Overlay Considerations for the Si114x Sensor

1. Introduction

The Si1141/42/43 infrared proximity detector with integrated ambient light sensor (ALS) is a flexible, high-performance solution for proximity-detection applications and (visible) ambient-light sensing challenges. The sensor is most commonly used under a glass or plastic overlay whose optical properties modify both the ALS response and the proximity-detection distance. The Si114x can also function through slotted optical ports or other apertures. This causes a certain amount of attenuation of transmitted LED power and received proximity and ALS light levels.

An overlay (used with or without a slot opening) has the following effects:

- Reduced incoming light for both ALS and proximity detection due to the cover material.
- A slight reduction of the Si114x's effective view angle due to the cover material's thickness (unless the cover is spherical).
- Reduced transmitted LED power.
- Changes in the system's spectral response compared with an uncovered Si114x.

This application note gives examples of common overlay materials with various spectral characteristics and discusses their influence on ALS and proximity detection. For other system and mechanical considerations, including emitter-to-receiver optical isolation, refer to “AN498: Si114x Designer’s Guide”.

2. Typical Application

Typically, the Si114x is configured to detect the proximity of an object to be detected, such as a user's hand, and may also need to report ambient light for the purpose of screen dimming. In addition to the photodiode used for proximity detection, the Si114x makes use of two photodiodes with different spectral responses for ALS. This scheme enables sensing of the visible light while rejecting infrared light, which is present in large amounts in incandescent light sources and in sunlight.

Infrared light affects the response of both ALS photodiodes to different extents. Rejection is accomplished by summing the two outputs with different coefficients so that information about visible light is obtained. The choice of coefficients varies depending on the cover material's spectral characteristics in the visible and infrared bands.

Proximity sensing is affected by the cover material's transmission characteristics at the LED wavelength (typically 850 to 950 nm). Since ambient light affects the performance of proximity detection, proximity detection can be enhanced by rejecting as much of the non-LED spectrum as possible; this is because more ambient light forces the Si114x’s ADC to operate at a less sensitive gain range in order to avoid saturation. Thus, the function of an integrated ALS and proximity sensor depends on a compromise between favoring IR light at the LED wavelength for proximity and allowing enough visible light for proper ALS operation. This trade-off depends on the cover material selected.

3. Common Overlay Materials

The main products used for optical cover are acrylic glass (Perspex®, Plexiglas®, etc.), polycarbonate (Lexan™, Makrolon®, etc.), and tempered glass. The advantages of acrylic glass are that it is inexpensive and readily available in sheet form, and it is easy to cut or drill. Polycarbonate is more resistant, less prone to scratching, and more aesthetically pleasing, and it is typically molded rather than machined. It is superior to acrylic in high-end and/or high-volume products. Both acrylic glass and polycarbonate are fairly transparent to IR light, unless they are tinted, and both stop UV light to varying extents depending on processing. Tempered glass is the material of choice for high-end products. It cannot be tinted; so, ink must be screen printed on it in order to obtain the desired tint.

4. The Need for Opaque Covers

A product cover is often required to hide the electronic components for aesthetic reasons. A completely opaque material is not necessary, nor is it desirable if ALS is required. A dark-gray tint that passes about 5 to 10% of visible light is normally sufficient and allows accurate ALS measurements. At the same time, IR transparency is desirable for proximity detection. Bayer's Makrolon® with color #750359 and Sabic's Lexan® with color #71509 represent ideal combinations. Other colors may be selected, each requiring a different trade-off between ALS and proximity detection.

Another option for opaque color is to silkscreen an opaque ink over clear polycarbonate or tempered glass. Their less-than-perfect cutoff characteristics are advantageous with respect to the visible-to-infrared balance needed for simultaneous ALS and proximity detection. Screen ink manufacturers include Nazdar, Seiko Advance Ltd., and Teikoku Printing Inks Mfg. Co., Ltd. Figure 1 shows an approximate spectral response of a single layer of Teikoku's MRX IR Black on clear polycarbonate. Many other combinations of visible color and infrared transparency are available from ink vendors.

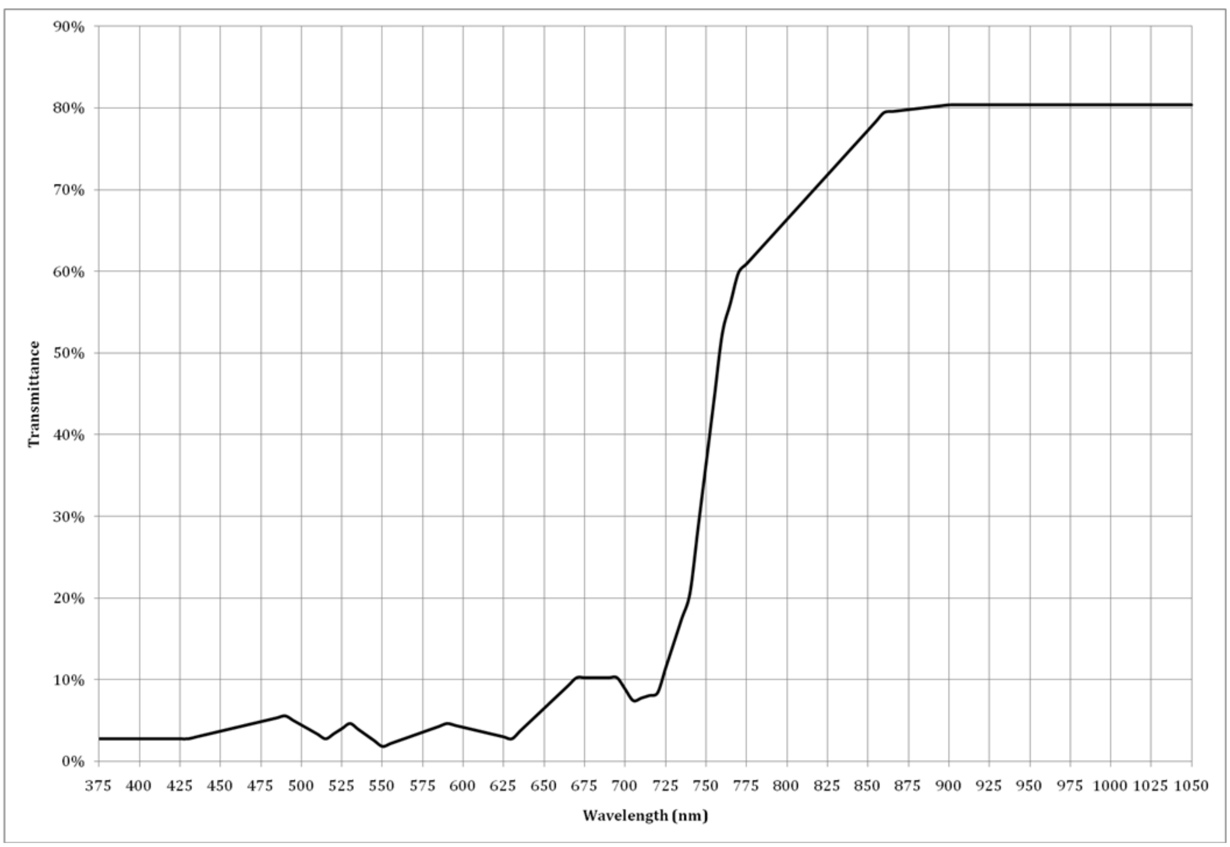


Figure 1. Spectral Response of Teikoku's MRX IR Black Ink, Single Layer over Polycarbonate

5. UV Stabilization

In high-end products where aesthetics are of primary importance, UV stabilization is desirable in order to prevent yellowing of a clear window. When a dark cover is selected, UV stabilization is of negligible value and can normally be dispensed with.

6. Evaluation of Various Materials and Colors

Table 1 summarizes various material and color selections along with ALS coefficients and expected ALS and proximity performance. The ALS reading in lux is given by the following equation:

$$\text{Lux level} = \Big[\ [(\text{ALS visible reading}) - (\text{ALS visible dark reading})] \times (\text{ALS visible coefficient}) + [(\text{ALSIR reading}) - (\text{ALS IR dark reading})] \times (\text{ALS IR coefficient})\ \Big] \times \text{gain correction}$$

This assumes a completely open field of view. In practice, an additional correction is needed to account for apertures and for the slight loss of Si114x viewing angle, which depends on the cover material's thickness. This single “gain correction” factor is adjusted empirically once the product is assembled. Proximity performance assumes the LED and the Si114x are under the same overlay. Contact Silicon Labs for support on the use of other cover materials.

Other assumptions for the above formula include the following:

- Small IR photodiode used for ALS (ALS_IR_ADCMUX = 0)
- Gain of 1 for both ALS channels (ALS_VIS_ADC_GAIN = ALS_IR_ADC_GAIN = 0)
- Normal sensitivity ranges for both ALS channels (VIS_RANGE = IR_RANGE = 0)

If any of the above are modified, the ALS coefficient for the respective channel must be scaled accordingly. Refer to the Si114x data sheet for more details on the effects of changing the above settings.

In practice, the above settings must be changed in order to obtain the best resolution possible for the maximum expected ambient light. Careful attention must be given to the amount of infrared light present in various light sources, e.g. incandescent light can saturate the IR photodiode with a much lower lux level than fluorescent light. Refer to the Si114x data sheet for sensitivity data.

If the overlay being considered is not described here, it is possible to determine ALS coefficients by prototyping the product and recording each ALS photodiode's response to two different light sources. Coefficients can then be adjusted so as to give the same lux value for both types of lamp. At Silicon Labs, best results were obtained using a rough-service, low-wattage incandescent light bulb with a color temperature of 2500 K (Westinghouse 03952 or equivalent) and a broad-spectrum metal-halide lamp with a color temperature of 6500 K and CRI (color-rendering index) of 96 (Iwasaki M150P36SD or equivalent). The lamps must be calibrated using an illuminance photometer. Incandescent bulbs must be allowed to stabilize for at least one minute after turning on. Metal-halide lamps typically require 15 mn of warm-up time. Narrow-spectrum lamps, such as tri-band fluorescents (including compact fluorescent bulbs), are not recommended for the computation of ALS coefficients.

Coefficients can be scaled to account for different gain settings. In general, it is best to set the infrared and visible ALS gains to the highest ranges that will not be saturated under the expected light conditions. However, if power consumption is critical, a lower gain setting may be desirable because the measuring time is proportional to the gain. On the other hand, in an application that also requires proximity detection, power consumption is usually dominated by the LED current.

Lux computation using photodiode coefficients may be prototyped with various non-standard overlays using the Si114x Control Panel. Refer to “AN576: Si114x Control Panel Application User's Guide”, Section 7.1.4 “Making Accurate Lux Measurements” for more details.

Table 1. Material and Color Selections

Material	Color	Visible-Light Percentage	ALS Visible Coefficient	ALS IR Coefficient	Proximity Distance Scaling[1,2]	Proximity Distance Scaling[1,3]
No cover	N/A	100%	5.41	–0.08	1.0 (reference)	1.0 (reference)
Acrylic Glass	Clear	95.7%	6.33	–0.094	0.96	0.96
Acrylic Glass	2074 gray ("12% transparent")	8.1%	76.4	–1.49	0.26	0.3
Polycarbonate	Makrolon® 2405 (clear)	93.5%	5.86	–0.089	0.94	0.94
Polycarbonate	Makrolon® 2407 (clear, UV-stabilized)	91.4%	6.616	–0.101	0.93	0.93
Polycarbonate	0.08" Makrolon® 750359 (gray + IR)	2.5%	109.3	–2.32	0.9	0.9
Polycarbonate	0.1" Lexan® 71509 (gray + IR)	3.1%	66.7	–1.463	0.91	0.92
Polycarbonate	Teikoku MRX IR Black screen ink, one layer	3.9%	111	–1.944	0.82	0.86
Tempered Glass	Teikoku GLS-HF 10415 SIL IR Black[4]	2%	239.3	–3.968	0.45	0.5
Tempered Glass	Teikoku GLS Gray screen ink, one layer	9%	57.97	–1.032	0.8	0.85
Various	90% infrared filter	0%	N/A	N/A	0.9	0.9
Various	80% infrared filter	0%	N/A	N/A	0.8	0.8

Notes:

1. The reflected light power is usually inversely proportional to the square of the distance. Distance derating does not take ambient light or internal reflection into account. Ambient light rejection improves proximity-detection performance. Lack of optical isolation and internal reflection will also degrade proximity detection, depending on the distance, separating materials, reflecting surface (i.e. the inside face of the overlay), etc. Refer to "AN498: Si114x Designer's Guide" for more details.
2. Using an 850 nm infrared LED.
3. Using a 950 nm infrared LED.
4. Preferred solution for Si114x.

Document Change List

Revision 0.1 to Revision 0.2

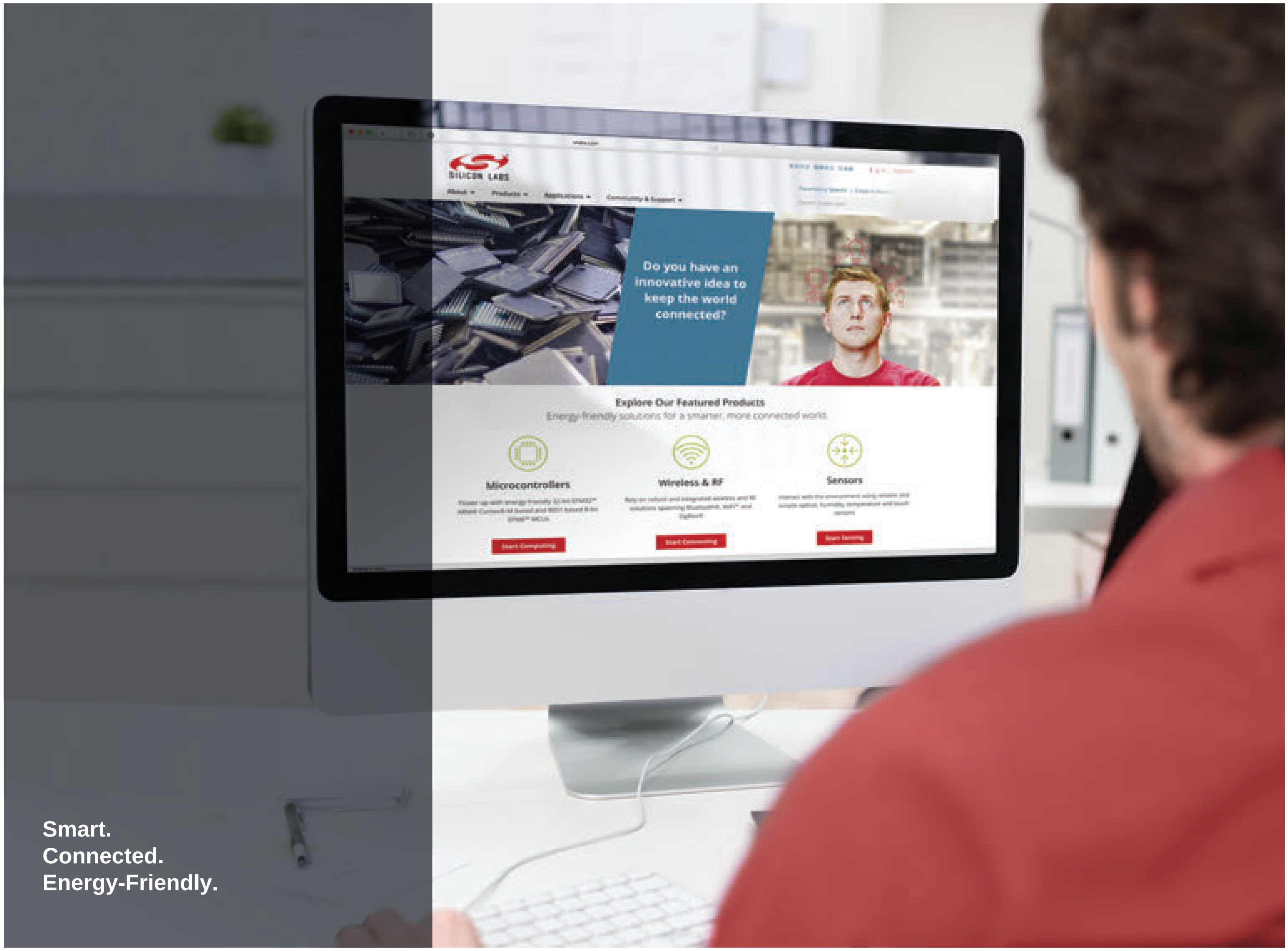
- Updated Figure 1 on page 2.
- Updated Equation on page 3.
- Updated Table 1 on page 4.

Revision 0.2 to Revision 0.3

- Details added for ALS formula assumptions.
- Custom Teikoku ink mix added.
- Coefficient table updated.
- Register setting discussion added.

Revision 0.3 to Revision 0.4

- Added reference to AN576 for lux computations.



Products
www.silabs.com/products

Quality
www.silabs.com/quality

Support and Community
community.silabs.com

Disclaimer

Trademark Information

SILICON LABS

Silicon Laboratories Inc.
400 West Cesar Chavez
Austin, TX 78701
USA

http://www.silabs.com