AN5638

Application note

CCT computation using VD6283

Introduction

This document is an application note about correlated color temperature (CCT), in general, and how it is calculated using ST's VD6283 device.

1 What is CCT?

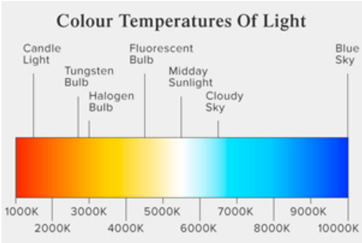
Color temperature is a visible light characteristic. The color temperature of a light source is the corresponding temperature of an ideal black body radiator producing a similar color.

CCT stands for Correlated Color Temperature (which is often shortened to color temperature). It defines a range of color (not brightness of a light source) and is measured in kelvin (K).

The CCT is an interesting metric to evaluate the atmosphere of the scene, and adapt a display or a camera to it.

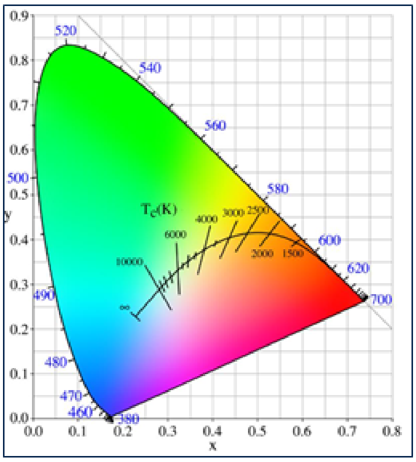
CCT is often represented on a scale from 1000 K to 10000 K, as illustrated in the image below, extracted from IES.org.

Figure 1. CCT scale



However, it is more accurately represented on the (x,y) chromaticity diagram as the black segments crossing the Planckian locus, as illustrated in the following figure.

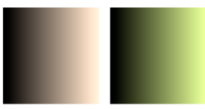
Figure 2. CCT on chromaticity diagram



To have a color temperature, the light should be on the Planckian locus. If it is not, the light does not correspond to a color temperature. Illuminant that are not exactly on the locus are assigned a Correlated Color Temperature (CCT). As colors get farther from the locus, the CCT concept becomes less applicable. CCT reduces color to 1 dimension.

Two lights can have the same CCT and intensity while having different light spectrum (i.e two different light spectrum). For example, the two lights illustrated below have a CCT of approximately 4850 K.

Figure 3. Example of two lights with same CCT



2 How is CCT calculated?

On the chromaticity diagram (shown in Figure 2. CCT on chromaticity diagram), colors are described with x and y coordinates from CIE 1931 color space.

With “x” and “y”, CCT can be calculated according to the McCamy’s approximation, with one of the following equations:

- $CCT_{(1)} = (437 \times n^3) + (3601 \times n^2) + (6861 \times n) + 5517$
- $CCT_{(2)} = (449 \times n^3) + (3525 \times n^2) + (6823.3 \times n) + 5520.33$

where $n = \frac{(x - 0.3320)}{(0.1858 - y)}$

These two equations lead to a very similar result. For example, if x = 0.3 and y = 0.3:

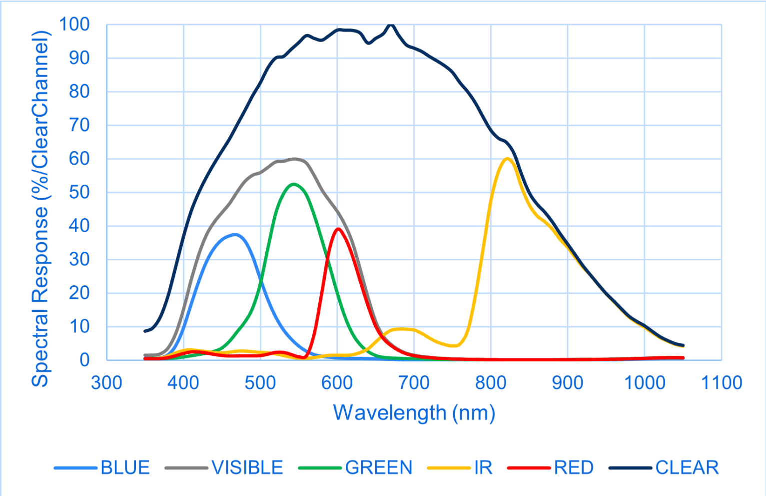
- $CCT_{(1)}$ = 7731.9 K
- $CCT_{(2)}$ = 7718.9 K

3 CCT with VD6283

3.1 Color sensing channels

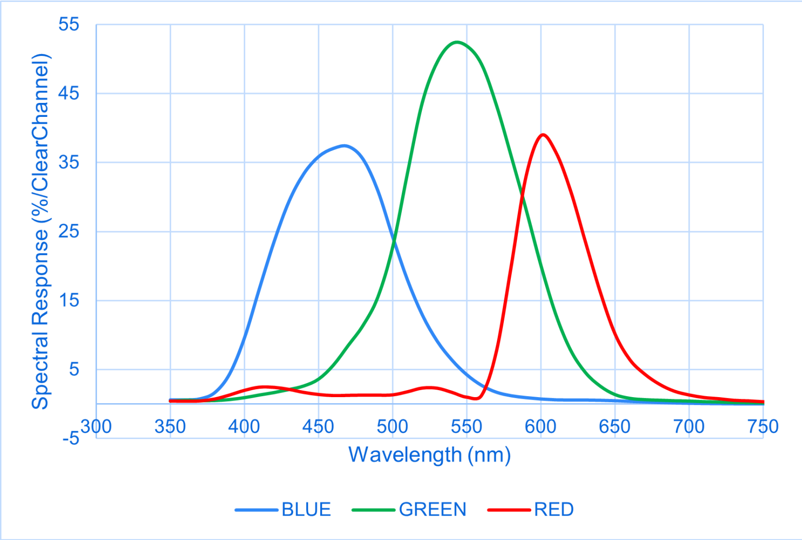
VD6283 sensor can retrieve RGB counts, in addition to a visible channel, a clear channel and an infrared channel, as shown in the following image.

Figure 4. VD6283 color filter typical transmittance (normalized)



For CCT calculation, only Red, Green and Blue channels are needed, as they cover the visible range of light.

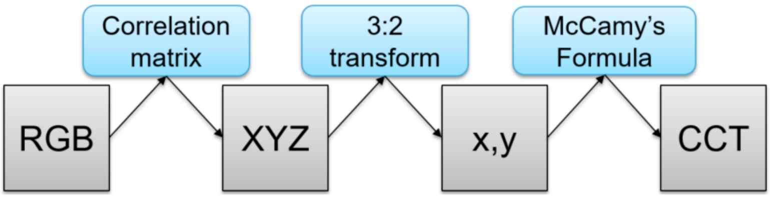
Figure 5. VD6283 RGB color filter typical transmittance (normalized)



3.2 CCT calculation algorithm

In order to calculate CCT from RGB counts, other metrics and equation are used. The global calculation schematic from RGB to CCT is the following:

Figure 6. Calculation schematic from RGB to CCT



“x” and “y” are calculated with X, Y, Z where Y corresponds to Lux and where

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

The first step is the conversion from RGB to XYZ, and it is done with a correlation matrix.

3.3 Correlation matrix

The correlation matrix is a 3 x 3 numerical matrix, to transform RGB data into XYZ data, where Y corresponds to the illuminance (Lux).

This matrix is generated from a various and representative amount of artificial and natural lights, in order to accurately cover the widest range of CCT.

It includes natural light such as sunset, sunrise, natural bush, and reflection of daylight on a building, as well as artificial light, such as incandescent lightbulb, White LED, fluorescent light sources, Daylight spectrums (D55, D65, D75) and many more.

Table 1. Matrix generation conditions

	Min	Max
CCT range	2300 K	7500 K
Lux range	0.5 Lux	30 000 Lux

These ranges allow VD6283 to accurately calculate the CCT and the Lux of a light as long as it is close enough to the Planckian Locus.

A typical matrix computed for VD6283 evalutation boards is provided in the GUI and CubeMX packages for evaluation.

Table 2. VD6283 typical correlation matrix

	R	G	B
X	0.20557	0.4167	-0.14382
Y	-0.02875	0.506372	-0.12061
Z	-0.55263	0.335866	0.494781

4 Measurement reference material

To accurately produce spectrums, ST uses natural light in real situations, and also a tunable light source, capable of emitting any spectrum with combinations of LEDs from 380 nm to 940 nm.

To accurately evaluate the light of a scene, and use it as a reference for the matrix generation, ST uses a professional spectrophotometer capable of evaluating CCT, Lux as well as X, Y and Z metrics.

5 Integration recommendation

The CCT and Illuminance (Lux) metrics are very sensitive to integration variation. CCT is directly related to the R,G and B channel ratios, and the Lux are directly linked to the amount of light received by the sensor.

5.1 Aperture recommendation

The VD6283 is not a symmetrical array of pixels (see Figure 7. Asymmetrical pixel array). If an aperture covers partially the sensor FoV (see Figure 8. Example of aperture impact on CCT), the color ratio between channels will change, therefore the CCT accuracy will be impacted.

Figure 7. **Asymmetrical pixel array**

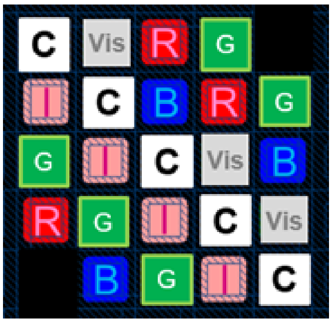


Figure 8. **Example of aperture impact on CCT**

If an aperture is centered on the device, and allows a FoV of +/- 60 °, the CCT computation will not be impacted, regardeless of its shape.

To avoid any issues with the CCT computation, ST recommends a symmetrical aperture, centered on the device.

5.2 Cover glass recommendation

The Illuminance (Lux) value is directly related to the amount of light received by the sensor. A cover glass on top of the sensor will reduce the amount of light received. Therefore, the Lux calculation will be biased.

ST recommends a cover glass as neutral as possible on RGB channels spectrum, and above 20 % transmittance, to avoid any CCT degradation.

Revision history

Table 3. Document revision history

Date	Version	Changes
12-Jul-2021	1	Initial release

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