APPLICATION NOTE

APM-16D24-310-DF8/TR8 Application Note

1. Introduction：

The APM-16D24-310-DF8/TR8 is a digital I2C interface sensor which integrates Ambient Light Sensor (ALS), Proximity Sensor (PS) and Infrared LED (IR LED). The ALSs can sense ambient light intensity that match the human eye's response and enable the device to implement display dimming or lighting brightness control functions, helping to reduce power consumption. PS using IR LED reflection to detect the away or close to the object then trigger device turning on/off or specific function.

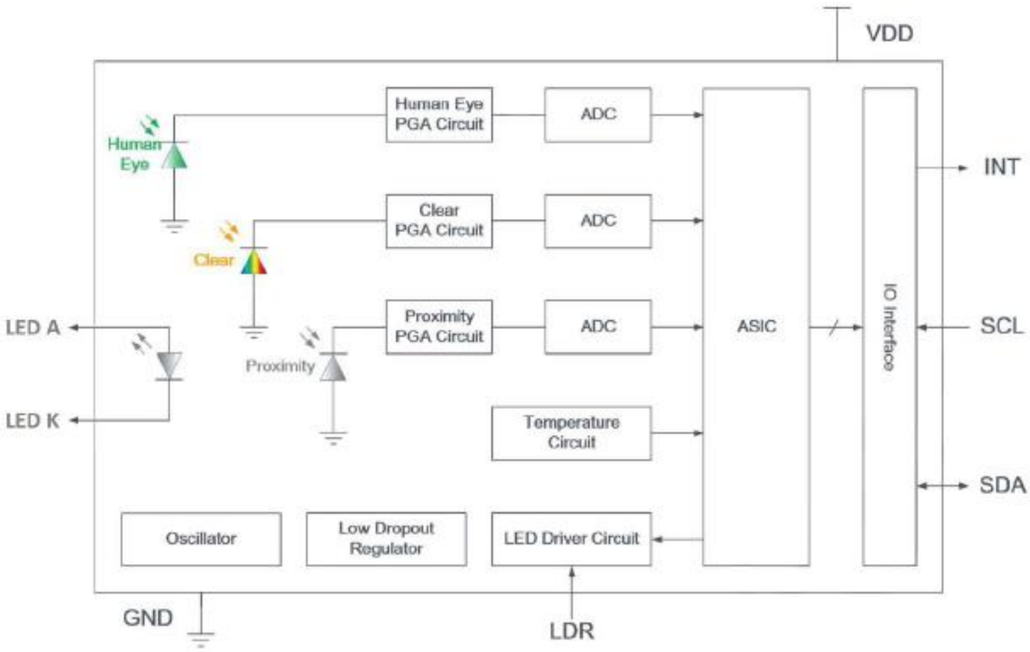


Figure 1. APM-16D24-310-DF8/TR8 internal block diagram

2. Ambient Light Sensor：Illuminance Transformation

The earth is filled with electromagnetic waves of various wavelengths, which can be classified into Ultraviolet (UV), visible light and infrared (IR) depends the wavelength from short to long. The illuminance is defined by human eye visible electromagnetic spectrum and its wavelength is between 380nm~770nm, and ALS is mainly detecting the electromagnetic wave intensity of this wavelength range.

Figure 2, electromagnetic wave wavelength classification

In the visible light band of 380nm~770nm, the human eye is most sensitive to green light of 555nm wavelength in brighter environments. Assume other visible wavelengths light produce the same brightness as the 555 nm light, required luminous flux is X(λ). Then the ratio of the luminous flux of 555 nm to the other wavelength X(λ) produces a visual sensitivity function (refer to the human eye curve in Figure 3 below). The definition of illuminance need to refer to the visual sensitivity function. Different light sources will have different radiation intensities at different wavelengths. The ALS coating is not exactly same as the visual sensitivity function, so the ALS count values cannot be directly converted into the illuminance value (Lux). Due to the coating of ALS is fixed, so different spectral light sources may obtain different count values under the same illumination. If only use one conversion formula to convert illuminance value, the result will not be accurate enough.

There are three different photodiodes (PDs) build in APM-16D24-310-DF8/TR8. As shown in Figure 3 below, each PD responds to different spectra of light. This feature can be used to distinguish different light sources and derive different illuminance conversion formulas according to different light sources. It can solve the problem that different spectral light sources obtain different ALS count values in the same formula under the same illumination.

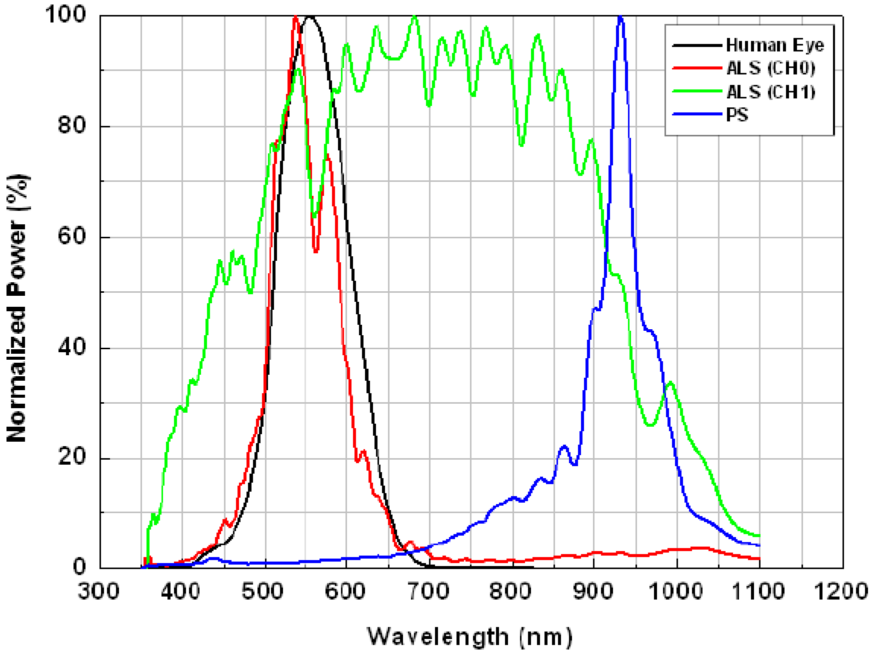


Figure 3. Spectral response of each PD of APM-16D24-310-DF8/TR8 and human eye

Convert the ALS count value into an illuminance(Lux meter) process as follows：

1. Prepare different light sources, such as white LEDs, fluorescent lamps, incandescent lamps, and standard light source D65, and standard parts (standard Lux meter), etc.
2. Use the first light source to irradiate both of the ALS and Lux meter at the same time, and record the reading value of the illuminometer Ev. Then appropriately adjust the settings of Register ALS_GAIN (0x04) and ALS_TIME (0x05), and record the value of ALS Registers CH0 (0x1C, 0x1D) and CH1 (0x1E, 0x1F). During adjusting procedures not only the maximum ambient illumination, but also ALS count saturated handling (reaches the highest value) should be considered.
3. The ratio of CH0/CH1 is R(1). This ratio is used to distinguish different light sources.
4. Calculation coefficient K(1) = Ev/CH0.
5. Illuminance conversion formula of this light source is CH0 * K(1) Lux. (K(n). (n is decided by how many light sources you prepared).
6. Change the second light source and repeat above steps 1~5 to obtain different ratios R(n) and coefficients K(n).
7. Combine the corresponding light source with the ratio R(n) and the coefficient K(n) to obtain the Lux conversion formula of different light sources.

The Figure 4 as below is the flow chart which shows how to convert ALS count value to illuminance.

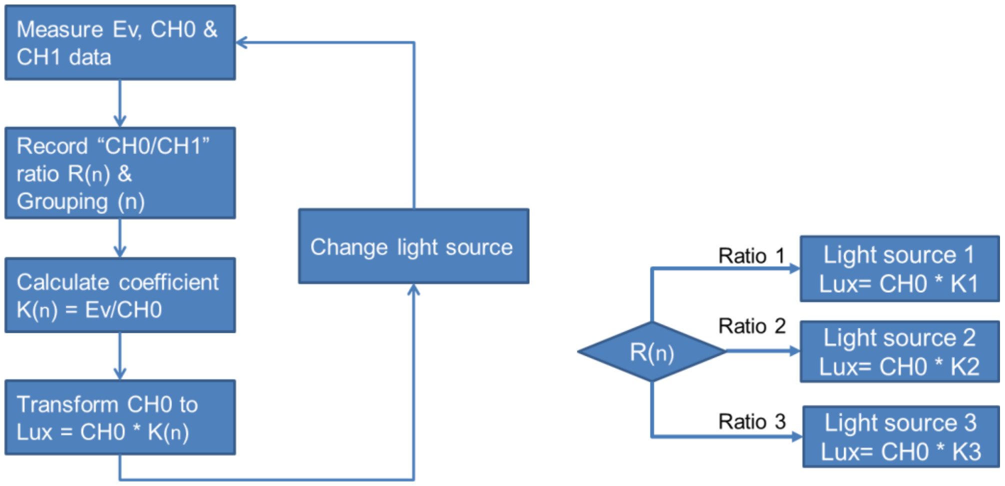


Figure 4. Flow chart for convert ALS count value to illuminance

- Setting light sources switching points should keep some margins between R(n) to distinguish the light source.
- Calculate coefficient K(n), its less than 2, which is recommended. If the K(n) value is too large, return to the second step to adjust the settings of the register ALS_GAIN (0x04) and ALS_TIME (0x05).
- Each APM sensor's coating and characteristic will be slightly different that cause the converted illuminance (Lux) value will have a variation. Therefore, if your application requires high accuracy, APM sensors individual calibration is necessary.
- Register 0x05(ALS_TIME) is for ADC Conversion time of ALS. The Large the value the integration time is longer and output resolution will be higher. The maximum value is 0xff, but as long as it is set to 0x3F, you can obtain the maximum output resolution of 16 bit (0~65535). Unless you need to measure very low brightness or ALS receiving light intensity is too weak due to the restricted by ID structure, otherwise you don't need to set the value above 0x3F. For more detail, you could refer to datasheet.
- Register 0x04(ALS_GAIN) is an adjusting the gain value of the ALS internal amplifier. (Usually, this value is set to 0x00, if the incident light is weak, it can be set to 0x01.) This setting does not increase the measurement time of the ALS.
- APM-16D24-310-DF8/TR8 has interrupted trigger function as well. If you need to use it, the detailed usage and register setting method can refer to the datasheet.
- It can be used program control to implement a de-bounce or smooth function to avoid flicker caused by rapidly changes in the ambient light.

3. Proximity Sensor

Proximity sensors are commonly used to detect distance between object and APM. The principle is using IR LED emitting infrared rays and PD detects the intensity of infrared light which is reflected from the object to decide the object distance. Refer to Figure 5 for the principle of proximity sensing (PS) operation.

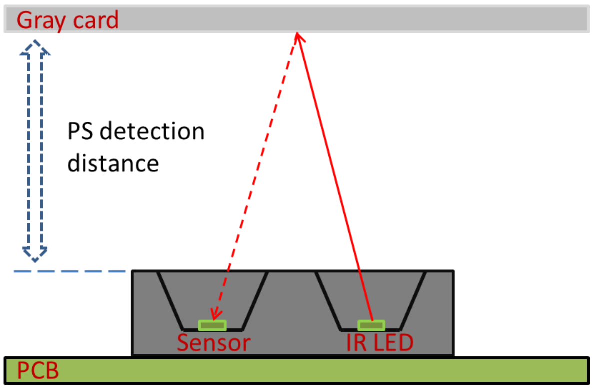


Figure 5. Schematic diagram of proximity sensing

There is also infrared interference in external environment. In order to avoid interference and consider power saving. Instead of continuously emitting IR signal, APM emits IR signal in pulses mode and APM compares the variation of reflected infrared intensity between there is IR emission and no IR emission, to determine whether the infrared intensity is caused by the object reflection or not. When the object is closer to the sensor, the PS count value will be higher. Record the difference distances of PS count value to draw distance vs count curve as Figure 6. Take Figure 6 as an example, the detect range is about 1cm to 7 cm.

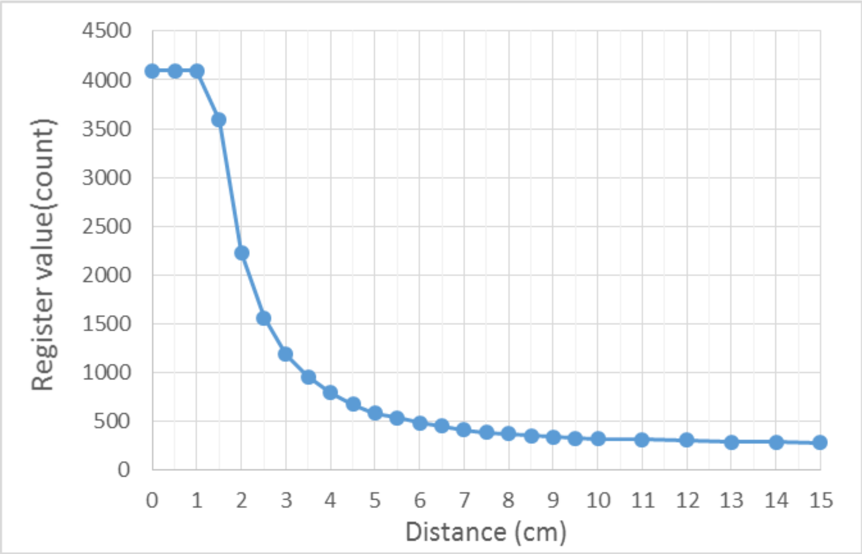


Figure 6. Object distance vs. Register value

- Different materials have different reflectance. More ~~a~~ dark or rough object surface is lower reflectance. The curves will also be different.
- Different register settings will result in different curves.

From Figure 6, it can be found that the PS count value is not zero when the detection distance is the farthest. The reason is, in most of application product designer does not want end users to see the APM, a translucent cover lens is usually added on top of the APM and this lens will cause internal reflection, so that APM will have a background noise. The gap between the APM and the lens also affects the performance of the PS. Referring to Figure 7, the gap between the APM and the lens also affect the performance of the PS. The gap should be short as possible to reduce internal reflection (cross talk).

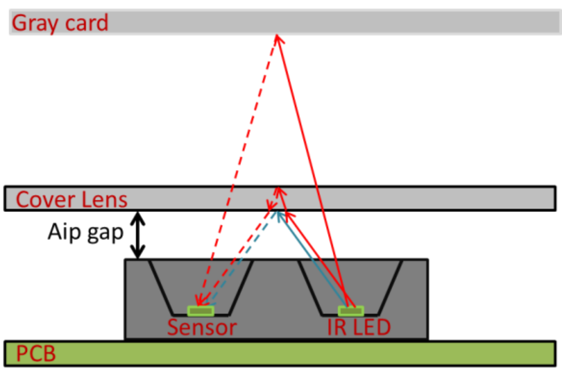


Figure 7. Internal reflections produced by cover lens

You can use registers as below to adjust parameters of PS performance, the registers are LED_CTRL (0x06), PS_GAIN (0x07), PS_PULSE (0x08), PS_TIME (0x09), PS_OFFSET_L (0x14) and PS_OFFSET_H (0x15), respectively. LED_CTRL and PS_PULSE are related to IR LED emission; PS_GAIN, PS_TIME, PS_OFFSET_L and PS_OFFSET_H are related to PD reception. The following is the description of the characteristics of the register:

- PS_GAIN is to adjust the gain value of the PS internal amplifier. The default value is 0. Generally, the value can be set to 0x00 or 0x01.
- PS_TIME is to set ADC conversion time of PS. The Larger the value the integration time of the register is longer and output resolution will be higher. The maximum value of PS_TIME is 0x0F and the maximum resolution is 12 bit (0~4095). The value is set to 0x0F (maximum resolution).
- The register LED_CTRL has two functions, the IR LED driving current controlled by bits 6 and 7, respectively, and the IR LED pulse width adjustment of bit 0~5. Figure 8 and Figure 9 show the PS response curve of different IR LED driving current and pulse width, respectively.

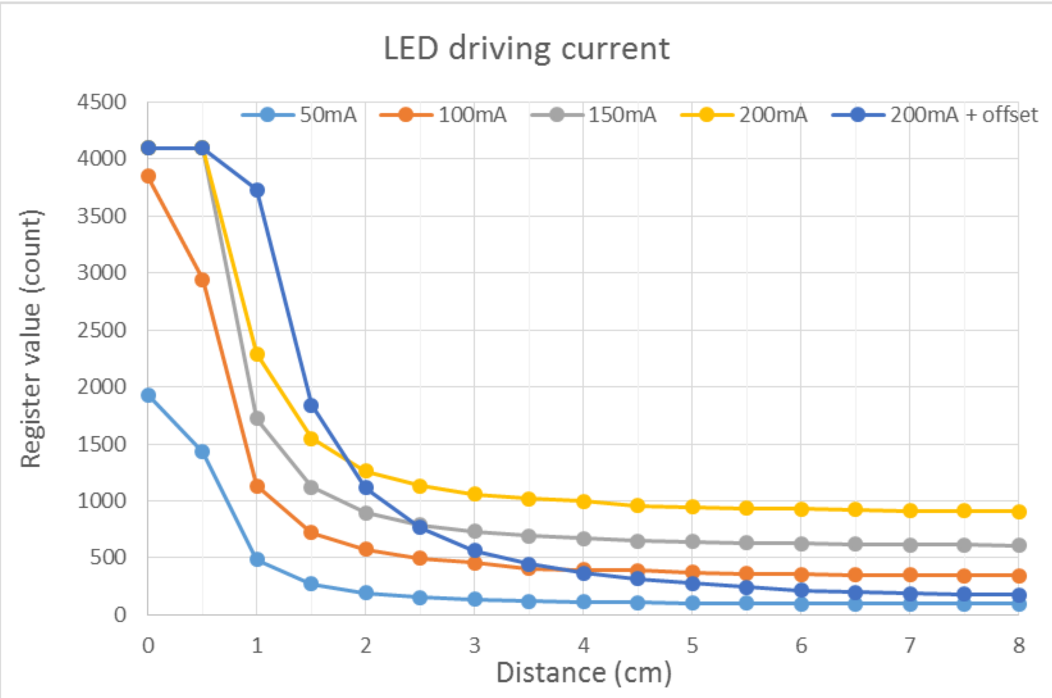


Figure 8. Adjusting the LED driving current

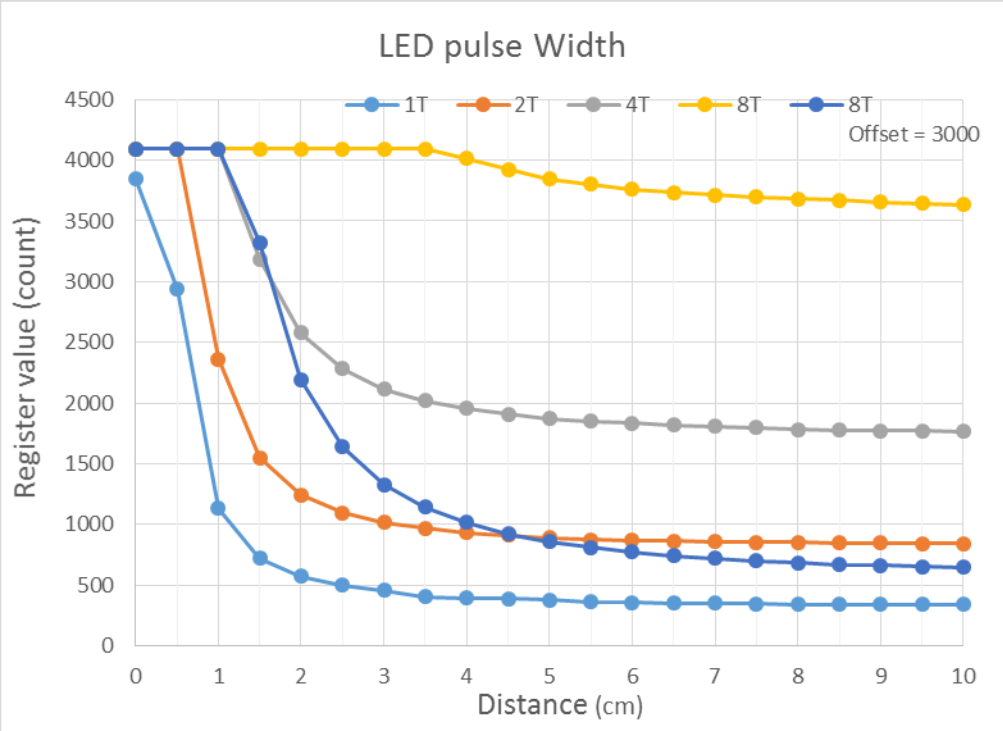


Figure 9. Adjusting the LED pulse width

- PS_PULSE is to adjust the number of IR PULSE emissions each cycle. The larger value will cause the detection cycle longer. Figure 10 shows the trend of the curve caused by the IR PULSE number.

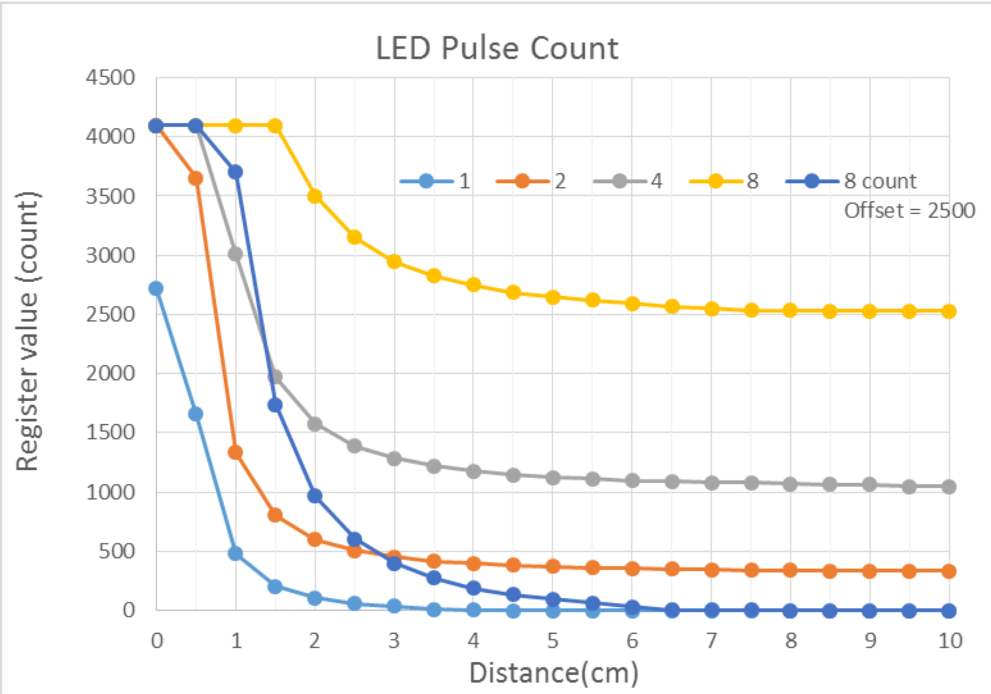


Figure 10. Adjust LED pulse count

● PS_OFFSET_L and PS_OFFSET_H are used to compensate background noise (including cross talk). Figure 8~10 shows the effect of adjusting the PS_OFFSET value. The set value is recommended to be slightly lower than the measured background noise value. If the setting is higher than the background noise value, the PS maximum detection distance will be shortened.

4. Suggestion of ID Structure

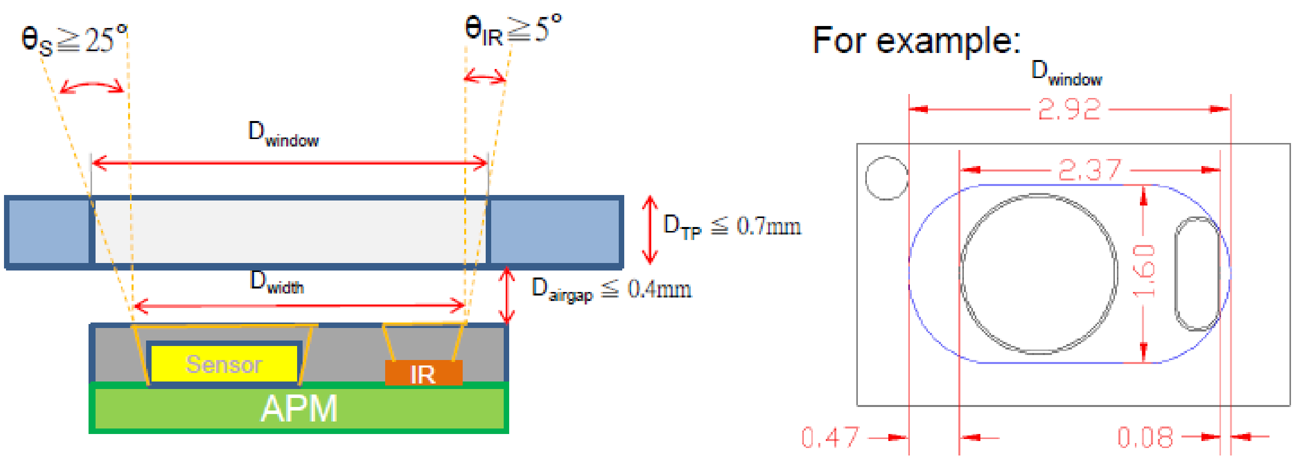


Figure 11. Optical Window Design

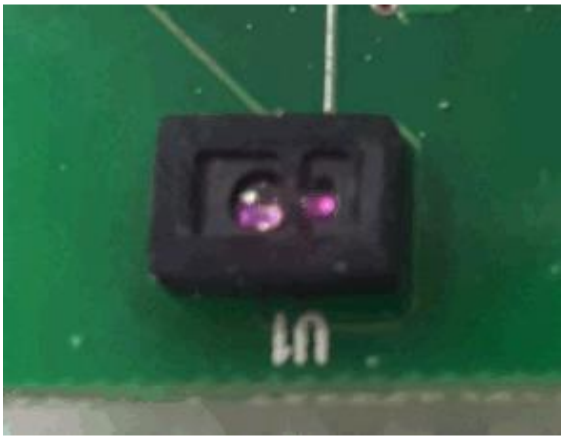
- Increasing D_{window} or shortening D_{airgap} or D_{TP} can improve the performance.
- D_{airgap} is recommended less than 0.4mm, D_{TP} is recommended less than 0.7mm.
- The calculation formula as below:

  $$\mathbf{D_{window} = \tan\theta_{IR} \times (D_{airgap} + D_{TP}) + \tan\theta_S \times (D_{airgap} + D_{TP}) + D_{width}}$$

- For example:

  If $\mathbf{D_{airgap}}$ = 0.3mm, $\mathbf{D_{TP}}$ = 0.7mm, $\mathbf{D_{width}}$ = 2.37mm, θ_{IR} = 5°, θ_S = 25°

  then D_{window} = tan25° x (0.3+0.7) + tan5° x (0.3+0.7) + 2.37 ≒ 2.92mm
- If cover lens is added, the higher transmittance rate is better. Recommend 550nm > 25%; 940nm > 85%。
- If the $\mathbf{D_{airgap}}$ is too large, add a soft rubber sleeve (Silicon cap) as shown in Figure 12 to increase the tightness and reduce the background noise.
- Figure 13 shows the Impact of D_{airgap} on APM.



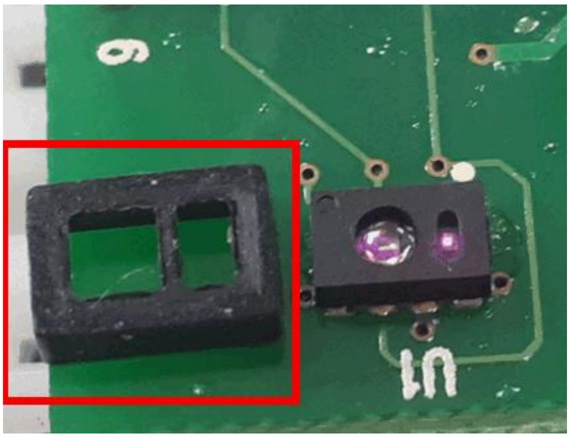


Figure 12, installation a soft rubber (Silicon cap)

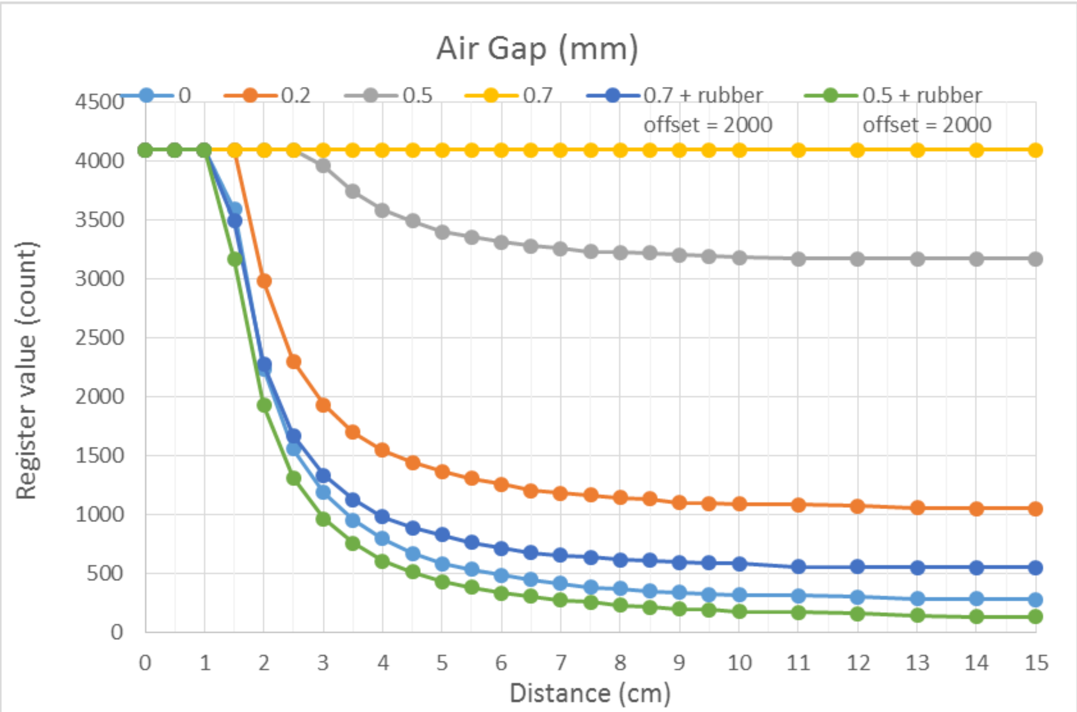


Figure 13. Influence of Air gap on APM

NOTICE

All shown measurement values and measurement diagrams are for reference only and do not represent guaranteed values! You are solely responsible for

(1) Selecting the appropriate EL products for your application.

(2) Designing, validating and testing your application.