Ambient Light Sensors
General Application Note

Abstract

This application note introduces ambient light sensing on a general level. The different types of ambient light sensors are described and related to specific applications.

Introduction

OSRAM OS offers a variety of ambient light sensors. This application note introduces the basic facts of ambient light sensing and describes the characteristics of various ambient light sensors. Detailed application notes for specific sensor types are available.

Applications for ambient light sensors

Ambient light sensors are photo detectors which are designed to perceive brightness in the same way as human eyes do. They are used wherever the settings of a system have to be adjusted to the ambient light conditions as perceived by humans. The below list describes typical applications for ambient light sensors:

- Saving battery power.
  Ambient light sensors provide power saving solutions for hand-held electronic devices such as PDAs, mobile phones and notebook PCs. Nearly all LCD displays and keypads have backlighting. Studies have shown that backlighting is only required about 40% of the time. An automatic adjustment (auto dimming) of the backlight offers considerable power savings.

- Automatic dimming of flat panel displays such as LCD screens to maintain the same display appearance under all lighting conditions from darkness to bright sunlight.

- Automatic dimming of instruments in automobiles to ensure reliable visibility under all circumstances.

- Automatic dimming of lamps for office buildings, exterior lightings and traffic signals.

- Headlamp control in cars improves road safety by automatically turning on the lights in twilight or when entering a tunnel.

Basic facts about ambient light sensing

Brightness

Brightness is a term that describes how intense a light source is perceived by the human eye. Brightness is measured in units called “LUX”. Light sources with the same LUX level appear at the same brightness to the human eye. Table 1 shows the brightness (LUX measurement) of some everyday light sources. The technical term for brightness is illuminance.

Light source	**brightness [Lux]**
candle (1m distance)	1
street light	20
office desk lighting	750
overcast day	3000
overcast sunny day	20 000
direct sunlight	100 000

Table 1: Lux measurement of every day light sources.

Spectral sensitivity

Spectral sensitivity relates to where on the light spectrum a sensor is most effective.

Standard silicon (Si) photo detectors have a spectral response ranging from 1100nm right down to 350nm with the peak sensitivity around 880nm. Human eyes, however, detect a much narrower wavelength range, namely from 400 nm to 700 nm with the peak sensitivity at 560nm (Figure 1).

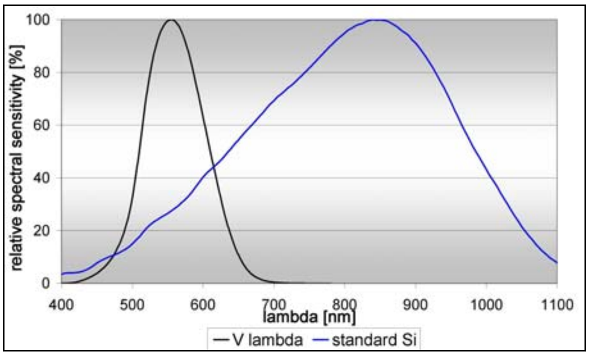


Figure 1: Spectral sensitivity of a standard Si-detector compared to the human eye

Ambient Light Sensors versus standard Silicon detectors

Most light sources emit both visible and IR light. Different light sources can have similar visible brightness (LUX) but different IR emissions (Figure 2).

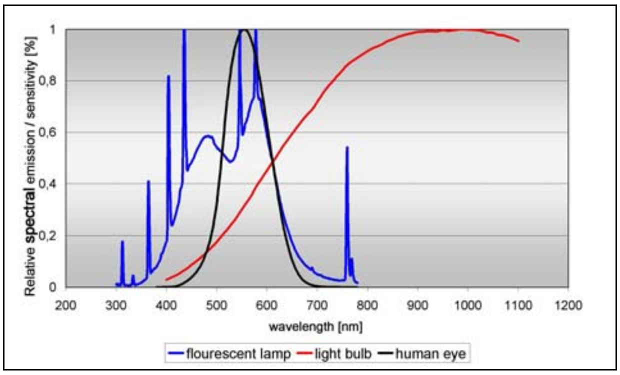


Figure 2: Spectral emission of different light sources compared to the spectral sensitivity of human eye (V lambda)

These differences in the emission characteristics and the spectral sensitivity of the detector have to be taken into account when measuring brightness. Standard Si-detectors that detect mostly IR radiation (peak sensitivity at 880nm) can give you a false reading as to what the real ambient visible conditions are. In other words, for light sources with a high contribution of IR light, the signal received by a standard Si-detector would suggest a much brighter situation than our eyes actually see.

Figure 3 illustrates this effect. It shows the signals a standard Si-detector yields for different light sources compared to the signals that a “human eye like” detector would see. For IR-rich light sources like light bulbs the Si-detector signals are much higher than those of the “human eye” detector. Lighting which is controlled by such Si-sensors will not resemble the optimum brightness as felt by humans. To establish a more suitable dimming or lighting control, it is essential to find a sensor which emulates human eyes as closely as possible.

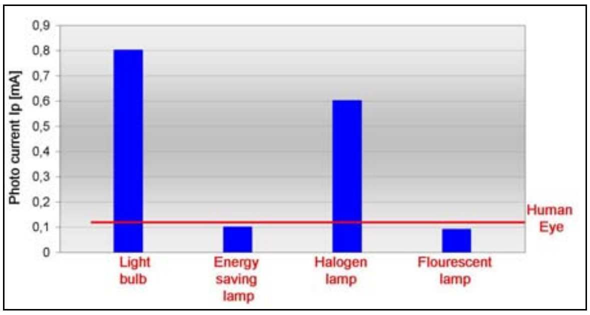


Figure 3: Signals received by a standard Si-detector for different light sources at the same brightness (500lx) compared to a detector with perfect human eye characteristics

Si-Ambient light sensors have a spectral response ranging from 1100nm right down to 350nm but with the peak sensitivity around 560nm. This peak is nearly identical to the human eye spectral sensitivity maximum. Most ambient light sensors are also based on Si, but they use different chip structures and filter layers to shift the peak sensitivity and to suppress as much IR radiation as possible. The degree of matching between the sensor’s spectral sensitivity and the human eye curve is an indicator of the performance of an ambient light sensor. Figure 4 shows the spectral sensitivity of a standard silicon photo transistor, an OSRAM ambient light sensor of the first generation and the human eye (V-lambda curve).

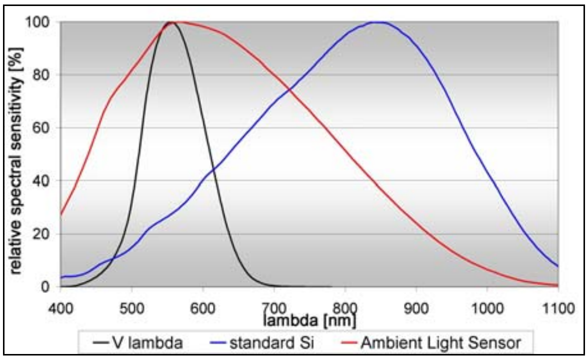


Figure 4: Spectral sensitivity of a standard Si-detector and an ambient light sensor (SFH 3410) compared to the human eye (V-lambda)

Because the IR portion of the spectral sensitivity of the ambient light sensor is greatly reduced compared to a standard Si-detector (see Figure 4), it is less sensitive to the effects of different lamps. Figure 5 shows the signals of the ambient light sensor SFH 3410 received from different lamps of the same brightness compared to the signals of a standard Si-detector.

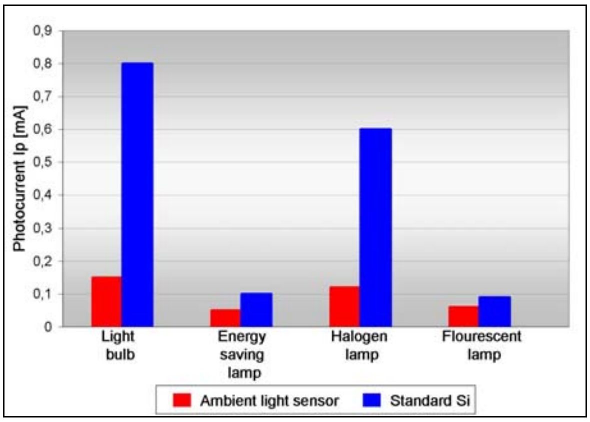


Figure 5: Signals received by a standard Si-photo detector and the ambient light sensor SFH 3410 for different light sources at the same brightness (500lx)

The difference of the signals indicates the accuracy of the brightness measurement. In the case of the standard Si-detector the signals vary by more than a factor 8 between light bulb and fluorescent lamp. This factor is reduced to 3 for the ambient light sensor, which therefore provides a much better accuracy for the brightness measurement.

Measuring ambient light levels (brightness)

Ambient light sensors are photo detectors. They yield a photo current which is related to the illuminance. In most cases, the correlation between photo current and illuminance is linear[1]. Figure 6 shows the photo current – illuminance relationship for the ambient light photo transistor SFH 3410. The efficiency of the sensor describes the amount of photo current the sensor yields for a certain illuminance. In the example of figure 6, the ambient light sensor yields a photocurrent of 300µA at 1000lx. Hence the efficiency of the sensor is 0,3µA/lx.
The efficiency of a photo detector depends on the illuminance under which it is operated. A change of the efficiency results in a deviation from the photo current - illuminance correlation. The linearity of a detector describes the magnitude of this deviation. Figure 7 shows the linearity for the ambient light sensor SFH 3410. The deviation from the linear correlation is < 5% within a brightness range of 30lx … 100klx. In lower light levels a correction might be necessary.

[1] OSRAM offers the high accuracy ambient light sensor SFH 5711 with logarithmic output.

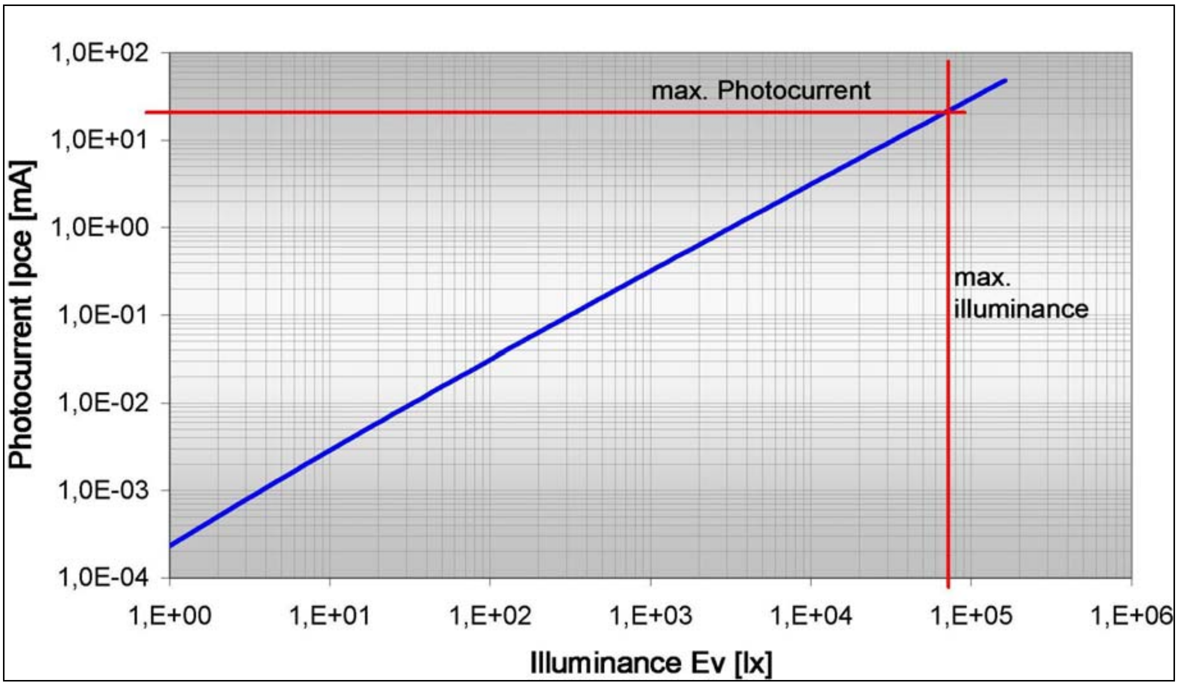


Figure 6: Photocurrent Ipce of the ambient light sensor SFH 3410 versus illuminance[2]

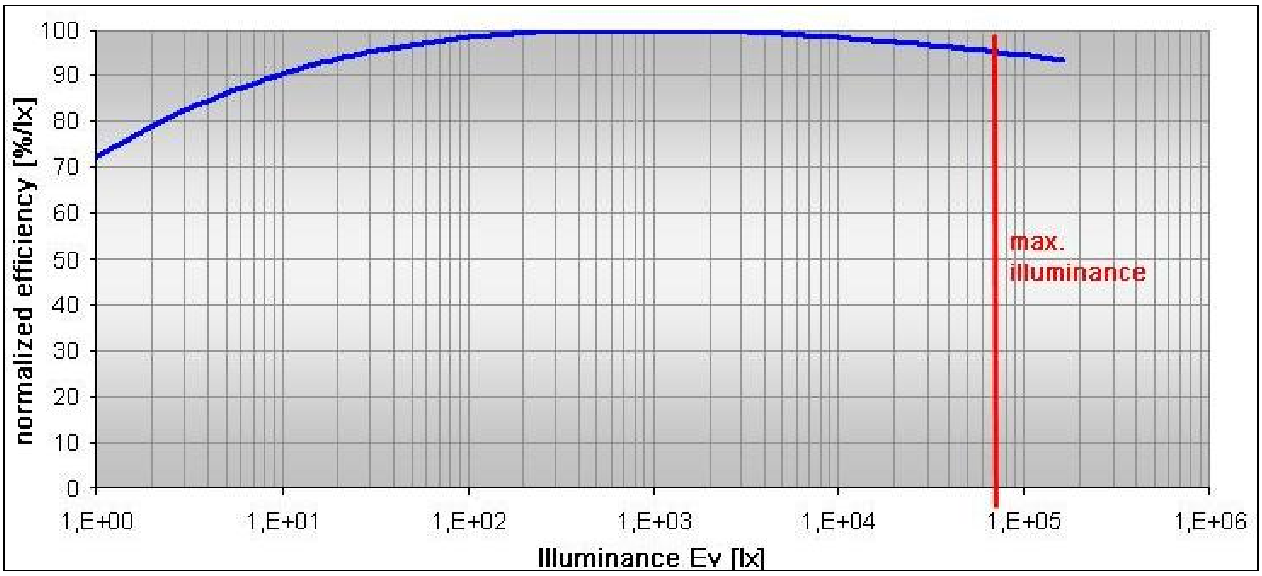


Figure 7: Linearity of the ambient light sensor SFH 3410: Efficiency versus illuminance normalized to 1000 lx[2]

[2] The characteristics of the SFH 3710 is similar.

Sensitivity Variation

Due to the manufacturing process ambient light sensors of different production lots will yield different outputs for the same illuminance. The magnitude of this sensitivity variation depends on the sensor type. To account for this, some ambient light sensors are offered in defined sensitivity bins. These are described in the datasheets and in the application notes of the respective sensors. The sensitivity variation can also be overcome by calibrating the assembled unit in the production line.

Accuracy of the ambient light measurement

Several factors determine the accuracy of an ambient light measurement:

- Spectral sensitivity:
  High detector sensitivity for IR results in low accuracy of the brightness measurement.
- Temperature coefficient:
  The output current of photo detectors varies with the operating temperature. Large temperature coefficients result in brightness measurement deviations at very high and low temperatures.
- Linearity:
  Linearity describes the deviation from the photo current - illuminance correlation function.
- Sensitivity variation
- System errors such as resistors, calibration, etc.

Each of these effects contributes with different magnitude to the ambient light measurement accuracy. Table 2 provides an overview of these characteristics for different detector types.

Different types of ambient light sensors

OSRAM OS offers three different types of ambient light sensors. Table 2 provides a selection guide for the different types and gives an overview of these types with their main criteria.

	Phototransistor	**Photodiode**	**Opto Hybrid (Diode + IC)**
Device	SFH 3410, SFH 3710	SFH 2430	SFH 5711
Output signal	high	low	high
Linearity	good	highest	high[3]
Temperature coefficient	high	lowest	low
Sensitivity variation	Factor 1:2 in illuminance per sensitivity bin	+-15%	Factor 1:2 in illuminance per sensitivity bin
Photo current – illuminance correlation	Linear	Linear	Logarithmic (high accuracy over entire dynamic range)
Spectral sensitivity	Low IR contribution	Low IR contribution	perfect V-λ characteristic
Size	Small	Large	medium

Table 2: Selection guide for OSRAM ambient light sensors. Different types with their main characteristics.

[3] For the SFH 5711, this term refers to the deviation from the logarithmic curve.

In short, phototransistors are small devices, with good functionality, whereas photodiodes offer high performance at a larger size.
The opto hybrid SFH 5711 is superior to both devices in terms of spectral sensitivity and dynamic range, as it combines high accuracy over the entire brightness range with low temperature dependence and perfect human eye characteristics. Please see the SFH 5711 application note for more information about this high accuracy ambient light sensor.

Figure 8 shows the spectral sensitivity of all OSRAM ambient light sensors. Starting from standard Si, it has been continuously improved and has reached perfection with the SFH 5711.
The resulting accuracy of the ambient light measurement for different lamp types is shown in Figure 9. There the signals of each photo detector type for the different light sources are normalized to standard light A (2865 K), which is a standard point of reference for brightness. Figure 9 shows how the signals of each detector type vary with respect to the different light sources. This variation is an indication for the accuracy of the brightness measurement, which can be achieved with this detector. For a standard Si detector, for instance, the maximum deviation is found between light bulbs and fluorescent lamps and amounts to over 90%. The same value is below 2% for the SFH 5711.

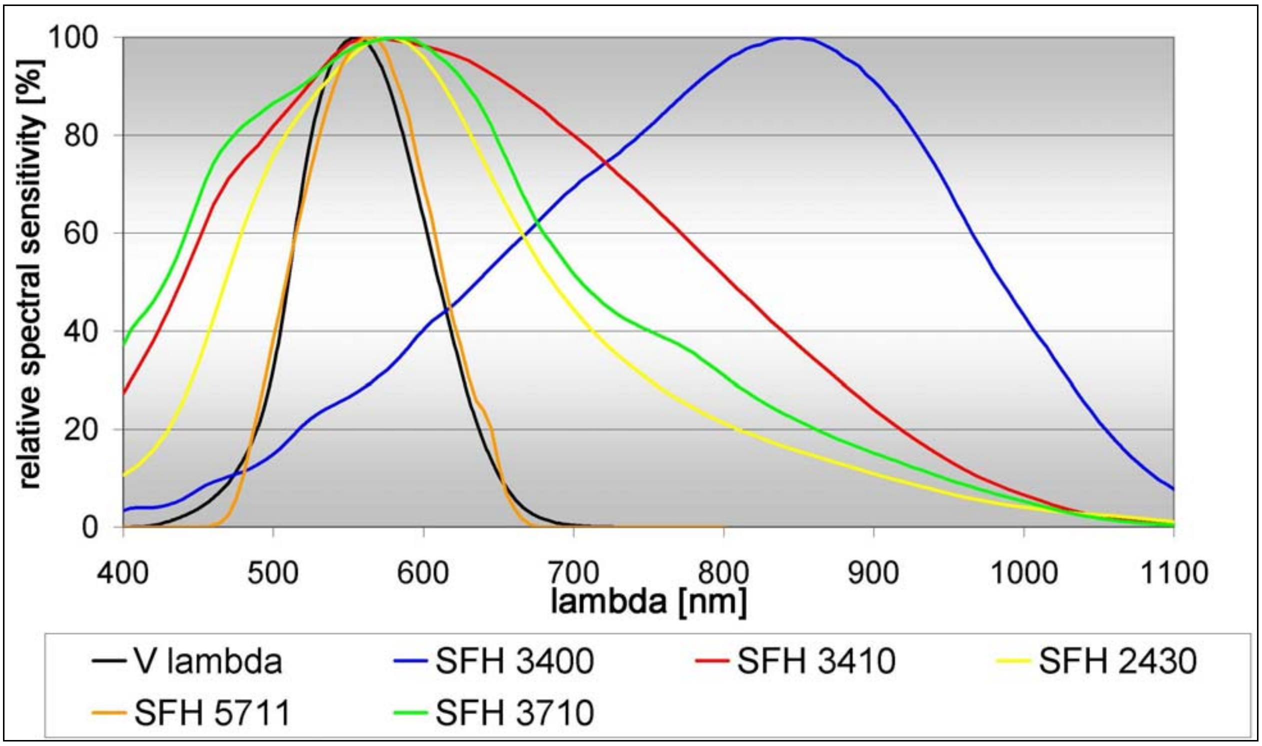


Figure 8: spectral sensitivity of all OSRAM ambient light detectors compared to a standard Si-photo detector and the human eye (V-lambda)

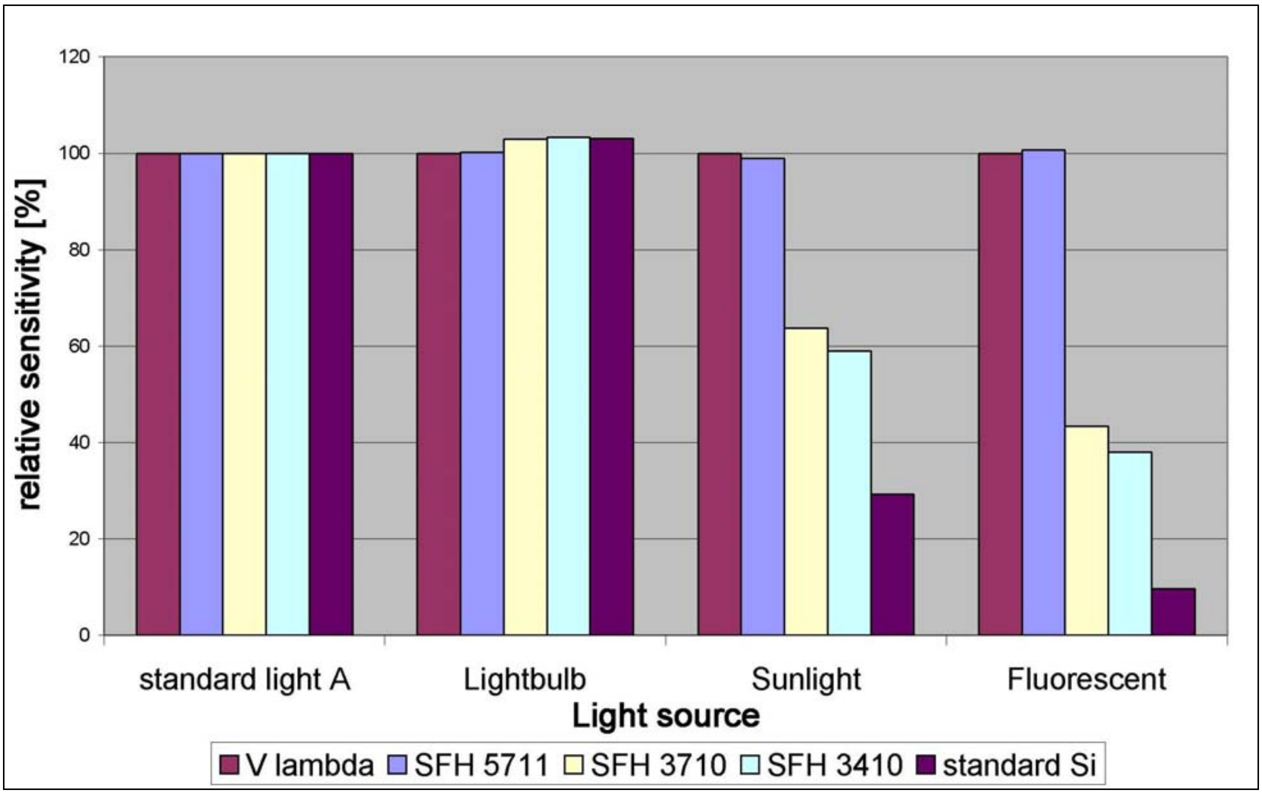


Figure 9: Photo detector readings for different light sources at the same brightness[4]. Values are normalized to standard light source A

Table 3 summarizes the main characteristic of the different types of OSRAM ambient light sensors.
It also serves as a guideline for choosing the suitable ambient light sensor for certain applications. For a mobile device, for instance, a phototransistor will be a suitable choice mainly due to the small size, whereas for automotive applications the photodiode may be the component of choice due to its high stability with temperature. For further details, please refer to the datasheets. All devices are RoHS compliant.

[4] The characteristic of the SFH 2430 is simliar to the SFH 3710

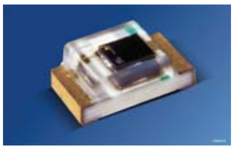
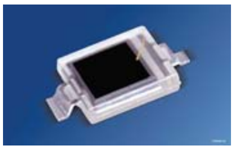
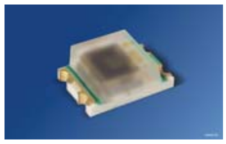
Parameter	SFH 3410	SFH 3710	SFH 2430	SFH 5711
				
Functionality	Phototransistor	Phototransistor	Photodiode	Opto hybrid *(Diode + IC)*
package	SmartDIL	ChipLED	DIL	ChipLED
Size (LxWxH)[mm]	4.6 x 2.0 x 1.1	2.0 x 1.6 x 0.8	3.8 x 4.4 x 1.1	2.8 x 2.2 x 1.1
Top [°C]	-40 … +100	-40 … + 85	- 40 … + 100	- 40 …. + 100
Wavelength of max. sensitivity	570nm	570nm	570nm	560nm
Radiant sensitive Area [mm²]	0.29	0.29	7.65	0.16
Tcoeff [%/K]	1	1	0.16	0.3 *(see datasheet)*
Linearity	~10%[5]	~10%[5]	~1%	*3% deviation from logarithmic. curve*
Photocurrent Ipce [µA] @ Ev = 1000lx	500	500	5.8	30 *(logarithmic Output)*
Sensitivity Binning	Factor 1:2 of detected illuminance		+-15%	Factor 1:2 of detected illuminance
Qualification profile	automotive	consumer/industrial	automotive	automotive

Table 3: Main characteristics of the different ambient light sensor devices by OSRAM

Authors: Dr. Christine Rüth, Andreas Vogler, Wilhelm Karsten

About Osram Opto Semiconductors

Osram Opto Semiconductors GmbH, Regensburg, is a wholly owned subsidiary of Osram GmbH, one of the world's three largest lamp manufacturers, and offers its customers a range of solutions based on semiconductor technology for lighting, sensor and visualisation applications. The company operates facilities in Regensburg (Germany), San José (USA) and Penang (Malaysia). Further information is available at www.osram-os.com.

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[5] This value increases below 10lx (see Figure 7).