

# INTERNATIONAL STANDARD



## AMENDMENT 2

**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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# INTERNATIONAL ELECTROTECHNICAL COMMISSION

## MULTIMEDIA SYSTEMS AND EQUIPMENT – COLOUR MEASUREMENT AND MANAGEMENT –

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

#### AMENDMENT 2

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Amendment 2 to IEC 61966-2-4:2006 has been prepared by technical area 2: Colour measurement and management, of IEC technical committee 100: Multimedia systems and equipment.

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

| Draft        | Report on voting |
|--------------|------------------|
| 100/3535/CDV | 100/3597/RVC     |

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

The language used for the development of this Amendment is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at [www.iec.ch/members\\_experts/refdocs](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/standardsdev/publications/](http://www.iec.ch/standardsdev/publications/).

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Add, after Annex D, the following new Annex E:

## Annex E (informative)

### xvYCCext – a method for encoding extended luminance signal

#### E.1 General

Recently, video standards for wide colour gamut and high dynamic range (HDR) colour space encoding, such as ITU-R BT.2020 (UHDTV) and ITU-R BT.2100 (HDR), were established. In contrast to the previous colour spaces, such as ITU-R BT.709 (high definition television) and IEC 61966-2-4 (xvYCC), it is a very demanding challenge for the display industry to realize wide colour gamut and/or high luminance displays. Therefore, recent mass produced displays for consumer electronics covered only a certain range of wide colour gamuts and high-luminance image contents.

To address this issue, the IEC standard xvYCC (IEC 61966-2-4) specified the extended wide colour gamut region in 2006. In addition, this annex specifies the extended high-luminance signal using the overhead region of xvYCC. This extended high-luminance region is able to encode and reproduce the high-luminance signal up to two times more than luminance of the reference white ( $R = G = B = 1$ ) of the standard dynamic range (SDR) (i.e. SDR-white).

As written in Annex A of this document, specular components can be recorded using a vendor-specific specular compression method for xvYCC signals. This Annex E describes a method of encoding an extended luminance signal, called xvYCCext. This coding can be used to exchange extended luminance signals. When both the encoder and the decoder use this same encoding method (xvYCCext), specular components will be recovered as defined.

#### E.2 Extended opto-electronic transfer characteristics

SDR range ( $R, G, B \leq 1$ ) of the opto-electronic transfer function (OETF) is already defined in Formulas (1) to (3). The expanded high-luminance signals are additionally encoded by the following Formulas (E.1) to (E.4), where  $R, G, B$  is the light linear signal that is normalized by reference white luminance, and  $R', G', B'$  is the resulting non-linear signal.

If  $t_1 (=1) \leq R, G, B \leq t_2 (=1,2)$ ,

$$\begin{aligned} R' &= d \cdot \ln(R - e) + f \\ G' &= d \cdot \ln(G - e) + f \\ B' &= d \cdot \ln(B - e) + f \end{aligned} \quad (\text{E.1})$$

NOTE  $\ln(\cdot)$  is the natural logarithm.

$$\text{with } \left\{ \begin{array}{l} \gamma(L_w) = a + b / L_w^c, \\ \text{with } a = 0,106535, b = -1,07359, c = 1,08025 \\ d = \frac{\gamma(L_w) \cdot t_2^{\gamma(L_w)} \cdot (t_2 - t_1)}{t_2 - 2,202204 \cdot \gamma(L_w) \cdot t_1^{0,55} \cdot t_2^{\gamma(L_w)}} = \frac{\gamma(L_w) \cdot (t_2 - 1)}{t_2^{1-\gamma(L_w)} - 2,202204 \cdot \gamma(L_w)} \text{ for } t_1 = 1 \\ e = 1 - 2,202204 \cdot d \\ f = 1,099 \cdot t_1^{0,45} - 0,099 - d \cdot \ln(t_1 - e) = 1 - d \cdot \ln(1 - e) \text{ for } t_1 = 1 \end{array} \right\} \quad (\text{E.2})$$

As a first step, the SDR-white luminance ( $L_w$  in  $\text{cd/m}^2$ ) dependent gamma values  $\gamma(L_w)$  will be determined using given constants ( $a, b$ , and  $c$ ) and a given  $L_w$ . Then, the further required values

( $d$ ,  $e$ , and  $f$ ) are determined by Formula (E.2). With these obtained values, the intermediate functions given in Formula (E.1) are calculated.

If  $R, G, B > t_2 (= 1,2)$ ,

$$\begin{aligned} R' &= O(L_w) + R^{\gamma(L_w)} \\ G' &= O(L_w) + G^{\gamma(L_w)} \end{aligned} \quad (E.3)$$

$$B' = O(L_w) + B^{\gamma(L_w)}$$

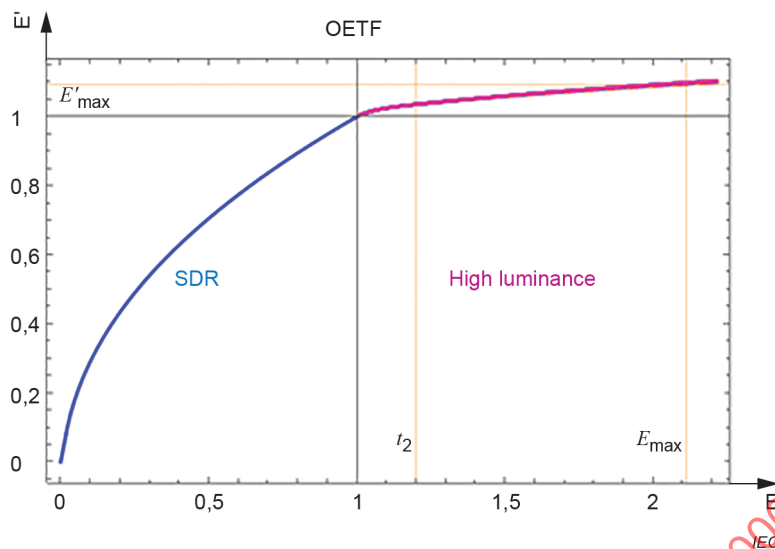
$$, \text{ with } O(L_w) = f - t_2^{\gamma(L_w)} + d \cdot \ln(t_2 - e) \quad (E.4)$$

Formula (E.3) is an approximation function in a certain luminance range of the PQ-OETF of ITU-R.BT.2100 and depends on a luminance of SDR-white ( $L_w$ ) and the offset  $O(L_w)$ .

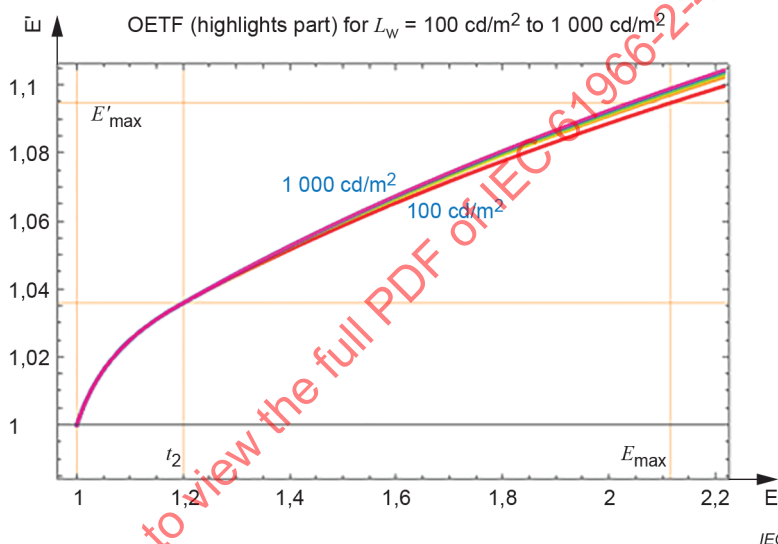
Figure E.1 shows an example of the high luminance region of xvYCCext. Over the reference white ( $E = 1$ ), the gamma function  $E^{\gamma(L_w)}$  is applied in order to include high-luminance colours such as specular and fluorescence, called "Super-white" [24].

NOTE  $E$  denotes linear  $R, G, B$  and  $E'$  denotes non-linear  $R', G', B'$ .

Formulas (E.1) and (E.3) are the approximation to OETF of ITU-R.BT.2100. The purpose of the first small region ( $1 < E < 1,2 (= t_2)$ ) described by the smoothing function (Formula (E.1)) is to maintain smooth transitions between SDR-OETF and the extended high-luminance OETF (Formula (E.3)). Formula (E.1) fulfils the same derivative values with the neighbour OETFs Formula (3) and Formula (E.3) at the boundaries  $E = 1$  and  $E = 1,2 (= t_2)$ .



a) Range for  $E = (0, 2, 2)$



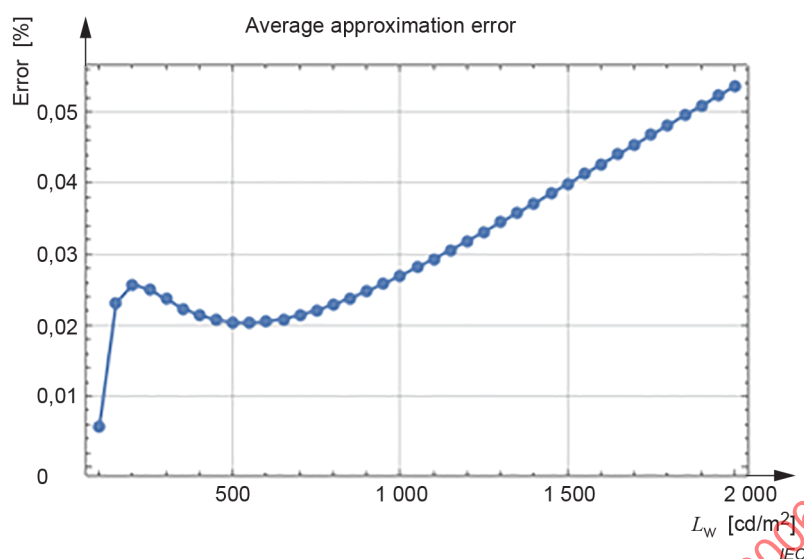
b) high luminance range for  $E = (1, 2, 2)$

**Figure E.1 – High luminance region of OETF for the variation of the reference white luminance from 100 cd/m<sup>2</sup> to 1 000 cd/m<sup>2</sup>**

In the display industry, the relative signal mapping is usual because white luminances of displays are individual. In contrast, PQ-OETF of ITU-R.BT.2100 is the function of the absolute luminance. With varying luminance of the reference white, the shape of OETF in the extended region ( $1 < E' \leq 1,09475$ ) for "Super-white" will be changed accordingly, where  $E' = 1,09475$  denotes a maximum non-linear signal of encoding, considering upper headroom of xvYCC for the full range of HDR-10bit system.

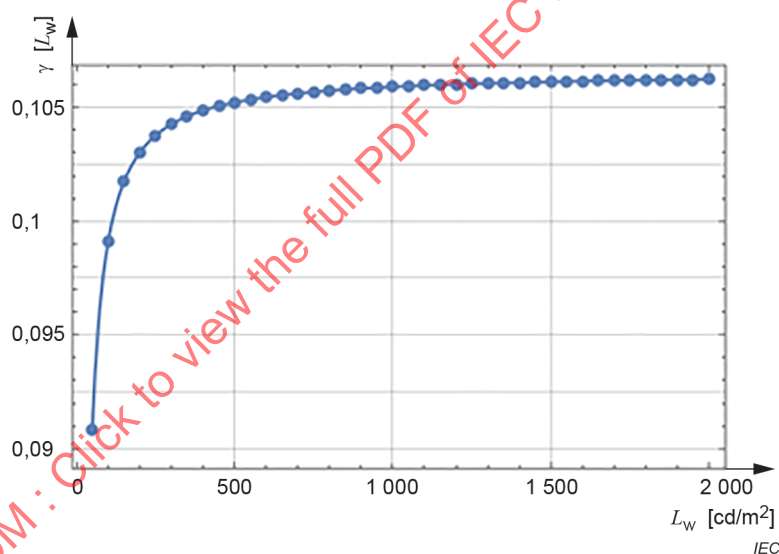
The complex equation of OETF of ITU-R.BT.2100 is approximated by the gamma function  $E^{\gamma(L_w)}$  considering of luminance  $L_w$  of the reference white at  $E = 1$ .

The fitting coefficients (a, b, c) are so optimized that the sufficient average error  $\left( \text{Mean} \left| OETF_{PQ}(E) - \left( O(L_w) + E^{\gamma(L_w)} \right) \right| \right)$  of the approximation below 0,054 percent for  $L_w = 2\,000\text{ cd/m}^2$  (0,55 levels for 10-bit encoding and 2,2 levels for 12-bit encoding). Figure E.2 shows the approximation error in dependence of the reference white luminance from 100 cd/m<sup>2</sup> to 2 000 cd/m<sup>2</sup>. The mean error increases slightly in proportion to the reference white luminance.



**Figure E.2 – Approximation error of OETF**

Figure E.3 shows the result of the fitted gamma values in dependence of the white luminance for the range of 100 cd/m<sup>2</sup> to 2 000 cd/m<sup>2</sup>. The gamma values are changed from 0,090 8 to 0,106 2.



**Figure E.3 – Approximated gamma values in function of reference white luminance**

The expanded OETF is able to encode the high-luminance signal to a value of more than two times that of the SDR-white luminance. This factor is shown in Figure E.4 for the range of 100 cd/m<sup>2</sup> to 2 000 cd/m<sup>2</sup> as a typical luminance range of displays on the market.

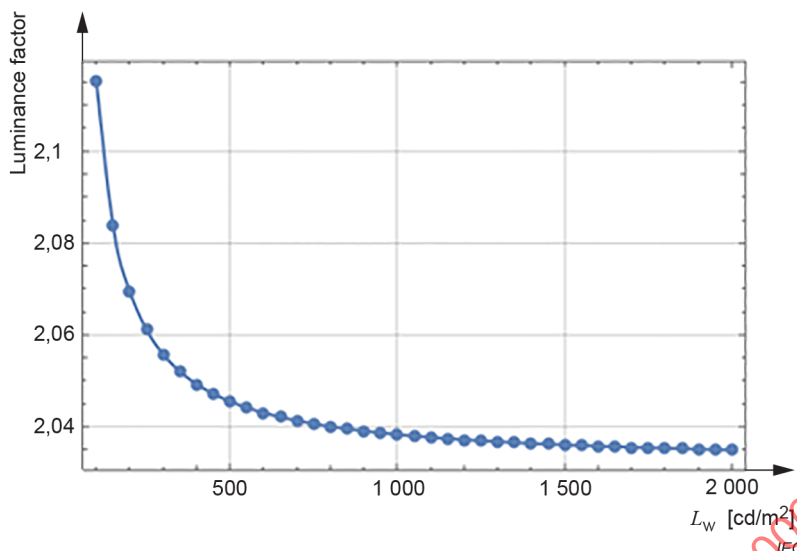


Figure E.4 – Encodable luminance in multiples of SDR-white luminance

### E.3 Extended electro-optical transfer characteristics

EOTF conversion for the SDR range ( $R', G', B' \leq 1$ ) is described in Formula (12) to Formula (14). EOTF conversion for the extended high-luminance region is as follows.

If  $1 \leq R', G', B' \leq 1,035\ 91$  ( $= E'(t = 1,2)$ ),

$$\begin{aligned} R &= \text{Exp}((R' - f) / d) + e \\ G &= \text{Exp}((G' - f) / d) + e \\ B &= \text{Exp}((B' - f) / d) + e \end{aligned} \quad (\text{E.5})$$

If  $R', G', B' > 1,035\ 91$ ,

$$\begin{aligned} R &= (R' - O(L_w))^{1/\gamma(L_w)} \\ G &= (G' - O(L_w))^{1/\gamma(L_w)} \\ B &= (B' - O(L_w))^{1/\gamma(L_w)} \end{aligned} \quad (\text{E.6})$$

NOTE For proper encoding and decoding of xvYCC with the extended high-luminance signal, the metadata of IEC 61966-12-1 and IEC 61966-12-2 can be used.

### E.4 Digital quantization methods

Signal conversion between the nonlinear R'G'B' and xvYCC signal is defined in Clause 4 and Clause 5. And the  $n$ -bits digitalization of xvYCC is also defined in these clauses. For proper encoding of the extended range of the high-luminance signals, more than 10 bits are required.

### E.5 Image processing consideration

The xvYCCext would be used for signal coding with extended luminance. If the luminance (Y) in the xvYCCext domain changes significantly for a given constant chroma, the hue can shift in the YCbCr domain owing to the enormous compression of signals by OETF. To ensure image processing with a constant colour tone, it is preferred that the xvYCCext signal is firstly converted into standard signals (e.g. linear light RGB, tri-stimulus XYZ (see 5.2)), uniform

colour space of CIELAB, CIE-CAM02 or HLG of ITU-R-BT-2100), and processed in these colour spaces.

As an example, a corresponding HLG signal ( $E'_{\text{HLG}}$ ) of ITU-R.BT.2100 is transformed from xvYCCext ( $E'$ ) as follows.

$$E'_{\text{HLG}} = \text{OETF}_{\text{HLG}}(\text{EOTF}(E'))$$

$$\text{with } E'_{\text{HLG}} = \{R'_{\text{HLG}}, G'_{\text{HLG}}, B'_{\text{HLG}}\} \text{ for HLG and } E' = \{R', G', B'\} \text{ for xvYCCext.} \quad (\text{E.7})$$

First,  $\text{EOTF}(E')$  transform can be performed with Formula (E.5) and Formula (E.6), and Subcluse 5.4 to Subclause 5.6. Then, the linear signal  $E = \{R, G, B\}$  can be transformed into the non-linear HLG signal using  $\text{OETF}_{\text{HLG}}$  as follows.

$$E'_{\text{HLG}} = \begin{cases} \sqrt{3 \cdot E} & \text{for } 0 \leq E < \frac{1}{12} \\ a \cdot \ln(12 \cdot E - b) + c & \text{for } \frac{1}{12} \leq E < 1 \end{cases}$$

$$\text{with } a = 0,178\,832\,77, b = 1 - 4a, c = 0,5 - a \cdot \ln(4 \cdot a) \quad (\text{E.8})$$

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