How to interpret the sRGB color space (specified in IEC 61966-2-1) for ICC profiles

A. Key sRGB color space specifications (see IEC 61966-2-1 https://webstore.iec.ch/publication/6168 for more information)**.**

1. Chromaticity co-ordinates of primaries:
R: x = 0.64, y = 0.33, z = 0.03;
G: x = 0.30, y = 0.60, z = 0.10;
B: x = 0.15, y = 0.06, z = 0.79.
Note: These are defined in ITU-R BT.709 (the television standard for HDTV capture).

2. Reference display'Gamma': Approximately 2.2 (see precise specification of color component transfer function below).

3. Reference display white point chromaticity: x = 0.3127, y = 0.3290, z = 0.3583 (equivalent to the chromaticity of CIE Illuminant D65).

4. Reference display white point luminance: 80 cd/m^2 (includes veiling glare).
Note: The reference display white point tristimulus values are: X_{abs} = 76.04, Y_{abs} = 80, Z_{abs} = 87.12.

5. Reference veiling glare luminance: 0.2 cd/m^2 (this is the reference viewer-observed black point luminance).
Note: The reference viewer-observed black point tristimulus values are assumed to be: X_{abs} = 0.1901, Y_{abs} = 0.2, Z_{abs} = 0.2178. These values are not specified in IEC 61966-2-1, and are an additional interpretation provided in this document.

6. Tristimulus value normalization: The CIE 1931 XYZ values are scaled from 0.0 to 1.0.
Note: The following scaling equations can be used. These equations are not provided in IEC 61966-2-1, and are an additional interpretation provided in this document.

$$X_N = \frac{76.04\left(X_{abs} - 0.1901\right)}{80\left(76.04 - 0.1901\right)} = 0.0125313\ (X_{abs} - 0.1901)$$

$$Y_N = \frac{Y_{abs} - 0.2}{80 - 0.2} = 0.0125313\ (Y_{abs} - 0.2)$$

$$Z_N = \frac{87.12\left(Z_{abs} - 0.2178\right)}{80\left(87.12 - 0.2178\right)} = 0.0125313\ (Z_{abs} - 0.2178)$$

7. Conversion from XYZ (D65) to linear sRGB values:

$$\begin{bmatrix} R_L \\ G_L \\ B_L \end{bmatrix} = \begin{bmatrix} 3.2406255 & -1.537208 & -0.4986286 \\ -0.9689307 & 1.8757561 & 0.0415175 \\ 0.0557101 & -0.2040211 & 1.0569959 \end{bmatrix} \begin{bmatrix} X_N \\ Y_N \\ Z_N \end{bmatrix}$$

Note: R_L, G_L *or* B_L values less than 0 or greater than 1 are clipped to 0 and 1.

8. Color component transfer function:
Note: Produces sRGB digital values with a range 0 to 1, which must then be multiplied by $2^{\text{bit depth}} - 1$ and quantized.

If R_L, G_L, B_L are less than or equal to 0.0031308

$R = 12.92\ R_L$

$G = 12.92\ G_L$

$B = 12.92\ B_L$

If R_L, G_L, B_L are greater than 0.0031308

$R = 1.055\ R_L^{(1/2.4)} – 0.055$

$G = 1.055\ G_L^{(1/2.4)} – 0.055$

$B = 1.055\ B_L^{(1/2.4)} – 0.055$

B. Hints for profile makers

1. Inverting the color component transfer function

Note: Starting from sRGB values in the range 0 to 1, which are obtained by dividing integer values by $2^{\text{bit depth}} – 1$.

It is common practice (but not required) to use black and white normalized colorimetry when making ICC v2 display profiles. When this is done, the inversion of the color component transfer function is accomplished using 1D LUTs created using the inverse color component transfer function without inverse black normalization (scaling), which is provided in IEC 61966-2-1 as follows:

If R, G, B are less than or equal to 0.04045

$R_L = R/12.92$

$G_L = G/12.92$

$B_L = B/12.02$

If R, G, B are greater than 0.04045

$R_L = ((R + 0.055)/1.055)^{2.4}$

$G_L = ((R + 0.055)/1.055)^{2.4}$

$B_L = ((R + 0.055)/1.055)^{2.4}$

Note: With ICC v2 profiles, the white-relative media black point tristimulus values can be provided in the mediaBlackPoint tag, for use cases where the accurate reproduction of dark colors is important, and the use of this tag to de-normalize the black is supported by the CMM (which is rare).

However, when making ICC v4 profiles, it is prohibited to encode black normalized values in the PCS, and the black scaling must be undone. The following equations invert both the color component transfer function and the black scaling:

If R, G, B are less than or equal to 0.04045

$$R_{LU} = \frac{\frac{(80-0.2)R}{12.92}+0.2}{80} = 0.0772059\ R + 0.0025$$

$$G_{LU} = \frac{\frac{(80-0.2)G}{12.92}+0.2}{80} = 0.0772059\ G + 0.0025$$

$$B_{LU} = \frac{\frac{(80-0.2)B}{12.92}+0.2}{80} = 0.0772059\ B + 0.0025$$

If R, G, B are greater than 0.04045

$$R_{LU} = \frac{(80-0.2)\left(\frac{R+0.055}{1.055}\right)^{2.4}+0.2}{80} = (0.946879\ R + 0.0520784)^{2.4} + 0.0025$$

$$G_{LU} = \frac{(80-0.2)\left(\frac{G+0.055}{1.055}\right)^{2.4}+0.2}{80} = (0.946879\ G + 0.0520784)^{2.4} + 0.0025$$

$$B_{LU} = \frac{(80-0.2)\left(\frac{B+0.055}{1.055}\right)^{2.4}+0.2}{80} = (0.946879\ B + 0.0520784)^{2.4} + 0.0025$$

Note: These equations can be incorporated in an ICC parametricCurveType tag using Type 4.

Note: Encoding black normalized values in the PCS is prohibited with ICC v4 profiles because it was decided the capability to reproduce dark colors accurately is important, and should not require a special CMM that uses the mediaBlackPoint tag. If black point scaling is required when using ICC v4 profiles, the CMM should apply black point compensation as specified in ISO 18619.

2. Chromatic adaptation and converting to the ICC XYZ PCS

The white point of the ICC PCS has the tristimulus values X = 0.9642, Y = 1, Z = 0.8249 (CIE Illuminant D50). Consequently, when the adapted white point of the device-side encoding is different from D50, it is necessary to apply a chromatic adaptation transform to the device-side colorimetry in order to convert it to corresponding colorimetry relative to a D50 adapted white point. In the case of sRGB, the chromatic adaptation transform is applied to the device primaries and white point, with the result encoded in the ICC profile.

Example: If D65 is selected as the sRGB adapted white, the chromatic adaptation transform will go from D65 to D50, the resulting D50 values will be encoded in the mediaWhitePoint tag, and the sRGB primaries will be adapted to D50 for encoding in the ICC profile. However, if D50 were selected as the sRGB adapted white, chromatic adaptation would not be necessary, D65 values would be encoded in the mediaWhitePoint tag, and the sRGB primaries would be used in the profile without adaptation.

IEC 61966-2-1 does not specify the colorimetry of the sRGB reference display adapted white point. Likewise, there is no requirement for choosing the device-side adapted white for ICC v2 profiles, so it is allowed to make different v2 sRGB ICC profiles with different sRGB adapted white assumptions. However, for ICC v4 display profiles, ISO 15076-1 requires that the display white point be used as the device-side adapted white point, for determining the chromatic adaptation to the PCS D50 white point. For better interoperability, it is recommended that this practice also be followed for v2 sRGB ICC profiles. The recommended chromatic adaptation matrix from D65 to D50, to be used for this purpose, is as follows:

$$\begin{bmatrix} X_{D50} \\ Y_{D50} \\ Z_{D50} \end{bmatrix} = \begin{bmatrix} 1.047844353856414 & 0.022898981050086 & -0.050206647741605 \\ 0.029549007606644 & 0.990508028941971 & -0.017074711360960 \\ -0.009250984365223 & 0.015072338237051 & 0.751717835079977 \end{bmatrix} \begin{bmatrix} X_{D65} \\ Y_{D65} \\ Z_{D65} \end{bmatrix}$$

Combining this matrix with the inverse of the matrix from X_N, Y_N, Z_N to R_L, G_L, B_L in A.7 results in the following matrix, which can be used for ICC Matrix/TRC sRGB profiles:

$$\begin{bmatrix} X_{D50} \\ Y_{D50} \\ Z_{D50} \end{bmatrix} = \begin{bmatrix} 0.436030342570117 & 0.385101860087134 & 0.143067806654203 \\ 0.222438466210245 & 0.716942745571917 & 0.060618777416563 \\ 0.013897440074263 & 0.097076381494207 & 0.713926257896652 \end{bmatrix} \begin{bmatrix} R_L \\ G_L \\ B_L \end{bmatrix}$$

Note: When making v4 sRGB ICC profiles, the R_{LU}, G_{LU} and B_{LU} values are used.

3. Converting to the ICC LAB PCS

It is not recommended to use the ICC LAB PCS in ICC v2 sRGB profiles, as this requires the use of a 3D LUT, resulting in significantly larger errors for the colorimetric intents.

It is possible to use the ICC LAB PCS with ICC v4 sRGB profiles by using the lutA2B and lutB2A transform types. This can be advantageous because then the ICC LAB PCS can also be used for the perceptual transform, providing greater control of the color rendering between sRGB and the ICC Perceptual Reference Medium. However, constructing such transforms is complex, and beyond the scope of this document. For an example of such a profile see http://www.color.org/srgbprofiles.xalter#v4pref.