Product Document

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Application Note

Improving Color Sensor Lux Accuracy

Content Guide

1 General Description

This Application Note is intended to explain how lux accuracy can be significantly improved. The prerequisites to this application note are “Developing a Custom Lux Equation” and “Lux and CCT Calculations using ams Color Sensors”. These documents explain how to generate lux equations for color devices. Although the TMG3993 was be used to collect raw data for real world demonstration purposes; the techniques described in this application note are applicable to all ams digital color sensors.

2 Color Lux Equations

From the prerequisite reading; the lux equation for color device takes on the form shown here:

$$Lux = \frac{R' * \mathrm{Rcoef} + G' * \mathrm{Gcoef} + B' * \mathrm{Bcoef}}{\mathrm{CPL}}$$

Where CPL is the color sensors (in system) shaped output response relative to lux. R’, G’, and B’ are the color sensor channel output minus infrared (IR) response. Rcoef, Gcoef, and Bcoef are the scalars for the Red, Green, and Blue color channels respectively.

3 Color Lux Equation Measurement

The following data was recorded for TMG3993 color sensor using a GTI light box with light sources:

Light Source	Clear	Red	Green	Blue	AGAIN	ATIME	Lux (M)	Lux Calc	Lux Err%
Office	243	111	87	85	1	200	1351	1446.32	7.06
LED	297	158	89	104	1	200	1407	1314.87	6.55
OPT	204	113	66	62	1	200	1193	1198.53	0.38
HOME	409	335	238	265	1	200	488	521.53	6.87
SUN	151	77	49	60	1	200	630	588.75	6.55

Table 1: TMG3993 Light Source measurement data and lux calculations. (see references)

The calculated lux equation is compared to the lux measured from a Konica Minolta CL-200A to determine the Lux Error percentage.

From the prerequisite reading, the following parameters were computed for the lux equation:

0.0344827	**CPL**
0.156	**Rcoef**
1	**Gcoef**
-0.482	**Bcoef**

Table 2: Table 1 Lux Equation Parameters

For many applications this would be sufficient with a lux error less than 10% across various light sources including fluorescent, incandescent, and LED. However, if an even more accurate lux equation is desired, then we need to evaluate ways to improve the accuracy. There is a simple yet elegant way to improve the accuracy of color sensor devices that use channel coefficients to shape the spectral response.

4 Improving Color Sensor Lux Equation Accuracy

Analyzing the structure of the lux equation, it is obvious that the coefficients are directly responsible for adjusting the color content that makes up the lux equation. The spectral content of the various light sources can vary widely in color content. This is evident in the dynamic range of correlated color temperature (CCT). In addition, IR (non-visible) spectral energy content can also cause additional lux measurement errors if the subtraction of this energy content is not precise. Therefore, light sources with high percentage IR content may have increased error in R', G', and B' values. For example, if the IR subtraction calculation removes 97% of the IR content, then there is 3% IR spectral energy remaining that may create lux calculation errors. A light source with only 3% IR would have less error in the R', G', and B' than a light source with 60% IR content. As a result the CPL would be skewed by calculating CPL from light sources with and without IR content. Since the color sensor can be used to calculate the CCT of the light source as well as calculate the amount of IR content, the information to classify the light source type is available. Thus allowing us to develop lux equation per light source type which may improve the overall lux accuracy. This is done by making the lux equation parameters adjustable based on light source classification. To see how this works let use the same color sensor measurements in section 3.

Using the same data to calculate IR:

From prerequisite material IR = (R+G+B-C) / 2

Light Source	IR	Clear	IR/Clear
Office	20	243	8%
LED	27	297	9%
OPT	18.5	204	9%
HOME	214.5	409	52%
SUN	17.5	151	11%

Table 3: Clear Channel and calculated IR content per light source

As seen in table 3, the IR content is very high for the HOME light source which is an incandescent bulb. The other light source bulbs are fluorescent or LED which have a much lower calculated IR content. Using this information, we can separate the light source by IR vs. non-IR energy content and recalculate the lux equation parameters per light source type as shown in Table 4 and Table 5.

0.048773	**CPL**
0.342	**Rcoef**
1	**Gcoef**
-0.497	**Bcoef**

Table 4: Lux Equation Parameters Non-IR

0.048773	**CPL**
0.244	**Rcoef**
1	**Gcoef**
-0.577	**Bcoef**

Table 5: Lux Equation Parameters IR

Using these IR and non-IR light source parameters, it is possible to improve the lux accuracy significantly as shown in Table 6.

Light Source	Clear	Red	Green	Blue	AGAIN	ATIME	Lux (M)	Lux Calc	Lux Err%
Office	243	111	87	85	1	200	1351	1350.28	0.05
LED	297	158	89	104	1	200	1407	1406.24	0.05
OPT	204	113	66	62	1	200	1193	1194.00	0.08
HOME	409	335	238	265	1	200	488	487.7	0.06
SUN	151	77	49	60	1	200	630	630.53	0.08

Table 6: TMG3993 Light Source measurement data and lux calculations using IR and Non-IR parameters. (see references)

5 Summary

Using the single set of regression fit RGB coefficients shown in table 2 yields a lux error range from +7.06% to -6.55%. By grouping the light sources and calculating coefficients based on the light IR content (in this case) we are able to yield a lux error range from +0.08% to -0.06%. We improved the lux accuracy from better than 10% to better than 0.1% in this example. This technique worked well for this example. Note, in some cases, it may be necessary categorized the light sources by more than just IR and non-IR types to obtain the desired lux accuracy. Regardless of how the light types are determined and categorized, lux accuracy can be improved by calculating color coefficient parameter based on light source types rather than the entire collection of data. The techniques shown in this application note apply to all ams digital color sensors.

Note CPL and Gcoef remain constant for IR and non-IR light sources in table 5 and table 6. Only the Red and Blue coefficient parameters are changed per the light source type. This makes the system implementation less cumbersome requiring only two adjustable parameters per light type to achieve much higher accuracy.

6 References

For additional information about TMG3993 or any ams color sensor please refer to their datasheets.

GTI light box model MM4e: light sources office, opt, and sun are 2 meter fluorescents with 3800K, 2800K, 5000K CCT respectively. The LED has a CCT of 3400K. The Home is incandescent with 2500K CCT.

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9 Revision Information

Initial version 1-00

Changes from previous version to current revision 1-00 (2015-Aug-07)	Page
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Note: Page numbers for the previous version may differ from page numbers in the current revision.
Correction of typographical errors is not explicitly mentioned.