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Blinding light in the rear mirror

See the light

Photonics enhances the safety and comfort of vehicles.

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Many features in modern cars are designed to support drivers on their journeys all over the world. Working in the background and usually being invisible, some of these hidden components provide us with increased comfort and safety – no matter what the driving conditions are like.

Since 2022, stricter EU regulations aim for advanced safety systems to improve the safety of both occupants and vulnerable road users [1]. Ultimately, technology will play a key role in achieving the EU's long-term goal of moving close to zero fatalities and serious injuries by 2050.

Hamamatsu Photonics, an expert in optoelectronic technology, develops high-quality optical sensors for the automotive industry. With more than thirty-five years of experience in this industry, it has grown to understand the specific challenges and developed customization capabilities to cater to customers' requirements ensuring reliability as well as the highest quality by testing in its manufacturing facilities and through its AECQ qualification, respectively. Hamamatsu has grown its portfolio with diverse advanced technologies to assist in safe, reliable, green, and comfortable car driving. Within the automotive devices range, photo ICs (integrated circuits) are a key component available in many shapes and forms which is essential for many light-sensing automotive applications.

A photo IC is an intelligent optical sensor with diverse functions that integrates a photodiode with a signal processing IC in one package. Hamamatsu designs different IC types that are matched to the working environment and the requirements of the applications. These compact and lightweight devices can be built or adapted to function as illuminance sensors, color sensors, encoder modules, photo sensors with front-end ICs, and photo ICs for optical links.

Detect ambient light

Illuminance sensors are ideal to detect the ambient light level. They are built with excellent linearity and a large dynamic range of five orders of magnitude in order to detect low light levels in the dark as well as to work properly in bright daylight. Smart headlights respond to the ambient light level and they automatically turn on or off. Mounted near the dashboard, an illuminance sensor monitors the brightness outside the car and turns on the lights when the brightness drops below a certain light level.

Auto antiglare rearview mirrors also use an illuminance sensor. When the sensor detects intense light, for example high-beam headlights from a rear-approaching car at night, it automatically adjusts the mirror reflectance. Therefore, the driver is not dazzled by the headlight glare.

Besides offering comfort, color sensors provide information on brightness or color functions for displays, dashboards, interior lighting, or dimming of the head-up display. Interior illumination according to certain situations or moods is one of the big topics for car manufacturers today: scientific studies show that light influences the mood and the condition of the driver.

Adjustment of the brightness or color can help the driver to remain attentive during the ride; special filters are used to achieve sensitivity close to the human eye. RGB sensors improve the categorization of the measured light in order to distinguish the different times of day and weather conditions, or between natural and artificial light sources. Encoder modules are applied in electric power-assisted steering motors, electric brakes, and traction motors to send accurate speed and direction signals to the car's control systems.

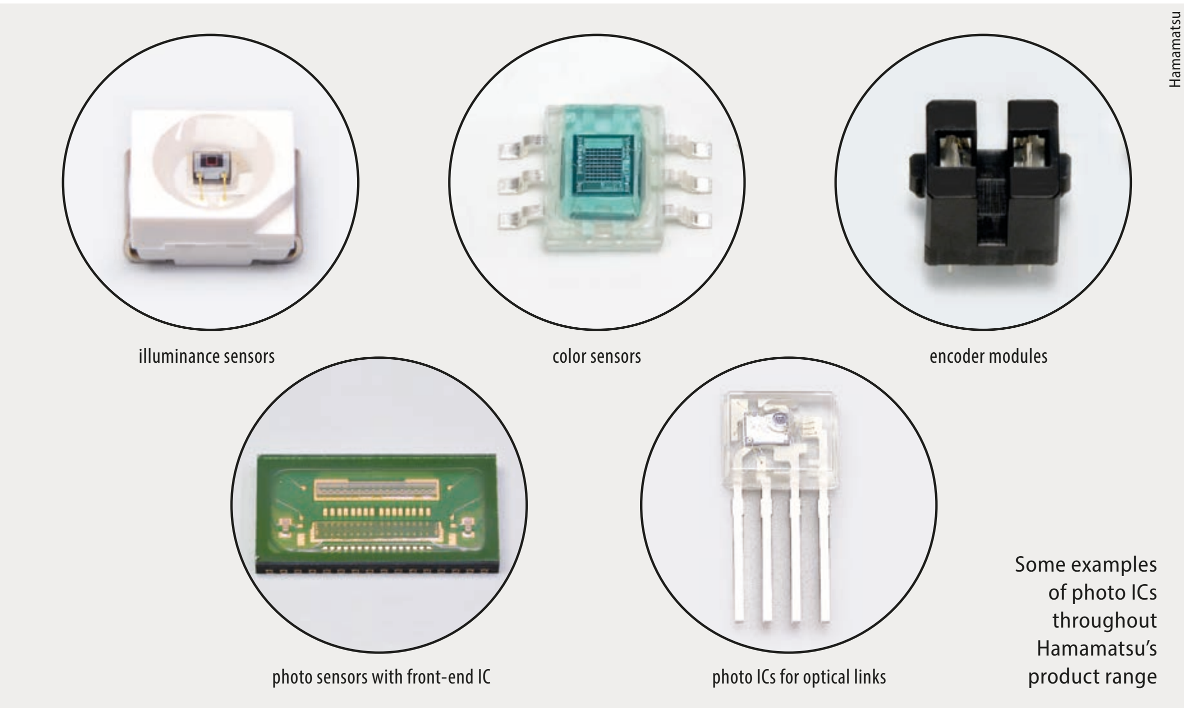
Optical data transmission

The large number of sensors in modern vehicles generates a large amount of data which is sent to the central unit board. Once processed, the data is transferred to the vehicle's network, which can be split into safety networks including cameras, mm-wave radar, or lidar, control networks managing engines or brakes, and information networks for the car‘s navigation, video or audio systems. At the same time, the industry is focussing more and more on electric vehicles with more batteries and electric components inside the motors. Thus, these modern cars rely on more information in shorter time and without electromagnetic impacts.

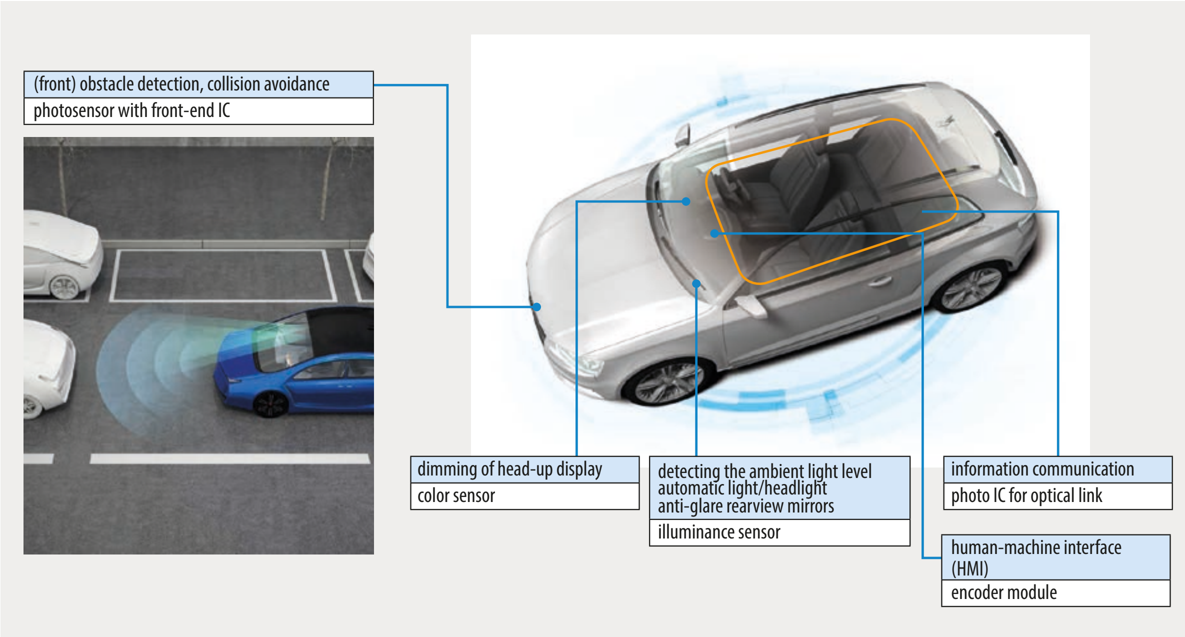
The ideal solution to meet the needs of these modern vehicles is an optical network that uses plastic optical fibers with photo ICs as optical links. Hamamatsu Photonics already supplies manufacturers with fiber optical transceivers (FOT). There are plans to use optical networks for conditional driving automation (ADAS level 3) including automatic braking. Work is also in progress to develop FOT for optical networks that run at 1 Gb/s or even 10 Gb/s and faster.

A look at automotive lidar

One of the most promising developments in recent years was the use of light detection and ranging (lidar) systems, an optical method to measure distances and speed. It measures distances by emitting



Some examples of photo ICs throughout Hamamatsu's product range



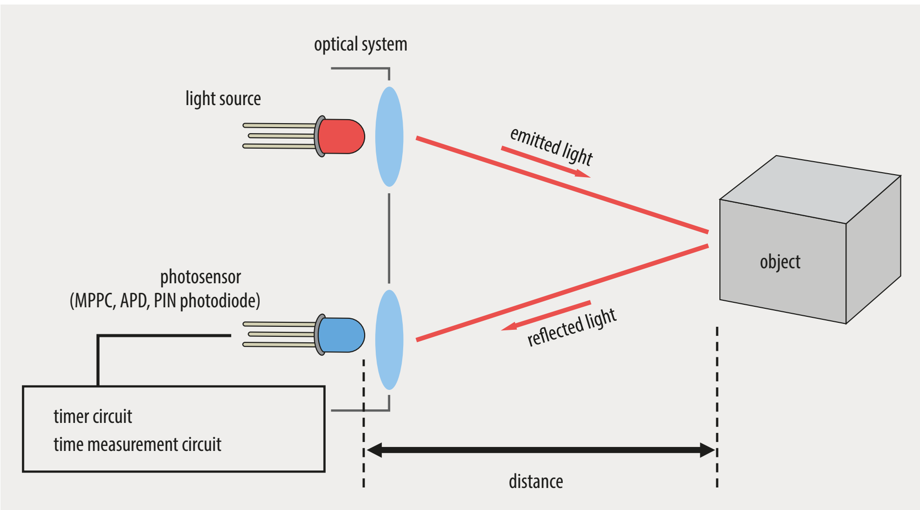
The photosensor with front-end IC optically measures the distance to the front car return and controls the distance to the vehicle.

laser light to a target and detecting its reflection with a photosensor. The technique is increasingly important in today's safety measures as it helps to detect obstacles and to avoid collisions. Photo sensors with front-end ICs assist by optically measuring the distance to the front car and by monitoring the gap between the vehicles. Complete accuracy and fast reaction times are essential to work at high speeds and in unforeseen situations.

Unlike the related radar system, lidar sensors identify the environment by means of light which is detected by a photosensor. But not all lidar systems are the same and not all photosensors work equally well. The most suitable technology is not always obvious to the manufacturer and depends on the specific application.

Currently, there are two different technological approaches to set-up a lidar system: the time-of-flight (TOF) method and the frequency-modulated continuous-wave (FMCW) method. While TOF lidars are recognized as the standard specification, the popularity of FMCW systems is growing since they promise to overcome some of the problems of the time-of-flight approach.

The basic principle of a TOF lidar is simple: a light source emits a concentrated beam of light which is reflected by an obstacle – such as



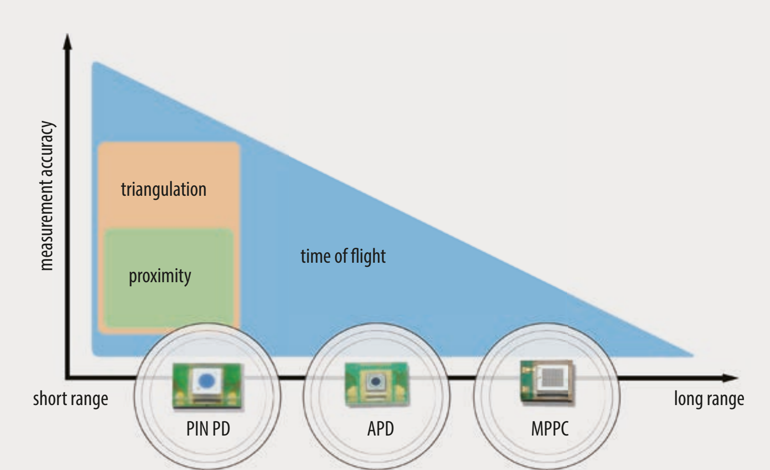
In automobiles, lidar mainly uses the direct time-of-flight method: The distance corresponds to the time duration a light pulse needs to travel from the source to an object, to be reflected, and to return to the sensor.

a pedestrian or a car – and bounces back to a photosensor. The sensor calculates the object's distance based on the time the reflected light needs to hit the sensor: the greater the distance to the detected object, the lower the accuracy of the measurement. However, this principle does not work equally for all types of photosensors but depends on the application. In fact, manufacturers can choose from three types: silicon PIN photodiodes (PIN PD), silicon avalanche photodiodes (APD), and multipixel photon counters (MPPC), also known as silicon photon multipliers (SiPMs) or SPADs (single photon avalanche diodes).

Depending on the amount of light, i. e. the number of photons, and the distance, some types will work better than others. For example, a high number of photons and highly reflective object at a short distance calls for the PIN PD since the APD and MPPC would be saturated. However, when the light decreases, i. e. the object is moving from the light source and the detector, a detector with a higher gain is favourable. Thus, the best solution is an APD. In yet another scenario, with a further decrease of light and a longer distance of 100 m, a single photon detector with a very high gain should be used: the MPPC.

However, sensor technologies are not the only aspect to be considered. Different sensor geometries and functions depend on the lidar scanning system; examples are the traditional system or a flooded light array type (Flash). In addition, the exact use changes the demands, like the long-range for a highway pilot or the short-range cocoon for parking. Therefore, one of the main challenges of a provider of sensors is the need for customization.

For example, there has been a recent increase in the need for two-dimensional MPPCs or SPAD detectors which are already similar



	PIN PD	APD	MPPC
quantum efficiency (@λ = 905 mm)	~70 %	~70 %	~20 %
gain	1	up to ~100	$10^5 – 10^6$
dynamic range	very large	very large	dependent on the number of microcells

Each different type of photosensor supports a specific lidar system

to image sensors but perform with much higher sensitivity. This customization could be as simple as changing the gap size between the detector elements in an array or as complex as designing a whole new ASIC. It could also include complete optical assemblies combining a light source such as a pulsed laser diode with sensors and bandpass filters. Hamamatsu Photonics has the capability and experience to produce such customized chips, starting with the manufacturing of semiconductors up to the special packaging that is necessary to meet the demanding automotive standards.

Greener driving

Tackling environmental challenges is also at the forefront of automotive industry concerns. Photo ICs for optical links can be useful to monitor and control the current, voltage, temperature, and functionality of each individual battery cell in order to ensure the best reliability and performance of the battery pack. Multimedia information, like the video and audio data enjoyed in a car, transmits via a wire harness or optical fiber cable between various devices such as a display, in-car camera, audio player, and loudspeakers. Light emitter and receiver photo ICs are used for such information exchange through optical fiber links.

[1] Vehicle Safety and automated/connected vehicles: *https://single-market-economy.ec.europa.eu/sectors/automotive-industry/vehicle-safety-and-automatedconnected-vehicles_en*

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