|  |
| --- |
| **INTERNATIONAL ORGANIZATION FOR STANDARDIZATION ORGANISATION INTERNATIONALE DE NORMALISATION ISO/IEC JTC 1/SC 29/WG 5 MPEG JOINT VIDEO CODING TEAM WITH ITU-T SG 16** |
| **ISO/IEC JTC 1 / SC 29 / WG 5 N 200** |
| **Antalya, TR – 21–28 April 2023** |
| |  |  | | --- | --- | | **Title:** | **Preliminary working draft 3 of additional colour type identifiers for AVC and HEVC** | | **Source:** | **Convenor (Jens-Rainer Ohm)** | | **Type:** | **Project** | | **Subtype:** | **Draft** | | **Status:** | **Approved** | | **Date:** | **2023-07-10** | | **Expected Action:** | **Info** | | **Action due date:** | **N/A** | | **No. of pages** | **14** (without this cover page) | | **Email of convenor:** | **ohm @ ient . rwth-aachen . de** | | **Committee URL:** | **https://sd.iso.org/documents/ui/#!/browse/iso/iso-iec-jtc-1/iso-iec-jtc-1-sc-29/iso-iec-jtc-1-sc-29-wg-5** | |

|  |  |
| --- | --- |
| **Joint Video Experts Team (JVET)**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29**  30th Meeting, Antalya, TR, 21–28 April 2023 | Document: JVET-AD1008-v1 |

|  |  |  |  |
| --- | --- | --- | --- |
| *Title:* | **Additional colour type identifiers for AVC and HEVC (Draft 4)** | | |
| *Status:* | Output document approved by JVET | | |
| *Purpose:* | Draft text | | |
| *Author(s) or Contact(s):* | Gary J. Sullivan  Walt Husak  Alexandros M. Tourapis | Email:  Email:  Email: | g-j.sullivan@outlook.com  wjh@dolby.com  atourapis@apple.com |
| *Source:* | Editors | | |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# Abstract

This document contains the draft text for the specification of additional colour type identifiers for AVC (Rec. ITU-T H.264 | ISO/IEC 14496-10) and HEVC (Rec. ITU-T H.265 | ISO/IEC 23008-2). Text modifications are provided for specification of code point identifiers for YCgCo-R colour representation with equal luma and chroma bit depths and for Draft SMPTE ST 2128. The new code points for YCgCo-R are referred to as YCgCo-Re and YCgCo-Ro, where the number of bits added to a source RGB bit depth is 2 (i.e., even) and 1 (odd), respectively. Draft SMPTE ST 2128 specifies a colour representation referred to as IPT-PQ-C2. The affected sections are provided relative to corresponding basis texts (based on the 2021-08 edition of Rec. ITU-T H.264 (the most recent edition), the 2020 edition of ISO/IEC 23008-2 (not the 5th edition). Equation numbers and their cross-references have been updated without revision marking. Change marks are included to show the changes since the January output (JVET-AC1008), which reflect a renumbering of the new matrix coefficients values and some minor refinements and corrections since the previous draft.

# Changes to the specification text of AVC in subclause E.2.1

*Starting with the sentence that says* “The application of the transfer characteristics function is denoted by ( x )′ for an argument x.”*, replace the remainder of the semantics of the matrix\_coefficients syntax element with the following:*

The application of the transfer characteristics function is denoted by ( x )′ for an argument x.

– If matrix\_coefficients is not equal to 14 or 15, the signals E′R, E′G, and E′B are determined by application of the transfer characteristics function as follows:

E′R = ( ER )′ (E-1)

E′G = ( EG )′ (E-2)

E′B = ( EB )′ (E-3)

In this case, the range of E′R, E′G, and E′B is specified as follows:

– If transfer\_characteristics is equal to 11 or 12, or transfer\_characteristics is equal to 13 and matrix\_coefficients is not equal to 0, E′R, E′G, and E′B are real numbers with values that have a larger range than the range of 0 to 1, and their range is not specified in this Specification.

– Otherwise, E′R, E′G, and E′B are real numbers with values in the range of 0 to 1.

– Otherwise (matrix\_coefficients is equal to 14 or 15), the signals E′L, E′M, and E′S are determined by the following ordered steps:

a) The "linear-domain" real-valued signals EL, EM, and ES are determined as follows:

– If matrix\_coefficients is equal to 14, the signals EL, EM, and ES are determined as follows:

EL = ( 1688 \* ER + 2146 \* EG + 262 \* EB ) ÷ 4096 (E-4)

EM = ( 683 \* ER + 2951 \* EG + 462 \* EB ) ÷ 4096 (E-5)

ES = ( 99 \* ER + 309 \* EG + 3688 \* EB ) ÷ 4096 (E-6)

– Otherwise (matrix\_coefficients is equal to 15), the signals EL, EM, and ES are determined as follows:

EL = ( 1747 \* ER + 2169 \* EG + 180 \* EB ) ÷ 4096 (E-7)

EM = ( 673 \* ER + 3029 \* EG + 394 \* EB ) ÷ 4096 (E-8)

ES = ( 50 \* ER + 207 \* EG + 3839 \* EB ) ÷ 4096 (E-9)

b) The signals E′L, E′M, and E′S are determined by application of the transfer characteristics function as follows:

E′L = ( EL )′ (E-10)

E′M = ( EM )′ (E-11)

E′S = ( ES )′ (E-12)

When matrix\_coefficients is equal to 0, 8, 16, or 17, the variables bitDepthRGB and maxValRGB are derived as follows:

a) The variable bitDepthRGB is derived as follows:

– If matrix\_coefficients is equal to 0 or 8, the following applies:

bitDepthRGB = BitDepthY (E-13)

– Otherwise, if matrix\_coefficients is equal to 16, the following applies:

bitDepthRGB = BitDepthY + 2 (E-14)

– Otherwise (matrix\_coefficients is equal to 17), the following applies:

bitDepthRGB = BitDepthY + 1 (E-15)

b) The variable maxValRGB is derived as follows:

maxValRGB = ( 1 << bitDepthRGB ) − 1 (E-16)

The interpretation of matrix\_coefficients is specified as follows:

– If video\_full\_range\_flag is equal to 0, the following applies:

– If matrix\_coefficients is equal to 1, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, or 15 the following equations apply:

Y = Clip1Y( Round( ( 1 << ( BitDepthY − 8 ) ) \* ( 219 \* E′Y + 16 ) ) ) (E-17)

Cb = Clip1C( Round( ( 1 << ( BitDepthC − 8 ) ) \* ( 224 \* E′PB + 128 ) ) ) (E-18)

Cr = Clip1C( Round( ( 1 << ( BitDepthC − 8 ) ) \* ( 224 \* E′PR + 128 ) ) ) (E-19)

– Otherwise, if matrix\_coefficients is equal to 0, 8, 16, or 17, the following equations apply:

R = Clip3( 0, maxValRGB, ( 1 << ( bitDepthRGB − 8 ) ) \* ( 219 \* E′R + 16 ) ) (E-20)

G = Clip3( 0, maxValRGB, ( 1 << ( bitDepthRGB − 8 ) ) \* ( 219 \* E′G + 16 ) ) (E-21)

B = Clip3( 0, maxValRGB, ( 1 << ( bitDepthRGB − 8 ) ) \* ( 219 \* E′B + 16 ) ) (E-22)

– Otherwise, if matrix\_coefficients is equal to 2, the interpretation of the matrix\_coefficients syntax element is unknown or is determined by the application.

– Otherwise (matrix\_coefficients is not equal to 0, 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, or 17), the interpretation of the matrix\_coefficients syntax element is reserved for future definition by ITU‑T | ISO/IEC.

– Otherwise (video\_full\_range\_flag is equal to 1), the following applies:

– If matrix\_coefficients is equal to 1, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, or 15, the following equations apply:

Y = Clip1Y( Round( ( ( 1 << BitDepthY ) − 1 ) \* E′Y ) ) (E-23)

Cb = Clip1C( Round( ( ( 1 << BitDepthC ) − 1 ) \* E′PB + ( 1 << ( BitDepthC − 1 ) ) ) ) (E-24)

Cr = Clip1C( Round( ( ( 1 << BitDepthC ) − 1 ) \* E′PR + ( 1 << ( BitDepthC − 1 ) ) ) ) (E-25)

– Otherwise, if matrix\_coefficients is equal to 0, 8, 16, or 17, the following equations apply:

R = Clip3( 0, maxValRGB, maxValRGB \* E′R ) (E-26)

G = Clip3( 0, maxValRGB, maxValRGB \* E′G ) (E-27)

B = Clip3( 0, maxValRGB, maxValRGB \* E′B ) (E-28)

– Otherwise, if matrix\_coefficients is equal to 2, the interpretation of the matrix\_coefficients syntax element is unknown or is determined by the application.

– Otherwise (matrix\_coefficients is not equal to 0, 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, or 17), the interpretation of the matrix\_coefficients syntax element is reserved for future definition by ITU‑T | ISO/IEC.

Reserved values for matrix\_coefficients shall not be present in bitstreams conforming to this version of this Specification. Decoders shall interpret reserved values of matrix\_coefficients as equivalent to the value 2.

It is a requirement of bitstream conformance to this version of this Specification that when colour\_primaries is not equal to 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, or 22, matrix\_coefficients shall not be equal to 12 or 13.

When matrix\_coefficients is equal to 1, 4, 5, 6, 7, 9, 10, 11, 12, or 13, the constants KR and KB are specified as follows:

– If matrix\_coefficients is not equal to 12 or 13, the constants KR and KB are specified in Table E‑5.

– Otherwise (matrix\_coefficients is equal to 12 or 13), the constants KR and KB are computed as follows, using the chromaticity coordinates (xR, yR), (xG, yG), (xB, yB), and (xW, yW) specified by Table E‑3 for the colour\_primaries syntax element for the red, green, blue, and white colour primaries, respectively:

KR =  (E-29)

KB =  (E-30)

where the values of zR, zG, zB, and zW, are given by.

zR = 1 − ( xR + yR ) (E-31)

zG = 1 − ( xG + yG ) (E-32)

zB = 1 − ( xB + yB ) (E-33)

zW = 1 − ( xW + yW ) (E-34)

The variables E′Y, E′PB, and E′PR (for matrix\_coefficients not equal to 0, 8, 16, or 17) or Y, Cb, and Cr (for matrix\_coefficients equal to 0, 8, 16, or 17) are specified as follows:

– If matrix\_coefficients is not equal to 0, 8, 10, 11, 13, 14, 15, 16, or 17, the following equations apply:

E′Y = KR \* E′R + ( 1 − KR − KB ) \* E′G + KB \* E′B (E-35)

E′PB = 0.5 \* ( E′B − E′Y ) ÷ ( 1 − KB ) (E-36)

E′PR = 0.5 \* ( E′R − E′Y ) ÷ ( 1 − KR ) (E-37)

E′Y is a real number with the value 0 associated with nominal black and the value 1 associated with nominal white. E′PB and E′PR are real numbers with the value 0 associated with both nominal black and nominal white. When transfer\_characteristics is not equal to 11 or 12, E′Y is a real number with values in the range of 0 to 1. When transfer\_characteristics is not equal to 11 or 12, E′PB and E′PR are real numbers with values in the range of −0.5 to 0.5. When transfer\_characteristics is equal to 11, or 12, E′Y, E′PB and E′PR are real numbers with a larger range not specified in this Specification.

– Otherwise, if matrix\_coefficients is equal to 0, the following equations apply:

Y = Round( G ) (E-38)

Cb = Round( B ) (E-39)

Cr = Round( R ) (E-40)

– Otherwise, if matrix\_coefficients is equal to 8 and BitDepthC is equal to BitDepthY, the following applies:

Y = Round( 0.5 \* G + 0.25 \* ( R + B ) ) (E-41)

Cb = Round( 0.5 \* G − 0.25 \* ( R + B ) ) + ( 1 << ( BitDepthC − 1 ) ) (E-42)

Cr = Round( 0.5 \* ( R − B ) ) + ( 1 << ( BitDepthC − 1 ) ) (E-43)

NOTE 6 – In this case, for purposes of the YCgCo nomenclature used in Table E‑5, Cb and Cr of Equations E-42 and E-43 would be referred to as Cg and Co, respectively. An appropriate inverse conversion for Equations E-41 to E-43 is as follows:

t = Y − ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) (E-44)

G = Clip1Y( Y + ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) ) (E-45)

B = Clip1Y( t − ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) ) (E-46)

R = Clip1Y( t + ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) ) (E-47)

– Otherwise, if matrix\_coefficients is equal to 8, 16, or 17, the following equations apply:

Cr = Round( R ) − Round( B ) + ( 1 << ( BitDepthC − 1 ) ) (E-48)

t = Round( B ) + ( ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) (E-49)

Cb = Round( G ) − t + ( 1 << ( BitDepthC − 1 ) ) (E-50)

Y = t + ( ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) (E-51)

NOTE 7 – In this case, for purposes of the YCgCo nomenclature used in Table E‑5, Cb and Cr of Equations E-50 and E-48 would be referred to as Cg and Co, respectively. An appropriate inverse conversion for Equations E-48 to E-51 is as follows:

t = Y − ( ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) (E-52)

G = Clip3( 0, maxValRGB, t + ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) ) (E-53)

B = Clip3( 0, maxValRGB, t − ( ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) ) (E-54)

R = Clip3( 0, maxValRGB, B + ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) ) (E-55)

– Otherwise, if matrix\_coefficients is equal to 10 or 13, the signal E′Y is determined by application of the transfer characteristics function as follows:

EY = KR \* ER + ( 1 − KR − KB ) \* EG + KB \* EB (E-56)

E′Y = ( EY )′ (E-57)

In this case, EY is defined from the "linear-domain" signals for ER, EG, and EB, prior to application of the transfer characteristics function, which is then applied to produce the signal E′Y. EY and E′Y are real values with the value 0 associated with nominal black and the value 1 associated with nominal white.

In this case, the signals E′PB and E′PR are determined as follows:

E′PB = ( E′B − E′Y ) ÷ ( 2 \* NB ) for −NB <= E′B − E′Y <= 0 (E-58)

E′PB = ( E′B − E′Y ) ÷ ( 2 \* PB ) for 0 < E′B − E′Y <= PB (E-59)

E′PR = ( E′R − E′Y ) ÷ ( 2 \* NR ) for −NR <= E′R − E′Y <= 0 (E-60)

E′PR = ( E′R − E′Y ) ÷ ( 2 \* PR ) for 0 < E′R − E′Y <= PR (E-61)

where the constants NB, PB, NR, and PR are determined by application of the transfer characteristics function to expressions involving the constants KB and KR as follows:

NB = ( 1 − KB )′ (E‑62)

PB = 1 − ( KB )′ (E‑63)

NR = ( 1 − KR )′ (E‑64)

PR = 1 − ( KR )′ (E‑65)

– Otherwise, if matrix\_coefficients is equal to 11, the following equations apply:

E′Y = E′G (E‑66)

E′PB = ( 0.986566 \* E′B − E′Y ) ÷ 2 (E‑67)

E′PR = ( E′R − 0.991902 \* E′Y ) ÷ 2 (E‑68)

NOTE 8 – In this case, for purposes of the Y′D′ZD′X nomenclature used in Table E‑5, E′PB and E′PR of Equations E‑67 and E‑68 would be referred to as D′Z and D′X, respectively.

– Otherwise, if matrix\_coefficients is equal to 14, the following applies:

– If transfer\_characteristics is not equal to 18, the following equations apply:

E′Y = 0.5 \* ( E′L + E′M ) (E‑69)

E′PB = ( 6610 \* E′L − 13613 \* E′M + 7003 \* E′S ) ÷ 4096 (E‑70)

E′PR = ( 17933 \* E′L − 17390 \* E′M − 543 \* E′S ) ÷ 4096 (E‑71)

– Otherwise, the following equations apply:

E′Y = 0.5 \* ( E′L + E′M ) (E‑72)

E′PB = ( 3625 \* E′L − 7465 \* E′M + 3840 \* E′S ) ÷ 4096 (E‑73)

E′PR = ( 9500 \* E′L − 9212 \* E′M − 288 \* E′S ) ÷ 4096 (E‑74)

NOTE 9 – In this case, for purposes of the ICTCP nomenclature used in Table E‑5, E′Y, E′PB, and E′PR of Equations E‑69, E‑70, and E‑71 may be referred to as I, CT, and CP, respectively. Equations E‑69 through E‑71 were designed specifically for use with transfer\_characteristics equal to 16 (PQ), and Equations E‑72 through E‑74 were designed specifically for use with transfer\_characteristics equal to 18 (HLG).

– Otherwise (matrix\_coefficients is equal to 15), the following applies:

E′Y = ( 1638 \* E′L + 1638 \* E′M + 820 \* E′S ) ÷ 4096 (E-75)

E′PB = ( 18248 \* E′L − 19870 \* E′M + 1622 \* E′S ) ÷ 4096 (E-76)

E′PR = ( 3300 \* E′L + 1463 \* E′M − 4763 \* E′S ) ÷ 4096 (E-77)

NOTE 10 – In this case, for purposes of the IPT nomenclature used in Table E‑5, E′Y, E′PB, and E′PR of Equations E-75, E-76, and E-77 may be referred to as I, P, and T, respectively.

**Table E‑5 – Matrix coefficients interpretation using the matrix\_coefficients syntax element**

|  |  |  |
| --- | --- | --- |
| **Value** | **Matrix** | **Informative remark** |
| 0 | GBR | The identity matrix.  Typically used for GBR (often referred to as RGB); however, may also be used for YZX (often referred to as XYZ)  IEC 61966-2-1 (sRGB)  Society of Motion Picture and Television Engineers ST 428-1 XYZ (2006)  See Equations E -1 to E-3 |
| 1 | KR = 0.2126; KB = 0.0722 | Rec. ITU‑R BT.709-6  Rec. ITU‑R BT.1361-0 conventional colour gamut system and extended colour gamut system (historical)  IEC 61966-2-4 xvYCC709  Society of Motion Picture and Television Engineers RP 177 (1993) Annex B  See Equations E-35 to E-37 |
| 2 | Unspecified | Image characteristics are unknown or are determined by the application. |
| 3 | Reserved | For future use by ITU‑T | ISO/IEC |
| 4 | KR = 0.30; KB = 0.11 | United States Federal Communications Commission Title 47 Code of Federal Regulations (2016) 73.682 (a) (20)  See Equations E-35 to E-37 |
| 5 | KR = 0.299; KB = 0.114 | Rec. ITU-R BT.470‑7 System B, G (historical)  Rec. ITU-R BT.601‑7 625  Rec. ITU-R BT.1358-0 625 (historical)  Rec. ITU-R BT.1700-0 625 PAL and 625 SECAM  IEC 61966-2-1 (sYCC)  IEC 61966-2-4 xvYCC601  (functionally the same as the value 6)  See Equations E-35 to E-37 |
| 6 | KR = 0.299; KB = 0.114 | Rec. ITU-R BT.601‑7 525  Rec. ITU-R BT.1358-1 525 or 625  Rec. ITU-R BT.1700-0 NTSC  Society of Motion Picture and Television Engineers 170M (2004)  (functionally the same as the value 5)  See Equations E-35 to E-37 |
| 7 | KR = 0.212; KB = 0.087 | Society of Motion Picture and Television Engineers 240M (1999, historical)  See Equations E-35 to E-37 |
| 8 | YCgCo or YCgCo-R | See Equations E-41 to E-47 for YCgCo (when BitDepthC is equal to BitDepthY)  See Equations E-48 to E-55 for YCgCo-R (when BitDepthC is equal to BitDepthY + 1) |
| 9 | KR = 0.2627; KB = 0.0593 | Rec. ITU-R BT.2020-2 non-constant luminance system  Rec. ITU-R BT.2100-2 Y′CbCr  See Equations E-35 to E-37 |
| 10 | KR = 0.2627; KB = 0.0593 | Rec. ITU-R BT.2020-2 constant luminance system  See Equations E-56 to E‑65 |
| 11 | Y′D′ZD′X | Society of Motion Picture and Television Engineers ST 2085 (2015)  See Equations E‑66 to E‑68 |
| 12 | See Equations E-29 to E-34. | Chromaticity-derived non-constant luminance system  See Equations E-35 to E-37. |
| 13 | See Equations E-29 to E-34. | Chromaticity-derived constant luminance system  See Equations E-56 to E‑65. |
| 14 | ICTCP | Rec. ITU-R BT.2100-2 ICTCP  See Equations E‑69 to E‑71. for transfer\_characteristics value 16 (PQ)  See Equations E‑72 to E‑74 for transfer\_characteristics value 18 (HLG) |
| 15 | IPT-C2 | Society of Motion Picture and Television Engineers ST 2128  See Equations E-75 to E-77 |
| 16 | YCgCo-Re | See Equations E-48 to E-55 |
| 17 | YCgCo-Ro | See Equations E-48 to E-55 |
| 18..255 | Reserved | For future use by ITU‑T | ISO/IEC |

# Changes to the specification text of HEVC in subclause E.3.1

*Starting with the sentence that begins with* “The application of the transfer characteristics function is denoted by ( x )′ for an argument x.”*, replace the remainder of the semantics of the matrix\_coeffs syntax element with the following:*

The application of the transfer characteristics function is denoted by ( x )′ for an argument x.

— If matrix\_coeffs is not equal to 14 or 15, the signals E′R, E′G, and E′B are determined by application of the transfer characteristics function as follows:

E′R = ( ER )′ (E‑1)

E′G = ( EG )′ (E‑2)

E′B = ( EB )′ (E‑3)

In this case, the range of E′R, E′G, and E′B is specified as follows:

— If transfer\_characteristics is not equal to 11 or 12, E′R, E′G, and E′B are real numbers with values in the range of 0 to 1 inclusive.

— Otherwise, (transfer\_characteristics is equal to 11 or 12), E′R, E′G and E′B are real numbers with a larger range not specified in this document.

— Otherwise (matrix\_coeffs is equal to 14 or 15), the signals E′L, E′M, and E′S are determined by the following ordered steps:

a) The "linear-domain" real-valued signals EL, EM, and ES are determined as follows:

— If matrix\_coeffs is equal to 14, the signals EL, EM, and ES are determined as follows:

EL = ( 1 688 \* ER + 2 146 \* EG + 262 \* EB ) ÷ 4 096 (E‑4)

EM = ( 683 \* ER + 2 951 \* EG + 462 \* EB ) ÷ 4 096 (E‑5)

ES = ( 99 \* ER + 309 \* EG + 3 688 \* EB ) ÷ 4 096 (E‑6)

— Otherwise (matrix\_coeffs is equal to 15), the signals EL, EM, and ES are determined as follows:

EL = ( 1 747 \* ER + 2 169 \* EG + 180 \* EB ) ÷ 4 096 (E‑7)

EM = ( 673 \* ER + 3 029 \* EG + 394 \* EB ) ÷ 4 096 (E‑8)

ES = ( 50 \* ER + 207 \* EG + 3 839 \* EB ) ÷ 4 096 (E‑9)

b) The signals E′L, E′M, and E′S are determined by application of the transfer characteristics function as follows:

E′L = ( EL )′ (E‑10)

E′M = ( EM )′ (E‑11)

E′S = ( ES )′ (E‑12)

When matrix\_coeffs is equal to 0, 8, 16, or 17, the variables bitDepthRGB and maxValRGB are derived using the following ordered steps:

a) The variable bitDepthRGB is derived as follows:

— If matrix\_coeffs is equal to 0 or 8, the following applies:

bitDepthRGB = BitDepthY (E‑13)

— Otherwise, if matrix\_coeffs is equal to 16, the following applies:

bitDepthRGB = BitDepthY + 2 (E‑14)

— Otherwise (matrix\_coeffs is equal to 17), the following applies:

bitDepthRGB = BitDepthY + 1 (E‑15)

b) The variable maxValRGB is derived as follows:

maxValRGB = ( 1 << bitDepthRGB ) − 1 (E‑16)

The interpretation of matrix\_coeffs is specified as follows:

— If video\_full\_range\_flag is equal to 0, the following applies:

— If matrix\_coeffs is equal to 1, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, or 15, the following formulae apply:

Y = Clip1Y( Round( ( 1 << ( BitDepthY − 8 ) ) \* ( 219 \* E′Y + 16 ) ) ) (E‑17)

Cb = Clip1C( Round( ( 1 << ( BitDepthC − 8 ) ) \* ( 224 \* E′PB + 128 ) ) ) (E‑18)

Cr = Clip1C( Round( ( 1 << ( BitDepthC − 8 ) ) \* ( 224 \* E′PR + 128 ) ) ) (E‑19)

— Otherwise, if matrix\_coeffs is equal to 0, 8, 16, or 17, the following formulae apply:

R = Clip3( 0, maxValRGB, ( 1 << ( bitDepthRGB − 8 ) ) \* ( 219 \* E′R + 16 ) ) (E‑20)

G = Clip3( 0, maxValRGB, ( 1 << ( bitDepthRGB − 8 ) ) \* ( 219 \* E′G + 16 ) ) (E‑21)

B = Clip1Y( 0, maxValRGB, ( 1 << ( bitDepthRGB − 8 ) ) \* ( 219 \* E′B + 16 ) ) (E‑22)

— Otherwise, if matrix\_coeffs is equal to 2, the interpretation of the matrix\_coeffs syntax element is unknown or is determined by the application.

— Otherwise (matrix\_coeffs is not equal to 0, 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, or 17), the interpretation of the matrix\_coeffs syntax element is reserved for future definition by ITU‑T | ISO/IEC.

— Otherwise (video\_full\_range\_flag is equal to 1), the following applies:

— If matrix\_coeffs is equal to 1, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, or 17, the following applies:

Y = Clip1Y( Round( ( ( 1 << BitDepthY ) − 1 ) \* E′Y ) ) (E‑23)

Cb = Clip1C( Round( ( ( 1 << BitDepthC ) − 1 ) \* E′PB + ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑24)

Cr = Clip1C( Round( ( ( 1 << BitDepthC ) − 1 ) \* E′PR + ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑25)

— Otherwise, if matrix\_coeffs is equal to 0 8, 16, or 17, the following applies:

R = Clip3( 0, maxValRGB, maxValRGB \* E′R ) (E‑26)

G = Clip3( 0, maxValRGB, maxValRGB \* E′G ) (E‑27)

B = Clip3( 0, maxValRGB, maxValRGB \* E′B ) (E‑28)

— Otherwise, if matrix\_coeffs is equal to 2, the interpretation of the matrix\_coeffs syntax element is unknown or is determined by the application.

— Otherwise (matrix\_coeffs is not equal to 0, 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12 13, 14, 15, 16, or 17), the interpretation of the matrix\_coeffs syntax element is reserved for future definition by ITU‑T | ISO/IEC. Reserved values for matrix\_coeffs shall not be present in bitstreams conforming to this version of this document. Decoders shall interpret reserved values of matrix\_coeffs as equivalent to the value 2.

It is a requirement of bitstream conformance to this version of this document that when colour\_primaries is not equal to 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, or 22, matrix\_coeffs shall not be equal to 12 or 13.

When matrix\_coeffs is equal to 1, 4, 5, 6, 7, 9, 10, 11, 12, or 13, the constants KB and KR are specified as follows:

— If matrix\_coeffs is not equal to 12 or 13, the constants KB and KR are specified in Table E.5.

— Otherwise (matrix\_coeffs is equal to 12 or 13), the constants KR and KB are computed as follows, using the chromaticity coordinates (xR, yR), (xG, yG), (xB, yB), and (xW, yW) specified by Table E.3 for the colour\_primaries syntax element for the red, green, blue, and white colour primaries, respectively.

KR =  (E‑29)

KB =  (E‑30)

where the values of zR, zG, zB, and zW, are given by:

zR = 1 − ( xR + yR ) (E‑31)

zG = 1 − ( xG + yG ) (E‑32)

zB = 1 − ( xB + yB ) (E‑33)

zW = 1 − ( xW + yW ) (E‑34)

The variables E′Y, E′PB, and E′PR (for matrix\_coeffs not equal to 0, 8, 16, or 17) or Y, Cb, and Cr (for matrix\_coeffs equal to 0, 8, 16, or 17) are specified as follows:

— If matrix\_coeffs is not equal to 0, 8, 10, 11, 13, 14, 15, 16, or 17, the following formulae apply:

E′Y = KR \* E′R + ( 1 − KR − KB ) \* E′G + KB \* E′B (E‑35)

E′PB = 0.5 \* ( E′B − E′Y ) ÷ ( 1 − KB ) (E‑36)

E′PR = 0.5 \* ( E′R − E′Y ) ÷ ( 1 − KR ) (E‑37)

NOTE 8 E′Y is a real number with the value 0 associated with nominal black and the value 1 associated with nominal white. E′PB and E′PR are real numbers with the value 0 associated with both nominal black and nominal white. When transfer\_characteristics is not equal to 11 or 12, E′Y is a real number with values in the range of 0 to 1 inclusive. When transfer\_characteristics is not equal to 11 or 12, E′PB and E′PR are real numbers with values in the range of −0.5 to 0.5 inclusive. When transfer\_characteristics is equal to 11 or 12, E′Y, E′PB and E′PR are real numbers with a larger range not specified in this document.

— Otherwise, if matrix\_coeffs is equal to 0, the following formulae apply:

Y = Round( G ) (E‑38)

Cb = Round( B ) (E‑39)

Cr = Round( R ) (E‑40)

— Otherwise, if matrix\_coeffs is equal to 8 and BitDepthC is equal to BitDepthY, the following formulae apply:

Y = Round( 0.5 \* G + 0.25 \* ( R + B ) ) (E‑41)

Cb = Round( 0.5 \* G − 0.25 \* ( R + B ) ) + ( 1 << ( BitDepthC − 1 ) ) (E‑42)

Cr = Round( 0.5 \* (R − B ) ) + ( 1 << ( BitDepthC − 1 ) ) (E‑43)

NOTE 9 In this case, for purposes of the YCgCo nomenclature used in Table E.5, Cb and Cr of Formulae (E‑42) and (E‑43) may be referred to as Cg and Co, respectively. An appropriate inverse conversion for Formulae (E‑41)to (E‑43) is as follows:

t = Y − ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) (E‑44)

G = Clip1Y( Y + ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑45)

B = Clip1Y( t − ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑46)

R = Clip1Y( t + ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑47)

— Otherwise, if matrix\_coeffs is equal to 8, 16, or 17, the following formulae apply:

Cr = Round( R ) − Round( B ) + ( 1 << ( BitDepthC − 1 ) ) (E‑48)

t = Round( B ) + ( ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) (E‑49)

Cb = Round( G ) − t + ( 1 << ( BitDepthC − 1 ) ) (E‑50)

Y = t + ( ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) (E‑51)

NOTE 10 In this case, for purposes of the YCgCo nomenclature used in Table E.5, Cb and Cr of Formulae (E‑50) and (E‑48) may be referred to as Cg and Co, respectively. An appropriate inverse conversion for Formulae (E‑48) to (E‑51) is as follows.

t = Y − ( ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) (E‑52)

G = Clip3( 0, maxValRGB, t + ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑53)

B = Clip3( 0, maxValRGB, t − ( ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) ) (E‑54)

R = Clip3( 0, maxValRGB, B + ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑55)

— Otherwise, if matrix\_coeffs is equal to 10 or 13, the signal E′Y is determined by application of the transfer characteristics function as follows, and Formulae (E‑58) to (E‑61) apply for specification of the signals E′PB and E′PR:

EY = KR \* ER + ( 1 − KR − KB ) \* EG + KB \* EB (E‑56)

E′Y = ( EY )′ (E‑57)

NOTE 11 In this case, EY is defined from the “linear-domain” signals for ER, EG, and EB, prior to application of the transfer characteristics function, which is then applied to produce the signal E′Y. EY and E′Y are real values with the value 0 associated with nominal black and the value 1 associated with nominal white.

while the signals E′PB and E′PR are determined as follows:

E′PB = ( E′B − E′Y ) ÷ ( 2 \* NB ) for −NB <= E′B − E′Y <= 0 (E‑58)

E′PB = ( E′B − E′Y ) ÷ ( 2 \* PB ) for 0 < E′B − E′Y <= PB (E‑59)

E′PR = ( E′R − E′Y ) ÷ ( 2 \* NR ) for −NR <= E′R − E′Y <= 0 (E‑60)

E′PR = ( E′R − E′Y ) ÷ ( 2 \* PR ) for 0 < E′R − E′Y <= PR (E‑61)

where the constants NB, PB, NR, and PR are determined by application of the transfer characteristics function to expressions involving the constants KB and KR as follows:

NB = ( 1 − KB )′ (E‑62)

PB = 1 − ( KB )′ (E‑63)

NR = ( 1 − KR )′ (E‑64)

PR = 1 − ( KR )′ (E‑65)

— Otherwise if matrix\_coeffs is equal to 11, the following formulae apply:

E′Y = E′G (E‑66)

E′PB = 0.5 \* ( 0.986 566 \* E′B − E′Y ) (E‑67)

E′PR = 0.5 \* ( E′R − 0.991 902 \* E′Y ) (E‑68)

NOTE 12 In this case, for purposes of the Y′D′ZD′X nomenclature used in Table E.5, E′PB may be referred to as D′Z and E′PR may be referred to as D′X.

— Otherwise, if matrix\_coeffs is equal to 14, the following formulae apply:

— If transfer\_characteristics is not equal to 18, the following formulae apply:

E′Y = 0.5 \* ( E′L + E′M ) (E‑69)

E′PB = ( 6 610 \* E′L − 13 613 \* E′M + 7 003 \* E′S ) ÷ 4 096 (E‑70)

E′PR = ( 17 933 \* E′L − 17 390 \* E′M − 543 \* E′S ) ÷ 4 096 (E‑71)

— Otherwise, the following formulae apply:

E′Y = 0.5 \* ( E′L + E′M ) (E‑72)

E′PB = ( 3 625 \* E′L − 7 465 \* E′M + 3 840 \* E′S ) ÷ 4 096 (E‑73)

E′PR = ( 9 500 \* E′L − 9 212 \* E′M − 288 \* E′S ) ÷ 4 096 (E‑74)

NOTE 13 In this case, for purposes of the ICTCP nomenclature used in Table E.5, E′Y, E′PB, and E′PR of Formulae (E‑69), (E‑70), and (E‑71) or Formulae (E‑72), (E‑73), and (E‑74) may be referred to as I, CT, and CP, respectively. Formulae (E‑69) to (E‑71) were designed specifically for use with transfer\_characteristics equal to 16 (PQ), and Formulae (E‑72) to (E‑74) were designed specifically for use with transfer\_characteristics equal to 18 (HLG).

— Otherwise (matrix\_coeffs is equal to 15), the following formulae apply:

E′Y = ( 1 638 \* E′L + 1 638 \* E′M + 820 \* E′S ) ÷ 4 096 (E‑75)

E′PB = ( 18 248 \* E′L − 19 870 \* E′M + 1 622 \* E′S ) ÷ 4 096 (E‑76)

E′PR = ( 3 300 \* E′L + 1 463 \* E′M − 4 763 \* E′S ) ÷ 4 096 (E‑77)

NOTE 14 In this case, for purposes of the IPT nomenclature used in Table E.5, E′Y, E′PB, and E′PR of Formulae (E‑75), (E‑76), and (E‑77) may be referred to as I, P, and T, respectively.

**Table E.5 — Matrix coefficients interpretation using the matrix\_coeffs syntax element**

|  |  |  |
| --- | --- | --- |
| **Value** | **Matrix** | **Informative remark** |
| 0 | Identity | The identity matrix.  Typically used for GBR (often referred to as RGB); however, may also be used for YZX (often referred to as XYZ)  IEC 61966-2-1 sRGB  SMPTE ST 428-1 (2006)  See Formulae (E‑38) to (E‑40) |
| 1 | KR = 0.212 6; KB = 0.072 2 | ITU‑R Rec. BT.709-6  ITU‑R Rec. BT.1361-0 conventional colour gamut system and extended colour gamut system (historical)  IEC 61966-2-4 xvYCC709  SMPTE RP 177 (1993) Annex B  See Formulae (E‑35) to (E‑37) |
| 2 | Unspecified | Image characteristics are unknown or are determined by the application. |
| 3 | Reserved | For future use by ITU‑T | ISO/IEC |
| 4 | KR = 0.30; KB = 0.11 | FCC Title 47 Code of Federal Regulations (2003) 73.682 (a) (20)  See Formulae (E‑35) to (E‑37) |
| 5 | KR = 0.299; KB = 0.114 | ITU‑R Rec. BT.470‑6 System B, G (historical)  ITU‑R Rec. BT.601‑7 625  ITU‑R Rec. BT.1358-0 625 (historical)  ITU‑R Rec. BT.1700-0 625 PAL and 625 SECAM  IEC 61966-2-1 sYCC  IEC 61966-2-4 xvYCC601  (functionally the same as the value 6)  See Formulae (E‑35) to (E‑37) |
| 6 | KR = 0.299; KB = 0.114 | ITU‑R Rec. BT.601‑7 525  ITU‑R Rec. BT.1358-1 525 or 625 (historical)  ITU‑R Rec. BT.1700-0 NTSC  SMPTE ST 170 (2004)  (functionally the same as the value 5)  See Formulae (E‑35) to (E‑37) |
| 7 | KR = 0.212; KB = 0.087 | SMPTE ST 240 (1999, historical)  See Formulae (E‑35) to (E‑37) |
| 8 | YCgCo or YCgCo-R | See Formulae (E‑41) to (E‑47) for YCgCo (when BitDepthC is equal to BitDepthY)  See Formulae (E‑48) to (E‑55) for YCgCo-R (when BitDepthC is equal to BitDepthY + 1) |
| 9 | KR = 0.262 7; KB = 0.059 3 | Rec. ITU-R BT.2020-2 non-constant luminance system  Rec. ITU-R BT.2100-2 Y′CbCr  See Formulae (E‑35) to (E‑37) |
| 10 | KR = 0.262 7; KB = 0.059 3 | Rec. ITU-R BT.2020-2 constant luminance system  See Formulae (E‑56) to (E‑65) |
| 11 | Y′D′ZD′X | SMPTE ST 2085 (2015)  See Formulae (E‑66) to (E‑68) |
| 12 | See Formulae (E‑29) to (E‑34) | Chromaticity-derived non-constant luminance system  See Formulae (E‑35) to (E‑37) |
| 13 | See Formulae (E‑29) to (E‑34) | Chromaticity-derived constant luminance system  See Formulae (E‑56) to (E‑65) |
| 14 | ICTCP | Rec. ITU-R BT.2100-2 ICTCP  See Formulae (E‑69) to (E‑71) for transfer\_characteristics value 16 (PQ)  See Formulae (E-72) to (E-74) for transfer\_characteristics value 18 (HLG) |
| 15 | IPT-C2 | Society of Motion Picture and Television Engineers ST 2128  See Formulae (E‑75) to (E‑77) |
| 16 | YCgCo-Re | See Formulae (E‑41) to (E‑55) |
| 17 | YCgCo-Ro | See Formulae (E‑41) to (E‑55) |
| 18..255 | Reserved | For future use by ITU‑T | ISO/IEC |