TAOS Inc.

is now

ams AG

The technical content of this TAOS application note is still valid.

Contact information:

Headquarters:
ams AG
Tobelbaderstrasse 30
8141 Unterpremstaetten, Austria
Tel: +43 (0) 3136 500 0
e-Mail: ams_sales@ams.com

Please visit our website at **www.ams.com**

NUMBER 26

INTELLIGENT OPTO SENSOR

DESIGNER'S NOTEBOOK

TAOS TEXAS ADVANCED OPTOELECTRONIC SOLUTIONS®

Ambient Light Sensing (ALS)

contributed by Joe Smith
March 31, 2009

ABSTRACT

The ability for a display to sense ambient light could be a powerful tool that can lead to increased power efficiency and customer satisfaction. This application note will discuss some of the benefits of implementing ambient light sensing as well as some considerations to keep in mind during the design.

WHAT IS ALS

Simply stated, ambient light sensing is the ability to measure the brightness of light incident on a surface. It is often useful to utilize this brightness information to control certain aspects of a system, such as the brightness of a display, or the size of an aperture. End products that can benefit from ALS implementation include laptops, monitors, cell phones, televisions, digital signage, cameras and any device with a visual user interface.

WHY ALS

There are two important drivers of ALS. The first is the added power management control that ALS affords a system. Display backlighting typically constitutes a large share of a systems power resources. It is common for a laptop PC display to consume between 30% and 40% of the total power budget. Substantial power savings can be realized when the brightness of a display is effectively controlled by ambient light.

A secondary ALS benefit is the improved visual experience to the user. Regulating system lighting based on ambient conditions in essence allows for the system to anticipate and act upon the needs of the user. This could be achieved by increasing display brightness in a bright setting or enabling system lights in a dark setting.

MEASURING LIGHT

To fully understand how to measure light, it is necessary to first discuss the units of light measurement and how they differ. Light is electromagnetic radiation that the human eye is sensitive to. Electromagnetic radiation can be characterized by its strength and how its energy is spectrally distributed. The human eye responds to energy with wavelengths between about 380 and 780nm, with a peak around 555nm (figure 1). This is called photopic response.

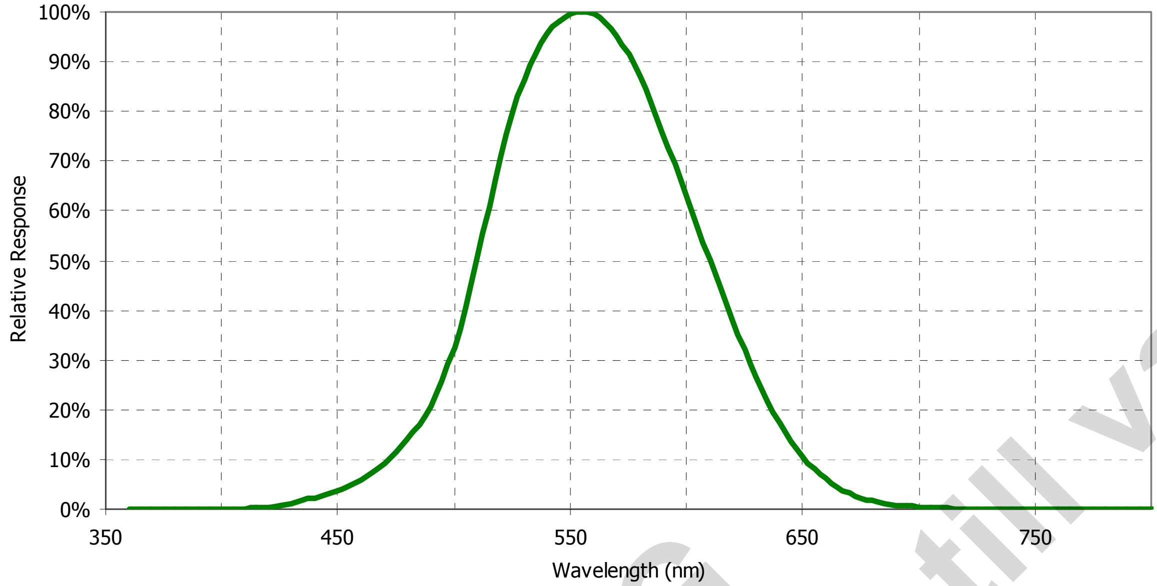

Figure 1. Normalized Photopic Response

The strength of the electromagnetic radiation can be characterized by its power. Radiant Energy, Q, measured in Joules (J), is the SI unit for energy and Radiant Flux, Φ, measured in Watts (W), is the SI unit for power (energy per unit time). When Radiant Flux is measured per unit area, one obtains Irradiance, E, measured in Watts per meter-squared (W/m^2).

Radiant Energy, Radiant Flux and Irradiance are all SI units describing all electromagnetic radiation. When these measurements are weighted against the spectral response of the human eye (Figure 1), we obtain photometric measurements. The photometric equivalents to previous units are Luminous Energy, Q_v, measured in lumen seconds (lm·s), Luminous Flux, F, measured in Lumens (lm), and Illuminance, E_v, measured in Lux (lx). These units, both radiometric and photometric, are summarized in Table 1. See the TAOS application note, "***DN21: Radiometric and Photometric Measurements with TAOS Photosensors***", for more information.

Table 1: Radiometric and Photometric Units

	Radiometric		**Photometric**	
	Name	**SI Unit**	**Name**	**SI Unit**
Energy	Radiant Energy, Q	Joules (J)	Luminous Energy, Q_v	Lumen second (lm·s)
Power	Radiant Flux, Φ	Watts (W)	Luminous Flux, F	Lumen (lm)
Power/Area	Irradiance, E	W/m^2	Illuminance, E_v	Lux (lx)

When Ambient light is measured, it is the illuminance that is quantified. This gives the system the ability to make decisions based on what a user would see. The goal of the ambient light sensor is to mimic the response of the human eye, in order to measure illuminance.

How it Works

Silicon based photosensors are responsive to radiation from about 300nm to about 1100nm. Figure 2 shows the spectral response of Silicon next to a photopic response.

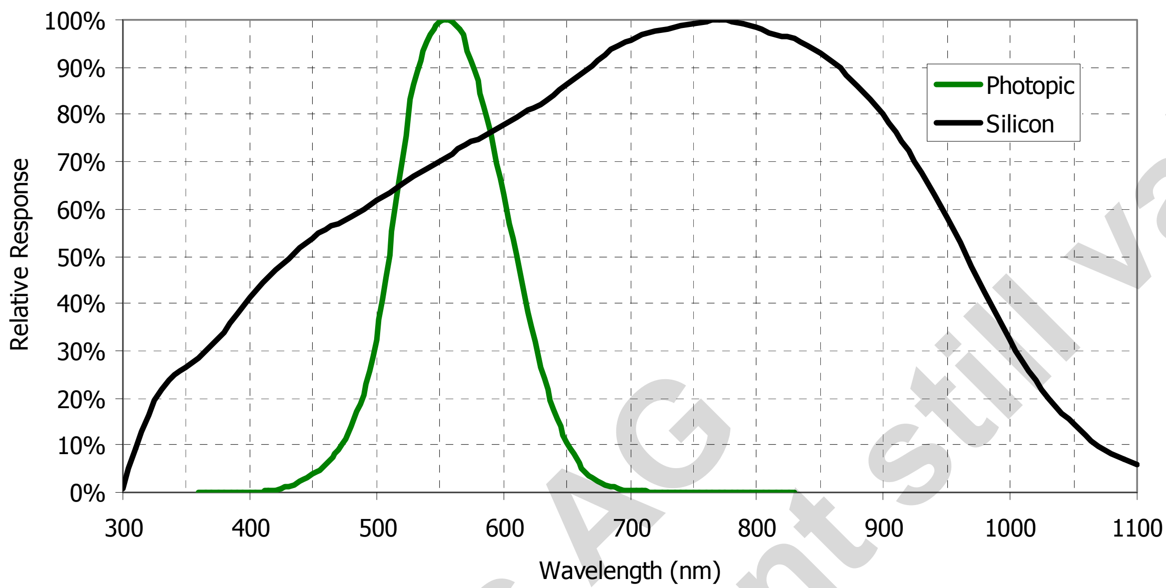

Figure 2. Normalized Silicon Response compared to Photopic Response

Since silicon overlaps the photopic response, it is generally a good material to sense ambient light with. Its low cost and accessibility make it easy to implement. The only problem is that it is responsive to non-photopic radiation, or radiation that a human eye cannot sense, such as UV-A and some UV-B (below 300nm) as well as some near infrared (NIR) (above 1100nm). To get a photopic response with a Silicon photodiode it is necessary to filter out this unwanted radiation.

There are several ways to accomplish this filtering. The first and obvious choice would seem to be the inclusion of UV and IR blocking filters in the optical path between the light source and the sensor. This can be an excellent way to achieve a photopic response, however, high quality UV and IR blocking filters can be quite expensive. All TAOS devices can be used in such an implementation.

The TAOS Solution

Taos has two unique solutions to generate a photopic Silicon response. The first is utilized in our line of Light-to-Digital ambient light sensors, including the TSL2581. This sensor utilizes the fact that different wavelengths of light contain different amounts of energy.

Shorter wavelengths of light contain more energy than longer wavelengths. Light that contains more energy will be absorbed by silicon at a faster rate than light with less energy. In other words, the light with less energy will penetrate into the silicon deeper than the light with more energy. By having photodiodes responsive to electrons generated at different silicon depths, TAOS photosensors can generate data with a limited range of the silicon response in addition to the full range. See the TAOS application note "***DN24: TAOS Photo Sensor Response Part II: Sensitivity to Temperature***", for more information.

TAOS utilizes this process in its patented dual photodiode approach. The result is a two channel response. Channel 0 is representative of the full range silicon response, while channel 1, has an IR only response. Figure 3 shows the normalized spectral response of both channels of the TSL2581 along with the photopic response.

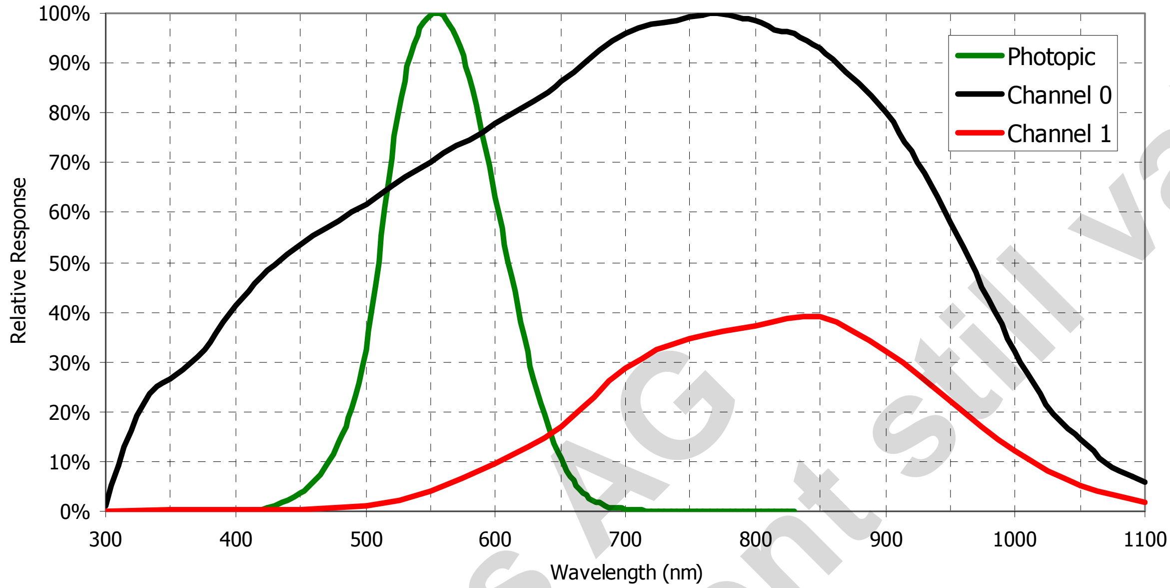

Figure 2. Normalized Silicon Response compared to Photopic Response

TAOS has shown that the ratio between these two channels (ch1/ch0) can be used to generate a piecewise linear lux equation. By utilizing this lux equation, developed by TAOS and specific to each new product, one can easily implement ambient light sensing into their application. As an example, below are the lux equations for the TSL2581CS.

Normalized at 1X Gain, 400ms Integration Time

For Ch1/Ch0=0.00 to <=0.25:
Lux=0.105*Ch0−0.208*Ch1

For Ch1/Ch0=>0.25 to <=0.38:
Lux=0.1088*Ch0−0.2231*Ch1

For Ch1/Ch0=>0.38 to <=0.45:
Lux=0.0729*Ch0−0.1286*Ch1

For Ch1/Ch0=>0.45 to <=0.60:
Lux=0.060*Ch0−0.10*Ch1

For Ch1/Ch0>0.60:
Lux/Ch0=0

The true test of an ambient light sensor is how well it performs when compared to a calibrated light sensor under different lighting conditions. Figure 3, shows how well the TSL2581CS tracks lux measured against the Extech 407026 Lux meter.

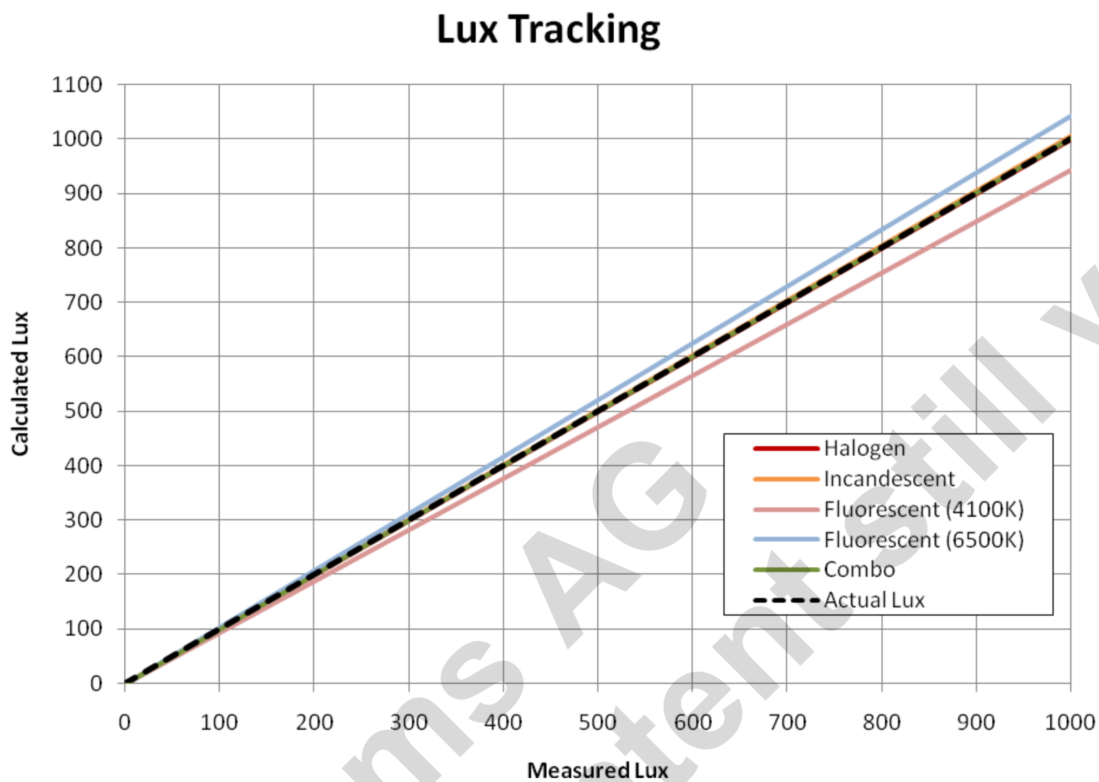

Figure 3. TSL2581CS Lux calculation vs. actual lux (measured with Extech 407026 Lux Meter)

A second solution involves using data from a color sensor, such as the TAOS TCS3414CS to measure lux. This method utilizes the separate responses from red, green and blue filtered photodiodes, as seen in figure 4.

The chipscale package used to house the TCS3414CS contains glass with an integrated IR blocking filter. This allows for the very sharp cutoff at around 660nm. Using a weighted average of the three channels, one can obtain a fair approximation of a photopic response. As shown in figure 5, the lux tracking with this method is not as good as it is using the TSL2581, although the advantage of using a device such as the TCS3414CS is that it allows for the calculation of CCT (Correlated Color Temperature) as well as lux. For more information regarding the calculation of CCT and lux, please see the TAOS application note "***DN25: Calculating Color Temperature and Illuminance using the TAOS TCS3414CS Digital Color Sensor***".

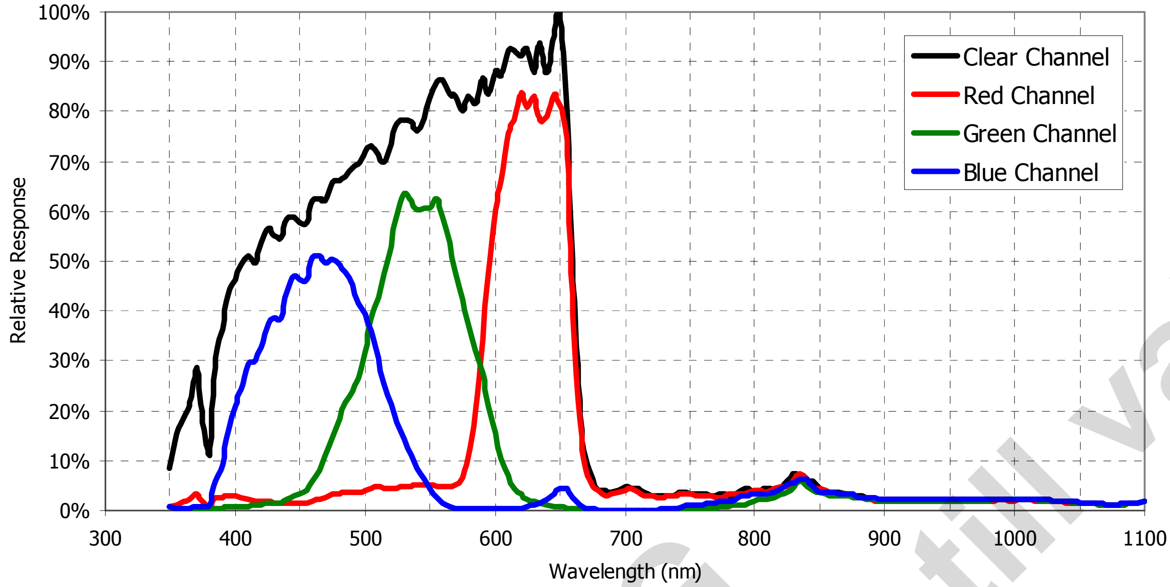

Figure 4. TCS3414CS Spectral Response

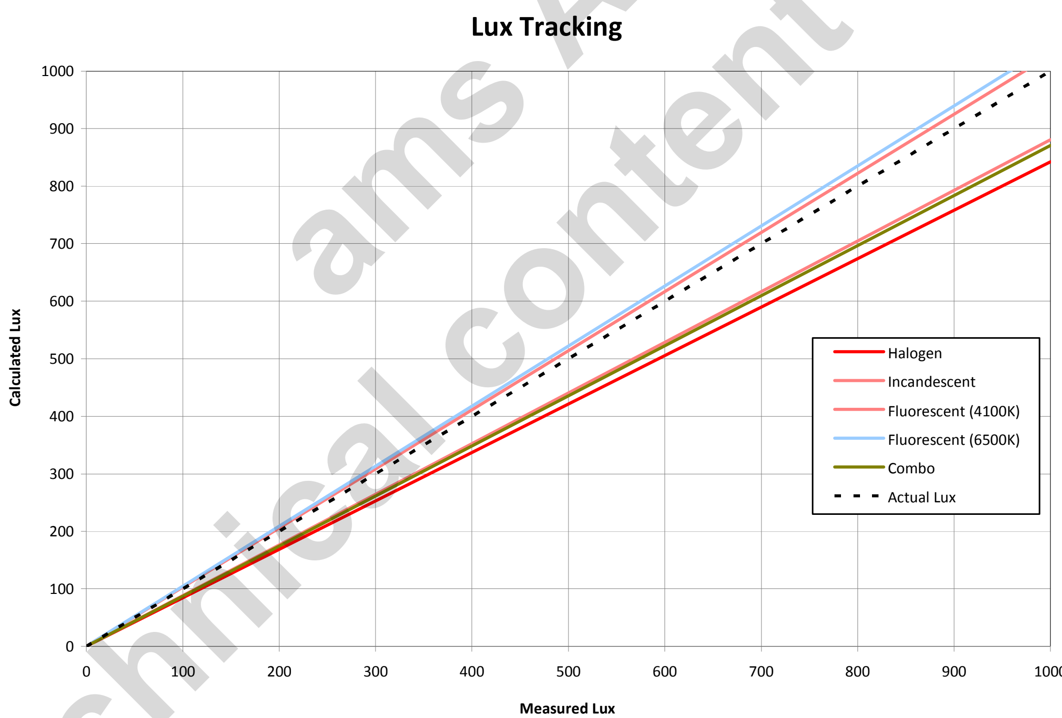

Figure 5. TCS3414CS Lux calculation vs. actual lux (measured with Konica Minolta CL-200 Lux Meter)

Design Considerations

There are many potential challenges to consider when designing ambient light sensing into your system. Some of these considerations are based on the light source being measured, while others are dependent on the manner in which the information is displayed to the end user. This section will address some of these considerations.

Infrared Radiation

The most obvious challenge has been addressed already in this paper. This is the removal of non-photopic energy from the ALS measurements. The biggest component of non-photopic energy that is common in many light sources is infrared (IR) energy. Incandescent bulbs and sunlight are two prevalent examples of light sources that emit a lot of IR energy as can be seen in Figure 6.

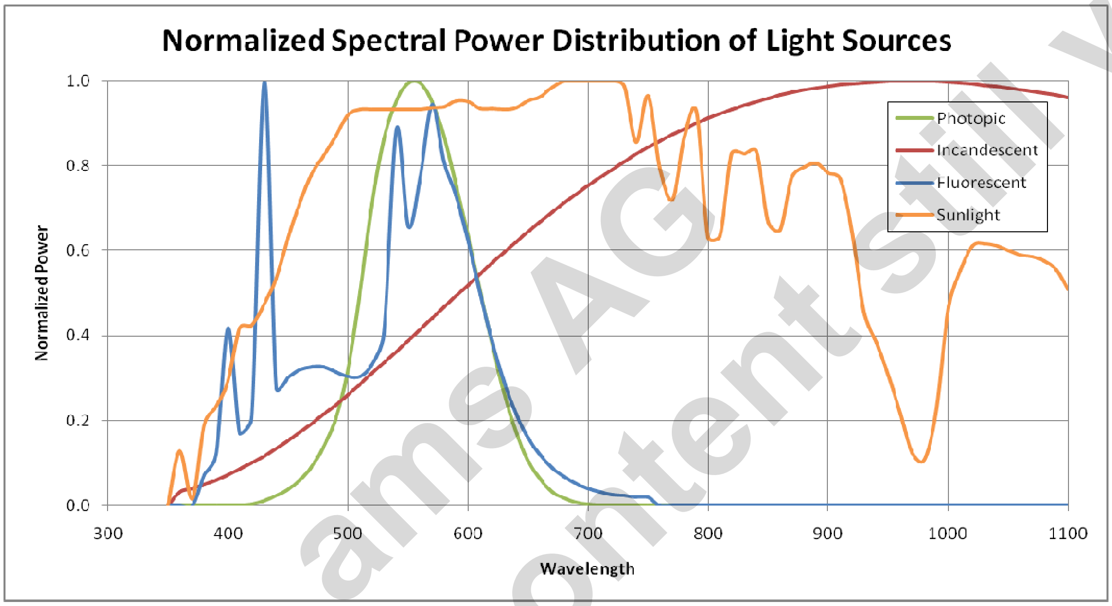

Figure 6. Normalized Spectral Power Distribution (SPD) of various Light Sources

IR energy is problematic, because it is energy that silicon is responsive to, but the human eye is not. Thus, if IR radiation is not taken into account, and you were using a silicon photodiode to determine the amount of ambient light on a surface lit by an incandescent bulb, your silicon-based reading would show that the ambient light were much higher than a viewer would perceive it to be.

There are several methods to account for IR radiation, when detecting ambient light. One method is to have the user select the dominant light source. Using the example stated earlier, you could more accurately determine the ambient light if the light source were known, by scaling the result based on the ratio of the light sources Spectral Power Distribution (SPD) to that of the photopic curve. This ratio is known as the efficacy of the light source and is used as a measure of the sources efficiency for lighting. The problem with this method is that the light source must be known and that it requires manual interaction.

Another method is to use IR blocking filters. There are many excellent IR and UV blocking filters available. Some of these filters are capable of effectively blocking out over 95% of non photopic radiation. This is the preferred method for many calibrated lux meters. These filters are usually very expensive and can be prohibitive in a mass production environment.

The final method, which is the method employed by the TAOS digital ALS sensors, is the two channel approach. As stated earlier, by utilizing information from a broadband channel as well as information from an IR only channel, photopic measurements can be made that are both accurate and inexpensive.

AC Ripple/Flicker

Light sources that are powered by alternating current (AC) power lines exhibit varying light intensity over time. This phenomenon is known as AC ripple or AC flicker and is common in incandescent and fluorescent bulbs. Since most AC lines in the world operate at either 50Hz or 60Hz, AC powered light source intensities will vary at frequencies of 100Hz and 120Hz, respectively. The frequency is doubled because the light source will be the least intense at the zero crossing of the AC line and maximum intensity when the AC line is at a maximum or minimum value.

One method for compensating for AC ripple is to integrate the response signal for a period of time that includes only whole integers of AC ripple periods. To accommodate both 100Hz and 120Hz AC ripple frequencies, the minimum integration time would be 50ms. Thus any integration period of any multiple of 50ms should be immune from variation due to AC ripple.

Another method to compensate for AC ripple is to effectively slow the response time of your photodiode by incorporating an RC delay circuit. The RC circuit makes the output signal more uniform and less reactive to AC ripple. This method is necessary for devices with a quick response time such as the TAOS Light-to-Voltage devices.

For more information on this, please see the TAOS application note "***DN22: Compensating for Light Flicker on Optical Sensors***".

Response Time

The response time of the sensor is an important point to consider when designing your system. In a control system, a fast response time, could be very important, however, ALS systems are often used to control a human interface such as a display. It could be beneficial to ensure that an ALS enabled display does not react too quickly to changing levels of light.

Imagine designing ambient light sensing into a desktop monitor. It would be possible that the monitor would be used in an area where the ambient light could drop briefly as someone walks by the monitor. In this instance you would not necessarily want the screen to react to these brief changes.

To slow the response time, it is necessary to average the output signal over a sufficient amount of time. If, for example, you are implementing a TAOS digital ALS device, such as the TSL2581 and would like to slow the response, you can calculate a moving average of several integration cycles. Additionally this part has a feature that allows you to set interrupt thresholds, that when crossed will assert an interrupt. Persistence capabilities are included with this feature, as you can set the interrupt to wait for up to 15 consecutive out-of-range values before the interrupt is asserted.

Optical Path
The optical path is the path from the light source to the sensor. Items such as apertures, lenses, and filters can have an impact on the output of the sensor and need to be understood before designing them into an optical system.

An aperture is an opening, through which light is admitted. An aperture can affect the angular response of the sensor as it will limit any off-axis light. The degree to which the angular response is affected is determined by the size, shape and depth of the aperture. A narrow and/or deep aperture would result in a very narrow angular response, whereas a very wide and/or shallow aperture would result in an angular response that more closely represents what is depicted in the TAOS datasheet for the sensor.

When light travels from one medium to another, refraction can occur if the two mediums have different indices of refraction. Lenses utilize this principle to bend light to a specific end. Lenses can and often are used to increase the angular response and/or the optical sensitivity of the sensor. By bending off axis light toward the sensor, the response may be greater than it would have been otherwise. Additionally, lenses can be used in low light applications to magnify the light incident upon the sensor.

Filters can be defined as anything that can attenuate some or all of the radiation that strikes them. They can accomplish this by absorbing this radiation or by reflecting it. Either way, all wavelengths of radiation are usually not attenuated equally. These filters could include IR blocking filters, color filters or even clear glass. Any light-transmissive items within the optical path are probably attenuating some light and this wavelength specific attenuation should be well understood and designed for.

CONCLUSION
TAOS offers several options when it comes to ambient light sensing. These devices vary on output (analog, frequency, or digital) and sensitivity. Please visit www.taosinc.com for more information.