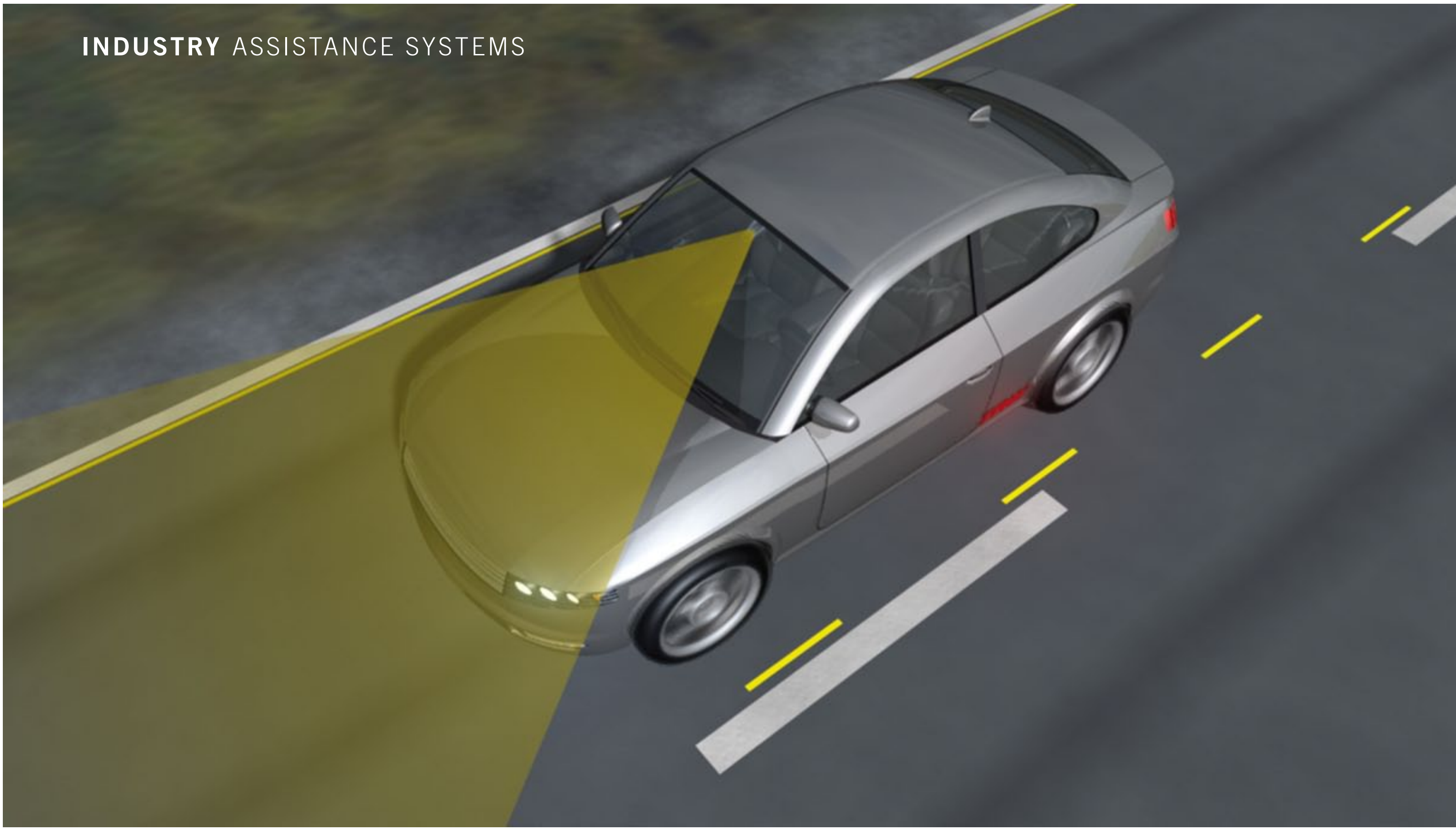

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INTRODUCTION

Automotive manufacturers are increasingly focusing on equipping vehicles with new and more sophisticated driver assist systems – supported by a raft of technologies based on proximity sensors, radar, laser-based lidar and the CMOS (Complementary Metal Oxide Semiconductor) camera. Of all these sensors, the camera is perhaps the most versatile because unlike to radar it can detect and classify a wide range of relevant "objects". Because of its multi-tasking capability, the CMOS video camera is of particular interest for vehicle manufacturers.

TRW's earlier T-CAM – which is currently in production on the Lancia Delta – is already established in the areas of lane keeping. It activates audible or visual warnings to prevent inadvertent lane changes or departures, and when integrated with electric power steering (EPS), can provide discreet inputs (torque overlay) via the steering wheel to guide the vehicle back towards the center of the lane. These functions are being continually improved. In the case of lane departure warning, a lane keeping function has evolved, while the high/low beam assistant is developing from one that simply switched the headlights between main beam and dipped, to one that offers a "staged" control. Vehicle manufacturers also use a forward-looking camera to support radar-based functions such as adaptive cruise control (ACC); city driving ACC Stop-and-Go systems; collision warning; and collision mitigation. Traffic sign recognition as well as video-based pedestrian safety functions that work in conjunction with radar sensors are also fast-expanding areas of development. These trends are gaining momentum due to their recognition by important vehicle test organizations such as Euro NCAP, which has launched awards to recognize the performance of active safety systems. Legislation is having an influence on the continuous development of driver assist systems, too. To fulfill current and future requirements for advanced video sensing, the engineers of "Driver Assist Systems" and "Integrated Active & Passive Safety Technologies" at TRW have developed a scalable camera with improved performance, the so called S-Cam. The highly integrated and compact sensor, ❶, is able to detect vehicles (by day and night), lanes, traffic signs, and pedestrians – enabling the vehicle manufacturers to offer features such as collision warning, lane departure warning, lane keeping, traffic sign indication, high/low beam, gliding light assistance and pedestrian safety function with one single unit.

"ALL-IN-ONE" – VIDEO-BASED DRIVER ASSISTANCE SYSTEMS

TRW has developed a new scalable and compact camera. The so called S-Cam is able to see and interpret what is happening on the road ahead of a vehicle more effectively than preceding systems. As a single component, it supports OEMs with an array of safety and driver assist functions, for example collision and lane departure warning, lane keeping, traffic sign indication, high/low beam, gliding light assistance as well as pedestrian safety functions.

DESIGN REQUIREMENTS

In order to deliver a wide range of customer functions, the new video camera sensor had to be capable of detecting, classifying and localizing objects to a high degree of accuracy and reliability. These include: lanes, light-emitting objects such as tail lights and headlights, road signs, vehicles and pedestrians (stationary or moving). Additionally the sensor needed to be as compact as possible to accommodate its ideal forward-looking mounting position – behind the windscreen near the rear-view mirror. The camera also had to deliver its many functions as cost-effectively as possible. In addition to all detection functions, all customer functions had to be integrated into a single module – in other words, a one-box solution. Another requirement was the easy mounting and dismounting during car manufacture, servicing or windscreen replacement. This impacts on the mechanical connection requirements and also means that camera calibration procedure must be exact, fast and as straightforward as possible.

SCALABLE S-CAM SOLUTION

With the newly developed scalable camera, TRW has developed a sensor meeting the most common requirements of vehicle manufacturers, ❷. At the heart of the system are the EyeQ2 chip with algorithms from the company Mobileye, and a customer-specific microprocessor. A magnesium housing provides both structural integrity and a sufficient heat sink to dissipate waste heat produced by the microprocessors and sunlight loading. The camera itself is a wide VGA (752 x 480 pixel) CMOS imager. Three out of four pixels are "clear", measuring pure light intensity independent of color while the fourth "red" pixel measures only the red component of the incident light. This so-called RCCC imager combines the advantages of a pure black-and white-imager – higher resolution and higher sensitivity – with the benefit of being able to distinguish the red channel. This helps to differentiate tail lights from white reflectors and it enables the camera to distinguish between, for example, the "speed limit 80" and the "highway exit number 80". Combined anti-reflective coatings minimize the effect of stray lights.

Two CAN controllers can be installed. Typically one is connected to the vehicle CAN to obtain specific information like host vehicle speed, yaw rate and the state of indicators, brakes, wipers, headlights and so on while also communicating with the vehicle's human machine interface

❶ TRW S-Cam: multifunctional sensor supporting an array of driver assistance and safety functions in a single unit

PARAMETER	VALUE
FIELD OF VIEW (DETECTION AREA)	42 ° horizontal, 27 ° vertical
IMAGER SIZE	752 x 480 pixel
VELOCITY RANGE	Up to 250 kph
UPDATE RATE	13,8 Hz (with 4 exposures)
POWER CONSUMPTION	3.50 W
MODULE WEIGHT	74 g
PACKAGING SPACE REQUIRED (CAMERA + BRACKET)	X – (fore/aft) 110 mm Y – (cross car) 60 mm Z – (up/down) 36 mm
OPERATING TEMPERATURE	-40 to +85 °C (+105 °C for CAN communication only)

❷ Key features of S-Cam

❸ PCB of S-Cam

(HMI). The second CAN interfaces exclusively with the radar sensor, if fitted, for high order data fusion in the radar.

The S-Cam is totally scalable with respect to the software modules which are executed on the EyeQ2 chip. At the moment the scalability of the hardware is restricted to the RAM and ROM modules used on the printed circuit board (PCB). The full software bundle requires the PCB, ❸ and ❹, to be equipped with 128 MB of SDRAM (Synchronous Dynamic Random Access Memory) and either 8 or 16 MB of flash memory. The second microprocessor is Autosar compliant and dedicated to the basic software modules like CAN communication and diagnosis as well as customer specific functions and HMI modules. Besides customer specific functions such as lane keeping control, pedestrian detection, and collision warning, it offers OEMs the opportunity to integrate their own application code so that their interfaces have a unique look and feel.

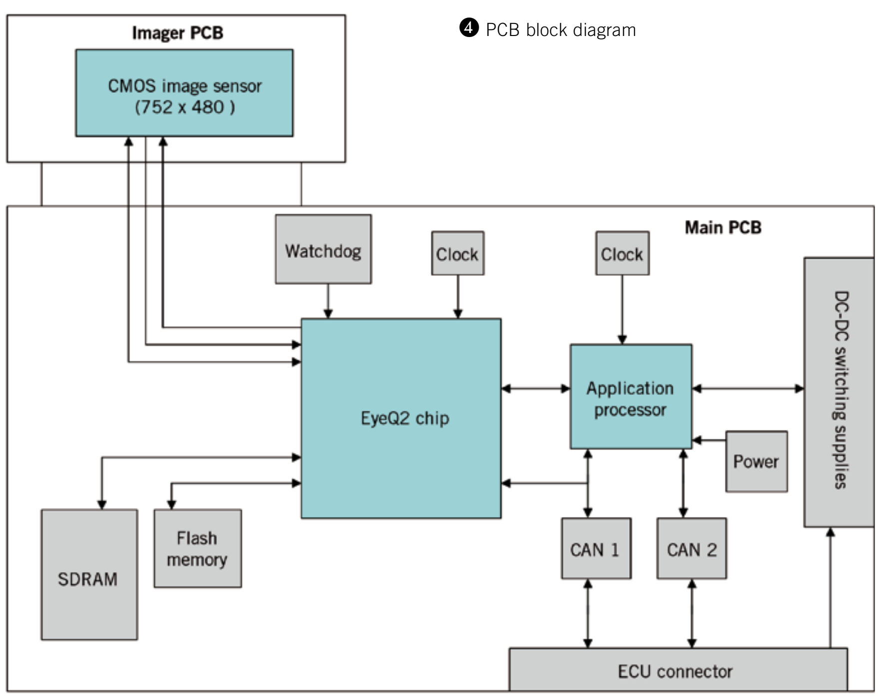
The EyeQ2 architecture consists of two floating point and hyper-thread 32 bit RISC CPUs (Central Processing Units). Based on its architecture the camera is able to perform intensive vision computations needed for functions and applications.

The assembly process of the S-Cam is easy and robust, ❺. The assembly is attached to the windscreen by a plastic bracket which is pre-bonded to the glass, using polyurethane (PU) adhesives. The camera module is snapped into this bracket, ❻, leaving a small but important gap between it and the glass. This ensures that there is some air flow in the area, ❼, so that any moisture that could affect the functionality of the camera is quickly removed by the heating and ventilating system. TRW carried out extensive airflow simulations to optimize the air flow.

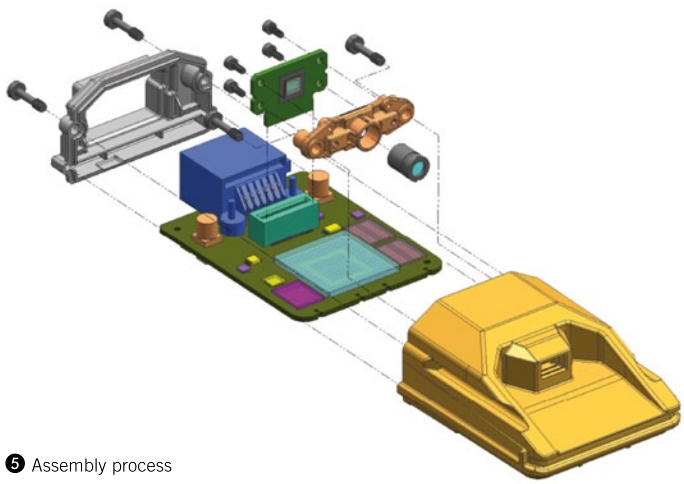
APPLICATION POTENTIAL

S-Cam builds on the capabilities of its predecessor. The lane-keeping algorithm is able to detect every kind of lane markings used whether they are solid, single, double or triple; or colored white, yellow or blue. Even dots and road edges, including grass verges, can be detected. This capability massively enhances the camera's capability in the application of lane departure warning systems, lane keeping and guidance systems. At night, the new camera is able to detect and classify objects from an analysis of their lights. It differentiates oncoming vehicles; transport traveling in the same direction; reflectors located around the road; and can tell whether the vehicle is in an urban area by detecting street lamps and other types of ambient light. S-Cam also keeps pace with advanced headlamp design, supporting actuation of complex beam patterns and graduated high-low beam control.

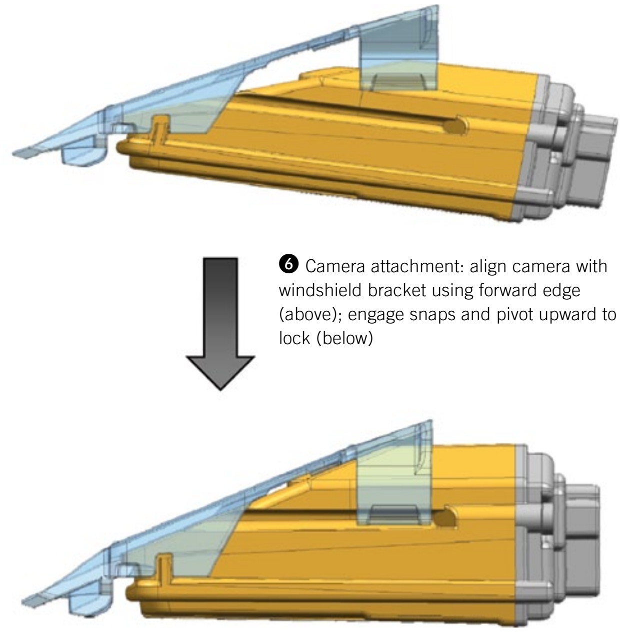
All motorized vehicles can be detected together with accompanying data – distance; lateral offset; position in angle; vehicle width; speed; acceleration; class



❹ PCB block diagram



❺ Assembly process

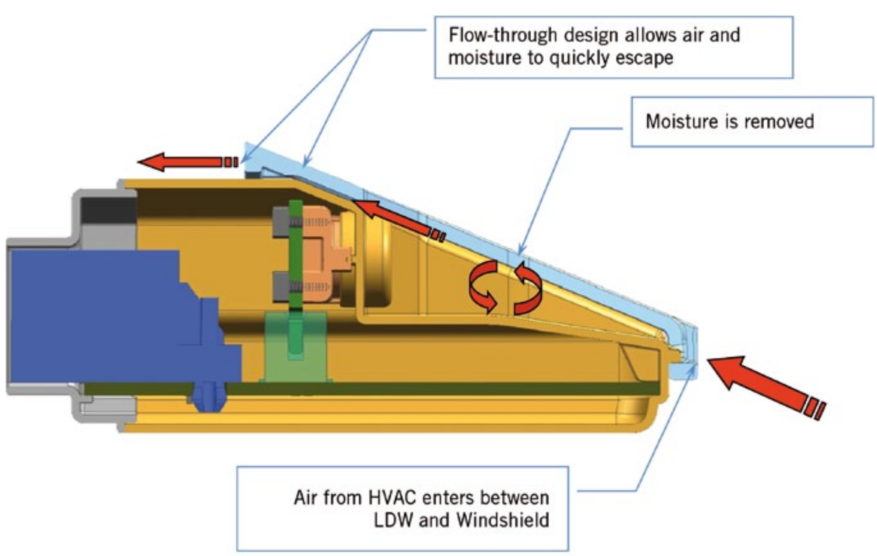


❻ Camera attachment: align camera with windshield bracket using forward edge (above); engage snaps and pivot upward to lock (below)

(car, motorcycle, truck); time-to-collision (TTC); and status of brake, indicator and hazard lights. The guaranteed detection range for cars is 90 m but, in reality, is 130 to 150 m. Due to their narrower width the detection range for motorcycles is 40 to 60 m. By combining the advantages of a video based sensor with the performance of a radar sensor through data fusion, vehicle manufactures are able to provide forward collision warning, collision mitigation braking and full emergency braking systems to further improve vehicle safety. While radar is precise in its measurement of distances and relatives speeds, the video camera is precise in determining an object's lateral position. Together these sensors are able to deliver the required precision for an automatic emergency braking although the camera is able to estimate the distance to the vehicle ahead. This is why the S-Cam is able to provide the less critical functionality of forward collision warning together with a distance warning.

Detection and recognition of traffic signs is mainly based on those specified by the Vienna Convention [1], but US and Arabic speed signs are also integrated into the system. Greater robustness in poor weather conditions, difficult light levels and world wide local differences in signage has been integrated. Ongoing development will lead to recognition of additional signs including: stop, no passing, city entrance, freeway entrance and end of freeway. Higher resolution images will also allow sub texts to be read – for example, the times when a speed limit is in operation.

Children and adults, both walking and standing, can also be detected. S-Cam's designers have put a lot of effort into this area and the capability now includes bicycles crossing the vehicle's path as an additional class of "pedestrian". Optical flow calculations are currently in development at TRW which – basically – allow the system to recognize whether any kind of object has entered a specific area in front of the vehicle.



❼ Air flow concept in order to remove possible moisture in front of the camera

SUMMARY

With its new camera, TRW has developed a high performance sensor that is the smallest and most compact unit on the market. Its ability to detect and classify a very wide range of objects – and the subsequent broad customer functions that this allows – should satisfy the requirements of vehicle manufacturers. As a single component, it supports an array of functions which – in the near future – will be delivering higher levels of comfort and safety to a growing number of vehicle platforms.

REFERENCE

[1] Economic Commission for Europe: Convention on Road Signs and Signals. Vienna, 1968

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