IEC 61966-2-4

Edition 1.0 2021-07

INTERNATIONAL STANDARD

colour inside

AMENDMENT 2

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

IEC 61966-2-4:2006-01/AMD2:2021-07(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC online collection - oc.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 18 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC 61966-2-4

Edition 1.0 2021-07

INTERNATIONAL STANDARD

colour inside

AMENDMENT 2

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

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 33.160.40 ISBN 978-2-8322-9952-4

Warning! Make sure that you obtained this publication from an authorized distributor.

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

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications/.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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 ≤ 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 $t_1(=1) \le R, G, B \le t_2(=1{,}2)$,

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

NOTE ln(.) is the natural logarithm.

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

As a first step, the SDR-white luminance (L_W in cd/m²) dependent gamma values $\gamma(L_\mathrm{W})$ 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),

$$R' = O(L_W) + R^{\gamma(L_W)}$$
$$G' = O(L_W) + G^{\gamma(L_W)} \quad \text{(E.3)}$$
$$B' = O(L_W) + B^{\gamma(L_W)}$$

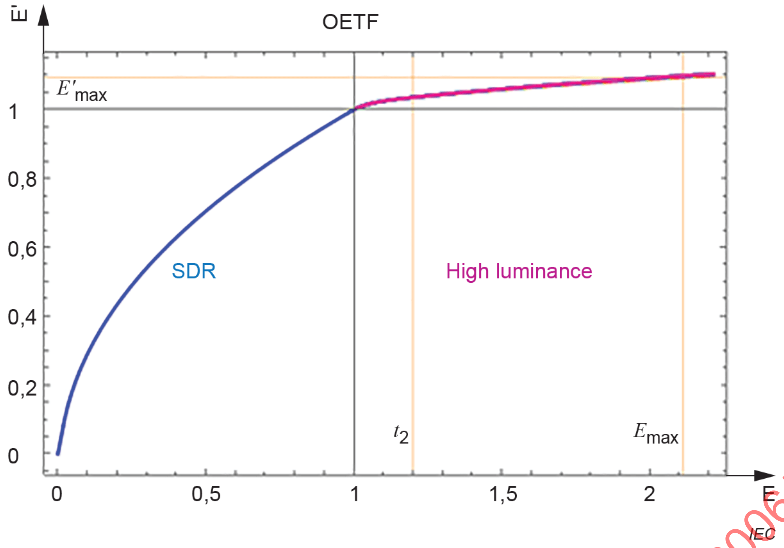
$$\text{, with } O(L_W) = f - t_2^{\gamma(L_W)} + d \cdot \ln(t_2 - e) \quad \text{(E.4)}$$

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 $O(L_W)$.

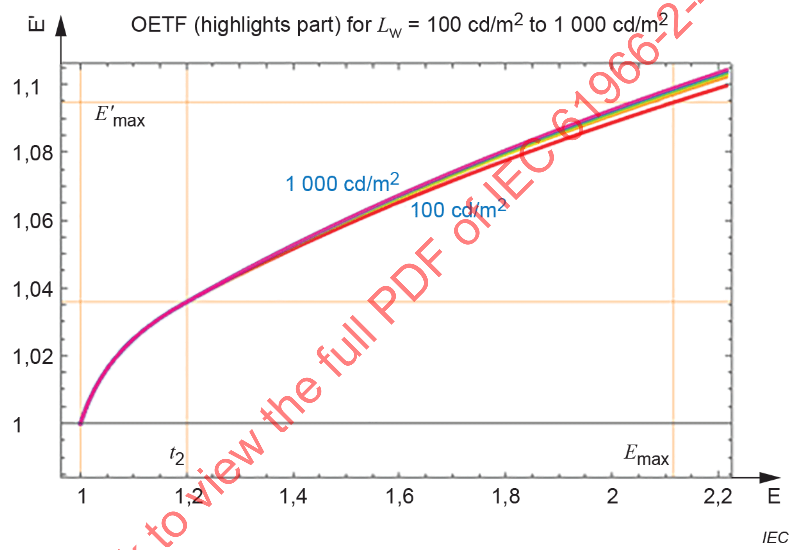
Figure E.1 shows an example of the high luminance region of xvYCCext. Over the reference white (E = 1), the gamma function $E^{\gamma(L_W)}$ is applied in order to include high-luminance colours such as specular and fluorescence, called "Super-white" [24].

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/m² to 1 000 cd/m²

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' = 1,094 75 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 cd/m² (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/m² to 2 000 cd/m². The mean error increases slightly in proportion to the reference white luminance.

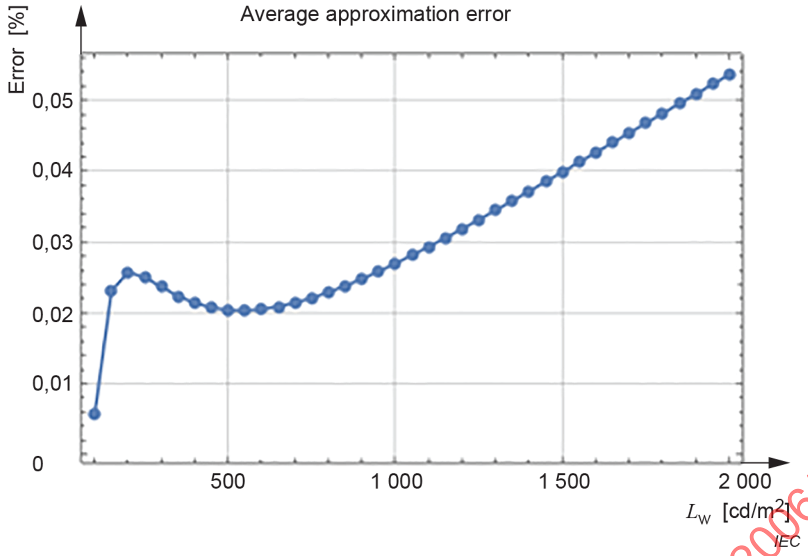


Figure E.2 – Approximation error of OETF

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

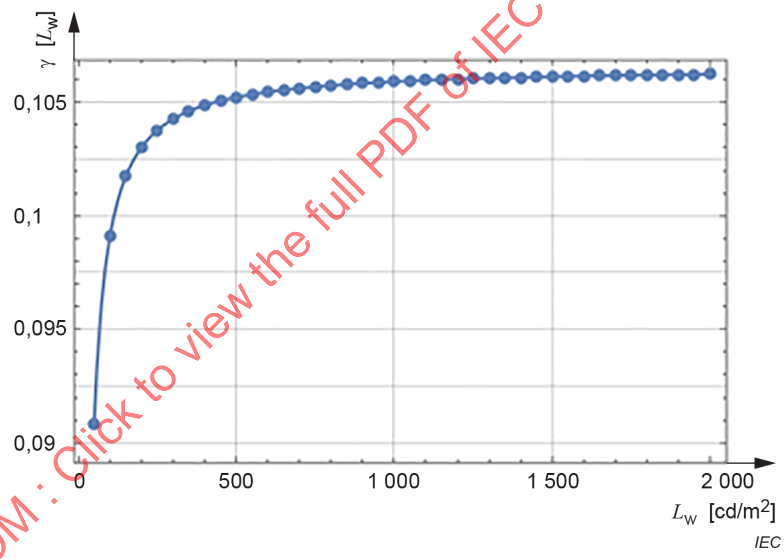


Figure E.3 – Approximated gamma values in function of reference white luminance

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^2 to 2 000 cd/m^2 as a typical luminance range of displays on the market.

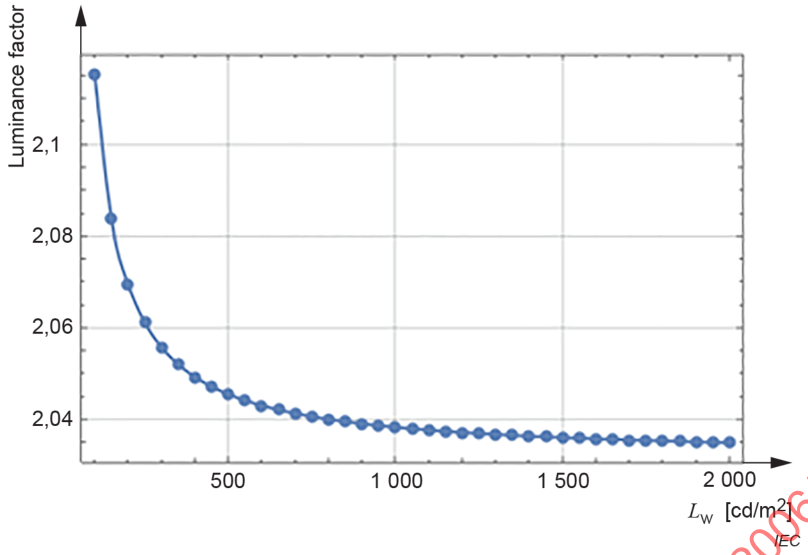


Figure E.4 – Encoderable luminance in multiples of SDR-white luminance

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

$$R = \text{Exp}\left(\left(R' - f\right) / d\right) + e$$
$$G = \text{Exp}\left(\left(G' - f\right) / d\right) + e \qquad \text{(E.5)}$$
$$B = \text{Exp}\left(\left(B' - f\right) / d\right) + e$$

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

$$R = \left(R' - O\left(L_W\right)\right)^{1/\gamma\left(L_W\right)}$$
$$G = \left(G' - O\left(L_W\right)\right)^{1/\gamma\left(L_W\right)} \qquad \text{(E.6)}$$
$$B = \left(B' - O\left(L_W\right)\right)^{1/\gamma\left(L_W\right)}$$

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'_{HLG}) of ITU-R.BT.2100 is transformed from xvYCCext (E') as follows.

$$E'_{\text{HLG}} = OETF_{\text{HLG}}\left(EOTF\left(E'\right)\right)$$

$$\text{with } E'_{\text{HLG}} = \left\{R'_{\text{HLG}}, G'_{\text{HLG}}, B'_{\text{HLG}}\right\} \text{ for HLG and } E' = \left\{R', G', B'\right\} \text{ for xvYCCext .} \tag{E.7}$$

First, 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 OETF_{HLG} as follows.

$$E'_{HLG} = \begin{cases} \sqrt{3 \bullet E} & \text{for } 0 \le E < \dfrac{1}{12} \\ a \bullet \ln\left(12 \bullet E - b\right) + c & \text{for } \dfrac{1}{12} \le E < 1 \end{cases}$$

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