

# Selecting a Photocell

Specifying the best photoconductive cell for your application requires an understanding of its principles of operation. This section reviews some fundamentals of photocell technology to help you get the best blend of parameters for your application.

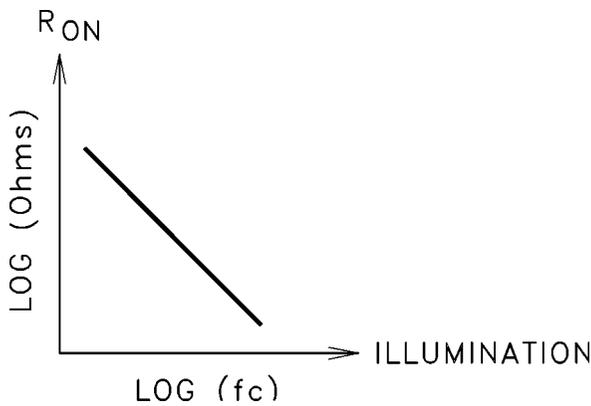
When selecting a photocell the design engineer must ask two basic questions:

1. What kind of performance is required from the cell?
2. What kind of environment must the cell work in?

## Performance Criteria

### Sensitivity

The sensitivity of a photodetector is the relationship between the light falling on the device and the resulting output signal. In the case of a photocell, one is dealing with the relationship between the incident light and the corresponding resistance of the cell.



Defining the sensitivity required for a specific application can prove to be one of the more difficult aspects in specifying a photoconductor. In order to specify the sensitivity one must, to some degree, characterize the light source in terms of its intensity and its spectral content.

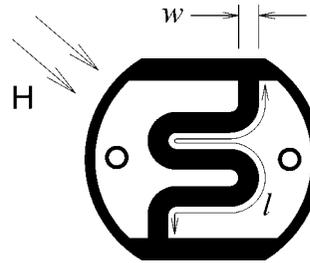
Within this handbook you will find curves of resistance versus light intensity or illumination for many of PerkinElmer's stock photocells. The illumination is expressed in units of fc (foot candles) and lux. The light source is an incandescent lamp. This lamp is special only in that the spectral composition of the light it generates matches that of a black body at a color temperature of 2850 K. This type of light source is an industry agreed to standard.

Over the years PerkinElmer has developed different "types" of photoconductive materials through modifications made to the chemical

composition of the detector. For a given type of photoconductor material, at a given level of illumination, the photoconductive film will have a certain sheet resistivity. The resistance of the photocell at this light level is determined by the electrode geometry.

$$R_H = \rho_H (w/l)$$

where:



$R_H$  = resistance of cell at light level H

$\rho_H$  = sheet resistivity of photoconductive film at light level H

$w$  = width of electrode gap

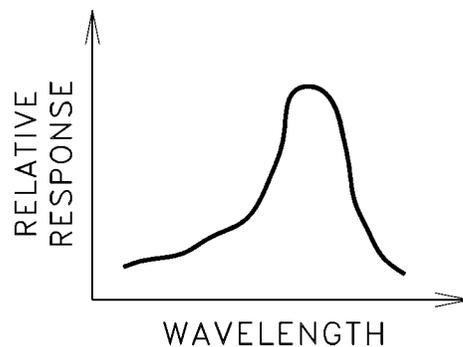
$l$  = length of electrode gap

Sheet sensitivity ( $\rho_H$ ) for photoconductive films at 2 fc are in the range of 20 M $\Omega$  per square.

The ratio  $w/l$  can be varied over a wide range in order to achieve design goals. Typical values for  $w/l$  run from 0.002 to 0.5, providing flexibility for terminal resistance and maximum cell voltage.

### Spectral Response

Like the human eye, the relative sensitivity of a photoconductive cell is dependent on the wavelength (color) of the incident light. Each photoconductor material type has its own unique spectral response curve or plot of the relative response of the photocell versus wavelength of light.

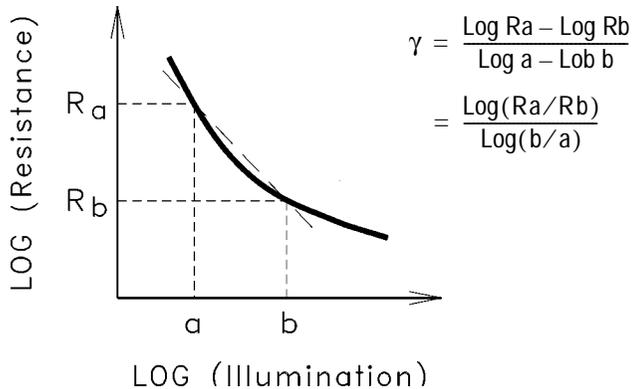


The spectral response curves for PerkinElmer's material types are given in the handbook and should be considered in selecting a photocell for a particular application.

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## Slope Characteristics

Plots of the resistance for the photocells listed in this catalog versus light intensity result in a series of curves with characteristically different slopes. This is an important characteristic of photocells because in many applications not only is the absolute value of resistance at a given light level of concern but also the value of the resistance as the light source is varied. One way to specify this relationship is by the use of parameter (gamma) which is defined as a straight line passing through two specific points on the resistance curve. The two points used by PerkinElmer to define  $\gamma$  are 10 lux (0.93 fc) and 100 lux (9.3 fc).

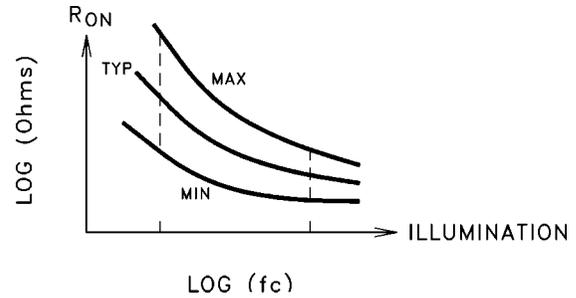


Applications for photocells are of one of two categories: digital or analog. For the digital or ON-OFF types of applications such as flame detectors, cells with steep slopes to their resistance versus light intensity curves are appropriate. For analog or measurement types of applications such as exposure controls for cameras, cells with shallow slopes might be better suited.

## Resistance Tolerance

The sensitivity of a photocell is defined as its resistance at a specific level of illumination. Since no two photocells are exactly alike, sensitivity is stated as a typical resistance value plus an allowable tolerance. Both the value of resistance and its tolerance are specified for only one light level. For moderate excursions from this specified light level the tolerance level remain more or less constant. However, when the light level the tolerance level remain more or less constant. However, when the light level is decades larger or smaller than the reference level the tolerance can differ considerably.

As the light level decreases, the spread in the tolerance level increases. For increasing light levels the resistance tolerance will tighten.



Likewise, for dual element photocells the matching factor, which is defined as the ratio of the resistance of between elements, will increase with decreasing light level.

Dual Element Photocell Typical Matching Ratios				
0.01 fc	0.1 fc	1.0 fc	10 fc	100 fc
0.63 - 1.39	0.74 - 1.27	0.75 - 1.25	0.76 - 1.20	0.77 - 1.23

## Dark Resistance

As the name implies, the dark resistance is the resistance of the cell under zero illumination lighting conditions. In some applications this can be very important since the dark resistance defines what maximum "leakage current" can be expected when a given voltage is applied across the cell. Too high a leakage current could lead to false triggering in some applications.

The dark resistance is often defined as the minimum resistance that can be expected 5 seconds after the cell has been removed from a light intensity of 2 fc. Typical values for dark resistance tend to be in the 500k ohm to 20M ohm range.

## Temperature Coefficient of Resistance.

Each type of photoconductive material has its own resistance versus temperature characteristic. Additionally, the temperature coefficients of photoconductors are also dependent on the light level the cells are operating at.

From the curves of the various types of materials it is apparent that the temperature coefficient is an inverse function of light level. Thus, in order to minimize temperature problems it is desirable to have the cell operating at the highest light level possible.

## Speed of Response

Speed of response is a measure of the speed at which a photocell responds to a change from light-to-dark or from dark-to-light. The rise time is defined as the time necessary for the light conductance of the photocell to reach 1-1/e (or about 63%) of its final value.

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The decay or fall time is defined as the time necessary for the light conductance of the photocell to decay to  $1/e$  (or about 73%) of its illuminated state. At 1 fc of illumination the response times are typically in the range of 5 msec to 100 msec.

The speed of response depends on a number of factors including light level, light history, and ambient temperature. All material types show faster speed at higher light levels and slower speed at lower light levels. Storage in the dark will cause slower response than if the cells are kept in the light. The longer the photocells are kept in the dark the more pronounced this effect will be. In addition, photocells tend to respond slower in colder temperatures.

## Light History

All photoconductive cells exhibit a phenomenon known as hysteresis, light memory, or light history effect. Simply stated, a photocell tends to remember its most recent storage condition (light or dark) and its instantaneous conductance is a function of its previous condition. The magnitude of the light history effect depends upon the new light level, and upon the time spent at each of these light levels. This effect is reversible.

To understand the light history effect, it is often convenient to make an analogy between the response of a photocell and that of a human eye. Like the cell, the human eye's sensitivity to light depends on what level of light it was recently exposed to. Most people have had the experience of coming in from the outdoors on a bright summer's day and being temporarily unable to see under normal room levels of illumination. Your eyes will adjust but a certain amount of time must elapse first. How quickly one's eyes adjust depends on how bright it was outside and how long you remained outdoors.

The following guide shows the general relationship between light history and light resistance at various light levels. The values shown were determined by dividing the resistance of a given cell, following infinite light history ( $R_{LH}$ ), by the resistance of the same cell following "infinite" dark history ( $R_{DH}$ ). For practical purposes, 24 hours in the dark will achieve  $R_{DH}$  or 24 hours at approximately 30 fc will achieve  $R_{LH}$ .

Typical Variation of Resistance with Light History Expressed as a Ratio  $R_{LH} / R_{DH}$  at Various Test Illumination Levels.

$R_{LH} / R_{DH}$ Ratio	Illumination				
	0.01 fc	0.1 fc	1.0 fc	10 fc	100 fc
	1.55	1.35	1.20	1.10	1.10

This guide illustrates the fact that a photocell which has been stored for a long time in the light will have a considerably higher light resistance than if it was stored for a long time in the dark. Also, if a cell is stored for a long period of time at a light level higher than the test level, it will have a higher light resistance than if it was stored at a light level closer to the test light level.

This effect can be minimized significantly by keeping the photocell exposed to some constant low level of illumination (as opposed to having it sit in the dark). This is the reason resistance specifications are characterized after 16 hours light adept.

## Environmental/Circuitry Considerations

### Packaging

In order to be protected from potentially hostile environments photocells are encapsulated in either glass/metal (hermetic) package or are covered with a clear plastic coating. While the hermetic packages provide the greatest degree of protection, a plastic coating represents a lower cost approach.

The disadvantage of plastic coatings is that they are not an absolute barrier to eventual penetration by moisture. This can have an adverse effect on cell life. However, plastic coated photocells have been used successfully for many years in such hostile environments as street light controls.

### Temperature Range

The chemistry of the photoconductive materials dictates an operating and storage temperature range of  $-40^{\circ}\text{C}$  to  $75^{\circ}\text{C}$ . It should be noted that operation of the cell above  $75^{\circ}\text{C}$  does not usually lead to catastrophic failure but the photoconductive surface may be damaged leading to irreversible changes in sensitivity.

The amount of resistance change is a function of time as well as temperature. While changes of several hundred percent will occur in a matter of a few minutes at  $150^{\circ}\text{C}$ , it will take years at  $50^{\circ}\text{C}$  to produce that much change.

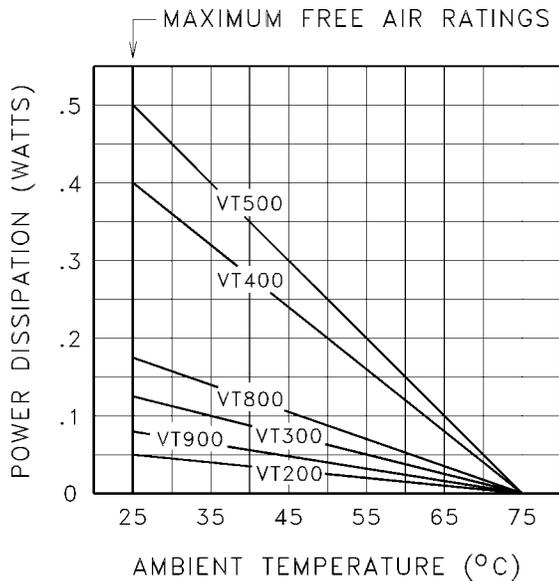
### Power Dissipation

During operation, a cell must remain within its maximum internal temperature rating of  $75^{\circ}\text{C}$ . Any applied power will raise the cell's temperature above ambient and must be considered.

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Many low voltage situations involve very little power, so that the photocell can be small in size, where voltages and/or currents are higher, the photocell must be physically larger so that the semiconductor film can dissipate the heat.

The following curve of power dissipation versus ambient temperature describes the entire series of cells for operation in free air at room ambient (25°C). Note that regardless the size, all photocells derate linearly to zero at an ambient temperature of 75°C. The adequate heat sinks can increase the dissipation by as much as four times the levels shown in this graph.



## Maximum Cell Voltage

At no time should the peak voltage of the cell exceed its maximum voltage. The designer should determine the maximum operating or peak voltage that the cell will experience in the circuit and choose an appropriately rated cell. Typical voltage rates range from 100V to 300V.

## What Type of Material is Best?

Each specific material type represents a trade off between several characteristics. Selecting the best material is a process of determining which characteristics are most important in the application.

PerkinElmer's standard photocells in this catalog are manufactured using one of two different material types offered: type "Ø" or type "3".

In general, material type "Ø" is used for applications such as nightlights, automotive sensors. Material type "3" is primarily used in camera, streetlight control, and flame detector applications.