cost of the number of devices per day, then per month, and finally per year.

Table. IV.14. The Fixed Costs of the Project.

Fixed Costs of the Project	Cost
Shop rent	15000 DZD
Insurance expenses	4000 DZD
Workers' Salaries	50000 DZD
Equipment and Tools	110000 DZD
Electricity Bill	2500 DZD
Internet and Telephone Bill	2000 DZD
Total	**183500** DZD

IV.10.2 Variable Cost per Unit (excluding the backup battery):

Table.IV.15. Variable Costs of the Project

Unit Components	Price
Sensors (Fire, Collision)	1400 DZD
Microcontroller	1500 DZD
Relai Card	500 DZD
Switch Off/On with LED	1000 DZD
Connection Wires	500 DZD
Sensor bracket	300 DZD
Total	**5200** DZD

Total project costs:

Total fixed costs + unit cost (without backup battery) =

183500 + 5200 = 188700 DZD.

IV.10.3 The cost of the backup battery system with all its components:

Table.IV.16. The Backup Battery Costs.

Components	Price
Small Solar Panel	**3000 DZD**
Voltage Regulator	**1500 DZD**
Battery	**2500 DZD**
Protection Circuits + Connections	**1300 DZD**
Total	8300 **DZD**

Total project costs: Total fixed costs + unit cost (including backup battery)

=183500 + 5200 + 8300 = 19700 DZD.

Table.IV.17. Total daily, monthly and annual costs.

Number of units performed	Total Costs	
	Without Battery (DZD)	With Battery (DZD)
01/day	188700	19700
22 /Month	13540	21840
264 /year	5895	14195

Note:

Total cost of one unit per month (based on one unit per day) =

$$\frac{(\text{Variable cost of one unit} \times \text{Number of units produced per month}) + \text{Fixed cost}}{\text{Number of units produced per month}}$$

$$\frac{(5200 \times 22) + 183500}{22} = 13540 \text{ DZD}$$

Table.IV.18. Estimated time period for launching the project

Procedure	Expected Time Period
Commercial Register	One Week
Searching for suppliers and conducting Negotiations	Four Weeks
Rent the Shop	Two Weeks
Preparing the Shop	Two Weeks

Note:

Shop fitting will be accompanied directly by the marketing process, which will include both direct marketing and digital marketing, relying heavily on artificial intelligence and social media platforms.

General Conclusion

General Conclusion.

Our project represents a serious attempt to find a solution to a realistic problem we are experiencing that affects human safety in general and the user of vehicles of all kinds in particular and constitutes a direct threat that may lead to catastrophic results, such a fire and collision incidents witnessed by cars, which sometimes lead to passengers being detained and suffocated due to fire smoke or risk of burns inside The car may be due to the delay of the ER teams or the inability to provide aid from others, because of the car doors not opening or there is no other exit to get out. Whether this is due to a malfunction in the car's electrical system, a loss of consciousness of the passengers, or they an inability to move. Based on that, our emergency system project came to provide an innovative technical solution that works automatically and independently. This system aims to facilitate the quick rescue and evacuation process, also enhances safety inside vehicles and reduces potential human losses. Through the results achieved in this applied and theoretical work, the system has succeeded in achieving its desired goals. By activating the mechanisms for lowering windows and opening the doors automatically and immediately when the pre-determined values are exceeded, the response time of the system performed in a period of time between 3 to 5 seconds, and this excellent results. This system is also implemented based on some electronic components such as sensors, Arduino Uno, and control units. The system is also distinguished by the simplicity and manufacturability, which enhances the possibility of performed it with a low cost, making it suitable for installing in various types of Vehicles. After completing this project, we proved that by using a simple electronic component can lead to achieve a tangible and valuable results, and with some future improvements, this system could become part of automotive safety used standards. We faced several challenges during the design and implementation phases of this project, including a lack of equipment locally, such as original sensors like a fire and collision sensors, which were purchased through websites electronic platforms from outside the country.

We also faced the same thing regarding the backup battery and its components, such as the solar panel, which we could not find one and also very expensive. In addition, we had to find software algorithms that rely on repetition to reduce false alarms. The added value of this emergency system lies in its ability to minimize material losses and save lives, as it directly contributes to reducing the possibility of burning and death of passengers resulting from being trapped during a collision or fire.

The system is useful in other cases, such as accidents that lead to fainting inside the car when it stops over the road, especially when children and the elderly are present inside it. In these such cases, this emergency system will be the savior, will be the difference among survival or death.

Finally, we can suggest to add the new features such as using mechanical components that can help to open doors completely, as well as integrating systems such as GPS and wireless communication to send notifications to either the vehicle owner or to ER Teams or EM Teams to ask for help, as well as connecting it to artificial intelligence (AI) platforms and integrating it into the command screen in the car, allowing the system settings and controlled it manually. AT the end, we can say that this system is an important practical step towards making cars safer.

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الجمهورية الجزائرية الديمقراطية الشعبية
وزارة التعليم العالي والبحث العلمي

جامعة غرداية
كلية العلوم والتكنولوجيا

Université de Ghardaïa
Faculté des Sciences et de la Technologie

قسم : الآلية والكهروميكانيك
شعبة : الكهروميكانيك
تخصص: الطاقات المتجددة ميكانيك

غرداية في : 2025/...../....

شهادة ترخيص بالتصحيح والايداع:

انا الاستاذ(ة) بكاري لقاسم

بصفتي المشرف المسؤول عن تصحيح مذكرة تخرج (ليسانس/ماستر/دكتورا) المعنونة بـ:

Automated Emergency System For lowering Vehicle Windows and opening Doors in case of Fire and collision

من انجاز الطالب (الطلبة):

مصاطفي الشيخ

سيراج محمد عبد الوادد

التي نوقشت/قيمت بتاريخ : 2025/06/22

اشهد ان الطالب/الطلبة قد قام /قاموا بالتعديلات والتصحيحات المطلوبة من طرف لجنة المناقشة وقد تم التحقق من ذلك من طرفنا

وقد استوفت جميع الشروط المطلوبة .

امضاء المسؤول عن التصحيح

مصادقة رئيس القسم

رئيس قسم الآلية والكهروميكانيك
عزاوي محمد

جامعة غرداية
قسم الآلية والكهروميكانيك-1
كلية العلوم و التكنولوجيا

الجمهورية الجزائرية الديمقراطية الشعبية
وزارة التعليم العالي والبحث العلمي
جامعة غرداية
حاضنة أعمال جامعة غرداية

رقم: 241/ ح.أ.ج.غ/2025

شهادة توطين مشروع مبتكر وفق القرار008 المعدل والمتمم للقرار1275

أنا الممضي أسفله، السيد: **د/ طالب أحمد نور الدين**

مسير حاضنة الأعمال: **جامعة غرداية**

المقر الاجتماعي/ العنوان: **المنطقة العلمية، ص ب 455، غرداية، 47000، الجزائر**

رقم علامة الحاضنة: **1004253146** بتاريخ: **2025/04/10**

طبيعة المشروع: **مؤسسة ناشئة**

أشهد أن الطالب(ة) / الطلبة التالية أسماؤهم:

الإسم واللقب	الطور الدراسي	التخصص	الكلية
محمد عبد الواحد سيراج	M2	طاقات متجددة في الميكانيك	العلوم والتكنولوجيا
الشيخ مصاطفى	M2	طاقات متجددة في الميكانيك	العلوم والتكنولوجيا

تحت إشراف الأستاذ(ة)/الأساتذة التالية أسماؤهم:

الإسم واللقب	الرتبة	التخصص	الكلية
حمزة ميدوكالي	أستاذ محاضر أ	الآلية والكهروميكانيك	العلوم والتكنولوجيا

تم توطينه على مستوى حاضنة أعمال جامعة غرداية - بمشروع تحت اسم:

Automated emergency sustem for vehicle lourring windows and opening doors in case of fire and collision.

خلال السنة الجامعية: **2025/2024**

سلمت هذه الشهادة بطلب من المعني للإدلاء بها في حدود ما يسمح به القانون.

حرر في غرداية بتاريخ: 16/06/2025

مدير الحاضنة

حاضنة الأعمال

مسؤول حاضنة الأعمال
★ طالب احمد نورالدين ★