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| *Title:* | **BT.HDR and its implications for VUI** | | |
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| *Source:* | Motion Picture Laboratories Inc., NBCUniversal Inc., Dolby Laboratories, Inc., British Broadcasting Corp. | | |

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# Abstract

At the February 2016 meeting of ITU-R WP6C, the document “Draft new Recommendation ITU-R BT.[HDR-TV]: Image parameter values for high dynamic range television for use in production and international programme exchange” was approved that combines color primaries identical to BT.2020 with independent selections in each aspect of : transfer function (PQ or Hybrid Log Gamma); color formats (Y'C'BC'R Non-constant luminance (NCL) , ICTCP Constant Intensity, or R'G'B'); integer code level range (full or narrow) and bit depth (10 or 12 bits). “BT.HDR” is a temporary name for this recommendation: it will be assigned a BT. series number when WP6C next meets in October 2016, approving the final recommendation. This JCT document suggests text changes to HEVC Annex E (VUI) that provide BT.HDR indicators as per WP6C liaison to MPEG and VCEG at this meeting in San Diego.

# Introduction

The following table summarizes the permitted BT.HDR DNR signal container combinations.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Transfer | PQ (*transfer\_characteristics*=16) | | - or - | HLG (*transfer\_characteristics*=18) |
| Range | Full range (*video\_full\_range\_flag*=1) 10-bit:0=black,1024=nominal peak, 1023=clipped nominal peak 12-bit:0=black,4096=nominal peak, 4092=clipped nominal peak | | - or - | Narrow range (same as BT.2020) (*video\_full\_range\_flag*=0) 10-bit: 64=black, 940=white 12-bit: 256=black, 3760=nominal peak white; 3840=peak color signal |
| Bit depth | 10 or 12 bit integer (same as BT.2020) for R'G'B' or Y'C'BC'R,, or ICTCP.  16-bit half float for linear R,G,B for file based production exchange (1.0 = 1 cd/m2 for PQ; 1.0=nominal peak white for HLG) | | | |
| Color primaries | *colour\_primaries* = 9 (same as BT.2020) | | | |
| Color 4:2:0 sub-pixel citing | Horizontally and vertically co-sited (same as BT.2020) (*chroma\_sample\_loc\_type\_top\_field* = *chroma\_sample\_loc\_type\_bottom\_field* = 2) | | | |
| Color formats | Y'C'BC'R*,*Non-Constant Luminance (*matrix\_coeffs*=9) | - or -  - or - | | ICTCP (*matrix\_coeffs*=14?)  R'G'B' (*matrix\_coeffs*=0) |

Applications such as DVB UHD Phase 2, ATSC 3.0, and UltraHD Blu-Ray would limit BitDepth and Range according to their respective requirements, and require specific values for matrix\_coeffs, transfer\_characteristics, etc. Existing “HDR-10” profiles in Ultra HD Blu-Ray, UHD Alliance, Ultra HD Forum, DECE Common File Format, and ARIB STD-B67 [9] are aligned with the BT.HDR VUI code points proposed in this document.

A full copy of BT.HDR DNR [1] and background on the BT.HDR application described in the BT.HDR draft Report BT.2390 are attached in the liaisons to MPEG [2] and VCEG [3].

Table 3 in BT.HDR DNR [1] also describes the reference viewing background and surround brightness, viewing distance, and display luminance range.

Although BT.2020 was designed for SDR/WCG video, and BT.HDR was designed for HDR, it may be worth noting a few key differences between BT.2020 and BT.HDR:

* full range was not explicitly included in BT.2020, while BT.HDR full range uses all 1024 code levels for active picture 10-bit signals, and 4093 code levels for 12-bit signals (clipped range: [0,4092] to better align with 10-bit clipped range: 4\*1023=4092).
* BT.HDR does not include constant luminance (Y'CC'BCC'RC)
* BT.HDR does not include a BT.709-style gamma transfer function.

## Signal range and scaling from real signals to integer code levels

The *full* range real-value signal (E′) to bit depth (n) integer code level (D) scaling formula is described in Table 9 of BT.HDR DNR (portions recreated in the table below), expressed in equations E-10a through E-12a and E-13a through E-15a in the proposed Annex E text change section of this document:

|  |  |  |
| --- | --- | --- |
| Quantization of *R', G', B', Y', I* | D=*INT*[ E′ \* 2n ] | |
| Quantization of *C'B, C'R, CT, CP* | D=*INT*[ (E′ + 0.5)\* 2n] | |
| Quantization levels | 10-bit coding | 12-bit coding |
| Black  (*R’* = *G’* = *B’* = *Y’* = *I* = 0)  *DR', DG', DB', DY', DI* | 0 | 0 |
| Achromatic  (*C’B* = *C’R* = 0)  *DC'B, DC'R, DCT, DCP* | 512 | 2048 |
| Nominal [Clipped] Peak  (*R’* = *G’* = *B’* = *Y’* = *I* = 1)  *DR', DG', DB', DY', DI* | 1023 | 4092 |
| Nominal [Clipped] Peak  (*C’B* = *C’R* = ±0.5)  *DC'B, DC'R, DCT, DCP* | 1023 | 4092 |

JCTVC-T0103 [7] section 2.3 suggested adding informative range information (video\_info\_range\_type) in SEI to distinguish the various flavours of full signal ranges practiced in industry. For example, SDI and SMPTE RP-2077 have full range conventions that clamp a 10-bit signal to [4,1019]. BT.HDR would present a scenario in the video\_info\_range\_type table entry for 10-bit clipped nominal peak range [0,1023] and 12-bit clipped nominal peak range [0,4092].

Regardless of the value for *video\_full\_range\_flag*, consumer distribution application systems such as DVB strongly recommend that HEVC (and AVC) decoders output all 1024 reconstructed 10-bit code levels and, likely in future 12-bit profiles, all 4096 reconstructed 12-bit code levels to facilitate transform coefficient sparseness in transcoding, among other motivations.

The DVB A157 Blue Book specification for HEVC video [8] states in section 5.14.1.5.2 (Video Range):

“Regardless of the value of the **video\_full\_range\_flag**, it is strongly recommended that the IRD preserves the full 8 or 10 bit signal range.”

NOTE: When the **video\_full\_range\_flag** is equal to "0", the HEVC IRD should not apply clipping at the indicated black and white reference levels or tone mapping between the indicated black and white reference levels.

Note 5h in BT.HDR DNR [1] makes a similar argument for passing all code levels in narrow range (video\_full\_range\_flag=0) signals to displays (from decoders):

**Note 5h**: During production signal values are expected to exceed the range *E´* = [0.0 : 1.0]. This provides processing headroom and avoids signal degradation during cascaded processing. Such values of *E´*, below 0.0 or exceeding 1.0, should not be clipped during production and exchange. Values exceeding 1.0 should not be shown on reference displays. Values below 0.0 should not be clipped in reference displays (even though they represent “negative” light) to allow the black level of the signal (*LB*) to be properly set using test signals known as “PLUGE” see Recommendation ITU-R BT.814.

## Color primaries

BT.HDR color primaries are identical to BT.2020. Therefore, it is suggested that BT.HDR signals indicators re-use the existing Table E.4 entry for the BT.2020 *colour\_primaries* code point. Background on the ICTCP color format is provided in [5].

## Transfer function characteristics

For Table E.4 HLG entry (*transfer\_characteristics*=18), an alternative equation could be substituted, at the discretion of the HEVC editors, which assumes an input signal range of [0,1] instead of [0,12]. The input signal range [0,1] HLG OETF is as described in the BT.HDR Note 5b copied below. Though the OETF style below (with normalized input range [0,1]) and the proposed Table E.4 transfer\_characteristics=18 OETF style (normalized to [0,12] input range) have the same meaning, the constants b and c below have been adjusted to so that output range of both equivalent OETF styles produce the same [0,1] output range. The [0,12] input range style has also been proposed at this meeting [4] for inclusion in a future AVC amendment.

**Note 5b**: If *E* is normalised to the range [0:1] then the equivalent equation for the OETF is:



where a= 0.17883277, b= 0.02372241, c= 1.00429347

## Translation of HEVC VUI signal container descriptors to HDMI

Only two new code points in HDMI would be necessary to represent the BT.HDR DNR signal container combinations in this document. BBC’s slide 38 in m37535\_r2.pdf attached with the JCTVC-W0037 / MPEG  m37536  .zip archive suggests using CEA 861.3 *EOTF* code = 3 to indicate Hybrid Log-Gamma.

|  |  |  |
| --- | --- | --- |
| VUI metadata bitstream elements (color difference signals) | Mapped HDMI elements (if video format is unaltered after HEVC decode) | |
| *colour\_primaries=9* (BT.2020) | (HDMI 2.0) AVI InfoFrame  Bits: *C1*=1,*C0*=1 | *EC2*=1,*EC1*=1,*EC0*=0 |
| *matrix\_coeffs=9* (Y'C'BC'R NCL) |
| *matrix\_coeffs=14* (ICTCP) | *EC2*=1,*EC1*=1,*EC0*=1 ? |
| *transfer\_characteristics=16* PQ (SMPTE ST 2084) | CEA 861.3 (Static Metadata Extensions): Dynamic Range and Mastering InfoFrame, Data Byte 1 | *EOTF* = 2 |
| *transfer\_characteristics=18* HLG (ARIB STD-B67) | *EOTF* = 3 |

# Modified text of Annex E

Suggested change text based on latest HEVC draft (JCTVC-V1005-v1.doc) [6] are highlighted in red.

Table E.3 – Colour primaries

|  |  |  |
| --- | --- | --- |
| Value | Primaries | Informative Remark |
| 0 | Reserved | For future use by ITU‑T | ISO/IEC |
| 1 | primary x y  green 0.300 0.600  blue 0.150 0.060  red 0.640 0.330  white D65 0.3127 0.3290 | Rec. ITU‑R BT.709-6  Rec. ITU-R BT.1361 conventional colour gamut system and extended colour gamut system  IEC 61966-2-1 (sRGB or sYCC)  IEC 61966-2-4  Society of Motion Picture and Television Engineers RP 177 (1993) Annex B |
| 2 | Unspecified | Image characteristics are unknown or are determined by the application. |
| 3 | Reserved | For future use by ITU‑T | ISO/IEC |
| 4 | primary x y  green 0.21 0.71  blue 0.14 0.08  red 0.67 0.33  white C 0.310 0.316 | Rec. ITU‑R BT.470‑6 System M (historical)  United States National Television System Committee 1953 Recommendation for transmission standards for colour television  United States Federal Communications Commission Title 47 Code of Federal Regulations (2003) 73.682 (a) (20) |
| 5 | primary x y  green 0.29 0.60  blue 0.15 0.06  red 0.64 0.33  white D65 0.3127 0.3290 | Rec. ITU‑R BT.470‑6 System B, G (historical)  Rec. ITU‑R BT.601‑6 625  Rec. ITU‑R BT.1358 625  Rec. ITU‑R BT.1700 625 PAL and 625 SECAM |
| 6 | primary x y  green 0.310 0.595  blue 0.155 0.070  red 0.630 0.340  white D65 0.3127 0.3290 | Rec. ITU‑R BT.601‑6 525  Rec. ITU‑R BT.1358 525  Rec. ITU‑R BT.1700 NTSC  Society of Motion Picture and Television Engineers 170M (2004)  (functionally the same as the value 7) |
| 7 | primary x y  green 0.310 0.595  blue 0.155 0.070  red 0.630 0.340  white D65 0.3127 0.3290 | Society of Motion Picture and Television Engineers 240M (1999)  (functionally the same as the value 6) |
| 8 | primary x y  green 0.243 0.692 (Wratten 58)  blue 0.145 0.049 (Wratten 47)  red 0.681 0.319 (Wratten 25)  white C 0.310 0.316 | Generic film (colour filters using Illuminant C) |
| 9 | primary x y  green 0.170 0.797  blue 0.131 0.046  red 0.708 0.292  white D65 0.3127 0.3290 | Rec. ITU-R BT.2020-2 Rec. ITU-R BT.HDR DNR |
| 10 | primary x y  green (Y) 0.0 1.0  blue (Z) 0.0 0.0  red (X) 1.0 0.0  centre white 1 ÷ 3 1 ÷ 3 | Society of Motion Picture and Television Engineers ST 428-1  (CIE 1931 XYZ) |
| 11 | primary x y  green 0.265 0.690  blue 0.150 0.060  red 0.680 0.320  white 0.314 0.351 | Society of Motion Picture and Television Engineers RP 431-2 (2011) |
| 12 | primary x y  green 0.265 0.690  blue 0.150 0.060  red 0.680 0.320  white D65 0.3127 0.3290 | Society of Motion Picture and Television Engineers EG 432-1 (2010) |
| 13..21 | Reserved | For future use by ITU‑T | ISO/IEC |
| 22 | primary x y  green 0.295 0.605  blue 0.155 0.077  red 0.630 0.340  white D65 0.3127 0.3290 | EBU Tech. 3213-E (1975) |
| 23..255 | Reserved | For future use by ITU‑T | ISO/IEC |

**transfer\_characteristics**, as specified in Table E.4., either indicates the reference opto-electronic transfer characteristic function of the source picture as a function of a source input linear optical intensity Lc with a nominal real-valued range of 0 to 1 for transfer\_characteristics equal to 1 through 17, and range 0 to 12 for transfer\_characteristics equal to 18, or indicates the inverse of the reference electro-optical transfer characteristic function as a function of an output linear optical intensity Lo with a nominal real-valued range of 0 to 1. For interpretation of entries in Table E.4**.** that are expressed in terms of multiple curve segments parameterized by the variable *α* over a region bounded by the variable *β* or by the variables *β* and *γ*, the values of *α* and *β* are defined to be the positive constants necessary for the curve segments that meet at the value *β* to have continuity of value and continuity of slope at the value *β*, and the value of *γ*, when applicable, is defined to be the positive constant necessary for the associated curve segments to meet at the value *γ*. For example, for transfer\_characteristics equal to 1, 6, 11, 14, or 15, *α* has the value 1 + 5.5 \* *β* = 1.099 296 826 809 442… and *β* has the value 0.018 053 968 510 807....

When the transfer\_characteristics syntax element is not present, the value of transfer\_characteristics is inferred to be equal to 2 (the transfer characteristics are unspecified or are determined by the application). Values of transfer\_characteristics that are identified as reserved in Table E.4 are reserved for future use by ITU-T | ISO/IEC and shall not be present in bitstreams conforming to this version of this Specification. Decoders shall interpret reserved values of transfer\_characteristics as equivalent to the value 2.

NOTE 5 – As indicated in Table E.4, some values of transfer\_characteristics are defined in terms of a reference opto-electronic transfer characteristic function and others are defined in terms of a reference electro-optical transfer characteristic function, according to the convention that has been applied in other Specifications. In the cases of Rec. ITU-R BT.709-6 and Rec. ITU-R BT.2020-2 (which may be indicated by transfer\_characteristics equal to 1, 6, 14, or 15), although the value is defined in terms of a reference opto-electronic transfer characteristic function, a suggested corresponding reference electro-optical transfer characteristic function for flat panel displays used in HDTV studio production has been specified in Rec. ITU-R BT.1886.

Table E.4 – Transfer characteristics

| Value | Transfer Characteristic | Informative Remark |
| --- | --- | --- |
| 0 | Reserved | For future use by ITU‑T | ISO/IEC |
| 1 | V = *α* \* Lc0.45 − ( *α* − 1 ) for 1 >= Lc >= *β*  V = 4.500 \* Lc for *β* > Lc >= 0 | Rec. ITU‑R BT.709-6  Rec. ITU‑R BT.1361 conventional colour gamut system  (functionally the same as the values 6, 14, and 15) |
| 2 | Unspecified | Image characteristics are unknown or are determined by the application. |
| 3 | Reserved | For future use by ITU‑T | ISO/IEC |
| 4 | Assumed display gamma 2.2 | Rec. ITU‑R BT.470‑6 System M (historical)  United States National Television System Committee 1953 Recommendation for transmission standards for colour television  United States Federal Communications Commission Title 47 Code of Federal Regulations (2003) 73.682 (a) (20)  Rec. ITU‑R BT.1700 (2007 revision) 625 PAL and 625 SECAM |
| 5 | Assumed display gamma 2.8 | Rec. ITU‑R BT.470-6 System B, G (historical) |
| 6 | V = *α* \* Lc0.45 − ( *α* − 1 ) for 1 >= Lc >= *β*  V = 4.500 \* Lc for *β* > Lc >= 0 | Rec. ITU‑R BT.601‑6 525 or 625  Rec. ITU‑R BT.1358 525 or 625  Rec. ITU‑R BT.1700 NTSC  Society of Motion Picture and Television Engineers 170M (2004)  (functionally the same as the values 1, 14, and 15) |
| 7 | V = *α* \* Lc0.45 − ( *α* − 1 ) for 1 >= Lc >= *β*  V = 4.0 \* Lc for *β* > Lc >= 0 | Society of Motion Picture and Television Engineers 240M (1999) |
| 8 | V = Lc for all values of Lc | Linear transfer characteristics |
| 9 | V = 1.0 + Log10( Lc ) ÷ 2 for 1 >= Lc >= 0.01  V = 0.0 for 0.01 > Lc >= 0 | Logarithmic transfer characteristic (100:1 range) |
| 10 | V = 1.0 + Log10( Lc ) ÷ 2.5 for 1 >= Lc >= Sqrt( 10 ) ÷ 1000  V = 0.0 for Sqrt( 10 ) ÷ 1000 > Lc >= 0 | Logarithmic transfer characteristic (100 \* Sqrt( 10 ) : 1 range) |
| 11 | V = *α* \* Lc0.45 − ( *α* − 1 ) for Lc >= *β*  V = 4.500 \* Lc for *β* > Lc > −*β*  V = −*α* \* ( −Lc )0.45 + ( *α* − 1 ) for −*β* >= Lc | IEC 61966-2-4 |
| 12 | V = *α* \* Lc0.45 − ( *α* − 1 ) for 1.33 > Lc >= *β*  V = 4.500 \* Lc for *β* > Lc >= −*γ*  V = −( *α* \* ( −4 \* Lc )0.45 − ( *α* − 1 ) ) ÷ 4 for −*γ* > Lc >= −0.25 | Rec. ITU‑R BT.1361 extended colour gamut system |
| 13 | V = *α* \* Lc( 1 ÷ 2.4 ) − ( *α* − 1 ) for 1 >= Lc >= *β*  V = 12.92 \* Lc for *β* > Lc >= 0 | IEC 61966-2-1 (sRGB or sYCC) |
| 14 | V =*α* \* Lc0.45 − ( *α* − 1 ) for 1 >= Lc >= *β*  V = 4.500 \* Lc for *β* > Lc >= 0 | Rec. ITU-R BT.2020-2 (functionally the same as the values 1, 6, and 15) |
| 15 | V =*α* \* Lc0.45 − ( *α* − 1 ) for 1 >= Lc >= *β*  V = 4.500 \* Lc for *β* > Lc >= 0 | Rec. ITU-R BT.2020-2 (functionally the same as the values 1, 6, and 14) |
| 16 | V = ( ( c1 + c2 \* Lon ) ÷ ( 1 + c3 \* Lon ) )m for all values of Lc  c1 = c3 − c2 + 1 = 3424 ÷ 4096 = 0.8359375  c2 = 32 \* 2413 ÷ 4096 = 18.8515625  c3 = 32 \* 2392 ÷ 4096 = 18.6875  m = 128 \* 2523 ÷ 4096 = 78.84375  n = 0.25 \* 2610 ÷ 4096 = 0.1593017578125  for which Lo equal to 1 for peak white is ordinarily intended to correspond to a reference output luminance level of 10 000 candelas per square metre | Society of Motion Picture and Television Engineers ST 2084 for 10, 12, 14, and 16-bit systems  Rec. ITU-R BT.HDR DNR |
| 17 | V = ( 48 \* Lo ÷ 52.37 )( 1 ÷ 2.6 ) for all values of Lo  for which Lo equal to 1 for peak white is ordinarily intended to correspond to a reference outputluminance level of 48 candelas per square metre | Society of Motion Picture and Television Engineers ST 428-1 |
| 18 | V = 0.5 \* Lc0.5 for 1 >= Lc >= 0  V = a \* Ln( Lc − b ) + c for Lc > 1  a = 0.17883277, b = 0.28466892, c = 0.55991073  Lc is the signal for each colour component proportional to scene linear light and scaled by camera exposure, normalized to the range [0:12]. V is the resulting non-linear signal in the range [0:1] | Association of Radio Industries and Businesses (ARIB) STD-B67  Rec. ITU-R BT.HDR DNR |
| 19..255 | Reserved | For future use by ITU‑T | ISO/IEC |

**matrix\_coeffs** describes the matrix coefficients used in deriving luma and chroma signals from the green, blue, and red, or Y, Z, and X primaries, as specified in Table E.1.

matrix\_coeffs shall not be equal to 0 unless one or more of the following conditions are true:

– BitDepthC is equal to BitDepthY.

– chroma\_format\_idc is equal to 3 (4:4:4 chroma format).

[Ed. (GJS): Search entire document for language German (Switzerland) and Spanish (Spain, Traditional Sort) and English (United States) and fix those – perhaps without using revision marking to avoid producing a hard-to-read result. There may also be other languages in here as well.]

The specification of the use of matrix\_coeffs equal to 0 under all other conditions is reserved for future use by ITU‑T | ISO/IEC.

matrix\_coeffs shall not be equal to 8 unless one of the following conditions is true:

– BitDepthC is equal to BitDepthY,

– BitDepthC is equal to BitDepthY + 1 and chroma\_format\_idc is equal to 3 (4:4:4 chroma format).

The specification of the use of matrix\_coeffs equal to 8 under all other conditions is reserved for future use by ITU‑T | ISO/IEC.

When the matrix\_coeffs syntax element is not present, the value of matrix\_coeffs is inferred to be equal to 2 (unspecified).

The interpretation of matrix\_coeffs, together with colour\_primaries and transfer\_characteristics, is specified by the equations below.

NOTE  – For purposes of YZX representation when matrix\_coeffs is equal to 0, the symbols R, G, and B are substituted for X, Y, and Z, respectively, in the following descriptions of Equations E‑1 to E‑3, E‑7 to E‑9, E‑13 to E‑15, and E‑25 to E‑27.

ER, EG, and EB are defined as "linear-domain" real-valued signals based on the indicated colour primaries before application of the transfer characteristics function. The application of the transfer characteristics function is denoted by ( x )′ for an argument x. 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)

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 (IEC 61966-2-4) or 12 (Rec. ITU-R BT.1361 extended colour gamut system) ), E′R, E′G and E′B are real numbers with a larger range not specified in this Specification.

Nominal white is specified as having E′R equal to 1, E′G equal to 1, and E′B equal to 1.

Nominal black is specified as having E′R equal to 0, E′G equal to 0, and E′B equal to 0.

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 or 14, the following equations apply:

Y = Clip1Y( Round( ( 1 << ( BitDepthY − 8 ) ) \* ( 219 \* E′Y + 16 ) ) ) (E‑4)

Cb = Clip1C( Round( ( 1 << ( BitDepthC − 8 ) ) \* ( 224 \* E′PB + 128 ) ) ) (E‑5)

Cr = Clip1C( Round( ( 1 << ( BitDepthC − 8 ) ) \* ( 224 \* E′PR + 128 ) ) ) (E‑6)

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

R = Clip1Y( ( 1 << ( BitDepthY − 8 ) ) \* ( 219 \* E′R + 16 ) ) (E‑7)

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

B = Clip1Y( ( 1 << ( BitDepthY − 8 ) ) \* ( 219 \* E′B + 16 ) ) (E‑9)

– 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, or 14), 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 or 14 the following equations apply:

– If transfer\_characteristics is not equal to 16 or 18 the following equations apply:

Y = Clip1Y( Round( ( ( 1 << BitDepthY ) − 1 ) \* E′Y ) ) (E‑10)

Cb = Clip1C( Round( ( ( 1 << BitDepthC ) − 1 ) \* E′PB + ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑11)

Cr = Clip1C( Round( ( ( 1 << BitDepthC ) − 1 ) \* E′PR + ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑12)

– Otherwise the following equations apply:

Y = Clip1Y( Round( ( 1 << BitDepthY ) \* E′Y ) ) (E‑10a)

Cb = Clip1C( Round( ( 1 << BitDepthC ) \* (E′PB + 0.5) ) ) (E‑11a)

Cr = Clip1C( Round( ( 1 << BitDepthC ) \* (E′PR + 0.5) ) ) (E‑12a)

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

– If transfer\_characteristics is not equal to 16 or 18 the following equations apply:

R = Clip1Y( ( ( 1 << BitDepthY ) − 1 ) \* E′R ) (E‑13)

G = Clip1Y( ( ( 1 << BitDepthY ) − 1 ) \* E′G ) (E‑14)

B = Clip1Y( ( ( 1 << BitDepthY ) − 1 ) \* E′B ) (E‑15)

– Otherwise the following equations apply:

R = Clip1Y( ( 1 << BitDepthY ) \* E′R ) (E‑13a)

G = Clip1Y( ( 1 << BitDepthY ) \* E′G ) (E‑14a)

B = Clip1Y( ( 1 << BitDepthY ) \* E′B ) (E‑15a)

– 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, or 14), 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 Specification. Decoders shall interpret reserved values of matrix\_coeffs as equivalent to the value 2.

It is a requirement of bitstreams 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\_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‑16)



KB = (E‑17)



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

zR = 1 − (xR + yR) (E‑18)

zG = 1 − (xG + yG) (E‑19)

zB = 1 − (xB + yB) (E‑20)

zW = 1 − (xW + yW) (E‑21)

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

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

E′Y = KR \* E′R + ( 1 − KR − KB ) \* E′G + KB \* E′B (E‑22)

E′PB = 0.5 \* ( E′B − E′Y ) ÷ ( 1 − KB ) (E‑23)

E′PR = 0.5 \* ( E′R − E′Y ) ÷ ( 1 − KR ) (E‑24)

NOTE 7 – 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 (IEC 61966‑2‑4), or 12 (ITU‑R BT.1361 extended colour gamut system), E′Y, E′PB and E′PR are real numbers with a larger range not specified in this Specification.

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

Y = Round( G ) (E‑25)

Cb = Round( B ) (E‑26)

Cr = Round( R ) (E‑27)

– Otherwise, if matrix\_coeffs is equal to 8, the following applies:

– If BitDepthC is equal to BitDepthY, the following equations apply:

Y = Round( 0.5 \* G + 0.25 \* ( R + B ) ) (E‑28)

Cb = Round( 0.5 \* G − 0.25 \* ( R + B ) ) + ( 1 << ( BitDepthC − 1 ) ) (E‑29)

Cr = Round( 0.5 \* (R − B ) ) + ( 1 << ( BitDepthC − 1 ) ) (E‑30)

NOTE 8 – For purposes of the YCgCo nomenclature used in Table E.5, Cb and Cr of Equations E‑29 and E‑30 may be referred to as Cg and Co, respectively. The inverse conversion for the above three equations should be computed as:

t = Y − ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) (E‑31)

G = Clip1Y( Y + ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑32)

B = Clip1Y( t − ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑33)

R = Clip1Y( t + ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑34)

– Otherwise (BitDepthC is not equal to BitDepthY), the following equations apply:

Cr = Round( R ) − Round( B ) + ( 1 << ( BitDepthC − 1 ) ) (E‑35)

t = Round( B ) + ( ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) (E‑36)

Cb = Round( G ) − t + ( 1 << ( BitDepthC − 1 ) ) (E‑37)

Y = t + ( ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) (E‑38)

NOTE 9 – For purposes of the YCgCo nomenclature used in Table E.5, Cb and Cr of Equations E‑37 and E‑35 may be referred to as Cg and Co, respectively. The inverse conversion for the above four equations should be computed as.

t = Y − ( ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) (E‑39)

G = Clip1Y( t + ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑40)

B = Clip1Y( t − ( ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) ) (E‑41)

R = Clip1Y( B + ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑42)

– 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 Equations E‑45 to E‑52 apply for specification of the signals E′PB and E′PR:

EY = KR \* ER + ( 1 − KR − KB ) \* EG + KB \* EB (E‑43)

E′Y = ( EY )′ (E‑44)

NOTE 10 – 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 analogue with the value 0 associated with nominal black and the value 1 associated with nominal white.

E′PB = ( E′B − E′Y ) ÷ ( 2 \* NB ) for − NB <= E′B − E′Y  <= 0 (E‑45)

E′PB = ( E′B − E′Y ) ÷ ( 2 \* PB ) for 0 < E′B − E′Y <= PB (E‑46)

E′PR = ( E′R − E′Y ) ÷ ( 2 \* NR ) for − NR <= E′R − E′Y  <= 0 (E‑47)

E′PR = ( E′R − E′Y ) ÷ ( 2 \* PR ) for 0 < E′R − E′Y  <= PR (E‑48)

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‑49)

PB = 1 − ( KB )′ (E‑50)

NR = ( 1 − KR )′ (E‑51)

PR = 1 − (  KR )′ (E‑52)

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

E′Y = E′G (E‑53)

E′PB = 0.5 \* ( 0.986566 \* E′B − E′Y ) (E‑54)

E′PR = 0.5 \* ( E′R − 0.991902 \* E′Y ) (E‑55)

NOTE  – In this case, E′PB may be referred to as D′Z and E′PR may be referred to as D′X.

– Otherwise (matrix\_coeffs is equal to 14), the following equations apply:

EL = ( 1688 \* ER + 2146 \* EG + 262 \* EB) ÷ 4096 (E‑56)

EM = ( 683 \* ER + 2951 \* EG + 462 \* EB) ÷ 4096 (E‑57)

ES = ( 99 \* ER + 309 \* EG + 3688 \* EB) ÷ 4096 (E‑58)

EL, EM, and ES are defined as "linear-domain" real-valued L, M, S colour space signals when colour\_primaries is equal to 9 (Rec. ITU-R BT. 2020-2) before application of the transfer characteristics function. The signals E′L, E′M, and E′S are determined by application of the transfer characteristics function, when transfer\_characteristics is equal to 16 or 18, as follows:

E′L = ( EL )′ (E‑59)

E′M = ( EM )′ (E‑60)

E′S = ( ES )′ (E‑61)

E′Y = 0.5 \* E′L + 0.5 \* E′M (E‑62)

E′PB = ( 6610 \* E′L − 13613 \* E′M + 7003 \* E′S) ÷ 4096 (E‑63)

E′PR = ( 17933 \* E′L − 17390 \* E′M − 543 \* E′S ) ÷ 4096 (E‑64)

NOTE 12 – For purposes of the ICTCP nomenclature used in Table E.5, E′Y, E′PB and E′PR of equations E-62, E-63, and E-64 may be referred to as I, CT and CP, respectively

.

Table E.5 – Matrix coefficients

|  |  |  |
| --- | --- | --- |
| 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); see Equations E‑25 to E‑27  IEC 61966-2-1 sRGB  Society of Motion Picture and Television Engineers ST 428-1 |
| 1 | KR = 0.2126; KB = 0.0722 | ITU‑R Rec. BT.709-6  ITU‑R Rec. BT.1361 conventional colour gamut system and extended colour gamut system  IEC 61966-2-1 sYCC  IEC 61966-2-4 xvYCC709  Society of Motion Picture and Television Engineers RP 177 (1993) Annex B |
| 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 (2003) 73.682 (a) (20) |
| 5 | KR = 0.299; KB = 0.114 | ITU‑R Rec. BT.470‑6 System B, G (historical)  ITU‑R Rec. BT.601‑6 625  ITU‑R Rec. BT.1358 625  ITU‑R Rec. BT.1700 625 PAL and 625 SECAM  IEC 61966-2-4 xvYCC601  (functionally the same as the value 6) |
| 6 | KR = 0.299; KB = 0.114 | ITU‑R Rec. BT.601‑6 525  ITU‑R Rec. BT.1358 525  ITU‑R Rec. BT.1700 NTSC  Society of Motion Picture and Television Engineers 170M (2004)  (functionally the same as the value 5) |
| 7 | KR = 0.212; KB = 0.087 | Society of Motion Picture and Television Engineers 240M (1999) |
| 8 | YCgCo | See Equations E‑28 to E‑42 |
| 9 | KR = 0.2627; KB = 0.0593 | Rec. ITU-R BT.2020-2 non-constant luminance system  Rec. ITU-R BT.HDR DNR  See Equations E‑22 to E‑24 |
| 10 | KR = 0.2627; KB = 0.0593 | Rec. ITU-R BT.2020-2 constant luminance system  See Equations E‑43 to E‑52 |
| 11 | Y′D′ZD′X | Society of Motion Picture and Television Engineers ST 2085 (2015)  See Equations E‑53 to E‑55 |
| 12 | See Equations E‑16 to E‑21 | General non-constant luminance system  See Equations E‑22 to E‑24 |
| 13 | See Equations E‑16 to E‑21 | General constant luminance system  See Equations E‑43 to E‑52 |
| 14 | ICTCP | Rec. ITU-R BT.HDR DNR  See Equations E-56 to E-64 |
| 15..255 | Reserved | For future use by ITU‑T | ISO/IEC |

# References

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[8] DVB A157: <https://www.dvb.org/resources/public/standards/a157_mpeg_2.pdf>

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**Motion Picture Laboratories, Inc. (“MovieLabs”) does not have any current or pending patent rights relating to the technology described in this contribution.**

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Type 1 patent statement for SMPTE ST 2084:

<https://kws.smpte.org/kws/public/document?document_id=36377&wg_abbrev=patents>

ITU-R WP6C “free of charge” patent statement for BT.HDR:

<http://www.itu.int/md/R15-WP6C-C-0057/en>

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