OSRAM
Opto Semiconductors

Ambient Light Sensors – General Application Note

Application Note

Valid for:
All Ambient Light Sensor products

Abstract

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

Part A starts with an overview over the applications for ambient light sensors (ALS).

Part B gives discusses the differences between a standard silicon photodetector and an ALS. Secondly, it's shown how brightness is measured and what influences the accuracy.

At the end in part C, the differences between various Ambient Light Sensors and about their performance are presented.

Further information:
High accuracy Ambient Light Sensor SFH 5711
Overview ALS portfolio

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A. 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 on our web page www.osram.com/os.

Applications for ambient light sensors

Ambient light sensors are photo detectors which are designed to perceive brightness with comparable spectral sensitivity as human eyes. Ambient light sensors are used when the settings of a system have to be adjusted to the ambient light conditions as perceived by the human eye. Typical applications for ambient light sensors are:

- Saving battery power using automatic dimming:

  Ambient light sensors provide power saving solutions for hand-held and backlit electronic devices such as PDAs, mobile phones and notebook PCs. An automatic adjustment (auto dimming) of the backlight to the ambient light conditions 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.

- Ambient light controlled automotive headlights improve road safety in twilight in tunnels or parking structures.

B. 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". LUX is lumen per square meter, where lumen is the emitted light power in Watt folded with the human eye sensitivity. Light sources which generate the same LUX level appear at the same brightness to the human eye. Table 1 shows the brightness of some everyday lighting conditions. The technical term for brightness is illuminance.

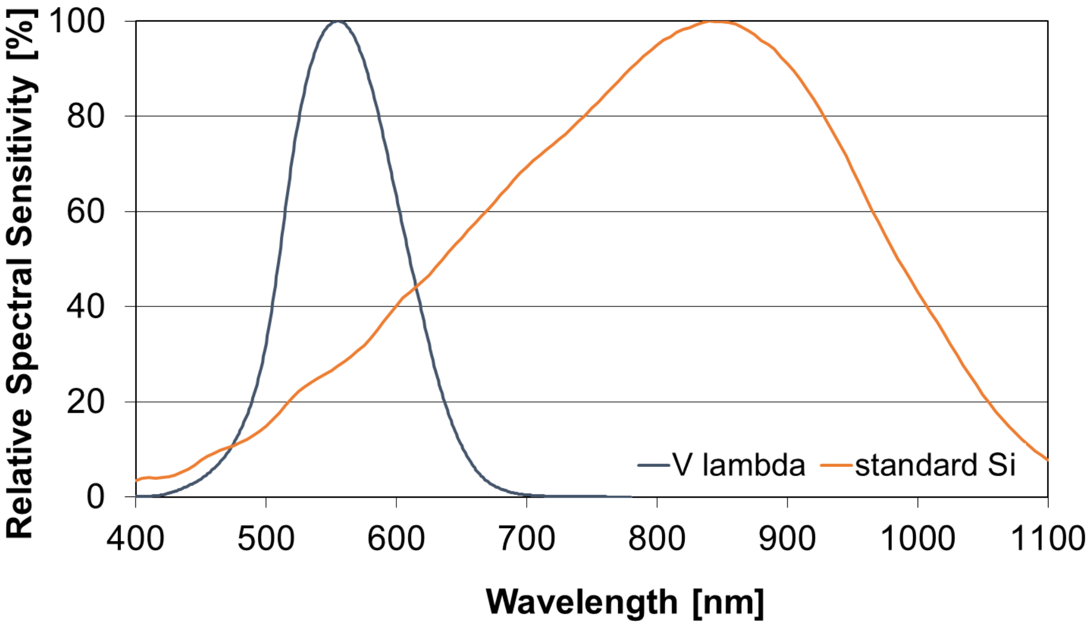
Table 1: Lux measurement of every day light sources

Light Source	Brightness in [Lux]
candle (1m distance)	1
street light at street level	20
office desk lighting	300
overcast day	3000
overcast sunny day	20 000
direct sunlight	100 000

Spectral sensitivity

Spectral sensitivity is the sensitivity of the sensor for various wavelengths. 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).

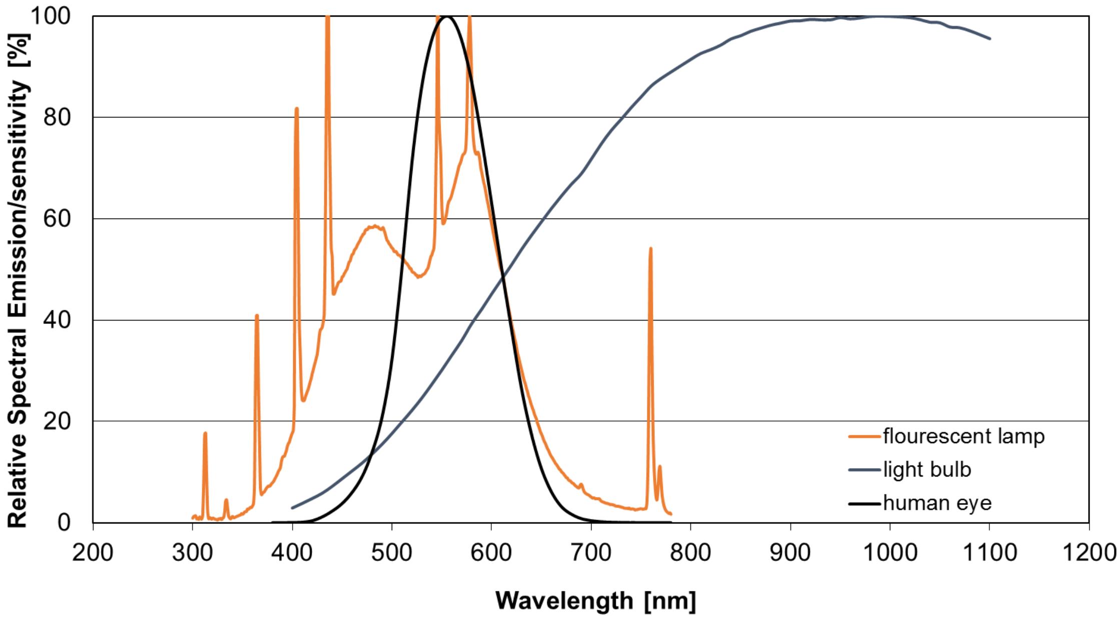
Figure 1: Spectral sensitivity of a standard Si-detector compared to the human eye (V lambda)



Ambient Light Sensors versus standard Silicon detectors

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

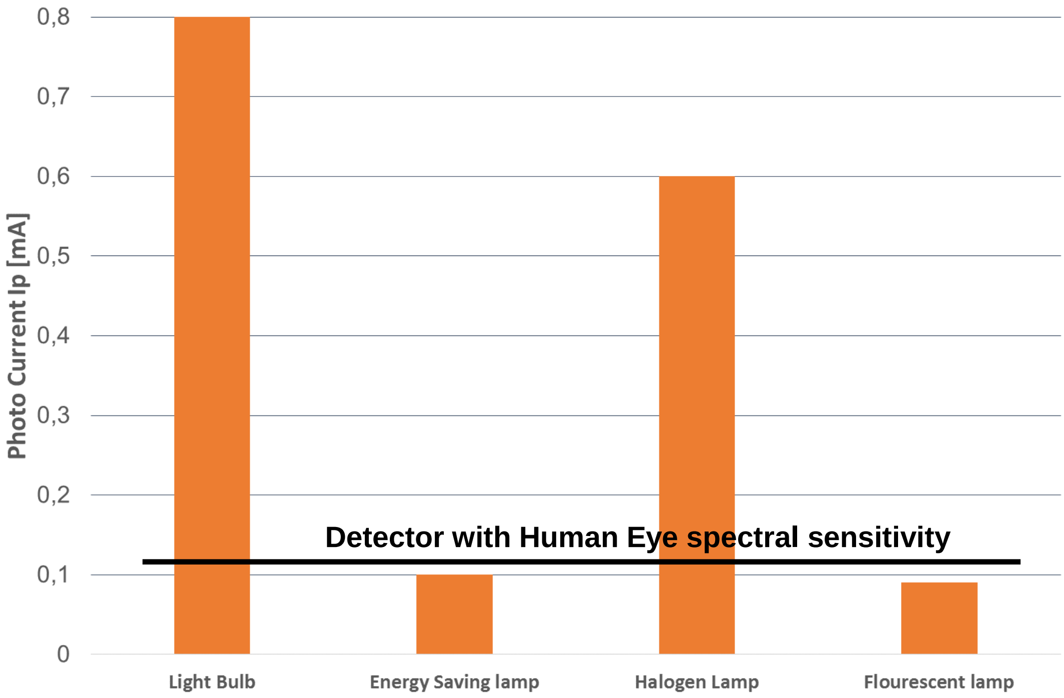
Figure 2: Spectral emission of different light sources compared to the spectral sensitivity of human eye



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 mostly detect IR radiation (peak sensitivity at 880nm) can give a false reading in terms of the visible ambient light level. In other words, for light sources with a high IR content a standard Si-detector suggests much brighter conditions than our eyes see.

Figure 3 illustrates this effect. It shows the signals a standard Si-detector yields for different light sources compared to the signals a “human eye like” detector would see. To establish a more suitable dimming or lighting control, it is essential to find a sensor with a more human eye like spectral sensitivity.

Figure 3: Signal received by a standard Si-detector for different light sources of 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 sensitivity maximum of the human eye. 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).

Because the IR portion of the spectral sensitivity of the ambient light sensor is greatly reduced compared to a standard Si-detector, 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.

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 SFH 3410, which therefore provides a much better accuracy for the brightness measurement.

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

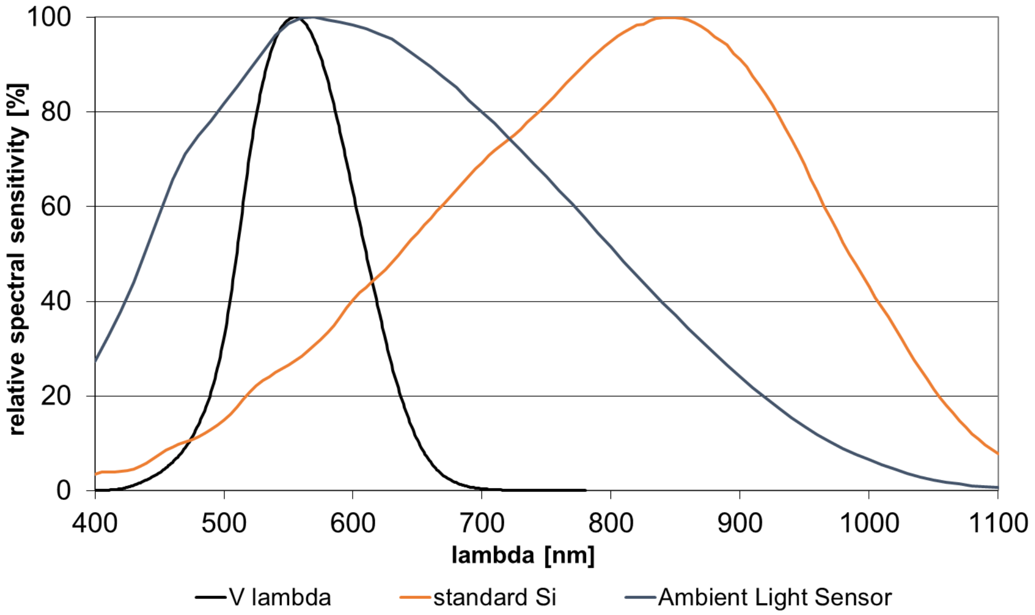
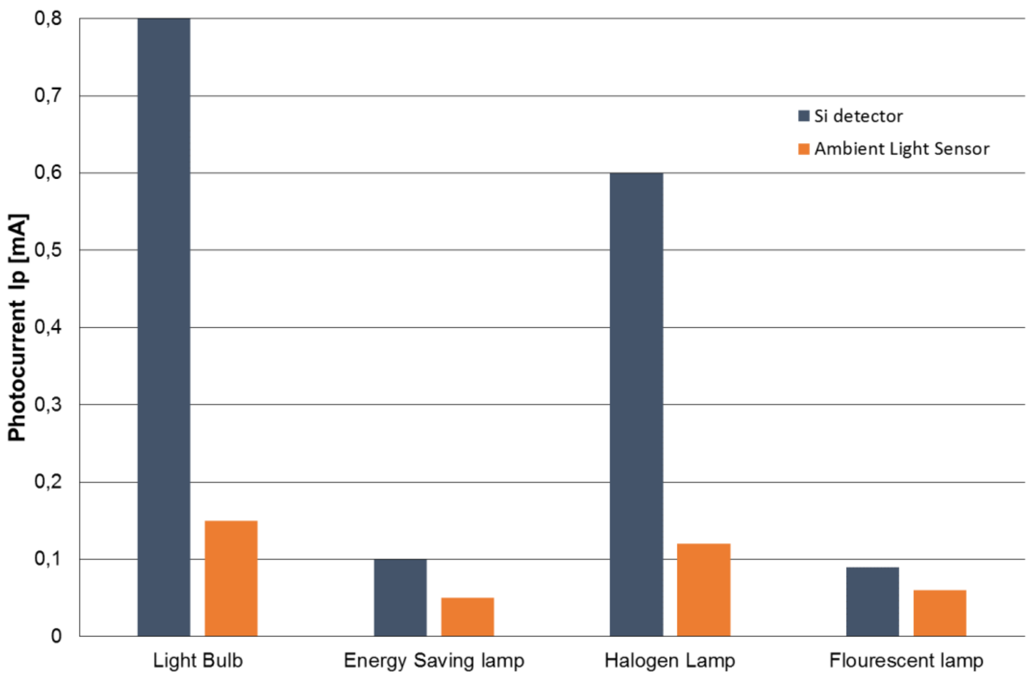


Figure 5: Signals received by a standard Si-photo detector and the ambient light sensor SFH 3410 for different light sources of the same brightness (500lx)



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, this relation is linear. Figure 6 shows the photo current – illuminance relationship for the ambient light photo transistor SFH 3410. The sensitivity of the sensor describes the amount of generated photo current per illuminance. In the example of the ambient light sensor SFH 3410 yields a photocurrent of 300µA at 1000lx or 0.3µA/lx. Figure 7 shows the linearity for the ambient light sensor SFH 3410. Its deviation from a linear behavior is < 5% within a brightness range of 30lx to 100klx. At lower light levels a larger correction might be necessary.

Figure 6: Photocurrent Ipce of the ambient light sensor SFH 3410 versus Illuminance

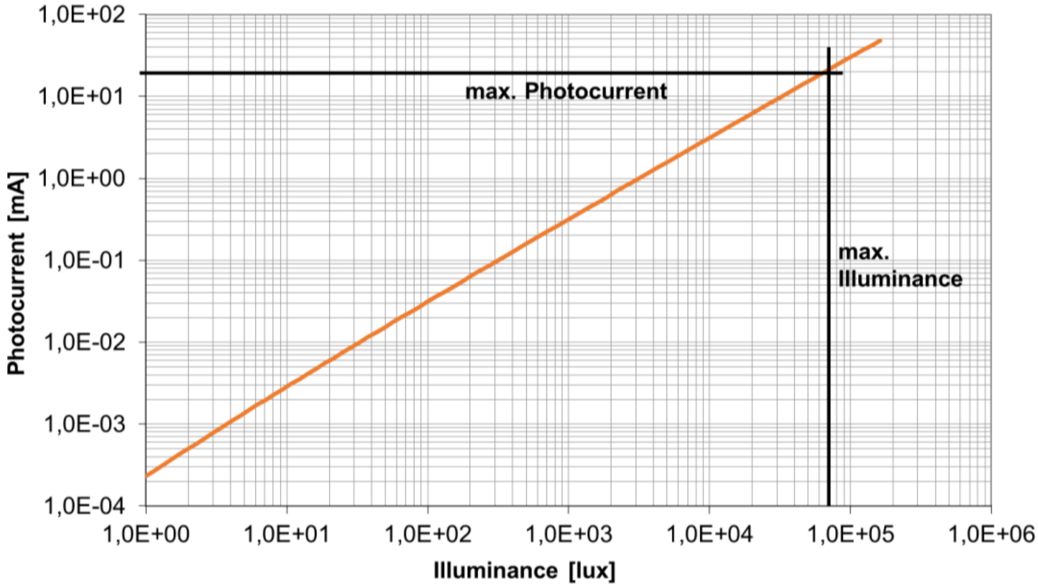
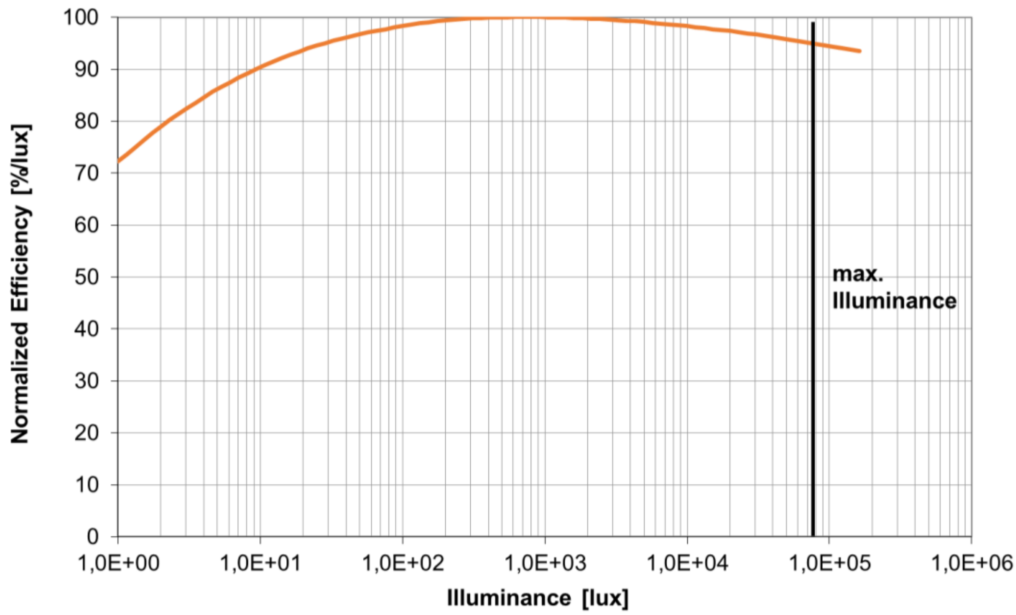


Figure 7: Linearity of the ambient light sensor SFH 3410: Sensitivity versus illuminance normalized to 1000lx



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 listed in the respective datasheets application notes. The sensitivity variation can be reduced 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 due to temperature.
- Non-linearity: The sensor output deviates from an ideal linear curve at different light levels
- Sensitivity variation from part to part.
- System errors such as resistors, calibration, etc.

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

C. Different types of ambient light sensors

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

Table 2: Selection guide for different OSRAM ambient light sensor type.

	Phototransistor	Photodiode	Opto IC (analog)
Output signal	High	Low	high
Linearity	Good	Highest	High
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	High linearity	High linearity	Logarithmic (e.g. SFH 5711, high accuracy over entire dynamic range)
Spectral sensitivity	Low IR contribution	Low IR contribution	Perfect V-λ characteristic
Size	Small	Large	Medium

In short, phototransistors are small devices, with good functionality, whereas photodiodes offer high performance at a larger size. Due to the large thermal drift of photo transistors their usage is often limited to switching functions, while photo diodes are used for light level measurements.

The opto IC SFH 5711 is superior to both devices in terms of spectral sensitivity and dynamic range. It combines high accuracy over the entire brightness range with low temperature dependence and excellent human eye characteristics. Please see the SFH 5711 application note for more information.

Figure 8 compares the spectral sensitivity of different OSRAM ambient light sensors. Starting from standard Si, it has been continuously improved and has reached an excellent match with the SFH 5711.

The resulting accuracy of the brightness measurement for different lamp types is shown in Figure 9. The signals of each photo detector type are normalized to standard light A (2865 K) For a standard Si detector 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 some OSRAM ambient light detectors compared to a standard Si-photo detector (SFH 3400) and the Human Eye

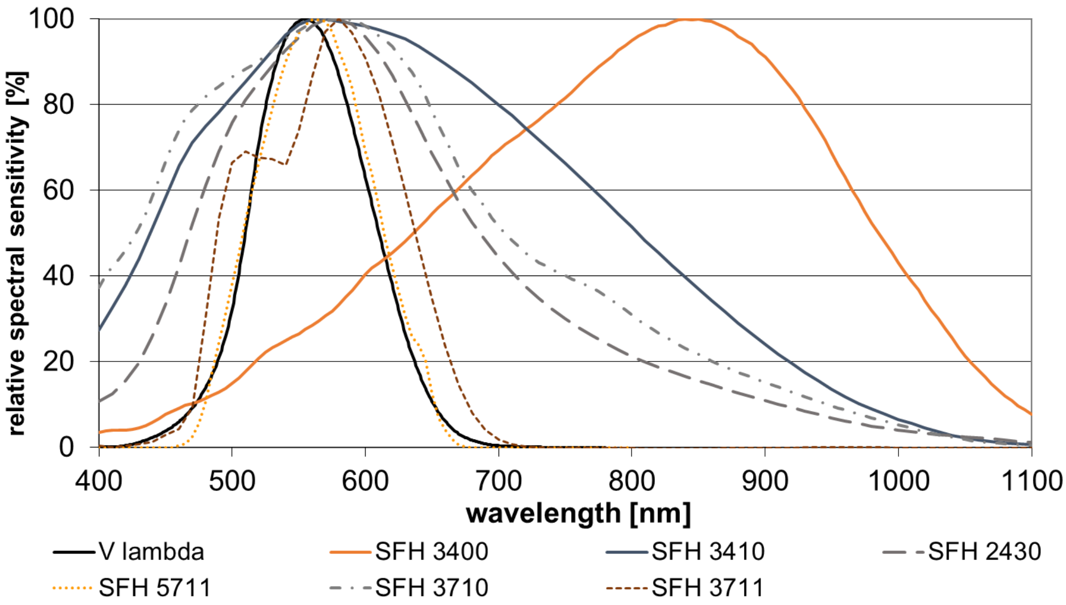


Figure 9: Photodetector readings for different light sources at the same brightness normalized to a standard light source A.

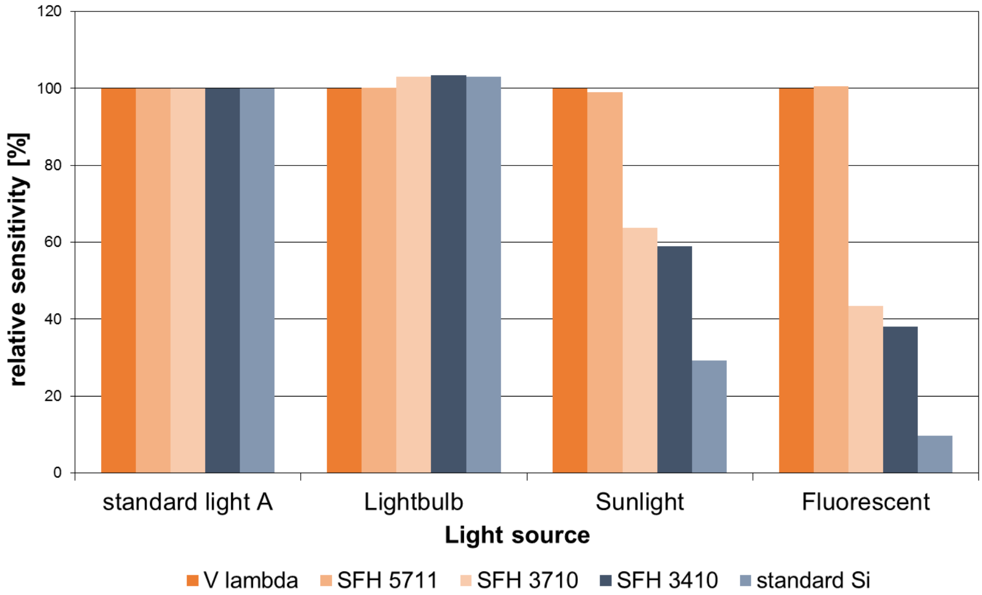
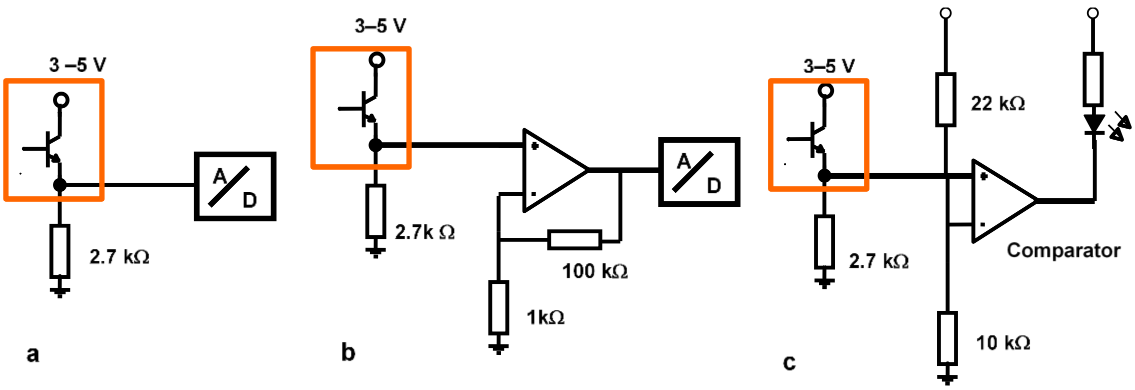


Figure 10 shows different circuits phototransistors:

a. Analog signal Ipce is used directly. This circuit is suitable for Ev = 10lx to 1000lx
b. Ipce is amplified. This circuit is suitable if sensor is mounted behind dark cover glasses, Ev = 0.1lx to 10lx
c. The light source is controlled by a comparator

Figure 10: Different circuits for ambient light phototransistors



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ABOUT OSRAM OPTO SEMICONDUCTORS

OSRAM, with its headquarters in Munich, is one of the two leading lighting manufacturers in the world. Its subsidiary, OSRAM Opto Semiconductors GmbH in Regensburg (Germany), offers its customers solutions based on semiconductor technology for lighting, sensor and visualization applications. OSRAM Opto Semiconductors has production sites in Regensburg (Germany) and Penang (Malaysia). Its headquarters for North America is in Sunnyvale (USA). Its headquarters for the Asia region is in Hong Kong. OSRAM Opto Semiconductors also has sales offices throughout the world. For more information go to www.osram-os.com.

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