# Passive Safety Systems

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## Sumário

- Introduction;
- Passive safety systems;
- Future trends.



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## Introduction



- Active safety:

  Active safety seeks to minimize the chances of having an accident while circulating in a road.

- Passive safety:

  Passive safety seeks to minimize the impact caused at the occupants at the time of the accident.



## Summary

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- Introduction;
- Passive safety systems;
  - **Seatbelt**;
  - Airbags;
  - Body structure with programmed deformation;
  - Retractable steering column;
  - Head restraints;
  - Seats with “anti-submarine” effect;
  - Fuel cut-off switch.
- Future trends.

## Seatbelt

- The function of a seatbelt is simple: keep a person from flying through the windshield or hurdling toward the dashboard or steering wheel when the car where the person is suffers an abrupt stop. [1]

- Why is this necessary?
  - Because of inertia


**Figure 1-** Seatbelt buckle [1]





## Seatbelt

- Types of seatbelts:
  - 2 points – Lap;
  - 2 points – Thoracic;
  - 3 points – Lap + thoracic;
  - 3 points with retractor mechanism;
  - 5 points – Lap + thoracic + between legs.


**Figure 2-** Types of seatbelts [2]

**Figure 3-** 5 points seatbelt [3]

## Seatbelt



3 points seatbelt with retractor mechanism consists in:

- a spool (cylinder), which is attached to one end of the webbing;
- A spring;
- A buckle.

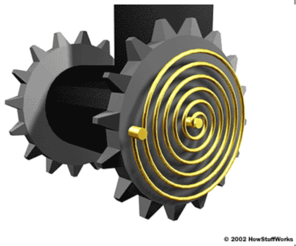


**Figure 4-** Seatbelt retractor mechanism [1]



## Seatbelt

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The retractor has two locking mechanisms that acts when the car is involved in a collision.

- system triggered by the car's movement ;
- system triggered by the belt's movement ;

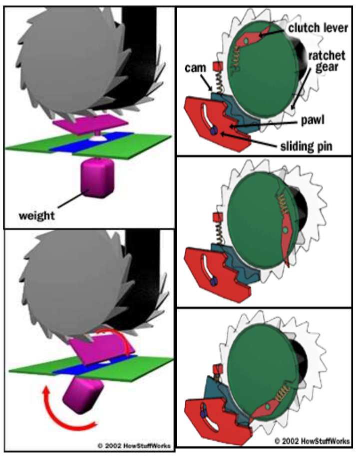


**Figure 5-** Locking mechanisms [1]

## System triggered by the car's movement

This system acts when the car makes a sudden stop (emergency brake or a hit).

The main element in this system is a weighted pendulum connected to a pawl that hold of a toothed ratchet gear attached to the spool.

This prevents the spool for rotating, and therefore, keeping the passengers on the seat.

When the webbing loosens again after the crash, the gear rotates clockwise and the pawl disengages.

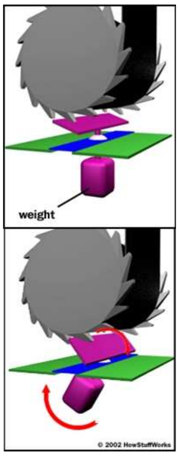


**Figure 6** - Car's movement locking mechanism [1]







## System triggered by the belt's movement

The trigger of this system is the speed of the spool rotation.

In this system the main element is a centrifugal clutch.

When the spool spins slowly, the lever doesn't move.

When the spool spins faster, the end of the lever is forced outward and pushes a cam piece (in blue).

This piece will act , as it shifts to the left, in other pawl that locks into the gear's teeth, preventing counter-clockwise rotation.

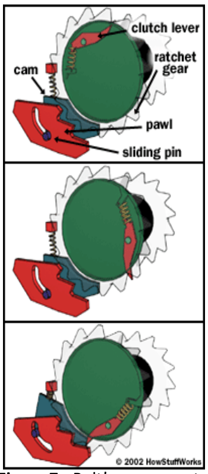


**Figure 7** - Belt's movement locking mechanism [1]

**Seatbelt pretensioner**

The pretensioner tights up any slack in the belt webbing when a crash occurs.

Activated by the central control unit (Airbag Central Unit - ACU) that also activates the airbags.

Some pretensioners pull the entire retractor mechanism backward and some rotate the spool itself.

The most usual designs use pyrotechnics to pull the webbing

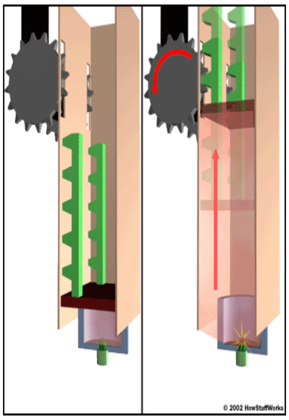


**Figure 8**- Seatbelt pretensioner [1]







**Seatbelt pretensioner**

There's another kind of pretensioner besides the one that acts on the retractor spool.

The other acts on the seat belt's buckle.

A steel cable links the seat belt's buckle to a piston that can move along a steel tube. Like the previous system, this is based on gas generated by the pyrotechnic charge, reducing the belt's slack.

**Figure 9 –** Buckle before pretensioner activation [4]

**Figure 10 –** Buckle after pretensioner activation [4]

## Seatbelt



### Seatbelt activation time sequence

| Moment (milliseconds) | Occurrence |
|---|---|
| 0 | The collision occurs |
| 10 | During the initial time, the system has assessed the need of intervention of pretensioners, according to the level of deceleration recorded by the respective sensors. |
| 12 | At this moment, the passenger is still in the right position. The activation of the pretensioner occurs, beginning the process of retracting the seat belts. |
| 24 | The belt retraction is already finished (7 to 15 cm), being more close to the body of the passenger. The conditions are optimal for sustain the passenger and gradually absorb their energy when projected forward. |
| 25 | About this time, the passenger begins to move forward. |

**Table 1 –** Seatbelt time sequency [5]



## Seatbelt

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### Load limiters

Some systems use load limiters to minimize de injuries caused by the belt.

A load limiter is designed to allow the seat belt force applied to the chest to rise only to a point where serious injury is unlikely. The seat belt is then allowed to extend in a controlled manner, maintaining a constant restraining force to absorb energy.

The simplest way to implement a load limiter is to sew a fold into the seat belt webbing. If the force of the impact is to high, the stitches are ripped out and the webbing unfolds, allowing a slightest forward motion.

## Seatbelt



### Load limiters

There is also some mechanical devices that uses the same principle.

The one in the picture, have the form of a ladder. The seat belt retractor is held in place at the bottom end of the ladder and its motion restricted by the presence of the teeth. As the seat belt force increases, the teeth begin to deform, allowing the seat belt anchor to move along the length of the ladder device.


**Figure 11 –** Seatbelt load limiters [6]



## Seatbelt



### Load limiters

An alternative type of load limiter uses a torsion bar built into the seat belt retractor. The torsion bar is a metal rod that will twist when sufficient force is applied. In minor collisions, the torsion bar will hold its shape, and the seat belt retractor will lock normally. But, when the force applied by the webbing, reaches the design limit, the torsion bar twists and allows the webbing to extend.

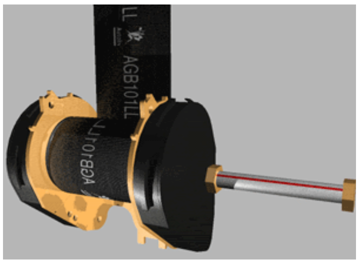


**Figure 12 –** Seatbelt load limiter [7]

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- Future trends.





## Airbags

The objective of an airbag is to slow the passenger's speed to zero with little or no damage. The constraints that it has to work within are huge. The airbag has the space between the passenger and the steering wheel or dashboard and a fraction of a second to work with.

**Figure 13 –** Airbag [8]



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## Airbags



The system consists in three parts:

- The bag – is made of a thin, nylon fabric, which is folded into the steering wheel or dashboard or, more recently, the seat or door; [9]

- The sensor – the device that gives the order to the inflation;

- The inflation system – A reaction between sodium azide and potassium nitrate produces nitrogen gas. This gas will inflate the airbag.

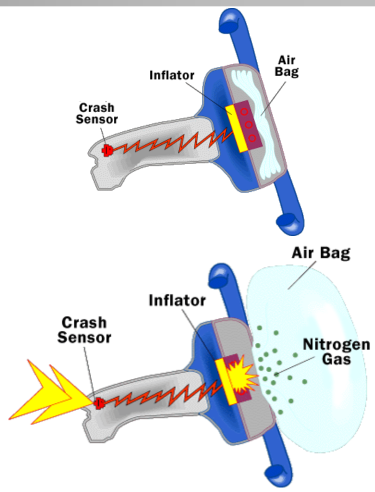


**Figure 14 –** Airbag activation [9]



## Airbags

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**The inflation system**

In order to overcome the problem of space in the car for a gas canister and the doubt whether the gas would remain contained at high pressure for the life of the car, the researchers choosed to use a system of chemical reaction.

The airbag system ignites a solid propellant, which burns extremely rapidly to create a large volume of gas to inflate the bag. The whole process happens in just 1/25 of a second. After a second, the gas in the bag begins to dissipate through tiny holes so that the person can move.

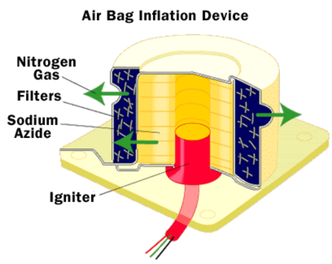


**Figure 15 –** Inflation system [9]

# Airbags



**The inflation system multi-stage**

These are airbags that effectively have twin inflators, which may be deployed independently or in sequence; [10]

In a crash at slowest speeds only one inflator acts, at highest speeds both inflators actuate to inflate the bag in less time;

Having two different gas generator types (or performance levels) would actually provide a more tuned response. In such a system, any one of 3 inflation rates could be used: Low power (Gas generator1), Medium power (Gas generator2), High power, (Both gas generators)

**Figure 16 –** Multi-stage inflation system [10]



# Airbags



## Airbags activation time sequence

| Moment (milliseconds) | Occurrence |
|---|---|
| 0 | The collision occurs |
| 30 | The bag begins to fill, causing it to exit from under the cover of the steering wheel, while the driver begins to be thrown forward |
| 40 | The passenger airbag begins to fill |
| 45 | The driver has moved about 12 cm forward, however, the belt slowed the movement of the body, absorbing some of their energy |
| 50 | The driver's airbag is completely full. |
| 60 | The passenger's airbag is also completely full |
| 90 | The airbag receives the impact of the head and chest of the driver |
| 100 | The airbag receives the impact of the head and chest of the passenger |
| 140 | Both airbags are empty and the driver and passenger returned to their initial positions (leaning on the seats) |

**Table 2 –** Airbag time sequency [5]

## Airbags



The front airbags are only activated by frontal hits in determined area.

Nowadays there are also side airbags:

- Curtain;
- On the doors;
- Or on the seats.

The working principle is the same as the front airbags although, designing effective side airbags is much more difficult.

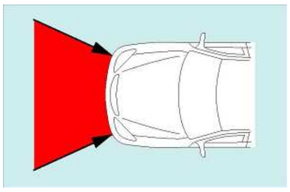

**Figure 17 –** Airbag frontal sensing zone [2]


**Figure 18 –** Frontal and side airbags



## Airbags



Nowadays, in some vehicles, starts to appear airbags for the knees.

This helps to prevent the legs from hitting in the dashboard.

In other cases there are footwell airbags.

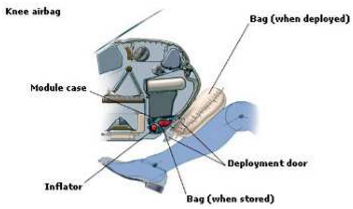


**Figure 19 –** Knees airbag [2]

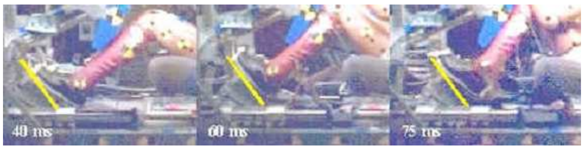


**Figure 20 –** Foot airbag [10]

## Spiral cable

In order to maintain the connections between the central control unit and the inflation system is used a rotary contact. [2]

This rotary contact is not more than 2 circular elements that rotates between them, housing a cable in a ribbon shape.

This permits that the steering wheel rotates the maximum to the both sides without breaking the connection

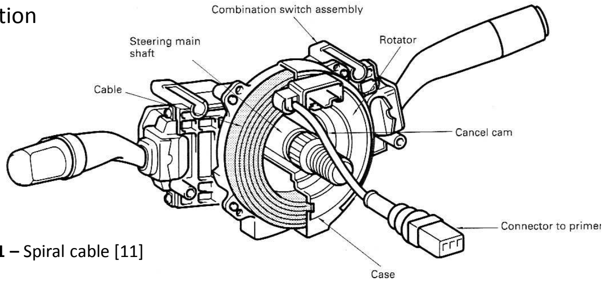


**Figure 21** – Spiral cable [11]







## Sensors

There's a considerable amount of sensors in a car. Here, the ones that will be studied are related to passive safety, especially to airbags.

The picture at the right side represents a sensor that detects the presence of a person on the seat.

This can be used to decide whether the passenger airbag actuates or not in case of accident.

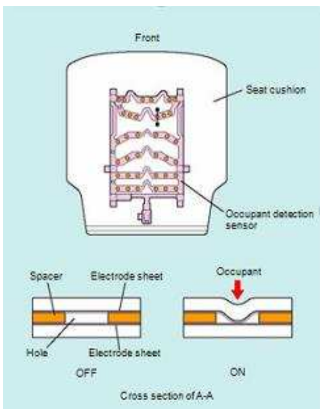


**Figure 22** – Passenger detection sensor [2]

# Airbags



## Sensors

**Frontal sensors:** This sensors are located at the front of the vehicle, one on each side of the radiator.

Each sensor have a accelerometer that detects a quick variation of speed, and that sends a signal to the ACU for the frontal airbags deployment. If the force of deceleration is bigger than the one stored in the ACU, the deployment occurs.

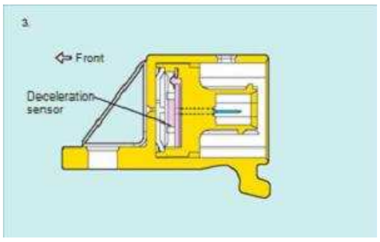


**Figure 23 –** Frontal airbag sensor [2]



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# Airbags



## Sensors

**Side sensors:** This sensors are normally located at doors of the vehicle.

In the case of an side accident the sensor sends a signal that activates the airbags. This is an deformation type of system.

In the case of sensors based on acceleration measures, the best location is at the seat cross member, near to the sill.

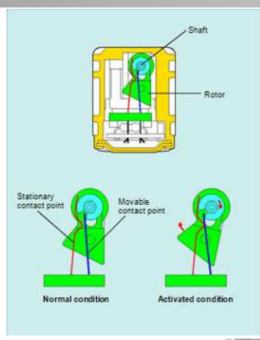


**Figure 24 –** Side airbag sensor [2]

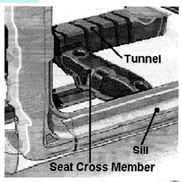


**Figure 25 –** Side accelerometer airbag sensor best location [12]



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## Airbags



**Sensors**

**Seat position sensor:** This sensor is located under the seat.

It uses the seat rail to calculate and inform the ACU about the position of the seat (closer or further away from the steering wheel). In this way, the ACU calculates the best inflation rate of the airbag.

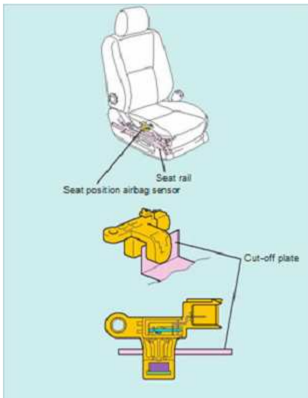


**Figure 26 –** Seat position sensor [2]



## Airbags



**Front airbags deployment conditions**

The ACU is constituted by an electrical and mechanic acceleration sensor, a supply module, and a microprocessor.

In the most cases, the deployment exists when a signal from the front airbag sensor is sent to the ACU and is confirmed by the two sensors (electrical and mechanic) of the own ACU

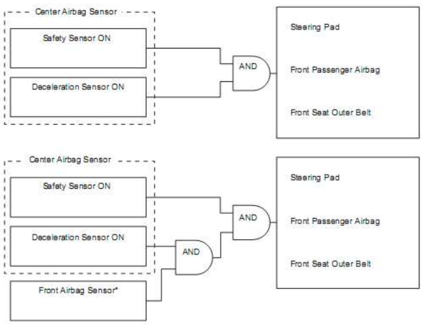


**Figure 27 –** Deployment conditions to the front seats airbags [13]

## Airbags



**Side airbags deployment conditions**

In case of a lateral accident the door airbag sensor sends a signal to the ACU. If the safety sensor is also activated the ACU gives order to the deployment of the side and curtain airbag.

If, in any case, the front seat side airbag is deployed, the curtain airbag will also be deployed even if the door sensor don't send a signal to the ACU.

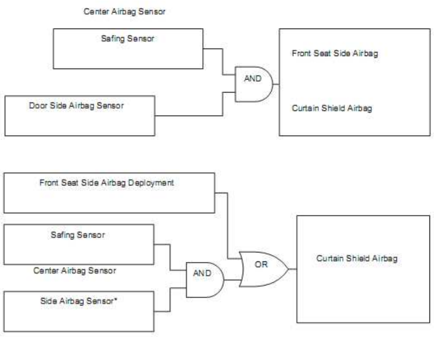


**Figure 28 –** Deployment conditions to the side airbags [13]



## Summary



- Introduction;
- Passive safety systems;
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  - Airbags;
  - **Body structure with programmed deformation**;
  - Retractable steering column;
  - Head restraints;
  - Seats with "anti-submarine" effect;
  - Fuel cut-off switch.
- Future trends.

# Body structure



The front structure consists of deformation zones of different grades of steel, each one with a certain role in a collision. The structure is designed to help providing increased protection in a frontal collision.

Side structures of different grades of steel and a number of tubes and members are all designed to "move" the body to the side, help reducing the risk of passenger compartment intrusion. [15]

The carrier (zone of the passengers) must be the one with more resistance in an impact to provide a better protection.

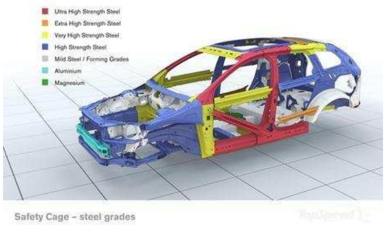


**Figure 29 –** Body structure [13]



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# Body structure



Despite all the reinforced structure in the area of the carrier, there is still an area where the car is more fragile – the roof.

That's not very usual the occurrence of a hit at the roof except in cases of roll over.

In competition the car's structure is reinforced with a roll cage

**Figure 30 –** Reinforced structure [14]



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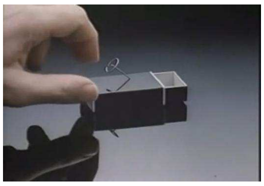
## Retractable steering column

The retractable steering column is a very rare system. It was used by Audi and Mercedes in the eighties.

The mechanical displacement of the engine pulls some cables connected to the steering column (which is pulled away from the driver) and at the same time activates the seat belts pretensioners. [10]



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## Head restraints



Normally, head restraints are referred as head rests. This is a wrong assumption.

The head restraints make part of passive safety systems.

In the case of a rear accident they help to prevent injuries in the neck due to whiplash. Whiplash is the movement that the head does, presented in the picture.

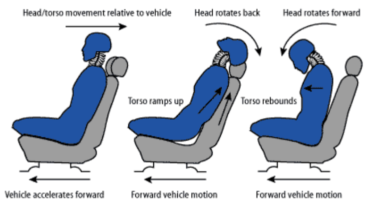


**Figure 31 –** Head movement in a crash



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## Head restraints



Nowadays, brands have a greater concern on the development of this safety system.

Some brands like Saab have developed an active head restraint.

An upper padded support is connected to a pressure plate in the backrest of the seat. In some rear collisions, the occupant's body will be forced by the crash pulse into the backrest, which moves the pressure plate towards the rear. Subsequently, the head restraint is moved up and forward to "catch" the occupant's head before the whiplash movement can start.

**Figure 32 –** Active head restraint [15]



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## Seats



**Seats with “anti-submarine” effect**

Used to prevent that the occupant slips under the lap portion of the seat belt.

Normally, this device located inside the seat, is made of metal that absorbs the impact energy in a controlled manner.

However, the optimal action depends on impact type, speed and occupant.

Some brands use an airbag that achieves this effect.

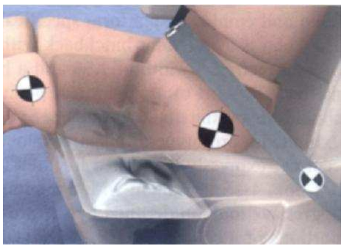

**Figure 33 –** Seat with airbag “anti-submarine” effect [10]



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## Fuel cut-off switch



**Fuel cut-off inertial switch**

In the event of an accident, this switch opens due to the force of impact and deactivates the fuel pump electrical circuit so that the flow will stop.

In order to activate the fuel pump, the reset button must be pressed. The location varies from vehicle to vehicle

**Figure 34 –** Fuel cut-off reset switch [16]



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## Future trends

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- Seatbelt airbag

Is a belt from which the bag inflates to provide a greater contact area with the chest. This type can also provide some head and neck protection in side and angled impacts on the diagonal upper anchorage side.


**Figure 35 –** Seatbelt airbag [10]



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