HiISP Color Optimization Description

Issue 00B07

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About This Document

Purpose

This document introduces the algorithm tuning and problem locating of automatic white balance (AWB), color correction matrix (CCM), and color look-up table (CLUT), and describes calibration and parameter adjustment to provide solutions and help for you to solve the problems in the development process.

NOTE

- Unless otherwise stated, Hi3559C V100, Hi3519A V100, Hi3556A V100, Hi3516C V500, Hi3516D V300, Hi3559 V200, Hi3556 V200, Hi3516A V300, Hi3516E V200, Hi3516E V300, Hi3518E V300, and Hi3559A V100 contents are consistent.
- Unless otherwise stated, Hi3516C V500, Hi3516D V300, Hi3516A V300, Hi3559 V200, and Hi3556 V200 contents are consistent.
- Unless otherwise stated, Hi3516EV200, Hi3516E V300, Hi3516D V200, and Hi3518E V300 contents are consistent.

Related Versions

The following table lists the product versions related to this document.

Product Name	Version
Hi3516A	V100
Hi3516D	V100
Hi3518E	V20X
Hi3516C	V200
Hi3516C	V300
Hi3516E	V100
Hi3519	V100
Hi3519	V101
Hi3516A	V200
Hi3559	V100
Hi3556	V100

Product Name	Version
Hi3559A	V100ES
Hi3559A	V100
Hi3559C	V100
Hi3519A	V100
Hi3556A	V100
Hi3516C	V500
Hi3516D	V300
Hi3516A	V300
Hi3559	V200
Hi3556	V200
Hi3516E	V200
Hi3516E	V300
Hi3518E	V300
Hi3516D	V200

Intended Audience

This document is intended for:

- Technical support engineers
- Software development engineers

Symbol Conventions

The symbols that may be found in this document are defined as follows.

Symbol	Description
DANGER	Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.
WARNING	Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
CAUTION	Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.

Symbol	Description
NOTICE	Indicates a potentially hazardous situation which, if not avoided, could result in equipment damage, data loss, performance deterioration, or unanticipated results. NOTICE is used to address practices not related to personal injury.
NOTE	Calls attention to important information, best practices and tips. NOTE is used to address information not related to personal injury, equipment damage, and environment deterioration.

Change History

Changes between document issues are cumulative. The latest document issue contains all changes made in previous issues.

Issue 00B07 (2019-02-28)

This issue is the seventh draft release, which incorporates the following changes:

Section 1.3 is added.

In section 2.1.2, table 2-2 is modified.

In section 2.1.3, table 2-4 is modified.

Issue 00B06 (2018-09-06)

This issue is the sixth draft release, which incorporates the following changes:

In section 2.4, Table 2-6 is modified.

The descriptions of the Hi3516C V500 and Hi3516D V300 are added.

Issue 00B05 (2018-06-15)

This issue is the fifth draft release, which incorporates the following changes:

In section 2.1.2, Table 2-1 is modified.

Section 2.1.4 is modified.

Sections 2.2.6.2, 2.2.6.5, 2.3, 2.5.2, and 2.5.4 are added.

In section 3.5.4, Table 3-1 is modified. Section 3.5.8 is modified.

Sections 4.2.5 and 4.2.6 are modified.

Issue 00B04 (2018-04-04)

This issue is the fourth draft release, which incorporates the following changes:

Sections 1.1 and 3.1 are added.

Sections 3.2.3 to 3.2.5 and chapter 4 are modified.

Issue 00B03 (2018-02-10)

This issue is the third draft release, which incorporates the following changes:

Section 1.2 is modified.

The layout of chapter 2 is updated.

Issue 00B02 (2018-01-12)

This issue is the second draft release, which incorporates the following changes:

The descriptions about the Hi3559A V100 and Hi3559C V100 are added.

Issue 00B01 (2017-09-05)

This issue is the first draft release.

Contents

Figures

Tables

1 Introduction to the Principles

1.1 Color Tuning Overview

HiISP provides two color tuning schemes. One is the basic color tuning scheme. The system colors are controlled by the combined results of the AWB, CCM, and Gamma modules, as shown in Figure 1-1. The color style is consistent across the entire color gamut. That is, the color space defined by the sRGB standard (device-independent colors) converted by the 3 x 3 CCM from the native color space (device colors) of the sensor. The sensor response is linearly expanded to the target space, that is, all colors can be linearly expanded in consistency. The color display varies according to the spectral response characteristics of the sensor.

Figure 1-1 Basic color tuning scheme

The saturation of all colors changes with the CCM. Conflicts may occur between different hues. That is, if some hues are adjusted first, the adjacent hues cannot be adjusted properly. The colors of the dark, medium-bright, and highlighted regions of the 3 x 3 matrix are consistently adjusted. The colors of the three kinds of luminance regions cannot be separately adjusted.

Apart from the basic color tuning scheme, you may choose the advanced color tuning scheme. The system colors are controlled by the combined results of the AWB, CCM CLUT, Gamma, CA modules, and the color style can be adjusted as required.

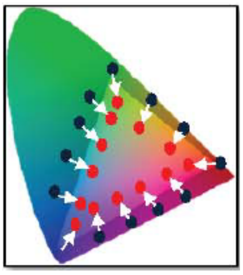
Figure 1-2 Advanced color tuning scheme

By using the advanced color tuning scheme, you can have different color styles. For example, different effects can be generated if you process the colors with high saturation in different ways.

The style mapped inwards from the gamut edges indicates the color style mapped inwards from gamut regions with high saturation based on the color effects achieved by the CCM.

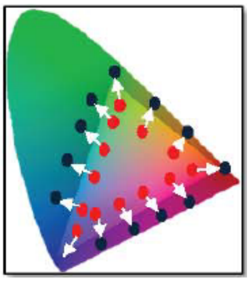
High saturation is reduced to avoid that a value of the RGB is less than **0** or greater than **1**. Colors with high saturation can be retained to extend the gamut. This style applies to sensors with good spectral response. Colors with medium and low saturation can have better performance with the CCM. The colors with medium and low saturation are retained first.

Figure 1-1 Style mapped inwards from the gamut edges



The style mapped outwards from the gamut edges indicates the color style mapped outwards from regions with high saturation based on the color effects achieved by the CCM. High saturation is strengthened, therefore, a value of the RGB is more likely to be less than **0** or greater than **1**. Colors become more vivid and the main body in the image are highlighted. This style applies to sensors with poor spectral response. The saturation is supplemented by the CLUT module to prevent the CCM coefficients from being too large. Colors with medium and low saturation are less bright with the CCM. The colors with high saturation are retained first.

Figure 1-2 Style mapped outwards from the gamut edges



1.2 Operating Principle of the AWB Module

The automatic white balance (AWB) module consists of the hardware WB statistics module and firmware AWB policy control algorithm.

The WB statistics module calculates the average values of R, G, and B color channels for pixels that meet the gray pixel conditions in raw images. It outputs the average RGB values of the entire image as well as those of each block in the entire image which is divided into *m* x *n* blocks.

$$awb_{mn} = \sum_{p \in \Omega_{mn}} \theta_p$$

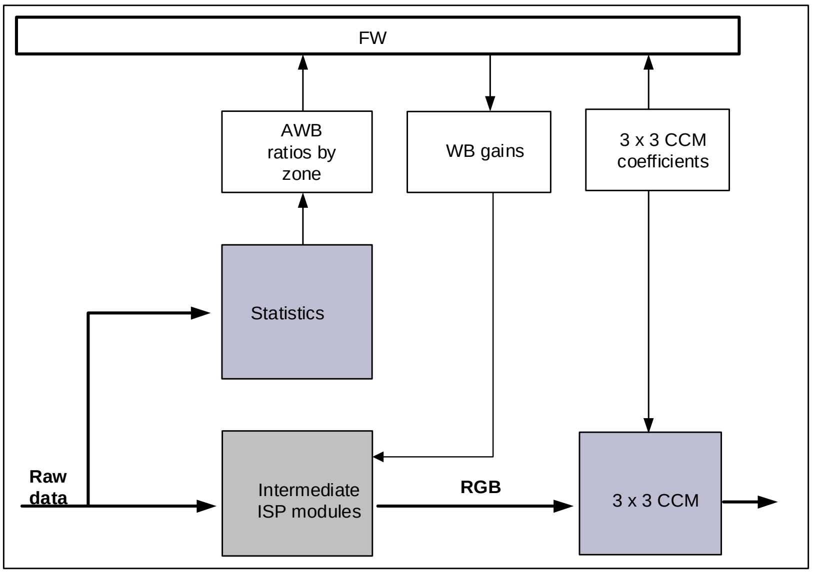
$$awb\_r = \sum_{p \in \Omega_{mn}} R_p * \theta_p / awb_{mn}$$

In the formulas, **θ** indicates whether the current pixel is a gray pixel and the value is **0** or **1**. awb_{mn} indicates the number of gray pixels in the blocks. **R** indicates the red channel value of pixels. awb_r indicates the average value of the R color channel.

The average values of the green (G) and blue (B) components can also be calculated in the same way as the red (R) component.

The AWB gain coefficient is obtained by calculating G/R and G/B based on the average values of the R, G, and B components provided by the AWB statistics module. The firmware (FW) algorithm determines the ambient color temperature based on the statistics of each block to calculate the optimal AWB coefficient.

Figure 1-3 Schematic diagram of the AWB module



1.2 Differences Between SpecAWB and GW AWB

SpecAWB is a machine-learning algorithm. HiSilicon completes machine learning and provides an empirical light source distribution table (device-independent). The customer collects color chart data of the standard light source, obtains the device-related distribution table of a specific light source based on the empirical light source distribution table, and completes the SpecAWB calibration.

The empirical light source distribution table provided by PQ Tools is obtained by learning data of a series of mobile cameras. Compared with GW AWB, SpecAWB has the following risks in IPC applications:

- When the ambient light source deviates greatly from the standard light source, SpecAWB fails to completely calibrate image defects, and the light source color is retained.

- When the ambient color temperature is higher than 10000K and lower than 2500K, SpecAWB fails to completely calibrate image defects, and the light source color is retained.
- In low illumination, SpecAWB fails to completely calibrate image defects, and the light source color is retained.
- The SpecAWB accuracy decreases when ColorShading is not fully calibrated.

SpecAWB outperforms GW AWB in large-area single-color scenarios.

1.3 Operating Principle of the CCM Module

The responses to the spectrum (R, G, and B components) are different between sensors and human eyes. A color correction matrix (CCM) is used to correct the spectrum response cross effect and spectral responsivity, ensuring that the colors of captured images are the same as visual colors.

The CCM calibration tool supports 3 x 3 CCM pre-correction for a ColorChecker.

The tool supports at least three groups of CCM with different color temperatures and at most seven such groups. When the image signal processor (ISP) is working, the FW adjusts the saturation coefficients based on the current illumination strength (that is, the ISO). The dynamic adjustment of the CCM is implemented through dynamic CCM coefficients (based on multiple groups of calibrated CCM interpolations) and saturation adjustment coefficients. Figure 1-4 shows a CCM.

Figure 1-4 CCM

$$\begin{pmatrix} R' \\ G' \\ B' \end{pmatrix} = \begin{pmatrix} m_{RR} & m_{RG} & m_{RB} \\ m_{GR} & m_{GG} & m_{GB} \\ m_{BR} & m_{BG} & m_{BB} \end{pmatrix} \bullet \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

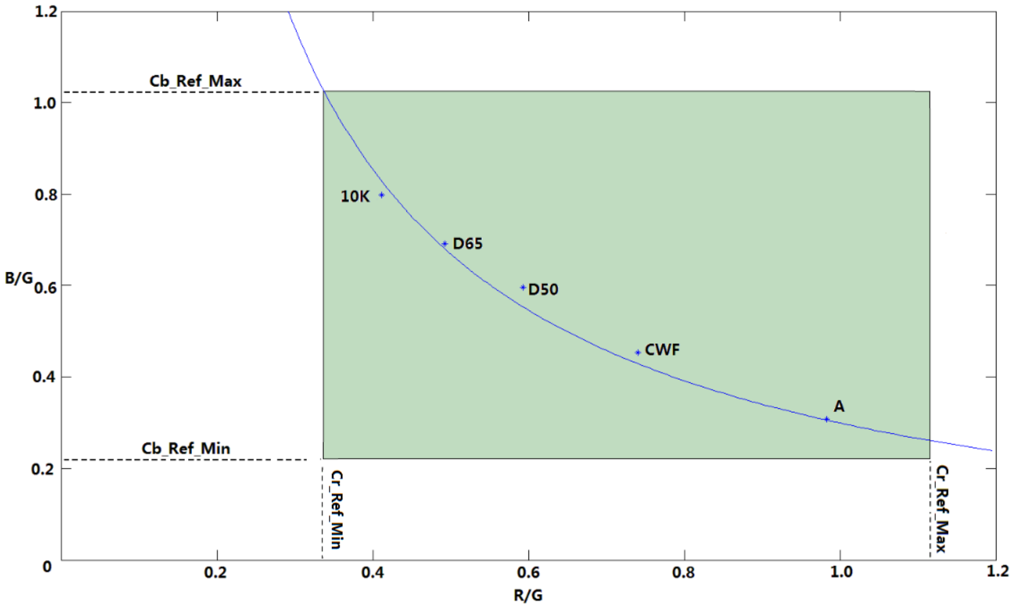
2 AWB Tuning

2.1 Tuning the Statistics Module

The WB statistics module collects only the average RGB values of gray pixels. Therefore, when the conditions of defining gray pixels are accurately configured, the accuracy of the firmware algorithm can be enhanced.

2.1.1 Chromatic Aberration Limit

Figure 2-1 Chromatic aberration limit of gray pixels



2.1.2 Gray Pixel Parameters and Chip Differences

Table 2-1 Gray pixel parameters in the WB statistics for the Bayer domain

Parameter	Description	Scenario
u16MeteringWhiteLevelAwb	Upper luminance limit of gray pixels The value range is [0x0, 0xFFFF] and the default value is **0xFFFF**. Note that the value of this parameter is fixed at **0xEE48** according to the SPECAWB algorithm. Difference exits between chips. For details, see Table 2-2.	When the sensor becomes nearly saturated, the linear ratio of gray pixels will be damaged. Therefore, it is advisable to decrease the value.
u16MeteringBlackLevelAwb	Lower luminance limit of gray pixels The value range is [0x0, 0xFFF] and the default value is **0x0**. Difference exits between chips. For details, see Table 2-2.	In WDR mode, the value of this parameter must be set to the minimum value of input raw data in the statistics module. In linear mode, the value of this parameter is the minimum value of input raw data in the statistics module plus offset which is less than or equal to 0x10 to ensure that bright regions take priority for AWB reproduction.
u16MeteringCrRefMaxAwb	Maximum R/G value of gray pixels (8 bit-precision) The value range is [0x0, 0xFFF] and the default value is **0x200** (equivalent to floating point number 2.0). Note that the value of this parameter is fixed at **0xFFF** according to the SPECAWB algorithm.	Chromatic aberration parameters are closely related to the sensor or optical components. It is advisable to implement fine-tuning for the parameters. AWB firmware associates the **CrMax**, **CrMin**, **CbMax**, and **CbMin** parameters with the color temperature and ISO. Each parameter must be set to an array with the length of 16 values. The measure to check whether the defining of gray pixels is configured properly is specified in section 2.2.3.5 "Confirming Calibration Results (SPECAWB)." The SPECAWB algorithm does not associate **CrMax**, **CrMin**, **CbMax**, and **CbMin** with the ISO. The parameters are set to fixed values.
u16MeteringCrRefMinAwb	Minimum R/G value of gray pixels (8 bit-precision) The value range is [0x0, 0xFFF] and the default value is **0x80** (equivalent to floating point number 0.5). Note that the value of this parameter is fixed at **0x0** according to the SPECAWB algorithm.	
u16MeteringCbRefMaxAwb	Maximum B/G value of gray pixels (8 bit-precision) The value range is [0x0, 0xFFF] and the default value is **0x200** (equivalent to floating point number 2.0). Note that the value of this parameter is fixed at **0xFFF** according to the	

Parameter	Description	Scenario
	SPECAWB algorithm.	
u16MeteringCbRefMinAwb	Minimum B/G value of gray pixels (8 bit-precision) The value range is [0x0, 0xFFF] and the default value is **0x80** (equivalent to floating point number 0.5). Note that the value of this parameter is fixed at **0x0** according to the SPECAWB algorithm.	

Table 2-2 Differences of statistics control parameters for the Bayer domain

Chip Type	Statistics Input Format	Description	Remarks
Hi3516A	12 bits Containing the black level Non-linear in WDR mode	Linear mode and WDR mode: The value range of **BlackLevelAwb** is [black level, 0xFFF]. The value range of **WhiteLevelAwb** is [black level, 0xFFF].	In WDR mode, the compression of parameters such as **CrMax** is implemented by the ISP library.
Hi3518E V200	12 bits Not containing the black level Linear in WDR mode	The linear mode and WDR mode are not differentiated: The value range of **BlackLevelAwb** is [0x0, 0xFFF]. The value range of **WhiteLevelAwb** is [0x0, 0xFFF].	-
Hi3519 V100	12 bits Not containing the black level Linear in WDR mode	The linear mode and WDR mode are not differentiated: The value range of **BlackLevelAwb** is [0x0, 0xFFF]. The value range of **WhiteLevelAwb** is [0x0, 0xFFF].	The logical statistics input data contains the black level and is compressed in WDR mode. The firmware masks the differences.
Hi3519 V101	12 bits Not containing the black level Linear in WDR mode	The linear mode and WDR mode are not differentiated: The value range of **BlackLevelAwb** is [0x0, 0xFFF]. The value range of **WhiteLevelAwb** is [0x0, 0xFFF].	-
Hi3516C V300	16 bits Not containing the black level Linear in WDR mode	The linear mode and WDR mode are not differentiated: The value range of **BlackLevelAwb** is [0x0, 0xFFFF].	-

Chip Type	Statistics Input Format	Description	Remarks
		The value range of **WhiteLevelAwb** is [0x0, 0xFFFF].	
Hi3559A V100ES	16 bits Not containing the black level Linear in WDR mode	The linear mode and WDR mode are not differentiated: The value range of **BlackLevelAwb** is [0x0, 0xFFFF]. The value range of **WhiteLevelAwb** is [0x0, 0xFFFF].	-
Hi3559A V100/Hi3519A V100/Hi3516C V500/Hi3516E V200	16 bits Not containing the black level Linear in WDR mode	The linear mode and WDR mode are not differentiated: The value range of **BlackLevelAwb** is [0x0, 0xFFFF]. The value range of **WhiteLevelAwb** is [0x0, 0xFFFF].	-

2.1.3 Statistics Output Description and Chip Differences

Table 2-3 Description of statistics results for the Bayer domain

Parameter	Description	Scenario
u16MeteringAwbAvgR	Average R value of gray pixels in the global statistics. Value range: [0, 0xFFFF]	There is difference in the data bit width of the average values of R, G, and B components between chips. For details, see Table 2-4.
u16MeteringAwbAvgG	Average G value of gray pixels in the global statistics. Value range: [0, 0xFFFF]	-
u16MeteringAwbAvgB	Average B value of gray pixels in the global statistics. Value range: [0, 0xFFFF]	-
u16MeteringAwbCountAll	Number of gray pixels in the global statistics, which has been normalized. Value range: [0, 0xFFFF]	-
u16MeteringAwbCountMin	Number of pixels less than **BlackLevel** in the global statistics, which has been normalized. Value range is [0, 0xFFFF]	
u16MeteringAwbCountMax	Number of pixels greater than **WhiteLevel** in the global statistics, which has been normalized.	

Parameter	Description	Scenario
	Value range: [0, 0xFFFF]	
au16MeteringMemArrayAvgR[]	Average R value of gray pixels in the zoned statistics Value range: [0, 0xFFFF]	-
au16MeteringMemArrayAvgG[]	Average G value of gray pixels in the zoned statistics Value range: [0, 0xFFFF]	-
au16MeteringMemArrayAvgB[]	Average B value of gray pixels in the zoned statistics Value range: [0, 0xFFFF]	-
au16MeteringMemArrayCountAll[]	Number of gray pixels in the zoned statistics, which has been normalized. Value range: [0, 0xFFFF]	-
au16MeteringMemArrayCountMin[]	Number of pixels less than **BlackLevel** in the zoned statistics, which has been normalized. Value range: [0, 0xFFFF]	-
au16MeteringMemArrayCountMax[]	Number of pixels greater than **WhiteLevel** in the zoned statistics, which has been normalized. Value range: [0, 0xFFFF]	-

NOTICE

Normalization of the number of pixels helps to eliminate the impact of resolution difference on the number of gray pixels.

The normalization formula is as follows: CountAll = (Count of gray pixels << 16)/(Count of all pixels).

Table 2-4 Statistics result differences for the Bayer domain

Chip Type	Statistics Output Format	Remarks
Hi3516A	The data bit width of the output average RGB values is 16 bits. Value range: [0, 0xFFFF]. The value consists of the 12-bit integral part and 4-bit decimal part. In linear mode, RGain = G/R. In WDR mode, RGain = DeComp(G)/DeComp(R). For details about the decompression mode, see the Sample 2.2 code.	The average RGB values by logical statistics output contain the black level, which is subtracted after the firmware reads the statistics result. Therefore, you do not need to process the black level. However, in WDR mode, the average RGB values need to be decompressed.

Chip Type	Statistics Output Format	Remarks
Hi3518E V200	The data bit width of the output average RGB values is 12 bits. Value range: [0, 0xFFF] The value consists of the 12-bit integral part and no decimal part. In both linear mode and WDR mode, RGain = G/R.	-
Hi3519 V100	The data bit width of the output average RGB values is 16 bits. Value range: [0, 0xFFFF]. The value consists of the 12-bit integral part and 4-bit decimal part. In both linear mode and WDR mode, RGain = G/R.	The average RGB values by logical statistics output contain the black level, which is subtracted after the firmware reads the statistics result. You do not need to process the black level or decompress the average RGB values. In WDR mode, the 12-bit statistics precision is insufficient. When there is no valid information in the Bayer statistics, the RGB average values for the Bayer domain will be calculated reversely by the RGB statistics.
Hi3519 V101	The data bit width of the output average RGB values is 16 bits. Value range: [0, 0xFFFF]. The value consists of the 12-bit integral part and 4-bit decimal part. In both linear mode and WDR mode, RGain = G/R.	In WDR mode, the 12-bit statistics precision is insufficient. When there is no valid information in the Bayer statistics, the RGB average values for the Bayer domain will be calculated reversely by the RGB statistics.
Hi3516C V300	The data bit width of the output average RGB values is 16 bits. Value range: [0, 0xFFFF]. The value consists of the 16-bit integral part and no decimal part. In both linear mode and WDR mode, RGain = G/R.	The **CountMax** and **CountMin** outputs are invalid.
Hi3559A V100ES	The data bit width of the output average RGB values is 16 bits. Value range: [0, 0xFFFF] The value consists of the 16-bit integral part and no decimal part. In both linear mode and WDR mode, RGain = G/R.	The **CountMax** and **CountMin** outputs are invalid.
Hi3559A V100/Hi3519A V100/Hi3516C V500/Hi3516E V200	The data bit width of the output average RGB values is 16 bits. Value range: [0, 0xFFFF] The value consists of the 16-bit integral part and no decimal part.	The **CountMax** and **CountMin** outputs are invalid.

Chip Type	Statistics Output Format	Remarks
	In both linear mode and WDR mode, RGain = G/R.	

The following is the sample of Hi3516A statistics result decompression:

```
ISP_AWB_INFO_S  stAwbInfo;  /* AWB statistics result structure*/
/*Bayer statistics, pow2 to get linear data. The average RGB values are
16 bit valid*/
stAwbInfo->pstAwbStat3->u16MeteringAwbAvgR =
(POW2((HI_U32) stAwbInfo->pstAwbStat3->u16MeteringAwbAvgR) >> 16);
…
/*process other R, G, B values in the same way*/
```

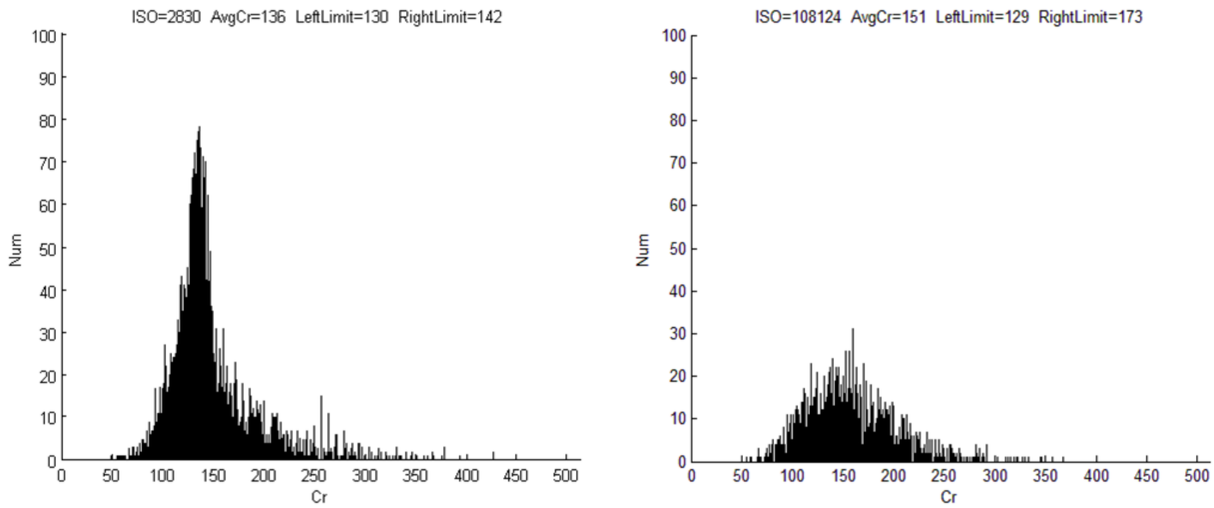
2.1.4 Statistics Adaptation

Automatic Adjustment of Statistics Parameters (AWB)

As the ambient illumination decreases, bigger noise of raw data is output by the sensor when the sensor and ISP have greater gains. For the same illuminant, the chromatic aberration distribution of white blocks (at the color temperature of 5000 K) changes, as shown in Figure 2-2.

Note that the SPECAWB algorithm does not require adaptive adjustment for statistics parameters.

Figure 2-2 Chromatic aberration distribution of white Cr blocks (at the color temperature of 5000 K) changes



Therefore, it is required to establish interaction between statistics parameters and ISOs to ensure that gray pixels are involved in the statistics as many as possible.

2.2 AWB Calibration

2.2.1 AWB Calibration Parameters

After determining the sensor and optical filter, perform AWB calibration first to ensure the normal running of the AWB algorithm. In AWB calibration, the Planckian fitting curve and color temperature fitting curve are calculated based on the gray pixel features (R/G and B/G) of the sensor under multiple standard illuminants.

Table 2-5 AWB calibration parameters

Parameter	Description	Scenario Description
u16RefColorTemp	Ambient color temperature for static WB coefficient calibration, also the medium color temperature of the three key illuminants (KIs) in AWB calibration (in Kelvin) Value range： [0, 0xFFFF].	It is recommended that the raw data of a ColorChecker is captured and calibrated under the Macbeth D50 standard illuminant or an outdoor 5000 K–5500 K illuminant.
au16StaticWB[4]	Static WB coefficient, provided by the AWB calibration tool Value range: [0, 0xFFF]	8-bit fixed-point number. The coefficient of the G channel is fixed at **0x100** (floating point number 1.0).
as32CurvePara[0-2]	Planckian curve coefficient, provided by the AWB calibration tool The Planckian curve depicts the color performance of white blocks under the standard illuminant with different color temperatures.	-
as32CurvePara[3-5]	Color temperature curve coefficient, provided by the AWB calibration tool The color temperature curve depicts the mapping relationships between the color performance of white blocks and color temperatures.	-

2.2.2 Raw Data Capture

2.2.2.1 Illuminant Selection

- Natural illuminants with the color temperature between 5000 K and 5500 K
- Artificial illuminant D50
- Illuminant A
- Artificial illuminant D75 or natural illuminants with the 7000 K and above color temperature

The preceding four groups of illuminants are mandatory. If more data of illuminants such as CWF, TL84, D65, and 3500 K–6500 K natural illuminants are supplemented, the calibration accuracy can be improved.

2.2.2.2 Capture Procedure

Step 1 Prepare the picture capture devices, including the standard X-Rite ColorChecker, even light sources with the 600 lux illumination (one light source on the left side and one on the right side; the intersection angle between the light source and the ColorChecker plane ranges from 25° to 45°), Internet Protocol camera (IPC), and color temperature meter. Capture the ColorChecker raw picture in an outdoor environment with natural lighting at a color temperature of about 5000 K to improve the accuracy of calibration.

Step 2 Adjust the AE target luminance so that the luminance of the G component in the block with the highest grayscale (block 19) is 0.8 times of the saturation (taking the 12-bit raw data as an example, the G component value ranges from 0xC00 to 0xD80).

Step 3 Capture the neutral gray raw picture, and check the lens shading level of the IPC. If shading is serious, calibrate the shading coefficient first. For the ColorChecker picture, implement lens shading correction (LSC) and then AWB calibration.

----End

2.2.3 Calibration

2.2.3.1 Performing Automatic AWB Calibration (AWB)

Step 1 Import raw data. For details, see the *HiSilicon PQ Tools User Guide*.

Step 2 Confirm whether the raw data import is configured properly. If the image brightness is proper and the color of the ColorChecker is correct, then the bit width of raw data and the RGGB sequence are correct. In this case, open any images, select the grayscale region of the ColorChecker, and calculate the R/G and B/G values, as shown in the red box of Figure 2-3. If different grayscales have basically the same R/G and B/G values, it indicates that the black level is configured correctly.

Step 3 Configure the color temperature of each raw image correctly, and calculate the R/G and B/G values of gray pixels in each image. When using a ColorChecker, the R/G and B/G values are generally calculated by using 20–22 color blocks. In actual use, do not use overexposed or over dark gray blocks for calculation.

Step 4 Select three illuminants of the raw files as the KIs, which serve as the calibration start points. It is recommended that illuminants A, D50, and D75 be selected as the KIs. The selection of D50 illuminants with a medium color temperature is crucial. It is recommended that natural illuminants between the 5000 K and 5500 K be used for optimizing outdoor AWB performance. When the medium color temperature of the selected illuminants is high, the image becomes warm. On the contrary, when the medium color temperature of the selected illuminants is low, the image becomes cold, as shown in Figure 2-4.

Step 5 The calibration tool supports a maximum of 32 groups of illuminants involved in AWB calibration. For outdoor products, it is recommended that calibration be implemented in the evening or at early morning when the color temperature is high, as shown in Figure 2-5.

Figure 2-3 Checking whether the black level is configured correctly

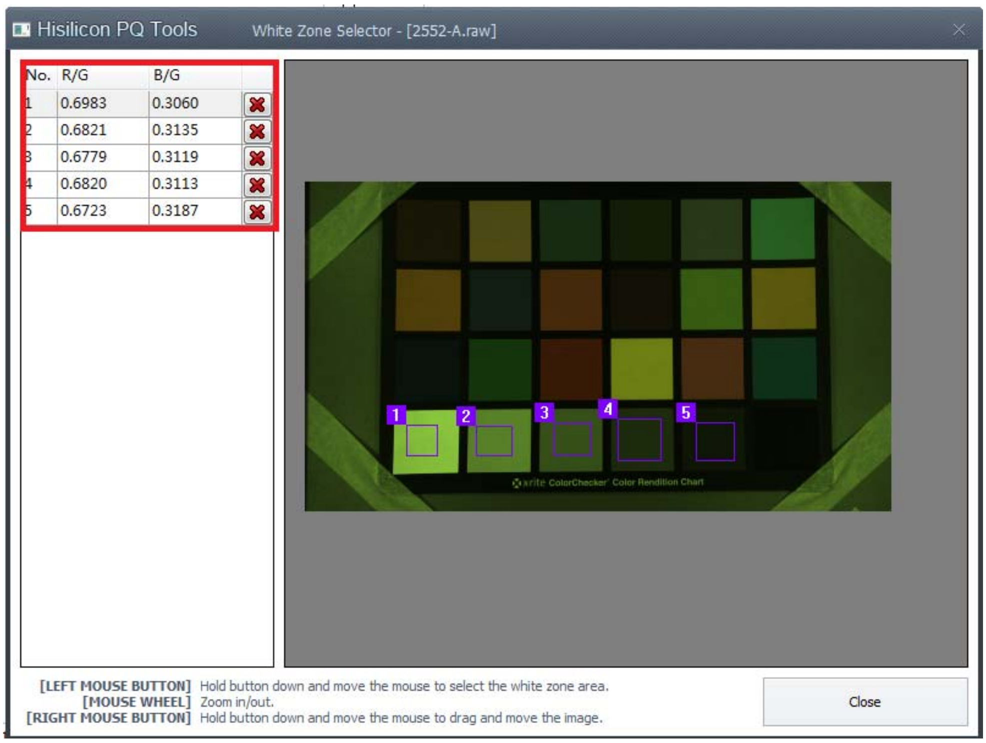
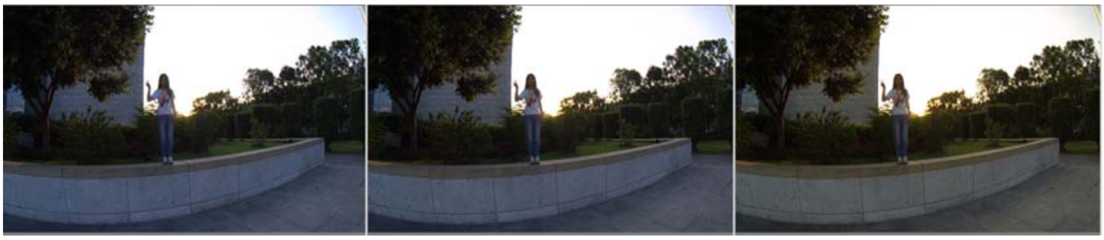


Figure 2-4 Image comparison among illuminants with the medium color temperatures of 4500 K, 5500 K, and 6500 K



----End

2.2.3.2 Performing Automatic AWB Calibration (SPECAWB)

Step 1 Import raw data. For details, see the *HiSilicon PQ Tools User Guide*.

Step 2 Confirm whether the raw data import is configured properly. If the image brightness is proper and the color of the ColorChecker is correct, it indicates that the bit width of raw data and the RGGB sequence are correct. In this case, open an image, select the grayscale region of the ColorChecker and calculate the G/R and G/B values, as shown in the red box of Figure 1-3. If different grayscales have basically the same G/R and G/B values, it indicates that the black level is configured correctly.

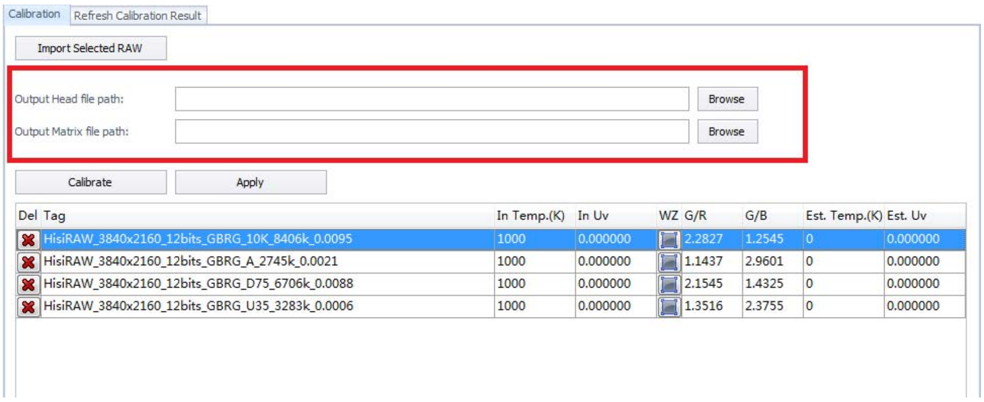
Step 3 Correctly configure the color temperature of each raw image. The ΔUv values (which can be obtained from the color temperature table) are used to calculate the G/R and G/B values of gray points of each image. When a ColorChecker is used, the G/R and G/B values are generally calculated by using 20–22 color blocks. In actual use, do not use overexposured or over dark gray blocks for calculation.

Step 4 The calibration tool supports a maximum of eight groups of illuminants involved in AWB calibration.

Step 5 Specify the path of the header file. After the calibration is complete, an .h file is generated in the specified path. The file content corresponds to the content of the SDK structure ISP_SPECAWB_ATTR_S. You need to copy the content to the header file of the sensor library to be used as the default AWB calibration value.

Take the Sony IMX277 sensor as an example. You need to copy the content of the .h file to the **imx277_cmos_slvs_ex.h** file.

Figure 1-3 Header file and matrix file paths



Step 6 Specify the matrix file path. The matrix file is the intermediate file generated after calibration. The file parameters are closely related to the sensor lens and optical filter. Because the SPECAWB is a machine learning algorithm, the file needs to be retained after the calibration. When the learning library is updated and released with HiSilicon PQ Tools, you need to click the **Refresh Calibration Result** tab to import the matrix file to generate the calibration result again.

Figure 1-4 Refresh Calibration Result tab page

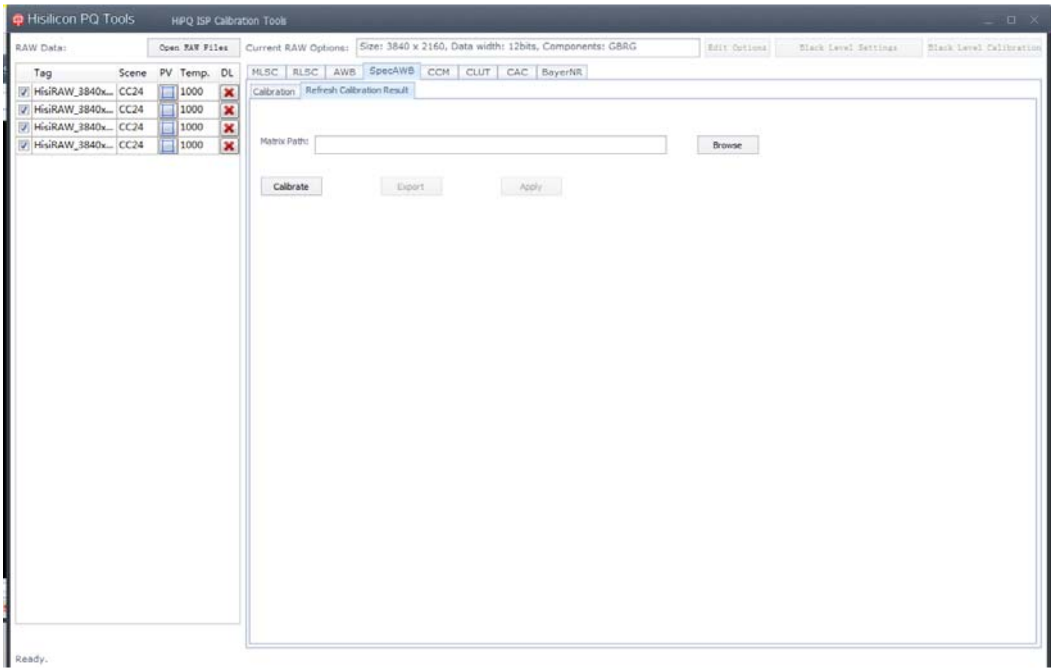
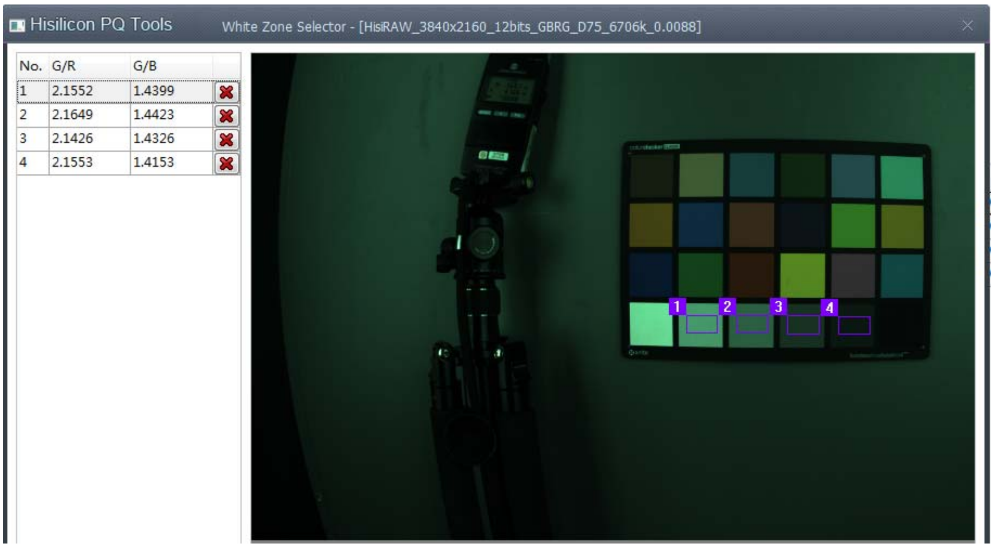


Figure 1-5 Black level configuration



2.2.3.3 Adjusting AWB Calibration Results Manually (Lack of Manual Calibration for SPECAWB)

In AWB calibration, the medium color temperature of KIs affects the hue. If outdoor data is captured at the 6000 K color temperature but the medium color temperature of AWB needs to be near 5200 K to achieve a cold hue, the following steps can be taken to manually calculate data, avoiding repeated data capture. (If data is collected at multiple outdoor color temperatures, the calibration result can be more reliable.)

Step 1 Use the existing data to perform automatic AWB calibration. For details about the calibration procedure, see 2.2.3.1 "Performing Automatic AWB Calibration." Since only 6000 K outdoor data is captured, specify A, 10K (which may also be D75), and 6000 K illuminants as KIs for calibration. Figure 2-5 shows the calibration result.

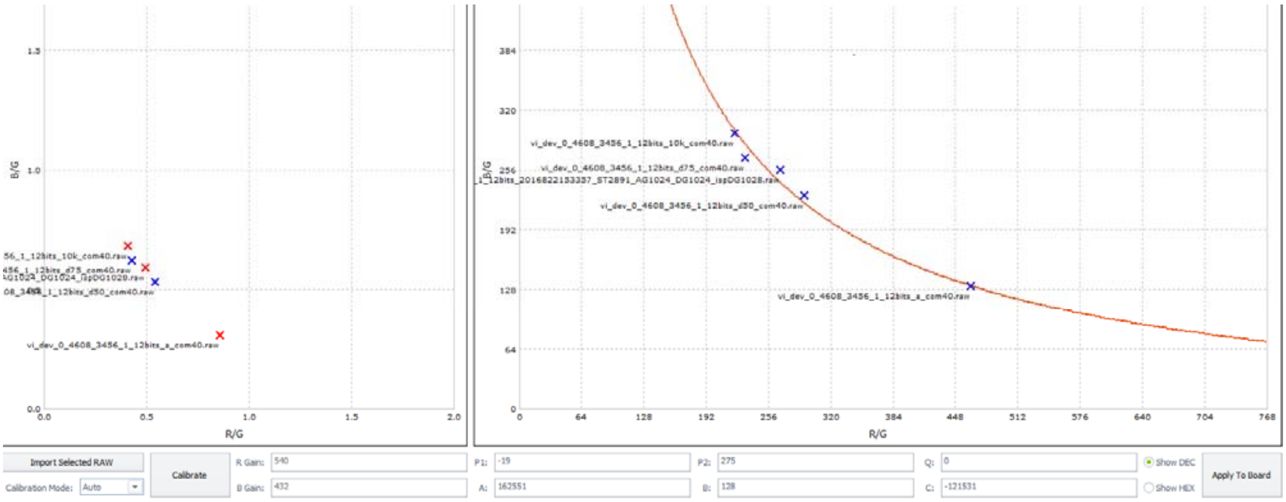
Step 2 Configure the preceding calibration result to the ISP through the MPI or HiSilicon PQ Tools, and disable the GainNorm function.

Step 3 Call **HI_MPI_ISP_CalGainByTemp()** to calculate the gain of the 5200 K illuminant. In the preceding figure, the gain of the 5200 K illuminant is [487, 256 256, 479]. Disable the GainNorm function to ensure that the gain of G component is 256.

Step 4 In semi-automatic mode, obtain the AWB parameters with 5200 K in the center after calibration, as shown in Figure 2-6.

Step 5 Figure 2-7 shows the image comparison between the 6000 K (the left image) and 5200 K (the right image) illuminants.

Figure 2-5 Auto AWB calibration



Tag	KI	Weight	WZ	In Temp.(K)	R/G	B/G	Shift	Es Temp.(K)
vi_dev_0_4608_3456_1_12bits_d75_com40.raw	☐	1		7200	0.4298	0.6236	-9	7272
vi_dev_0_4608_3456_1_12bits_a_com40.raw	☑	1		2600	0.8599	0.3062	-4	2605
vi_dev_0_4608_3456_1_12bits_10k_com40.raw	☑	1		8200	0.4084	0.6818	-3	8578
vi_dev_0_4608_3456_1_12bits_2016822153357_ST2891_AG1024_DG1024_ispDG1028.raw	☑	1		6000	0.4963	0.5935	9	5965
vi_dev_0_4608_3456_1_12bits_d50_com40.raw	☐	1		5000	0.5420	0.5306	6	5031

Figure 2-6 Semi-Auto AWB calibration

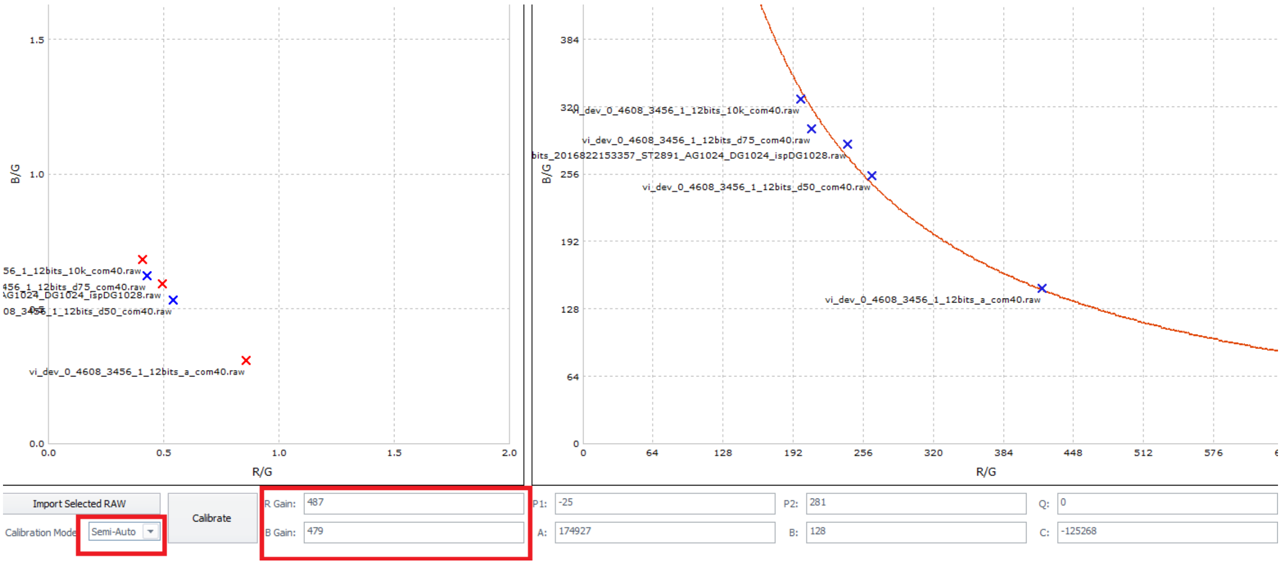


Figure 2-7 Image comparison between the Auto and Semi-Auto AWB modes

2.2.3.4 Confirming Calibration Results (AWB)

After the calibration is complete, check the Planckian curve, whether the illuminants are distributed at both sides of the curve, whether the illuminant points are far away from the Planckian curve, and whether the estimated color temperature is correct. If certain illuminants have large deviation, adjust the weight value and calibrate the illuminants again.

You can also use the AWB function of HiPQ 3A Analyzer to verify the calibration accuracy online. If the gray blocks are near the Planckian curve under multiple illuminants, then the calibration is reliable.

Figure 2-8 Planckian curve after the completion of AWB calibration

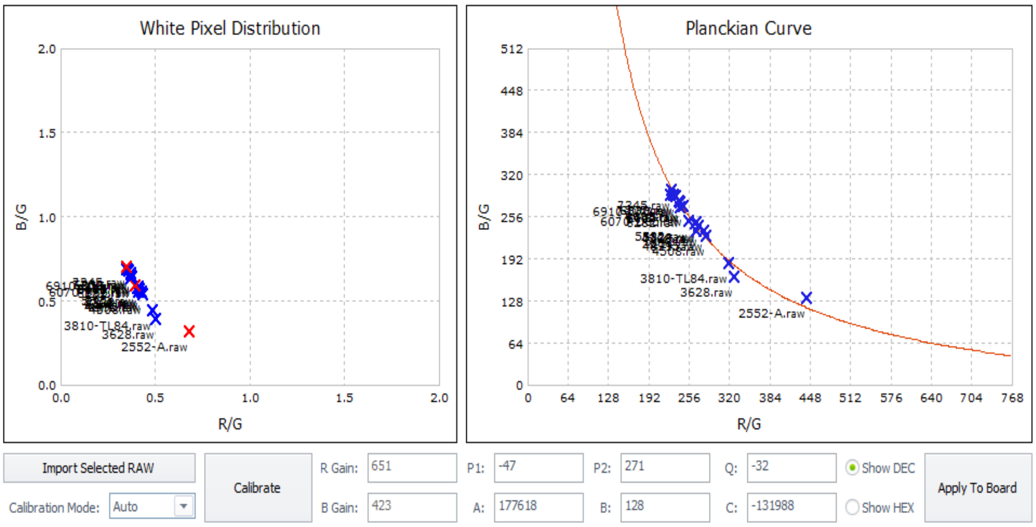


Figure 2-9 Confirming AWB calibration results

Tag	KI	Weight	WZ	In Temp.(K)	R/G	B/G	Shift	Es Temp.(K)
2552-A.raw	☑	1		2552	0.6786	0.3139	13	2571
3628.raw	☐	1		3628	0.5046	0.3881	-14	3595
3810-TL84.raw	☐	1		3810	0.4884	0.4394	-3	3862
4508.raw	☐	1		4508	0.4342	0.5354	2	4731
4768.raw	☐	1		4768	0.4073	0.5793	2	5328
4871.raw	☐	1		4871	0.4098	0.5554	-4	5043

As shown in Figure 2-9, when the Shift absolute value is less than 32 and the deviation between estimated and measured color temperatures under 6500 K and below illuminants is less than 500 K, then the calibration result is correct.

NOTICE

In Figure 2-9, since the measured color temperature of **4768.raw** is 4768K, while the estimated color temperature is 5328K, the deviation of the color temperatures is large. However, the **4768.raw** has a larger B/G value than **4508.raw** and **4871.raw**, indicating that the blue component of the illuminant is strong. Therefore, the high color temperature is reasonable.

2.2.3.5 Confirming Calibration Results (SPECAWB)

After calibration is complete, as shown in Figure 2-10, check the values of **Est.Temp** and **Est.Uv**. The difference between **Est.Temp** and the input color temperature should be less than 300 K, and the difference between **Est.Uv** and △Uv should be less than 0.005.

Figure 2-10 Confirming SPECAWB calibration results

Del	Tag	In Temp.(K)	In Uv	WZ	G/R	G/B	Est. Temp.(K)	Est. Uv
	HisiRAW_3840x2160_12bits_GBRG_10K_8406k_0.0095	8406	0.009500		2.2827	1.2545	8365	0.007706
	HisiRAW_3840x2160_12bits_GBRG_A_2745k_0.0021	2745	0.002100		1.1437	2.9601	2776	0.002197
	HisiRAW_3840x2160_12bits_GBRG_D75_6706k_0.0088	6706	0.008800		2.1545	1.4325	6777	0.009644
	HisiRAW_3840x2160_12bits_GBRG_U35_3283k_0.0006	3283	0.000600		1.3516	2.3755	3321	0.001129

2.2.4 Adjustment of Statistics Parameter Configurations (No Need to be Considered for SPECAWB)

Taking advantage of the calibration tool, check whether the conditions for defining chromatic aberration of gray pixels are properly set.

Step 1 Calculate the R/G and B/G values of gray blocks at the lowest color temperature. In Figure 2-11, illuminant A has the following features: R/G = 1.66, B/G = 0.47, 8 bit fixed-point processing, R/G = round(1.66 x 256) = 0x1A9, B/G = round(0.47 x 256) = 0x78. Therefore, **CrMax** must be greater than or equal to 0x1A9 and **CbMin** must be less than or equal to 0x78 to ensure that the WB statistics module can obtain correct gray pixel information in this scenario. Since different illuminance leads to spectrum changes and noise in low illumination is bigger, the **CrMax** value must be increased to narrow down the **CbMin** value.

Step 2 Calculate the R/G and B/G values of gray blocks at the highest color temperature. In Figure 2-12, the outdoor illuminant at a high color temperature has the following features: R/G = 0.41, B/G = 1.13, 8 bit fixed-point processing, R/G = round(0.41 x 256) = 0x69, B/G = round(1.13 x 256) = 0x122. Therefore, **CrMin** must be less than or equal to 0x69 and **CbMax** must be greater than or equal to 0x122 to ensure that the WB statistics module can obtain correct gray pixel information in this scenario. The **CbMax** value must be increased to narrow down the **CrMin** value.

Step 3 After adjusting the **CrMax**, **CrMin**, **CbMax**, and **CbMin** parameters in normal illumination, capture raw data in different ISOs, calculate the chromatic aberration information of gray pixels, and adjust the adaptive table.

Figure 2-11 Chromatic aberration information of gray pixels at a low color temperature

No.	R/G	B/G	
1	1.6628	0.4748	

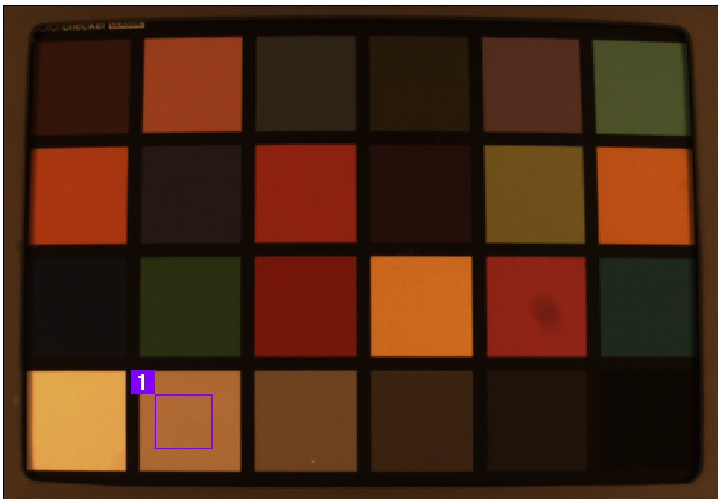
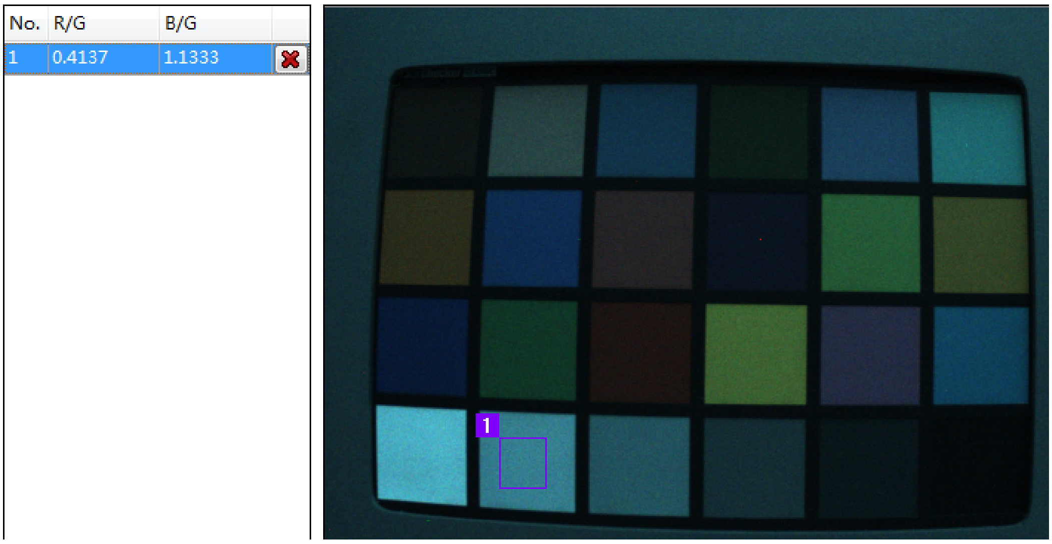


Figure 2-12 Chromatic aberration information of gray pixels at a high color temperature



----End

2.3 SPECAWB Color Temperature Conversion Tables

The SPECAWB algorithm adjusts the AWB color tendency based on the color temperature conversion table. The adjustment principle and tuning procedure of the color temperature conversion table are as follows:

- Select a proper .matrix file, as shown in Figure 1-6. The file is generated by calibration and determines the generation of the color temperature conversion table.
- The horizontal coordinate of the color temperature curve is the original image color temperature, and the vertical coordinate is the target color temperature. The three color temperature conversion tables are arranged in descending order of the Bv values. They can be enabled and disabled separately. When only one color temperature conversion table is enabled, the Bv value in the color temperature conversion table is invalid. This table covers all scenarios. When the three color temperature conversion tables are all disabled, the color temperature conversion function is disabled. In this case, you cannot adjust the color temperature.
- Assume that the three color temperature conversion tables are all enabled. Obtain the color temperature and Bv value of the current image. If the Bv value is greater than that of color temperature conversion Table 1, then Table 1 is used. If the Bv value is between Table 1 and Table 2, then the color temperature conversion results of Table 1 and Table 2 are used for interpolation.
- If the value in Table 1 is used for conversion, the original color temperature of the image is 5047 K. For details, see Figure 1-7. According to Data Table 1 in Figure 1-8, the color temperature is not converted, and the color temperature remains unchanged.See Figure 1-9. If the value 5050 is decreased to 4600, the color temperature is shifted to the cold direction.
- After setting a proper color temperature conversion table, you need to click **Export** to copy the content to the header file of the sensor library. The file content corresponds to the content of the SDK structure ISP_SPECAWB_CAA_CONTROl_S to be used as the

AWB default color temperature conversion table. Take the Sony IMX277 sensor as an example. You need to copy the content of the exported file to the **imx277_cmos_slvs_ex.h** file.

Figure 1-6 Selecting a proper .matrix file

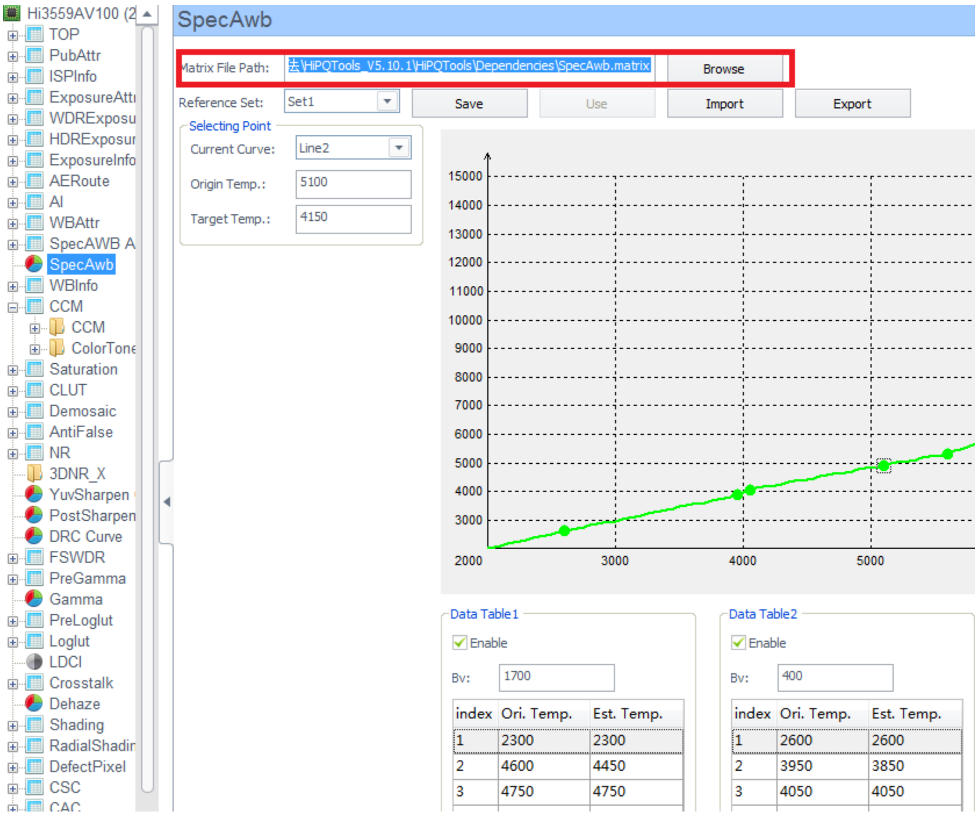


Figure 1-7 Color temperature and Bv value of the current image

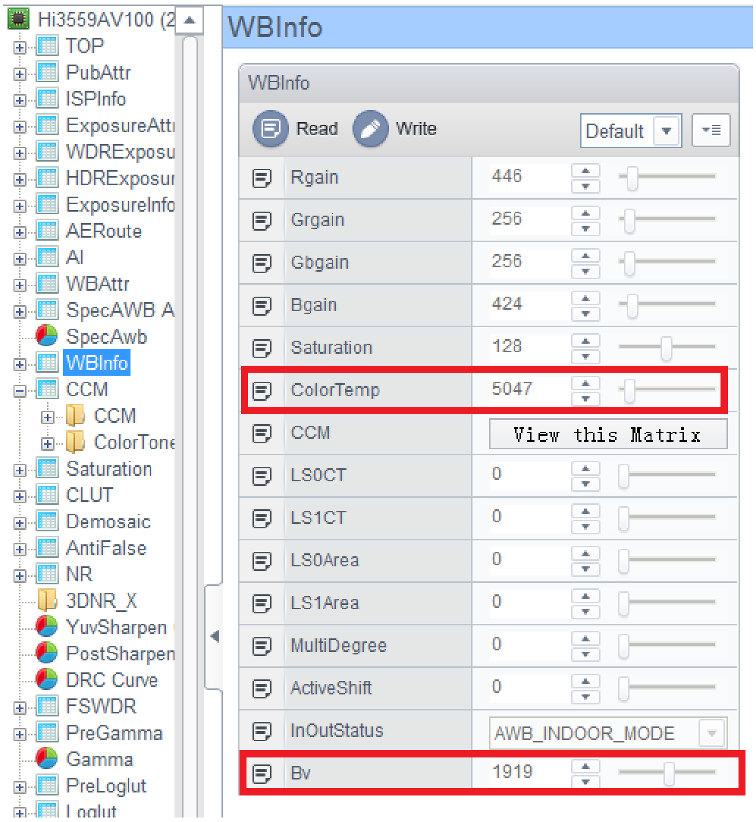


Figure 1-8 Three color temperature conversion tables

Data Table1

Enable

Bv: 1700

index	Ori. Temp.	Est. Temp.
1	2300	2300
2	4600	4450
3	4750	4750
4	5050	5050
5	5700	5600
6	6800	6800
7	7500	8000
8	12000	10000

Data Table2

Enable

Bv: 400

index	Ori. Temp.	Est. Temp.
1	2600	2600
2	3950	3850
3	4050	4050
4	5100	4900
5	5600	5300
6	6150	6150
7	8100	8300
8	12000	10000

Data Table3

Enable

Bv: -45

index	Ori. Temp.	Est. Temp.
1	2500	2500
2	3100	3200
3	4700	4700
4	4950	4850
5	6000	6000
6	6900	7450
7	9000	9000
8	12000	10000

Figure 1-9 Decreasing 5050 to a smaller value using the curve

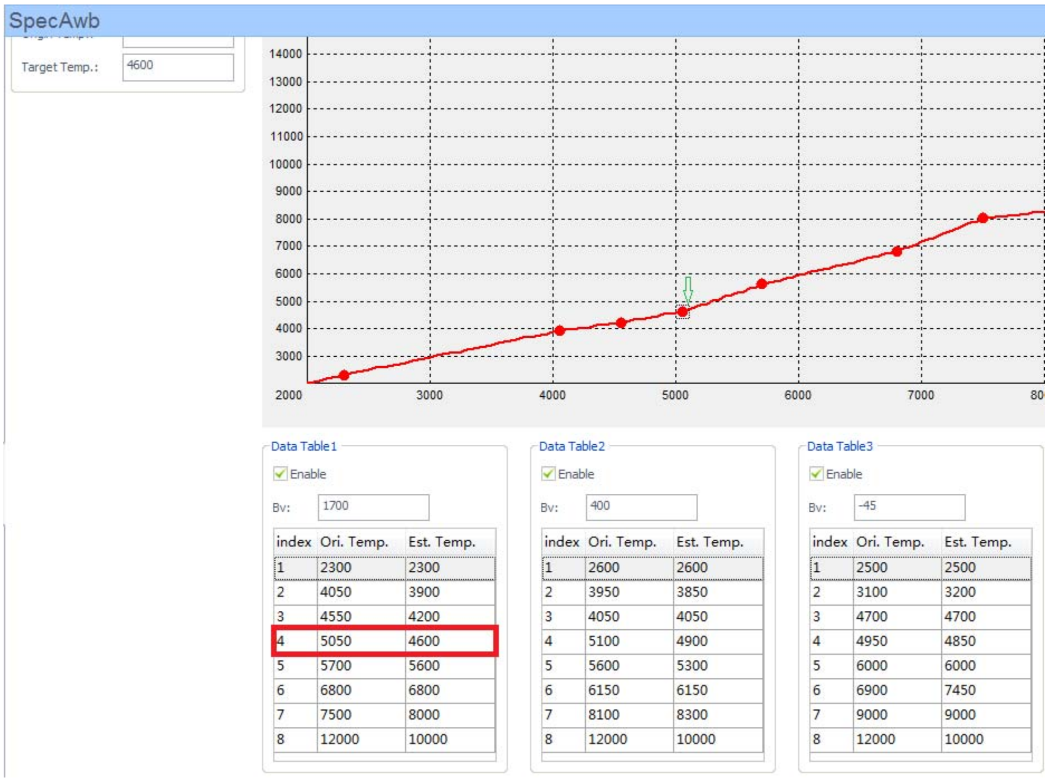


Figure 1-10 Images before and after the adjustment

2.4 AWB FW (AWB)

2.4.1 AWB ATTR Parameters

The AWB ATTR data structure defines adjustable parameters, such as color temperature limit and gray pixel range limit, commonly for the AWB FW algorithm. This data structure uses the following data structures:

- stCTLimit
- stCbCrTrack
- stLumaHist

Table 2-6 AWB ATTR parameters

Parameter	Description	Scenario
enAlgType	AWB algorithm type Value range: **AWB_ALG_LOWCOST**, **AWB_ALG_ADVANCE**	If this parameter is set to **AWB_ALG_LOWCOST**, the CPU usage is low, and the adaptability to the illuminant is better. If this parameter is set to **AWB_ALG_ADVANCE**, AWB precision is improved. **AWB_ALG_ADVANCE** is recommended for calibration with specified requirements, and **AWB_ALG_LOWCOST** is recommended for simple calibration.
u16ZoneSel	A similar gray world algorithm adopted by the AWB when this parameter is set to **0**	This parameter is mainly used for problem locating. You are not advised to modify its value. If the AWB algorithm needs to be enabled in case of infrared lights, it is recommended that **u16ZoneSel** be set to **0**.
u16Speed	AWB convergence speed A larger value of this parameter indicates a faster AWB convergence speed. Value range: [0x0, 0xFFF]	If this parameter is set to **0xFFF**, AWB gains are calculated without referring to historical AWB information. If this parameter is set to **0**, the AWB is frozen.
u16HighColorTemp	Upper color temperature limit supported by the AWB Recommended value range: [10000, 15000]	If color casts occur at a high color temperature, preferentially adjust this parameter.
u16LowColorTemp	Lower color temperature limit supported by the AWB Recommended value range: [1500, 2500]	If color casts occur at a low color temperature, preferentially adjust this parameter. When this parameter is set to an excessively small value in motorway surveillance scenarios, flickers occur.
stCTLimit	Action of the AWB This parameter is valid only when the detected color temperature is out of the configured color temperature range. The recommended value is **Auto**.	This parameter can be set to **Manual** or **Auto**. • In manual mode, AWB gains are user-defined. • In automatic mode, the AWB determines the AWB gains based on AWB calibration parameters.
u8ShiftLimit	Radius for determining the illuminant range The Planckian curve is used as the	A larger value of this parameter indicates wider illuminant support. The AWB algorithm precision is affected in a scenario where there is a large region with a single color.

Parameter	Description	Scenario
	central point. Value range: [0x30, 0x50]	
bGainNormEn	Whether to normalize the final AWB gain Gain normalization is enabled by default.	After gain normalization is enabled, the signal-to-noise ratio (SNR) can be increased at a low color temperature in a low-illumination scenario.
bNaturalCastEn	AWB style preference enable at low color temperatures	If **bNaturalCastEn** is set to **enabled**, the AWB reserves the illuminant colors at low color temperatures and the image colors are more natural.
u8RGStrength u8BGStrength	AWB correction strength	There are three possibilities: It is recommended that **u8RGStrength** be set to the same value of **u8BGStrength** and this value be less than or equal to **0x80**. • When **u8RGStrength** is set to **0x80**, the white color resumes white. • When **u8RGStrength** is set to a value larger than **0x80**, the white color changes in a reverse manner as the illuminant. Specifically, the white color turns bluish at a low color temperature and turns reddish at a high color temperature. • When **u8RGStrength** is set to a value smaller than **0x80**, the white color changes the same way as the illuminant. Specifically, the white color turns reddish at a low color temperature and turns bluish at a high color temperature. These colors are closer to the visual feelings of human eyes.
stCbCrTrack	Range of gray pixels under different ISOs There are four lookup tables: CrMax, CrMin, CbMax, and CbMin.	You are advised to adjust this parameter according to the sensor to optimize the effect in a low-illumination scenario.
stLumaHist	Luminance weight–related parameter	In automatic mode, the ABW FW automatically calculates the threshold for grouping different luminance. You can configure the weights of gray pixels in different luminance. In manual mode, you can configure the threshold for grouping different luminance and the weights of gray pixels in different luminance.
bAWBZoneWtEn	AWB zone weight enable Default value: HI_FALSE	-

Parameter	Description	Scenario
au8ZoneWt	AWB 1024-zone weight table Value range: [0x0, 0xFF]	After **bAWBZoneWtEn** is enabled for a specific application, you can set the weight table to change the weight of each zone to optimize the AWB performance. When the shading is severe, you can increase the weight of the central zone to restore accurate AWB and reduce the impact of shading on AWB. For application in dash cams, ROI is generally below the center of the image. You can increase the weight of the ROI to reduce the interference of regions, such as the sky and trees, to the AWB.

stCTLimit Parameters

Table 2-7 stCTLimit parameter description

Parameter	Description	Scenario
bEnable	Whether AWB gains are clipped on the condition that the ambient color temperature is out of the configured color temperature range	In outdoor road surveillance scenarios, light source is switched between street lamps and car lights at night. In this case, you can set this parameter to **1** to ensure color consistency.
enOpType	AWB gain calculation mode on the condition that the ambient color temperature is out of the configured color temperature range If this parameter is set to **Auto**, AWB gains are calculated according to the color temperature curve. If this parameter is set to **Manual**, AWB gains are user-defined.	The recommended value is **Auto**.
u16HighRgLimit u16HighBgLimit	Whether R and B gains are user-defined at a high color temperature when the ambient color temperature exceeds the upper limit These two parameters take effect only in manual mode	-
u16LowRgLimit u16LowBgLimit	Whether R and B gains are user-defined at a low color temperature when the ambient color temperature exceeds the lower limit	-

Parameter	Description	Scenario
	These two parameters take effect only in manual mode	

stCbCrTrack Parameters

Table 2-8 stCbCrTrack parameter description

Parameter	Description	Scenario
bEnable	Whether to enable the function of associating gray pixels with ISOs	If this function is enabled, you can control the color effect in low illumination by configuring parameters such as **CrMax**.
au16CrMax[]	Association array of R/G and ISO at a low color temperature The values in the array must be monotonically increasing.	Calibrate these parameters by following instructions in section 2.2.3.5 "Confirming Calibration Results (SPECAWB)." When the ISO is the same, the value of **CrMax** is slightly greater than that of **CbMax**, and the value of **CrMin** is basically the same as that of **CbMin**.
au16CrMin[]	Association array of R/G and ISO at a high color temperature The values in the array must be monotonically decreasing.	
au16CbMax[]	Association array of B/G and ISO at a high color temperature The values in the array must be monotonically increasing.	
au16CbMin[]	Association array of B/G and ISO at a low color temperature The values in the array must be monotonically decreasing.	

stLumaHist Parameters

Table 2-9 stLumaHist parameter description

Parameter	Description	Scenario
bEnable	Whether to enable the luminance adjustment AWB weight function	It is recommended that this function be enabled.
enOpType	Configuration mode of the luminance histogram and weights If this parameter is set to **Auto**, the AWB automatically collects the luminance histogram statistics and you can also manually configure	The recommended value is **Auto**. You can manually configure the luminance weights of the bright region and the dark region, thereby setting a high priority to the bright region or the dark region.

Parameter	Description	Scenario
	luminance weights. If this parameter is set to **Manual**, you can manually configure the threshold and weight of the luminance histogram statistics.	
au8HistThresh[]	Configured threshold of the luminance histogram This parameter takes effect only in manual mode. Value range: [0x0, 0xFF]. The values in the array must be monotonically increasing.	-
au16HistWt[]	Configured weight of the luminance histogram (8-bit decimal precision) This parameter takes effect only in manual mode. Value range: [0x0, 0xFFFF]	The following is the formula that involves elements affecting luminance weight: $Rgain = (\sum_{i=0:7} Rgain_i * Wt_i) / \sum_{i=0:7} W$

2.4.2 AWB ATTR_Ex Parameters

The AWB Attr_Ex data structure defines adjustable parameters, such as separate illuminant definition and multi-illuminant weight configuration, for the Advance algorithm. This data structure uses the following data structures:

- stLumaHist
- stInOrOut
- stLightInfo

stLumaHist Parameters

Table 2-10 stLumaHist parameter description

Parameter	Description	Scenario
u8Tolerance	Tolerance among frames If it is set to **0**, the AWB updates AWB gains every two frames. If it is set to a non-zero value, the AWB updates AWB gains only when detecting a scenario change greater than the tolerance. Default value: **0x2**	When identifying an outdoor scenario, the AWB FW automatically disables association among frames and automatically updates AWB gains every two frames. A larger value of this parameter indicates higher stability but lower sensitivity of the AWB. When the light source or color temperature changes, the AWB cannot make adjustment accordingly. Recommended value range: [0x2, 0x4]
u8ZoneRadius	Radius for classifying block statistics	When the sensor has inconsistent

Parameter	Description	Scenario
	Default value: **0x10**	sensitiveness to gray blocks in different luminance, this parameter can be set to a larger value. In WDR mode, this parameter can be set to a larger value.
u16CurveLLimit	Left edge of the Planckian curve Value range: [0x0, 0x100]	This parameter is used to exclude the green blocks. If color casts occur in the large green area scenario, modify the value of this parameter to optimize the color casts.
u16CurveRLimit	Right edge of the Planckian curve Value range: [0x100, 0xFFF]	This parameter is used to exclude the purple blocks. If the sensor has serious black level shift in low illumination, optimize it by modifying the value of this parameter. In normal cases, the value of this parameter needs no modification.
bExtraLightEn	Whether to enable the separate illuminant function	This function can optimize color casts in specified scenarios.
stLightInfo	Information about an interference color or a separate illuminant	You can use HiPQ 3A Analyzer to add a separate illuminant or delete an interference color.
stInOrOut	Parameter for determining an outdoor or indoor detection scenario	You are advised to enable this function to optimize AWB effect in outdoor scenarios with a large area of grass, trees, or sky. You can obtain the cool hue or warm hue by configuring parameters.
bMultiLightSourceEn	Special policy in multi-illuminant scenarios	If this policy is configured, the AWB FW automatically detects the multi-illuminant degree and adjusts the saturation or CCM based on the multi-illuminant degree, thereby improving color casts.
enMultiLSType	Adjustment policy in the multi-illuminant scenario The saturation or CCM can be adjusted.	If the saturation policy is selected, the picture saturation decreases. If the CCM policy is selected, the saturation of the green color is slightly affected, and the hue of the red and blue colors is changed.
u16MultiLSScaler	Maximum adjustment amplitude of the saturation or CCM in the multi-illuminant scenario The actual adjustment amplitude is related to the degree of the multi-illuminant in the scenario. Value range: [0x0, 0x100]	N/A
au16MultiCTBin[]	Color temperature segment parameter in the multi-illuminant scenario Value range: [0x0, 0xFFFF]	Recommended values: [2300, 2800, 3500, 4800, 5500, 6300, 7000, 8500]

Parameter	Description	Scenario
	The values in the range must be monotonically increasing.	
au16MultiCTWt[]	Color temperature weight parameter in the multi-illuminant scenario Value range: [0x0, 0x400]	Recommended values: [0x20, 0x40, 0x100, 0x200, 0x200, 0x100, 0x40, 0x20] Weight of color temperatures ranging from 4800 K to 5500 K is large, and that of high and low color temperatures decrease. In this way, color effect is better in multi-illuminant scenarios.
bFineTunEn	Special processing, such as complexion detection	This function is enabled only in indoor scenarios and is automatically disabled in outdoor scenarios.

stInOrOut Parameters

Table 2-11 stInOrOut parameter description

Parameter	Description	Scenario
bEnable	Switch for determining an indoor or outdoor scenario	The AWB determines whether the current scenario is an indoor or outdoor scenario based on the exposure information.
enOpType	Automatic or manual determination mode	In manual mode, you can enter the indoor or outdoor status. In automatic mode, the AWB FW determines the status based on the environment luminance and luminance threshold.
bOutdoorStatus	Indoor or outdoor determination result **1** indicates indoor, and **0** indicates outdoor.	-
u32OutThresh	Threshold for determining the outdoor/indoor scenario (exposure time in µs) If the exposure time is less than this threshold, the scenario is outdoor.	When you use a non-HiSilicon AE algorithm library, transfer the current exposure information to the AWB algorithm library. For Internal Protocol cameras (IPCs), adjust the luminance threshold according to their light sensitivity and product forms. A larger value of this parameter is recommended for products such as DV. A smaller value of this parameter is recommended for IPCs.

Parameter	Description	Scenario
u16LowStop	Start point extension of the natural illuminant color temperature Recommended value: **4500 K**	If a scenario is determined as an outdoor scenario, the weight of gray blocks within the color temperature range of [u16LowStart, u16HighStart] is the largest, and color temperature ranges [u16LowStop, u16LowStart] and [u16HighStart, u16HighStop] are two transition ranges. If all values of these four parameters increase, warm hue is obtained. If these values decrease, cool hue is obtained.
u16LowStart	Start point of the natural illuminant color temperature range Recommended value: **5000 K**	
u16HighStart	Stop point of the natural illuminant color temperature range Recommended value: **6500 K**	
u16HighStop	Stop point extension of the natural illuminant color temperature Recommended value: **7500 K**.	
bGreenEnhanceEn	Whether to enhance the green channel in the green plant scenario	This parameter takes effect only in large dark green grass scenarios.

stLightInfo Parameters

Table 2-12 stLightInfo parameter description

Parameter	Description	Scenario
u16WhiteRgain	Cr coordinate of the center point in the circular region to be added or deleted Value range: [0x0, 0xFFF] Precision: 8-bit	You can use HiPQ 3A Analyzer to configure these two parameters.
u16WhiteBgain	Cb coordinate of the center point in the circular region to be added or deleted Value range: [0x0, 0xFFF] Precision: 8-bit	
u16ExpQuant	External environment luminance This parameter is not supported and does not need to be configured.	-
u8LightStatus	Illuminant status 0: disabled 1: Add the region corresponding to the illuminant. 2: Delete the region corresponding to an interference color.	In the current version, an illuminant can be added or deleted only when it does not exceed the Shift limit range.
u8Radius	Radius of the region to be added or deleted	Avoid overlapping between the Planckian curve and the circle with [u16WhiteRgain, u16WhiteBgain] as the central point and the value

Parameter	Description	Scenario
	Value range: [0x0, 0xFF]	of **u8Radius** as the radius. This avoids illuminant overlapping.

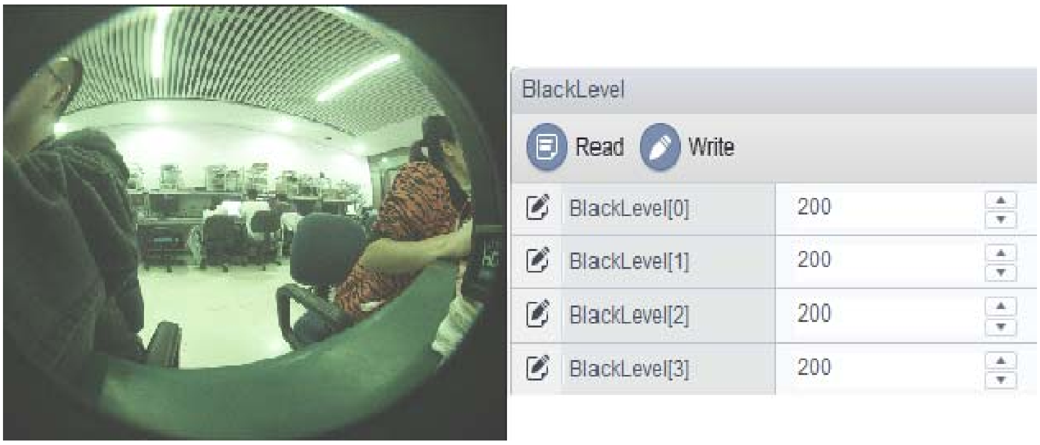
2.5 Problem Locating

2.5.1 Analyzing Raw Data (AWB)

Analyze raw data for a partial color cast problem to determine whether this problem is caused by the capture end or subsequent algorithms. You are advised to export the raw data to the HiISP board and use HiSilicon PQ Tools to locate the problem.

Step 1 Confirm the black level and RGGB sequence.

Figure 2-13 Confirming black level parameter configurations

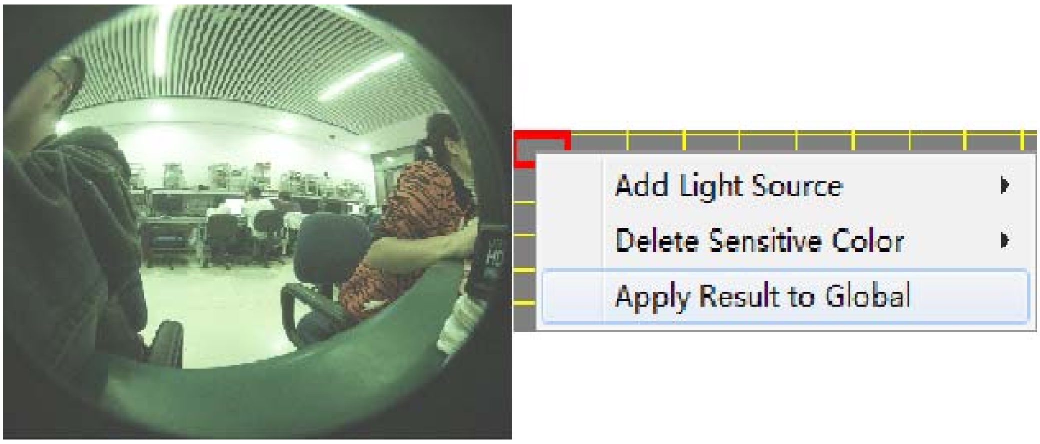


Step 2 Bypass or disable color-affected modules, such as CCM, gamma, and automatic color management (ACM), thereby distinguishing between problems of the AWB and other modules.

Figure 2-14 Disabling other color modules

Step 3 Open HiPQ 3A Analyzer and configure the AWB coefficient. In the picture on the left, right-click a gray block and choose **Apply Result to Global** from the shortcut menu. The expected AWB gains for the gray block take effect.

Figure 2-15 Selecting a gray block and configuring manual AWB



Step 4 Check whether the color of the gray region is normal. The gray region has a partial pink cast although only manual AWB is implemented. This indicates a raw data problem. Trace the problem from the front end.

Figure 2-16 Manual AWB

Step 5 If the raw data is normal, check whether the gamma curve is proper. Configure manual AWB on the HiISP board and enable only the black level correction (BLC), AWB, demosaic, and gamma modules. Then, detect color casts by disabling and enabling the gamma module.

Step 6 Check whether a multi-illuminant scenario exists for partial color casts. Use HiPQ 3A Analyzer to select different areas and manually calculate the AWB coefficients. If the expected gains of these areas differ from each other greatly, a multi-illuminant scenario exists. In this situation, optimize color effect by decreasing the saturation or color temperature weight.

----End

2.5.2 Analyzing Raw Data (SPECAWB)

Step 1 to Step 5 are the same as those of the AWB algorithm.

In the case of partial color cast, check whether multiple light sources are used in this scenario. You can use HiPQ 3A Analyzer to choose different regions and manually calculate the white balance coefficients. If the expected white balance gains in different regions differ greatly, it indicates that multiple light sources are used. If you want to adjust the white balance tendency in this case, check the Bv value and color temperature value of the target scenario on the **WbInfo** window of HiSilicon PQ Tools. Build the color temperature conversion table based on the corresponding Bv value to adjust or shift the color temperature tendency.

Figure 1-11 Images before and after adjustment towards cold color temperature

Figure 1-12 Color temperature and BV value of the current image

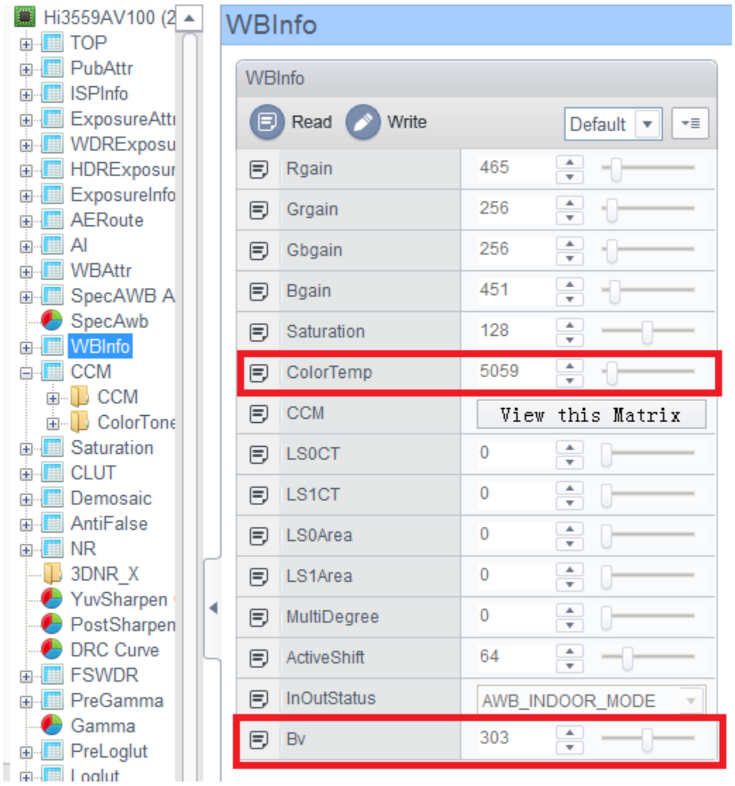
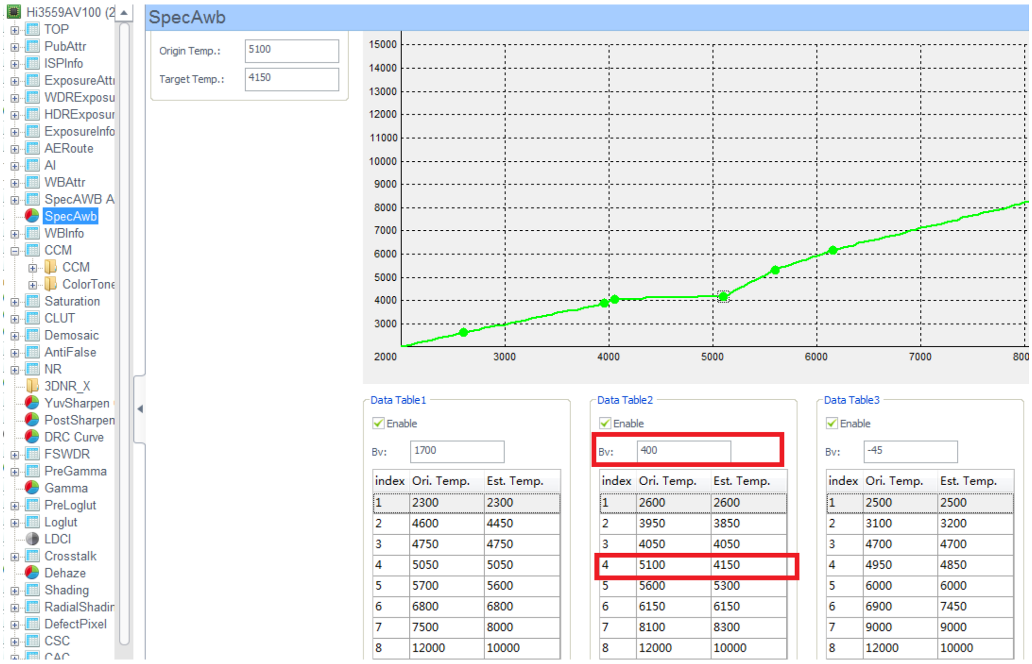


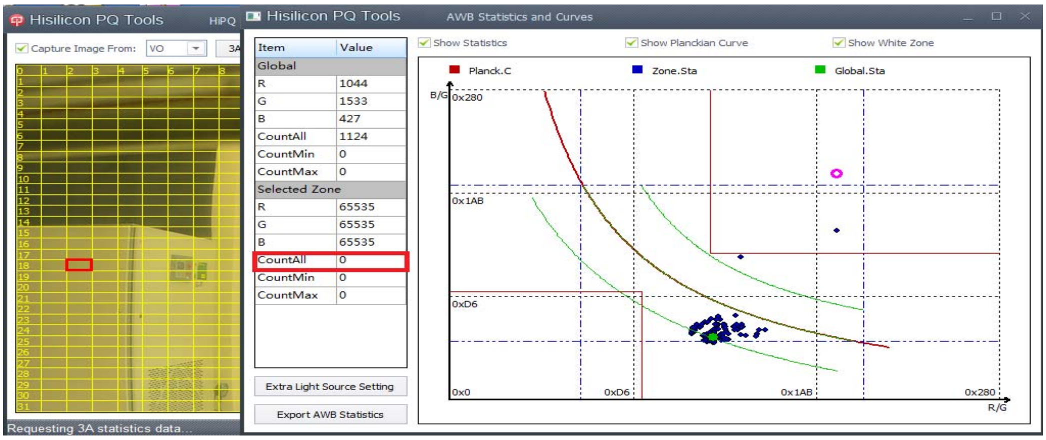
Figure 1-13 Data table corresponding to the Bv value of the image



2.5.3 Using HiPQ 3A Analyzer to Check White Area Property (AWB)

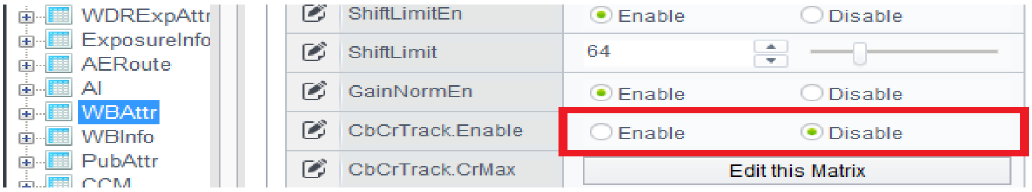
Step 1 Check whether AWB statistics parameter configurations are proper based on statistics results. Select a white block to check the value of **CountAll**. In normal cases, the value of this parameter approximates to **0xFFFF**. However, the value of this parameter in Figure 2-17 is **0**, which indicates that no gray pixel is found.

Figure 2-17 Confirming statistics results



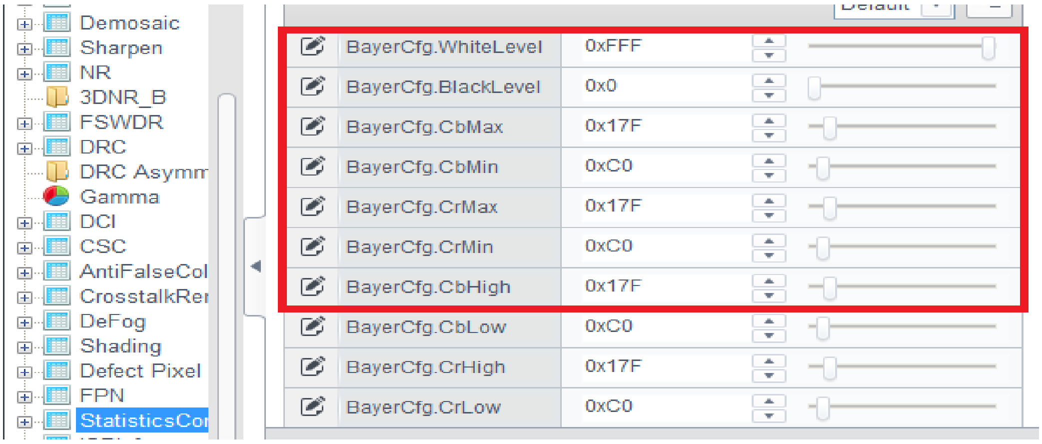
Step 2 Disable gray pixel condition adaptation functions, such as CrMax.

Figure 2-18 Disabling the adaptive adjustment function of statistics parameters



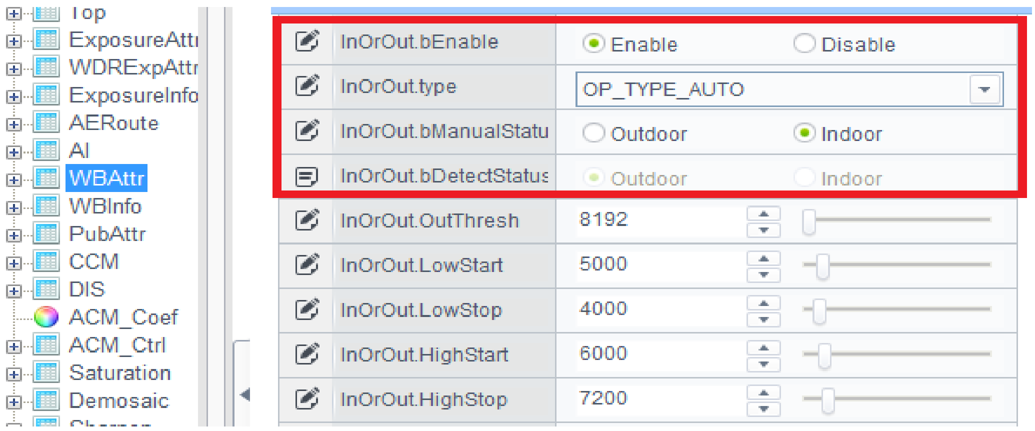
Step 3 Adjust gray pixel configuration parameters according to the following principles: Increase the upper limit and decrease the lower limit until the value of **CountAll** approximates **0xFFFF**. After the problem parameter is confirmed, adjust required parameters, for example, default WhiteLevel and BlackLevel parameters and Cr arrays.

Figure 2-19 Manually configuring statistics parameters



Step 4 After the statistics module is normal, check whether an indoor or outdoor scenario is correctly detected. If not, manually configure a correct indoor or outdoor mode.

Figure 2-20 Checking indoor/outdoor configuration parameters



Step 5 Check whether the color temperature is within the color temperature range. If not, increase the upper color temperature limit or decrease the lower color temperature limit for improvement.

Step 6 Check whether any gray block exists in a white area.

The following parameters affect the range of white areas: **u16HighColorTemp**, **u16LowColorTemp**, **u8ShiftLimit**, **u16CurveLLimit**, and **u16CurveRLimit**. Check whether there is a parameter configured for excluding gray blocks from white areas. In Figure 2-21, gray blocks are out of the range indicated by the value of **u8ShiftLimit**. Increasing the value can solve this problem, as shown in Figure 2-22.

Figure 2-21 Effect before u8shiftlimit adjustment

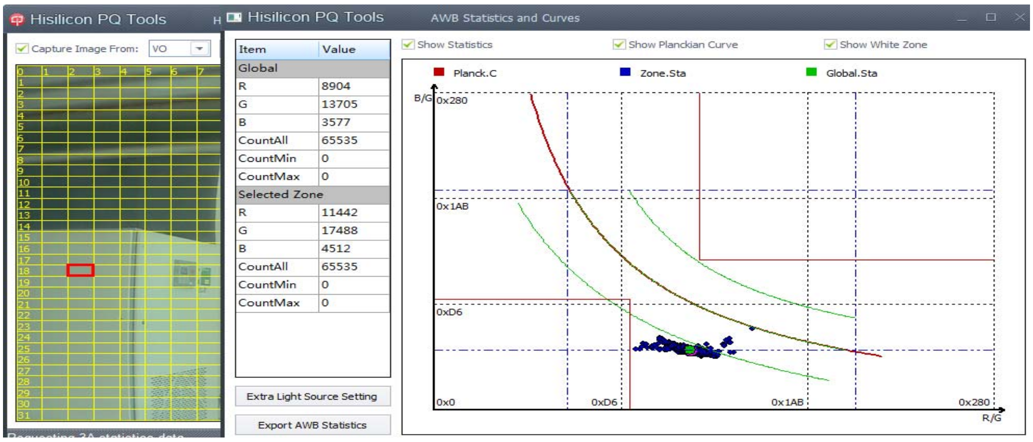
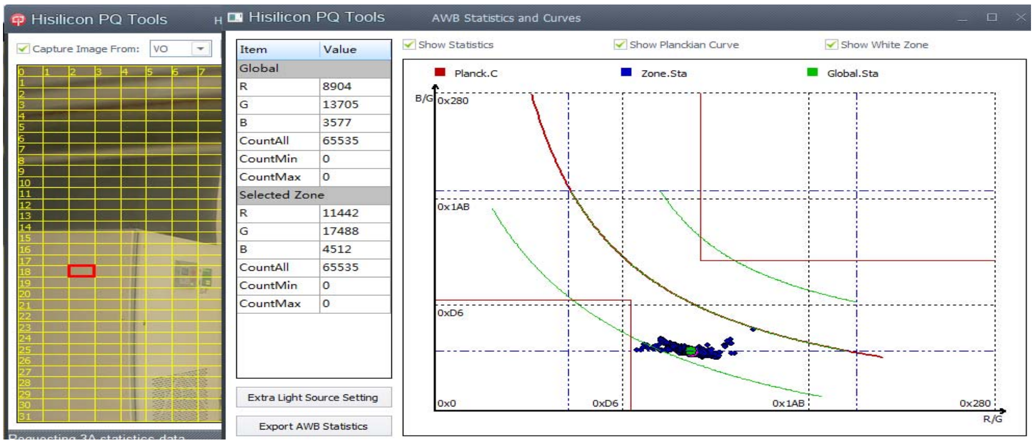


Figure 2-22 Effect after u8shiftlimit adjustment



Step 7 If multiple illuminants exist, exclude the effect of the complexion detection module on the algorithm.

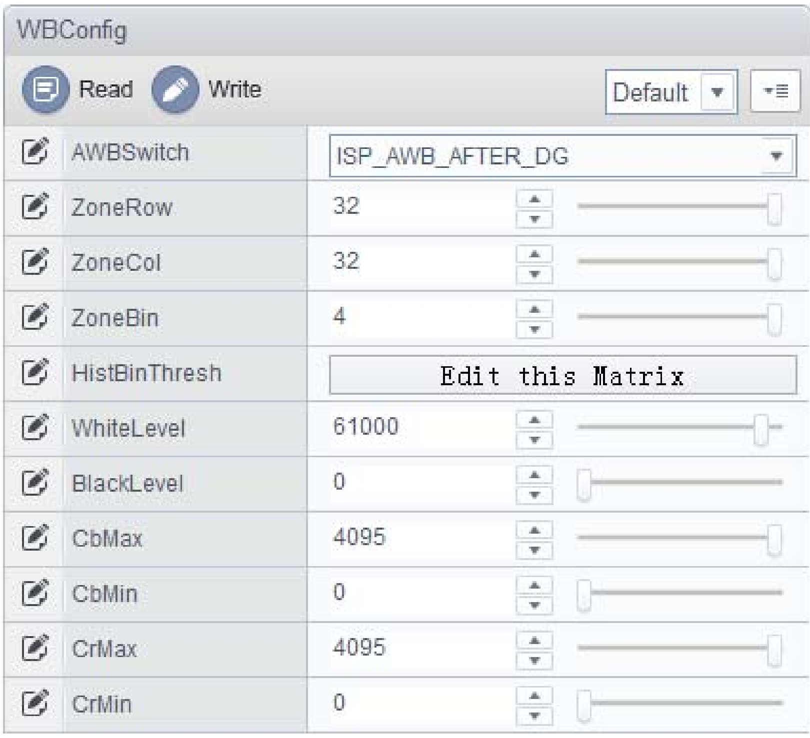
Step 8 If color cast causes still cannot be determined, change the algorithm from Advance to LowCost. If the problem persists, set the value of **ZoneSel** in the AWB ATTR data structure to **0**. If the problem persists, analyze it from modules, such as optical filter and black level.

----End

2.5.4 Checking the Statistics Configuration (SPECAWB)

Confirm the statistics configuration. The SPECAWB algorithm needs to set **CbMax**, **CbMin**, **CrMax**, **CrMin**, and **WhiteLevel** to fixed values, as shown in Figure 1-14. If the values have been changed, you need to restore them.

Figure 1-14 AWB statistics information



3 Basic Color Tuning Scheme

3.1 Overview

This chapter describes how to tune the modules (such as the CCM module) involved in the basic color tuning scheme. After the modules are tuned, the colors of the product can meet the requirements for normal use.

3.2 CCM Tuning

3.2.1 CCM Calibration Parameters

In CCM calibration, the actual color information about the first 18 color blocks captured by the sensor in the ColorChecker scenario and the expected values are used for calculating the 3 x 3 CCM. The smaller the difference between the values of the colors after CCM processing and the expected values of the input colors, the better the effect of the CCM.

Table 3-1 CCM calibration parameters

Parameter	Description	Scenario
u16ColorTemp	Color temperature for the current CCM Value range: [500, 30000]	-
au16CCM [CCM_MATRIX_SIZE]	CCMs at different color temperatures, 8-bit decimal precision Bit 15 is a sign bit. The value **0** indicates positive, and the value **1** indicates negative. For example, **0x8010** indicates **−16**. Value range: [0x0, 0xFFFF]	The color reproduction matrices for a maximum of seven different color temperatures and a minimum of three color temperatures are supported. The CCMs must be configured in descending order of the color temperatures. The typical three groups of CCMs are CCMs in illuminants D50, TL84, and A. The typical five groups of CCMs are CCMs in illuminants 10 K, D65, D50, TL84, and A. The color

Parameter	Description	Scenario
		temperature value of the previous group and that of the next group must comply with the following rule: T_{pre} x (15/16) > T_{post} x (17/16). The ISP obtains the actual color correction matrix at the end by interpolation based on the actual color temperature.

3.2.2 Raw Data Capture

3.2.2.1 Illuminant Selection

- Artificial illuminant D50 or natural illuminants with the color temperature between 5000 K and 5500 K
- Illuminant TL84
- Illuminant A

3.2.2.2 Procedure

Step 1 Prepare the picture capture devices, including the standard X-Rite ColorChecker, even light sources with the 600 lux illumination (one light source on the left side and one on the right side; the intersection angle between the light source and the ColorChecker plane ranges from 25° to 45°), and IPC.

Step 2 Adjust the AE target luminance so that the luminance of the G component in the block with the highest grayscale (block 19) is 0.8 times of the saturation (taking the 12-bit raw data as an example, the G component value ranges from 0xC00 to 0xD80).

Step 3 Capture the neutral gray raw picture, and check the lens shading level of the IPC. If shading is serious, calibrate the shading coefficient first. Implement LSC and then CCM calibration for the ColorChecker picture.

----End

3.2.3 Calibration

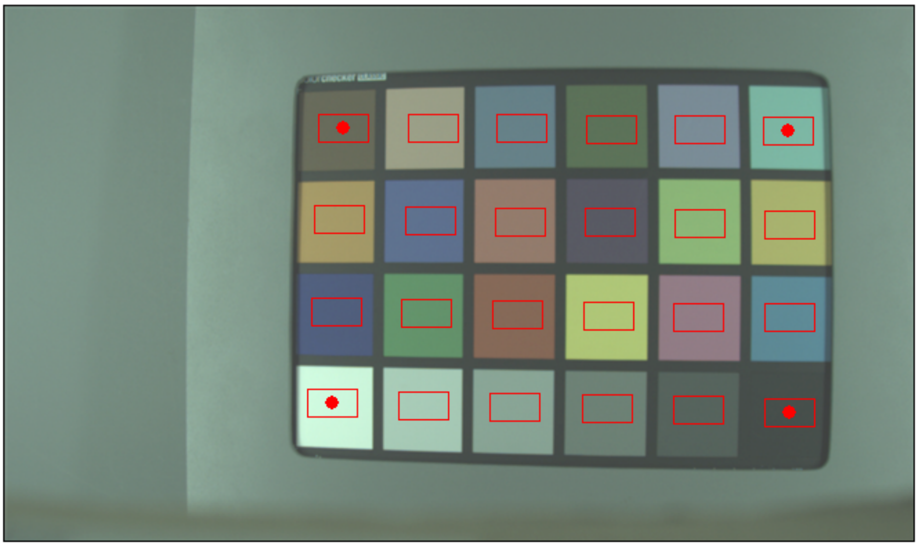
3.2.3.1 Procedure

Step 1 Import raw data by referring to the *HiSilicon PQ Tools User Guide*.

Step 2 Select a 24-color region.

To be specific, drag the red handle in the center of the color frame to change the layout of the 24-color frames until the 24-color frames match the 24-color region of the raw picture, as shown in Figure 3-1.

Figure 3-1 24-color frames



Step 3 Configure the calibration parameters (gamma, LAB reference, color block weight, and difference standard).

- Set the ISP gamma. You can select the gamma preset value (sRGB or Rec709) from the **ISP Gamma** drop-down box, or enter the name of the effective ISP gamma table.

NOTE

When customizing an ISP gamma value, match the corresponding LAB reference value. The target picture effect may not be achieved by the linearly changed AWB and CCM due to mismatch between these two values.

- Set the display gamma. To be specific, select the gamma preset value (sRGB or Rec709) from the **Display Gamma** drop-down box.
- Set the LAB reference value. You can select the LAB preset value (X-rite standard value under the D65 illuminant) from the **LAB Reference** drop-down box, or enter a value.

NOTE

When customizing an LAB reference value, match the corresponding ISP gamma value. The target picture effect may not be achieved by the linearly changed AWB and CCM due to mismatch between these two values.

- Configure the color block weights in a 6 x 4 table. The color blocks correspond to the 24 cells in the table. The weight is a floating-point number ranging from 0.0 to 16.0, and one digit after the decimal point is reserved.
- Select the standard for evaluating the differences (CIE76, CIE94, or CIE2000) and the difference matrix (Delta C*ab or Delta E*ab). The combinations of CIE76 Delta E*ab and CIE2000 Delta C*ab are recommended for calibration.
- Select **autoGain** or not.
  - When **autoGain** is selected, the luminance of the raw image and target image is compensated. By default, **autoGain** is selected. When the raw image is collected, the exposure is controlled, so that the collected raw data is close to the luminance of the target image after gamma correction. **autoGain** can help the raw data achieve the best luminance performance by using the digital gain, reducing the difficulty of raw data collecting.
  - If **autoGain** is not selected, you can control the luminance of the raw data so that different CCM parameters can be obtained.

- Select **BT.2020** or not.
  - If **BT.2020** is selected, the ISP output complies with the BT.2020 standard. The ISP gamma value can be user-defined. The gamma and LAB reference values are displayed. The raw image and target image share the same gamma and LAB reference values. If the target image uses the sRGB standard, set **GAMMA** to **sRGB**. If the target image uses the BT.2020 standard, set **GAMMA** to **Rec709**.
  - If **BT.2020** is not selected, the ISP output complies with the sRGB standard.

Step 4 Click **Calibrate** to start calibration, and obtain the result CCM. Implement manual hue/saturation adjustment on the **Result** page until the obtained CCM meets the requirement.

----End

3.2.3.2 Manually Adjusting CCM Calibration Results

You can manually adjust the picture if you are not satisfied with the effect of the corrected picture. To manually adjust the picture, go to the **Result** tab page, change the corrected hue (**Hue Corr**) and saturation (**Sat Corr**), and click **Manual Adjust** to recalculate the CCM and correct the picture. Repeat the operations until you are satisfied with the picture effect.

3.2.4 Adjusting the CCM Manually

The following is the CCM calculation formula:

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} a_{00} & a_{01} & a_{02} \\ a_{10} & a_{11} & a_{12} \\ a_{20} & a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

To prevent WB damage, parameter values in the formula must meet the following requirement:

$$a_{i0} + a_{i1} + a_{i2} = 1$$

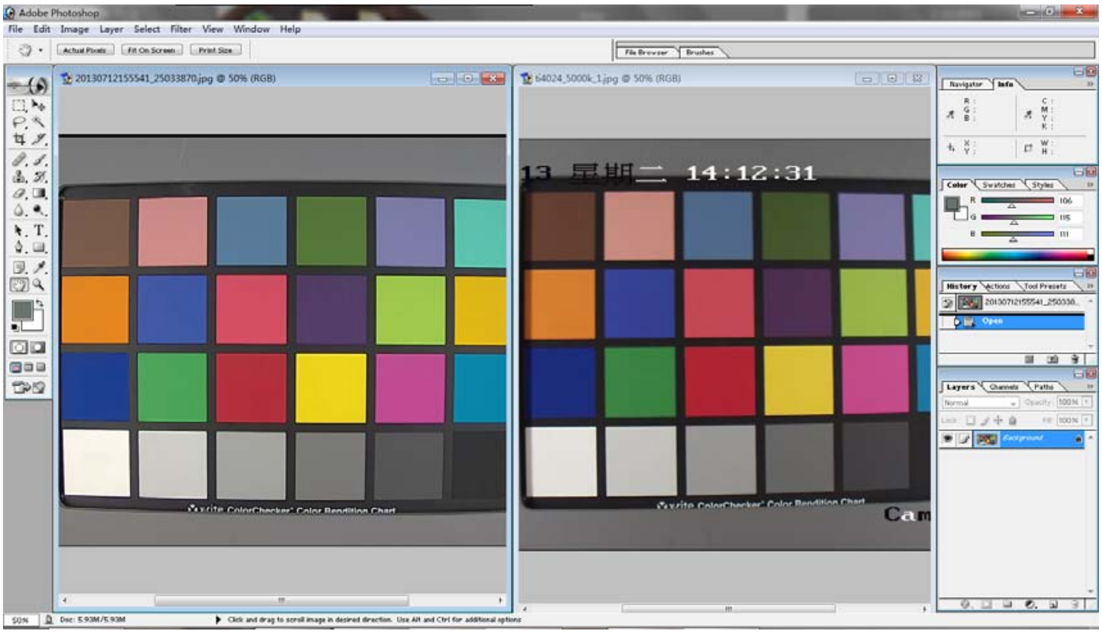
The ratio of R in R' is large, and therefore the following requirement must be met:

$$a_{ii} \geq 1$$

When the preceding conditions are met, you can adjust the CCM slightly without bringing destructive damage.

After configuring the CCM corrected by the HiPQ ISP Calibration Tool on the hardware register, capture your own ColorChecker picture and a benchmark ColorChecker picture, and compare the colors using the Adobe Photoshop.

Figure 3-2 Comparing colors of the captured picture and benchmark picture



On the **Info** tab page on the right, compare the R/G/B component of these two pictures. In normal cases, correction of the complexion, red color, and green color is concerned. Alternatively, compare the R/G/B component of the standard ColorChecker.

Figure 3-3 Standard ColorChecker values

No.	Number		sRGB			CIE L*a*b*			Munsell Notation Hue Value / Chroma	
			R	G	B	L*	a*	b*		
1.	dark skin		115	82	68	37.986	13.555	14.059	3 YR	3.7 / 3.2
2.	light skin		194	150	130	65.711	18.13	17.81	2.2 YR	6.47 / 4.1
3.	blue sky		98	122	157	49.927	-4.88	-21.925	4.3 PB	4.95 / 5.5
4.	foliage		87	108	67	43.139	-13.095	21.905	6.7 GY	4.2 / 4.1
5.	blue flower		133	128	177	55.112	8.844	-25.399	9.7 PB	5.47 / 6.7
6.	bluish green		103	189	170	70.719	-33.397	-0.199	2.5 BG	7 / 6
7.	orange		214	126	44	62.661	36.067	57.096	5 YR	6 / 11
8.	purplish blue		80	91	166	40.02	10.41	-45.964	7.5 PB	4 / 10.7
9.	moderate red		193	90	99	51.124	48.239	16.248	2.5 R	5 / 10
10.	purple		94	60	108	30.325	22.976	-21.587	5 P	3 / 7
11.	yellow green		157	188	64	72.532	-23.709	57.255	5 GY	7.1 / 9.1
12.	orange yellow		224	163	46	71.941	19.363	67.857	10 YR	7 / 10.5
13.	blue		56	61	150	28.778	14.179	-50.297	7.5 PB	2.9 / 12.7
14.	green		70	148	73	55.261	-38.342	31.37	0.25 G	5.4 / 8.65
15.	red		175	54	60	42.101	53.378	28.19	5 R	4 / 12
16.	yellow		231	199	31	81.733	4.039	79.819	5 Y	8 / 11.1
17.	magenta		187	86	149	51.935	49.986	-14.574	2.5 RP	5 / 12
18.	cyan		8	133	161	51.038	-28.631	-28.638	5 B	5 / 8
19.	white (.05*)		243	243	242	96.539	-0.425	1.186	N	9.5 /
20.	neutral 8 (.23*)		200	200	200	81.257	-0.638	-0.335	N	8 /
21.	neutral 6.5 (.44*)		160	160	160	66.766	-0.734	-0.504	N	6.5 /
22.	neutral 5 (.70*)		122	122	121	50.867	-0.153	-0.27	N	5 /
23.	neutral 3.5 (.1.05*)		85	85	85	35.656	-0.421	-1.231	N	3.5 /
24.	black (1.50*)		52	52	52	20.461	-0.079	-0.973	N	2 /

In this case, adjust parameters by comparing the formula. For example:

If the B component of the red block is large and the red color becomes water red, according to the formula $B' = a_{20}R + a_{21}G + a_{22}B$ and positive/negative of a_{20}, a_{21}, and a_{22} (negative, negative, positive), the sequence of values of the R, G, and B components of the water red color is **R** > **B** > **G**. Additionally, the target values of R, G, and B components are (175,54,60) and the sum of a_{20}, a_{21}, and a_{22} is 256. Therefore, you can decrease the value of B' using any of the following methods:

- Increase the absolute value of a_{20} and decrease the absolute value of a_{21} by the same value.
- Increase the absolute value of a_{21} and increase the absolute value of a_{22} by the same value.
- Increase the absolute value of a_{20} and increase the absolute value of a_{22} by the same value.

Use any of these methods to decrease the B' component of the red clock, and therefore correct the red block of the water red color.

NOTE

When you modify the B component of the red color, the effect of other colors may be affected due to RGB sequence conflicts. Therefore, during the modification, consider other colors as well, especially the green and complexion blocks, to prevent typical color casts caused by CCM modification.

Components of the dark complexion and light complexion are similar, and implementation of independent adjustment is difficult. You are advised to accurately adjust the red, green, and blue colors. In this way, other colors will be accurate because they are combined by these three colors.

Due to the influence of the samples involved in the CCM calibration, the calibration result may be close to the best but not the best. You can manually adjust the CCM calibration result by referring to the following methods.

- Set the elements away from the diagonal line of the CCM to negative values. If the value of a_{02} is positive, the red color with high saturation will gain a purple cast. If the value of a_{20} is positive, the blue color with high saturation will gain a purple cast. You can manually change the value of a_{02} or a_{20} to a value close to a small negative from a small positive when encountering such problems.
- If the value of a_{02} is negative, the greater the absolute value of a_{10}, the smaller the value of the G channel for the red color after CCM, and the higher the saturation for the red color. If the value of a_{12} is negative, the greater the absolute value of a_{12}, the smaller the value of the G channel for the blue color after CCM, and the higher the saturation for the blue color. If the saturation of the red or blue color is high, you can reduce the absolute value of a_{10} or a_{12}.

3.2.5 Calibrating the CCM in WDR Mode

In WDR mode, CCM can be easily affected by dynamic range control (DRC), which makes it harder to correct a color. Therefore, note the following when adjusting a color in WDR mode:

- When photographing a standard ColorChecker under the standard illuminant (the common three groups of illuminants are D50, TL84, and A illuminants), adjust the exposure ratio to the maximum value manually. At the same time, you need to adjust the luma value to avoid long frame overexposure and collect the raw data of long frames for CCM calibration. During the calibration, you can appropriately decrease the saturation, but **autoGain** cannot be enabled.
- Reduce DRC curve's effect on the picture brightness so that DRC changes the color weakly. In this way, the picture brightness is reduced and cannot reach the desired brightness. You can use the gamma to improve brightness accordingly. By associating the DRC with the gamma module, you can make the overall color tuning more precise.
- In WDR mode, since mixed illuminants are used in most cases, the color in bright regions becomes reddish including human faces. In addition to decreasing the saturation value, you can use the chroma adjustment (CA) module to reduce the saturation properly in the regions.

3.2.6 Factors Affecting CCM Calibration

Figure 3-4 describes the color characteristics of the ColorChecker before CCM.

Figure 3-4 2D ColorChecker values before CCM

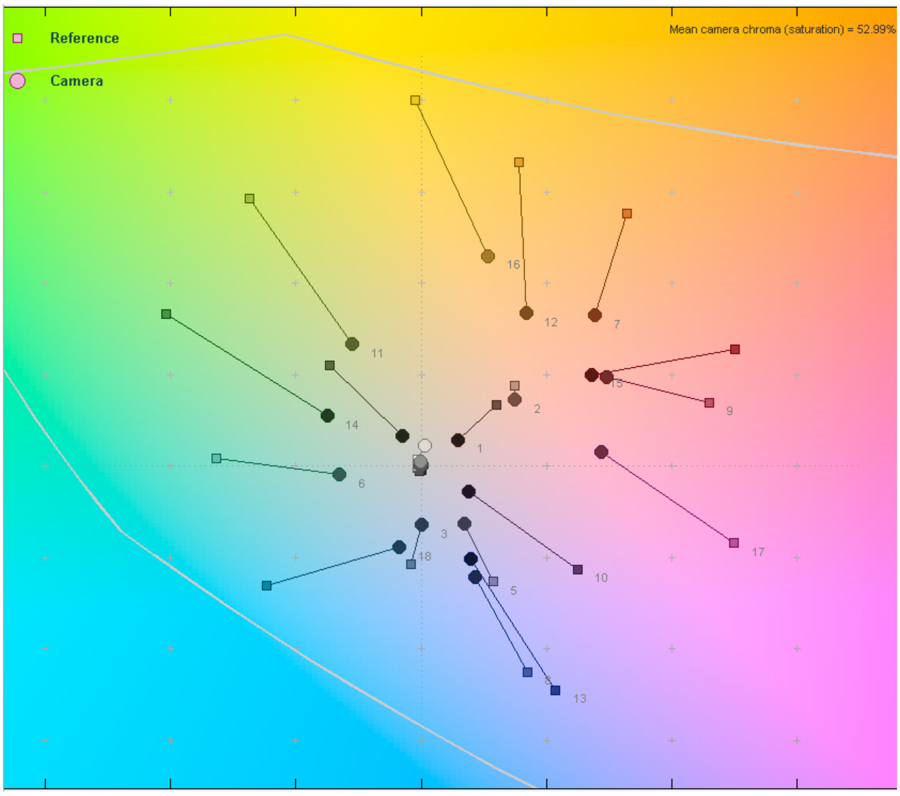
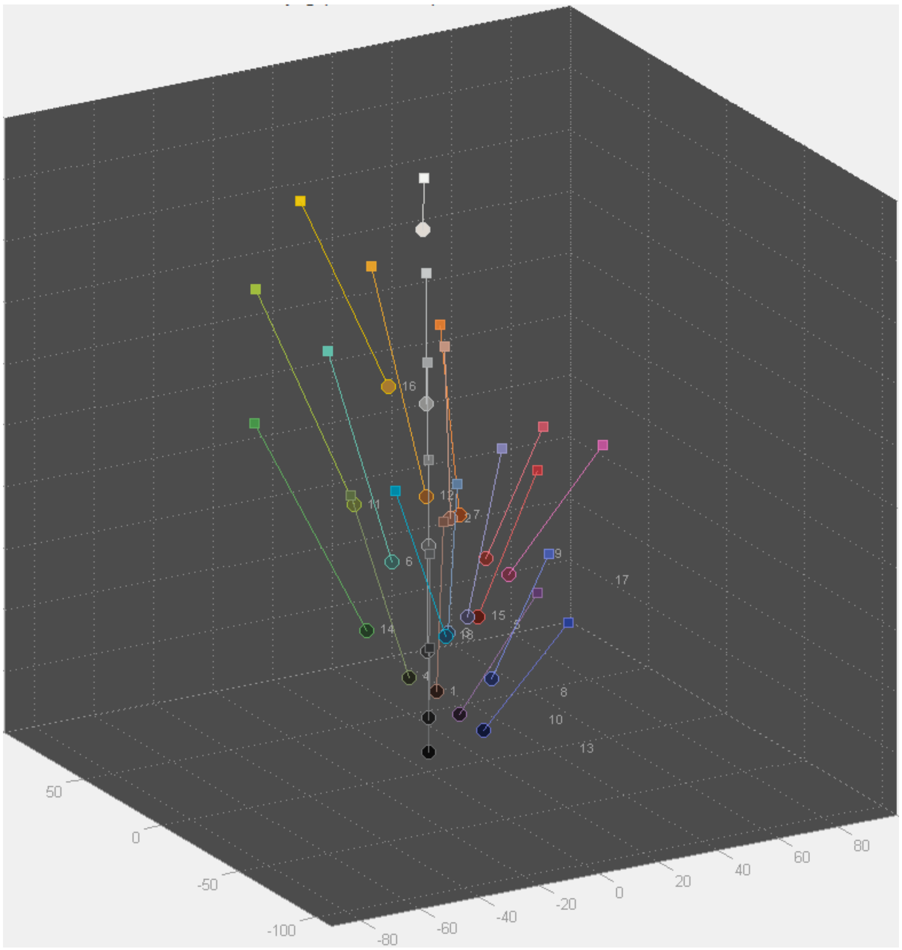


Figure 3-5 3D ColorChecker values before CCM



The 2D chart shows that the saturation and luminance are low before the CCM.

If the luminance of the captured raw data does not meet the requirements and the gamma value is also customized, you are advised to select the CIEDE2000 and LCAB color errors for the CCM calculation. Try to distribute the color errors in the direction of luminance, instead of the directions of saturation and chrominance. Make sure that the colors with low saturation are correct. If certain colors are poor, adjust the weight parameters of the color blocks for CCM calculation, and then recalculate the colors.

Figure 3-6 shows the color characteristics of the ColorChecker output by the ISP after CCM tuning.

Figure 3-6 Final 2D ColorChecker values output by the ISP

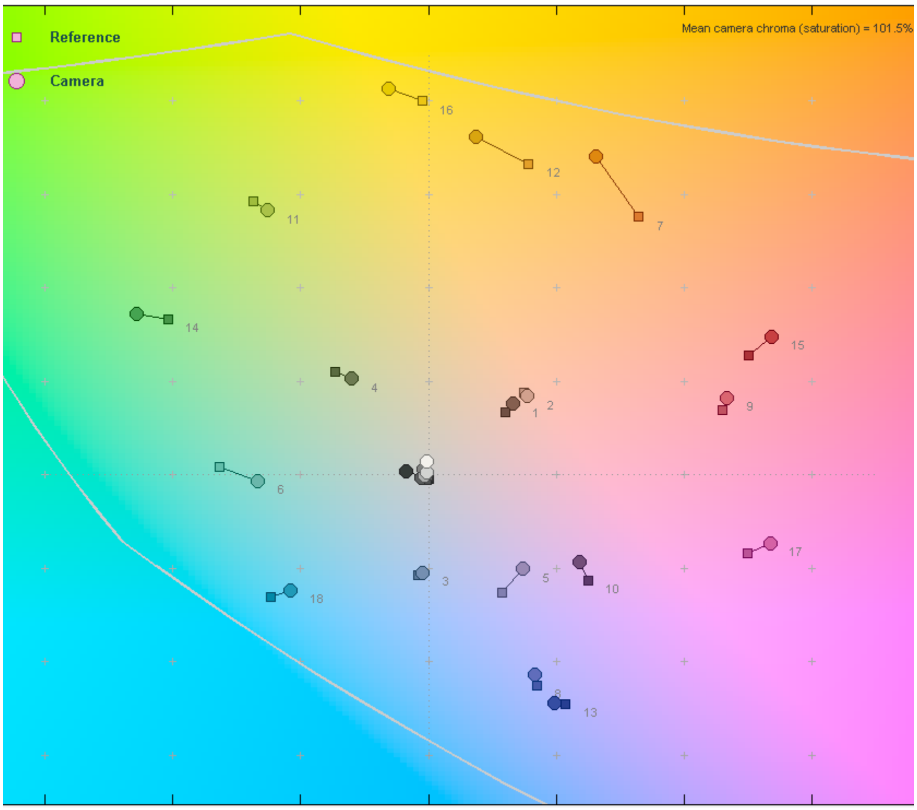
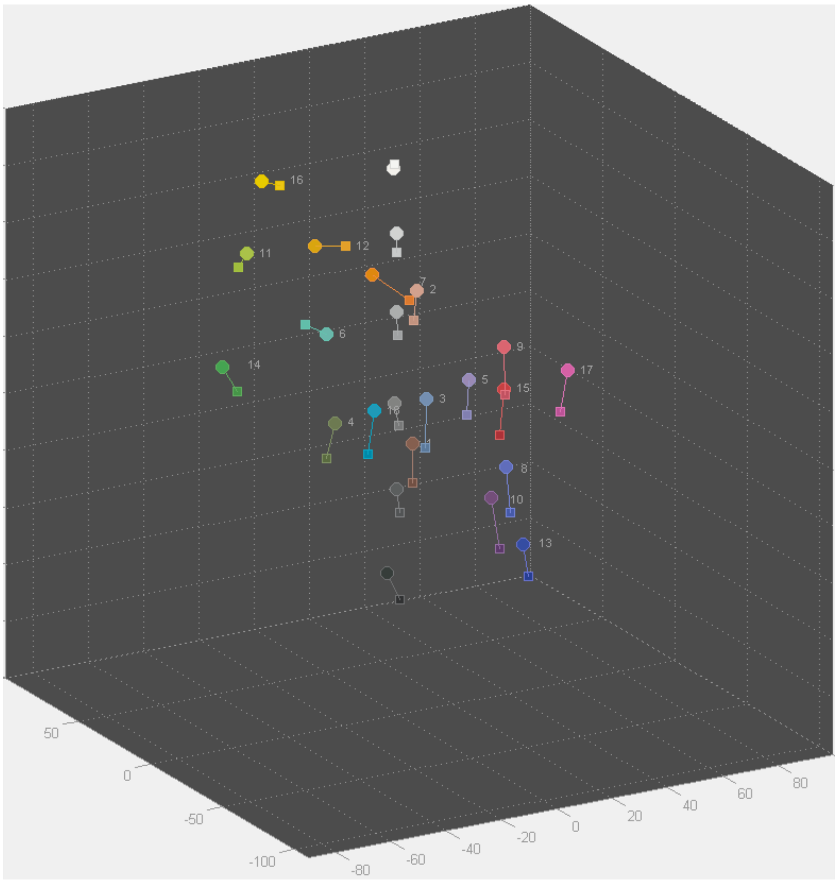


Figure 3-7 Final 3D ColorChecker values output by the ISP



As shown in Figure 3-7, the blue and red errors are best distributed on the luminance dimension. If they are distributed on the saturation dimension, the colors may oversaturate and exceed the color gamut. You can ignore the color errors of the yellow blocks, because yellow blocks are the brightest in the ColorChecker. Once you reduce the brightness of this image by one level, the color differences of the yellow blocks are optimized.

Pay attention to the following points before ColorChecker calibration:

- The ColorChecker must be evenly illuminated. No shadow or illuminant change on the ColorChecker is allowed.
- The RGB values of the color blocks on the ColorChecker cannot be clipped.
- The luminance of the gray blocks must be between 70 IRE and 95 IRE.
- The gamma curve of the target image is required.
- The collected raw data must be illuminated by a proper blackbody radiator, such as the sun.
- The captured raw data must not have mixed color temperatures. If the color temperature of the ColorChecker differs greatly from that of the background, ignore the color of the background after calibration.

Factors that may affect the CCM calibration result are as follows:

- Source gamma
- Target gamma

- Target color space: sRGB or BT.2020
- White balance of the source and target images
- Source luminance gain: ISPDgain

The source gamma and target gamma are important because the color optimization depends on the synergy of CCM and gamma. Briefly, the CCM is used to fine-tune the colors, while gamma correction can greatly change the color effect. The main reason of such a difference lies in the requirement of the end-to-end system for the ISP. The display device performs the DeGamma operation on the data sent by the ISP according to the protocol, restores the linear RGB data, processes the data, and then displays the data on the screen. In the HDR era, the requirements for protocol compliance are even stricter. Mismatches between the source gamma and the target gamma directly result in color errors.

The white balance of the source and target images is important because the AWB gain of the benchmark plays a decisive role in the color style of the benchmark. The AWB can reflect color temperature of the actual illuminant or the D65 illuminant.

The ISPDgain of the source is important because the solution of the 3 x 3 CCM requires that the matrix include as little luminance adjustment as possible. If the raw image is too bright or too dark, the saturation characteristic of the calibrated CCM is different from that when the luminance is properly adjusted. With an over-bright raw image, the saturation of the calibrated CCM is low. With an over-dark raw image, the saturation of the calibrated CCM is high.

The preceding five factors can strongly influence the CCM calibration result. Find the best CCM solutions by changing the input variables of them to obtain desired color results.

4 Advanced Color Tuning Scheme

4.1 Overview

After the modules involved in the basic color tuning scheme are tuned, adjust the modules involved in the advanced color tuning scheme. With most colors adjusted, you can adjust the system colors in a more refined and personalized manner. This chapter describes how to tune the modules (such as the CLUT module) involved in the advanced color tuning scheme.

4.1.1 Typical Application Mode

4.1.1.1 Normal Mode

In normal mode, the adjustment of the system colors is relatively simple.

- The system colors are realized by the synergy of the AWB, CCM, and gamma functions.
- With the CA module, you can adjust the saturation based on the colors determined by the CCM to have gradations of color.

4.1.1.2 Preference Enhancement Mode

The adjustment policies of the system colors in the preference enhancement mode are as follows:

- The CCM adjustment lays equal stress on all colors, that is, the error of each color is equal.
- Based on stably tuned CCM, the CLUT enhances the preference colors or corrects the remaining color errors after the CCM is adjusted.

4.1.1.3 Color Style Replication Mode

The adjustment policies of the system colors in color style replication mode are as follows:

- The system exposure policy is adjusted to keep consistent with that of the target device.
- To keep consistent with the gamma values of the target device, a grayscale chart or 15-grayscale calibration in a 140-patch chart is used.
- The CCM is adjusted to realize consistent chart colors with the target device.
- After the CCM is adjusted, the CLUT is used to further correct the remaining color errors.

4.2 CLUT Tuning

4.2.1 CLUT Calibration Parameters

The CLUT is a module can be used to change the linear RGB values. This module converts the user color tuning requirements into the data mapping relationship between the source and target RGB patches. You can gradually improve the adjustment targets of the CLUT in the ISP to generate a CLUT that applies to all scenarios. Perform adjustment with the interactive tools and then you can obtain a CLUT that matches your color tuning requirements. Before a CLUT is exported, the contradictory requirements are eliminated.

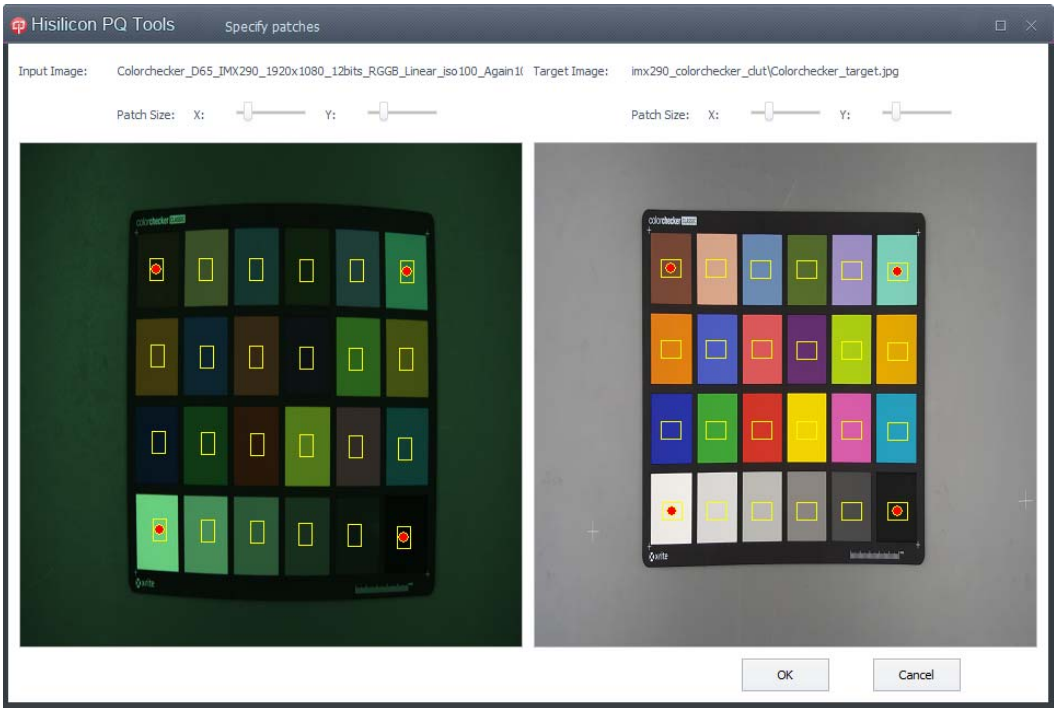
4.2.2 Inputting the Requirements

For details, see the *HiSilicon PQ Tools User Guide*.

4.2.2.1 Color Pairs of ColorChecker

Shooting the ColorChecker with both the source and target devices at the same time, you can easily obtain a wide range of color samples, which can be used to guide the generation of the CLUT. The X-Rite ColorChecker can be used to obtain 24 color pairs as color samples. The X-Rite ColorChecker SG can be used to obtain 140 color pairs as color samples.

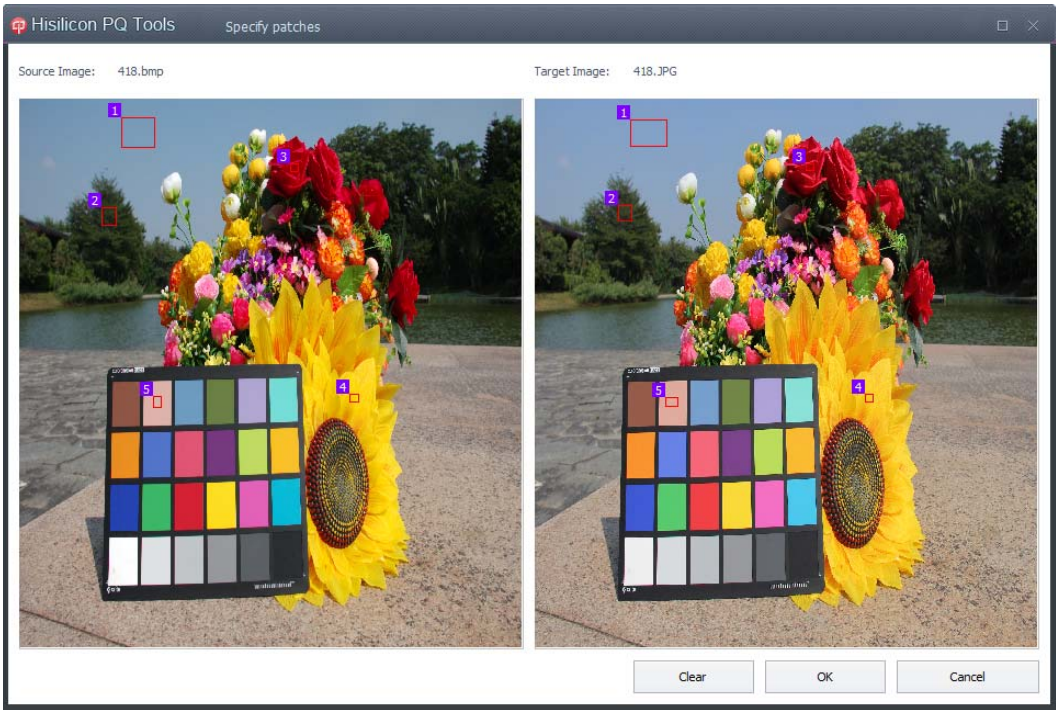
Figure 4-1 Color pairs



4.2.2.2 Random Color Pairs

If you shoot a scene with both the source and target devices at the same time, you can select the surfaces of the objects from the scene, and obtain random color pairs, which can be used to guide the generation of the CLUT.

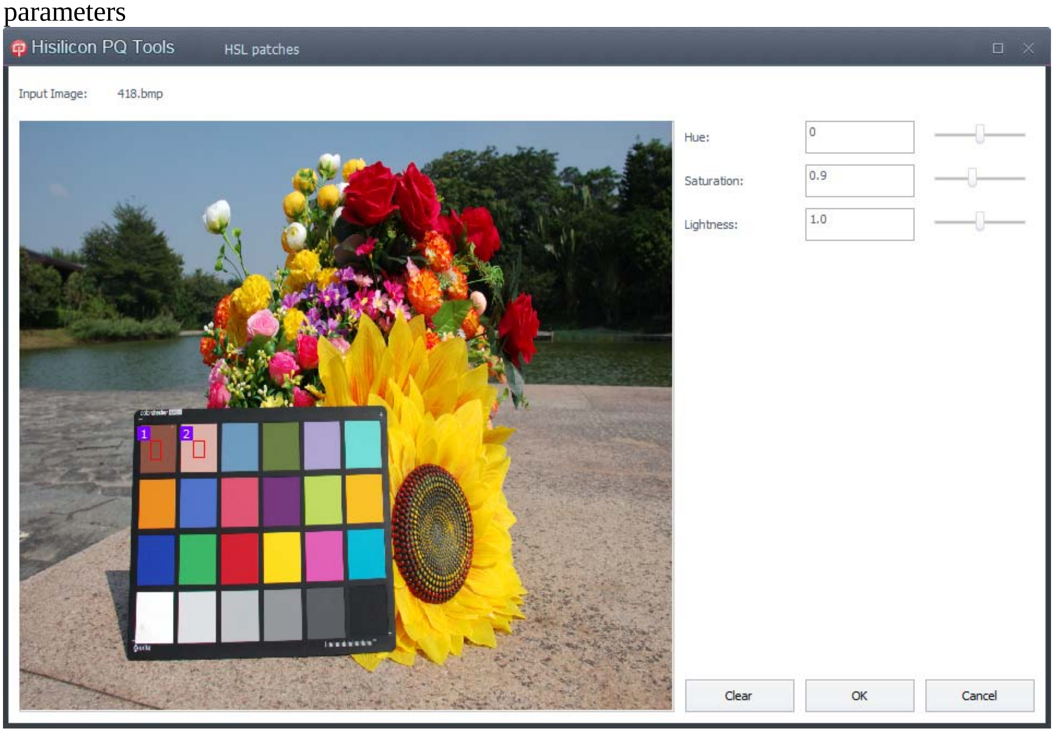
Figure 4-2 Random color pairs



4.2.2.3 HSL Parameters

If no target device is available, and you shoot the scene with the source device and select the color surface to be adjusted, you can obtain the target RGB values by adjusting the HSL parameters, which can be used to guide the generation of the CLUT. The value range of **Hue** is from –20 to +20, the value range of **Saturation** is 0.4–1.6 times, and the value range of **Lightness** is 0.6–1.4 times.

Adjusting the HSL parameters



4.2.3 CLUT Application Samples

4.2.3.1 Using ColorChecker for Adjustment

You can use the ColorChecker to quickly adjust the CLUT.

You can use a source device and a target device to capture images of multiple ColoCheckers in different brightness outdoors. The source device collects raw data, and the target device collects JPG data.

Import collected raw data to the board. Adjust the brightness and white balance to be the same as those of the target image. Use the expected parameters for the CCM and Gamma to capture the images output by the ISP.

You can use the Color Check Free function to generate two or three groups of RGB pairs based on the color blocks of the ColoCheckers in different brightness. See Figure 4-3.

Figure 4-3 Using JPG images with ColorChecker

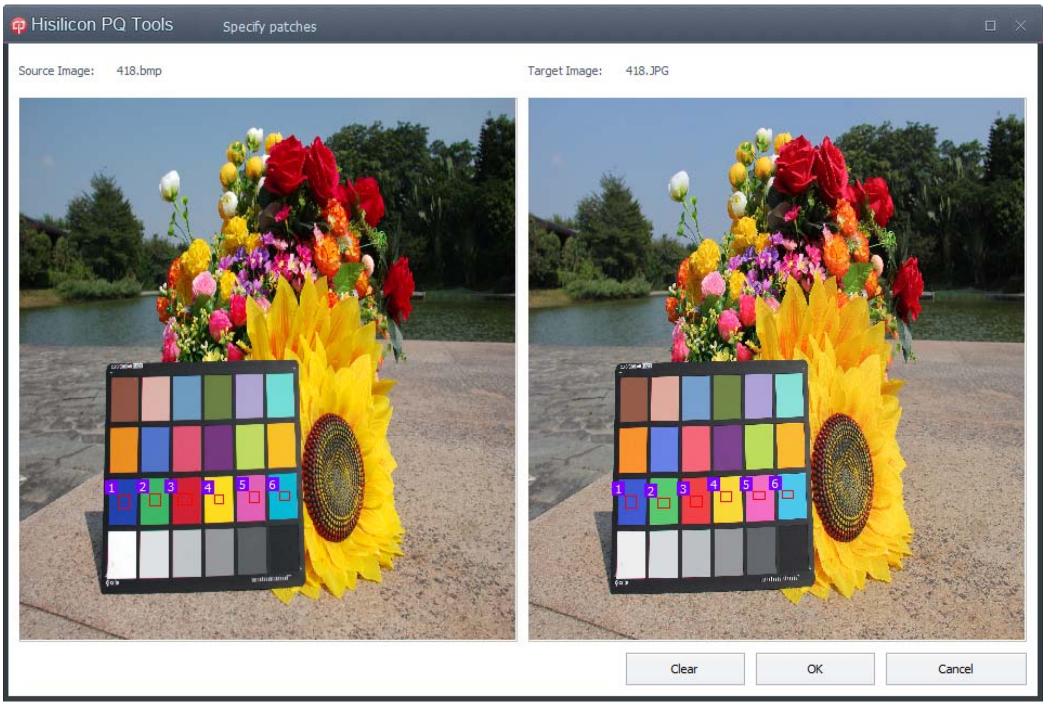


Figure 4-4 Generating RGB pairs of ColorChecker

Import RGB | Export RGB | Clear RGB

Sel	OriClr	EstClr	OriR	OriG	OriB	EstR	EstG	EstB	ErrorRGB	Del
☑			0.754664	0.201774	0.082088	0.779706	0.164372	0.001295	0.000000	
☑			0.098546	0.150353	0.589797	0.079708	0.115011	0.588304	0.000000	
☑			0.691443	0.113553	0.166396	0.648264	0.089005	0.120507	0.000000	
☑			0.108687	0.058890	0.150305	0.108687	0.058890	0.150305	0.000000	
☑			0.481745	0.573050	0.138501	0.395484	0.568033	0.038151	0.000000	
☑			0.868586	0.416797	0.101071	0.854510	0.327329	0.000300	0.000000	
☑			0.044788	0.077175	0.331241	0.032530	0.060779	0.404988	0.000000	
☑			0.117612	0.326936	0.118120	0.081549	0.331308	0.080020	0.000000	
☑			0.447556	0.057732	0.071579	0.545414	0.040801	0.040884	0.000000	
☑			0.938745	0.631095	0.117378	0.931778	0.592107	0.000300	0.000000	
☑			0.670373	0.153215	0.463723	0.657591	0.096883	0.411656	0.000000	
☑			0.083849	0.383352	0.640663	0.022141	0.292379	0.617707	0.000000	

As shown in Figure 4-4, two or three groups of RGB pairs of ColorCheckers in different brightness can be obtained after multiple operations. If the colors meet the adjustment requirements, the CLUT generated by the RGB pairs can be considered as a basic adjustment table. Export the RGB pairs. The subsequent adjustment can be performed on this basis.

4.2.3.2 Using Color Values for Adjustment

You can use color values in the CLUT to adjust the color. The following describes how to adjust the skin color.

Import the same image with the color distributed into both the source and target images. The image that contains various skin color values is imported here.

You can use the Color Check Free function to convert the color adjustment trend to RGB pairs. See Figure 4-5.

Figure 4-5 Using color values for adjustment

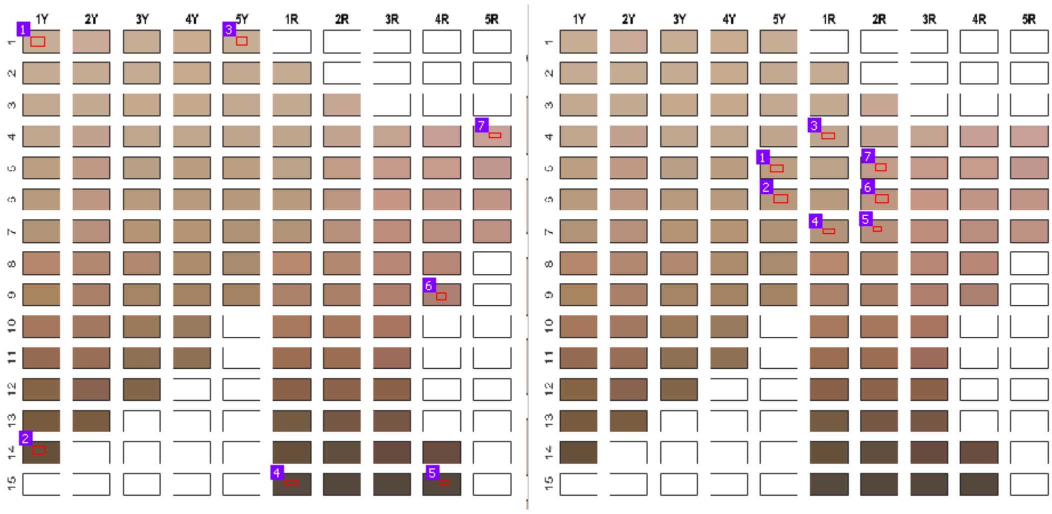
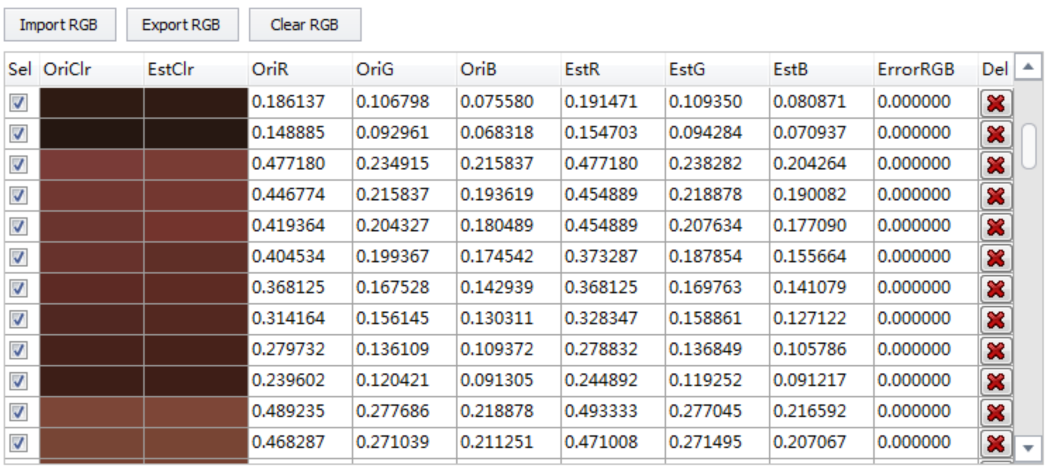


Figure 4-6 shows the generated RGB pairs.

Figure 4-6 Generating RGB pairs of the skin color



Sel	OriClr	EstClr	OriR	OriG	OriB	EstR	EstG	EstB	ErrorRGB	Del
			0.186137	0.106798	0.075580	0.191471	0.109350	0.080871	0.000000	
			0.148885	0.092961	0.068318	0.154703	0.094284	0.070937	0.000000	
			0.477180	0.234915	0.215837	0.477180	0.238282	0.204264	0.000000	
			0.446774	0.215837	0.193619	0.454889	0.218878	0.190082	0.000000	
			0.419364	0.204327	0.180489	0.454889	0.207634	0.177090	0.000000	
			0.404534	0.199367	0.174542	0.373287	0.187854	0.155664	0.000000	
			0.368125	0.167528	0.142939	0.368125	0.169763	0.141079	0.000000	
			0.314164	0.156145	0.130311	0.328347	0.158861	0.127122	0.000000	
			0.279732	0.136109	0.109372	0.278832	0.136849	0.105786	0.000000	
			0.239602	0.120421	0.091305	0.244892	0.119252	0.091217	0.000000	
			0.489235	0.277686	0.218878	0.493333	0.277045	0.216592	0.000000	
			0.468287	0.271039	0.211251	0.471008	0.271495	0.207067	0.000000	

The CLUT generated by the RGB pairs needs to be loaded to the board. You can further confirm the CLUT by importing raw data of the actual image containing the skin color.