



Electronic Design®

BUYING AMBIENT LIGHT SENSORS:

***A Buyer's Guide for
Ambient Light Sensors***

From the Editors of *Electronic Design*

A Buyer's Guide for Ambient Light Sensors (ALS)

According to Market Research Future, the optical sensing market is expected to grow at SD 3.10 Billion by 2023, at 14.3 % of CAGR between 2017 and 2023. The number of optical sensors (e.g. Ambient Light Sensors) in smartphone is increasing and with 5G technology around the corner, the adoption of optical sensors in portable devices will only grow more. Into the future, this increase in volume will also be affected by computing, wearable and automotive applications adopting the optical sensors as well.

The guide contains articles that will help ALS buyers to choose the right product.

Turning the Spotlight on Ambient Light Sensors

By controlling the brightness and providing optimum lighting conditions for LCD products, ambient light sensors can improve battery power utilization.

BY MARIA GUERRA

AMBIENT LIGHT SENSORS (ALSS) are photodetectors that approximate the human eye's response to light intensity under a variety of lighting conditions and through different attenuation materials. They're most commonly found in industrial lighting, consumer electronics, and automotive systems. But they have seen increased usage in LCD-equipped portable products—especially smartphones—because an ALS IC can automatically control the brightness level of the display backlight.

Aside from improving visibility, they help reduce power consumption. LCD backlighting can draw as much as 51% of the power in the input standby mode. One of the main challenges now is selecting an ALS for LCD products with the ability to detect wavelengths visible to the human eye (400-700 nm). There are many types of ALSs; some technologies have been around for decades while others are still maturing.

TYPES OF AMBIENT LIGHT SENSORS

Ambient-light-sensor technologies include photoresistors, photodiodes, phototransistors, and ALS ICs:

Photoresistors: Both a passive electronic component and the simplest optical sensor, the photoresistor has a resistance that varies depending on the light intensity. It also can respond in a way that's similar to the human eye. In darkness, the resistance is very high (e.g., 1 M Ω) and in the light, the resistance tends to fall down (e.g., 10-20 k Ω at 10 lux). Cadmium-sulfide (CdS) photoresistors (Fig. 1) were very common many years ago, but since 2006, cadmium has



1. A 20-mm CDS photoresistor is made of semiconductor material; its conductance changes with luminance variation. (Courtesy of Senbastana)

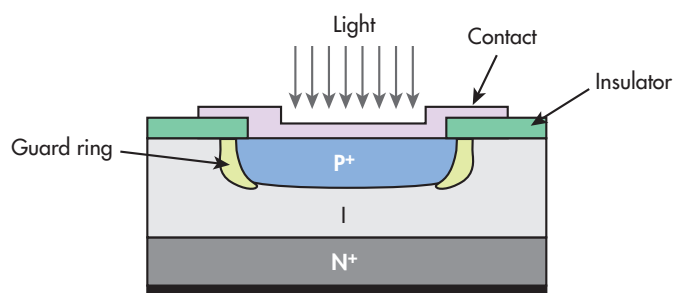
PHOTODIODE MATERIAL WAVELENGTHS	
Material	Wavelength sensitivity (nm)
Germanium	800-1700
Indium gallium arsenide	800-2600
Lead sulfide	100-3500
Silicon	190-1100

been designated as a prohibited RoHS (Restriction of Hazardous Substances) material.

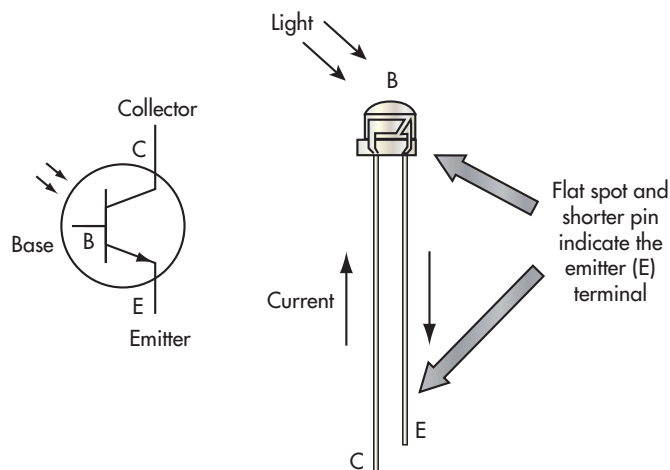
Photodiodes: A photodiode is a semiconductor device with a PN or PIN structure that converts light into an electrical current. The PIN structure offers a better area for the collection of light (Fig. 2). Photodiodes have a low output current that

requires an external amplification circuit, which commonly operates in reverse bias. Light absorbed in the depletion region or the intrinsic region generates electron-hole pairs, most of which contribute to a photocurrent.

A photodiode conducts electric current directly proportional to the



2. Placing the electrical contacts at the side of the device ensures that the maximum amount of light reaches the intrinsic layer. (Courtesy of electronics notes)



3. A commonly used phototransistor symbol has two arrows pointing toward the transistor. (Courtesy of learn.parallax)

amount of light entering the intrinsic region. One of the key characteristics of a photodiode is its response to the wavelength of light, which can vary depending on the material (*see the table*).

Other types of photodiodes have slightly different modes of operation, such as the avalanche diode and the Schottky photodiode, which promise to adjust better to the needs of a circuit. Photodiodes are used in many applications, such as light meters, flame monitors, bar-code scanners, light pens, and more.

Phototransistors: These semiconductor light sensors are formed from a basic transistor with a much larger base and collector areas that make them more light-sensitive (*Fig. 3*). A small reverse saturation current, called dark current, flows through the phototransistor even in the absence of light. Its value rises with an increase in the value

of temperature, a property identical to that exhibited by ordinary transistors.

Phototransistors have a higher output signal than photodiodes. They're sensitive to a wide range of wavelengths ranging from ultraviolet (UV) to infrared (IR) through visible radiation. But they can't handle high voltages if made of silicon. In addition, they have poor high-frequency response due to a large-base collector capacitance. Phototransistors are used in wide range of applications, such as object detection, CD players, infrared receivers, printers and copiers, night-vision systems, etc.

Ambient-light-sensor ICs: Both analog and digital ICs exist—each version is in high demand and still maturing. Such ICs typically perform better than the other ALSs mentioned; for example, the output current is easier to obtain. They also can integrate more functions, which results in less circuitry, thus saving board space and reducing design cost.

The analog current output of an analog ALS is proportional to the incident light level and spectrum sensitivity, similar to the human eye. It can then be converted to a voltage that's applied to an analog-to-digital converter (ADC) interface on an MCU or directly as an input to an LED driver IC. A digital ALS IC typically has a 16-bit digital I²C output. An integrated ADC converts the output of the photodiode to an I²C signal. ALS ICs are now commonly found in LCD backlighting applications.

Ambient-light-sensor technologies will further evolve due to escalating needs for sensors in portable devices like smartphones. Such devices include more than 10 sensors, and they include ALS ICs. As they evolve, expect to see more ICs integrating ALS with proximity sensors, which is already occurring with a handful of developers. •

Why Does Accuracy Matter So Much With an Ambient Light Sensor?

The ability of an ambient light sensor to closely match a photopic response is key to maximizing human-machine interaction, extending the life of an electronics system, and improving power utilization.

THE PURPOSE OF AN AMBIENT LIGHT SENSOR (ALS) is to allow electronic systems to “see” light like a human eye. The spectrum of the human eye is called the photopic response. Matching the photopic response as closely as possible will improve the human-

machine interaction, extend the life of the system, and improve system power utilization.

To understand why accuracy matters with an ALS, we first need to understand exactly the concept behind an ALS. An ALS is a light-sensing device that provides an electronic signal that's proportional to the amount of light it senses. Specifically, the photopic response is of interest (*Fig. 1*).

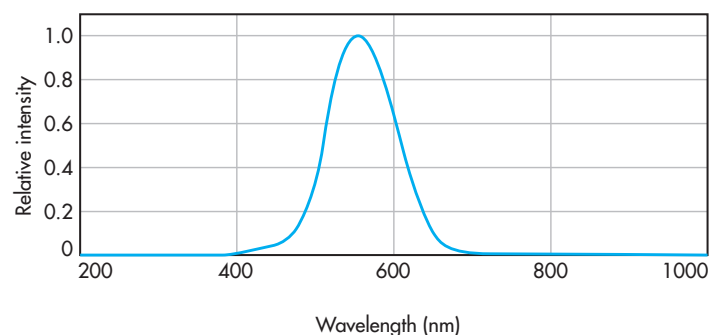
DAN HARMON, Sensing Business Development Manager, Texas Instruments

So if this is how the eye sees light, why is it important for the ALS to closely match that ability? To answer this question, let's look at the spectral response of two different light sources: a typical incandescent bulb (Fig. 2), and a typical fluorescent bulb (Fig. 3).

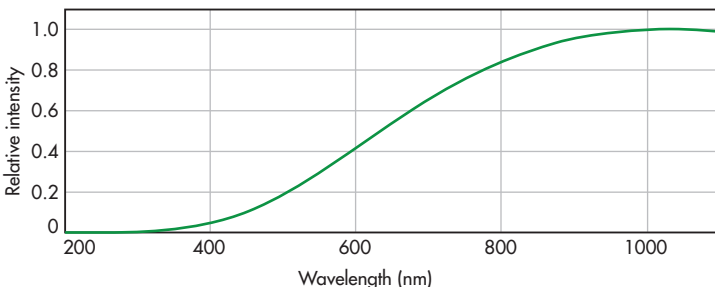
The amazing thing when we look at these two graphs is to understand that if you "integrate" each of the two curves with the photopic spectrum, the relative energy under the curve is the same. In other words, humans perceive both graphs as having equivalent outputs (Fig. 4). Note that these two source spectral responses are normalized and don't represent the power output relative to one another.

If we compare the photopic response to that of a typical photodiode (Fig. 5), an electronic device converts the light energy into an electric signal. It's clear that the photodiode sees light very differently than we do. However, if the two spectral curves are integrated with that of a typical photodiode, we see that the output energy "seen" is quite differently, too (Fig. 6).

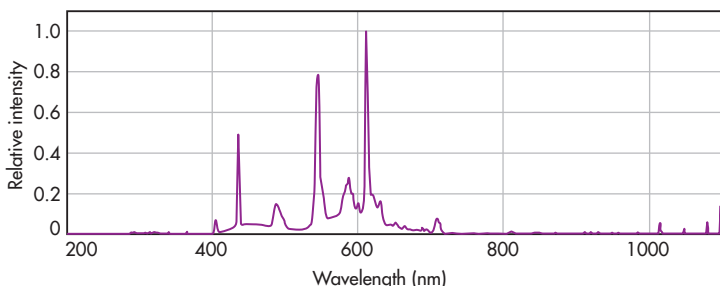
With the typical photodiode shown, we see light-source variation of



1. The photopic spectrum is based on CIE 1931 luminosity.



2. Theoretical spectral response of a typical incandescent bulb.

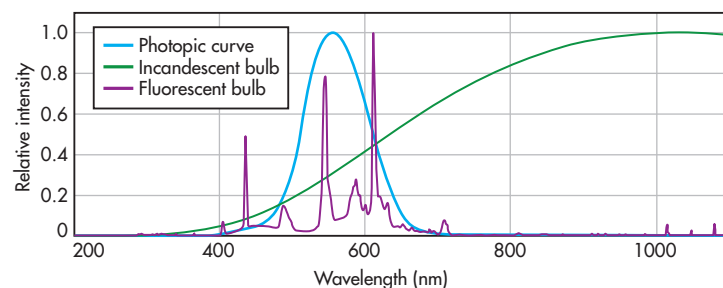


3. Measured spectral response for a typical fluorescent bulb.

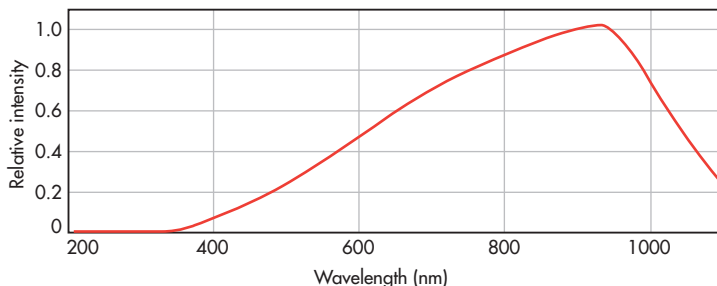
nearly 1500%. In other words, the photodiode sees the incandescent bulb as being almost 16 times brighter than the fluorescent bulb.

Why does this occur? Look at the spectral response of each of the devices involved. The incandescent bulb outputs significant amounts of energy in the near-IR and IR wavelengths (>700 nm), unlike the fluorescent bulb. The photodiode "sees" this wavelength, but the human eye does not. Therefore, an electronic device that uses a typical photodiode responds to disparate light sources very differently than a human.

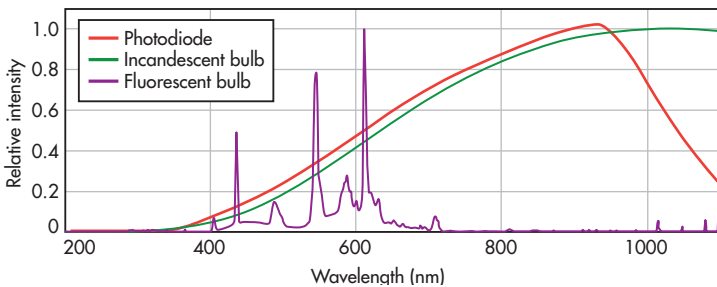
Now that we understand how an ALS improves performance significantly versus that of a photodiode, let's consider how close matching is really required. We already established that different types of light sources output very different spectral content, specifically in the area



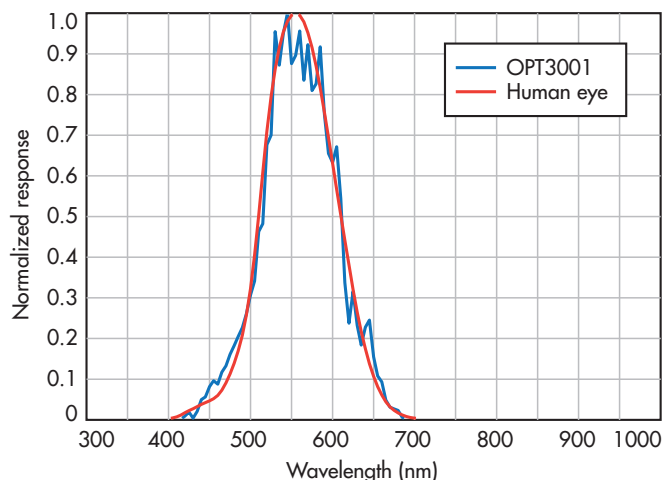
4. This graph shows how the photopic spectrum compares to the spectral responses of both an incandescent bulb and a fluorescent bulb. (Note: The light-source spectral responses are normalized and do not represent the relative output power.)



5. Spectral response of a typical photodiode.



6. Shown is a comparison of the spectral response of a typical photodiode versus the spectral responses of a fluorescent bulb and an incandescent bulb. (Note: The light-source spectral responses are normalized and do not represent the relative output power.)



7. The spectral response of an ambient light sensor is compared to a photopic response.

of IR light. One key to matching the human eye is to understand how well an ALS rejects IR energy. For example, the OPT3001 from Texas Instruments offers IR rejection of approximately 99% as shown in the datasheet (Fig. 7).

This results in less than a 4% error when comparing the response of the OPT3001 between typical fluorescent and incandescent bulbs (the photopic matching is claimed as amongst the best in the industry for this device). It's critical to review the device's datasheet to understand how well they match the photopic response. Key items to look for are the amount of IR leakage, a shift in the peak spectral response, or a narrowing of the spectral response.

ALS devices currently on the market have over 20% error when comparing their relative response to different illumination sources. This is an order of magnitude better than a standard photodiode as shown above, but it's an order of magnitude worse than the best available ALS devices.

HUMAN EXPERIENCE ENHANCEMENTS

Now that we see why an ambient light sensor offers significant improvements over a photodiode, the next question is how does this improvement affect our experiences? To answer this question, let's look at a two use cases and discuss the experiential improvement offered by an ALS.

Mobile consumer electronics such as smartphones, tablets, ultra-books, and other personal electronics have identified that varying lighting conditions require adjusting the screen's backlight level to improve the user experience. This is accomplished with an ALS. However, non-consumer displays haven't taken this into account until recently.

Consider today's nearly ubiquitous smart thermostat, all of which have a small format display. At first blush, it seems that a thermostat

mounted on an interior wall of your house or place of business doesn't experience varying lighting conditions other than lights on/off.

What if the wall faces a window that faces east? In the morning on a sunny day, that wall will need to overcome a significant sunlight load that contains a high level of red and infrared light. In this case, the backlight needs to be turned up so that the display is readable in the high glare created by the sunlight. As the day progresses, the morning sun no longer causes that glare and the backlight needs to be turned down to prevent the display from washing out in a dimmer environment. This same thought process can be applied to a multitude of displays with similar varying lighting conditions, such as ATMs, movie-theatre ticket kiosks, and vehicle infotainment systems, to name a few.

Similarly, consider interior lighting in commercial buildings. Energy cost due to lighting is one of the largest expenses in commercial real estate (HVAC being the largest!). As buildings transition more to LED lighting rather than the more power-hungry fluorescent lights, or even worse incandescent lights, they're already achieving savings.

Since it's much easier to control the power consumption of LED lighting, you can save even more by what's referred to as daylight harvesting.^{1,2} Daylight harvesting is simply using natural daylight to supplement artificial electronic lighting. This allows for energy savings while maintaining a "proper" light level within the defined area of usage. The target is to provide the proper lighting level for people to perform their defined tasks for the given area.

An ALS measures the naturally provided light and feeds this information to the controller, which in turn controls the artificial lighting level to allow the sum to meet the guidelines for the defined usage. What do I mean by the proper lighting level for the defined usage? Consider a library versus an average corporate cubicle farm. In the library, you will want brighter lights to make reading easier. The PC screens in the cubicle complex will drive a lower required lighting level to keep their backlight levels (and power consumption) down.

ENHANCED PERFORMANCE AND EFFICIENCY

In addition to the experiential improvement offered by using a more accurate ALS, system performance and efficiency improve as well. If we reconsider the same two examples discussed above, what system improvements can be expected?

Lowering the backlight level on a display will actually extend the life of the display. All displays (whether CRT, LCD, OLED, or PLASMA) have a "half-life." The half-life or half-brightness is defined as the time it takes for the display's brightness to degrade until it's half that of the new display.³ The higher the backlight is driven, the faster the degradation.

Therefore, by managing the backlight level to a viewable level based on a ALS rather than what has historically been done, which is to keep the backlight at its maximum value, will extend the life of the display.

For most portable consumer devices, this isn't a big concern because usage of the device will be significantly less than the half-life. However, for many of the displays mentioned above (ATMs, ticket kiosks, thermostats, and so on), expected lifetime could be measured in decades. In this case, the half-life could become an issue.

Similarly, in a lighting system, the less power that's applied, the longer the lifetime of the bulbs. We're all probably familiar with the kilowatt-hour lifetime that appears on the packaging of light bulbs. This is simply a measurement of power over time. The less the average power is being applied due to dimming based on daylight harvesting, the longer before the bulb needs to be replaced, which reduces the luminary maintenance cost.

SUMMARY

As you can see, how well an ALS matches the photopic response is critical to maximizing the human-machine interaction, extending the life of the system, and improving system power utilization. Devices with improved photopic response, like the OPT3001, are available for many industrial ALS applications.

About the author

DAN HARMON is sensing business development manager for TI's Sensing group. In his 29 year career at TI, he has supported a wide variety of technologies and products including interface products, imaging analog front-ends (AFEs), and charge-coupled device (CCD) sensors. He also has served as TI's USB-IF representative and TI's USB 3.0 Promoter's Group Chair. Dan earned a BSEE from the University of Dayton, Ohio, and a MSEE from the University of Texas, Arlington. You can reach Dan at ti_danharmon@list.ti.com. •

References

1. ANSI/ASHRAE/IES Standard 90.1-2013 -- Energy Standard for Buildings Except Low-Rise Residential Buildings
 2. Title 24 – California Energy Commission – State of California
 3. Geoffry Morrison, How long do TVs last? CNET Morrison's Mailbag, February 23, 2012.
- Further reading:
Backlight and Smart Lighting Control by Ambient Light and Proximity Sensor Reference Design, TI Design (TIDA-00373), March 2015.

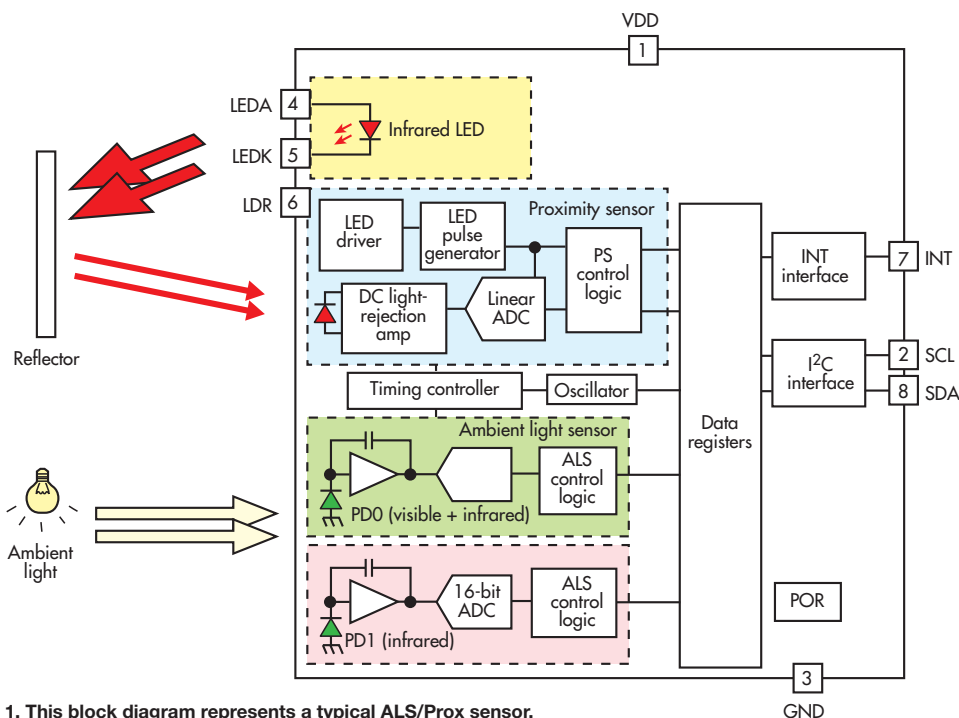
11 Myths About the ALS/Proximity Sensor

This article looks to set the record straight regarding ambient light and proximity sensors, which can be effective for small-area measurements.

MOST DESIGN ENGINEERS of consumer and industrial products always look for various ways to achieve their desired goals in applications ranging from wearables to handheld devices to industrial appliances. One common thread between these applications is that they need some type of sensor(s) and actuators or decision engines to determine the actions to be taken.

Ambient light and proximity sensors (ALS/Prox sensors) are used in many of these Internet of Things (IoT) devices, home and factory automation, and handheld and wearable devices to reduce power consumption, determine screen brightness, turn on/off the screen, detect the level of the liquid in a tank, measure the proximity of the piston in a chamber, and so on.

SATYA DIXIT, Senior Director, Solutions Marketing, Systems and Applications, Rohm



What follows are the conventional myths that surround ALS/Prox sensor usage in various scenarios and applications—and reasons why they can all be debunked.

1. IR-based proximity sensing cannot be done under direct sunlight.

Proximity sensors can be used outdoors under direct sunlight to determine proximation. The ALS/Prox sensor detects, and subsequently cancels out, the ambient IR. It depends on the IR emitter intensity and pulse to detect the proximity. *Figure 1* shows a typical ALS/Prox sensor block diagram.

2. Different light types affect the performance of an ALS.

An ambient light sensor provides consistent light reading irrespective of the different light sources.

3. An integrated IR-LED proximity sensor experiences more crosstalk than separate sensors.

It's been shown that integrated IR-LED proximity sensors don't have any more cross-talk than an individual sensor due to its double-molding type of package (*Fig. 2*).

4. The ALS/Prox sensor doesn't work properly behind dark-tinted glass.

ALS/Prox sensors have enough sensitivity whereby they will work effectively behind dark-tinted glass. The software controller's high-sensitivity mode allows light to be measured even behind the dark glass.

5. An ALS/Prox sensor requires external analog-to-digital converters (ADCs) to provide digital information.

These sensors have an internal ADC block, therefore they don't require the end user to design an external block. A microcontroller can directly read the ALS and proximity data using an I2C bus.

6. IR-based proximity sensors can detect objects at distances over several yards.

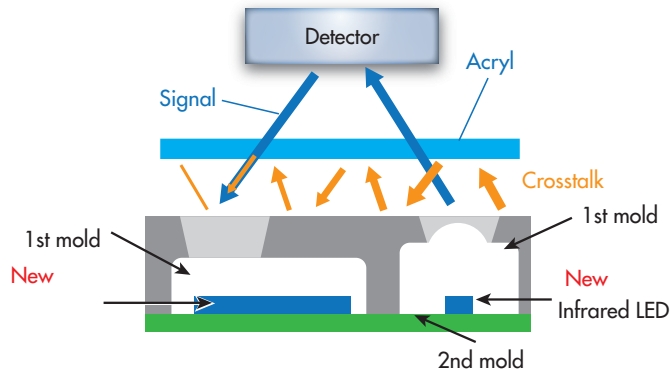
These sensors can only detect distance in the range of 1 to 100 mm. Hence, they're used to detect proximity in small areas as well as in handheld and wearable devices. This capability also is useful in certain devices targeted for the industrial space.

7. Indoor artificial lights with 50/60-Hz power affect ALS performance.

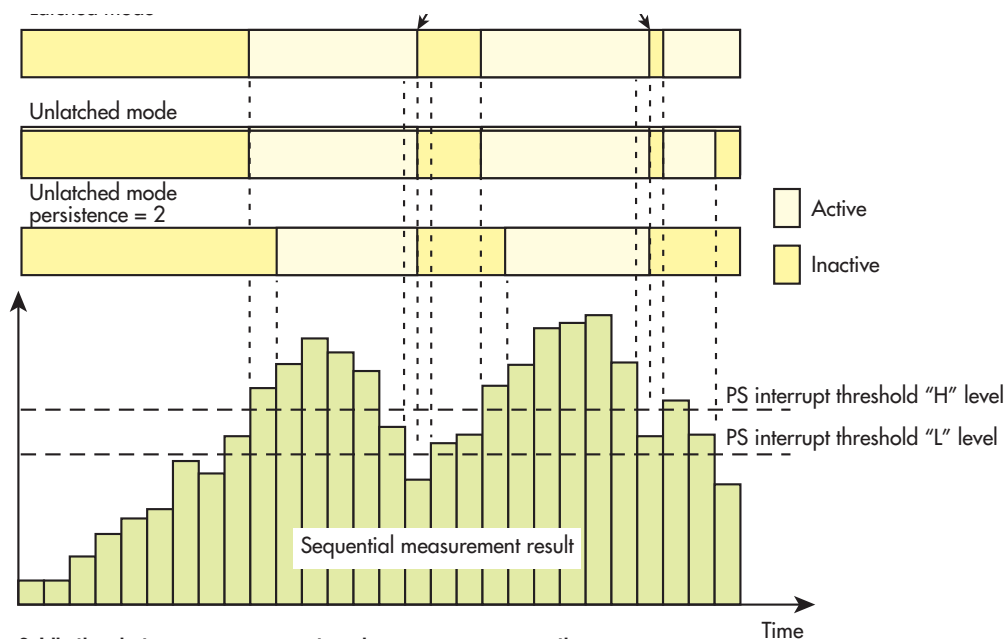
Most ALS/Prox sensors will have built-in 50/60-Hz light noise filtering to provide consistent ALS output, even in indoor light conditions.

8. An IR-based proximity sensor consumes very high power (hundreds of mA).

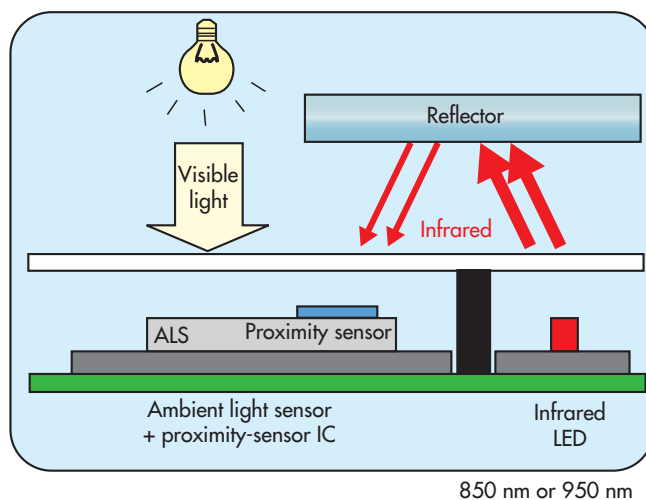
The ALS/Prox sensor has the ability to control the IR-LED ON time to minimize power consumption. As a result, the IR-LED will be ON only during measurement time, which drastically reduces total power con-



2. Double-molding packaging helps minimize crosstalk in ALS+Prox sensors.



3. Idle time between measurements reduces power consumption.



4. An external light source isn't needed for a proximity sensor to work in the dark. It only requires its IR source.

sumption (Fig. 3).

9. IR-based proximity sensor can't work in dark environments.

Not true. Such sensors can work in the dark or inside the enclosure. Since the IR-LED is built into the sensor module, there's no need for an external light source to measure the distance from the sensor to the object (Fig. 4).

10. Assembly requires special handling.

IR-based proximity sensors are robust devices; there's no need for any special assembly techniques (Fig. 5). Sensors can be used like any other surface-mount component.

11. Proximity sensors discriminate in terms of color.

ALS/Prox does NOT discriminate against different colors; the sensor still emits same amount of light. The reflection of the light heavily depends on the color and type of reflective material. •

Hardware Design Guide for Smartphone Ambient-Light Sensing, Proximity Detection

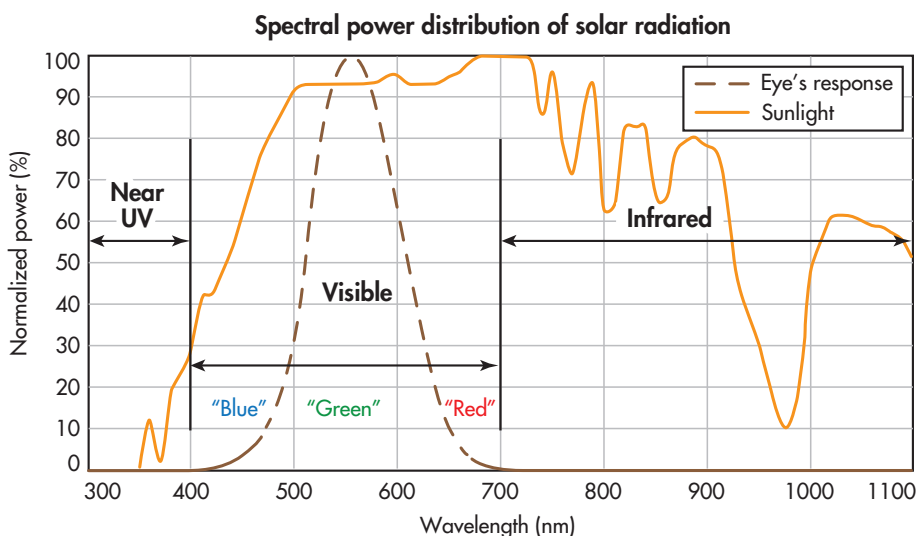
The backlight of the LCD panel in a smartphone accounts for about 40% of the device's total power consumption, so the ability to adjust its brightness in response to ambient-light levels becomes a key design challenge.

SINCE THE BACKLIGHT of the LCD panel in a smartphone accounts for around 40% of the device's total power consumption, one can benefit greatly by adjusting the brightness in response to changes in ambient-light levels. In a relatively dark environment, the brightness of the display can be reduced to save power. This is also easier on the user's eyes, thus improving the user experience at the same time.

Ambient-light sensors (ALSs) are in fact now widely used in smartphones to provide information about ambient light levels, in support of the backlight LED power circuit. But while this application is simple to describe, in practice it's difficult to implement successfully—i.e., in a way that achieves worthwhile power savings while remaining unobtrusive to the user.

An ALS must be mounted behind a display screen in which every square millimeter of area is valuable. In addition, it must be able to perform proximity detection (to turn the display off when held to the user's face) as well as the core ambient-light measurement function. These and other constraints seriously limit the design engineer's freedom to optimize the design.

This article describes the main challenges in implementing successful ambient-light response in a smartphone. It also offers ways to overcome these challenges to achieve highly responsive and accurate adjustment of the backlight's brightness in response to



1. The spectral power distribution of sunlight shows a strong IR element that's invisible to the human eye.

ambient light.

PHOTOPIC RESPONSE

The first difficulty is that photodiodes respond differently to light than the human eye. The human eye is insensitive to infrared (IR) light (a wavelength greater than 780 nm) and ultraviolet (UV) light (a wavelength less than 380 nm). A standard silicon photodiode, on the other hand, normally senses light at any wavelength between 300 and 1100 nm.

This means that the designer's first challenge is to remove the IR and UV components from the sensor's output. The function of the ALS is to capture a measurement of the illuminance (of which the unit of measurement is the lux) incident on the display of the smartphone.

STEVEN LI, Applications Manager, ams
www.ams.com

If this lux measurement includes UV and IR as well as visible light, the display's backlight controller will receive a distorted representation of the human, or "photopic," response to ambient-light conditions. In short, the ambient light will tend to appear brighter to the sensor than to the human eye.

This is because both natural and artificial light contain an IR element. This is true, for example, of both sunlight (Fig. 1) and the light from an incandescent lamp. An obvious way to remove the IR light is to overlay an optical IR filter on the sensor. But in a smartphone, this same sensor is also typically used for proximity detection (in tandem with an IR LED) to turn off the display and touch controller while the phone is held to the user's face.

Of course, the smartphone designer could then add a separate IR photodiode just for proximity sensing. However, this is an inelegant solution—now the design must carry the cost of the optical filter on the ALS as well as a discrete IR photodiode. Moreover, additional space will be occupied by the IR photodiode, which requires an aperture in the face of the display to allow for the passage of IR light.

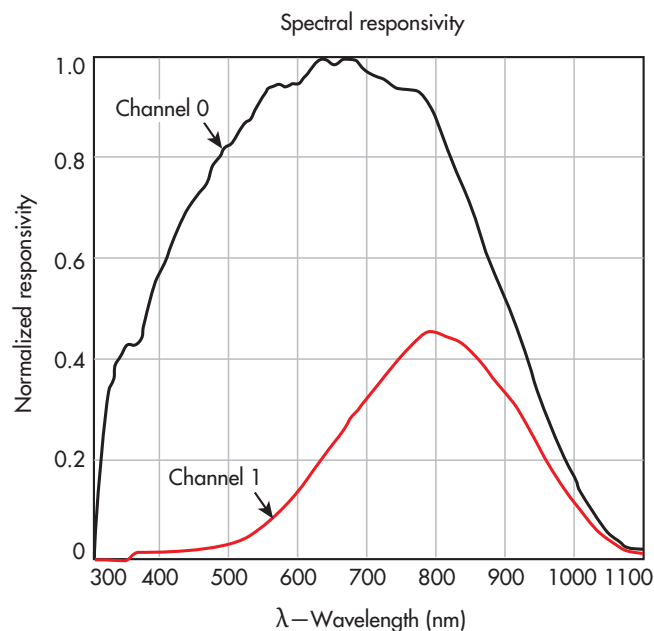
A more streamlined solution to the problem is a dual-diode module, which has been developed by ams. One photodiode (shown as Channel 0 in Figure 2) senses the full spectrum, while the other (shown as Channel 1) senses light mainly in the IR portion of the spectrum. Subtracting the IR photodiode's output from the full-spectrum sensor's output produces a measurement of visible light.

The sensor is fairly insensitive to UV light, and in any case, the common light sources emit little UV radiation. In most cases, a packaging material that can absorb UV light is sufficient to remove it for the purpose of ambient-light sensing.

Having removed the IR component of light from the ALS's output, the smartphone designer now has a second problem to solve: How do you limit the angle of view of the ALS/proximity-sensor module without impairing its performance? This is a matter of trading off the ALS against the proximity sensor.

For ambient-light sensing, the ideal angle of view is a (practically impossible) 180°, since this is the angle of view of the display on which ambient light is incident. But for proximity sensing, the opposite applies—a narrow viewing angle is required in order to limit the potential for crosstalk between the IR LED and the IR sensor. Ideally, the IR sensor should only be able to sense IR light reflected from the user's face, and the LED should not be able to illuminate the sensor directly, or to reflect light from the top or bottom surface of the touch panel.

This conflict between the requirements of the ALS and the IR sensor therefore requires a tradeoff. Through experimentation, smartphone designers have found that a 90° to 110° viewing angle provides for high-performance proximity detection while still enabling relatively good performance in the ambient-light sensing system. Narrowing the angle below 90° dramatically impairs the performance of the ALS. In



2. Shown is the spectral responsivity of the TMD2772, a family of dual-diode modules developed by ams that includes the TMD27721 and TMD27723.

addition, for the system to work with a 90° viewing angle, a very small air gap must exist between the bottom of the touchscreen and the top of the sensor module.

The viewing angle is not the only question of mechanical design that affects the ALS. For light to pass through the screen to the sensor module, the designer must leave an aperture open. OEMs want this hole to be as small as possible, though, to avoid spoiling the sleek, smooth appearance of the touchscreen. They also mask the aperture's appearance with ink added to the screen's glass surface, which darkens it and blends its color with that of the phone's case. The ink and the small aperture both reduce the intensity of light incident on the sensor module.

In addition, on the production line, the OEM must strictly control the variation in the ink's transmissiveness. If, for example, a 17% transmissive ink is used, a variation of just ±1% in the transmissiveness of the ink will cause a 5.9% additional error ($1/17 \times 100$) in the ALS's output.

The third important design challenge in implementing ambient light sensing in a smartphone is to handle a very high dynamic range of light inputs. Smartphone manufacturers want the display backlight's brightness to be set appropriately whether the device is being used in almost total darkness (illuminance as low as 0.1 lux) or in direct sunlight (illuminance as high as 220 klux). This requires that the sensor offer high sensitivity over a very wide dynamic range while maintaining a very low noise floor. In addition, the device's gain

should be controllable in response to changes in the brightness of the ambient light.

FINE-TUNING THE IMPLEMENTATION

This article has described the tradeoffs that govern the implementation of ambient-light sensing in smartphones, the advantages of a dual-diode solution, and the characteristics of the ALS module that the OEM needs to specify. But every device's appearance, mechanical design, and ink are different, which calls for individual characterization in order to develop a customized lux equation. This equation is required to accurately remove the IR component of ambient light, and to compensate for the restricted angle of view.

To perform this characterization, the smartphone should be exposed to various types of light sources that emit varying proportions of IR and UV light. The lux measurements of a reference, ultra-accurate lux meter and the ALS module under the same lighting conditions are then compared in order to calibrate the module's output. The lux meter should be covered by a hood so that it mimics the light sensor's restricted angle of view.

To characterize a sensor module such as the ams TMD27721 or TMD27723, for example, the following equations would be used:

$$\text{CPL} = (\text{ATIME_ms} \times \text{AGAINx}) / 20$$

$$\text{Lux1} = (\text{C0DATA} - a0 \times \text{C1DATA}) / \text{CPL}$$

$$\text{Lux2} = (b0 \times \text{C0DATA} - b1 \times \text{C1DATA}) / \text{CPL}$$

$$\text{Lux} = \text{MAX}(\text{Lux1}, \text{Lux2}, 0)$$

where CPL, a0, b0, and b1 are the parameters to be characterized. CPL = counts per lux; C0DATA = data read from Channel 0; C1DATA = data read from Channel 1; C0DATA - a0 × C1DATA = weighted count for a light source with a high proportion of IR light; b0 × C0DATA - b1 × C1DATA = weighted count for a light source with a low proportion of IR light; and MAX = maximum value of Lux1, Lux2, and 0.

In general, the more data sets that are collected under more light sources, the more accurate the characterization.

Given an appropriate mechanical design, strict control of ink transmissiveness in production, and careful characterization, error in the ambient-light sensing system can be limited to no more than ±15%. In some cases, it's possible to achieve as little as ±10% error. This is good enough to serve the purpose of adjusting the backlight's brightness to save power and improve the user's experience.

Of course, an OEM might require much higher accuracy for a function other than display backlight control. This would call for a very high-sensitivity ambient-light sensor (as a standalone device with no proximity detection). One such example is ams's TSL25911.

SUMMARY

Ambient-light sensors (ALS) are widely used in smartphones to provide information about ambient-light levels, in support of the

backlight LED power circuit. But while this application may be simple to describe, in practice it's difficult to implement successfully—i.e., in a way that achieves worthwhile power savings while remaining unobtrusive to the user.

An ALS must be mounted behind a display screen in which every square millimeter of area is valuable. It also must be able to perform proximity detection (to turn the display off when held to the user's face) as well as the core ambient-light measurement function. These and other constraints severely limit the design engineer's freedom to optimize the design.

To overcome the main challenges in implementing successful ambient-light response in a smartphone, designers must:

- Remove the IR component from the light measured by the ALS.
- Overcome limitations in the viewing angle that's exposed to the ALS.
- Provide accurate measurements of ambient light over a very wide dynamic range •

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PRODUCTS

Analog current output type ambient light sensor IC:

The output of Rohm's BH1682FVC is proportion to logarithm of illuminance. It has wide illuminance detection range and is suitable for the application of display brightness control. It can be used in a wide range of applications such as mobile phone, LCD, TV, Note PC, Portable Game Machine, Digital Cameras, etc.

Key specifications:

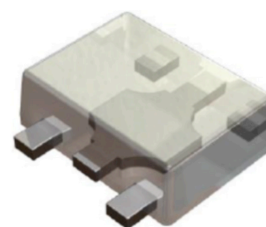
Vcc voltage range: 2.3V to 5.5V

Detection Range: 55klx (Typ)

Output Current (IOUT) at 100lx: 20µA (Typ)

Shutdown Current: 0.1µA (Typ)

Operating Temperature Range: -40°C to +85 °C



PIN Photodiode: Vishay's TEMD5510FX01 ambient light sensor is a PIN photodiode with high photo sensitivity in a miniature surface mount device

(SMD). The detector chip has 7.5 mm² sensitive area. It is sensitive to visible light much like the human eye and has peak sensitivity at 540 nm. It can be used in several applications notebooks, computer, backlight dimmers, etc.

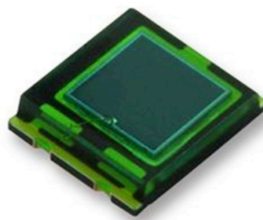
Key Specifications:

Reverse voltage (VR): 16V

Power dissipation (PV): 215 mW

Operating temperature range: -40 to +100 °C

Angle of sensitivity: $\phi = \pm 65^\circ$



$I_{ra} = 1 \mu A$

Digital UV and Ambient Light Sensor:

The Broadcom APDS-9200 device provides ultra-violet (UV-A and UV-B) sensing and ambient light sensing in a specially designed matrix arrangement for optimization. This allows the device to have optimal angular response for ultra-violet and ambient light sensing. APDS-9200 can be used in the following applications: ultra-violet and ambient light sensing, mobile devices, outdoor navigation display, wearable devices, etc.

Key Specifications:

Operating Ambient Temperature -40 to 85 °C

Supply voltage 1.7v to 3.6V

I2C Interface Compatible Up to 400 kHz

Standby current 1 μA (Typ)



Active mode current 110 μA (Typ)

Analog Output Ambient Light Sensor: Intersil's ISL29112 is a light-to-voltage silicon optical sensor combining a photodiode array, a non-linear current amplifier, and a micropower op amp on a single monolithic IC. It is ideal for applications such as mobile devices, computing devices, consumer devices, industrial and medical.

Key specifications:

1.8v to 3v supply range

0.01lux to 100 lux range

Operating temperature: -40 to +85 °C

Built-in 1 μA op amp gives

