OSRAM
Opto Semiconductors

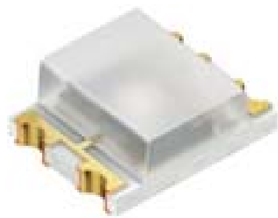
High accuracy ambient light sensor SFH 5711

Application Note

Valid for:
SFH 5711

Abstract

This application note describes the technical details as well as the operation of the ambient light sensor SFH 5711.



Further information:
Ambient light sensor —general application note
Product page SFH 5711

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Table of contents

A. Features of the SFH 5711

The ambient light sensor SFH 5711 is a photo detector with the following features:

- Perfect V (λ) characteristics
- Opto hybrid with logarithmic current output
- Low temperature coefficient
- High accuracy over wide illumination range
- 2.8 x 2.2 x 1.1 mm SMT package
- Automotive qualified

The SFH 5711 consists of a photodiode which is used for the light detection and an IC with the following functions: amplification of the photodiode output signal, logarithmic converter and temperature correction.

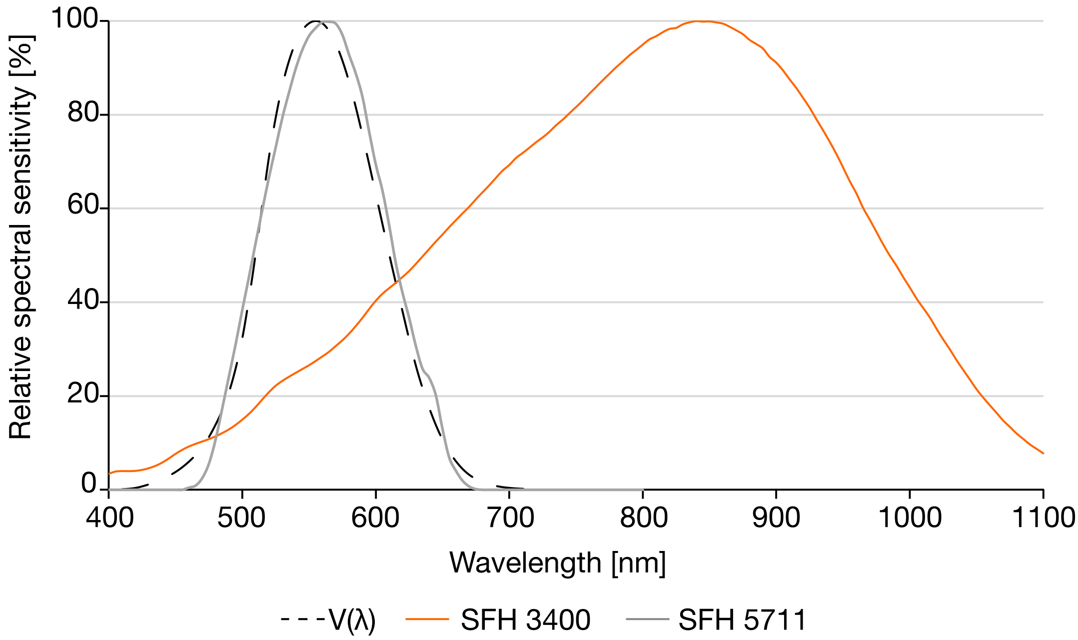
This application note describes the technical details of the sensor. For more general information about ambient light sensing there is a special application note about this topic available “Ambient light sensors — general application note”.

B. Basic facts about SFH 5711

Spectral sensitivity

Ambient light sensors are used wherever the settings of a system need to be adjusted to the ambient light conditions as perceived by humans. They are designed to detect light with a comparable spectral sensitivity as human eyes do. Figure 1 shows the spectral sensitivity of a standard silicon (Si) photo sensor, the SFH 5711 and the human eye (V(λ)- curve).

Figure 1: Relative spectral sensitivity of a standard Si-detector and the SFH 5711 compared to the human eye

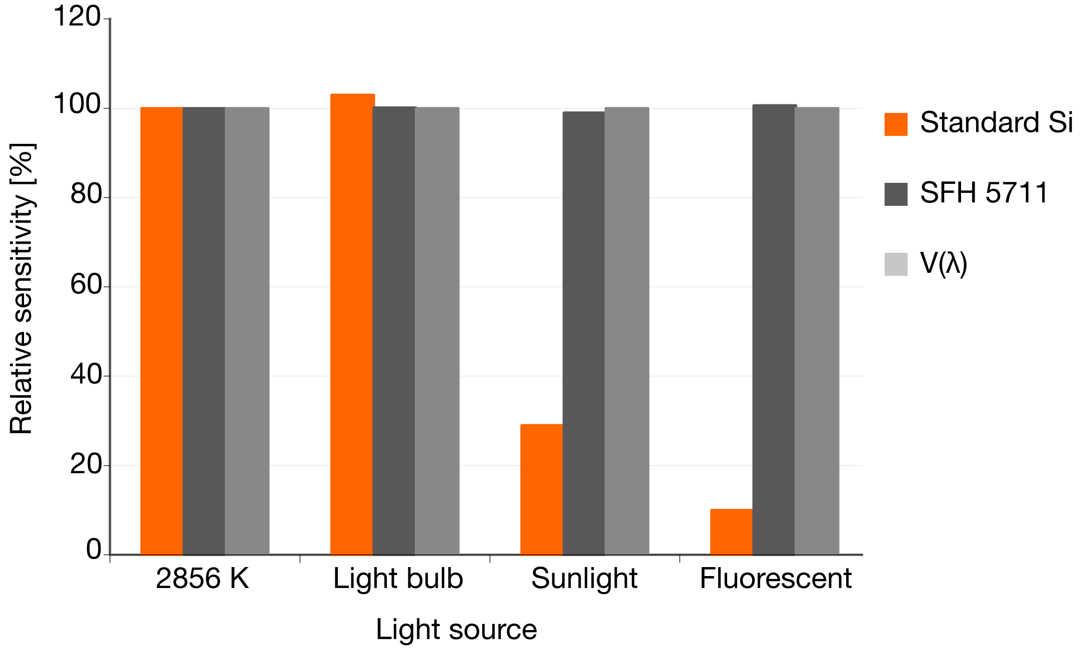


From Figure 1 one can see that a standard Si-detector has its maximum sensitivity in the IR range, which is invisible to human eyes. Incandescent lights or the sun emit light in this “invisible range”, which then leads a standard Si-detector to “see” a higher brightness than a human would do. This match with the human eye characteristics is the most important parameter for the performance of an ambient light sensor.

The effect can be seen in Figure 2. It shows the detector signals for different light spectra adjusted to the same brightness level for the human eye.

All signals in Figure 2 are normalized to standard light A (2856 K), which is a general point of reference for ambient light sensors. Figure 2 illustrates the brightness measurement deviations of the different detectors compared to the human eye. An incandescent light bulb, for instance, emits a high portion of IR light, which is fully detected by the standard Si-detector, but not seen by the human eye. Fluorescent lamps, on the other hand, do not emit much IR light. Hence the signals yielded by the standard Si-detectors are much higher for light bulbs than they are for fluorescent lamps, even though both lamps appear equally bright to the human eye. The deviation of the brightness measurement for the different light sources can directly be derived from Figure 2. Compared to the human eye, the standard Si-detector signal is 3 % too high in case of a light bulb and over 90 % too low for a fluorescent lamp. The respective values for the SFH 5711 are ~1 % only. When designing an ambient light sensor application, all possible light sources have to be taken into account.

Figure 2: Detector readings for different light sources at the same brightness. The values are normalized to a standard light A (2856 K). The brightness measurement data of the standard Si-detector shows large deviations due to the high sensitivity to IR light.



Logarithmic output

In order to represent the wide dynamic range of ambient light illuminance E_V (Lux) correctly, the SFH 5711 is equipped with an analog logarithmic current output.

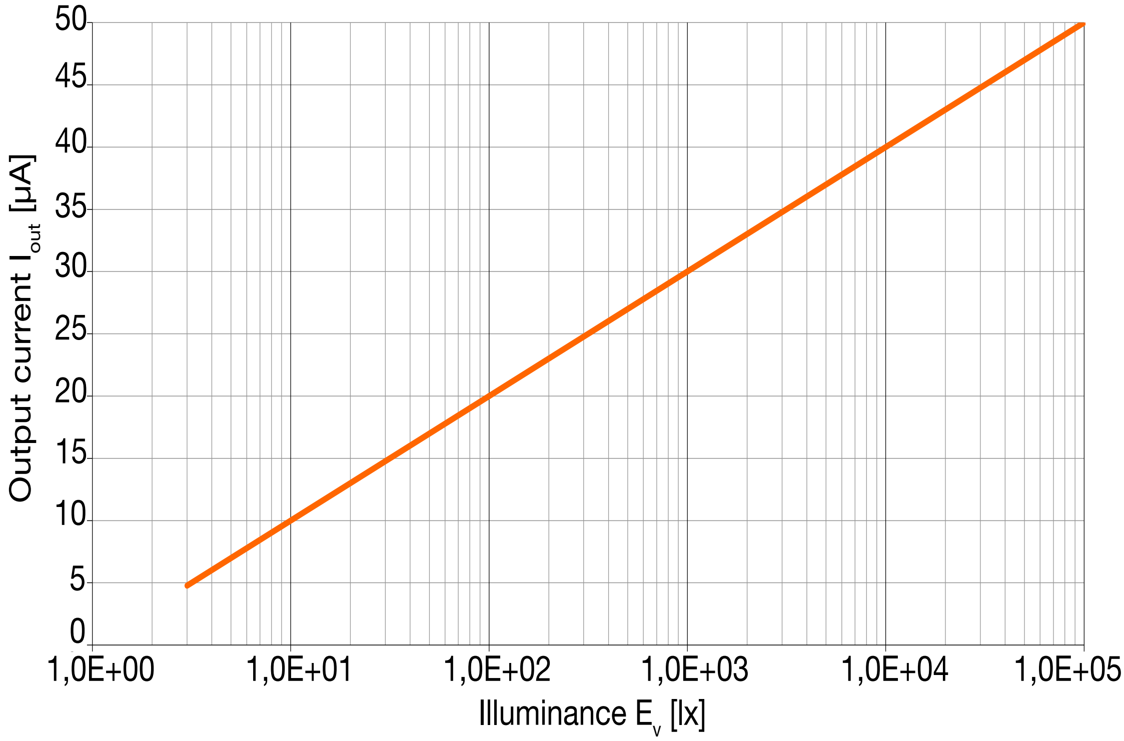
$$I_{out} = S \cdot \log\left(\frac{E_v}{E_o}\right)$$

, with E_0 =1 lx and sensitivity S = 10 μA/dec.

Figure 3 shows the output signal I_{out} versus illuminance E_V.

Advantages of a logarithmic output. For brightness measurements a good relative resolution over the entire brightness range is important. In other words: when measuring low brightness levels, small changes in those levels need to be detected, whereas when high brightness levels are measured, only relatively large variations are of interest. A change from 100 lx to 200 lx is considerable, whereas the step from 10000 lx to 10200 lx is negligible. For linear output detectors such as phototransistors or photodiodes, brightness changes ΔE_V result in changes ΔI_{out} of the output current, which are linear proportional to ΔE_V. To resolve small variations in low illumination levels it is necessary to measure in small current steps. At high brightness levels, however, it makes little sense to collect data with such fine absolute resolution.

Figure 3: Output current of the SFH 5711 versus illuminance



A logarithmic connection implements this selection already: Constant relative changes of the input values are converted into constant absolute changes of the output value. Figure 4 explains this: Equal ratios of detected illuminance levels are converted into output current levels of equal steps.

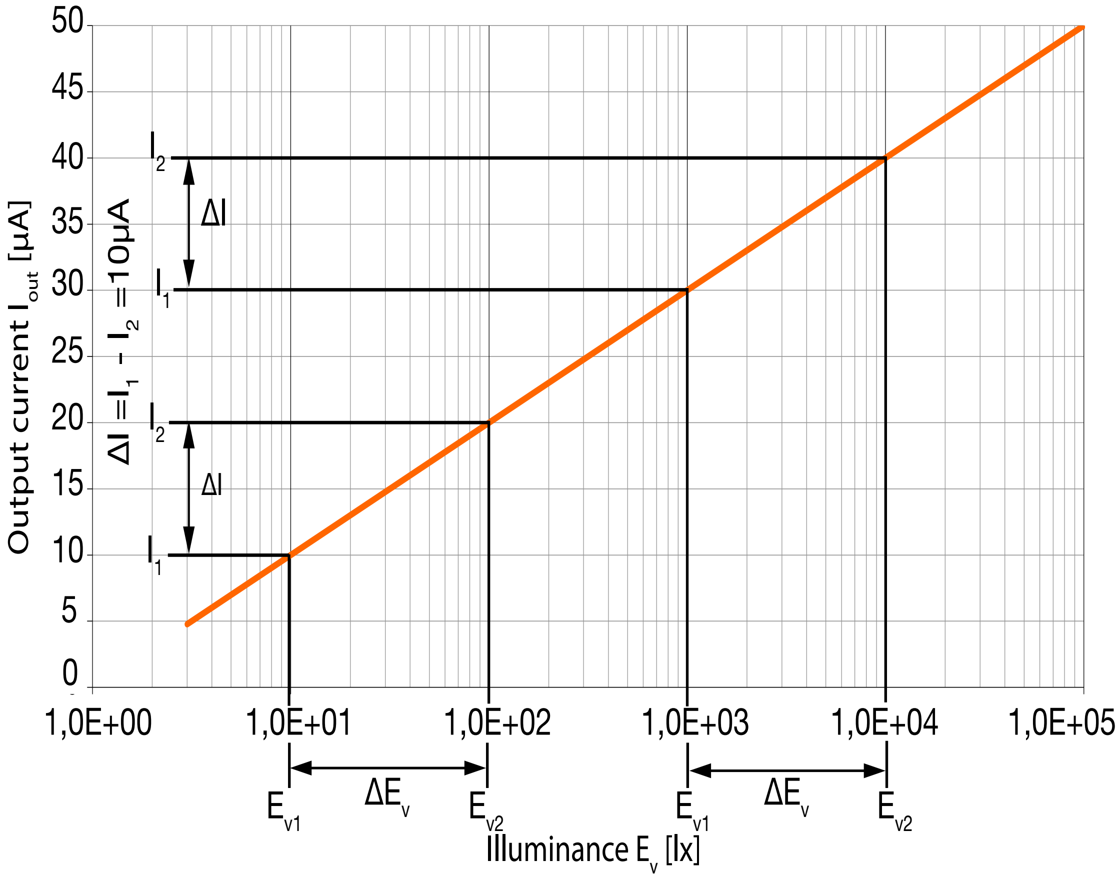
The following example illustrates this effect:

In many applications, the output signals are processed by an A/D converter. In this example an 8 bit converter is used. A linear output photo detector detects a maximum of 100 klx. Hence 256 different values are available to resolve the 100 klx. Because of the linear relationship between output current and illuminance, the 256 values are equally distributed over the entire detection range, which yields a fixed value of 390 lx/bit. This setting cannot resolve light levels below 1000 lx with sufficient accuracy.

Therefore the operating range is changed to 0 lx to 1000 lx by switching to a different resistor value in order to achieve a resolution of 3.9 lx/bit for levels below 1000 lx (for example see Figure 5). The relative accuracy of the measurement is defined by the bit size and it varies depending on the operating range. For a typical value of 0.4 mA photocurrent at 1 klx, a 6.9 kΩ resistor yields 2.8 V voltage drop at the A/D converter. To enhance the detection range to 100 klx, the 2.8 V must resemble 100 klx and the resistor needs to be decreased to 69 Ω.

In the case of a logarithmic output, the 256 bits are not evenly distributed over the detection range, but at a fixed ratio with the absolute detected value. Equal ratios of detected illuminance levels are converted into output current levels of equal steps (see Figure 4). The relative accuracy of the measurement in this case is a constant value over the entire illuminance range.

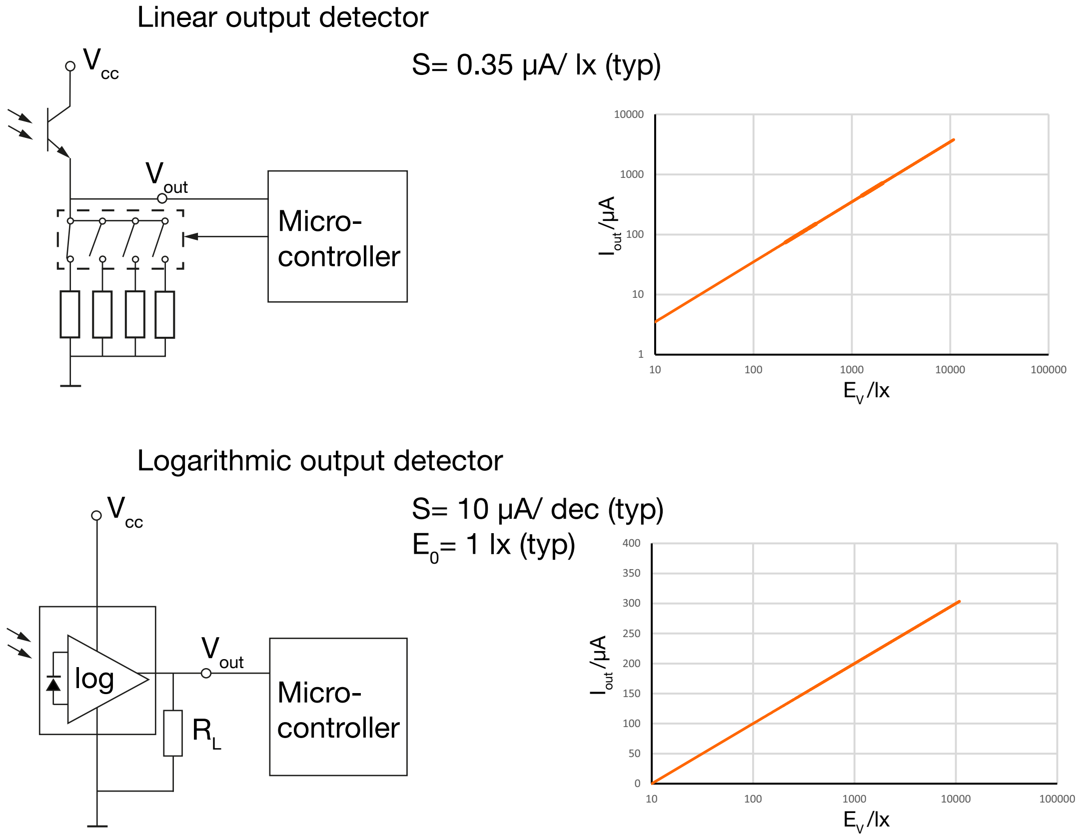
Figure 4: A logarithmic output converts equal ratios of detected illuminance levels (E_V1, E_V2) into current levels of equal steps (I_2, I_1)



$$\Delta Ev_1 = \frac{Ev_1}{Ev_2} = 10 \cdot Ev_1$$

Figure 5 illustrates this procedure. A linear photodetector needs to be operated with different resistors to change between different detection ranges, which is not necessary for the logarithmic output signal device. In the above example, the sensor can directly be connected to an ADC input via external load resistor.

Figure 5: A linear output detector and a logarithmic output detector are used to detect ambient light. To achieve sufficient resolution over all brightness levels, the operating range of the linear detector is adjusted by using different resistors.

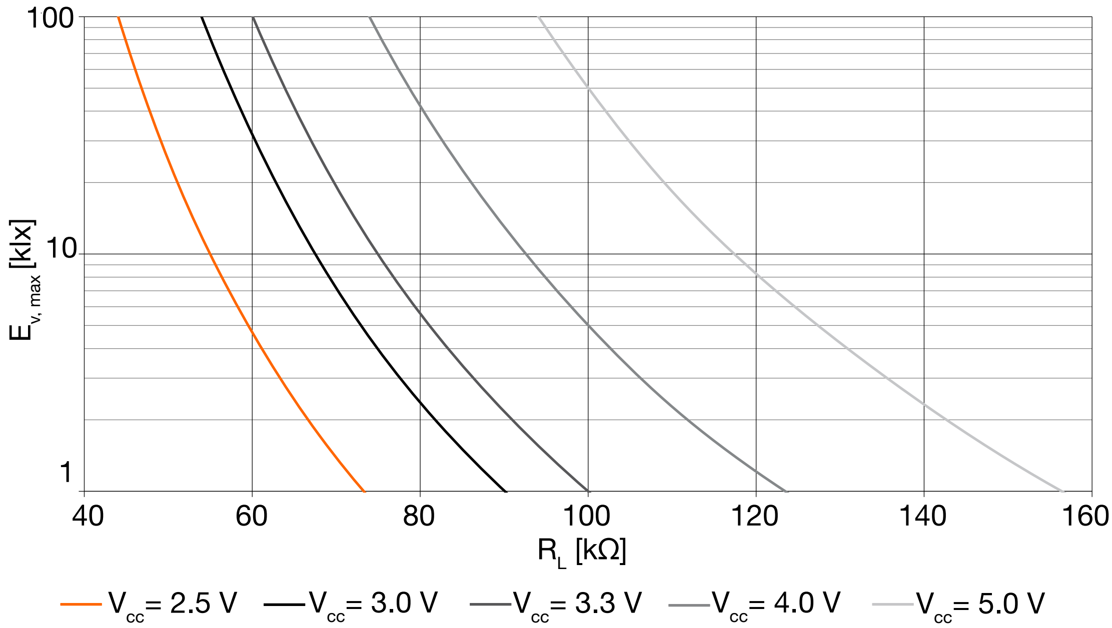


Load resistance

If the SFH 5711 is operated with an external load resistance R_L, then the upper detection limit of the sensor depends on the resistor value of R_L. The load resistance does not directly determine the maximum detection level, but it does determine the output voltage of the sensor, which is limited by the supply voltage V_{CC}. At high illuminance levels the output current I_{out} is high and the load resistance must be reduced in order to stay below V_{CC} ($V_{out} \leq V_{CC} = I_{out} * R_L$)

Figure 6 shows the relationship between load resistance and maximum detectable brightness levels. For 2.5 V supply voltage, the detection limit for a 56 kΩ resistor is ~ 9 klx. To increase this level, a lower resistor value is necessary. With 47 kΩ up to 60 klx can be detected. For higher V_{CC}, the reachable detection limit increases with the same resistor values.

Figure 6: Typical maximum detectable light level vs. load resistance (resistance values are taken from E12 series)



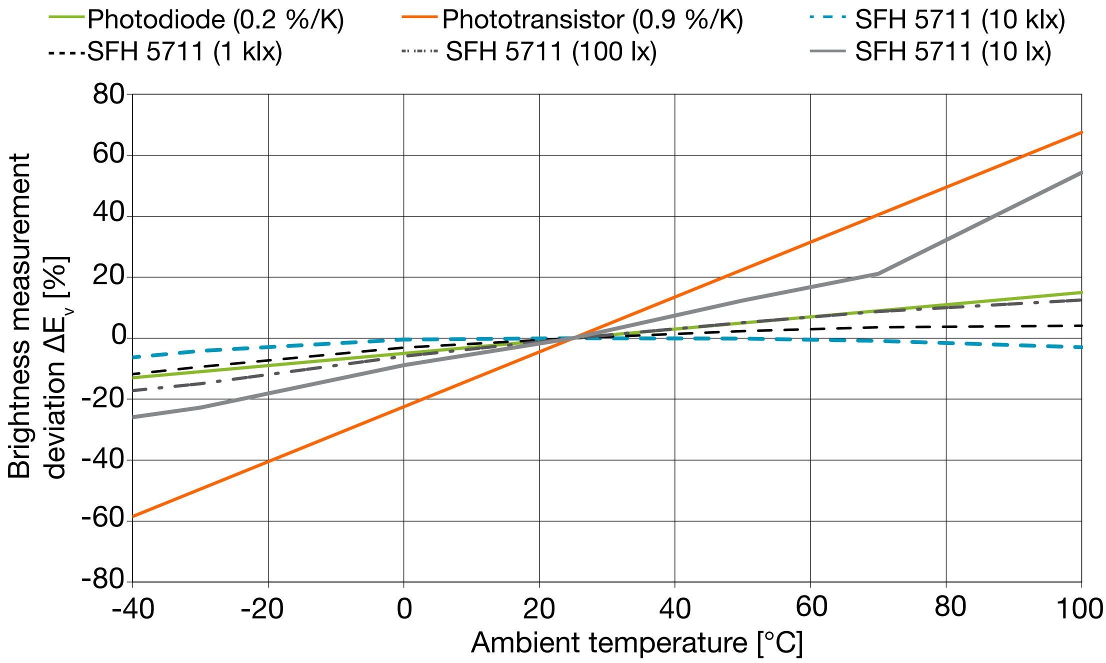
Temperature dependence

The temperature coefficient of the SFH 5711 is not a constant value like it is the case for phototransistors and photodiodes. It depends on the illuminance range under which the device is operated.

Figure 7 shows the deviation of the brightness measurements relative to 25 °C for the SFH 5711 at different brightness levels. Corresponding data for phototransistors and photodiodes are also shown.

In comparison to a phototransistor, the SFH 5711 yields a better accuracy at all brightness levels. Above 100 lx, the temperature behavior of the SFH 5711 is comparable to that of a photodiode. At 10 lx and high temperatures, greater deviations than those of photodiodes have to be taken into account.

Figure 7: Brightness measurement deviation relative to 25 °C for the SFH 5711 compared to photodiode and phototransistor



Sensitivity variation

Due to the manufacturing process there is a sensitivity variation within the SFH 5711. To account this, OSRAM Opto Semiconductors offers a choice of binning options. Table 1 gives a summary of the binning options for the SFH 5711. The width of each bin is 3 µA. This corresponds to a spread of 1:2 in detected illuminance.

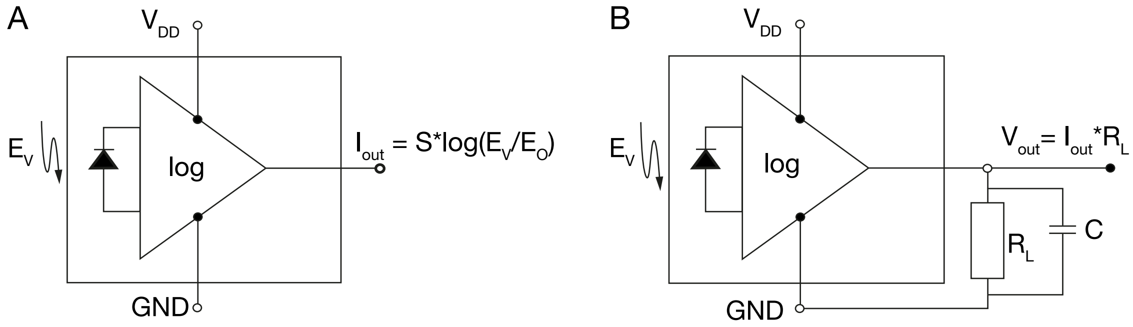
Table 1: Sensitivity binning for the SFH 5711. Each bin corresponds to a spread of 1:2 in detected illuminance

Bin	**Output current I_{out} [µA]** λ = 560 nm , V_{DD} = 2.5 V; E_V = 180 µW/m²
1	25 ... 28
2	27 ... 30
3	29 ... 32
4	31 ... 34

Operation of the SFH 5711

The SFH 5711 yields an analog output current I_{out}. This signal can either be directly transferred into a microcontroller or transformed into voltage. The voltage drop at the load resistor R_L is then used as input signal into a microcontroller. Many applications also use an A/D converter for signal processing. An additional capacitance C (see Figure 8 right) allows the adjustment of the reaction time of the sensor. The sensor has been tested up to C= 1 nF. Figure 8 show exemplary operating circuits for the SFH 5711.

Figure 8: Operating circuit for the SFH 5711. The analog output current is directly processed (A) or the voltage drop at the load resistance RL is used for further processing (B). An additional capacitance C can be used to adjust the reaction time



Supply voltage

The SFH 5711 is suitable for a supply voltage range of (2.3 ... 5) V.

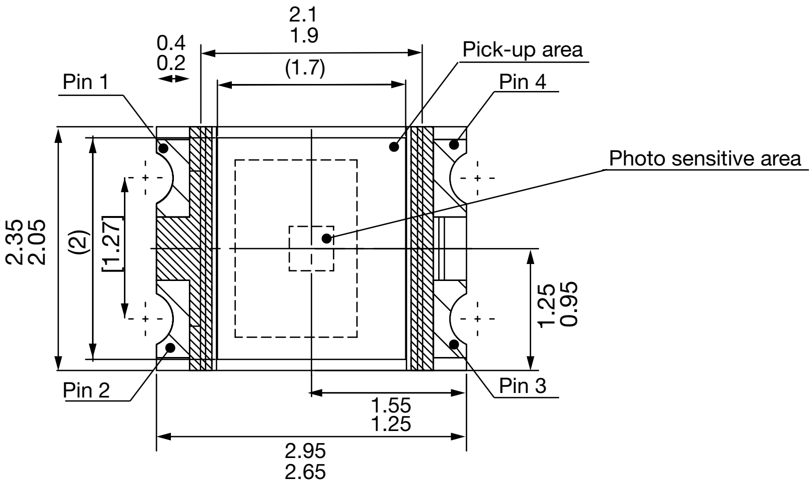
Placement of the SFH 5711

The sensitive area of the SFH 5711 is 0.4 mm x 0.4 mm and much smaller than the device itself. When placing the part behind a light guide, only this sensitive area has to be taken into account. Figure 9 shows the position and size of the sensitive area within the package. Table 2 provides the pin configuration.

Table 2: Pin configuration of the SFH 5711

Pin	Description
1	V_{SS}
2	V_{SS}
3	V_{DD}
4	I_{out}

Figure 9: Position and size of the sensitive area within the SFH 5711



Main characteristics of the SFH 5711

Table 3 summarizes the main characteristics of the SFH 5711. For further details, please refer to the respective data sheet. The device is RoHS compliant.

Table 3: Main characteristics of SFH 5711

Parameter	Value
Size L x W x H [mm]	2.8 x 2.2 x 1.1
Sensitive area [mm^2]	0.4 x 0.4
typ. Signal I_{out} [µA] @1000 lx, V_{CC}= 2.5V	30
Sensitivity variation	3 µA/ bin
Current consumption I_{DD} [µA]	410 @ 0 lx; 460 @ 1000 lx

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