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AMENDMENT 1
2003-01

Amendment 1

Multimedia systems and equipment –
Colour measurement and management –

Part 2-1:
Colour management –
Default RGB colour space - sRGB

Amendement 1

Mesure et gestion de la couleur dans les systèmes et appareils multimédia –

Partie 2-1:
Gestion de la couleur –
Espace chromatique RVB par défaut - sRVB

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FOREWORD

This amendment has been prepared by Technical Area 2: Colour measurement and management, of IEC technical committee 100: Audio, video and multimedia systems and equipment and ISO TC 42: Photography.

The text of this amendment is based on the following documents:

FDIS	Report on voting
100/555A/FDIS	100/625/RVD

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

It is published as a double logo standard.

In the ISO the Standard has been approved by 10 P-members out of 10 having cast the vote.

Page 5

CONTENTS

Add the titles of Annexes F, G and H as follows:

Page 49

Add the following new Annexes F, G and H after Annex E:

Annex F
(normative)

Default YCC encoding transformation for a standard luma-chroma-chroma colour space: sYCC

The method of digitization in this annex is designed to complement current sRGB-based colour management strategies by explicitly standardizing a default transformation between sRGB and a standard luma-chroma-chroma colour space (sYCC). Application and hardware developers who want to support various colour compression schemes based on luma-chroma-chroma spaces can utilize this annex. Since this sYCC colour space is a simple extension of the sRGB colour space as defined in this standard, the same reference conditions are shared by both colour spaces.

F.1 General

The encoding transformations between sYCC values and CIE 1931 XYZ values provide unambiguous methods to represent optimum image colorimetry when viewed on a hypothetical reference display that is capable of producing all colours defined by sYCC encoding, in the reference viewing conditions by the reference observer. Non-linear floating point sR′G′B′ represent the appearance of the image as displayed on the reference display in the reference viewing condition described in Clause 4 of this standard.

F.2 Transformation from sYCC values ($Y_{\mathrm{sYCC}}, Cb_{\mathrm{sYCC}}, Cr_{\mathrm{sYCC}}$) to CIE 1931 XYZ values

The non-linear $sY'C_b'C_r'$ values can be computed using the following relationship:

$$\begin{aligned} Y'_{\mathrm{sYCC}} &= (Y_{\mathrm{sYCC}} - KDC)/(WDC - KDC) \\ Cb'_{\mathrm{sYCC}} &= (Cb_{\mathrm{sYCC}} - Offset)/Range \\ Cr'_{\mathrm{sYCC}} &= (Cr_{\mathrm{sYCC}} - Offset)/Range \end{aligned} \quad \text{(F.1)}$$

For 24-bit encoding (8-bit/channel), WDC = 255, KDC = 0, *Range* = 255, and *Offset* = 128, and the relationship is defined as;

$$\begin{aligned} Y'_{\mathrm{sYCC}} &= \left(Y_{\mathrm{sYCC}_{(8)}} - 0\right)/(255 - 0) = Y_{\mathrm{sYCC}_{(8)}}/255 \\ Cb'_{\mathrm{sYCC}} &= \left(Cb_{\mathrm{sYCC}_{(8)}} - 128\right)/255 \\ Cr'_{\mathrm{sYCC}} &= \left(Cr_{\mathrm{sYCC}_{(8)}} - 128\right)/255 \end{aligned} \quad \text{(F.2)}$$

24-bit encoding (8-bit/channel) shall be the default sYCC encoding bit depth. Other bit depths may be unsupported for general use.

Where other N-bit/channel encoding is supported ($N > 8$), the relationship is defined as;

$$
\begin{aligned}
Y'_{\text{sYCC}} &= Y_{\text{sYCC(N)}} \Big/ \left(2^{N} - 1\right) \\
Cb'_{\text{sYCC}} &= \left(Cb_{\text{sYCC(N)}} - 2^{N-1}\right) \Big/ \left(2^{N} - 1\right) \\
Cr'_{\text{sYCC}} &= \left(Cr_{\text{sYCC(N)}} - 2^{N-1}\right) \Big/ \left(2^{N} - 1\right)
\end{aligned}
\tag{F.2′}
$$

For 24-bit encoding (8-bit/channel), the non-linear sY′C_b′C_r′ values are transformed to the non-linear sR′G′B′ values as follows;

$$
\begin{bmatrix} R'_{\text{sRGB}} \\ G'_{\text{sRGB}} \\ B'_{\text{sRGB}} \end{bmatrix} =
\begin{bmatrix} 1{,}000\ 0 & 0{,}000\ 0 & 1{,}402\ 0 \\ 1{,}000\ 0 & -0{,}344\ 1 & -0{,}714\ 1 \\ 1{,}000\ 0 & 1{,}772\ 0 & 0{,}000\ 0 \end{bmatrix}
\begin{bmatrix} Y'_{\text{sYCC}} \\ Cb'_{\text{sYCC}} \\ Cr'_{\text{sYCC}} \end{bmatrix}
\tag{F.3}
$$

For N-bit/channel encoding ($N > 8$), it is recommended to replace the matrix coefficients in the equation F.3 with the coefficients of the inverse matrix of the equation F.12 with enough accuracy decimal points. For example, following matrix with 6 decimal points has enough accuracy for the case of 16-bit/channel.

$$
\begin{bmatrix} R'_{\text{sRGB}} \\ G'_{\text{sRGB}} \\ B'_{\text{sRGB}} \end{bmatrix} =
\begin{bmatrix} 1{,}000\ 000 & 0{,}000\ 037 & 1{,}401\ 988 \\ 1{,}000\ 000 & -0{,}344\ 113 & -0{,}714\ 104 \\ 1{,}000\ 000 & 1{,}771\ 978 & 0{,}000\ 135 \end{bmatrix}
\begin{bmatrix} Y'_{\text{sYCC}} \\ Cb'_{\text{sYCC}} \\ Cr'_{\text{sYCC}} \end{bmatrix}
\tag{F.3′}
$$

The non-linear sR′G′B′ values are then transformed to CIE 1931 XYZ values as follows:

If $R'_{\text{sRGB}}, G'_{\text{sRGB}}, B'_{\text{sRGB}} < -0{,}040\ 45$

$$
\begin{aligned}
R_{\text{sRGB}} &= -\left[\left(-R'_{\text{sRGB}} + 0{,}055\right) \big/ 1{,}055\right]^{2{,}4} \\
G_{\text{sRGB}} &= -\left[\left(-G'_{\text{sRGB}} + 0{,}055\right) \big/ 1{,}055\right]^{2{,}4} \\
B_{\text{sRGB}} &= -\left[\left(-B'_{\text{sRGB}} + 0{,}055\right) \big/ 1{,}055\right]^{2{,}4}
\end{aligned}
\tag{F.4}
$$

If $-0{,}040\ 45 \le R'_{\text{sRGB}}, G'_{\text{sRGB}}, B'_{\text{sRGB}} \le 0{,}040\ 45$,

$$
\begin{aligned}
R_{\text{sRGB}} &= R'_{\text{sRGB}} \div 12{,}92 \\
G_{\text{sRGB}} &= G'_{\text{sRGB}} \div 12{,}92 \\
B_{\text{sRGB}} &= B'_{\text{sRGB}} \div 12{,}92
\end{aligned}
\tag{F.5}
$$

If $R'_{\text{sRGB}}, G'_{\text{sRGB}}, B'_{\text{sRGB}} > 0{,}040\ 45$,

$$
\begin{aligned}
R_{\text{sRGB}} &= \left[\left(R'_{\text{sRGB}} + 0{,}055\right) \big/ 1{,}055\right]^{2{,}4} \\
G_{\text{sRGB}} &= \left[\left(G'_{\text{sRGB}} + 0{,}055\right) \big/ 1{,}055\right]^{2{,}4} \\
B_{\text{sRGB}} &= \left[\left(B'_{\text{sRGB}} + 0{,}055\right) \big/ 1{,}055\right]^{2{,}4}
\end{aligned}
\tag{F.6}
$$

For 24-bit encoding (8-bit/channel), the linear sRGB values are transformed to CIE 1931 XYZ values as follows:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0{,}412\ 4 & 0{,}357\ 6 & 0{,}180\ 5 \\ 0{,}212\ 6 & 0{,}715\ 2 & 0{,}072\ 2 \\ 0{,}019\ 3 & 0{,}119\ 2 & 0{,}950\ 5 \end{bmatrix} \begin{bmatrix} R_{\mathrm{sRGB}} \\ G_{\mathrm{sRGB}} \\ B_{\mathrm{sRGB}} \end{bmatrix} \qquad \text{(F.7)}$$

F.3 Transformation from CIE 1931 XYZ values to sYCC values ($Y_{\mathrm{sYCC}}, Cb_{\mathrm{sYCC}}, Cr_{\mathrm{sYCC}}$)

The CIE 1931 XYZ values can be transformed to non-linear sR′G′B′ values as follows

$$\begin{bmatrix} R_{\mathrm{sRGB}} \\ G_{\mathrm{sRGB}} \\ B_{\mathrm{sRGB}} \end{bmatrix} = \begin{bmatrix} 3{,}240\ 6 & -1{,}537\ 2 & -0{,}498\ 6 \\ -0{,}968\ 9 & 1{,}875\ 8 & 0{,}041\ 5 \\ 0{,}055\ 7 & -0{,}204\ 0 & 1{,}057\ 0 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \qquad \text{(F.8)}$$

For N-bit/channel encoding ($N > 8$), it is recommended to replace the matrix coefficients in the equation F.8 with the coefficients of the inverse matrix of the equation F.7 with enough accuracy decimal points. For example, following matrix with 7 decimal points has enough accuracy for the case of 16-bit/channel.

$$\begin{bmatrix} R_{\mathrm{sRGB}} \\ G_{\mathrm{sRGB}} \\ B_{\mathrm{sRGB}} \end{bmatrix} = \begin{bmatrix} 3{,}240\ 625\ 5 & -1{,}537\ 208\ 0 & -0{,}498\ 628\ 6 \\ -0{,}968\ 930\ 7 & 1{,}875\ 756\ 1 & 0{,}041\ 517\ 5 \\ 0{,}055\ 710\ 1 & -0{,}204\ 021\ 1 & 1{,}056\ 995\ 9 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \qquad \text{(F.8′)}$$

In the sYCC encoding process, negative sRGB tristimulus values, and sRGB tristimulus values greater than 1,0 are retained.

If $R_{\mathrm{sRGB}}, G_{\mathrm{sRGB}}, B_{\mathrm{sRGB}} < -0{,}003\ 130\ 8$

$$\begin{aligned} R'_{\mathrm{sRGB}} &= -1{,}055 \times (-R_{\mathrm{sRGB}})^{(1{,}0/2{,}4)} + 0{,}055 \\ G'_{\mathrm{sRGB}} &= -1{,}055 \times (-G_{\mathrm{sRGB}})^{(1{,}0/2{,}4)} + 0{,}055 \\ B'_{\mathrm{sRGB}} &= -1{,}055 \times (-B_{\mathrm{sRGB}})^{(1{,}0/2{,}4)} + 0{,}055 \end{aligned} \qquad \text{(F.9)}$$

If $-0{,}003\ 130\ 8 \le R_{\mathrm{sRGB}}, G_{\mathrm{sRGB}}, B_{\mathrm{sRGB}} \le 0{,}003\ 130\ 8$,

$$\begin{aligned} R'_{\mathrm{sRGB}} &= 12{,}92 \times R_{\mathrm{sRGB}} \\ G'_{\mathrm{sRGB}} &= 12{,}92 \times G_{\mathrm{sRGB}} \\ B'_{\mathrm{sRGB}} &= 12{,}92 \times B_{\mathrm{sRGB}} \end{aligned} \qquad \text{(F.10)}$$

If $R_{\text{sRGB}}, G_{\text{sRGB}}, B_{\text{sRGB}} > 0{,}003\ 130\ 8$,

$$\begin{aligned} R'_{\text{sRGB}} &= 1{,}055 \times (R_{\text{sRGB}})^{(1{,}0/2{,}4)} - 0{,}055 \\ G'_{\text{sRGB}} &= 1{,}055 \times (G_{\text{sRGB}})^{(1{,}0/2{,}4)} - 0{,}055 \\ B'_{\text{sRGB}} &= 1{,}055 \times (B_{\text{sRGB}})^{(1{,}0/2{,}4)} - 0{,}055 \end{aligned} \tag{F.11}$$

The relationship between non-linear sRGB and sYCC is defined as follows:

$$\begin{bmatrix} Y'_{\text{sYCC}} \\ Cb'_{\text{sYCC}} \\ Cr'_{\text{sYCC}} \end{bmatrix} = \begin{bmatrix} 0{,}299\ 0 & 0{,}587\ 0 & 0{,}114\ 0 \\ -0{,}168\ 7 & -0{,}331\ 3 & 0{,}500\ 0 \\ 0{,}500\ 0 & -0{,}418\ 7 & -0{,}081\ 3 \end{bmatrix} \begin{bmatrix} R'_{\text{sRGB}} \\ G'_{\text{sRGB}} \\ B'_{\text{sRGB}} \end{bmatrix} \tag{F.12}$$

NOTE The coefficients in equation F.12 are from ITU-R BT.601-5. The ITU-R BT.601-5 defines Y′ of YCC to the three decimal place accuracy. An additional decimal place is defined above to be consistent with the other matrix coefficients defined in this standard.

And quantization for sYCC is defined as;

$$\begin{aligned} Y_{\text{sYCC}} &= \text{round}\left[(WDC - KDC) \times Y'_{\text{sYCC}} + KDC\right] \\ Cb_{\text{sYCC}} &= \text{round}\left[(Range \times Cb'_{\text{sYCC}}) + Offset\right] \\ Cr_{\text{sYCC}} &= \text{round}\left[(Range \times Cr'_{\text{sYCC}}) + Offset\right] \end{aligned} \tag{F.13}$$

For 24-bit encoding (8-bit/channel), the relationship is defined as:

$$\begin{aligned} Y_{\text{sYCC}(8)} &= \text{round}\left[(255 - 0) \times Y'_{\text{sYCC}} + 0\right] = \text{round}\left[255 \times Y'_{\text{sYCC}}\right] \\ Cb_{\text{sYCC}(8)} &= \text{round}\left[(255 \times Cb'_{\text{sYCC}}) + 128\right] \\ Cr_{\text{sYCC}(8)} &= \text{round}\left[(255 \times Cr'_{\text{sYCC}}) + 128\right] \end{aligned} \tag{F.14}$$

For 24-bit encoding, the $\text{sYCC}_{(8)}$ values shall be limited to a range from 0 to 255 after equation F.14.

24-bit encoding (8-bit/channel) shall be the default sYCC encoding bit depth. Other bit depths may be unsupported in general use.

Where other N-bit/channel encoding is supported ($N > 8$), the relationship is defined as;

$$\begin{aligned} Y_{\text{sYCC}(N)} &= \text{round}\left[(2^N - 1) \times Y'_{\text{sYCC}}\right] \\ Cb_{\text{sYCC}(N)} &= \text{round}\left[\left((2^N - 1) \times Cb'_{\text{sYCC}}\right) + 2^{N-1}\right] \\ Cr_{\text{sYCC}(N)} &= \text{round}\left[\left((2^N - 1) \times Cr'_{\text{sYCC}}\right) + 2^{N-1}\right] \end{aligned} \tag{F.14′}$$

For N-bit/channel encoding ($N > 8$), the $\text{sYCC}_{(N)}$ values shall be limited to a range from 0 to 2^N–1 after equation F.14′.

F.4 Transformation from 8-bit sYCC values ($Y_{\text{sYCC}_{(8)}}$, $Cb_{\text{sYCC}_{(8)}}$, $Cr_{\text{sYCC}_{(8)}}$) to 8-bit sRGB values ($R_{\text{sRGB(8)}}$, $G_{\text{sRGB(8)}}$, $B_{\text{sRGB(8)}}$)

$$\begin{aligned} Y'_{\text{sYCC}} &= Y_{\text{sYCC}_{(8)}} / 255 \\ Cb'_{\text{sYCC}} &= \left(Cb_{\text{sYCC}_{(8)}} - 128\right) / 255 \\ Cr'_{\text{sYCC}} &= \left(Cr_{\text{sYCC}_{(8)}} - 128\right) / 255 \end{aligned} \qquad \text{(F.15)}$$

$$\begin{bmatrix} R'_{\text{sRGB}} \\ G'_{\text{sRGB}} \\ B'_{\text{sRGB}} \end{bmatrix} = \begin{bmatrix} 1{,}000\ 0 & 0{,}000\ 0 & 1{,}402\ 0 \\ 1{,}000\ 0 & -0{,}344\ 1 & -0{,}714\ 1 \\ 1{,}000\ 0 & 1{,}772\ 0 & 0{,}000\ 0 \end{bmatrix} \begin{bmatrix} Y'_{\text{sYCC}} \\ Cb'_{\text{sYCC}} \\ Cr'_{\text{sYCC}} \end{bmatrix} \qquad \text{(F.16)}$$

$$\begin{aligned} R_{\text{sRGB(8)}} &= \text{round}(255 \times R'_{\text{sRGB}}) \\ G_{\text{sRGB(8)}} &= \text{round}(255 \times G'_{\text{sRGB}}) \\ B_{\text{sRGB(8)}} &= \text{round}(255 \times B'_{\text{sRGB}}) \end{aligned} \qquad \text{(F.17)}$$

NOTE Since 8 bit sYCC values are not limited by the gamut of 8 bit sRGB values, some kind of mapping is needed for the colours that contains over-ranged non-linear floating point sR′G′B′ tristimulus values (under 0,0 or over 1,0), when converting 8 bit sYCC to 8 bit sRGB.

F.5 Transformation from 8-bit sRGB values ($R_{\text{sRGB(8)}}$, $G_{\text{sRGB(8)}}$, $B_{\text{sRGB(8)}}$) to 8-bit sYCC values ($Y_{\text{sYCC}_{(8)}}$, $Cb_{\text{sYCC}_{(8)}}$, $Cr_{\text{sYCC}_{(8)}}$)

$$\begin{aligned} R'_{\text{sRGB}} &= R_{\text{sRGB(8)}} / 255 \\ G'_{\text{sRGB}} &= G_{\text{sRGB(8)}} / 255 \\ B'_{\text{sRGB}} &= B_{\text{sRGB(8)}} / 255 \end{aligned} \qquad \text{(F.18)}$$

$$\begin{bmatrix} Y'_{\text{sYCC}} \\ Cb'_{\text{sYCC}} \\ Cr'_{\text{sYCC}} \end{bmatrix} = \begin{bmatrix} 0{,}299\ 0 & 0{,}587\ 0 & 0{,}114\ 0 \\ -0{,}168\ 7 & -0{,}331\ 3 & 0{,}500\ 0 \\ 0{,}500\ 0 & -0{,}418\ 7 & -0{,}081\ 3 \end{bmatrix} \begin{bmatrix} R'_{\text{sRGB}} \\ G'_{\text{sRGB}} \\ B'_{\text{sRGB}} \end{bmatrix} \qquad \text{(F.19)}$$

$$\begin{aligned} Y_{\text{sYCC}_{(8)}} &= \text{round}\left(255 \times Y'_{\text{sYCC}}\right) \\ Cb_{\text{sYCC}_{(8)}} &= \text{round}\left[\left(255 \times Cb'_{\text{sYCC}}\right) + 128\right] \\ Cr_{\text{sYCC}_{(8)}} &= \text{round}\left[\left(255 \times Cr'_{\text{sYCC}}\right) + 128\right] \end{aligned} \qquad \text{(F.20)}$$

Annex G
(informative)

Extended gamut encoding for sRGB: bg-sRGB and its YCC transformation: bg-sYCC

G.1 General

This annex provides equations necessary for extended gamut encoding for sRGB. While the main body of this standard imply that extended gamut encoding is possible by replacing the *KDC* and *WDC* variables in equations 2 and 11, no clear recommendation is given. This annex provides such specific recommendations, where for 10 bits, *KDC* = 384 and *WDC* = 894 ($KDC = 3\times 2^{(N-3)}$ and $WDC = 255\times 2^{(N-9)} + KDC$, for N bits where $N > 10$). This encoding is called bg-sRGB, and its YCC transformation is called bg-sYCC.

G.2 Transformation from bg-sRGB values ($R_{\text{bg-sRGB}}, G_{\text{bg-sRGB}}, B_{\text{bg-sRGB}}$) to CIE 1931 XYZ values

The non-linear floating point sR′G′B′ values can be computed using following relationship

$$
\begin{aligned}
R'_{\text{sRGB}} &= \left(R_{\text{bg-sRGB}} - KDC\right)/\left(WDC - KDC\right)\\
G'_{\text{sRGB}} &= \left(G_{\text{bg-sRGB}} - KDC\right)/\left(WDC - KDC\right)\\
B'_{\text{sRGB}} &= \left(B_{\text{bg-sRGB}} - KDC\right)/\left(WDC - KDC\right)
\end{aligned}
\tag{G.1}
$$

For 30-bit encoding (10-bit/channel), *WDC* = 894, *KDC* = 384, and the relationship is defined as;

$$
\begin{aligned}
R'_{\text{sRGB}} &= \frac{\left(R_{\text{bg-sRGB(10)}} - 384\right)}{510}\\
G'_{\text{sRGB}} &= \frac{\left(G_{\text{bg-sRGB(10)}} - 384\right)}{510}\\
B'_{\text{sRGB}} &= \frac{\left(B_{\text{bg-sRGB(10)}} - 384\right)}{510}
\end{aligned}
\tag{G.2}
$$

30-bit encoding (10-bit/channel) shall be the default bg-sRGB encoding bit depth. Other bit depths may be unsupported in general use.

Where other N-bit/channel encoding is supported ($N > 10$), the relationship is defined as;

$$
\begin{aligned}
R'_{\text{sRGB}} &= \frac{\left(R_{\text{bg-sRGB(N)}} - \left(3\times 2^{(N-3)}\right)\right)}{255\times 2^{(N-9)}}\\
G'_{\text{sRGB}} &= \frac{\left(G_{\text{bg-sRGB(N)}} - \left(3\times 2^{(N-3)}\right)\right)}{255\times 2^{(N-9)}}\\
B'_{\text{sRGB}} &= \frac{\left(B_{\text{bg-sRGB(N0)}} - \left(3\times 2^{(N-3)}\right)\right)}{255\times 2^{(N-9)}}
\end{aligned}
\tag{G.2'}
$$

The non-linear sR′G′B′ values are then transformed to CIE 1931 XYZ values as follows:

If $R'_{\text{sRGB}}, G'_{\text{sRGB}}, B'_{\text{sRGB}} < -0{,}040\ 45$

$$R_{\text{sRGB}} = -\left[\left(-R'_{\text{sRGB}} + 0{,}055\right)\big/1{,}055\right]^{2{,}4}$$
$$G_{\text{sRGB}} = -\left[\left(-G'_{\text{sRGB}} + 0{,}055\right)\big/1{,}055\right]^{2{,}4} \qquad \text{(G.3)}$$
$$B_{\text{sRGB}} = -\left[\left(-B'_{\text{sRGB}} + 0{,}055\right)\big/1{,}055\right]^{2{,}4}$$

If $-0{,}040\ 45 \le R'_{\text{sRGB}}, G'_{\text{sRGB}}, B'_{\text{sRGB}} \le 0{,}040\ 45$,

$$R_{\text{sRGB}} = R'_{\text{sRGB}} \div 12{,}92$$
$$G_{\text{sRGB}} = G'_{\text{sRGB}} \div 12{,}92 \qquad \text{(G.4)}$$
$$B_{\text{sRGB}} = B'_{\text{sRGB}} \div 12{,}92$$

If $R'_{\text{sRGB}}, G'_{\text{sRGB}}, B'_{\text{sRGB}} > 0{,}040\ 45$,

$$R_{\text{sRGB}} = \left[\left(R'_{\text{sRGB}} + 0{,}055\right)\big/1{,}055\right]^{2{,}4}$$
$$G_{\text{sRGB}} = \left[\left(G'_{\text{sRGB}} + 0{,}055\right)\big/1{,}055\right]^{2{,}4} \qquad \text{(G.5)}$$
$$B_{\text{sRGB}} = \left[\left(B'_{\text{sRGB}} + 0{,}055\right)\big/1{,}055\right]^{2{,}4}$$

For 24-bit encoding (8-bit/channel), the linear sRGB values are transformed to CIE 1931 XYZ values as follows:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0{,}412\ 4 & 0{,}357\ 6 & 0{,}180\ 5 \\ 0{,}212\ 6 & 0{,}715\ 2 & 0{,}072\ 2 \\ 0{,}019\ 3 & 0{,}119\ 2 & 0{,}950\ 5 \end{bmatrix} \begin{bmatrix} R_{\text{sRGB}} \\ G_{\text{sRGB}} \\ B_{\text{sRGB}} \end{bmatrix} \qquad \text{(G.6)}$$

G.3 Transformation from CIE 1931 XYZ values to bg-sRGB values ($R_{\text{bg-sRGB}}, G_{\text{bg-sRGB}}, B_{\text{bg-sRGB}}$)

The CIE 1931 XYZ values can be transformed to non-linear sR′G′B′ values as follows

$$\begin{bmatrix} R_{\text{sRGB}} \\ G_{\text{sRGB}} \\ B_{\text{sRGB}} \end{bmatrix} = \begin{bmatrix} 3{,}240\ 6 & -1{,}537\ 2 & -0{,}498\ 6 \\ -0{,}968\ 9 & 1{,}875\ 8 & 0{,}041\ 5 \\ 0{,}055\ 7 & -0{,}204\ 0 & 1{,}057\ 0 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \qquad \text{(G.7)}$$

For N-bit/channel encoding ($N > 10$), it is recommended to replace the matrix coefficients in the equation G.7 with the coefficients of the inverse matrix of the equation G.6 with enough accuracy decimal points. For example, following matrix with 7 decimal points has enough accuracy for the case of 16-bit/channel.

$$\begin{bmatrix} R_{\text{sRGB}} \\ G_{\text{sRGB}} \\ B_{\text{sRGB}} \end{bmatrix} = \begin{bmatrix} 3{,}240\,625\,5 & -1{,}537\,208\,0 & -0{,}498\,628\,6 \\ -0{,}968\,930\,7 & 1{,}875\,756\,1 & 0{,}041\,517\,5 \\ 0{,}055\,710\,1 & -0{,}204\,021\,1 & 1{,}056\,995\,9 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \qquad \text{(G.7′)}$$

In the bg-sRGB encoding process, negative sRGB tristimulus values, and sRGB tristimulus values greater than 1,0 are retained.

If $R_{\text{sRGB}}, G_{\text{sRGB}}, B_{\text{sRGB}} < -0{,}003130\,8$

$$\begin{aligned} R'_{\text{sRGB}} &= -1{,}055 \times (-R_{\text{sRGB}})^{(1{,}0/2{,}4)} + 0{,}055 \\ G'_{\text{sRGB}} &= -1{,}055 \times (-G_{\text{sRGB}})^{(1{,}0/2{,}4)} + 0{,}055 \\ B'_{\text{sRGB}} &= -1{,}055 \times (-B_{\text{sRGB}})^{(1{,}0/2{,}4)} + 0{,}055 \end{aligned} \qquad \text{(G.8)}$$

If $-0{,}003130\,8 \le R_{\text{sRGB}}, G_{\text{sRGB}}, B_{\text{sRGB}} \le 0{,}003130\,8$,

$$\begin{aligned} R'_{\text{sRGB}} &= 12{,}92 \times R_{\text{sRGB}} \\ G'_{\text{sRGB}} &= 12{,}92 \times G_{\text{sRGB}} \\ B'_{\text{sRGB}} &= 12{,}92 \times B_{\text{sRGB}} \end{aligned} \qquad \text{(G.9)}$$

If $R_{\text{sRGB}}, G_{\text{sRGB}}, B_{\text{sRGB}} > 0{,}003130\,8$,

$$\begin{aligned} R'_{\text{sRGB}} &= 1{,}055 \times (R_{\text{sRGB}})^{(1{,}0/2{,}4)} - 0{,}055 \\ G'_{\text{sRGB}} &= 1{,}055 \times (G_{\text{sRGB}})^{(1{,}0/2{,}4)} - 0{,}055 \\ B'_{\text{sRGB}} &= 1{,}055 \times (B_{\text{sRGB}})^{(1{,}0/2{,}4)} - 0{,}055 \end{aligned} \qquad \text{(G.10)}$$

Quantization for bg-sRGB is defined as;

$$\begin{aligned} R_{\text{bg-sRGB}} &= \text{round}[(WDC - KDC) \times R'_{\text{sRGB}} + KDC] \\ G_{\text{bg-sRGB}} &= \text{round}[(WDC - KDC) \times G'_{\text{sRGB}} + KDC] \\ B_{\text{bg-sRGB}} &= \text{round}[(WDC - KDC) \times B'_{\text{sRGB}} + KDC] \end{aligned} \qquad \text{(G.11)}$$

For 30-bit encoding (10-bit/channel), WDC = 894, KDC = 384, and the relationship is defined as;

$$\begin{aligned} R_{\text{bg-sRGB(10)}} &= \text{round}(R'_{\text{sRGB}} \times 510 + 384) \\ G_{\text{bg-sRGB(10)}} &= \text{round}(G'_{\text{sRGB}} \times 510 + 384) \\ B_{\text{bg-sRGB(10)}} &= \text{round}(B'_{\text{sRGB}} \times 510 + 384) \end{aligned} \qquad \text{(G.12)}$$

For 30-bit encoding, the bg-sRGB$_{(10)}$ values shall be limited to a range from 0 to 1023 after equation G.12.

30-bit encoding (10-bit/channel) shall be the default bg-sRGB encoding bit depth. Other bit depths may be unsupported in general use.

Where other N-bit/channel encoding is supported ($N > 10$), the relationship is defined as;

$$\begin{aligned} R_{\text{bg-sRGB(N)}} &= \text{round}\left[R'_{\text{sRGB}} \times \left(255 \times 2^{(N-9)}\right) + \left(3 \times 2^{(N-3)}\right)\right] \\ G_{\text{bg-sRGB(N)}} &= \text{round}\left[G'_{\text{sRGB}} \times \left(255 \times 2^{(N-9)}\right) + \left(3 \times 2^{(N-3)}\right)\right] \\ B_{\text{bg-sRGB(N)}} &= \text{round}\left[B'_{\text{sRGB}} \times \left(255 \times 2^{(N-9)}\right) + \left(3 \times 2^{(N-3)}\right)\right] \end{aligned} \quad \text{(G.12′)}$$

For N-bit/channel encoding ($N > 10$), the bg-sRGB$_{(N)}$ values shall be limited to a range from 0 to $2^N - 1$ after equation G.12′.

G.4 Transformation between sRGB 8-bit values ($R_{\text{sRGB(8)}}, G_{\text{sRGB(8)}}, B_{\text{sRGB(8)}}$) and bg-sRGB 10-bit values($R_{\text{bg-sRGB(10)}}, G_{\text{bg-sRGB(10)}}, B_{\text{bg-sRGB(10)}}$)

The transformation between sRGB 8-bit values and bg-sRGB 10-bit values can be computed using following relationship

$$\begin{aligned} R_{\text{bg-sRGB(10)}} &= \left(R_{\text{sRGB(8)}} \times 2\right) + 384 \\ G_{\text{bg-sRGB(10)}} &= \left(G_{\text{sRGB(8)}} \times 2\right) + 384 \\ B_{\text{bg-sRGB(10)}} &= \left(B_{\text{sRGB(8)}} \times 2\right) + 384 \end{aligned} \quad \text{(G.13)}$$

$$\begin{aligned} R_{\text{sRGB(8)}} &= \text{round}\left[\left(R_{\text{bg-sRGB(10)}} - 384\right) \div 2\right] \\ G_{\text{sRGB(8)}} &= \text{round}\left[\left(G_{\text{bg-sRGB(10)}} - 384\right) \div 2\right] \\ B_{\text{sRGB(8)}} &= \text{round}\left[\left(B_{\text{bg-sRGB(10)}} - 384\right) \div 2\right] \end{aligned} \quad \text{(G.14)}$$

After equation G.14, the sRGB$_{(8)}$ values shall be limited to a range from 0 to 255.

For the case of N bit encoding;

$$\begin{aligned} R_{\text{bg-sRGB(N)}} &= \left(R_{\text{sRGB(8)}} \times 2^{N-9}\right) + \left(3 \times 2^{(N-3)}\right) \\ G_{\text{bg-sRGB(N)}} &= \left(G_{\text{sRGB(8)}} \times 2^{N-9}\right) + \left(3 \times 2^{(N-3)}\right) \\ B_{\text{bg-sRGB(N)}} &= \left(B_{\text{sRGB(8)}} \times 2^{N-9}\right) + \left(3 \times 2^{(N-3)}\right) \end{aligned} \quad \text{(G.13′)}$$

$$\begin{aligned} R_{\text{sRGB(8)}} &= \text{round}\left[\left(R_{\text{bg-sRGB(N)}} - \left(3 \times 2^{(N-3)}\right)\right) \div 2^{N-9}\right] \\ G_{\text{sRGB(8)}} &= \text{round}\left[\left(G_{\text{bg-sRGB(N)}} - \left(3 \times 2^{(N-3)}\right)\right) \div 2^{N-9}\right] \\ B_{\text{sRGB(8)}} &= \text{round}\left[\left(B_{\text{bg-sRGB(N)}} - \left(3 \times 2^{(N-3)}\right)\right) \div 2^{N-9}\right] \end{aligned} \quad \text{(G.14′)}$$

After equation G.14′, the sRGB$_{(8)}$ values is limited to a range from 0 to 2^N–1.

G.5 Transformation from bg-sYCC values ($R_{\text{bg-sRGB}}, G_{\text{bg-sRGB}}, B_{\text{bg-sRGB}}$) to CIE 1931 *XYZ* values

The non-linear floating point sY′C′$_b$C′$_r$ values can be computed using following relationship

$$
\begin{aligned}
Y'_{\text{sYCC}} &= \left(Y_{\text{bg-sYCC}} - KDC\right) / \left(WDC - KDC\right) \\
Cb'_{\text{sYCC}} &= \left(Cb_{\text{bg-sYCC}} - Offset\right) / Range \\
Cr'_{\text{sYCC}} &= \left(Cr_{\text{bg-sYCC}} - Offset\right) / Range
\end{aligned}
\tag{G.15}
$$

For 30-bit encoding (10-bit/channel), WDC = 1023, KDC = 0, *Range* = 1023/2, *Offset* = 512, and the relationship is defined as;

$$
\begin{aligned}
Y'_{\text{sYCC}} &= \frac{Y_{\text{bg-sYCC(10)}}}{1023} \\
Cb'_{\text{sYCC}} &= \frac{Cb_{\text{bg-sYCC(10)}} - 512}{511{,}5} \\
Cr'_{\text{sYCC}} &= \frac{Cr_{\text{bg-sYCC(10)}} - 512}{511{,}5}
\end{aligned}
\tag{G.16}
$$

30-bit encoding (10-bit/channel) shall be the default bg-sYCC encoding bit depth. Other bit depths may be unsupported in general use.

Where other N-bit/channel encoding is supported ($N > 10$), the relationship is defined as;

$$
\begin{aligned}
Y'_{\text{sYCC}} &= \frac{Y_{\text{bg-sYCC(N)}}}{\left(2^N - 1\right)} \\
Cb'_{\text{sYCC}} &= \frac{Cb_{\text{bg-sYCC(N)}} - 2^{N-1}}{\left(2^N - 1\right)/2} \\
Cr'_{\text{sYCC}} &= \frac{Cr_{\text{bg-sYCC(N)}} - 2^{N-1}}{\left(2^N - 1\right)/2}
\end{aligned}
\tag{G.16′}
$$

For 30-bit encoding (10-bit/channel), the non-linear sY′C′$_b$C′$_r$ values are then transformed to the non-linear sR′G′B′ values as follows,

$$
\begin{bmatrix} R'_{\text{sRGB}} \\ G'_{\text{sRGB}} \\ B'_{\text{sRGB}} \end{bmatrix}
=
\begin{bmatrix} 1{,}000\,0 & 0{,}000\,0 & 1{,}402\,0 \\ 1{,}000\,0 & -0{,}344\,1 & -0{,}714\,1 \\ 1{,}000\,0 & 1{,}772\,0 & 0{,}000\,0 \end{bmatrix}
\begin{bmatrix} Y'_{\text{sYCC}} \\ Cb'_{\text{sYCC}} \\ Cr'_{\text{sYCC}} \end{bmatrix}
\tag{G.17}
$$

For N-bit/channel encoding ($N > 10$), it is recommended to replace the matrix coefficients in the equation G.17 with the coefficients of the inverse matrix of the equation G.18 with enough accuracy decimal points. For example, following matrix with 6 decimal points has enough accuracy for the case of 16-bit/channel.

$$\begin{bmatrix} R'_{\text{sRGB}} \\ G'_{\text{sRGB}} \\ B'_{\text{sRGB}} \end{bmatrix} = \begin{bmatrix} 1{,}000\ 000 & 0{,}000\ 037 & 1{,}401\ 988 \\ 1{,}000\ 000 & -0{,}344\ 113 & -0{,}714\ 104 \\ 1{,}000\ 000 & 1{,}771\ 978 & 0{,}000\ 135 \end{bmatrix} \begin{bmatrix} Y'_{\text{sYCC}} \\ Cb'_{\text{sYCC}} \\ Cr'_{\text{sYCC}} \end{bmatrix} \qquad \text{(G.17')}$$

The non-linear sR′G′B′ values are then transformed to CIE 1931 XYZ values using G.3, G.4, G.5, and G.6

G.6 Transformation from CIE 1931 XYZ values to bg-sYCC values ($Y_{\text{bg-sYCC}}, Cb_{\text{bg-sYCC}}, Cr_{\text{bg-sYCC}}$)

Transformation from CIE 1931 XYZ values to the non-linear sR′G′B′ values are defined in G.7 (or G.7′), G.8, G.9, and G.10.

The relationship between non-linear sR′G′B′ and sY′C′$_b$C′$_r$ is defined as follows:

$$\begin{bmatrix} Y'_{\text{sYCC}} \\ Cb'_{\text{sYCC}} \\ Cr'_{\text{sYCC}} \end{bmatrix} = \begin{bmatrix} 0{,}299\ 0 & 0{,}587\ 0 & 0{,}114\ 0 \\ -0{,}168\ 7 & -0{,}331\ 3 & 0{,}500\ 0 \\ 0{,}500\ 0 & -0{,}418\ 7 & -0{,}081\ 3 \end{bmatrix} \begin{bmatrix} R'_{\text{sRGB}} \\ G'_{\text{sRGB}} \\ B'_{\text{sRGB}} \end{bmatrix} \qquad \text{(G.18)}$$

NOTE The coefficients in equation F.18 are from ITU-R BT.601-5. The ITU-R BT.601-5 defines Y of YCC to the three decimal place accuracy. An additional decimal place is defined above to be consistent with the other matrix coefficients defined in this standard.

Quantization for bg-sYCC is defined as;

$$\begin{aligned} Y_{\text{bg-sYCC}} &= \text{round}\left[(WDC - KDC) \times Y'_{\text{sYCC}} + KDC\right] \\ Cb_{\text{bg-sYCC}} &= \text{round}\left[(Range \times Cb'_{\text{sYCC}}) + Offset\right] \\ Cr_{\text{bg-sYCC}} &= \text{round}\left[(Range \times Cr'_{\text{sYCC}}) + Offset\right] \end{aligned} \qquad \text{(G.19)}$$

For 30-bit encoding (10-bit/channel), WDC = 1023, KDC = 0, *Range* = 1023/2, *Offset* = 512, and the relationship is defined as;

$$\begin{aligned} Y_{\text{bg-sYCC(10)}} &= \text{round}(1023 \times Y'_{\text{sYCC}}) \\ Cb_{\text{bg-sYCC(10)}} &= \text{round}\left(\frac{1023 \times Cb'_{\text{sYCC}}}{2} + 512\right) \\ Cr_{\text{bg-sYCC(10)}} &= \text{round}\left(\frac{1023 \times Cr'_{\text{sYCC}}}{2} + 512\right) \end{aligned} \qquad \text{(G. 20)}$$

For 30-bit encoding, the bg-sYCC$_{(10)}$ values shall be limited to a range from 0 to 1023 after equation G.20.

30-bit encoding (10-bit/channel) shall be the default bg-sYCC encoding bit depth. Other bit depths may be unsupported in general use.

Where other N-bit/channel encoding is supported ($N > 10$), the relationship is defined as;

$$Y_{\text{bg-sYCC(N)}} = \text{round}\left[\left(2^{N}-1\right)\times Y'_{\text{sYCC}}\right]$$

$$Cb_{\text{bg-sYCC(N)}} = \text{round}\left(\frac{\left(2^{N}-1\right)\times Cb'_{\text{sYCC}}}{2}+2^{N-1}\right) \quad \text{(G.20')}$$

$$Cr_{\text{bg-sYCC(N)}} = \text{round}\left(\frac{\left(2^{N}-1\right)\times Cr'_{\text{sYCC}}}{2}+2^{N-1}\right)$$

For N-bit/channel encoding ($N > 10$), the bg-sYCC$_{(N)}$ values shall be limited to a range from 0 to 2^N–1 after equation G.20'.

The maximum luminance of the achromatic axis of bg-sYCC is equal to 1,0. The minimum luminance of the achromatic axis of bg-sYCC is equal to 0,0.

NOTE The denominator "2" for Cb and Cr is for covering all optimal colour range. See pp.179 - 181 of [16]

G.7 Transformation from bg-sRGB ($R_{\text{bg-sRGB}}, G_{\text{bg-sRGB}}, B_{\text{bg-sRGB}}$) to bg-sYCC values ($Y_{\text{bg-sYCC}}, Cb_{\text{bg-sYCC}}, Cr_{\text{bg-sYCC}}$)

The transformation from bg-sRGB 10-bit values to bg-sYCC 10-bit values can be computed using the equations, G.2, G.18 and G.20. For the case of N bit encoding, equations, G.2′, G.18 and G.20′ should be used.

G.8 Transformation from bg-sYCC ($Y_{\text{bg-sYCC}}, Cb_{\text{bg-sYCC}}, Cr_{\text{bg-sYCC}}$) to bg-sRGB values ($R_{\text{bg-sRGB}}, G_{\text{bg-sRGB}}, B_{\text{bg-sRGB}}$)

The transformation from bg-sYCC 10-bit values and bg-sRGB 10-bit values can be computed using the equations, G.16, G.17 and G.12. For the case of N bit encoding, equations, G.16′, G.17 and G.12′ should be used.

Annex H
(informative)

CIELAB (L*a*b*) transformation

H.1 General

The following equations describe the relation between sRGB and L*a*b* coordinates according to CIE 15.2:1986. It should be noted that the degree of non-linearity is different from the non-linear relation between components R'_{sRGB} and R_{sRGB}, B'_{sRGB} and B_{sRGB} and G'_{sRGB} and G_{sRGB}.

H.2 Transformation from sRGB into CIELAB (L*a*b*) coordinates

Use equation (7) in 5.2 to determine XYZ coordinates from R_{sRGBg}, G_{sRGB}, B_{sRGB} and calculate L*a*b* coordinates according to:

$$\begin{aligned} L^* &= 116\ f(Y/Yn) - 16 \text{ if } Y/Yn > 0{,}008856 \\ L^* &= 903.3 * (Y/Yn) \text{ if } Y/Yn <= 0.008856 \\ a^* &= 500\ [\ f(X/X_\mathrm{n}) - f(Y/Y_n)\ ] \\ b^* &= 200\ [\ f(Y/Y_\mathrm{n}) - f(Z/Z_\mathrm{n})\ ] \end{aligned} \qquad \text{(H.1)}$$

where

$f(Y/Y_\mathrm{n}) = (Y/Y_\mathrm{n})^{1/3}$ if $Y/Y_\mathrm{n} > 0{,}008856$

$f(Y/Y_\mathrm{n}) = 7{,}787\ (Y/Y_\mathrm{n}) + 16/116$ if $Y/Y_\mathrm{n} \le 0{,}008856$

$f(X/X_\mathrm{n}) = (X/X_\mathrm{n})^{1/3}$ if $X/X_\mathrm{n} > 0{,}008856$

$f(X/X_\mathrm{n}) = 7{,}787\ (X/X_\mathrm{n}) + 16/116$ if $X/X_\mathrm{n} \le 0{,}008856$

$f(Z/Z_\mathrm{n}) = (Z/Z_\mathrm{n})^{1/3}$ if $Z/Z_\mathrm{n} > 0{,}008856$

$f(Z/Z_\mathrm{n}) = 7{,}787\ (Z/Z_\mathrm{n}) + 16/116$ if $Z/Z_\mathrm{n} \le 0{,}008856$

and X_n, Y_n, Z_n are the reference display white point coordinates of illuminant D65 (4.1) with

$X_\mathrm{n} = 0{,}9505$

$Y_\mathrm{n} = 1{,}0000$

$Z_\mathrm{n} = 1{,}0890$

H.3 Transformation from CIELAB (L*a*b*) coordinates to R_{sRGBg}, G_{sRGB}, B_{sRGB}

Determine:

$$f(Y/Yn) = (L^* + 16) / 116$$
$$f(X/X_n) = a^* / 500 + f(Y/Y_n) \quad \text{(H.2)}$$
$$f(Z/Z_n) = f(Y/Y_n) - b^* / 200$$

Calculate XYZ from:

$$X = X_n [f(X/X_n)]^3 \quad \text{if } f(X/X_n) > 0{,}206893 \text{ or } L^* > 7{,}99959$$
$$X = X_n [f(X/X_n) - 16/116] / 7{,}787 \quad \text{if } f(X/X_n) \leq 0{,}206893 \text{ or } L^* \leq 7{,}99959$$
$$Y = Y_n [f(Y/Y_n)]^3 \quad \text{if } f(Y/Y_n) > 0{,}206893 \quad \text{(H.3)}$$
$$Y = Y_n [f(Y/Y_n) - 16/116] / 7{,}787 \quad \text{if } f(Y/Y_n) \leq 0{,}206893$$
$$Z = Z_n [f(Z/Z_n)]^3 \quad \text{if } f(Z/Z_n) > 0{,}206893$$
$$Z = Z_n [f(Z/Z_n) - 16/116] / 7{,}787 \quad \text{if } f(Z/Z_n) \leq 0{,}206893$$

XYZ coordinates are converted to $R_{sRGBg,}$ G_{sRGB}, B_{sRGB} using equation (9) in 5.3.

Page 51

Bibliography

Add the following references to the existing list:

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