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**

INTELLIGENT OPTO SENSOR

DESIGNER'S NOTEBOOK

Optical Window Design for ALS Devices

updated by Kerry Glover and Dave Mehrl
February 2010

Overview

One of the most important aspects of incorporating a Digital Ambient Light Sensor (DALS) in a system is the design of the optical window. In order to maximize the device performance and effectiveness, the optical window placement, dimensions, tolerances, and material must all be considered. This application note is targeted to laptop applications with a hole in the bezel.

Figure 1. Recommended Placement of the ALS Device

Placement

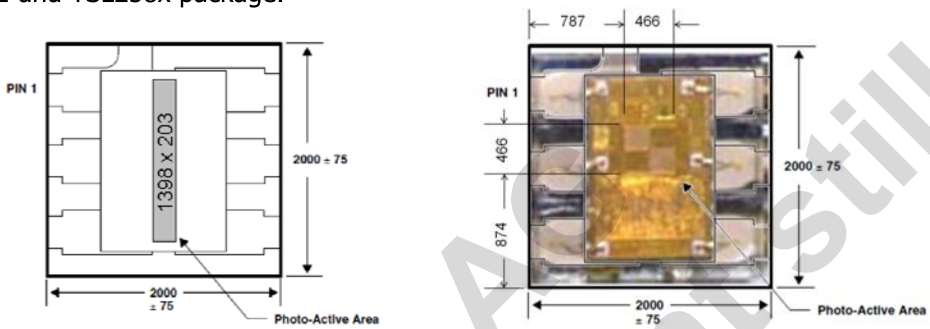
The ALS is best placed anywhere along the top of the bezel around the LCD panel. This allows the sensor to be in a prominent place, away from possible shadows. In this configuration, the ALS should be mounted parallel to the LCD panel to measure the illuminance striking the display. This is also the recommended location described in the Microsoft article "Integrating Ambient Light Sensor with Windows 7 Computers".

In some systems it may be desirable to enhance the light sensing capabilities by implementing a second ALS device for measuring the light striking the back side of the display and shining towards the user. In such an implementation, one device can be mounted along the bezel on the front of the LCD panel facing the user and a second device can be mounted on the backside of the LCD panel facing the opposite direction.

Mechanical Design

The mechanical design of the enclosure surrounding the device is one of the key factors impacting the sensor responsivity. The device is normally mounted underneath a plastic or metal bezel allowing the sensor to have a field of view through a hole (or aperture) through which it senses ambient light. For this case, it is assumed that the enclosure material will absorb all visible and IR light. In some cases, a light pipe is used instead of an open aperture or dark plastic to hide the sensor.

The analysis of the illuminance, or light energy striking the sensor depends upon the dimensions of the photo-active sensor area and upon the package type. In the TSL256x series of sensors, the photo-active area is oblong. In the TSL2571 and TSL258x the photo-active area is square. For this application note, the FN package will be analyzed. The following shows the placement of the sensor in the TSL2561 and TSL258x package.



TSL2561 TSL2581

Figure 2. Photodiode Active Area Location

Viewing Angle

The reduction in the viewing angle caused by the aperture directly affects the amount of light available to the sensor. Typically, the sensor has a cosine response to the light hitting the photodiode. For calculations, it is best to discuss the half viewing angle and express the viewing angle as +/- half angle, as shown in Figure 3.

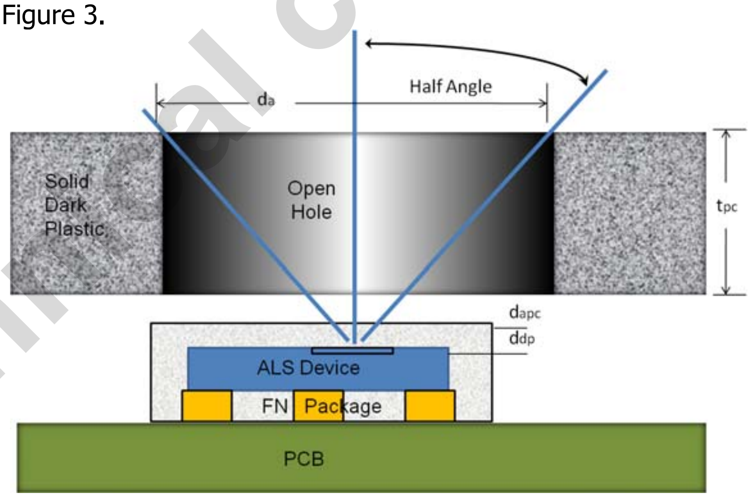


Figure 3. Half Viewing Angle of a Sensor

The calculations related to determining the reduction in light available to the sensor are very complex and several simplifications are needed to provide simplified analysis. From comparison with simulated results, calculating the viewing angle from the center of the die provides the best results.

From this, the half viewing angle (θ) can be calculated using the following formula:

$$\tan(\theta) = (d_a / 2) \; / \; (d_{dp} + t_{pc} + d_{apc})$$

where

- d_a is the diameter of the aperture
- d_{dp} is the distance between the top of the die and the top of the ALS package
- d_{apc} is the distance between the top of the ALS package and the enclosure
- t_{pc} is the thickness of the plastic case

For the FN package, d_{dp} is 0.25 mm. The distance between the top of the package and the plastic case will depend on several factors including the solder thickness.

Cosine Response

The response of the ALS device is dependent upon the angle of the light entering the package. For a package in open air, the maximum viewing angle is 180 degrees or ±90 degrees from the optical axis of the device. Figure 4A shows the variation in response, as a function of the angular displacement, for the TSL2581, in the FN package. Figure 4B highlights the truncated portions of the device response if the aperture reduced the effective viewing angle to ±45^{O}.

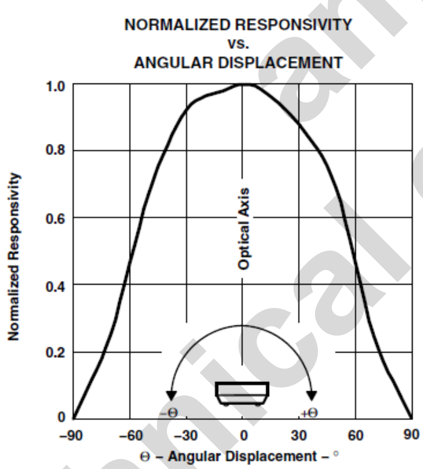


Figure 4A. TSL2581 Normalized Responsivity vs Angular Displacement

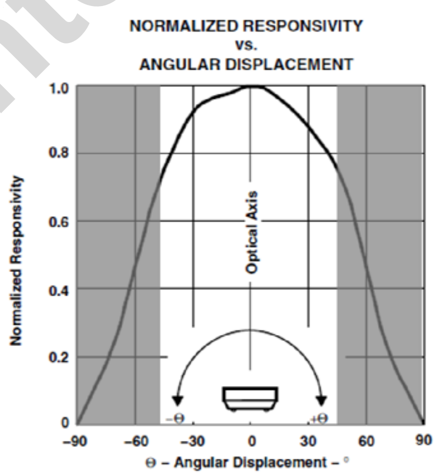


Figure 4B. TSL2581 Truncated Response due to ±45^{O} viewing angle.

This response can be estimated as a cosine function giving us a method to estimate the relative available energy as a function of the viewing angle of the device.

Spherical Response

The reduction in the amount of light due to an aperture can be modeled as a reduction in the surface of a sphere of unit radius enclosing the device. The surface of a sphere can be calculated as:

$$\int_{-\pi}^{\pi} \int_{0}^{\theta} \sin\theta' \, d\theta' \, d\phi$$

ϕ is the circular angle which goes for $-\pi$ to $+\pi$. The angle θ is the variable related to the half-angle of the opening. For a circular opening, this becomes:

$$2\pi \int_{0}^{\theta} \sin\theta' \, d\theta'$$

The cosine response must be included to the calculations yielding:

$$2\pi \int_{0}^{\theta} \cos\theta' \sin\theta' \, d\theta' \qquad = \pi \sin^2\theta$$

Since we are dealing with relative response, π can be dropped.
For a square sensor in open air, the maximum response = $\sin^2(90) = 1.00$

Design Example

The following shows an example of the mechanical design of a sensor.

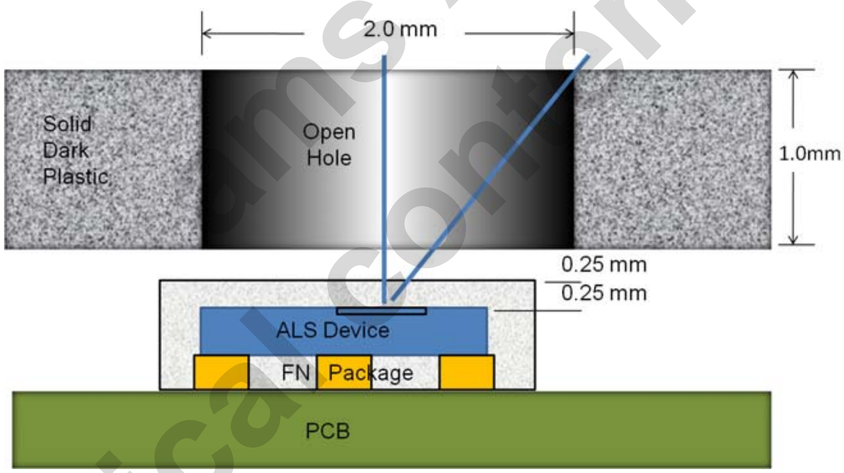


Figure 5. Example of an Aperture

Calculations then follow as:

$\tan(\theta) = d_a/2 \, / \, (d_{dp} + t_{pc} + d_{apc}) = 1 \, / \, (0.25 + 1 + 0.25) = 0.667$
$\theta = 34°$

The reduced response would then be: $\sin^2(34°) = 0.31$

In this design example, the smaller viewing angle reduced the available light energy to ~ 31%.
Simulation results for the same setup show a reduction in the available light energy to ~ 30%.

Aperture Impact

A table of calculated results is shown below indicated the amount of light reduction as a function of the aperture.

Half Angle	45°	30°	20°	15°
% Light Energy	50%	25%	12%	6.7%

As seen from the calculations, the light is greatly reduced for angles greater than 30°. For the TSL2561 with the rectangular sensor, it is recommended that the edge of the active area of the sensor be at least 0.5mm away from the edge of the aperture.

Mechanical Tolerances

The mechanical tolerances include the device location on the PCB, the PCB placement and the aperture location. The following shows an example the various tolerances and the total possible error.

Table 1. Optical Window Mechanical Tolerances Design Considerations

Description	Tolerance
Active area placement in a package	±0.08 mm
Package placement on PCB*	±0.15 mm
PCB placement in case*	±0.15 mm
Aperture location in the case*	±0.12 mm
Total	±0.5 mm

*Assumptions dependent upon application

It is recommended that the aperture be widened by the amount of the tolerances. If the tolerances are normally distributed, they can be added as the square root of the sum of the squares. For the above example, this would reduce the total error to ±0.26mm and the aperture should be widened by 0.52mm.

Viewing Area

While the sensor is not focused and only sees a burred version of the environment, the best was to get an intuitive feel is with a photographic equivalent. The following shows a photographic equivalent of the sensor with different apertures.

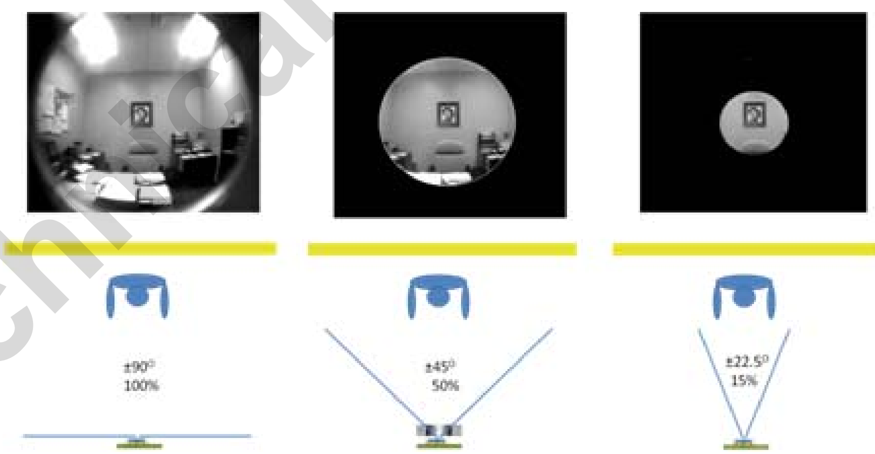


Figure 6. Photographic Equivalent of Viewing Window

With the "fish-eye" view, the sensor sees the entire room and may be overwhelmed by the bright ceiling lights. With the narrow view, the sensor is not able to average enough of the information and the reading will be heavily dependent upon the object directly in front of the view port. The correct answer will depend upon the application and human factors involved.

Light Pipe

If the ALS device does not have sufficient viewing angle, then a light pipe should be considered. When a light pipe is used, the light present at the aperture can be efficiently channeled allowing the ALS to be more conveniently located on a PCB with other components. The light pipe can be injection plastic molded and made of several possible materials.

In the light pipe, the window material should have high visible light transmission. The two ends and the side surface of the light pipe should be highly polished, and the contact points should be minimized since they can absorb light and result in some loss. The light pipe itself should be a clear cylinder, flush with the surface of the enclosure, and be in contact or in close proximity with the top of the ALS device.

Conclusions

It is recommended that the aperture be placed at the top of the display screen to reduce the possibility of shadowing the senor.

It is recommended that the viewing angle be greater than $\pm 30^{O}$. This limits the reduction of the light energy to 25% and allows a wider field of view.

The edge of the sensor should be at least 0.5mm away from the edge of the aperture.

A mechanical tolerance will increase the width requirements of the aperture.

If the aperture cannot meet the size recommendations or the device is too deep inside the enclosure, a light pipe should be utilized.