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Multimedia systems and equipment – Colour measurement and management – Part 2-4: Colour management – Extended-gamut YCC colour space for video applications – xvYCC

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Multimedia systems and equipment – Colour measurement and management – Part 2-4: Colour management – Extended-gamut YCC colour space for video applications – xvYCC

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MULTIMEDIA SYSTEMS AND EQUIPMENT – COLOUR MEASUREMENT AND MANAGEMENT –

Part 2-4: Colour management – Extended-gamut YCC colour space for video applications – xvYCC

FOREWORD

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IEC 61966-2-4 edition 1.2 contains the first edition (2006-01) [documents 100/967/CDV and 100/1026/RVC] and its corrigendum 1 (2006-11), its amendment 1 (2016-04) [documents 100/2457A/CDV and 100/2601/RVC] and its amendment 2 (2021-07) [documents 100/3535/CDV and 100/3597/RVC].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendments 1 and 2. Additions and deletions are displayed in red, with deletions being struck through. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 61966-2-4 has been prepared by IEC technical committee 100: Audio, video and multimedia systems and equipment.

The French version of this standard has not been voted upon.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

IEC 61966 consists of the following parts, under the general title *Multimedia systems and equipment – Colour measurement and management:*

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

Part 2-2: Colour management – Extended RGB colour space – scRGB

Part 2-4: Colour management – Extended-gamut YCC colour space for video applications – xvYCC

Part 2-5: Colour management – Optional RGB colour space – opRGB ~~(under consideration)~~

Part 3: Equipment using cathode ray tubes

Part 4: Equipment using liquid crystal display panels

Part 5: Equipment using plasma display panels

Part 6: Front projection displays

Part 7-1: Colour printers – Reflective prints – RGB inputs

~~Part 7-2: Colour printers – Reflective prints – CMYK inputs (proposed work item)~~

Part 8: Multimedia colour scanners

Part 9: Digital cameras

~~Part 10: Quality assessment (proposed work item)~~

~~Part 11: Quality assessment – Impaired video in network systems (proposed work item)~~

Part 12-1: Metadata for identification of colour gamut (Gamut ID)

Part 12-2: Simple Metadata format for identification of colour gamut

The committee has decided that the contents of the base publication and its amendments will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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INTRODUCTION

After the publication of IEC 61966-2-1, Amendment 1, the sYCC colour encoding was used to capture, store and print extended colour gamut for still image applications. Users received pleasant benefit by exchanging and reproducing wide-gamut colour images.

Recently, various kinds of displays that are capable of producing a wider gamut of colour than the conventional CRT-based displays are emerging. However, most of the current video contents that are displayed on conventional displays, are rendered for the sRGB-gamut. Users of wide-gamut displays could benefit from wide-gamut colour images by video colour encoding that supports a larger colour gamut.

This standard defines the "extended-gamut YCC colour space for video applications". It is based on the current implementation of YCC colour encoding that is used in the video industry (namely ITU-R BT.709-5) and extends its definition to the wider gamut of colour range.

MULTIMEDIA SYSTEMS AND EQUIPMENT – COLOUR MEASUREMENT AND MANAGEMENT –

Part 2-4: Colour management – Extended-gamut YCC colour space for video applications – xvYCC

1 Scope

This part of IEC 61966 is applicable to the encoding and communication of YCC colours used in video systems and similar applications by defining encoding transformations for use in defined reference capturing conditions. If actual conditions differ from the reference conditions, additional rendering transformations may be required. Such additional rendering transformations are beyond the scope of this standard.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-845:1987, *International Electrotechnical Vocabulary (IEV) – Part 845: Lighting*

ITU-R Recommendation BT.601-5:1995, *Studio encoding parameters of digital television for standard 4:3 and wide-screen 16:9 aspect ratios*

ITU-R Recommendation BT.709-5:2002, *Parameter values for the HDTV standards for production and international programme exchange*

3 Terms and definitions

For the purposes of this document, the following terms and definitions, as well as those concerning illuminance, luminance, tristimulus, and other related lighting terms given in IEC 60050-845, apply.

3.1
scene-referred colour encoding
representation of estimated colour-space coordinates of the elements of an original scene, where a scene is defined to be the relative spectral radiance

3.2
output-referred colour encoding
representation of estimated colour-space coordinates of image data that are appropriate for specified output device and viewing conditions

3.3
extended gamut
colour gamut extending outside that of the standard sRGB CRT display defined in IEC 61966-2-1

3.4
luma
luminance signal as defined by SMPTE/EG28:1993

NOTE 1 To avoid interdisciplinary confusion resulting from the two distinct definitions of luminance, it has been proposed that the video documents use “luma” for “luminance, television” (i.e., the luminance signal).

NOTE 2 Video systems approximate the lightness response of vision by computing a luma component Y' as a weighted sum of non-linear (or gamma-corrected) R'G'B' primary components. Luma is often carelessly referred to as luminance.

4 Colorimetric parameters and related characteristics

This clause defines colorimetric parameters and the related characteristics of reference capturing devices.

4.1 Primary colours and reference white

The CIE chromaticities for the reference red, green, and blue primary colours, and for reference white CIE standard illuminant D65, are given in Table 1. These primaries and white point values are identical to those of ITU-R BT.709-5.

Table 1 – CIE chromaticities for reference primary colours and reference white

	Red	Green	Blue	White/D65
x	0,640 0	0,300 0	0,150 0	0,312 7
y	0,330 0	0,600 0	0,060 0	0,329 0
z	0,030 0	0,100 0	0,790 0	0,358 3

4.2 Opto-electronic transfer characteristics

Opto-electronic transfer characteristics are defined as follows.

If $R,G,B \le -0{,}018$,

$$\begin{aligned} R' &= -1{,}099 \times (-R)^{0{,}45} + 0{,}099 \\ G' &= -1{,}099 \times (-G)^{0{,}45} + 0{,}099 \\ B' &= -1{,}099 \times (-B)^{0{,}45} + 0{,}099 \end{aligned} \qquad (1)$$

If $-0{,}018 < R,G,B < 0{,}018$,

$$\begin{aligned} R' &= 4{,}50 \times R \\ G' &= 4{,}50 \times G \\ B' &= 4{,}50 \times B \end{aligned} \qquad (2)$$

If $R,G,B \ge 0{,}018$,

$$\begin{aligned} R' &= 1{,}099 \times (R)^{0{,}45} - 0{,}099 \\ G' &= 1{,}099 \times (G)^{0{,}45} - 0{,}099 \\ B' &= 1{,}099 \times (B)^{0{,}45} - 0{,}099 \end{aligned} \qquad (3)$$

where R, G, B is a voltage normalized by reference white level and proportional to the implicit light intensity that would be detected with a reference camera colour channel; R', G', B' is the resulting non-linear primary signal.

4.3 YCC (luma-chroma-chroma) encoding methods

The encoding equations from the primary RGB (red-green-blue) signal: R', G', B' to the YCC (luma-chroma-chroma) signal: Y', Cb', Cr' is defined by the following two methods. It is important to follow one of the encodings in the specified application.

$xvYCC_{601}$, which is implemented mainly in the SDTV (standard-definition television) applications as defined in ITU-R BT. 601-5, is defined as follows:

$$\begin{bmatrix} Y'_{601} \\ Cb'_{601} \\ Cr'_{601} \end{bmatrix} = \begin{bmatrix} 0{,}299\,0 & 0{,}587\,0 & 0{,}114\,0 \\ -0{,}168\,7 & -0{,}331\,3 & 0{,}500\,0 \\ 0{,}500\,0 & -0{,}418\,7 & -0{,}081\,3 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} \tag{4}$$

NOTE The coefficients in equation (4) are from ITU-R BT.601-5 which 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.

$xvYCC_{709}$, which is implemented mainly in the HDTV (high-definition television) applications as defined in ITU-R BT. 709-5, is defined as follows:

$$\begin{bmatrix} Y'_{709} \\ Cb'_{709} \\ Cr'_{709} \end{bmatrix} = \begin{bmatrix} 0{,}212\,6 & 0{,}715\,2 & 0{,}072\,2 \\ -0{,}114\,6 & -0{,}385\,4 & 0{,}500\,0 \\ 0{,}500\,0 & -0{,}454\,2 & -0{,}045\,8 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} \tag{5}$$

4.4 Digital quantization methods

Quantization of YCC (luma-chroma-chroma) signal: Y', Cb', Cr' is defined as follows.

For 8-bit representation:

$$\begin{aligned} Y_{\text{xvYCC(8)}} &= \text{round}\left[219 \times Y' + 16\right] \\ Cb_{\text{xvYCC(8)}} &= \text{round}\left[224 \times Cb' + 128\right] \\ Cr_{\text{xvYCC(8)}} &= \text{round}\left[224 \times Cr' + 128\right] \end{aligned} \tag{6}$$

For n-bit (n > 8) representation:

$$\begin{aligned} Y_{\text{xvYCC}(N)} &= \text{round}\left[(219 \times Y' + 16) \times 2^{n-8}\right] \\ Cb_{\text{xvYCC}(N)} &= \text{round}\left[(224 \times Cb' + 128) \times 2^{n-8}\right] \\ Cr_{\text{xvYCC}(N)} &= \text{round}\left[(224 \times Cr' + 128) \times 2^{n-8}\right] \end{aligned} \tag{7}$$

NOTE Bit levels “from 0 to 2^{N-8}-1” and “from 255 × 2^{N-8} to 2^{N}-1” (0 and 255, for the case of 8-bit encoding) are used exclusively for synchronization and are not allowed for storing colour values. Levels from “2^{N-8}” to “255 × 2^{N-8}-1” (from 1 to 254, for the case of 8-bit encoding) are available.

5 Encoding transformations

5.1 Introduction

The encoding transformations between xvYCC values and CIE 1931 XYZ values provide unambiguous methods to represent optimum image colorimetry of the captured scene. Scene colorimetry is defined as relative to the white objects, assuming that the exposure is properly controlled. It should be noted that dynamic range compression is needed when storing the wide dynamic range images (see Annex A for descriptions). Additionally, if the condition of the capturing device deviates from the ideal condition defined in Clause 4, operations such as colour compensation, colour correction and a certain degree of colour rendering can be performed. However, the methods for these operations are beyond the scope of this standard.

5.2 Transformation from xvYCC values to CIE 1931 XYZ values

For 24-bit encoding (8-bit/channel), the relationship between 8-bit values and Y', Cb', Cr' is defined as:

$$
\begin{aligned}
Y' &= \left(Y_{\mathrm{xvYCC(8)}} - 16\right)/219 \\
Cb' &= \left(Cb_{\mathrm{xvYCC(8)}} - 128\right)/224 \\
Cr' &= \left(Cr_{\mathrm{xvYCC(8)}} - 128\right)/224
\end{aligned}
\qquad (8)
$$

For N-bit/channel ($N > 8$) encoding, the relationship between N-bit values and Y', Cb', Cr' is defined as:

$$
\begin{aligned}
Y' &= \left(\frac{Y_{\mathrm{xvYCC}(N)}}{2^{N-8}} - 16\right)\Big/219 \\
Cb' &= \left(\frac{Cb_{\mathrm{xvYCC}(N)}}{2^{N-8}} - 128\right)\Big/224 \\
Cr' &= \left(\frac{Cr_{\mathrm{xvYCC}(N)}}{2^{N-8}} - 128\right)\Big/224
\end{aligned}
\qquad (9)
$$

For xvYCC$_{601}$ encoding, the non-linear Y', Cb', Cr' values are transformed to the non-linear R', G', B' values as follows:

$$
\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} =
\begin{bmatrix} 1{,}000\,0 & 0{,}000\,0 & 1{,}402\,0 \\ 1{,}000\,0 & -0{,}344\,1 & -0{,}714\,1 \\ 1{,}000\,0 & 1{,}772\,0 & 0{,}000\,0 \end{bmatrix}
\begin{bmatrix} Y'_{601} \\ Cb'_{601} \\ Cr'_{601} \end{bmatrix}
\qquad (10)
$$

NOTE The possible range for non-linear R'G'B'$_{(601)}$ calculated from, for example, equation (10) will be between -1,0732 and 2,0835.

For xvYCC$_{709}$ encoding, the non-linear Y', Cb', Cr' values are transformed to the non-linear R', G', B' values as follows:

$$
\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} =
\begin{bmatrix} 1{,}000\,0 & 0{,}000\,0 & 1{,}574\,8 \\ 1{,}000\,0 & -0{,}187\,3 & -0{,}468\,1 \\ 1{,}000\,0 & 1{,}855\,6 & 0{,}000\,0 \end{bmatrix}
\begin{bmatrix} Y'_{709} \\ Cb'_{709} \\ Cr'_{709} \end{bmatrix}
\qquad (11)
$$

NOTE The possible range for non-linear R'G'B'$_{(709)}$ calculated from, for example, equation (11) will be between -1,1206 and 2,1305.

The non-linear R',G',B' values are then transformed to linear R,G,B values as follows.

If $R',G',B' \le -0{,}081$

$$R = -\left(\frac{R' - 0{,}099}{-1{,}099}\right)^{\frac{1}{0{,}45}}$$
$$G = -\left(\frac{G' - 0{,}099}{-1{,}099}\right)^{\frac{1}{0{,}45}} \qquad (12)$$
$$B = -\left(\frac{B' - 0{,}099}{-1{,}099}\right)^{\frac{1}{0{,}45}}$$

If $-0{,}081 < R',G',B' < 0{,}081$

$$R = R'/4{,}50$$
$$G = G'/4{,}50 \qquad (13)$$
$$B = B'/4{,}50$$

If $R',G',B' \ge 0{,}081$

$$R = \left(\frac{R' + 0{,}099}{1{,}099}\right)^{\frac{1}{0{,}45}}$$
$$G = \left(\frac{G' + 0{,}099}{1{,}099}\right)^{\frac{1}{0{,}45}} \qquad (14)$$
$$B = \left(\frac{B' + 0{,}099}{1{,}099}\right)^{\frac{1}{0{,}45}}$$

The linear R,G,B values are transformed to CIE 1931 XYZ values as follows:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0{,}412\,4 & 0{,}357\,6 & 0{,}180\,5 \\ 0{,}212\,6 & 0{,}715\,2 & 0{,}072\,2 \\ 0{,}019\,3 & 0{,}119\,2 & 0{,}950\,5 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (15)$$

NOTE When the capturing device performs dynamic range compression of the brighter-than-white (for example, specular) components, the compressed colours will be displayed at the top-end range of the "reference" display as described in Annex C. In this case, the XYZ tristimulus values of the compressed components represent the colorimetry of the rendered scene, not the colorimetry of the original scene.

5.3 Transformation from CIE 1931 XYZ values to xvYCC values

The CIE 1931 XYZ values can be transformed to linear R,G,B values as follows:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 3{,}241\,0 & -1{,}537\,4 & -0{,}498\,6 \\ -0{,}969\,2 & 1{,}876\,0 & 0{,}041\,6 \\ 0{,}055\,6 & -0{,}204\,0 & 1{,}057\,0 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \qquad (16)$$

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

The linear R, G, B values are then transformed to non-linear R', G', B' values as follows.

If $R, G, B \leq -0{,}018$,

$$\begin{aligned} R' &= -1{,}099 \times (-R)^{0{,}45} + 0{,}099 \\ G' &= -1{,}099 \times (-G)^{0{,}45} + 0{,}099 \\ B' &= -1{,}099 \times (-B)^{0{,}45} + 0{,}099 \end{aligned} \tag{17}$$

If $-0{,}018 < R, G, B < 0{,}018$,

$$\begin{aligned} R' &= 4{,}50 \times R \\ G' &= 4{,}50 \times G \\ B' &= 4{,}50 \times B \end{aligned} \tag{18}$$

If $R, G, B \geq 0{,}018$,

$$\begin{aligned} R' &= 1{,}099 \times (R)^{0{,}45} - 0{,}099 \\ G' &= 1{,}099 \times (G)^{0{,}45} - 0{,}099 \\ B' &= 1{,}099 \times (B)^{0{,}45} - 0{,}099 \end{aligned} \tag{19}$$

The relationship between non-linear R', G', B' and xvYCC$_{601}$ is defined as follows:

$$\begin{bmatrix} Y'_{601} \\ Cb'_{601} \\ Cr'_{601} \end{bmatrix} = \begin{bmatrix} 0{,}299\ 0 & 0{,}587\ 0 & 0{,}114\ 0 \\ -0{,}168\ 7 & -0{,}331\ 3 & 0{,}500\ 0 \\ 0{,}500\ 0 & -0{,}418\ 7 & -0{,}081\ 3 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} \tag{20}$$

The relationship between non-linear R', G', B' and xvYCC$_{709}$ is defined as follows:

$$\begin{bmatrix} Y'_{709} \\ Cb'_{709} \\ Cr'_{709} \end{bmatrix} = \begin{bmatrix} 0{,}212\ 6 & 0{,}715\ 2 & 0{,}072\ 2 \\ -0{,}114\ 6 & -0{,}385\ 4 & 0{,}500\ 0 \\ 0{,}500\ 0 & -0{,}454\ 2 & -0{,}045\ 8 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} \tag{21}$$

NOTE If the capturing device is capable of storing Y' greater than 238/219 (or 1,086 758), dynamic range compression can be performed at this stage. Please refer to Annex A for the descriptions.

and quantization for xvYCC for 24-bit encoding (8-bit/channel) is defined as:

$$\begin{aligned} Y_{\text{xvYCC(8)}} &= \text{round}[219 \times Y' + 16] \\ Cb_{\text{xvYCC(8)}} &= \text{round}[224 \times Cb' + 128] \\ Cr_{\text{xvYCC(8)}} &= \text{round}[224 \times Cr' + 128] \end{aligned} \tag{22}$$

For 24-bit encoding, the xvYCC values shall be limited to a range from 1 to 254 according to equation (22).

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