Ambient light sensor ICs

Digital 16bit Serial Output Type Color Sensor IC

BH1745NUC ***illuminance and color temperature formula***

General Description

BH1745NUC is digital color sensor IC with I2C bus interface. This IC senses Red, Green and Blue light (RGB) and converts them to digital values. The high sensitivity, wide dynamic range and excellent Ircut characteristics makes this IC the most suitable to obtain the illuminance and color temperature of ambient light for adjusting LCD backlight of TV, mobile phone and tablet PC. It is possible to detect very wide range light intensity. (0.005 – 40k lx)

In order to calculate illuminance and color temperature from RGB data, it is necessary to make formula every application set window. This document shows how to make them.

● Measurement and data rearrangement

It is necessary to measure under some light source. Color temperature and infrared intensity depends on light source. Some fluorescent light (or LED) and incandescent light source data is effective to get formula. Below list is light source example.

- Fluorescent light 2800K
- Fluorescent light 4000K (CWF)
- Daylight (D65)
- Incandescent light (A)
- Incandescent light with dimming 2300K (Horizon)

It is possible to measure illuminance and color temperature by chroma meter (ex. KONICA MINOLTA: CL-200A)
Measured raw data would be summarized in Table1. Register setting of sensor IC should be same. Recommended illuminance to measure is around 1000lx. C/G means the ratio of Clear data and Green data.

Table1: Example of measured raw data under window

	R	G	B	C	C/G	Measured Illuminance [lx]	Actual CCT [K]
Fluorescent 2800K	1650	1600	500	220	0.138	1000	2800
Fluorescent 4000K (CWF)	1100	1800	700	200	0.111	1000	4000
Daylight (D65)	1700	2100	1500	400	0.190	1000	6500
Incandescent (A)	3400	1600	500	600	0.375	1000	2800
Incandescent with dimming (Horizon)	2000	700	150	500	0.714	500	2300

If measured illuminance condition is not same, data rearrangement following in Table2 is necessary.

Table2: Example of rearranged data 1000lx conversion

	R	G	B	C	C/G	converted Illuminance [lx]	Actual CCT [K]
Fluorescent 2800K *1	1650	1600	500	220	0.138	1000	2800
Fluorescent 4000K (CWF)	1100	1800	700	200	0.111	1000	4000
Daylight (D65)	1700	2100	1500	400	0.190	1000	6500
Incandescent (A)	3400	1600	500	600	0.375	1000	2800
Incandescent with dimming (Horizon)	4000	1400	300	1000	0.714	1000	2300

*1 : If Fluorescent 2800K is not available, Fluorescent 2800K is estimated with following calculation.
$R_{F2800K} = 1.5 * R_{F4000K}$, $G_{F2800K} = 0.9 * G_{F4000K}$,
$B_{F2800K} = 0.7 * B_{F4000K}$, $C_{F2800K} = 1.1 * C_{F4000K}$

Rearrangement data seeing in Table2 (1000lx conversion) is used to make illuminance and color temperature formula.

● Illuminance formula

Illuminance formula format is seeing in below. It is applicable in same measurement conditions (gain and measurement time) for making formula. It is necessary to modify data according to gain setting and measurement time of sensor IC, when each setting is different.

```
if (G < 1)
    lx = 0
else If (C/G < r1)
    lx = coef1 * R + coef2 * G
else
    lx = coef3 * R + coef4 * G
```

Fig1: Illuminance formula format

5 parameters are needed about illuminance formula. Table3 is used to get them.
(r1, coef1, coef2, coef3, coef4)

Table3: Example of rearranged data 1000lx conversion

	R	G	B	C	C/G	converted Illuminance [lx]	Actual CCT [K]
Fluorescent 2800K	1650	1600	500	220	0.138	1000	2800
Fluorescent 4000K (CWF)	1100	1800	700	200	0.111	1000	4000
Daylight (D65)	1700	2100	1500	400	0.190	1000	6500
Incandescent (A)	3400	1600	500	600	0.375	1000	2800
Incandescent with dimming (Horizon)	4000	1400	300	1000	0.714	1000	2300

Step3 Step2 Step1

Step1: Calculate Value C/G: (r1)

r1 is average value of C/G of Fluorescent 4000K and Daylight.

In case of Table3
*r1 = (C/G(CWF) + C/G (D65)*2) / 3 = (0.111 + 0.190*2) / 3 = 0.164*

Step2: Make scatter diagram by Excel and display the trendline about Fluorescent (coef1, coef2)

It is easy to get coef1 and coef2 by Microsoft Excel. Scatter diagram is made by R and G data of Fluorescent.

1) Plot R and G data of Fluorescent in scatter diagram. (X-axis: R, Y-axis: G)
2) Display the trendline (Linear) and the equation on chart.
3) Calculate to get coef1 and coef2

coef1 = converted illuminance / var_B * var_A * (-1)
coef2 = converted illuminance / var_B

In case of Table3,
Scatter diagram is seeing in Fig2
***coef1** = 1000 / 2200 * (-0.3636) * (-1)*
= 0.165
***coef2** = 1000 / 2200*
= 0.455

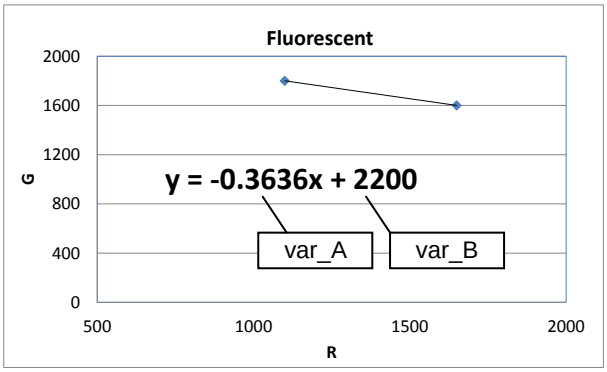

Fig2

Step3: Make scatter diagram by Excel and display the trendline about Incandescent and Daylight (coef3, coef4)

Method is same as step2
(Incandescent and Daylight are used.)

coef3 = converted illuminance / var_D * var_C * (-1)
coef4 = converted illuminance / var_D

In case of Table3
Scatter diagram is seeing in Fig3
***coef3** = 1000 / 2616.4 * (-0.3021) * (-1)*
= 0.115
***coef4** = 1000 / 2616.4*
= 0.382

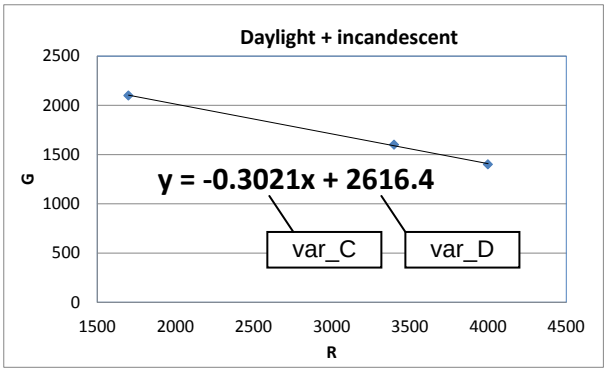

Fig3

● Color temperature formula

Color temperature formula format is seeing in below.

```
if (G<1 || R+G+B<1) {
    CCT = 0
     return
}

R_ratio = R / (R+G+B)
B_ratio = B / (R+G+B)

if (C/G < r1) {
     B_eff = MIN(B_ratio * coef5, 1)
     CCT = (1-B_eff) * coef6 * EXP(coef7 * R_ratio) + B_eff * coef8 * EXP(coef9 * B_ratio)
} else {
     B_eff = MIN(B_ratio * coef10, 1)
     CCT = (1-B_eff) * coef11 * EXP(coef12 * R_ratio) + B_eff * coef13 * EXP(coef14 * B_ratio)
}

if (CCT > 10000) CCT = 10000
```

Fig4: Color temperature formula format

11 parameters are needed about color temperature formula. Table4 is used to get them.
(r1, coef5, coef6, coef7, coef8, coef9, coef10, coef11, coef12, coef13, coef14)

Table4: Example of rearranged data 1000lx conversion

	R	G	B	C	C/G	converted Illuminance [lx]	Actual CCT [K]
Fluorescent 2800K	1650	1600	500	220	0.138	1000	2800
Fluorescent 4000K (CWF)	1100	1800	700	200	0.111	1000	4000
Daylight (D65)	1700	2100	1500	400	0.190	1000	6500
Incandescent (A)	3400	1600	500	600	0.375	1000	2800
Incandescent with dimming (Horizon)	4000	1400	300	1000	0.714	1000	2300

Step3 Step2 Step1

Step1: Calculate Value C/G: (r1)

r1 is same as illuminance formula, please refer it.

Step2: Calculate Value C/G: (coef5, coef10)

coef5 = 0.9 / B_ratio of Daylight
coef10 = 0.9 / B_ratio of Incandescent

* “0.9” is fixed value.

In case of Table4

coef5 *= 0.9 / (1500 / (1700+2100+1500))*
= 3.18
coef10 *= 0.9 / (500 / (3400+1600+500))*
= 9.90

Step3: Make scatter diagram by Excel and display the trendline
(coe6, coef7, coef8, coef9, coef11, coef12, coef13, coef14)

It is easy to get each coefficient by Microsoft Excel. Scatter diagram is made by R_ratio and B_ratio and Actual CCT.

1) Plot R_ratio and color temperature data of Fluorescent and Daylight in scatter diagram and display the trendline(Exponential) and the equation on chart.
(X-axis: R_ratio, Y-axis: actual CCT)

2) Plot B_ratio and color temperature data of Fluorescent and Daylight in scatter diagram and display the trendline(Exponential) and the equation on chart.
(X-axis: B_ratio, Y-axis: actual CCT)

3) Plot R_ratio and color temperature data of Daylight and Incandescent in scatter diagram and display the trendline(Exponential) and the equation on chart.
(X axis: R_ratio, Y axis: actual CCT)

4) Plot B_ratio and color temperature data of Daylight and Incandescent in scatter diagram and display the trendline(Exponential) the equation on chart.
(X axis: B_ratio, Y axis: actual CCT)

It is possible to get each coefficient from equation of trendline.

In case of Table4, scatter diagram is below Fig.

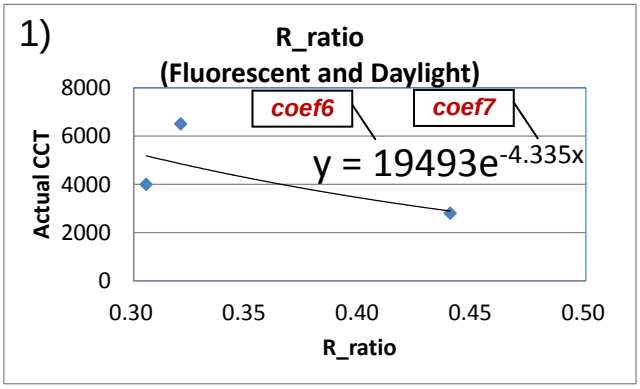

Fig5

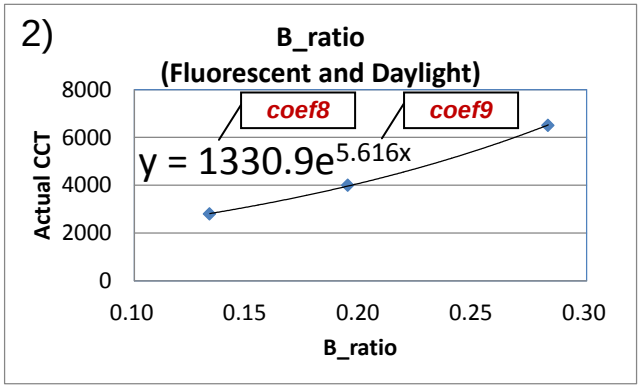

Fig6

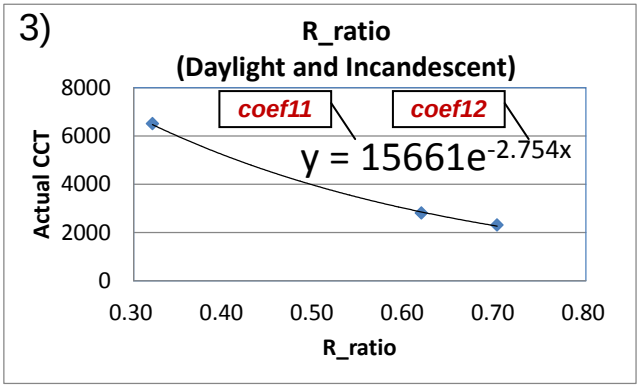

Fig7

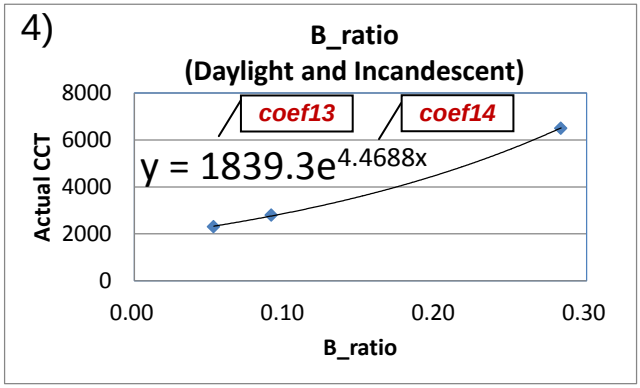

Fig8

coef6 *= 19493*
coef7 *= -4.335*
coef8 *= 1330.9*
coef9 *= 5.616*
coef11 *= 15661*
coef12 *= -2.754*
coef13 *= 1839.3*
coef14 *= 4.4688*

● Calibration method with each product.

It is possible to reduce influence of variation of optical window by testing RGBC data and making calibration coefficients in each product.
Calibration coefficients should be stored in memory.

1) Measure reference RGBC value with typical window under Daylight (D65).

2) Measure RGBC value with MP product under Daylight (D65).
Illuminance should be same or converted to the measured reference value.

3) Make calibration coefficients.
Coefficients are calculated using Daylight (D65) result with typical window and MP product.

$CoefR = R_{ref} / R_{product}$
$CoefG = G_{ref} / G_{product}$
$CoefB = B_{ref} / B_{product}$
$CoefC = C_{ref} / C_{product}$

4) Multiply raw data of each product by calibration coefficients.
These calculations are done in each measurement.

$R_{clb} = CoefR * R_{raw}$
$G_{clb} = CoefG * G_{raw}$
$B_{clb} = CoefB * B_{raw}$
$C_{clb} = CoefC * C_{raw}$

Table5: Example of calibration

	R	G	B	C
1) Daylight (D65) reference data	1700	2100	1500	400
2) Daylight (D65) product data	2330	2940	1950	570
3) Calibration coefficients	0.730	0.714	0.769	0.702
4) Daylight (D65) calibrated data	1701	2099	1500	400

● Troubleshooting

i) Way of the fine adjustment of illuminance.

In case of adjusting Fluorescent, multiply coef1 and coef2 by same value.
In case of adjusting Incandescent and Daylight, multiply coef3 and coef4 by same value.

Ex) if you want to decrease calculated illuminance value of Incandescent and Daylight to -5%, multiply coef3 and coef4 by 0.95.

ii) Way of the fine adjustment of color temperature.

In case of adjusting Fluorescent, multiply coef6 and coef8 by same value.
In case of adjusting Incandescent and Daylight, multiply coef11 and coef13 by same value.

Ex) if you want to decrease calculated color temperature value of Incandescent and Daylight to -5%, multiply coef11 and coef13 by 0.95.

iii) How to make trendline on Microsoft Excel.

1) Make graph.
2) Right click at data point on graph. Then new menu appears.

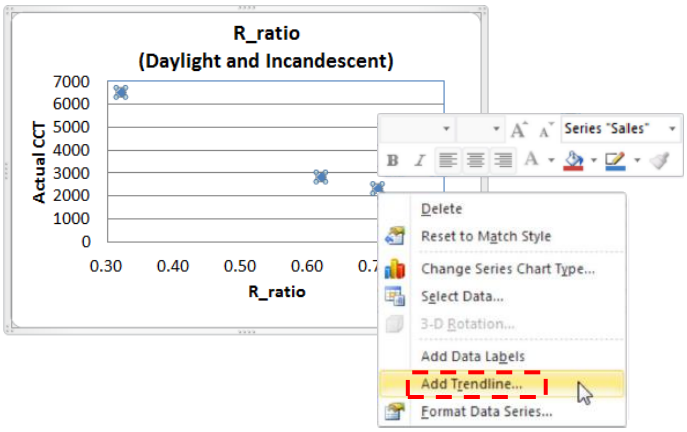

Fig9

3) Choose “Add Trendline…”. Then following menu appears.

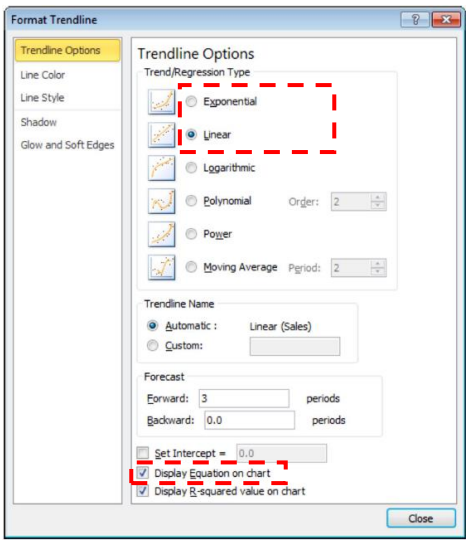

Fig10

4) Choose “Linear” for illuminance or “Exponential” for color temperature, check “Display Equation on chart”, and push “Close”.

5) Then trendline and equation are drawn on graph.