Ambient Light Sensors

Abstract

The purpose of an ambient light sensor is to simulate sensitivity to the human eye. A good ambient light sensor must possess two important characteristics: a good electromagnetic spectrum response and accuracy. This application note intends to discuss characteristics of an ambient light sensor and its implementation considerations.

Contents

List of Figures

Browse Products

- Ambient Light Sensors

1. Overview

Light is electromagnetic radiation with a wavelength that is visible to the human eye (see Figure 1). Ambient light is defined as the visible portion of the electromagnetic spectrum. However, not all light is visible. Both ultraviolet spectrum and the infrared spectrum are considered wavelengths of light, yet are not within the frequencies that the eye can see. Within the visible spectrum, the human eye does not see all colors equally. A typical human eye is most sensitive to yellowish-green light, with sensitivity centered around 550nm. While scientifically, the optical spectrum is defined between 380nm and 770nm.

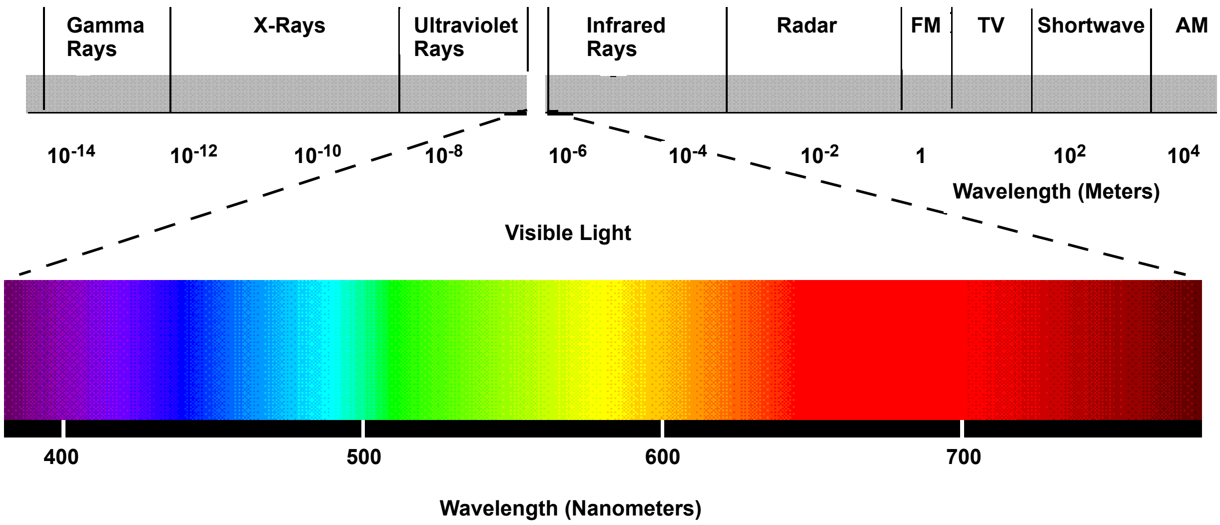


Figure 1. The Electromagnetic Spectrum

Ambient light is the surrounding environmental light that is everywhere - equally intense and with no directionality. Even though the light is equally intense, the brightness can vary greatly. The measurement of the amount of visible light illuminating a point on a surface is called a Lux. Typical Lux values are given in Table 1. An ambient light sensor must be sensitive over the same range of intensities. The ambient light sensor is asked to operate beyond these extremes, especially on the dimmer side. It is not unusual that a sensor be placed inside a device where it only receives a fraction of the ambient light.

The light sources in Table 1 can emanate from different sources. An Ambient Light Sensor (ALS) must be sensitive to the different frequency ranges of these sources. A plot of the frequency composition of different light sources is given in Figure 2.

Table 1. Typical LUX Values for Common Brightness Levels

Direct Sunlight	100,000 to 130,000 Lux
Full Daylight	10,000 to 20,000 Lux
Cloudy Day	1,000 Lux
Office Lights	300 to 500 Lux
Candle Light	10 Lux to 15 Lux

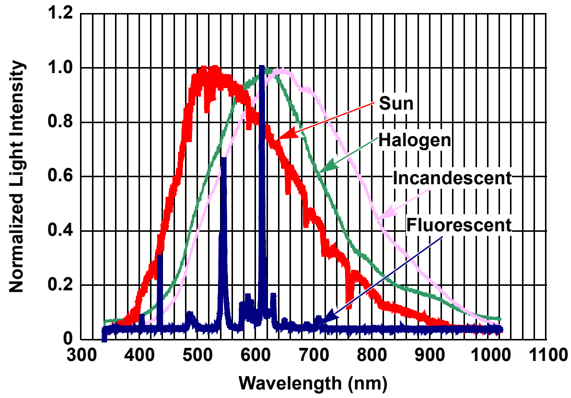


Figure 2. Frequency Composition of Different Light Sources

2. Principle of an Ambient Light Sensor

Most light source emission is composed of both visible and infrared spectrum content. A light sensor must be able to detect a broad range of frequencies to handle both spectrum contents. The standard photo detector implemented using typical CMOS process that detects mostly infrared radiation (peak sensitivity at 880nm) can cause false readings as to the real ambient visible conditions. Instead of trying to detect every bit of energy at every wavelength, a good ambient light sensor closely mimics the human eye spectrum response.

Ambient light sensors developed by Renesas have a spectral response ranging from 350nm up to 1100nm with the peak sensitivity around 560nm. This peak is nearly identical to the maximum spectral sensitivity of the human eye. These ambient light sensors are implemented using standard CMOS process to be cost effective, but they use special chip structures and proprietary optical filter layer arrangement to shift the peak sensitivity and to suppress as much infrared radiation as possible. The degree of matching between the spectral sensitivity of the sensor and the human eye curve is one of the most important indicators for the performance of a ambient light sensor product. The result of a Renesas ALS spectrum response is shown in Figure 3.

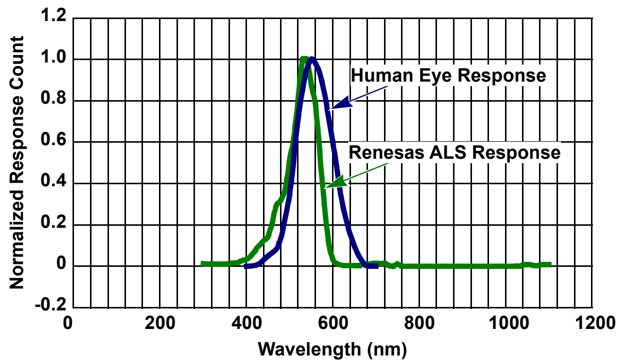


Figure 3. Renesas ALS Has Ideal Spectral Response with No IR Sensitivity

Renesas offers product families to cover various ambient light sensing applications for different light intensity environments, from direct sunlight as high as 130,000 Lux, to low light intensity, like 0.1 Lux. The products are available with an analog current or voltage outputs proportional to ambient light or with a digital output. The Renesas ambient light sensor digital output branch includes products that integrate ADC and I^2C interface, providing 15-bit effective resolution while rejecting 50Hz and 60Hz flicker noise caused by artificial light source.

2.1 Mechanical Design Considerations

To ensure accurate light sensing operations, you must give detailed attention to the mechanical designs around the light sensor. The cover glass required in most applications can act as a lens for the ambient light. The cover glass window dimensions, placement relative to the light sensor, glass material, and glass coating are critical factors in determining the final light sensing results.

2.2 Cover Glass Density/Reflective Index

In most applications, a cover glass is required on top of the light sensor to protect it from the environment. The flat surface glass which acts as a lens, (the viewing angle) is a function of the refractive index of the plastic material. A more dense material (higher refractive index) has a less effective viewing angle. Snell's law states that when a light ray strikes at an angle and continues through a more dense material (plastic), the light bends towards the norm of the surface of the more dense material (see Figure 4).

Consequently, a less dense medium has a wider viewing angle than denser material. As an example, a plastic with refractive index of 1.57 has a limited viewing angle of less than 80° (see Figure 4). On the other hand, a glass with an index of refraction of 1.3 has a 101° viewing angle.

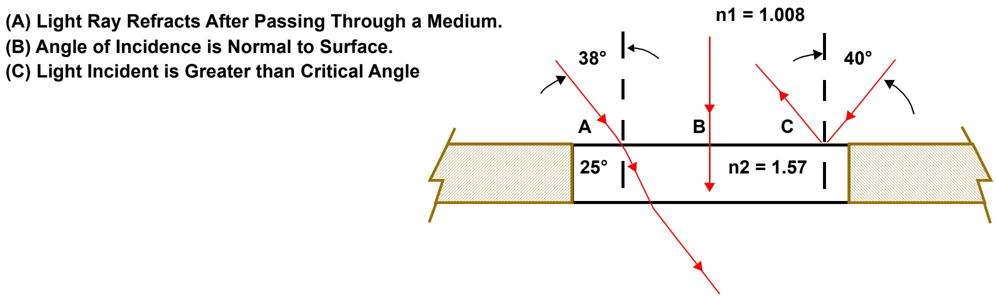


Figure 4. Flat Surface Lens.

2.3 Cover Glass Window Placement

A window lens can limit the viewing angle of an ambient light sensor. The window lens should be placed directly on top of the device. The thickness of the lens should be kept at a minimum to minimize loss of power because of reflection and absorption of energy in the plastic material. Renesas recommends using a thickness of t = 1mm for a window lens design. The bigger the diameter of the window lens, the wider the viewing angle is of the ambient light sensor. Table 2 shows the recommended dimensions of the optical window to ensure both 35° and 45° viewing angles. These dimensions are based on a window lens thickness of 1.0mm and a refractive index of 1.59.

Table 2. Recommended Dimensions for a Flat Window Design

D_{TOTAL}	D1	D_{LENS} at 35° Viewing Angle	D_{LENS} at 45° Viewing Angle
1.5	0.50	2.25	3.75
2.0	1.00	3.00	4.75
2.5	1.50	3.75	5.75
3.0	2.00	4.30	6.75
3.5	2.50	5.00	7.75

t = 1 Thickness of lens
D1 = Distance between the ALS sensitive area and inner edge of lens
D_{LENS} = Diameter of lens
D_{TOTAL} = Distance constraint between the ALS sensitive area and lens outer edge

Note: All dimensions are in mm.

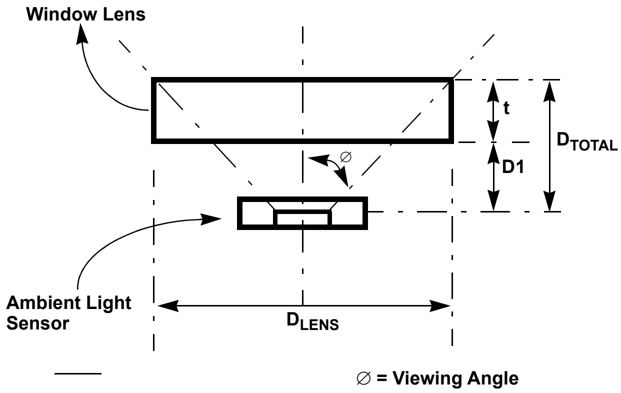


Figure 5. Flat Window Lens

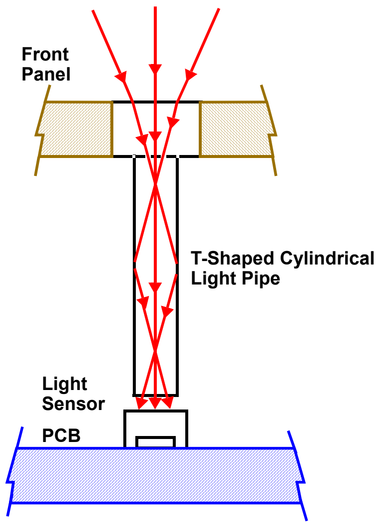


Figure 6. T-Shaped Light Pipe to Direct Surface Light to the Light Sensor

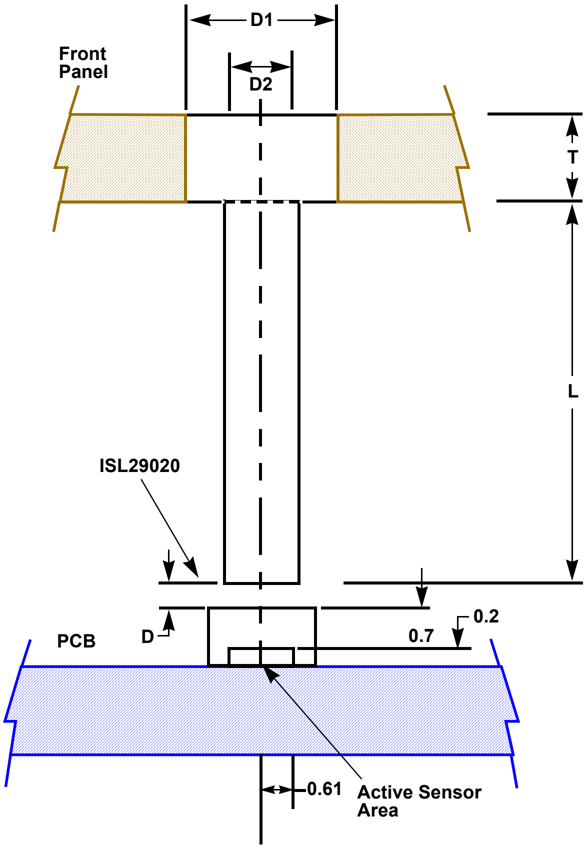
See AN1782 for a detailed discussion on window design.

2.4 Optical Enhancement - Light Pipe

If a smaller window is required, a light pipe can maintain a wide effective viewing angle. A light pipe provides a method for transmitting the ambient light from the surface of a panel to the light sensor mounted on the PCB. A light pipe is commonly a cylindrical piece of transparent plastic which makes use of total internal reflection to trap and focus the light onto the light sensor. Renesas recommends implementing a light pipe when the PCB is more than 5mm away from the front panel. The light pipe minimizes the window diameter and the light pipe with proper geometrical design aids in the effective viewing angle of the system.

The diameter of a T-shaped light pipe, D1, determines the capture area for the beam of light. It does not determine the viewing angle of the system.

D2 should be wide enough to cover the entire sensor area. For a typical ambient light sensor, D2 should be at least 1.5mm. T is the thickness of the window and should be as minimal as possible to avoid reflection losses. L, the length of the pipe, should be long enough such that D is at most 1mm. The light pipe should be placed directly on top of the light sensor, as shown in Figure 7. D is the distance of the sensor to the end of the light pipe.



D1: Diameter of the Window
D2: Diameter of the Light Pipe
D: Distance from Sensor to End of Light Pipe
L: Length of Light Pipe
T: Thickness of the Window

Figure 7. Window and Light Pipe Design

2.5 Light Pipe Optical Material

Renesas recommends using polycarbonate or an optical grade acrylic for the material of the light pipe assembly. The suggested plastic material for use of a light pipe is available from Bayer AG and Bayer Antwerp N.V. (Europe), Bayer, Corp. (USA) and Bayer Polymers Co., Ltd. (Thailand).

Table 3. Suggested Plastic Materials

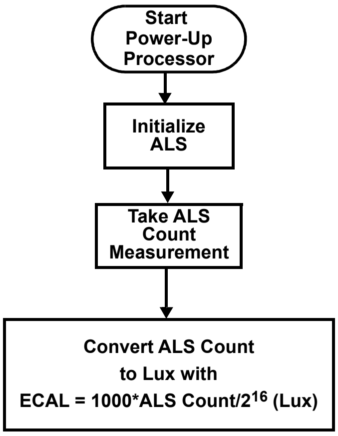
Product Number	Transmitivity (%)	Refractive Index
Makralon LQ2647	87	1.587
Makralon LQ3147	87	1.587
Makralon LQ3187	85	1.587

2.6 Algorithm to Convert ALS Output to Lux Reading

When the electrical and mechanical design considerations of an ambient light sensor are determined, you should test your light sensor in your product scenario. The designer needs to employ an algorithm to convert the light sense digital output into a Lux reading. The algorithm used depends on factors such as any obstructions to the light path and type of glass covering the sensor. Obstructions to the light path diminish the light reading and must be dealt with on a case-by-case basis.

2.7 Transparent Cover Glass - No Coating

Transparent cover glass passes all frequencies of light without any attenuation. Therefore, the algorithm to translate the output into Lux is quite straightforward (see Figure 8).



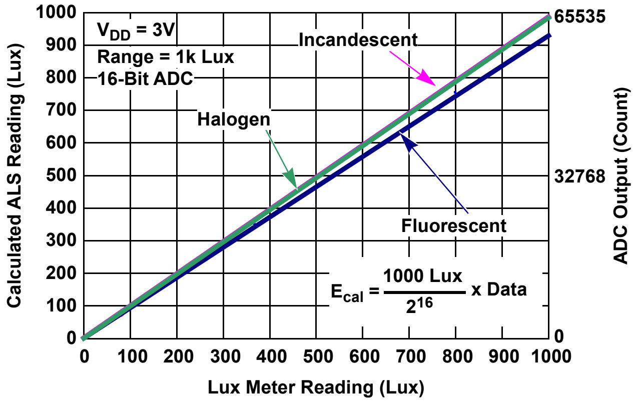


Figure 8. Case 1: Algorithm for Ambient Light Sensing (ISL29020) with Transparent Glass

The output of the ambient light sensor is linear with respect to incoming Lux, no matter what type of source is generating the light. This is expected because no filtering of the light is occurring. The Lux can be calculated as a direct proportion to the output reading.

2.8 Filtering Cover Glass - With Glass Coating

The material, coating and printing of the glass, window opening, and the location of the sensor have great impact on the ambient light sensor sensitivity range. Figure 9 shows an example of the spectrum response of a typical cell phone cover glass. This cover glass has large visible spectrum attenuation and passes 80% of the IR spectrum.

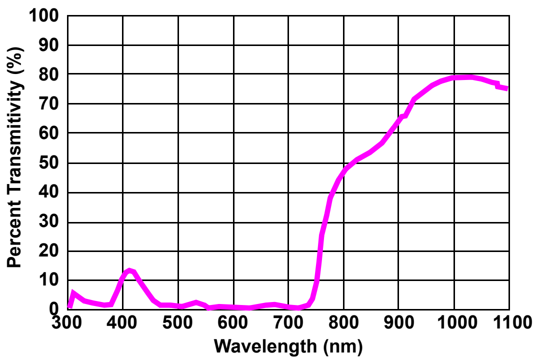


Figure 9. Spectrum Response of a Worst Case Cover Glass

Figure 10 shows the ALS and IR spectrum response of the ISL29020. The ISL29020 ambient light sensor (ALS) spectrum response rejects most of the IR content and the IR sensor has excellent sensitivity.

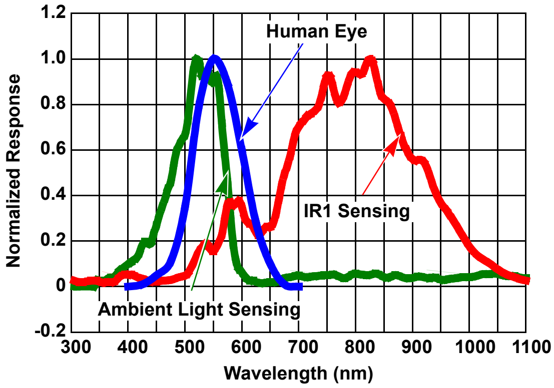


Figure 10. Spectrum Response for Ambient Light Sensing

As discussed previously, various light sources have various spectrum content. As a result, the ALS and IR output results can vary depending on the light source and the spectrum characteristics of the cover glass. The ambient light sensing results are shown in Figure 11. Various techniques can be applied to compensate for the inaccuracies due to the IR content.

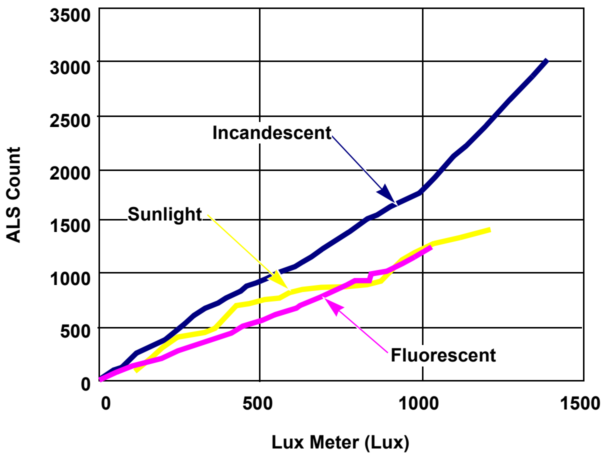


Figure 11. Ambient Light Sensing Results with Glass that Passes the IR Spectrum and Blocks Out Visible Spectrum

3. Revision History

Rev.	Date	Description
1.00	Nov.5.20	Applied Renesas template. Added Revision History

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