APPLICATION NOTE

Digital RGBW Color Light Sensor CLS-16D24-44-DF8/TR8 Application Note

Introduction

The package size of CLS-16D24-44-DF8/TR8 Color Light Sensor is $2mm \times 2mm \times 0.63mm$. It contains five light-receiving diodes, which can detect Red, Green, Blue, white and Infrared light. It could adjust amplifier gain, output resolution and operation time by microcontroller with Inter-Integrated Circuit. In addition, CLS also has power saving mode for low-power application development.

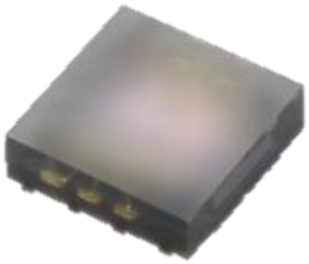

Figure 1. CLS-16D24-44-DF8/TR8 package

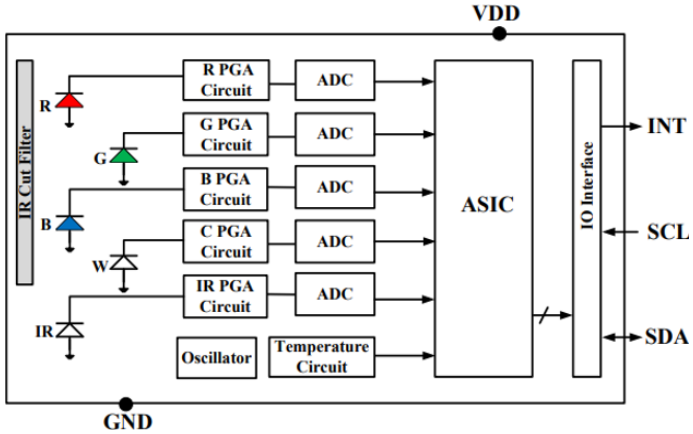

Figure 2. CLS-16D24-44-DF8/TR8 diagram

The following will introduce how to detect the color of objects by CLS, and how to further convert the CLS count data to such as CIE 1931 xyY, CIE 1931 XYZ, etc. Also briefly introduce CLS internal register function. The suggestions just for development reference. It still needs to adjust according to the application situation in use.

Use CLS Detect Objects Color

According to the difference of the object to be detected, different detection methods need to be designed, it can be roughly divided into two situations.

1. Detecting non-self-illuminating objects
2. Detecting self-illuminating objects

Refer Figure 3 adding external light source, according to different color surfaces reflect different spectrums to detect colors when detecting non-self-illuminating objects. In addition to isolating ambient light source, it also necessary to increase the isolation between CLS and light source to avoid interference caused when using external light source.Refer to Figure 4 for detecting self-illuminating objects. Simply isolate ambient light to detect the emission spectrum of the object.

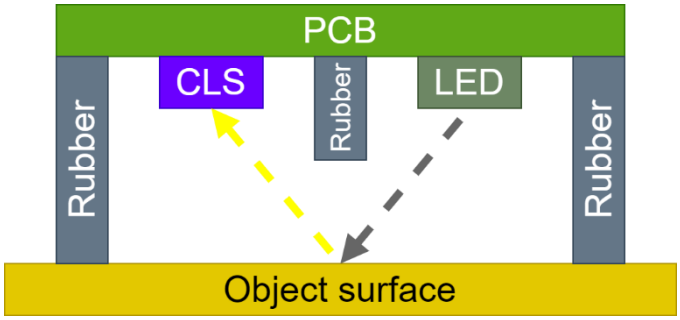

Figure 3. Detecting non-self-illuminating objects

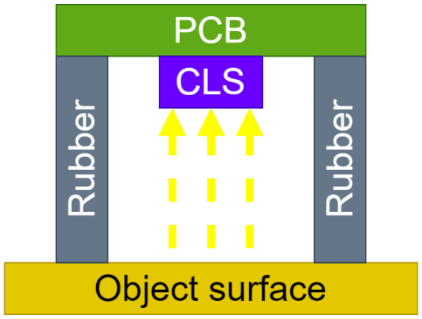

Figure 4. Detecting self-illuminating objects

CLS Data Converted to CIE 1931 Color Coordinate

Earth is full of electromagnetic waves of various wavelengths, as shown in Figure 5, which can be divided into Ultraviolet(UV), Visible Light and Infrared(IR) in order from short to long wavelengths. Among them, Visible Light is the electromagnetic spectrum which human eye visible with a wavelength range of 380–770 nm. Different wavelengths of Visible Light show different colors.

There are 5 light-receiving diodes inside CLS, which have different response to electromagnetic waves of different wavelengths. Figure 6 below is the response spectrum.

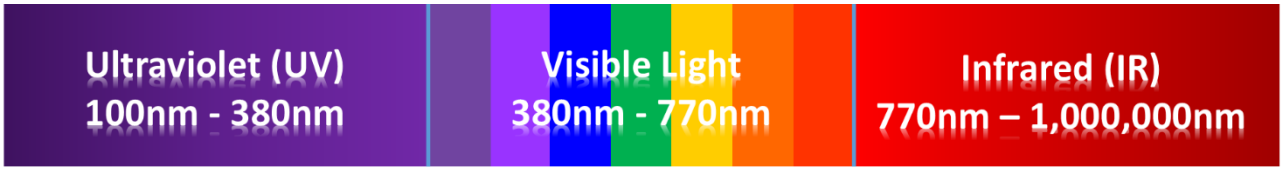

Figure 5. Electromagnetic wave classification

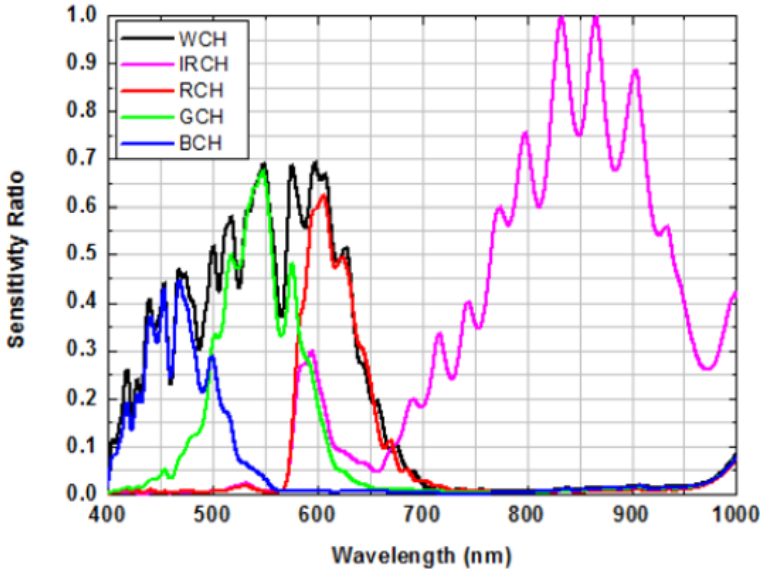

Figure 6. CLS-16D24-44-DF8/TR8 response spectrum

The following describes how to convert RGB data read by CLS into CIE 1931 XYZ, CIE 1931 Yxy and color temperature calculation.

1. Prepare different light sources and illuminometer (such as CL-200A, CS-200, etc.).
2. Choose a light source to illuminate CLS and illuminometer, and adjust CLS_GAIN and CLS_TIME appropriately.
3. Record the illuminometer XYZ and CLS RGB data. Switch different light source and repeat this step.
4. Calculate the coefficient matrix C_{XYZ} according to formula (1).
5. After C_{XYZ} is obtained, the RGB data read can be converted into CIE 1931 XYZ through formula (2).
6. CIE 1931 Yxy can be calculated through formula (3).
7. The color temperature can be calculated by formula (4).
8. This conversion process can also refer to the process in Figure 7.

Notice

- When adjusting CLS_GAIN and CLS_TIME, it is recommended to keep the CLS data around 1000, and pay attention to avoid saturation.
- In formula (1), the numbers in the subscripts of the matrix respectively represent the data obtained by different light sources.
- Each CLS will be slightly different due to coating and manufacturing process, it will cause CLS data different under same light source. If a high accuracy required, then adjust the formula as needs.

$$\begin{bmatrix} C_{X1} & C_{X2} & C_{X3} \\ C_{Y1} & C_{Y2} & C_{Y3} \\ C_{Z1} & C_{Z2} & C_{Z3} \end{bmatrix} = \begin{bmatrix} X_1 & X_2 & X_3 \\ Y_1 & Y_2 & Y_3 \\ Z_1 & Z_2 & Z_3 \end{bmatrix} \cdot \begin{bmatrix} R_1 & R_2 & R_3 \\ G_1 & G_2 & G_3 \\ B_1 & B_2 & B_3 \end{bmatrix}^{-1} \quad (1)$$

$$\Rightarrow \quad C_{XYZ} = \begin{bmatrix} X_1 & X_2 & X_3 \\ Y_1 & Y_2 & Y_3 \\ Z_1 & Z_2 & Z_3 \end{bmatrix} \cdot \begin{bmatrix} R_1 & R_2 & R_3 \\ G_1 & G_2 & G_3 \\ B_1 & B_2 & B_3 \end{bmatrix}^{-1}$$

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = C_{XYZ} \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (2)$$

$$\text{CIE 1931 xyY} = \begin{cases} x = \frac{X}{X+Y+Z} \\ y = \frac{Y}{X+Y+Z} \\ Y_{(Lux)} = Y \end{cases} \quad (3)$$

$$CCT = -449n^3 + 3525n^2 - 6823.3n + 5520.33, \text{Where } n = \frac{x-0.332}{y-0.1858} \quad (4)$$

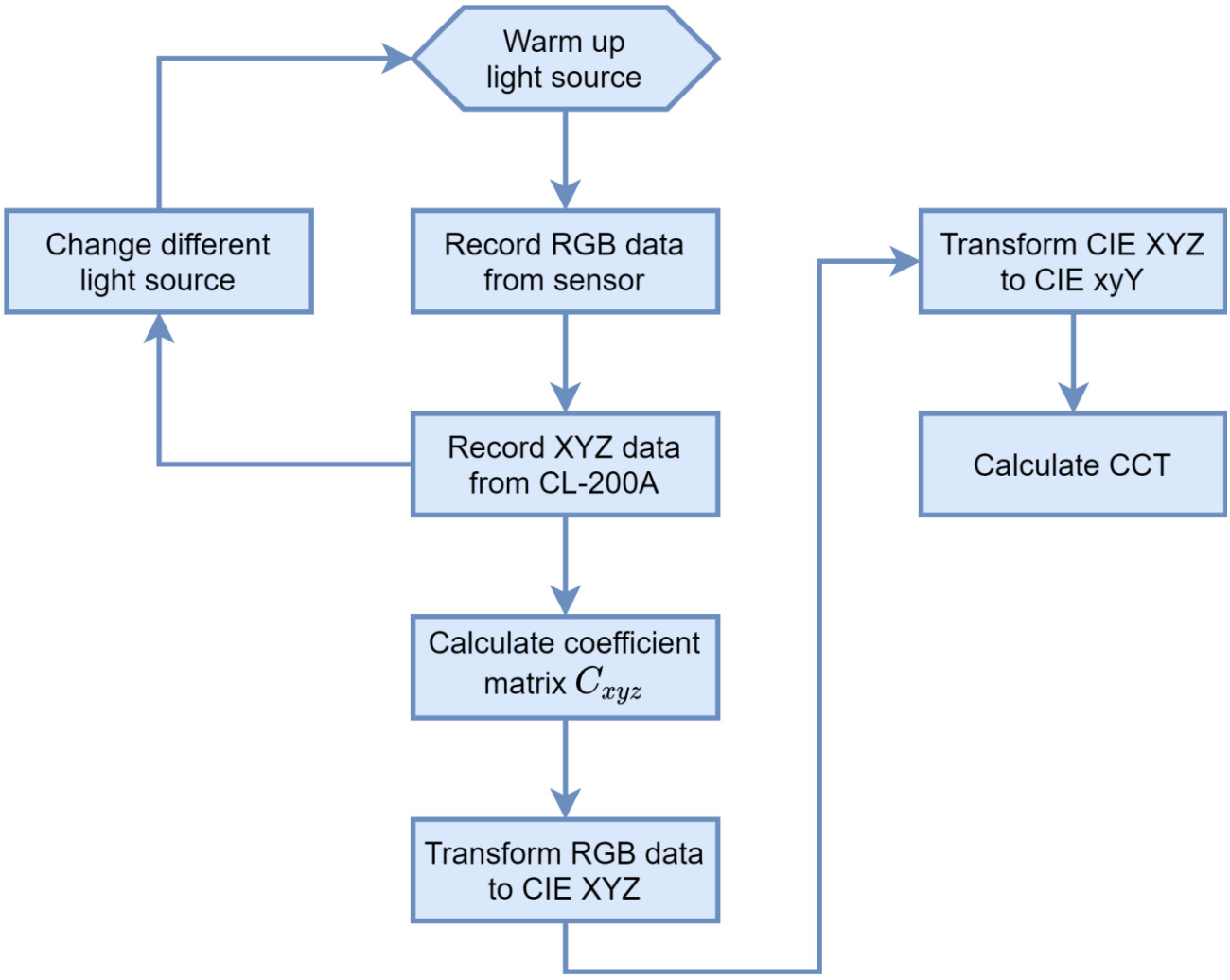

Figure 7. CLS-16D24-44-DF8/TR8 data and CIE 1931 conversion flow chart

Register Function and Firmware Flow Chart

The I2C address of CLS-16D24-44-DF8/TR8 is 0x38(7 bits), initialization steps are as follows.

1. After system stabilizes, you can first read register PROD_ID(0xBC, 0xBD), and confirm that the values are 0x12, 0x07 to judge I2C is working correctly.
2. Set INT_POR to 0 (0x02 bit 7), this bit will be automatically set to 1 after power up, voltage drop, software reset. Therefore, it is necessary to confirm this bit is 0 before each reading of CLS data to ensure that registers are not reset.
3. Set register EN_CLS to 1 (0x00 bit 0) to enable CLS.
4. Initialize WAIT_TIME(0x03), CLS_GAIN(0x04) and CLS_TIME(0x05).

5. After $(T_{CLS} + \text{Total waiting time})$ milliseconds and confirm INT_POR=0, each color data (0x1D-0x25) can be read.

Notice

- Register CLS_TIME can set ADC conversion time of CLS. The longer the time, the longer the integration time and the higher the output resolution. When set to 64T(0x03, 0x32 or 0xF1), CLS will have highest output resolution(16 bits; 0-65535).
- Because the larger the CLS_TIME, the longer the CLS measurement time, if there is a low brightness application or less incoming light due to limitation of appearance design, then it will necessary to set to more than 64T.
- The conversion time T_{CLS} consists of CLSCONV(CLS_TIME first 4 bits) and INT_TIME(CLS_TIME last 2bits). Its formula is: $T_{CLS} = \text{INT\_TIME} \times (\text{CLSCONV} + 1)$.
- To enable wait time function, need to set register EN_WAIT(SYSM_CTRL bit 6) to 1. The IC will enter power saving mode when CLS is not detecting, thereby reducing the average power consumption.
- Total waiting time is controlled by WAIT_TIME, and its calculation formula is: $\text{Total waiting time} = \text{WAIT\_TIME} \times 10\text{ms}$.
- CLS internal amplifier is controlled by DIOD_SELT(CLS_GAIN bit 7) and PGA_CLS(CLS_GAIN last 5 bits). Gain formula is: $\text{Gain} = \text{DIOD\_SELT} \times \text{PGA\_CLS}$.
- It is recommended to adjust CLS_GAIN for detection light source, that the output data of each color around 1000(in order to subsequent conversion of CIE 1931 xyY to have at least three decimal places). Under the same light source, the higher the setting of CLS_GAIN, the greater the obtained data. In addition, this setting does not affect the CLS measurement time, which can be adjusted according to the application.
- About interrupt trigger function of CLS-16D24-44-DF8/TR8, please refer to datasheet for detailed usage and related register settings.

Figure 8 shows the basic firmware process of CLS-16D24-44-DF8/TR8. If there is any problem in use, please refer to the suggested process in the figure to confirm that the sensor is working properly.

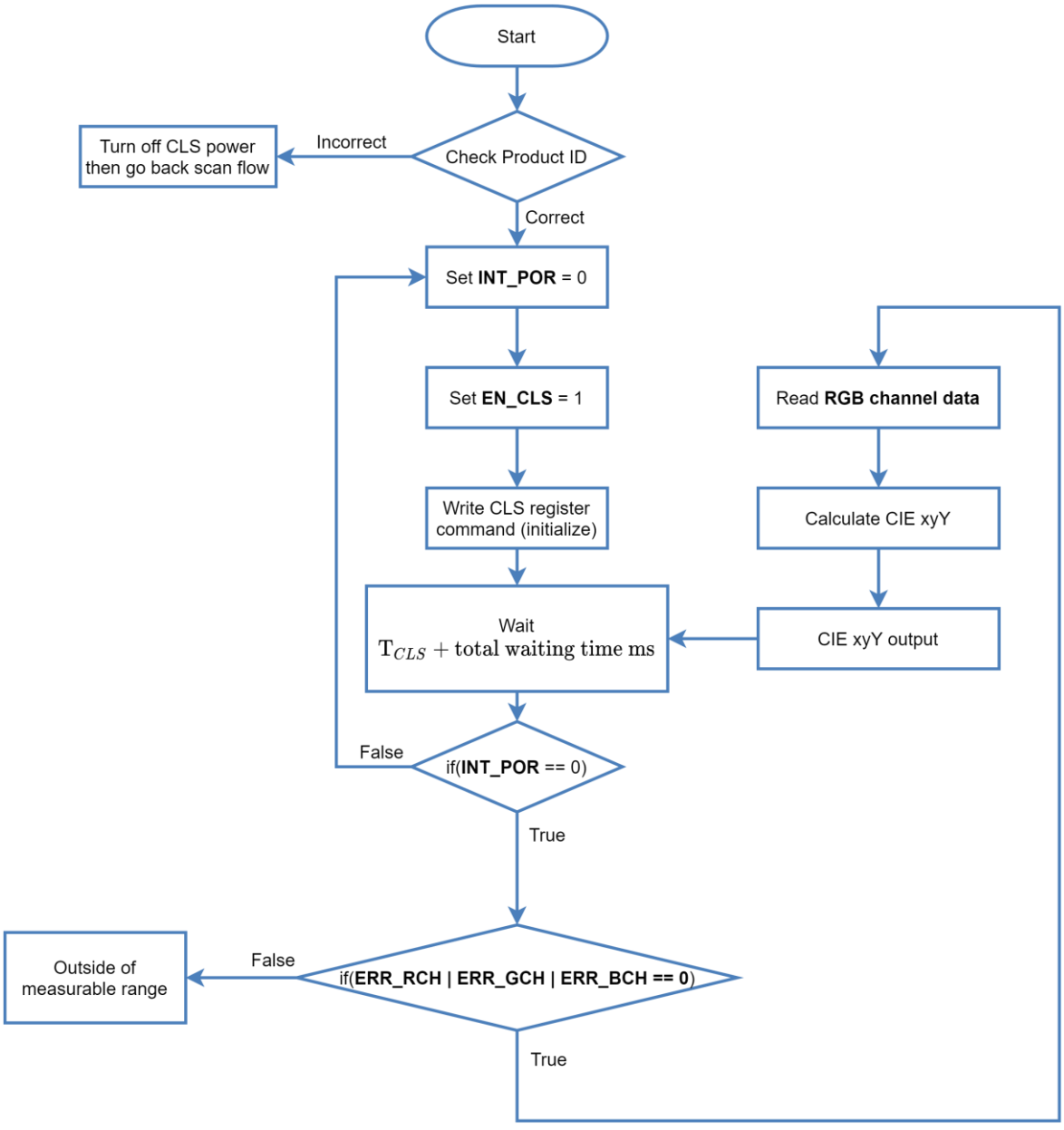

Figure 8. Firmware design flow chart

This application note is only for design reference. Please verify actual use by self. If any other questions, please contact Everlight for further support.