APPLICATION NOTE

Digital ambient light sensor ALS-DPDIC17-78C/L749/TR8 application note

Introduction

Ambient light sensor (ALS) can sense light source similar to the human eye. ALS application product on, off or automatically are determined by light source information to reach the goal of power saving and safety.

Analog ALS has poor accuracy cause by adjust load resistance to set threshold value. Digital ALS is more accurate cause by read and write to registers through the I2C interface control by the Microcontroller Unit (MCU). Everlight's ALS-DPDIC17-78C/L749/TR8 has two sets of photodiode (PD) sensing elements with different spectrums in the package. Different light sources can be distinguished by the sensing different frequency spectrums, so higher accuracy can be achieved.

Optical window design

Regardless of whether the ALS is used indoors or outdoors, the ambient light is usually irradiated from above or diagonally above. Therefore, it is recommended that the direction of the window is upward first, followed by forward, and try to let the ambient light directly reach the ALS. Generally speaking, a higher amount of light can get higher accuracy and speed up the measurement speed, but it should be noted that if too strong light (such as noon sunlight) is directly exposed, it may cause ALS saturation. Some have the window facing down for beautiful design, and use reflection to detect ambient light. However, this method will cause by reflectivity of the reflector to decrease ALS accuracy.

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Figure 1 is the recommended facing upwards window design.

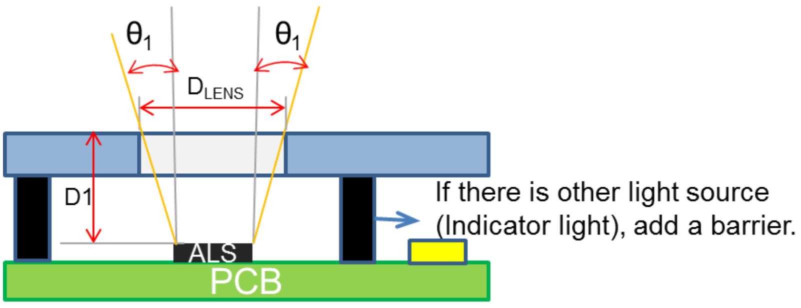

Figure 1. Window size determination (upward)

Based on the consideration of the amount of light entering.

- θ_1 is recommended to be greater than 35° and D1 is recommended to be less than 2.6mm.
- Recommend window size formula： **D_{LENS}= tanθ_1 x D1 x 2 + Package Width**.
- Assuming D1= 1mm, θ_1= 35°, then D_{LENS}= tan35° x 1mm x 2 + 2.0 = 3.4mm.
- Increasing the window size or shortening the distance of D_1 can increase the amount of light entering to make ALS more accurate.

If the window is facing forward, the ambient light is irradiated from diagonally above (Figure 2). With the same window size, let θ_1 greater than θ_2.

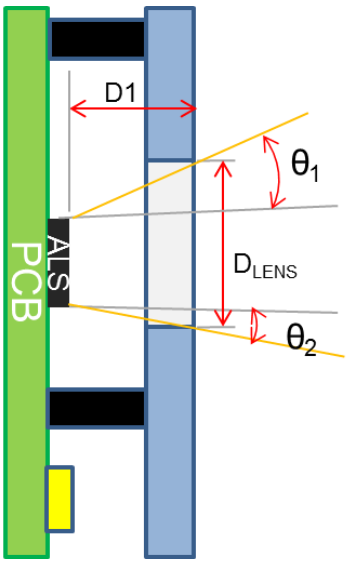

Figure 2. Window size determination (forward)

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Generally ID design does not want users to see ALS directly, so a translucent cover lens is usually added above ALS. The higher transmittance of the Lens is better, but not lower than 30%.

Illuminance conversion method

Electromagnetic waves of different wavelengths are all around us. According to the wavelength from short to long, it can be divided into ultraviolet (UV), visible light and infrared (IR). The illuminance defines the electromagnetic spectrum visible to humans with wavelength of 380~770nm. ALS mainly measures the intensity of electromagnetic waves in this band.

Figure 3. Spectral wavelength classification

In visible light band, human eyes is most sensitive to green light (555nm) in a bright environment. Assuming that the luminous flux required for other visible light wavelengths to produce the same bright sensation as 555nm light is X(λ), the ratio of 555nm luminous flux to other X(λ) can describe as visual sensitivity function. The definition of illuminance refers to the viewing function, because different light sources have different radiation intensities at different wavelengths, and the coating of ALS cannot be exactly to the visual sensitivity function, so the value obtained by ALS cannot convert into illuminance (Lux).

ALS-DPDIC17-78C/L749/TR8 has two types of PDs with different coatings inside, as shown in Figure 4. Two PDs will have different responses to light of different spectra, and different light sources can be distinguished by this feature. According to the corresponding conversion formulas given by different light sources, the above-mentioned problem that light sources with different spectrums under the same illuminance can get different converted illuminance values can be solved.

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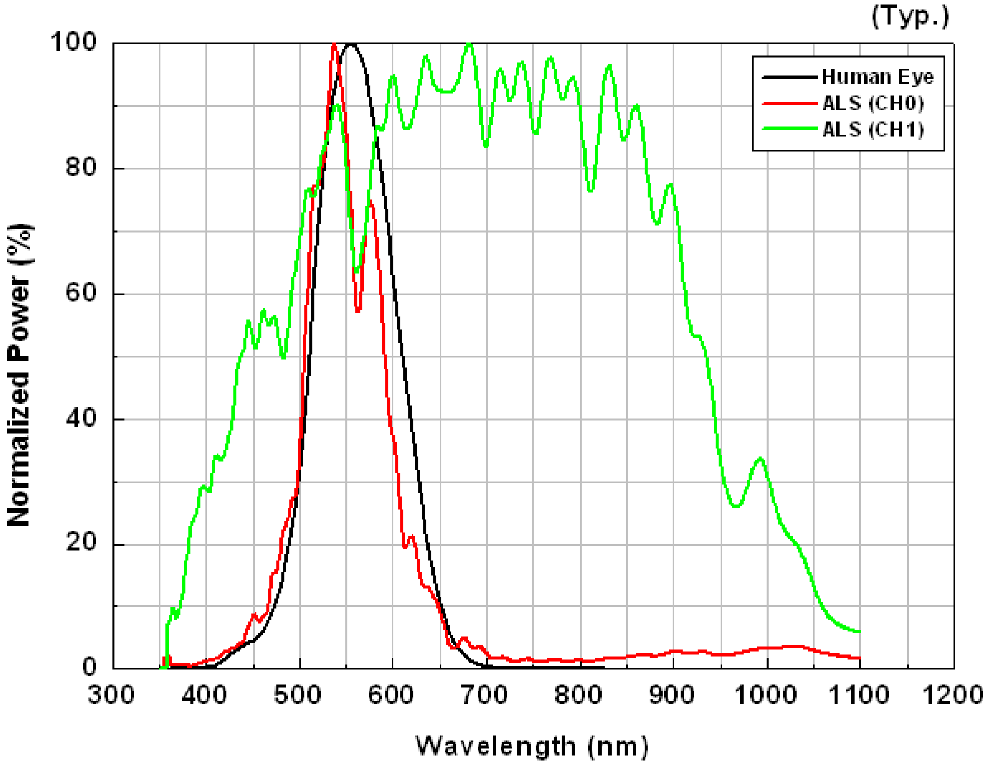

Figure 4. ALS-DPDIC17-78C/L749/TR8 PDs and human eye spectral response

The process of converting the value read by ALS-DPDIC17-78C/L749/TR8 into illuminance is as follows：

1. Prepare standard parts (illuminance meter) and different light sources (white light LED, incandescent lamp and standard light source D65...etc.)
2. The first light source illuminates ALS and illuminance meter, records reading value Ev of the illuminance meter, adjusts the settings of the register ALS_GAIN (0x04) and ALS_TIME (0x05), while recording ALS CH0 (0x1C, 0x1D) and CH1 (0x1E) , 0x1F). When adjusting, consider maximum ambient illuminance and design the processing when the output of the ALS is saturated.
3. Consider the ratio of CH0/CH1 as R(1).
4. Calculation coefficient K(1) = Ev/CH0.
5. The illuminance of this light source Lux = CH0 * K(1)
6. Change to different light source and repeat steps 1~5 to get different ratio R(n) and coefficient K(n).
7. Match the corresponding light source with the ratio R(n) and coefficient K(n) can get the Lux conversion formula for different light sources.

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- When calculating the coefficient K(n), it is recommended to make the K value less than 2. If the K value is too large, you can go back to step 2 to adjust the settings of register ALS_GAIN (0x04) and ALS_TIME (0x05).

Table 1 is ALS bare test data (without cover lens), refer to this table can get the following formula.

- **If CH0/CH1 <= 0.42, Lux = CH0/GAIN_value x 64/(ALS_TIME+1) x 0.41**
- **If 0.42 < CH0/CH1 < 0.66, Lux = CH0/GAIN_value x 64/(ALS_TIME+1) x 0.57**
- **If CH0/CH1 >= 0.66, Lux = CH0/GAIN_value x 64/(ALS_TIME+1) x 1.58**

Note: There will be some slight differences in the coating and process of each ALS, so converted Lux will also have some different. Therefore, if required higher accuracy, will need to calibrate and modify the formula.

Light Source	Ev	CH0 / Gain	CH1 / Gain	R (CH0 / CH1)	Group	K (Ev / CH0)	K AVG	Lux (CH0 * K)	Error
Incandescent Lamp	200	467	1520	0.31	R <= 0.42 (Group 1)	0.43	0.41	191.33	-4.53%
	600	1414	4385	0.32		0.42		579.74	-3.49%
	1000	2315	7023	0.33		0.43		949.15	-5.36%
D65	126	215	422	0.51	0.42 < R < 0.66 (Group 2)	0.59	0.57	122.65	-2.73%
	331	580	1129	0.51		0.57		330.58	-0.04%
	520	937	1815	0.52		0.56		534.08	2.58%
	1005	1789	3481	0.51		0.56		1020.00	1.50%
Fluorescent Lamp (2700K)	200	118	147	0.8	R >= 0.66 (Group 3)	1.69	1.58	187.03	-6.93%
	600	363	447	0.81		1.65		573.20	-4.67%
	1000	605	741	0.82		1.65		956.47	-4.55%
LED (3000K)	200	125	168	0.74		1.61		196.72	-1.67%
	600	375	512	0.73		1.60		593.07	-1.17%
	1000	626	853	0.73		1.60		988.93	-1.12%
Fluorescent Lamp (6500K)	200	124	149	0.83		1.61		195.75	-2.17%
	600	376	453	0.83		1.60		594.04	-1.00%
	1000	628	753	0.83		1.59		992.32	-0.77%
LED (6500K)	200	125	151	0.83		1.59		198.17	-0.92%
	600	381	458	0.83		1.58		601.79	0.30%
	1000	635	765	0.83		1.58		1002.98	0.30%

Table 1. ALS actual bare test data (without cover lens)

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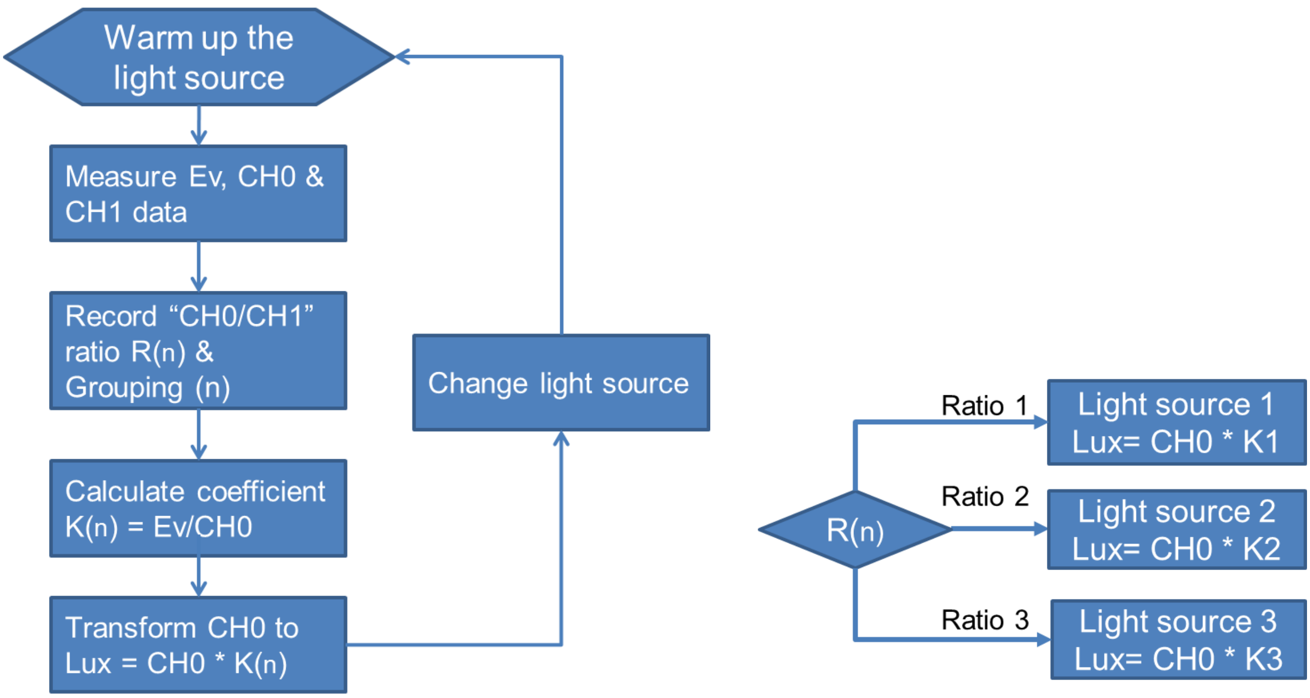
Process of converting ALS-DPDIC17-78C/L749/TR8 readings into illuminance shown in Figure 5.



Sensor		D65	CWF	A	TL84
CL200	Ev (Y)	$Y_{d0...dn}$	$Y_{c0...cn}$	$Y_{a0...an}$	$Y_{t0...tn}$
Sensor	CH0	$CH0_{d0...dn}$	$CH0_{c0...cn}$	$CH0_{a0...an}$	$CH0_{t0...tn}$
	CH1	$CH1_{d0...dn}$	$CH1_{c0...cn}$	$CH1_{a0...an}$	$CH1_{t0...tn}$

Ratio Range	y	x	K
CH0 / CH1 $\leq$ TH1	$Y_{0...n}$	$CH0_{0...n}$	K_1
TH1 < CH0 / CH1 < TH2	$Y_{0...n}$	$CH0_{0...n}$	K_2
CH0 / CH1 $\geq$ TH2	$Y_{0...n}$	$CH0_{0...n}$	K_3

Ratio Range	Lux Equation
CH0 / CH1 $\leq$ TH1 Group 1	$Lux = K_1 \times CH0$
TH1 < CH0 / CH1 < TH2 Group 2	$Lux = K_2 \times CH0$
CH0 / CH1 $\geq$ TH2 Group 3	$Lux = K_3 \times CH0$

Figure 5. ALS-DPDIC17-78C/L749/TR8 reading value conversion illuminance flow chart

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Register description and firmware flow chart

ALS-DPDIC17-78C/L749/TR8 I2C address is 0x38, and initialization steps are as follows :

1. After system is stable, check the values of the register 0xBC and 0xBD are 0x14 and 0x16, judge whether I2C is operating normally.
2. Set bit7 of register 0x02 INT_POR = 0, this bit will be set to 1 after power-on, voltage drop or ALS is reset, confirm whether this bit is 0 before each subsequent reading. If is 1 means ALS is reset to the default value and ALS must be re-initialized.
3. Set register 0x00 bit 0 EN_ALS=1 to enable ALS.
4. Set initial setting of 0x04 ALS_GAIN and 0x05 ALS_TIME.
5. After ALS_TIME + WTIME ms, check whether INT_POR is 0. If is 0 then read 0x1C~0x1F to calculate the Lux value.

- ALS_TIME (register 0x05) is the ADC conversion time of ALS. The larger register value, the longer integration time and the higher output resolution. The maximum value is 0xFF, but as long as it is set to 0x3F, can get maximum output resolution (16 bits 0~65535). Unless need to measure very low brightness or ID design causes less light entering, can set ALS_TIME more than 0x3F. The larger the value, the longer measurement time of ALS. Please refer to specification for more detail.
- Enable wait time function need to set register 0x00 bit 6 (EN_WAIT) to 1. This function puts the IC into a power saving mode during non-detection time, thereby reducing average power consumption.
- ALS internal amplifier gain is adjust by ALS_GAIN (register 0x04), generally set to 0x00, unless light entering is weak then set to 0x01. The greater the value, the greater output value under the same light source. This setting will not increase the measurement time of ALS.
- ALS-DPDIC17-78C/L749/TR8 also has an interrupt function. If necessary, please refer to the specification for more detail.
- If the application of ALS only take few switching points and directly change the brightness (or other actions). It is recommended to add a debounce function to avoid jitter (flicker) when the light source falls near the switching point.

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The firmware flow chart of ALS-DPDIC17-78C/L749/TR8 as shown in Figure 6.

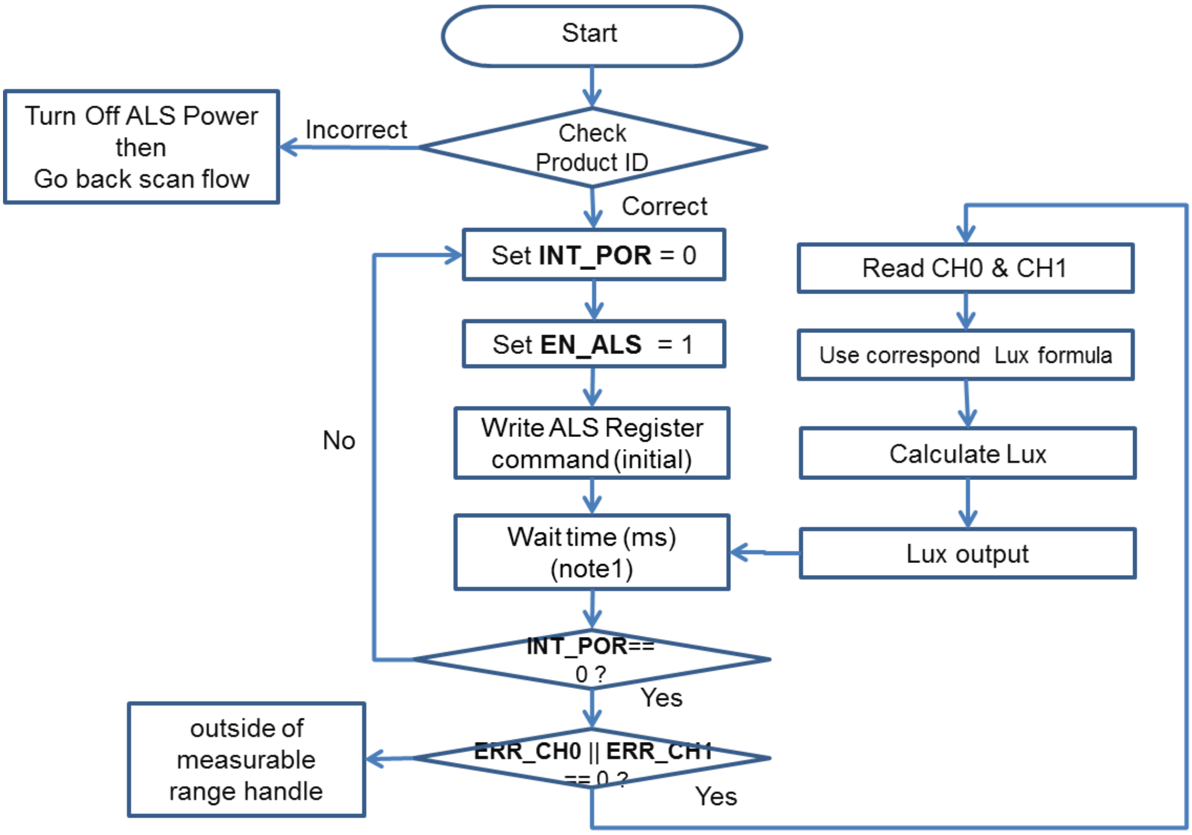

Figure 6. Firmware flow chart

The information in this application manual is only for customers' design reference. Please verify when actually use it. If have any other questions, please contact Everlight for further technical support.

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