Product Document

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Application Note

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TCS3430 Factory Calibration Procedure

How to reduce impact of variations in the optical stack.

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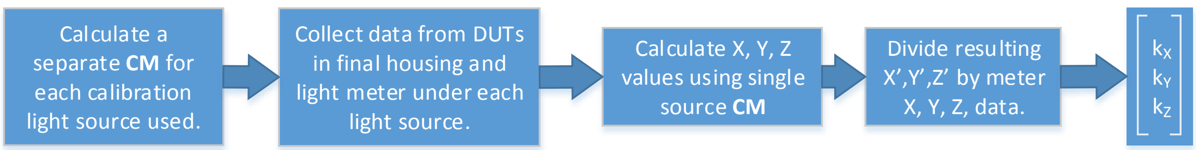
Content Guide

1 Introduction

The TCS3430 is a color ambient light sensor that can produce accurate CIE Tristimulus (XYZ) measurements of ambient light when the raw data is multiplied by a color calibration matrix (**CM**). The color calibration matrix corrects for the limitations in silicon absorption of light, effects from the diffuser, cover glass, and the optical stack in the system. It does not however adjust for part to part variation in the diffuser, glass, or device. The effect of these variations can be minimized with a factory calibration procedure. While the calculation of the **CM** is covered in the Optical Design guide, since it is used in the calibration process it will be reviewed here as well.

The purpose of factory calibration is to measure the relative differences between the sensor, optical stack, and diffuser. This difference can then be used to adjust the results for more consistent results. There are other methods for calibrating the units such as comparing results to a “golden” unit. The procedure described in this application note is independent of any such “golden” unit by comparing the data collected to a light meter such as a Konica Minolta CL200A. It is also independent of the **CM** used in the application.

The relative difference for calibration are calculated in the XYZ color space rather than on the raw data inputs. Each unit is measured under standard light sources; the output is calculated using a **CM** calculated from the calibration light source data rather than the **CM** used in the final application. The result is then divided by the light source meter data to provide a relative comparison between units that can be used to adjust future data to improve accuracy. This app note will explain the factory calibration procedure, show an example of the calculations, and show how to apply the results to raw data.



2 Two Point Calibration Procedure

2.1 Light Source Calibration

Since there are two **CM** used with the TCS3430 in most applications, it is best to use a two point calibration process. Separate sets of calibration values should be calculated for each **CM** used in the application. Data is collected on each unit using two different types of white light sources. One light source should be a low IR source (i.e. white LED, CFL). It is best to use lights with a high Color Rendering Index (CRI) rating (CRI > 90). The second source should be a light source with a relatively high amount of IR content (i.e. incandescent, halogen).

Since calibration is more effective in the XYZ color space, a color calibration matrix is needed for each calibration light source used to convert the DUT data to XYZ. This **CM** is calculated by collecting DUT data in the final housing under the same conditions as the calibration process. To provide the most accurate **CM,** a relative sampling of the types of optical stack variation should be included (min, max, and typical) in this data. To calculate the **CM** coefficients, a multiple linear regression using ordinary least squares on each channel. The DUT data is used as the inputs and the meter data as the known output values.

An example of calculating the X' **CM** coefficients is shown here using Excel's LINEST function:

X' X_coef = INDEX(LINEST(meter_data_X, DUT_data, false, false), 4)

X' Y_coef = INDEX(LINEST(meter_data_X, DUT_data, false, false), 3)

X' Z_coef = INDEX(LINEST(meter_data_X, DUT_data, false, false), 2)

X' IR_coef = INDEX(LINEST(meter_data_X, DUT_data, false, false), 1)

				Dut Data				Meter Data		
DUT	Light Type	ATIME	AGAIN	X	Y	Z	IR1	X	Y	Z
1000	LED	100.8	64	3987.3	3795.85	1121.35	1254.4	1340	1391	1061
1001	LED	100.8	64	4151.95	3968.2	1172.65	1309.5	1338	1388	1060
1002	LED	100.8	64	4107.65	4002.75	1137.9	1326.4	1338	1388	1060
1003	LED	100.8	64	3604	3503.55	1009.55	1078.85	1338	1388	1060
1004	LED	100.8	64	3940.2	3810.7	1110	1194.6	1338	1388	1060
1005	LED	100.8	64	4196.35	4100.9	1178.35	1360.95	1338	1388	1060
1006	LED	100.8	64	3854.25	3790.35	1077.1	1183.05	1338	1388	1060
1007	LED	100.8	64	3796.95	3499.05	1108	1116.55	1338	1388	1059
1008	LED	100.8	64	3855.4	3766.45	1097	1160.2	1338	1388	1059
1009	LED	100.8	64	4082.5	4002.75	1121.35	1271.85	1338	1388	1059
1010	LED	100.8	64	4110.4	3893.6	1159.6	1275.05	1338	1388	1059
1011	LED	100.8	64	4224.3	3959.4	1195.5	1291.75	1338	1388	1059
1012	LED	100.8	64	3717.1	3751.35	1061.5	1192.15	1337	1388	1059

The Y' and Z' coefficients are then calculated by changing the meter data column used.

	Low IR			
	X	Y	Z	IR
X'	-0.28837	0.58484	1.55207	-1.21521
Y'	-0.30518	0.60817	1.62203	-1.25651
Z'	-0.23132	0.46517	1.22896	-0.95905

The same procedure is used for a high IR light source. For this example a Halogen source was used.

			Dut Data				Meter Data			
DUT	ATIME	AGAIN	X	Y	Z	IR1	X	Y	Z	CCT
1000	100.8	4	95910.4	79086.4	21751.2	332763.2	35560	32400	11450	2857
1001	100.8	4	96669.6	80464.8	21432	339632.8	36070	32810	11650	2852
1002	100.8	4	100596.8	85710.4	22583.2	350930.4	36000	32730	11620	2849
1003	100.8	4	90654.4	75825.6	19080.8	309015.2	35950	32670	11600	2847
1004	100.8	4	99648	82402.4	21615.2	336438.4	35960	32680	11600	2846
1005	100.8	4	103755.2	87648	24163.2	367916	35910	32620	11580	2844
1006	100.8	4	97154.4	81876.8	20813.6	333632	36040	32730	11640	2845
1007	100.8	4	94903.2	76023.2	20851.2	314373.6	35910	32610	11590	2843
1008	100.8	4	95067.2	81482.4	20796	336157.6	35720	32420	11510	2840
1009	100.8	4	101631.2	86456	22924.8	346556.8	35750	32450	11520	2840
1010	100.8	4	100032	83087.2	21800	347505.6	35510	32220	11420	2838
1011	100.8	4	103649.6	85233.6	22401.6	350422.4	35480	32190	11410	2837
1012	100.8	4	93144	79585.6	20288	330307.2	35500	32200	11420	2836

	High IR			
	X	Y	Z	IR
X'	0.582690	-0.183675	-1.583206	0.082557
Y'	0.529610	-0.178553	-1.416517	0.076360
Z'	0.188025	-0.057204	-0.506941	0.025853

Once these two color calibration matrices are determined, they are used to calibrate the production units. These matrices are only used in the factory calibration process. If multiple stations are used, it is best to calculate unique CM for each station unless the light spectral characteristics are the same.

The meter data from the calibration stations should be monitored to ensure the light source has not changed significantly from when the **CM** was calculated.

2.2 Production Unit Calibration

Once a unit has its final optical stack up and the **CM** has been calculated, the calibration can begin. Data is collected under the two light sources for each production unit. The light source should also be measured with a meter that can measure 1931 CIE Tristimulus values. The raw data from the TCS3430 is multiplied by the corresponding light source matrix. The resulting XYZ data is then divided by the light source meter data to calculate the unit's k_X, k_Y, and k_Z values.

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = [Light\ Source\ Matrix] \times \begin{bmatrix} X_{raw} \\ Y_{raw} \\ Z_{raw} \\ IR_{raw} \end{bmatrix}$$

$$k_X = \frac{X'}{X_{meter}},\quad k_Y = \frac{Y'}{Y_{meter}},\quad k_Z = \frac{Z'}{Z_{meter}}$$

From the previous example data, the 'k' values for DUT 1000 under an LED source will use the following equation:

$$\begin{bmatrix} 1286.17 \\ 1334.35 \\ 1018.46 \end{bmatrix} = \begin{bmatrix} -0.28837 & 0.58484 & 1.55207 & -1.21521 \\ -0.30518 & 0.60817 & 1.62203 & -1.25651 \\ -0.23132 & 0.46517 & 1.22896 & -0.95905 \end{bmatrix} \times \begin{bmatrix} 3987.3 \\ 3795.85 \\ 1121.35 \\ 1254.4 \end{bmatrix}$$

The resulting X', Y', and Z' values are then divided by the light meter values to get the 'k' values for each channel.

$$k_X = \frac{1286.17}{1340} = 0.95983,\quad k_Y = \frac{1334.35}{1391} = 0.95927,\quad k_Z = \frac{1018.46}{1061} = 0.95990$$

The High IR source 'k' values are calculated in the same way. As example using the same DUT data:

$$\begin{bmatrix} 34395.15 \\ 31272.82 \\ 11085.80 \end{bmatrix} = \begin{bmatrix} 0.58269 & -0.18367 & -1.58321 & 0.08256 \\ 0.52961 & -0.17855 & -1.41651 & 0.07636 \\ 0.188025 & -0.0572 & -0.50694 & 0.02585 \end{bmatrix} \times \begin{bmatrix} 95910.4 \\ 79086.4 \\ 21751.2 \\ 332763.2 \end{bmatrix}$$

The resulting X', Y', and Z' values are again divided by the light meter values to get the 'k' values for each channel.

$$k_X = \frac{34395.15}{35560} = 0.96724,\quad k_Y = \frac{31272.82}{32400} = 0.96521,\quad k_Z = \frac{11085.80}{11450} = 0.96819$$

2.3 Using the Calibration Values

Since the calibration 'k' values were calculated in the XYZ space rather than the raw data space, the 'k' values are used on the data after it is multiplied by the **CM** rather than the raw data.

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = [CM] \times \begin{bmatrix} X_{raw} \\ Y_{raw} \\ Z_{raw} \\ IR_{raw} \end{bmatrix}$$

$$X = \frac{X'}{k_X}, \ \ Y = \frac{Y'}{k_Y}, \ \ Z = \frac{Z'}{k_Z}$$

When a two point calibration is used, there are both low IR and High IR 'k' values. The 'k' values used should match the version of **CM** matrix uses.

2.4 Calibrating When Using the Smoother Step Function

When using the Smoother Step function to mix the results of the Low IR and Hi IR matrix as described in the TCS3430 Optical Design Guide, the calibration 'k' values are used on the results of each matrix prior to calculating the Smoother Step weighting value.

3 Single Point Calibration

It is possible to calibrate a device using the TCS3430 with only a single point light source, however the results should only be applied to the low-IR results. This will result in a reduction in the accuracy for the hi-IR results unless any optical stack variations are uniform across the light spectrum.

A single point calibration will improve the results significantly over no calibration at all and if the results meet the application requirements it is sufficient.

4 Summary

Unit to unit variation is a source of error in the ALS reading on any product. A factory calibration process can be employed to reduce the error due to these variations. A single light source calibration will remove some of the error due to these variations. However, some unit to unit differences and cover glass transmissivity varies significantly over the light spectrum. Due to these facts, a multi-point calibration with both low and high IR light sources is recommended for ambient light measurement applications. To be the most effective it is recommended to have a calibration point for each **CM** used in the application. For most ambient light measurement applications this will mean a two point calibration consisting of a low IR light source and a high IR light source is recommended.

5 Revision Information

Changes from previous version to current revision v1-00	Page
Initial version 1-00	

- Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
- Correction of typographical errors is not explicitly mentioned.

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