



# Ambient Light Sensors - Circuit and Window Design

**Ambient light sensors** are used to detect light or brightness in a manner similar to the human eye. They are most commonly found in industrial lighting, consumer electronics, and automotive systems, where they allow settings to be adjusted automatically in response to changing ambient light conditions. By turning on, turning off, or adjusting features, ambient light sensors can conserve battery power and provide extra safety while eliminating the need for manual adjustments.

Vishay offers a wide variety of ambient light sensors in leaded and surface mount packages, with photodiode or phototransistor outputs, narrow to broad viewing angles or angles of half sensitivity, and automotive qualified to the AEC-Q101 standard (Table 1). Sensors that are automotive qualified have an "X01" in the part number.

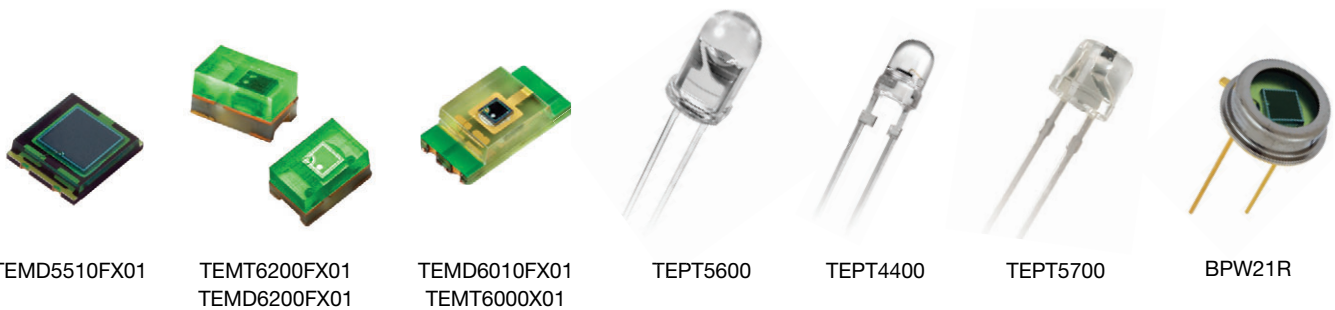


Table 1

| PART NUMBER                   | MOUNTING | SIZE (mm)        | PEAK WAVELENGTH (nm) | BANDWIDTH (nm) | ANGLE OF HALF SENSITIVITY (± °) | LIGHT CURRENT <sup>(1)</sup> STANDARD A (µA) | LIGHT CURRENT <sup>(2)</sup> FLUORESCENT (µA) |
|-------------------------------|----------|------------------|----------------------|----------------|---------------------------------|--|---|
| <b>PHOTODIODE OUTPUT</b>      |          |                  |                      |                |                                 |  |   |
| <a href="#">TEMD6010FX01</a>  | SMD      | 2.0 x 4.0 x 1.0  | 540                  | 430 to 610     | 60                              | 0.04   | 0.03  |
| <a href="#">TEMD5510FX01</a>  | SMD      | 4.2 x 5.0 x 1.1  | 540                  | 430 to 610     | 65                              | 1.00   | 0.70  |
| <a href="#">TEMD6200FX01</a>  | SMD      | 1.2 x 2.0 x 0.85 | 540                  | 430 to 610     | 60                              | 0.04   | 0.03  |
| <a href="#">BPW21R</a>        | Leaded   | TO5 - 8 mm       | 565                  | 420 to 675     | 50                              | 0.90   | 0.75  |
| <b>PHOTOTRANSISTOR OUTPUT</b> |          |                  |                      |                |                                 |  |   |
| <a href="#">TEMT6200FX01</a>  | SMD      | 1.2 x 2.0 x 0.85 | 550                  | 450 to 610     | 60                              | 12   | 7   |
| <a href="#">TEMT6000X01</a>   | SMD      | 2.0 x 4.0 x 1.0  | 570                  | 430 to 800     | 60                              | 50   | 21  |
| <a href="#">TEPT5700</a>      | Leaded   | 5 mm, flat top   | 570                  | 430 to 800     | 50                              | 75   | 31  |
| <a href="#">TEPT5600</a>      | Leaded   | 5 mm             | 570                  | 430 to 800     | 20                              | 350  | 145   |
| <a href="#">TEPT4400</a>      | Leaded   | 3 mm             | 570                  | 430 to 800     | 30                              | 200  | 83  |

**Notes**

- (1)  $E_v = 100$  lux,  $V_{CE} = 5$  V, CIE illuminant A, typical
- (2)  $E_v = 100$  lux,  $V_{CE} = 5$  V, e.g., Sylvania color abbrev. D830, typical

## Ambient Light Sensors - Circuit and Window Design

### FILTERING

Most photodiodes and some phototransistors feature an epoxy filter that improves the relative spectral sensitivity to be closer to the sensitivity of the human eye; this is sometimes called the  $v(\lambda)$  curve. Part numbers that contain the letter “F” feature this epoxy. Figure 1 shows an ambient light sensor without the epoxy filter and figure 2 shows the sensor with the epoxy filter. With this epoxy filter the bandwidth ( $\lambda_{0.5}$ ) is reduced from 430 nm to 800 nm to 430 nm to 610 nm.

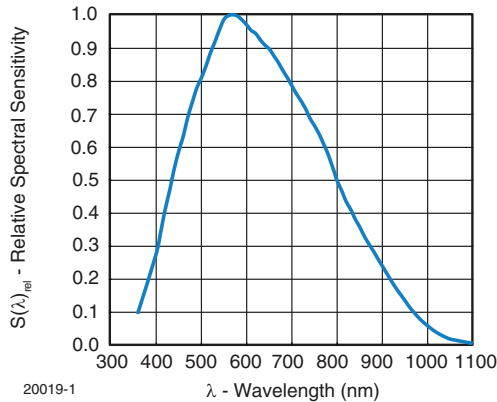


Fig. 1 - Graph without Epoxy Filter

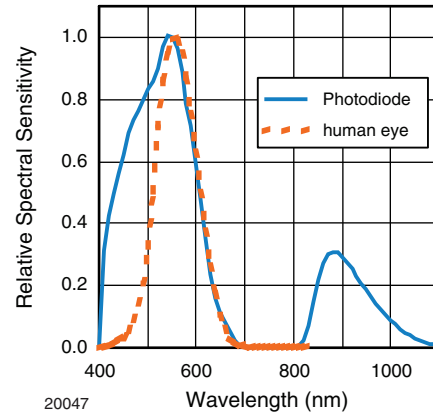


Fig. 2 - Graph with Epoxy Filter

### BINNING

Vishay offers phototransistor- and photodiode-based ambient light sensors. For a given irradiance, phototransistors may show lot-to-lot variability of the output current caused by variability of the photosensitivity of the chip and the transistor gain. The lot-to-lot variability of photodiodes is significantly lower because it is caused only by the variability of the photosensitivity. Vishay offers its ambient light sensors with phototransistor output in binned groups (Table 2). These groups cannot be ordered separately but each reel is marked with a label A, B, or C that will allow the user to select the appropriate load resistor to compensate for these wide tolerances.

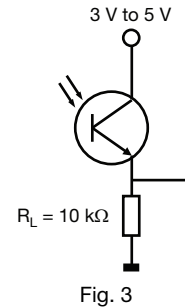
Table 2 - TEMT6200FX01

| TYPE DEDICATED CHARACTERISTICS ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified) |  |              |           |      |      |               |
|---|--|--------------|-----------|------|------|---------------|
| PARAMETER   | TEST CONDITION   | BINNED GROUP | SYMBOL    | MIN. | MAX. | UNIT          |
| Photo current   | $E_V = 100\text{ lux}$ , CIE illuminant A, $V_{CE} = 5\text{ V}$ | A            | $I_{PCE}$ | 7.5  | 15   | $\mu\text{A}$ |
|   |  | B            | $I_{PCE}$ | 12   | 24   | $\mu\text{A}$ |
|   |  | C            | $I_{PCE}$ | 19.5 | 39   | $\mu\text{A}$ |

## Ambient Light Sensors - Circuit and Window Design

### CHOOSING THE LOAD RESISTOR

In order to minimize the output variability of the sensor, the load resistor ( $R_L$ ) needs to be selected based on the illuminance expected or measured in the application. A typical circuit for operating an ambient light sensor with phototransistor output is shown in Figure 3. For the TEMT6200FX01, the typical output current is  $4.6 \mu\text{A}$  at 20 lux. At 100 lux the output current ranges from  $7.5 \mu\text{A}$  to  $39 \mu\text{A}$ . With the binning mentioned previously, this 100 lux range is split into three bins. A different load resistor should be used for each bin so the output is relatively consistent for a given lux level.



Let's assume that the application detection range is from 10 lux to 1000 lux. With a  $10 \text{ k}\Omega$  load resistor, a voltage from  $0.023 \text{ V}$  to  $2.3 \text{ V}$  is produced. The photo current based on the voltage equates to  $2.3 \mu\text{A}$  to  $230 \mu\text{A}$ .

The goal in choosing the resistor is to have the same output voltage for the mean value of each bin, Table 3.

Table 3

| PART NUMBER  | BIN | PHOTO CURRENT, $I_{PCE}$ at 100 lux ( $\mu\text{A}$ ) |       |      |
|--------------|-----|---|-------|------|
|              |     | MIN.  | MEAN  | MAX. |
| TEMT6200FX01 | A   | 7.5   | 11.25 | 15   |
|              | B   | 12  | 18.00 | 24   |
|              | C   | 19.5  | 29.25 | 39   |

Table 4

| BIN B   | BIN A   | BIN C  |
|---|---|--|
| $I_{PCE} = 18 \mu\text{A}$ , $R_L = 10 \text{ k}\Omega$<br>$V = 18 \mu\text{A} \times 10 \text{ k}\Omega$<br>$V = 180 \text{ mV}$ | $0.18 \text{ V} = 0.00001125 \text{ A} \times R_L$<br>$R_L = 0.18 \text{ V} / 0.00001125 \text{ A}$<br>$R_L = 16 \text{ k}\Omega$ | $0.18 \text{ V} = 0.00002925 \text{ A} \times R_L$<br>$R_L = 0.18 \text{ V} / 0.00002925 \text{ A}$<br>$R_L = 6.2 \text{ k}\Omega$ |

By changing the resistor based on the bin, the overall tolerance of the TEMT6200FX01 is reduced from a factor of 5 (7.5 to 39) to a factor 2 (e.g. 12 to 24).

## Ambient Light Sensors - Circuit and Window Design

### OPERATING FROM 1 lux TO 100 000 lux

The sensitivity of TEMENT6200FX01 allows detection of ambient light from 1 lux to 100 000 lux. In many applications, the detection range of an ambient light sensor is from 1 lux to 1000 lux. The calculations for the load resistor on the previous page were for this range. The maximum allowable current for the TEMENT6200FX01 is 20 mA. Extrapolating the graph of the photo current versus illuminance in figure 4, a photo current of 18 mA is approximately equal to 100 000 lux. The relationship between photo current and ambient light is linear. Given the extremely low dark current for this part of 50 nA, and again extrapolating the graph, results in approximately 180 nA of photo current for 1 lux. The output current from 1 lux to 100 000 lux is 180 nA to 18 mA.

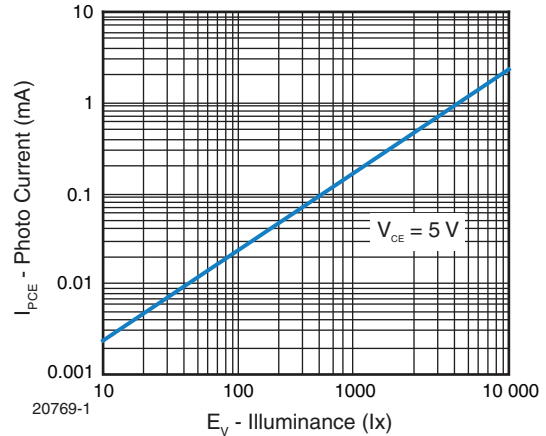


Fig. 4 - Photo Current vs. Illuminance

Depending on the sensitivity of the analog-to-digital converter, an operational amplifier could be placed at the output of the sensor as shown in figure 5. In this case, a load resistor of 10 kΩ results in an output voltage of 2 mV to 2.0 V for an ambient level of 1 lux to 1000 lux.

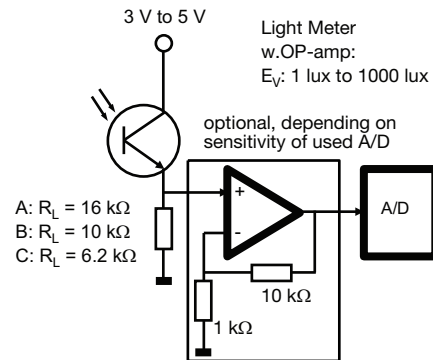


Fig. 5

Operating over the full ambient range of 1 lux to 100 000 lux and using a 1 kΩ load resistor would result in an output voltage from 0.18 mV to 18 V. Given a typical operating voltage of 5 V or less, this circuit design is not adequate. The load resistor will need to switch based on the output of the operational amplifier (figure 6). Switching a low-ohm resistor that is in parallel to the divider resistor when the operational amplifier is above a certain value, for example 3 V, allows full-range operation.

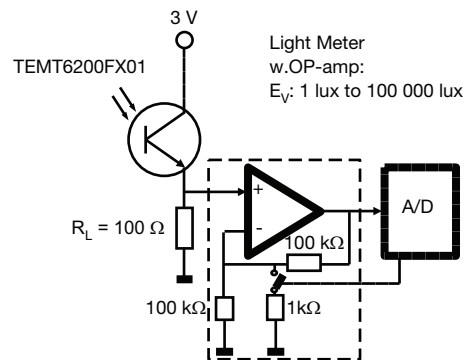


Fig. 6

APPLICATION NOTE

#### 1 lux to 1000 lux

$I_{PCE} = 180 \text{ nA to } 180 \text{ }\mu\text{A}$   
 $R_L = 100 \text{ }\Omega \rightarrow$   
 $V_{RL} = 18 \text{ }\mu\text{V to } 18 \text{ mV}$   
 with  $v_a = 100$   
 $V_{ADC} = 1.8 \text{ mV to } 1.8 \text{ V}$

#### 1000 lux to 100 000 lux

$I_{PCE} = 180 \text{ }\mu\text{A to } 18 \text{ mA}$   
 $R_L = 100 \text{ }\Omega$   
 $V_{RL} = 18 \text{ mV to } 1.8 \text{ V}$   
 with  $v_a = 1$   
 $V_{ADC} = 18 \text{ mV to } 1.8 \text{ V}$

## Ambient Light Sensors - Circuit and Window Design

### RISE AND FALL TIMES FOR ALS PHOTOTRANSISTORS

Rise and fall times depend (drastically) on the load resistor that is used. For all these ALS phototransistors these are in the range of 45  $\mu$ s with a 50  $\Omega$  load resistor and rises linearly to 310  $\mu$ s with a 10 k $\Omega$  load resistor. To achieve faster rise and fall times, it is also important that the collector current is as high as possible.

The collector current depends strongly on the strength of illumination so lower illumination strengths lead to longer rise and fall times.

### APPLICATION SCHEMATICS

Some simple application circuits for ambient light sensors with phototransistor output are shown below.

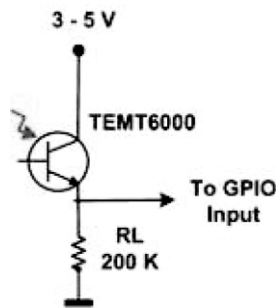


Fig. 7 - Switch, Output High at  $E_V > 25$  lux,  $I_{PCE}$ : 10  $\mu$ A,  $V_{OUT}$ : 2.0 V, Input Leakage Current: < 1  $\mu$ A

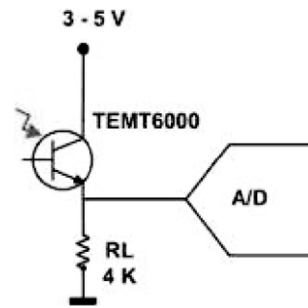


Fig. 10 - Light Meter,  $E_V$ : 10 lux to 1000 lux,  $I_{PCE}$ : 4  $\mu$ A to 400  $\mu$ A,  $V_{OUT}$ : 16 mV to 1.6 V

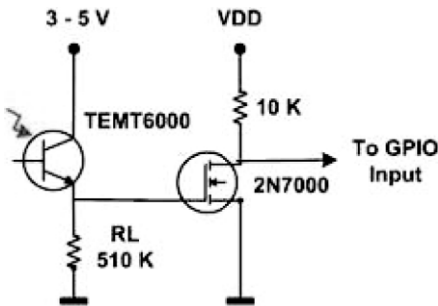


Fig. 8 - Switch, Output Low at  $E_V > 10$  lux,  $I_{PCE}$ : 4  $\mu$ A, Gate Threshold: 2.0 V, Input Leakage Current: < 1  $\mu$ A

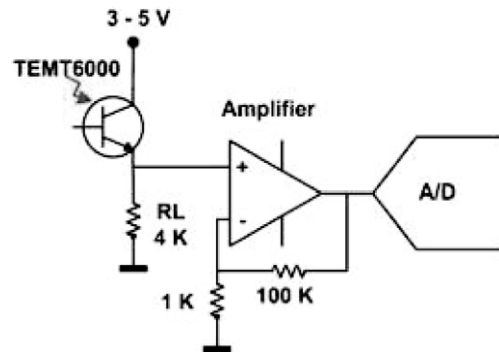


Fig. 11 - Low Illuminance Light Meter,  $E_V$ : 0.1 lux to 10 lux,  $I_{PCE}$ : 40 nA to 4  $\mu$ A,  $V_{OUT}$ : 16 mV to 1.6 V

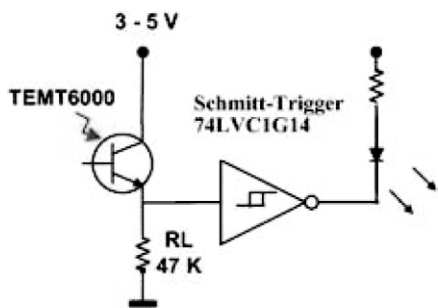


Fig. 9 - Light Switch, (Schmitt Trigger), Switch Off at  $E_V < 100$  lux,  $I_{PCE}$ : < 40  $\mu$ A, Input Leakage Current: < 5  $\mu$ A

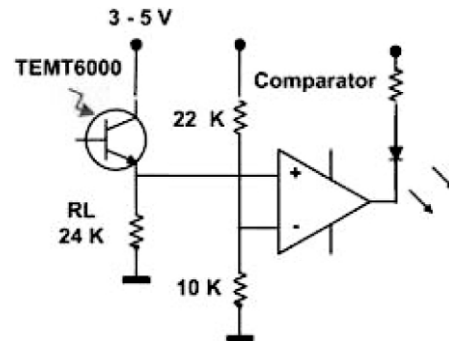


Fig. 12 - Light Switch, Switch On at  $E_V < 100$  lux,  $I_{PCE}$ : < 40  $\mu$ A



## Ambient Light Sensors - Circuit and Window Design

### PHOTODIODE-BASED AMBIENT LIGHT SENSORS

The basic characteristics of the ambient light sensors with photodiode outputs are shown in Table 5 below. All photodiode-based ambient light sensors have an additional epoxy filter that brings the relative spectral sensitivity close to the  $v[\lambda]$  or “Human Eye” curve. BPW21R comes with a color correction filter in its flat glass window that provides a similar effect. The low photocurrent output requires a noise-free amplification which can be achieved with the appropriate op amp. Examples of noise-free op amps that could be used with the photodiode output devices and related circuitry are shown on the next page.

Table 5 - TEMD6010FX01

| BASIC CHARACTERISTICS ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified) |   |                 |      |          |      |               |
|--|---|-----------------|------|----------|------|---------------|
| PARAMETER  | TEST CONDITION  | SYMBOL          | MIN. | TYP.     | MAX. | UNIT          |
| Breakdown voltage  | $I_R = 100\text{ }\mu\text{A}$ , $E = 0\text{ lux}$                       | $V_{(BR)}$      | 16   | -        | -    | V             |
| Reverse dark current   | $V_{CE} = 10\text{ V}$ , $E = 0\text{ lux}$                               | $I_{ro}$        | -    | 0.1      | 5    | nA            |
| Diode capacitance  | $V_R = 0\text{ V}$ , $f = 1\text{ MHz}$ , $E = 0\text{ lux}$              | $C_D$           | -    | 60       | -    | pF            |
|  | $V_R = 5\text{ V}$ , $f = 1\text{ MHz}$ , $E = 0\text{ lux}$              | $C_D$           | -    | 24       | -    | pF            |
| Reverse light current  | $E_e = 1\text{ mW/cm}^2$ , $\lambda = 550\text{ nm}$ , $V_R = 5\text{ V}$ | $I_{ra}$        | -    | 1        | -    | $\mu\text{A}$ |
|  | $E_v = 100\text{ lux}$ , CIE illuminant A, $V_R = 5\text{ V}$             | $I_{ra}$        | 0.03 | 0.04     | 0.09 | $\mu\text{A}$ |
| Temperature coefficient of $I_{ra}$  | $E_v = 100\text{ lux}$ , CIE illuminant A, $V_R = 5\text{ V}$             | $TK_{I_{ra}}$   | -    | 0.2      | -    | %/K           |
| Angle of half sensitivity  |   | $\varphi$       | -    | $\pm 60$ | -    | $^{\circ}$    |
| Wavelength of peak sensitivity   |   | $\lambda_p$     | -    | 540      | -    | nm            |
| Range of spectral bandwidth  |   | $\lambda_{0.5}$ | 430  | -        | 610  | nm            |

Compared to phototransistor-based ambient light sensors, the lot-to-lot variability of photodiodes is significantly lower because it is caused only by the variability of the photosensitivity resulting in tolerances of 20 % to 30 %. Variability of the output current of photodiode-based ambient light sensors is also due to chip size. A larger detection area or chip size will result in greater photo current. The TEMD5510FX01 and the BPW21R produce double the current of the TEMD6200FX01 and TEMD6010FX01. The TEMD5510FX01 contains a 7.5 mm<sup>2</sup> chip while the size of the sensitive area of the chip in the TEMD6x is just 0.27 mm<sup>2</sup>.

## Ambient Light Sensors - Circuit and Window Design

### APPLICATION SCHEMATICS FOR PHOTODIODE-BASED AMBIENT LIGHT SENSORS

A sensitive, FET-input type of photodiode preamplifier, with a very low input noise, should be used, such as:

- Linear Technology LTC6240
- Texas Instruments (OPA827)
- Burr-Brown (OPA128)
- Analog Devices (AD549)

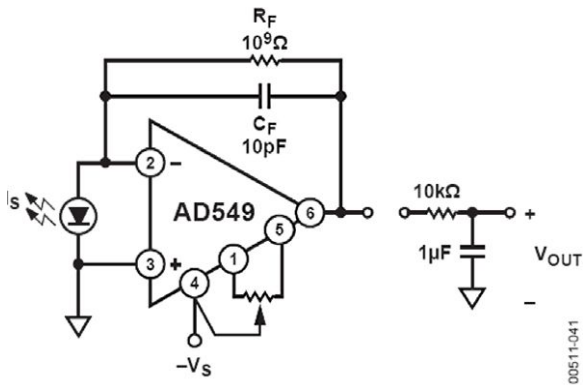
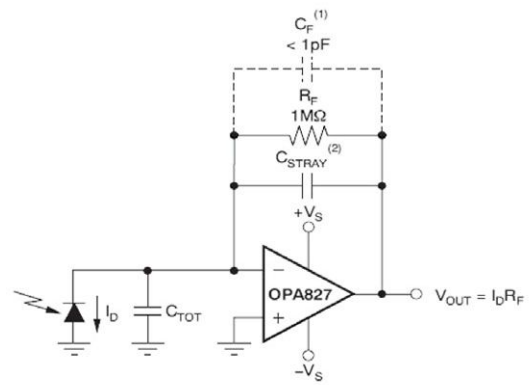


Fig. 13 - Photodiode Preamp



NOTES: (1)  $C_F$  is optional to prevent gain peaking.  
(2)  $C_{STRAY}$  is the stray capacitance of  $R_F$  (typically, 2pF for a surface-mount resistor).

Fig. 15 - Transimpedance Amplifier

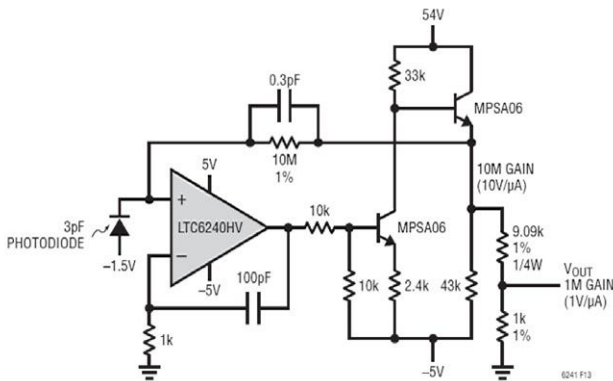


Fig. 14 - 1M Transimpedance Amplifier with 43 nV/Hz<sup>2</sup> Output Noise

### OPA128

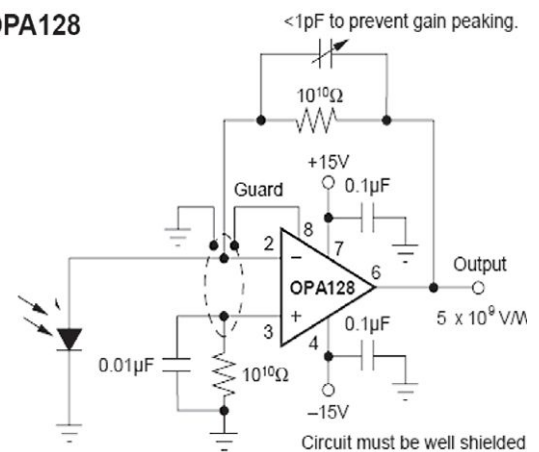


Fig. 16 - Sensitive Photodiode Amplifier

## Ambient Light Sensors - Circuit and Window Design

### RISE AND FALL TIMES FOR ALS PHOTOTRANSISTORS

All these ALS photodiodes are not very fast when compared to standard photodiodes and even slower when operated with higher load resistors.

The rise / fall times will increase with respect to the load resistor leading to a smaller bandwidth as shown as in figure below, which can be found in the following measurement notes [www.vishay.com/doc?80085](http://www.vishay.com/doc?80085), [www.vishay.com/doc?48454](http://www.vishay.com/doc?48454).

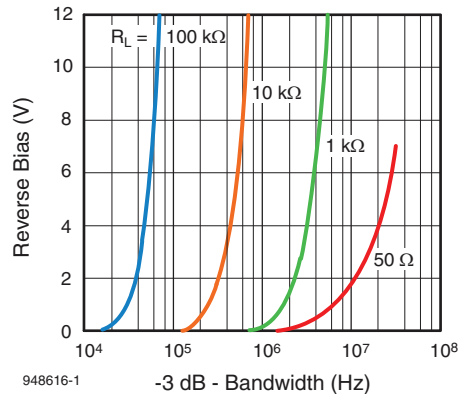


Fig. 17 - BPW34, TEMD5010X01, Bandwidth vs. Reverse Bias Voltage, Parameter: Load Resistance,  $\lambda = 820 \text{ nm}$

The main reason that a standard photodiode is faster than an ALS photodiode is their lower diode capacitance, which directly correlates with the die size. Below you can see an example of such a low diode capacitance, e.g. of the VEMD1060X01: [www.vishay.com/ppg?84295](http://www.vishay.com/ppg?84295), which is considerably lower to those found in ALS photodiodes.

| BASIC CHARACTERISTICS ( $T_{\text{amb}} = 25 \text{ }^\circ\text{C}$ , unless otherwise specified) |   |                   |      |             |      |               |
|--|---|-------------------|------|-------------|------|---------------|
| PARAMETER  | TEST CONDITION  | SYMBOL            | MIN. | TYP.        | MAX. | UNIT          |
| Forward voltage  | $I_F = 50 \text{ mA}$   | $V_F$             | -    | 0.9         | 1.1  | V             |
| Breakdown voltage  | $I_R = 100 \text{ } \mu\text{A}$ , $E = 0$                                    | $V_{(\text{BR})}$ | 20   | -           | -    | V             |
| Reverse dark current   | $V_R = 10 \text{ V}$ , $E = 0$  | $I_{ro}$          | -    | 0.01        | 5    | nA            |
| Diode capacitance  | $V_R = 0 \text{ V}$ , $f = 1 \text{ MHz}$ , $E = 0$                           | $C_D$             | -    | 3.8         | -    | pF            |
|  | $V_R = 3 \text{ V}$ , $f = 1 \text{ MHz}$ , $E = 0$                           | $C_D$             | -    | 1.7         | -    | pF            |
| Open circuit voltage   | $E_e = 1 \text{ mW/cm}^2$ , $\lambda = 950 \text{ nm}$                        | $V_o$             | -    | 350         | -    | mV            |
| Temperature coefficient of $V_o$   | $E_e = 1 \text{ mW/cm}^2$ , $\lambda = 950 \text{ nm}$                        | $TK_{V_o}$        | -    | -2.6        | -    | mV/K          |
| Short circuit current  | $E_e = 1 \text{ mW/cm}^2$ , $\lambda = 950 \text{ nm}$                        | $I_k$             | -    | 1.8         | -    | $\mu\text{A}$ |
| Temperature coefficient of $I_k$   | $E_e = 1 \text{ mW/cm}^2$ , $\lambda = 835 \text{ nm}$                        | $TK_{I_k}$        | -    | 0.1         | -    | %/K           |
| Reverse light current  | $E_e = 1 \text{ mW/cm}^2$ , $\lambda = 950 \text{ nm}$ , $V_R = 5 \text{ V}$  | $I_{ra}$          | 1.4  | 1.8         | 3    | $\mu\text{A}$ |
|  | $E_e = 1 \text{ mW/cm}^2$ , $\lambda = 890 \text{ nm}$ , $V_R = 5 \text{ V}$  | $I_{ra}$          | -    | 2.6         | -    | $\mu\text{A}$ |
| Angle of half sensitivity  |   | $\phi$            | -    | $\pm 70$    | -    | $^\circ$      |
| Wavelength of peak sensitivity   |   | $\lambda_p$       | -    | 820         | -    | nm            |
| Range of spectral bandwidth  |   | $\lambda_{0.1}$   | -    | 350 to 1070 | -    | nm            |
| Rise time  | $V_R = 5 \text{ V}$ , $R_L = 50 \text{ } \Omega$ , $\lambda = 830 \text{ nm}$ | $t_r$             | -    | 60          | -    | ns            |
| Fall time  | $V_R = 5 \text{ V}$ , $R_L = 50 \text{ } \Omega$ , $\lambda = 830 \text{ nm}$ | $t_f$             | -    | 80          | -    | ns            |

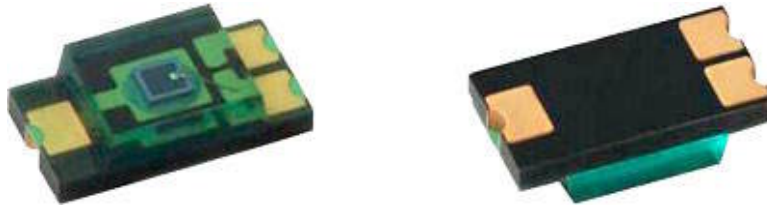
APPLICATION NOTE



## Ambient Light Sensors - Circuit and Window Design

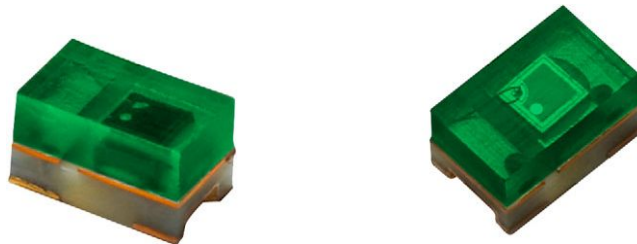
The TEMD6010FX01 and TEMD6200FX01 use the same chip, so all the data is identical including the rise-and fall times.

### TEMD6010FX01



| <b>BASIC CHARACTERISTICS</b> ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified) |   |                 |      |            |      |               |
|---|---|-----------------|------|------------|------|---------------|
| PARAMETER   | TEST CONDITION  | SYMBOL          | MIN. | TYP.       | MAX. | UNIT          |
| Breakdown voltage   | $I_R = 100\text{ }\mu\text{A}$ , $E = 0\text{ lx}$                        | $V_{(BR)}$      | 16   | -          | -    | V             |
| Reverse dark current  | $V_{CE} = 10\text{ V}$ , $E = 0\text{ lx}$                                | $I_{ro}$        | -    | 0.1        | 5    | nA            |
| Diode capacitance   | $V_R = 0\text{ V}$ , $f = 1\text{ MHz}$ , $E = 0\text{ lx}$               | $C_D$           | -    | 60         | -    | pF            |
|   | $V_R = 5\text{ V}$ , $f = 1\text{ MHz}$ , $E = 0\text{ lx}$               | $C_D$           | -    | 24         | -    | pF            |
| Reverse light current   | $E_e = 1\text{ mW/cm}^2$ , $\lambda = 550\text{ nm}$ , $V_R = 5\text{ V}$ | $I_{ra}$        | -    | 1          | -    | $\mu\text{A}$ |
|   | $E_V = 100\text{ lx}$ , CIE illuminant A, $V_R = 5\text{ V}$              | $I_{ra}$        | 0.03 | 0.04       | 0.09 | $\mu\text{A}$ |
| Temperature coefficient of $I_{ra}$   | $E_V = 100\text{ lx}$ , CIE illuminant A, $V_R = 5\text{ V}$              | $TK_{I_{ra}}$   | -    | 0.2        | -    | %/K           |
| Angle of half sensitivity   |   | $\varphi$       | -    | $\pm 60$   | -    | $^{\circ}$    |
| Wavelength of peak sensitivity  |   | $\lambda_p$     | -    | 540        | -    | nm            |
| Range of spectral bandwidth   |   | $\lambda_{0.5}$ | -    | 430 to 610 | -    | nm            |

### TEMD6200FX01

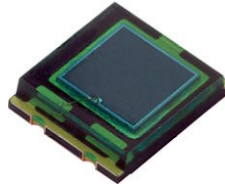


| <b>BASIC CHARACTERISTICS</b> ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified) |   |                 |      |            |      |               |
|---|---|-----------------|------|------------|------|---------------|
| PARAMETER   | TEST CONDITION  | SYMBOL          | MIN. | TYP.       | MAX. | UNIT          |
| Breakdown voltage   | $I_R = 100\text{ }\mu\text{A}$ , $E = 0\text{ lx}$                        | $V_{(BR)}$      | 16   | -          | -    | V             |
| Reverse dark current  | $V_R = 10\text{ V}$ , $E = 0\text{ lx}$                                   | $I_{ro}$        | -    | 0.1        | 5    | nA            |
| Diode capacitance   | $V_R = 0\text{ V}$ , $f = 1\text{ MHz}$ , $E = 0\text{ lx}$               | $C_D$           | -    | 60         | -    | pF            |
|   | $V_R = 5\text{ V}$ , $f = 1\text{ MHz}$ , $E = 0\text{ lx}$               | $C_D$           | -    | 24         | -    | pF            |
| Reverse light current   | $E_e = 1\text{ mW/cm}^2$ , $\lambda = 550\text{ nm}$ , $V_R = 5\text{ V}$ | $I_{ra}$        | -    | 1          | -    | $\mu\text{A}$ |
|   | $E_V = 100\text{ lx}$ , CIE illuminant A                                  | $I_{ra}$        | 0.03 | 0.04       | 0.09 | $\mu\text{A}$ |
| Angle of half sensitivity   |   | $\varphi$       | -    | $\pm 60$   | -    | $^{\circ}$    |
| Wavelength of peak sensitivity  |   | $\lambda_p$     | -    | 540        | -    | nm            |
| Range of spectral bandwidth   |   | $\lambda_{0.5}$ | -    | 430 to 610 | -    | nm            |
| Rise time   | $U_R = 5\text{ V}$ , $R_L = 50\text{ }\Omega$ , TLMW3300                  | $t_r$           | -    | 150        | -    | ns            |
| Fall time   | $U_R = 5\text{ V}$ , $R_L = 50\text{ }\Omega$ , TLMW3300                  | $t_f$           | -    | 150        | -    | ns            |

## Ambient Light Sensors - Circuit and Window Design

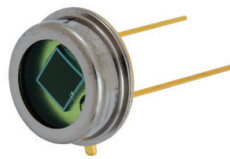
Also both of the devices shown below use a similarly large chip so the chip related data is comparable, including the rise / fall times.

### TEMD5510FX01



| BASIC CHARACTERISTICS ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified) |   |                 |      |            |      |               |
|--|---|-----------------|------|------------|------|---------------|
| PARAMETER  | TEST CONDITION  | SYMBOL          | MIN. | TYP.       | MAX. | UNIT          |
| Breakdown voltage  | $I_R = 100\text{ }\mu\text{A}$ , $E = 0$                                  | $V_{(BR)}$      | 16   | -          | -    | V             |
| Reverse dark current   | $V_R = 10\text{ V}$ , $E = 0$   | $I_{ro}$        | -    | 2          | 30   | nA            |
| Diode capacitance  | $V_R = 0\text{ V}$ , $f = 1\text{ MHz}$ , $E = 0$                         | $C_D$           | -    | 1600       | -    | pF            |
|  | $V_R = 3\text{ V}$ , $f = 1\text{ MHz}$ , $E = 0$                         | $C_D$           | -    | 730        | -    | pF            |
| Reverse light current  | $E_e = 1\text{ mW/cm}^2$ , $\lambda = 550\text{ nm}$ , $V_R = 5\text{ V}$ | $I_{ra}$        | -    | 26         | -    | $\mu\text{A}$ |
|  | $E_v = 100\text{ lx}$ , CIE illuminant A, $V_R = 5\text{ V}$              | $I_{ra}$        | 0.8  | 1          | 1.4  | $\mu\text{A}$ |
| Temperature coefficient of $I_{ra}$  | $E_v = 100\text{ lx}$ , CIE illuminant A, $V_R = 5\text{ V}$              | $TK_{I_{ra}}$   | -    | 0.2        | -    | %/K           |
| Angle of half sensitivity  |   | $\phi$          | -    | $\pm 65$   | -    | $^{\circ}$    |
| Wavelength of peak sensitivity   |   | $\lambda_p$     | -    | 540        | -    | nm            |
| Range of spectral bandwidth  |   | $\lambda_{0.5}$ | -    | 430 to 610 | -    | nm            |

### BPW21R



| BASIC CHARACTERISTICS ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified) |   |                 |      |            |      |                  |
|--|---|-----------------|------|------------|------|------------------|
| PARAMETER  | TEST CONDITION  | SYMBOL          | MIN. | TYP.       | MAX. | UNIT             |
| Forward voltage  | $I_F = 50\text{ mA}$  | $V_F$           | -    | 1.0        | 1.3  | V                |
| Breakdown voltage  | $I_R = 20\text{ }\mu\text{A}$ , $E = 0$                                   | $V_{(BR)}$      | 10   | -          | -    | V                |
| Reverse dark current   | $V_R = 5\text{ V}$ , $E = 0$  | $I_{ro}$        | -    | 2          | 30   | nA               |
| Diode capacitance  | $V_R = 0\text{ V}$ , $f = 1\text{ MHz}$ , $E = 0$                         | $C_D$           | -    | 1.2        | -    | nF               |
|  | $V_R = 5\text{ V}$ , $f = 1\text{ MHz}$ , $E = 0$                         | $C_D$           | -    | 400        | -    | pF               |
| Dark resistance  | $V_R = 10\text{ mV}$  | $R_D$           | -    | 38         | -    | $\text{G}\Omega$ |
| Open circuit voltage   | $E_A = 1\text{ klx}$  | $V_o$           | 280  | 450        | -    | mV               |
| Temperature coefficient of $V_o$   | $E_A = 1\text{ klx}$  | $TK_{V_o}$      | -    | -2         | -    | mV/K             |
| Short circuit current  | $E_A = 1\text{ klx}$  | $I_k$           | 4.5  | 9          | -    | $\mu\text{A}$    |
| Temperature coefficient of $I_k$   | $E_A = 1\text{ klx}$  | $TK_{I_k}$      | -    | -0.05      | -    | %/K              |
| Reverse light current  | $E_A = 1\text{ klx}$ , $V_R = 5\text{ V}$                                 | $I_{ra}$        | 4.5  | 9          | -    | $\mu\text{A}$    |
| Sensitivity  | $V_R = 5\text{ V}$ , $E_A = 10^{-2}$ to $10^5\text{ lx}$                  | S               | -    | 9          | -    | nA/lx            |
| Angle of half sensitivity  |   | $\phi$          | -    | $\pm 50$   | -    | $^{\circ}$       |
| Wavelength of peak sensitivity   |   | $\lambda_p$     | -    | 565        | -    | nm               |
| Range of spectral bandwidth  |   | $\lambda_{0.5}$ | -    | 420 to 675 | -    | nm               |
| Rise time  | $V_R = 0\text{ V}$ , $R_L = 1\text{ k}\Omega$ , $\lambda = 660\text{ nm}$ | $t_r$           | -    | 3.1        | -    | $\mu\text{s}$    |
| Fall time  | $V_R = 0\text{ V}$ , $R_L = 1\text{ k}\Omega$ , $\lambda = 660\text{ nm}$ | $t_f$           | -    | 3.0        | -    | $\mu\text{s}$    |

## Ambient Light Sensors - Circuit and Window Design

The VEMD5510C and VEMD5510CF are devices with a peak sensitivity at about 550 nm. These devices have a similarly sized chip, that is optimized for an increased response at green wavelengths, and is optimized with regard to speed.

Although the VEMD5510C and VEMD5510CF have the same chip size as the TEMD5510FX01, their diode capacitances are considerably lower but also the reverse light current is much lower.

### VEMD5510C

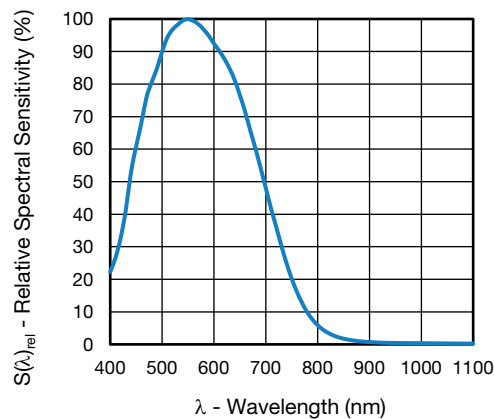
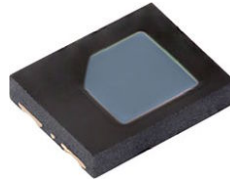


Fig. 18 - Relative Spectral Sensitivity vs. Wavelength

| BASIC CHARACTERISTICS ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified) |   |                 |      |            |      |               |
|--|---|-----------------|------|------------|------|---------------|
| PARAMETER  | TEST CONDITION  | SYMBOL          | MIN. | TYP.       | MAX. | UNIT          |
| Forward voltage  | $I_F = 50\text{ mA}$  | 5               | -    | 0.9        | 1.3  | V             |
| Breakdown voltage  | $I_R = 100\text{ }\mu\text{A}$ , $E = 0$                                    | $V_{(BR)}$      | 20   | -          | -    | V             |
| Reverse dark current   | $V_R = 10\text{ V}$ , $E = 0$   | $I_{ro}$        | -    | 0.2        | 10   | nA            |
| Diode capacitance  | $V_R = 0\text{ V}$ , $f = 1\text{ MHz}$ , $E = 0$                           | $C_D$           | -    | 80         | -    | pF            |
|  | $V_R = 3\text{ V}$ , $f = 1\text{ MHz}$ , $E = 0$                           | $C_D$           | -    | 30         | 40   | pF            |
| Open circuit voltage   | $E_V = 100\text{ lx}$ , CIE illuminant A                                    | $V_o$           | -    | 240        | -    | mV            |
| Temperature coefficient of $V_o$   | $E_V = 100\text{ lx}$ , CIE illuminant A                                    | $TK_{V_o}$      | -    | -2.5       | -    | mV/K          |
| Short circuit current  | $E_V = 100\text{ lx}$ , CIE illuminant A                                    | $I_k$           | -    | 0.6        | -    | $\mu\text{A}$ |
| Reverse light current  | $E_e = 0.2\text{ mW/cm}^2$ , $\lambda = 525\text{ nm}$ , $V_R = 5\text{ V}$ | $I_{ra}$        | 2.0  | 2.6        | -    | $\mu\text{A}$ |
|  | $E_V = 100\text{ lx}$ , CIE illuminant A, $V_R = 5\text{ V}$                | $I_{ra}$        | 0.46 | 0.55       | -    | $\mu\text{A}$ |
| Angle of half sensitivity  |   | $\phi$          | -    | $\pm 65$   | -    | $^{\circ}$    |
| Wavelength of peak sensitivity   |   | $\lambda_p$     | -    | 550        | -    | nm            |
| Range of spectral bandwidth  |   | $\lambda_{0.5}$ | -    | 440 to 700 | -    | nm            |
| Rise time  | $V_R = 5\text{ V}$ , $R_L = 50\text{ }\Omega$ , $\lambda = 525\text{ nm}$   | $t_r$           | -    | 40         | -    | ns            |
| Fall time  | $V_R = 5\text{ V}$ , $R_L = 50\text{ }\Omega$ , $\lambda = 525\text{ nm}$   | $t_f$           | -    | 30         | -    | ns            |

APPLICATION NOTE

## Ambient Light Sensors - Circuit and Window Design

The VEMD5510CF has a spectral sensitivity close to the  $v(\lambda)$  curve as shown below, and is therefore also suitable for use as an ALS sensor.

The VEMD5510CF has a slightly lower reverse light current at green wavelengths (illumination at 525nm) compared to the VEMD5510C. However for an illumination with daylight or halogen- / incandescent light the VEMD5510CF has only half of the reverse light current than the VEMD5510C and only a quarter of the reverse light current of the TEMD5510FX01.

### VEMD5510CF

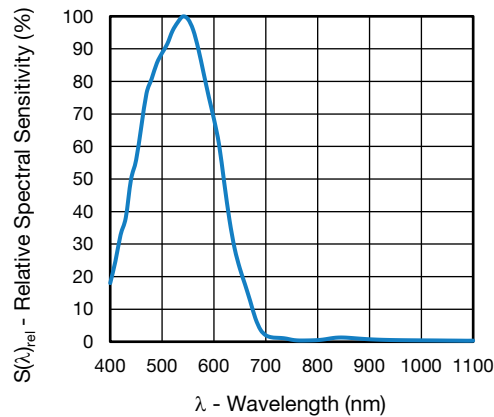
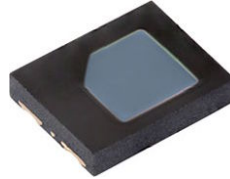


Fig. 19 - Relative Spectral Sensitivity vs. Wavelength

| <b>BASIC CHARACTERISTICS</b> ( $T_{amb} = 25\text{ }^{\circ}\text{C}$ , unless otherwise specified) |   |                 |      |            |      |               |
|---|---|-----------------|------|------------|------|---------------|
| PARAMETER   | TEST CONDITION  | SYMBOL          | MIN. | TYP.       | MAX. | UNIT          |
| Forward voltage   | $I_F = 50\text{ mA}$  | $V_F$           | -    | 0.9        | 1.3  | V             |
| Breakdown voltage   | $I_R = 100\text{ }\mu\text{A}$ , $E = 0$                                    | $V_{(BR)}$      | 20   | -          | -    | V             |
| Reverse dark current  | $V_R = 10\text{ V}$ , $E = 0$   | $I_{ro}$        | -    | 0.2        | 10   | nA            |
| Diode capacitance   | $V_R = 0\text{ V}$ , $f = 1\text{ MHz}$ , $E = 0$                           | $C_D$           | -    | 80         | -    | pF            |
|   | $V_R = 3\text{ V}$ , $f = 1\text{ MHz}$ , $E = 0$                           | $C_D$           | -    | 30         | 40   | pF            |
| Open circuit voltage  | $E_V = 100\text{ lx}$ , CIE illuminant A                                    | $V_o$           | -    | 210        | -    | mV            |
| Temperature coefficient of $V_o$  | $E_V = 100\text{ lx}$ , CIE illuminant A                                    | $TK_{V_o}$      | -    | -2.3       | -    | mV/K          |
| Short circuit current   | $E_V = 100\text{ lx}$ , CIE illuminant A                                    | $I_k$           | -    | 0.25       | -    | $\mu\text{A}$ |
| Reverse light current   | $E_e = 0.2\text{ mW/cm}^2$ , $\lambda = 525\text{ nm}$ , $V_R = 5\text{ V}$ | $I_{ra}$        | 1.35 | 2.1        | 3.05 | $\mu\text{A}$ |
|   | $E_V = 100\text{ lx}$ , CIE illuminant A, $V_R = 5\text{ V}$                | $I_{ra}$        | 0.16 | 0.25       | 0.39 | $\mu\text{A}$ |
| Angle of half sensitivity   |   | $\phi$          | -    | $\pm 65$   | -    | $^{\circ}$    |
| Wavelength of peak sensitivity  |   | $\lambda_p$     | -    | 540        | -    | nm            |
| Range of spectral bandwidth   |   | $\lambda_{0.5}$ | -    | 440 to 620 | -    | nm            |
| Rise time   | $V_R = 5\text{ V}$ , $R_L = 50\text{ }\Omega$ , $\lambda = 525\text{ nm}$   | $t_r$           | -    | 40         | -    | ns            |
| Fall time   | $V_R = 5\text{ V}$ , $R_L = 50\text{ }\Omega$ , $\lambda = 525\text{ nm}$   | $t_f$           | -    | 30         | -    | ns            |

APPLICATION NOTE

## Ambient Light Sensors - Circuit and Window Design

### WINDOW SIZE

If the ambient light sensor will be placed behind a window or cover, the window material should be completely transmissive to visible light (400 nm to 700 nm). For optimal performance the window size should be large enough to maximize the light irradiating the sensor. In calculating the window size, the only dimensions that the design engineer needs to consider are the distance from the top surface of the sensor to the outside surface of the window and the size of the window. These dimensions will determine the size of the detection zone.

First, the center of the sensor and center of the window should be aligned. Most ambient light sensors have an angle of half sensitivity of  $\pm 60^\circ$  as shown in figure 17 and 18.

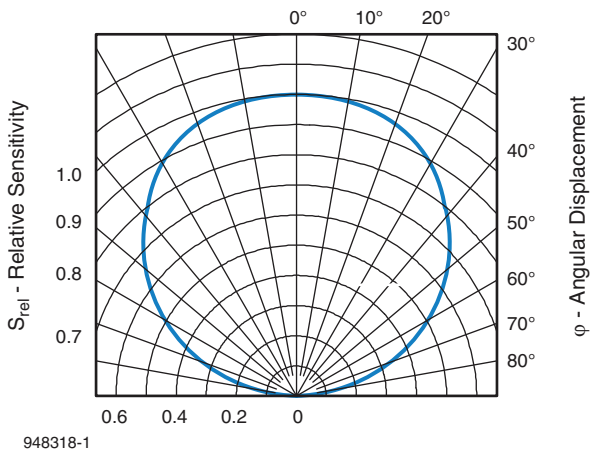


Fig. 20 - Relative Sensitivity vs. Angular Displacement

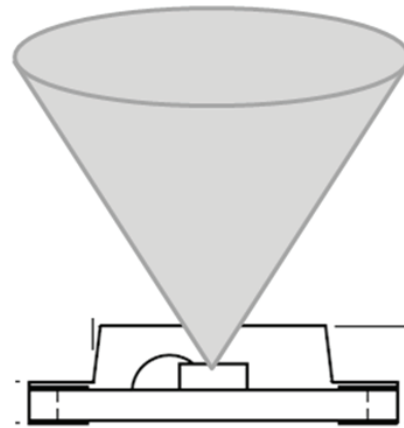


Fig. 21 - Angle of Half Sensitivity, Cone

With the assumption that the detection zone is a cone shaped region with an angle of  $\pm 60^\circ$ , the following are dimensions for the distance from the top surface of the sensor to the outside surface of the glass,  $d$ , and the width of the window,  $w$ .

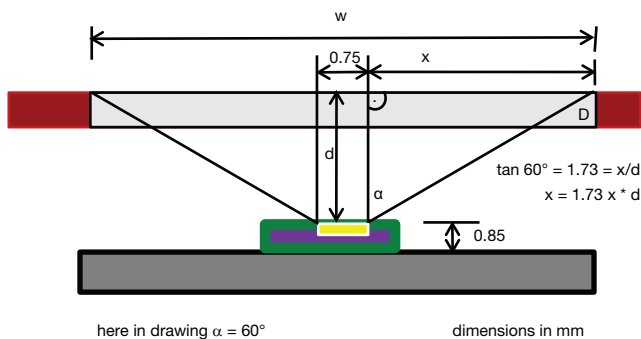


Fig. 22 - Angle of Half Sensitivity, Cone

#### Calculation

$$\tan \alpha = x/d$$

$$\alpha = 60^\circ$$

$$\tan 60^\circ = 1.73$$

$$x/d = 1.73$$

$$x = (1.73)d$$

With the length of the chip equal to 0.75 mm, the width of the window can be calculated:

$$w = 0.75 \text{ mm} + 2 (1.73d)$$

## Ambient Light Sensors - Circuit and Window Design

Shown below are results for different distances from the sensor to the outside of the window surface.

| d   | x    | CALCULATION  | w     |
|-----|------|--------------|-------|
| 0.5 | 0.87 | 0.75 + 1.74  | 2.49  |
| 1.0 | 1.73 | 0.75 + 3.46  | 4.21  |
| 1.5 | 2.60 | 0.75 + 5.20  | 5.95  |
| 2.0 | 3.46 | 0.75 + 6.92  | 7.67  |
| 2.5 | 4.33 | 0.75 + 8.66  | 9.41  |
| 3.0 | 5.19 | 0.75 + 10.38 | 11.13 |

A smaller window size also could be used. If so, reference measurements should be made if the output is expected to be similar to a light meter.

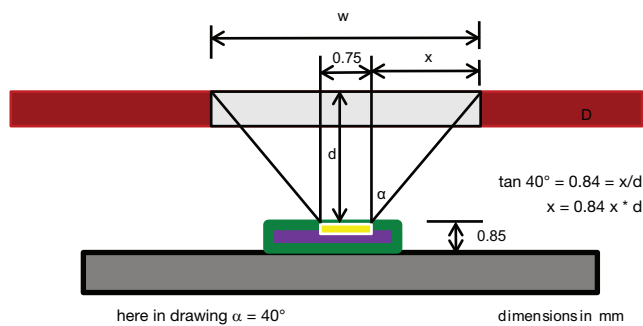


Fig. 23 - Angle of Half Sensitivity, Cone

### Calculation

$$\tan \alpha = x/d$$

$$\alpha = 40^\circ$$

$$\tan 40^\circ = 0.84$$

$$x/d = 0.84$$

$$x = (0.84)d$$

With the length of the chip equal to 0.75 mm, the width of the window can be calculated:

$$w = 0.75 \text{ mm} + 2(0.84d)$$

Shown below are results for different distances from the sensor to the outside of the window surface.

| d   | x    | CALCULATION | w    |
|-----|------|-------------|------|
| 0.5 | 0.42 | 0.75 + 0.84 | 1.59 |
| 1.0 | 0.84 | 0.75 + 1.68 | 2.43 |
| 1.5 | 1.28 | 0.75 + 2.56 | 3.31 |
| 2.0 | 1.68 | 0.75 + 3.36 | 4.11 |
| 2.5 | 2.10 | 0.75 + 4.20 | 4.95 |
| 3.0 | 5.52 | 0.75 + 5.04 | 5.79 |



## Ambient Light Sensors - Circuit and Window Design

### TYPICAL ILLUMINANCE VALUES

| ILLUMINANCE               | EXAMPLE  |
|---------------------------|--|
| 10 <sup>-5</sup> lux      | Light from Sirius, the brightest star in the night sky |
| 10 <sup>-4</sup> lux      | Total starlight, overcast sky                          |
| 0.002 lux                 | Moonless clear night sky with airflow                  |
| 0.01 lux                  | Quarter moon 0.27 lux full moon on a clear night       |
| 1 lux                     | Full moon overhead at tropical latitudes               |
| 3.4 lux                   | Dark limit of civil twilight under a clear sky         |
| 50 lux                    | Family living room                                     |
| 80 lux                    | Hallway/toilet   |
| 100 lux                   | Very dark overcast day                                 |
| 320 lux to 500 lux        | Office lighting  |
| 400 lux                   | Sunrise or sunset on a clear day                       |
| 1000 lux                  | Overcast day; typical TV studio lighting               |
| 10 000 lux to 25 000 lux  | Full daylight (not direct sun)                         |
| 32 000 lux to 130 000 lux | Direct sunlight  |