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Usage of Infrared Camera in Active Safety Systems

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ABSTRACT

The intelligent systems supporting the driver start to play a decisive role in avoiding vehicle collisions in dynamically changing road conditions. Systems cover the following fields: prevention, passengers safety, support and information. In that case we are dealing with an integrated safety system, which is much broader then an individual car or personal skills of a driver. The implementation into a common usage of sophisticated safety systems is aimed at early warning, monitoring the situation on the road, mutual interaction and functionality of the systems in changing road conditions. The huge technological investments of car producers result in safety improvement and avoidance of majority of car collisions. The most recent safety active systems, which are broader described in the article, include the systems, which use IR cameras, such as: Driver Alert System - DAC (Driver Alert Control) and LDW (Lane Departure Warning) as well as City Safety System.

KEYWORDS: safety systems, car collisions, prevention

1. The intelligent systems supporting the driver

The intelligent systems supporting the driver start to play a decisive role in avoiding vehicle collisions in dynamically changing road conditions.

For a long time car producers in cooperation with systems suppliers have been working on the development of technologies which would protect against car collisions and as a result against consequences they may cause. One can observe a visible trend in ways of placing orders by car producers. Car producers are ordering whole systems for the new car models. For example, a brake system supplier secures for car producer the whole range of products – starting from electronic units ending on a brake fluid.

Similar situation is in safety systems. They consist of many functions of active and passive safety, called by suppliers CAPS – Combined Active & Passive Safety Systems. System suppliers have to guarantee system delivery in the following fields: prevention, passengers safety, support and information.

In that case we are dealing with an integrated safety system, which is much broader, then an individual car or personal skills of a driver. The implementation into a common usage of the sophisticated safety systems is aimed at early warning, monitoring the situation on the road, mutual interaction and functionality of the systems in changing road conditions.

These huge technological investments result in safety improvement and avoidance of majority of car collisions.

The most recent safety active systems include the systems, which use IR cameras, such as:

- Driver Alert System [DAC (Driver Alert Control), LDW (Lane Departure Warning)]
- City Safety

2. Driver Alert System.

The Driver Alert System warns the driver when the vehicle is being driven in an unsteady way or is about to leave its lane unintentionally, e.g. due to the driver

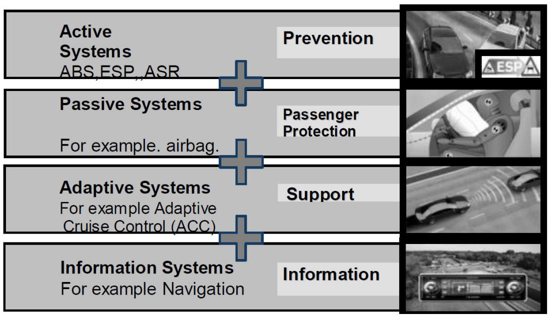


Fig. 1. Idea of CAPS (Combined Active & Passive Safety)
Source: [3]

being distracted or being tired. Clear side markings on the carriageway are required for the Driver Alert System to function. The Driver Alert System also warns a driver whose driving is deteriorating or who is unintentionally leaving the current lane.

The Driver Alert System consists of the following functions:

DAC (Driver Alert Control): informs and warns the driver that his/her attention, and accordingly driving style, has deteriorated due to fatigue, for example.

LDW (Lane Departure Warning): alerts the driver when the vehicle is about to unintentionally leave its lane.

The FSM (Forward Sensing Module) uses the information from the camera in the windscreen to continuously read the carriageway's side markings. As the camera has similar limitations to the human eye the performance of the Driver Alert System is affected by external factors such as light conditions, road conditions, rain and snow and fog.

For the camera to have mist-free vision through the windscreen, there are electric coils in front of the camera's field of vision controlled by the FSM.

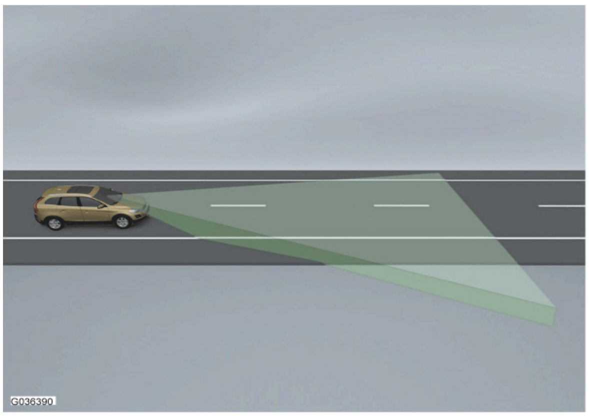


Fig. 2. The way of monitoring the space by the Driver Alert System
Source: [4]

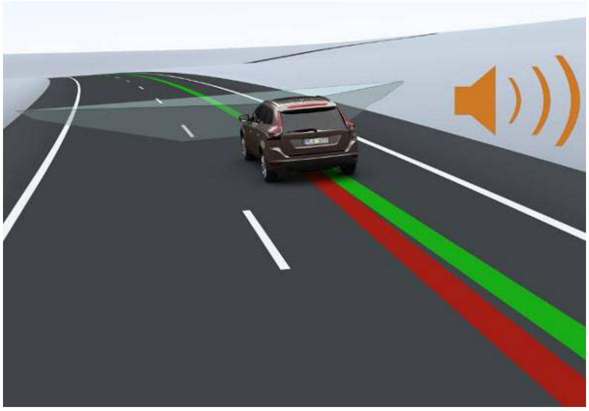


Fig. 3. Information from IR Camera used for identification of road width and driver's reactions
Source: [4]

2.1 DAC (Driver Alert Control)

The DAC warns the driver when his/her attention, and accordingly driving style, has deteriorated due to fatigue, for example.

The FSM uses the information from the camera to identify the carriageway's side markings and then by these means to calculate the extent of the road. The FSM can assess whether the vehicle follows the lane consistently by continuously comparing the road's assessed stretch with the information about the driver's steering wheel movements. This means that if the driver is tired but is still driving well enough then the system does not detect anything. It may also mean that the system warns when the vehicle is affected by strong side winds.

If the driver's driving style deteriorates then this is indicated on the information display in the driver information module (DIM). The driving style is indicated by a level marking of 1–5 bars, where 5 bars means a stable driving style and 1 bar means unstable driving style.

Fig. 4. Warning the driver to take a break
Source: [4]

Fig. 5. Information from an IR Camera used to calculate the position of the vehicle
Source: [4]

Fig. 6. City Safety
Source: [4]

When the level marker drops below 1 bar, the driver is alerted by an audible signal. At the same time, a message is displayed on the information display in the DIM warning the driver to take a break.

The DAC is switched off and on in the menu system in the ICM. When the DAC is switched on the function is activated at 65 km/h and is then active at all speeds above 60 km/h. The driver can check whether or not the function is available (i.e. whether or not the camera can detect the side markings) by selecting Driver Alert's trip computer page using the left-hand stalk switch. Current status is then shown on the information display in the driver information module (DIM).

2.2. LDW (Lane Departure Warning)

LDW warns the driver when the vehicle is about to leave its lane unintentionally.

The FSM uses the information from the camera to calculate the position of the vehicle in relation to the side markings. If the vehicle crosses the left or right-hand side markings unintentionally, the driver is alerted by an audible signal.

The switch for the LDW is located in the CCM. Using the ICM menu system, the driver can select whether the function should always be switched on from the start and the degree of sensitivity for the function.

When the LDW is switched on the function is activated at 65 km/h and is then active at all speeds above 60 km/h. The information display on the driver information module (DIM) shows whether the function is active and whether or not the function is available (depending on whether or not the camera can detect the side markings).

3. City Safety

The City Safety is a function for helping the driver to limit or avoid collisions at low speeds. In a situation where a collision is likely to happen, for example, when the vehicle in front brakes without the driver behind reacting, the vehicle will brake itself by applying the foot brake.

According to statistics, 75 % of all reported collisions occur at speeds below 30 km/h. The figure may even be higher because the consequences of minor collisions may be limited and not always reported to insurance companies. With the City Safety these collisions can be limited or fully avoided.

The City Safety is active at speeds below 30 km/h and it can detect both stationary vehicles and those driving in the same direction as the City Safety system's own vehicle. The driver can switch off the function during the current operating cycle via the menu in the trip computer. The system is designed to report to vehicles the size of a passenger car or larger.

A rangefinder is used in order to detect the vehicles in front. The rangefinder is part of the control unit, CVM (Closing Velocity Module), and is fitted in the upper part of the windscreen.

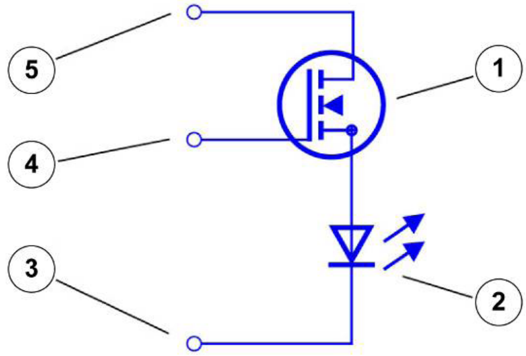
The CVM is standard on all XC60 and is used for:

- City Safety
- Prepares the vehicle's SRS in the event of an imminent collision.

The driver is always responsible for ensuring that an adequate distance is maintained to the vehicle in front and that the speed is adapted to the current traffic situation.

If the vehicle is equipped with the CMS then these functions complement each other.

Fig. 7. CVM (Closing Velocity Module)
Source: [4]



1. FET Transistor, 2. Laser Diode, 3. Earthing, 4.Steering Voltage, 5. Voltage
Fig. 9. CVM (Closing Velocity Module)
Source: [4]

The CVM is located in the windscreen's upper edge and, besides the CVM control module, also contains a rangefinder.

The rangefinder reads an area around 6 meters in front of the vehicle by means of a laser sensor. The laser sensor projects an infrared light invisible to the eye every 10th millisecond with a wavelength of 905 nm.

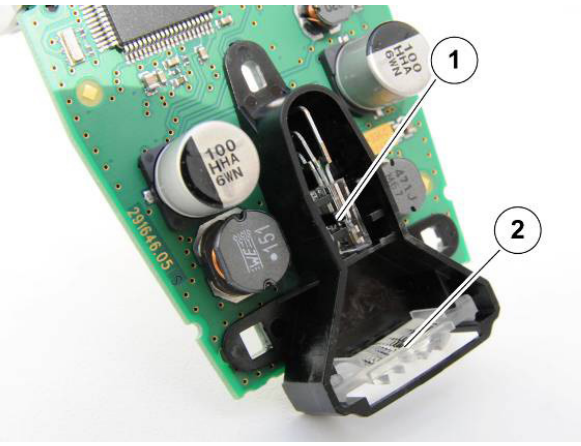
A laser diode produces the infrared light which is projected through a lens in three fields:

- Left
- Centre
- Right

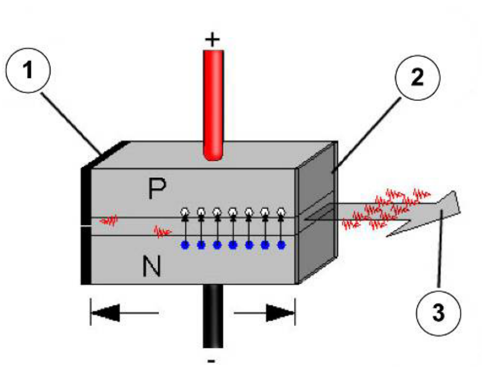
Together the fields cover an angle of 27°. If any object is in front of the vehicle the light is reflected and recorded by three photodiodes. The CVM measures the time it takes for the light to travel from the sensor, reflected from the object in front, and back to the photodiodes. The time is used in conjunction with the vehicle's speed to calculate the distance to the object in front, and also the speed difference between the vehicle and the object in front.

The laser diode produces an infrared light invisible to the eye which is projected through a lens in three fields. The laser diode is a further development of the LED. The light's wavelength, 905 nm, is constant. Following the illumination of a laser diode it is gradually heated by the operating current.

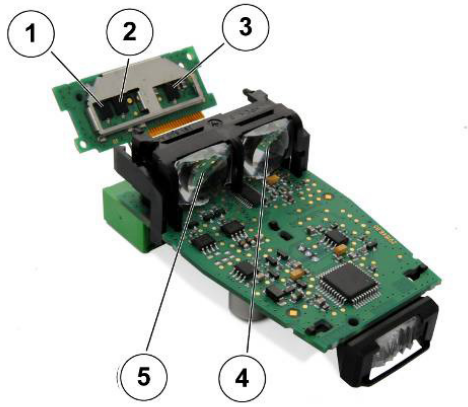
If the operating current is not adjusted there is a risk that the laser diode will be overloaded. An operating current that is too high results in the laser diode failing



1. Laser diode unit, 2. Lens
Fig. 8. Laser diode unit
Source: [4]



1.Mirror, 2.Semitransparent Mirror, 3.Laser light
Fig. 10. Laser diode
Source: [4]



1. Photo diode for right-hand field
2. Photo diode for left-hand field
3. Photo diode for centre field
4. Magnification lens centre field
5. Magnification lens right/left-hand field

Fig. 11. Photo diodes
Source: [4]

quickly. In order to regulate the operating current there is a transistor (FET = Field Effect Transistor) built into the laser diode. The transistor is controlled by the CVM.

The photons (light particles) are reflected between mirrors to the diode's short sides. The distance between the mirrors is adjusted so that a whole range of wavelengths of the light emitted is accommodated. The mirror on one of the diode's short sides is only "semi-transparent", i.e. it both reflects and admits a certain amount of light, and most of the light beam can leave the laser diode here.

If any object is in front of the vehicle the light is reflected and recorded by three photodiodes.

4. Theoretical Analysis of Conditions of Systems Operation with an IR Camera

Laser light can occur throughout the whole infrared, visible and ultraviolet spectra down to X-ray emission. However, red laser light is the least expensive to produce and is therefore the most common.

An IR Camera, which uses the infrared laser emits photons in phase with each other in a narrow well-defined light beam in a single wavelength. The laser can be concentrated into a small area and so be much more intense, the smaller the surface of the same amount of laser light, the stronger the point of light.

A very dark surface may have only 5 % reflection. An object with a low degree of reflection means that the maximum measuring distance drops significantly. The best measurement objects are those with a special reflective tape that provides very high reflection values, such as a number plate.

Something that also affects measurements is the structure of the object's surface. If the beam is aimed at an object that has a structure that is not uniform, the beams are reflected in a variety of different directions. This also affects the measuring distance because the energy in the light that is reflected decreases when the reflected light is not aimed back to the transmitter.

The rangefinder reads an area around 6 meters in front of the vehicle by means of a laser sensor. The field covers an angle of 27°. As the IR camera has similar limitations to the human eye the performance of the system is affected by external factors such as light conditions, road conditions, rain and snow and fog.

As the speed of the laser diode's light is known, the CVM module can calculate the distance to the object in front. The CVM module can also calculate the difference in speed between the vehicle and the vehicle in front. Based on this information, the CVM module can calculate the retardation (braking effect) required to reduce the speed of the vehicle so that a collision is reduced or avoided.

The rangefinder in the CVM module uses laser light within the wavelength for IR light, which means that this function would otherwise be filtered away by the IR windscreen unless the heat insulating film has been removed in the area in front of the rangefinder.

This means that the IR light transmission in front of the rangefinder on the IR windscreen will be slightly higher than for a standard windscreen which has a certain heat insulation in the laminated film.

The CVM module receives information about the type of windscreen fitted in the vehicle via the vehicle configuration file in the CEM (Central Electronic Module).

It is important that the same type of windscreen is fitted when replacing the windscreen, as the light transmission through the windscreen is known by the CVM module.

If this is changed, whether it be higher or lower, the performance of the system will deteriorate. If a scratch, crack or stone chip occurs on the windscreen in the field of vision in front of the CVM module which is greater than 0.5 x 3.0 mm, then the windscreen must be replaced.

The rangefinder emits the invisible laser light from ignition position II, regardless of whether or not the vehicle's engine is running. Looking directly into the opening of the rangefinder (which emits invisible laser radiation) with magnifying optics such as a magnifying glass, lens or similar optical instruments at a distance of less than 100 mm involves a risk of injury to the eyes. A dismantled CVM module fulfils laser class 3B. Laser class 3B is not safe for the eyes and accordingly constitutes a risk of injury.

5. Conclusions for Practical Purposes of Diagnostic Systems with an IR Camera

The operation of the systems with IR camera may be disrupted by:

- ice or snow on the bonnet
- ice, snow or dirt on the windscreen
- heavy rain, snow/snow flurries or fog
- hanging load on the roof
- accessories such as auxiliary lamps, grille guard etc. in excess of the bonnet's height
- decals adhered to the windscreen in the rangefinder's field of vision
- the structure of the object's surface
- scratch, crack or stone chip on the windscreen in the field of vision in front
- not illegible marking of horizontal lines of the road
- false data in the configuration file in the CEM module (for example the information on the type of windscreen)
- Faults in CAN bus communication protocol between system modules

For effective diagnostics of systems with an IR camera the unique data regarding the analyzed system are necessary. As it has been proved in the article the only step by step diagnosis may not lead to effective system improvement, it leads only to unwanted change of vehicle modules.

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