1. Annex E  
     
   Video usability information

(This annex forms an integral part of this Recommendation | International Standard)

* 1. General

This annex specifies syntax and semantics of the VUI parameters of the SPSs.

VUI parameters are not required for constructing the luma or chroma samples by the decoding process. Conforming decoders are not required to process this information for output order conformance to this Specification (see Annex C for the specification of output order conformance). Some VUI parameters are required to check bitstream conformance and for output timing decoder conformance.

In Annex E, specification for presence of VUI parameters is also satisfied when those parameters (or some subset of them) are conveyed to decoders (or to the HRD) by other means not specified in this Specification. When present in the bitstream, VUI parameters shall follow the syntax and semantics specified in this annex. When the content of VUI parameters is conveyed for the application by some means other than presence within the bitstream, the representation of the content of the VUI parameters is not required to use the same syntax specified in this annex. For the purpose of counting bits, only the appropriate bits that are actually present in the bitstream are counted.

* 1. VUI syntax
     1. VUI parameters syntax

|  |  |
| --- | --- |
| vui\_parameters( ) { | Descriptor |
| **aspect\_ratio\_info\_present\_flag** | u(1) |
| if( aspect\_ratio\_info\_present\_flag ) { |  |
| **aspect\_ratio\_idc** | u(8) |
| if( aspect\_ratio\_idc = = EXTENDED\_SAR ) { |  |
| **sar\_width** | u(16) |
| **sar\_height** | u(16) |
| } |  |
| } |  |
| **overscan\_info\_present\_flag** | u(1) |
| if( overscan\_info\_present\_flag ) |  |
| **overscan\_appropriate\_flag** | u(1) |
| **video\_signal\_type\_present\_flag** | u(1) |
| if( video\_signal\_type\_present\_flag ) { |  |
| **video\_format** | u(3) |
| **video\_full\_range\_flag** | u(1) |
| **colour\_description\_present\_flag** | u(1) |
| if( colour\_description\_present\_flag ) { |  |
| **colour\_primaries** | u(8) |
| **transfer\_characteristics** | u(8) |
| **matrix\_coeffs** | u(8) |
| } |  |
| } |  |
| **chroma\_loc\_info\_present\_flag** | u(1) |
| if( chroma\_loc\_info\_present\_flag ) { |  |
| **chroma\_sample\_loc\_type\_top\_field** | ue(v) |
| **chroma\_sample\_loc\_type\_bottom\_field** | ue(v) |
| } |  |
| **neutral\_chroma\_indication\_flag** | u(1) |
| **field\_seq\_flag** | u(1) |
| **frame\_field\_info\_present\_flag** | u(1) |
| **default\_display\_window\_flag** | u(1) |
| if( default\_display\_window\_flag ) { |  |
| **def\_disp\_win\_left\_offset** | ue(v) |
| **def\_disp\_win\_right\_offset** | ue(v) |
| **def\_disp\_win\_top\_offset** | ue(v) |
| **def\_disp\_win\_bottom\_offset** | ue(v) |
| } |  |
| **vui\_timing\_info\_present\_flag** | u(1) |
| if( vui\_timing\_info\_present\_flag ) { |  |
| **vui\_num\_units\_in\_tick** | u(32) |
| **vui\_time\_scale** | u(32) |
| **vui\_poc\_proportional\_to\_timing\_flag** | u(1) |
| if( vui\_poc\_proportional\_to\_timing\_flag ) |  |
| **vui\_num\_ticks\_poc\_diff\_one\_minus1** | ue(v) |
| **vui\_hrd\_parameters\_present\_flag** | u(1) |
| if( vui\_hrd\_parameters\_present\_flag ) |  |
| hrd\_parameters( 1, sps\_max\_sub\_layers\_minus1 ) |  |
| } |  |
| **bitstream\_restriction\_flag** | u(1) |
| if( bitstream\_restriction\_flag ) { |  |
| **tiles\_fixed\_structure\_flag** | u(1) |
| **motion\_vectors\_over\_pic\_boundaries\_flag** | u(1) |
| **restricted\_ref\_pic\_lists\_flag** | u(1) |
| **min\_spatial\_segmentation\_idc** | ue(v) |
| **max\_bytes\_per\_pic\_denom** | ue(v) |
| **max\_bits\_per\_min\_cu\_denom** | ue(v) |
| **log2\_max\_mv\_length\_horizontal** | ue(v) |
| **log2\_max\_mv\_length\_vertical** | ue(v) |
| } |  |
| } |  |

* + 1. HRD parameters syntax

|  |  |
| --- | --- |
| hrd\_parameters( commonInfPresentFlag, maxNumSubLayersMinus1 ) { | Descriptor |
| if( commonInfPresentFlag ) { |  |
| **nal\_hrd\_parameters\_present\_flag** | u(1) |
| **vcl\_hrd\_parameters\_present\_flag** | u(1) |
| if( nal\_hrd\_parameters\_present\_flag | | vcl\_hrd\_parameters\_present\_flag ){ |  |
| **sub\_pic\_hrd\_params\_present\_flag** | u(1) |
| if( sub\_pic\_hrd\_params\_present\_flag ) { |  |
| **tick\_divisor\_minus2** | u(8) |
| **du\_cpb\_removal\_delay\_increment\_length\_minus1** | u(5) |
| **sub\_pic\_cpb\_params\_in\_pic\_timing\_sei\_flag** | u(1) |
| **dpb\_output\_delay\_du\_length\_minus1** | u(5) |
| } |  |
| **bit\_rate\_scale** | u(4) |
| **cpb\_size\_scale** | u(4) |
| if( sub\_pic\_hrd\_params\_present\_flag ) |  |
| **cpb\_size\_du\_scale** | u(4) |
| **initial\_cpb\_removal\_delay\_length\_minus1** | u(5) |
| **au\_cpb\_removal\_delay\_length\_minus1** | u(5) |
| **dpb\_output\_delay\_length\_minus1** | u(5) |
| } |  |
| } |  |
| for( i = 0; i <= maxNumSubLayersMinus1; i++ ) { |  |
| **fixed\_pic\_rate\_general\_flag**[ i ] | u(1) |
| if( !fixed\_pic\_rate\_general\_flag[ i ] ) |  |
| **fixed\_pic\_rate\_within\_cvs\_flag**[ i ] | u(1) |
| if( fixed\_pic\_rate\_within\_cvs\_flag[ i ] ) |  |
| **elemental\_duration\_in\_tc\_minus1**[ i ] | ue(v) |
| else |  |
| **low\_delay\_hrd\_flag**[ i ] | u(1) |
| if( !low\_delay\_hrd\_flag[ i ] ) |  |
| **cpb\_cnt\_minus1**[ i ] | ue(v) |
| if( nal\_hrd\_parameters\_present\_flag ) |  |
| sub\_layer\_hrd\_parameters( i ) |  |
| if( vcl\_hrd\_parameters\_present\_flag ) |  |
| sub\_layer\_hrd\_parameters( i ) |  |
| } |  |
| } |  |

* + 1. Sub-layer HRD parameters syntax

|  |  |
| --- | --- |
| sub\_layer\_hrd\_parameters( subLayerId ) { | Descriptor |
| for( i = 0; i <= CpbCnt; i++ ) { |  |
| **bit\_rate\_value\_minus1[** i ] | ue(v) |
| **cpb\_size\_value\_minus1[** i ] | ue(v) |
| if( sub\_pic\_hrd\_params\_present\_flag ) { |  |
| **cpb\_size\_du\_value\_minus1**[ i ] | ue(v) |
| **bit\_rate\_du\_value\_minus1**[ i ] | ue(v) |
| } |  |
| **cbr\_flag[** i ] | u(1) |
| } |  |
| } |  |

* 1. VUI semantics
     1. VUI parameters semantics

**aspect\_ratio\_info\_present\_flag** equal to 1 specifies that aspect\_ratio\_idc is present. aspect\_ratio\_info\_present\_flag equal to 0 specifies that aspect\_ratio\_idc is not present.

**aspect\_ratio\_idc** specifies the value of the sample aspect ratio of the luma samples. Table E‑1 shows the meaning of the code. When aspect\_ratio\_idc indicates EXTENDED\_SAR, the sample aspect ratio is represented by sar\_width : sar\_height. When the aspect\_ratio\_idc syntax element is not present, aspect\_ratio\_idc value is inferred to be equal to 0. Values of aspect\_ratio\_idc in the range of 17 to 254, inclusive, 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 values of aspect\_ratio\_idc in the range of 17 to 254, inclusive, as equivalent to the value 0.

Table E‑1 – Interpretation of sample aspect ratio indicator

|  |  |  |
| --- | --- | --- |
| **aspect\_ratio\_idc** | **Sample aspect ratio** | **(informative) Examples of use** |
| 0 | Unspecified |  |
| 1 | 1:1 ("square") | 7680x4320 16:9 frame without horizontal overscan 3840x2160 16:9 frame without horizontal overscan 1280x720 16:9 frame without horizontal overscan 1920x1080 16:9 frame without horizontal overscan (cropped from  1920x1088) 640x480 4:3 frame without horizontal overscan |
| 2 | 12:11 | 720x576 4:3 frame with horizontal overscan 352x288 4:3 frame without horizontal overscan |
| 3 | 10:11 | 720x480 4:3 frame with horizontal overscan 352x240 4:3 frame without horizontal overscan |
| 4 | 16:11 | 720x576 16:9 frame with horizontal overscan 528x576 4:3 frame without horizontal overscan |
| 5 | 40:33 | 720x480 16:9 frame with horizontal overscan 528x480 4:3 frame without horizontal overscan |
| 6 | 24:11 | 352x576 4:3 frame without horizontal overscan 480x576 16:9 frame with horizontal overscan |
| 7 | 20:11 | 352x480 4:3 frame without horizontal overscan 480x480 16:9 frame with horizontal overscan |
| 8 | 32:11 | 352x576 16:9 frame without horizontal overscan |
| 9 | 80:33 | 352x480 16:9 frame without horizontal overscan |
| 10 | 18:11 | 480x576 4:3 frame with horizontal overscan |
| 11 | 15:11 | 480x480 4:3 frame with horizontal overscan |
| 12 | 64:33 | 528x576 16:9 frame without horizontal overscan |
| 13 | 160:99 | 528x480 16:9 frame without horizontal overscan |
| 14 | 4:3 | 1440x1080 16:9 frame without horizontal overscan |
| 15 | 3:2 | 1280x1080 16:9 frame without horizontal overscan |
| 16 | 2:1 | 960x1080 16:9 frame without horizontal overscan |
| 17..254 | Reserved |  |
| 255 | EXTENDED\_SAR |  |

NOTE 1 – For the examples in Table E‑1, the term "without horizontal overscan" refers to display processes in which the display area matches the area of the cropped decoded pictures and the term "with horizontal overscan" refers to display processes in which some parts near the left and/or right border of the cropped decoded pictures are not visible in the display area. As an example, the entry "720x576 4:3 frame with horizontal overscan" for aspect\_ratio\_idc equal to 2 refers to having an area of 704x576 luma samples (which has an aspect ratio of 4:3) of the cropped decoded frame (720x576 luma samples) that is visible in the display area.

NOTE 2 – For the examples in Table E‑1, the frame spatial resolutions shown as examples of use would be the dimensions of the conformance cropping window when field\_seq\_flag is equal to 0, and would have twice the height of the dimensions of the conformance cropping window when field\_seq\_flag is equal to 1.

**sar\_width** indicates the horizontal size of the sample aspect ratio (in arbitrary units).

**sar\_height** indicates the vertical size of the sample aspect ratio (in the same arbitrary units as sar\_width).

sar\_width and sar\_height shall be relatively prime or equal to 0. When aspect\_ratio\_idc is equal to 0 or sar\_width is equal to 0 or sar\_height is equal to 0, the sample aspect ratio is unspecified in this Specification.

**overscan\_info\_present\_flag** equal to 1 specifies that the overscan\_appropriate\_flag is present. When overscan\_info\_present\_flag is equal to 0 or is not present, the preferred display method for the video signal is unspecified.

**overscan\_appropriate\_flag** equal to 1 indicates that the cropped decoded pictures output are suitable for display using overscan. overscan\_appropriate\_flag equal to 0 indicates that the cropped decoded pictures output contain visually important information in the entire region out to the edges of the conformance cropping window of the picture, such that the cropped decoded pictures output should not be displayed using overscan. Instead, they should be displayed using either an exact match between the display area and the conformance cropping window, or using underscan. As used in this paragraph, the term "overscan" refers to display processes in which some parts near the borders of the cropped decoded pictures are not visible in the display area. The term "underscan" describes display processes in which the entire cropped decoded pictures are visible in the display area, but they do not cover the entire display area. For display processes that neither use overscan nor underscan, the display area exactly matches the area of the cropped decoded pictures.

NOTE 3 – For example, overscan\_appropriate\_flag equal to 1 might be used for entertainment television programming, or for a live view of people in a videoconference, and overscan\_appropriate\_flag equal to 0 might be used for computer screen capture or security camera content.

**video\_signal\_type\_present\_flag** equal to 1 specifies that video\_format, video\_full\_range\_flag and colour\_description\_present\_flag are present. video\_signal\_type\_present\_flag equal to 0, specify that video\_format, video\_full\_range\_flag and colour\_description\_present\_flag are not present.

**video\_format** indicates the representation of the pictures as specified in Table E‑2, before being coded in accordance with this Specification. When the video\_format syntax element is not present, video\_format value is inferred to be equal to 5. The values 6 and 7 for video\_format 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 the values 6 and 7 for video\_format as equivalent to the value 5.

Table E‑2 – Meaning of video\_format

|  |  |
| --- | --- |
| **video\_format** | **Meaning** |
| 0 | Component |
| 1 | PAL |
| 2 | NTSC |
| 3 | SECAM |
| 4 | MAC |
| 5 | Unspecified video format |

**video\_full\_range\_flag** indicates the black level and range of the luma and chroma signals as derived from E′Y, E′PB, and E′PR or E′R, E′G, and E′B real-valued component signals.

When the video\_full\_range\_flag syntax element is not present, the value of video\_full\_range\_flag is inferred to be equal to 0.

**colour\_description\_present\_flag** equal to 1 specifies that colour\_primaries, transfer\_characteristics and matrix\_coeffs are present. colour\_description\_present\_flag equal to 0 specifies that colour\_primaries, transfer\_characteristics and matrix\_coeffs are not present.

**colour\_primaries** indicates the chromaticity coordinates of the source primaries as specified in Table E‑3 in terms of the CIE 1931 definition of x and y as specified in ISO 11664-1.

When the colour\_primaries syntax element is not present, the value of colour\_primaries is inferred to be equal to 2 (the chromaticity is unspecified or is determined by the application). Values of colour\_primaries that are identified as reserved in Table E‑3 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 colour\_primaries as equivalent to the value 2.

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.709-5  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 |
| 10 | primary x y  Y 0.0 1.0  Z 0.0 0.0  X 1.0 0.0  center white 0.333 0.333 | Society of Motion Picture and Television Engineers ST 428-1  (CIE 1931 XYZ , Digital Cinema) |
| 11..255 | Reserved | For future use by ITU‑T | ISO/IEC |

**transfer\_characteristics** indicates the opto-electronic transfer characteristic of the source picture as specified in Table E‑4 as a function of a linear optical intensity input Lc with a nominal real-valued range of 0 to 1.

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.

Table E‑4 – Transfer characteristics

| Value | Transfer Characteristic | Informative Remark |
| --- | --- | --- |
| 0 | Reserved | For future use by ITU‑T | ISO/IEC |
| 1 | V = 1.099 \* Lc0.45 − 0.099 for 1 >= Lc >= 0.018  V = 4.500 \* Lc for 0.018 > Lc >= 0 | Rec. ITU‑R BT.709-5  Rec. ITU‑R BT.1361 conventional colour gamut system  (functionally the same as the value 6) |
| 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 = 1.099 \* Lc0.45 − 0.099 for 1 >= Lc >= 0.018  V = 4.500 \* Lc for 0.018 > 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 value 1) |
| 7 | V = 1.1115 \* Lc0.45 − 0.1115 for 1 >= Lc >= 0.0228  V = 4.0 \* Lc for 0.0228 > Lc >= 0 | Society of Motion Picture and Television Engineers 240M (1999) |
| 8 | V = Lc for 1 > Lc >= 0 | 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 = 1.099 \* Lc0.45 − 0.099 for Lc >= 0.018  V = 4.500 \* Lc for 0.018 > Lc > −0.018  V = −1.099 \* ( −Lc )0.45 + 0.099 for −0.018 >= Lc | IEC 61966-2-4 |
| 12 | V = 1.099 \* Lc0.45 − 0.099 for 1.33 > Lc >= 0.018  V = 4.500 \* Lc for 0.018 > Lc >= −0.0045  V = −( 1.099 \* ( −4 \* Lc )0.45 − 0.099 ) ÷ 4 for −0.0045 > Lc >= −0.25 | Rec. ITU‑R BT.1361 extended colour gamut system |
| 13 | V = 1.055 \* Lc( 1 ÷ 2.4 ) − 0.055 for 1 >= Lc >= 0.0031308  V = 12.92 \* Lc for 0.0031308 > Lc >= 0 | IEC 61966-2-1 (sRGB or sYCC) |
| 14 | V =1.099 \* Lc0.45 − 0.099 for 1 >= Lc >= 0.018  V = 4.500 \* Lc for 0.018 > Lc >= 0 | Rec. ITU-R BT.2020 for 10 bit system |
| 15 | V =1.0993\* Lc0.45 − 0.0993 for 1 >= Lc >= 0.0181  V = 4.500 \* Lc for 0.0181 > Lc >= 0 | Rec. ITU-R BT.2020 for 12 bit system |
| 16 | , where 0 ≤ C ≤ 10000  C is absolute luminance value, represented in candelas per square meter (cd/m2) | Society of Motion Picture and Television Engineers ST 2084 for 10, 12, 14, and 16-bit systems. |
| 17..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 primaries, as specified in Table E‑5.

matrix\_coeffs shall not be equal to 0 or 11 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).

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).

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.

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, or 10, 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, or 10), 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 or 10 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, if matrix\_coeffs is equal to 0 or 8, 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, 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 or 10), 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.

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, or 10, the following equations apply:

E′Y = KR \* E′R + ( 1 − KR − KB ) \* E′G + KB \* E′B (E‑16)

E′PB = 0.5 \* ( E′B − E′Y ) ÷ ( 1 − KB ) (E‑17)

E′PR = 0.5 \* ( E′R − E′Y ) ÷ ( 1 − KR ) (E‑18)

NOTE 4 – 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‑19)

Cb = Round( B ) (E‑20)

Cr = Round( R ) (E‑21)

– 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‑22)

Cb = Round( 0.5 \* G − 0.25 \* ( R + B ) ) + ( 1 << ( BitDepthC − 1 ) ) (E‑23)

Cr = Round( 0.5 \* (R − B ) ) + ( 1 << ( BitDepthC − 1 ) ) (E‑24)

NOTE 5 – For purposes of the YCgCo nomenclature used in Table E‑5, Cb and Cr of Equations E‑23 and E‑24 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‑25)

G = Clip1Y( Y + ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑26)

B = Clip1Y( t − ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑27)

R = Clip1Y( t + ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑28)

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

Cr = Round( R ) − Round( B ) + ( 1 << ( BitDepthC − 1 ) ) (E‑29)

t = Round( B ) + ( ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) (E‑30)

Cb = Round( G ) − t + ( 1 << ( BitDepthC − 1 ) ) (E‑31)

Y = t + ( ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) (E‑32)

NOTE 6 – For purposes of the YCgCo nomenclature used in Table E‑5, Cb and Cr of Equations E‑31 and E‑29 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‑33)

G = Clip1Y( t + ( Cb − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑34)

B = Clip1Y( t − ( ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) >> 1 ) ) (E‑35)

R = Clip1Y( B + ( Cr − ( 1 << ( BitDepthC − 1 ) ) ) ) (E‑36)

– Otherwise (matrix\_coeffs is equal to 10), the following equations apply:

EY = KR \* ER + ( 1 − KR − KB ) \* EG + KB \* EB (E‑37)

E′Y = ( EY )′ (E‑38)

NOTE 7 – 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 ) ÷ 1.9404 for −0.9702 <= E′B − E′Y  <= 0 (E‑39)

E′PB = ( E′B − E′Y ) ÷ 1.5816 for 0 < E′B − E′Y <= 0.7908 (E‑40)

E′PR = ( E′R − E′Y ) ÷ 1.7184 for −0.8592 <= E′R − E′Y  <= 0 (E‑41)

E′PR = ( E′R − E′Y ) ÷ 0.9936 for 0 < E′R − E′Y  <= 0.4968 (E‑42)

The variables EX, EY, and EZ 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′X, E′Y, and E′Z are determined by application of the transfer characteristics function as follows:

E′X = ( EX )′ (E‑43)

E′Y = ( EY )′ (E‑44)

E′Z = ( EZ )′ (E‑45)

E′X, E′Y, and E′Z are real numbers with values in the range of 0 to 1 inclusive.

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

Y = Round( ) (E‑46)

Cb = Round( ) (E‑47)

Cr = Round( ) (E‑48)

Table E‑5 – Matrix coefficients

|  |  |  |
| --- | --- | --- |
| Value | Matrix | Informative remark |
| 0 | GBR | Typically referred to as RGB; see Equations E‑19 to E‑21  IEC 61966-2-1 (sRGB) |
| 1 | KR = 0.2126; KB = 0.0722 | ITU‑R Rec. BT.709-5  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‑22 to E‑36 |
| 9 | KR = 0.2627; KB = 0.0593 | Rec. ITU-R BT.2020 non-constant luminance system  See Equations E‑16 to E‑18 |
| 10 | KR = 0.2627; KB = 0.0593 | Rec. ITU-R BT.2020 constant luminance system  See Equations E‑37 to E‑42 |
| 11 | YZX | Society of Motion Picture and Television Engineers ST 428-1 See Equations E-43 to E-48 |
| 12..255 | Reserved | For future use by ITU‑T | ISO/IEC |

**chroma\_loc\_info\_present\_flag** equal to 1 specifies that chroma\_sample\_loc\_type\_top\_field and chroma\_sample\_loc\_type\_bottom\_field are present. chroma\_loc\_info\_present\_flag equal to 0 specifies that chroma\_sample\_loc\_type\_top\_field and chroma\_sample\_loc\_type\_bottom\_field are not present.

When chroma\_format\_idc is not equal to 1, chroma\_loc\_info\_present\_flag should be equal to 0.

**chroma\_sample\_loc\_type\_top\_field** and **chroma\_sample\_loc\_type\_bottom\_field** specify the location of chroma samples as follows:

– If chroma\_format\_idc is equal to 1 (4:2:0 chroma format), chroma\_sample\_loc\_type\_top\_field and chroma\_sample\_loc\_type\_bottom\_field specify the location of chroma samples for the top field and the bottom field, respectively, as shown in Figure E‑1.

– Otherwise (chroma\_format\_idc is not equal to 1), the values of the syntax elements chroma\_sample\_loc\_type\_top\_field and chroma\_sample\_loc\_type\_bottom\_field shall be ignored. When chroma\_format\_idc is equal to 2 (4:2:2 chroma format) or 3 (4:4:4 chroma format), the location of chroma samples is specified in subclause 6.2. When chroma\_format\_idc is equal to 0, there is no chroma sample array.

The value of chroma\_sample\_loc\_type\_top\_field and chroma\_sample\_loc\_type\_bottom\_field shall be in the range of 0 to 5, inclusive. When the chroma\_sample\_loc\_type\_top\_field and chroma\_sample\_loc\_type\_bottom\_field are not present, the values of chroma\_sample\_loc\_type\_top\_field and chroma\_sample\_loc\_type\_bottom\_field is inferred to be equal to 0.

NOTE 8 – When coding progressive source material, chroma\_sample\_loc\_type\_top\_field and chroma\_sample\_loc\_type\_bottom\_field should have the same value.



Figure E‑1 – Location of chroma samples for top and bottom fields for chroma\_format\_idc equal to 1 (4:2:0 chroma format) as a function of chroma\_sample\_loc\_type\_top\_field and chroma\_sample\_loc\_type\_bottom\_field

**neutral\_chroma\_indication\_flag** equal to 1 indicates that the value of all decoded chroma samples is equal to 1  <<  ( BitDepthC − 1 ). neutral\_chroma\_indication\_flag equal to 0 provides no indication of decoded chroma sample values. When neutral\_chroma\_indication\_flag is equal to 1, it is a requirement of bitstream conformance that the value of all decoded chroma samples produced by the decoding process shall be equal to 1  <<  ( BitDepthC − 1 ). When neutral\_chroma\_indication\_flag is not present, it is inferred to be equal to 0.

NOTE 9 – When neutral\_chroma\_indication\_flag is equal to 1, it is not necessary for the decoder to apply the specified decoding process in order to determine the value of the decoded chroma samples.

**field\_seq\_flag** equal to 1 indicates that the CVS conveys pictures that represent fields, and specifies that a picture timing SEI message shall be present in every access unit of the current CVS. field\_seq\_flag equal to 0 indicates that the CVS conveys pictures that represent frames and that a picture timing SEI message may or may not be present in any access unit of the current CVS. When field\_seq\_flag is not present, it is inferred to be equal to 0. When general\_frame\_only\_constraint\_flag is equal to 1, the value of field\_seq\_flag shall be equal to 0.

NOTE 10 – The specified decoding process does not treat access units conveying pictures that represent fields or frames differently. A sequence of pictures that represent fields would therefore be coded with the picture dimensions of an individual field. For example, access units containing pictures that represent 1080i fields would commonly have cropped output dimensions of 1920x540, while the sequence picture rate would commonly express the rate of the source fields (typically between 50 and 60 Hz), instead of the source frame rate (typically between 25 and 30 Hz).

**frame\_field\_info\_present\_flag** equal to 1 specifies that picture timing SEI messages are present for every picture and include the pic\_struct, source\_scan\_type, and duplicate\_flag syntax elements. frame\_field\_info\_present\_flag equal to 0 specifies that the pic\_struct syntax element is not present in picture timing SEI messages.

When frame\_field\_info\_present\_flag is present and either or both of the following conditions are true, frame\_field\_info\_present\_flag shall be equal to 1:

– field\_seq\_flag is equal to 1.

– general\_progressive\_source\_flag is equal to 1 and general\_interlaced\_source\_flag is equal to 1.

When frame\_field\_info\_present\_flag is not present, its value is inferred as follows:

– If general\_progressive\_source\_flag is equal to 1 and general\_interlaced\_source\_flag is equal to 1, frame\_field\_info\_present\_flag is inferred to be equal to 1.

– Otherwise, frame\_field\_info\_present\_flag is inferred to be equal to 0.

**default\_display\_window\_flag** equal to 1 indicates that the default display window parameters follow next in the VUI. default\_display\_window\_flag equal to 0 indicates that the default display window parameters are not present. The default display window parameters identify the area that is within the conformance cropping window and that is suggested to be displayed in the absence of any alternative indication (provided within the bitstream or by external means not specified in this Specification) of preferred display characteristics.

**def\_disp\_win\_left\_offset**, **def\_disp\_win\_right\_offset**, **def\_disp\_win\_top\_offset**, and **def\_disp\_win\_bottom\_offset** specify the samples of the pictures in the CVS that are within the default display window, in terms of a rectangular region specified in picture coordinates for display. When default\_display\_window\_flag is equal to 0, the values of def\_disp\_win\_left\_offset, def\_disp\_win\_right\_offset, def\_disp\_win\_top\_offset, and def\_disp\_win\_bottom\_offset are inferred to be equal to 0.

The following variables are derived from the default display window parameters:

leftOffset = conf\_win\_left\_offset + def\_disp\_win\_left\_offset (E‑43)

rightOffset = conf\_win\_right\_offset + def\_disp\_win\_right\_offset (E‑44)

topOffset = conf\_win\_top\_offset + def\_disp\_win\_top\_offset (E‑45)

bottomOffset = conf\_win\_bottom\_offset + def\_disp\_win\_bottom\_offset (E‑46)

The default display window contains the luma samples with horizontal picture coordinates from SubWidthC \* leftOffset to pic\_width\_in\_luma\_samples − ( SubWidthC \* rightOffset + 1 ) and vertical picture coordinates from SubHeightC \* topOffset to pic\_height\_in\_luma\_samples − ( SubHeightC \* bottomOffset + 1 ), inclusive.

The value of SubWidthC \* ( leftOffset + rightOffset ) shall be less than pic\_width\_in\_luma\_samples, and the value of SubHeightC \* ( topOffset + bottomOffset ) shall be less than pic\_height\_in\_luma\_samples.

When ChromaArrayType is not equal to 0, the corresponding specified samples of the two chroma arrays are the samples having picture coordinates ( x / SubWidthC, y / SubHeightC ), where ( x, y ) are the picture coordinates of the specified luma samples.

**vui\_timing\_info\_present\_flag** equal to 1 specifies that vui\_num\_units\_in\_tick, vui\_time\_scale, vui\_poc\_proportional\_to\_timing\_flag, and vui\_hrd\_parameters\_present\_flag are present in the vui\_parameters( ) syntax structure. vui\_timing\_info\_present\_flag equal to 0 specifies that vui\_num\_units\_in\_tick, vui\_time\_scale, vui\_poc\_proportional\_to\_timing\_flag, and vui\_hrd\_parameters\_present\_flag are not present in the vui\_parameters( ) syntax structure.

**vui\_num\_units\_in\_tick** is the number of time units of a clock operating at the frequency vui\_time\_scale Hz that corresponds to one increment (called a clock tick) of a clock tick counter. vui\_num\_units\_in\_tick shall be greater than 0. A clock tick, in units of seconds, is equal to the quotient of vui\_num\_units\_in\_tick divided by vui\_time\_scale. For example, when the picture rate of a video signal is 25 Hz, vui\_time\_scale may be equal to 27 000 000 and vui\_num\_units\_in\_tick may be equal to 1 080 000, and consequently a clock tick may be equal to 0.04 seconds.

When vps\_num\_units\_in\_tick is present in the VPS referred to by the SPS, vui\_num\_units\_in\_tick, when present, shall be equal to vps\_num\_units\_in\_tick.

**vui\_time\_scale** is the number of time units that pass in one second. For example, a time coordinate system that measures time using a 27 MHz clock has a vui\_time\_scale of 27 000 000. The value of vui\_time\_scale shall be greater than 0.

When vps\_time\_scale is present in the VPS referred to by the SPS, vui\_time\_scale, when present, shall be equal to vps\_time\_scale.

**vui\_poc\_proportional\_to\_timing\_flag** equal to 1 indicates that the picture order count value for each picture in the CVS that is not the first picture in the CVS, in decoding order, is proportional to the output time of the picture relative to the output time of the first picture in the CVS. vui\_poc\_proportional\_to\_timing\_flag equal to 0 indicates that the picture order count value for each picture in the CVS that is not the first picture in the CVS, in decoding order, may or may not be proportional to the output time of the picture relative to the output time of the first picture in the CVS.

When vps\_poc\_proportional\_to\_timing\_flag is present in the VPS referred to by the SPS and the value is equal to 1, vui\_poc\_proportional\_to\_timing\_flag, when present, shall be equal to 1.

**vui\_num\_ticks\_poc\_diff\_one\_minus1** plus 1 specifies the number of clock ticks corresponding to a difference of picture order count values equal to 1. The value of vui\_num\_ticks\_poc\_diff\_one\_minus1 shall be in the range of 0 to 232 − 2, inclusive.

When vps\_num\_ticks\_poc\_diff\_one\_minus1 is present in the VPS referred to by the SPS, vui\_num\_ticks\_poc\_diff\_one\_minus1, when present, shall be equal to sps\_num\_ticks\_poc\_diff\_one\_minus1.

**vui\_hrd\_parameters\_present\_flag** equal to 1 specifies that the syntax structure hrd\_parameters( ) is present in the vui\_parameters( ) syntax structure. vui\_hrd\_parameters\_present\_flag equal to 0 specifies that the syntax structure hrd\_parameters( ) is not present in the vui\_parameters( ) syntax structure.

**bitstream\_restriction\_flag** equal to 1, specifies that the bitstream restriction parameters for the CVS are present. bitstream\_restriction\_flag equal to 0, specifies that the bitstream restriction parameters for the CVS are not present.

**tiles\_fixed\_structure\_flag** equal to 1 indicates that each PPS that is active in the CVS has the same value of the syntax elements num\_tile\_columns\_minus1, num\_tile\_rows\_minus1, uniform\_spacing\_flag, column\_width\_minus1[ i ], row\_height\_minus1[ i ] and loop\_filter\_across\_tiles\_enabled\_flag, when present. tiles\_fixed\_structure\_flag equal to 0 indicates that tiles syntax elements in different PPSs may or may not have the same value. When the tiles\_fixed\_structure\_flag syntax element is not present, it is inferred to be equal to 0.

NOTE 11 – The signalling of tiles\_fixed\_structure\_flag equal to 1 is a guarantee to a decoder that each picture in the CVS has the same number of tiles distributed in the same way which might be useful for workload allocation in the case of multi-threaded decoding.

**motion\_vectors\_over\_pic\_boundaries\_flag** equal to 0 indicates that no sample outside the picture boundaries and no sample at a fractional sample position for which the sample value is derived using one or more samples outside the picture boundaries is used for inter prediction of any sample. motion\_vectors\_over\_pic\_boundaries\_flag equal to 1 indicates that one or more samples outside the picture boundaries may be used in inter prediction. When the motion\_vectors\_over\_pic\_boundaries\_flag syntax element is not present, motion\_vectors\_over\_pic\_boundaries\_flag value is inferred to be equal to 1.

**restricted\_ref\_pic\_lists\_flag** equal to 1 indicates that all P and B slices (when present) that belong to the same picture have an identical reference picture list 0, and that all B slices (when present) that belong to the same picture have an identical reference picture list 1.

**min\_spatial\_segmentation\_idc**, when not equal to 0, establishes a bound on the maximum possible size of distinct coded spatial segmentation regions in the pictures of the CVS. When min\_spatial\_segmentation\_idc is not present, it is inferred to be equal to 0. The value of min\_spatial\_segmentation\_idc shall be in the range of 0 to 4095, inclusive.

The variable minSpatialSegmentation is derived from min\_spatial\_segmentation\_idc as follows:

minSpatialSegmentationTimes4 = min\_spatial\_segmentation\_idc + 4 (E‑47)

A slice is said to contain a specific luma sample when the coding block that contains the luma sample is contained in the slice. Correspondingly, a tile is said to contain a specific luma sample when the coding block that contains the luma sample is contained in the tile.

Depending on the value of min\_spatial\_segmentation\_idc, the following applies:

– If min\_spatial\_segmentation\_idc is equal to 0, no limit on the maximum size of spatial segments is indicated.

– Otherwise (min\_spatial\_segmentation\_idc is not equal to 0), it is a requirement of bitstream conformance that exactly one of the following conditions shall be true:

– In each PPS that is activated within the CVS, tiles\_enabled\_flag is equal to 0 and entropy\_coding\_sync\_enabled\_flag is equal to 0, and there is no slice in the CVS that contains more than ( 4 \* PicSizeInSamplesY )  minSpatialSegmentationTimes4 luma samples.

– In each PPS that is activated within the CVS, tiles\_enabled\_flag is equal to 1 and entropy\_coding\_sync\_enabled\_flag is equal to 0, and there is no tile in the CVS that contains more than ( 4 \* PicSizeInSamplesY )  minSpatialSegmentationTimes4 luma samples.

– In each PPS that is activated within the CVS, tiles\_enabled\_flag is equal to 0 and entropy\_coding\_sync\_enabled\_flag is equal to 1, and the syntax elements pic\_width\_in\_luma\_samples, pic\_height\_in\_luma\_samples and the variable CtbSizeY obey the following constraint:

( 2 \* pic\_height\_in\_luma\_samples + pic\_width\_in\_luma\_samples ) \* CtbSizeY  
 <=  ( 4 \* PicSizeInSamplesY )  minSpatialSegmentationTimes4 (E‑48)

NOTE 12 – The syntax element min\_spatial\_segmentation\_idc can be used by a decoder to calculate the maximum number of luma samples to be processed by one processing thread, making the assumption that the decoder maximally utilizes the parallel decoding information. However, it is important to be aware that there may be some inter-dependencies between the different threads – e.g. due to entropy coding synchronization or deblocking filtering across tile or slice boundaries. To aid decoders in planning the decoding workload distribution, encoders are encouraged to set the value of min\_spatial\_segmentation\_idc to the highest possible value for which one of the above three conditions is true. For example, for the case when tiles\_enabled\_flag is equal to 0 and entropy\_coding\_sync\_enabled\_flag is equal to 1, encoders should set min\_spatial\_segmentation\_idc equal to 4 \* PicSizeInSamplesY / ( ( 2 \* pic\_height\_in\_luma\_samples + pic\_width\_in\_luma\_samples ) \* CtbSizeY ) − 4.

**max\_bytes\_per\_pic\_denom** indicates a number of bytes not exceeded by the sum of the sizes of the VCL NAL units associated with any coded picture in the CVS.

The number of bytes that represent a picture in the NAL unit stream is specified for this purpose as the total number of bytes of VCL NAL unit data (i.e. the total of the NumBytesInNalUnit variables for the VCL NAL units) for the picture. The value of max\_bytes\_per\_pic\_denom shall be in the range of 0 to 16, inclusive.

Depending on the value of max\_bytes\_per\_pic\_denom the following applies:

– If max\_bytes\_per\_pic\_denom is equal to 0, no limits are indicated.

– Otherwise (max\_bytes\_per\_pic\_denom is not equal to 0), it is a requirement of bitstream conformance that no coded picture shall be represented in the CVS by more than the following number of bytes.

( PicSizeInMinCbsY \* RawMinCuBits ) ÷ ( 8 \* max\_bytes\_per\_pic\_denom ) (E‑49)

When the max\_bytes\_per\_pic\_denom syntax element is not present, the value of max\_bytes\_per\_pic\_denom is inferred to be equal to 2.

**max\_bits\_per\_min\_cu\_denom** indicates an upper bound for the number of coded bits of coding\_unit( ) data for any coding block in any picture of the CVS. The value of max\_bits\_per\_min\_cu\_denom shall be in the range of 0 to 16, inclusive.

Depending on the value of max\_bits\_per\_min\_cu\_denom, the following applies:

– If max\_bits\_per\_min\_cu\_denom is equal to 0, no limit is specified by this syntax element.

– Otherwise (max\_bits\_per\_min\_cu\_denom is not equal to 0), it is a requirement of bitstream conformance that no coded coding\_unit( ) shall be represented in the bitstream by more than the following number of bits:

( 128 + RawMinCuBits ) ÷ max\_bits\_per\_min\_cu\_denom \* ( 2 << ( log2CbSize − MinCbLog2SizeY ) ) (E‑50)

where log2CbSize is the value of log2CbSize for the given coding block and the number of bits of coding\_unit( ) data for the same coding block is given by the number of times read\_bits( 1 ) is called in subclauses 9.3.4.3.3 and 0.

When the max\_bits\_per\_min\_cu\_denom is not present,thevalue of max\_bits\_per\_min\_cu\_denom is inferred to be equal to 1.

**log2\_max\_mv\_length\_horizontal** and **log2\_max\_mv\_length\_vertical** indicate the maximum absolute value of a decoded horizontal and vertical motion vector component, respectively, in quarter luma sample units, for all pictures in the CVS. A value of n asserts that no value of a motion vector component is outside the range of −2n to 2n − 1, inclusive, in units of quarter luma sample displacement. The value of log2\_max\_mv\_length\_horizontal shall be in the range of 0 to 16, inclusive. The value of log2\_max\_mv\_length\_vertical shall be in the range of 0 to 15, inclusive. When log2\_max\_mv\_length\_horizontal is not present, the values of log2\_max\_mv\_length\_horizontal and log2\_max\_mv\_length\_vertical is inferred to be equal to 15.

NOTE 13 – The maximum absolute value of a decoded vertical or horizontal motion vector component is also constrained by profile, tier and level limits as specified in Annex A.

* + 1. HRD parameters semantics

The hrd\_parameters( ) syntax structure provides HRD parameters used in the HRD operations for a layer set. When the hrd\_parameters( ) syntax structure is included in a VPS, the applicable layer set to which the hrd\_parameters( ) syntax structure applies is specified by the corresponding hrd\_layer\_set\_idx[ i ] syntax element in the VPS. When the hrd\_parameters( ) syntax structure is included in an SPS, the layer set to which the hrd\_parameters( ) syntax structure applies is the layer set for which the associated layer identifier list contains all nuh\_layer\_id values present in the CVS.

For interpretation of the following semantics, the bitstream (or a part thereof) refers to the bitstream subset (or a part thereof) associated with the layer set to which the hrd\_parameters( ) syntax structure applies.

**nal\_hrd\_parameters\_present\_flag** equal to 1 specifies that NAL HRD parameters (pertaining to Type II bitstream conformance) are present in the hrd\_parameters( ) syntax structure. nal\_hrd\_parameters\_present\_flag equal to 0 specifies that NAL HRD parameters are not present in the hrd\_parameters( ) syntax structure.

NOTE 1 – When nal\_hrd\_parameters\_present\_flag is equal to 0, the conformance of the bitstream cannot be verified without provision of the NAL HRD parameters and all buffering period and picture timing SEI messages, by some means not specified in this Specification.

The variable NalHrdBpPresentFlag is derived as follows:

– If one or more of the following conditions are true, the value of NalHrdBpPresentFlag is set equal to 1:

– nal\_hrd\_parameters\_present\_flag is present in the bitstream and is equal to 1.

– The need for presence of buffering periods for NAL HRD operation to be present in the bitstream in buffering period SEI messages is determined by the application, by some means not specified in this Specification.

– Otherwise, the value of NalHrdBpPresentFlag is set equal to 0.

**vcl\_hrd\_parameters\_present\_flag** equal to 1 specifies that VCL HRD parameters (pertaining to all bitstream conformance) are present in the hrd\_parameters( ) syntax structure. vcl\_hrd\_parameters\_present\_flag equal to 0 specifies that VCL HRD parameters are not present in the hrd\_parameters( ) syntax structure.

NOTE 2 – When vcl\_hrd\_parameters\_present\_flag is equal to 0, the conformance of the bitstream cannot be verified without provision of the VCL HRD parameters and all buffering period and picture timing SEI messages, by some means not specified in this Specification.

The variable VclHrdBpPresentFlag is derived as follows:

– If one or more of the following conditions are true, the value of VclHrdBpPresentFlag is set equal to 1:

– vcl\_hrd\_parameters\_present\_flag is present in the bitstream and is equal to 1.

– The need for presence of buffering periods for VCL HRD operation to be present in the bitstream in buffering period SEI messages is determined by the application, by some means not specified in this Specification.

– Otherwise, the value of VclHrdBpPresentFlag is set equal to 0.

The variable CpbDpbDelaysPresentFlag is derived as follows:

– If one or more of the following conditions are true, the value of CpbDpbDelaysPresentFlag is set equal to 1:

– nal\_hrd\_parameters\_present\_flag is present in the bitstream and is equal to 1.

– vcl\_hrd\_parameters\_present\_flag is present in the bitstream and is equal to 1.

– The need for presence of CPB and DPB output delays to be present in the bitstream in picture timing SEI messages is determined by the application, by some means not specified in this Specification.

– Otherwise, the value of CpbDpbDelaysPresentFlag is set equal to 0.

**sub\_pic\_hrd\_params\_present\_flag** equal to 1 specifies that sub-picture level HRD parameters are present and the HRD may operate at access unit level or sub-picture level. sub\_pic\_hrd\_params\_present\_flag equal to 0 specifies that sub‑picture level HRD parameters are not present and the HRD operates at access unit level. When sub\_pic\_hrd\_params\_present\_flag is not present, its value is inferred to be equal to 0.

**tick\_divisor\_minus2** is used to specify the clock sub-tick. A clock sub-tick is the minimum interval of time that can be represented in the coded data when sub\_pic\_hrd\_params\_present\_flag is equal to 1.

**du\_cpb\_removal\_delay\_increment\_length\_minus1** plus 1 specifies the length, in bits, of the du\_cpb\_removal\_delay\_increment\_minus1[ i ] and du\_common\_cpb\_removal\_delay\_increment\_minus1 syntax elements of the picture timing SEI message and the du\_spt\_cpb\_removal\_delay\_increment syntax element in the decoding unit information SEI message.

**sub\_pic\_cpb\_params\_in\_pic\_timing\_sei\_flag** equal to 1 specifies that sub-picture level CPB removal delay parameters are present in picture timing SEI messages and no decoding unit information SEI message is available (in the CVS or provided through external means not specified in this Specification). sub\_pic\_cpb\_params\_in\_pic\_timing\_sei\_flag equal to 0 specifies that sub-picture level CPB removal delay parameters are present in decoding unit information SEI messages and picture timing SEI messages do not include sub-picture level CPB removal delay parameters. When the sub\_pic\_cpb\_params\_in\_pic\_timing\_sei\_flag syntax element is not present, it is inferred to be equal to 0.

**dpb\_output\_delay\_du\_length\_minus1** plus 1 specifies the length, in bits, of the pic\_dpb\_output\_du\_delay syntax element in the picture timing SEI message and the pic\_spt\_dpb\_output\_du\_delay syntax element in the decoding unit information SEI message.

**bit\_rate\_scale** (together with bit\_rate\_value\_minus1[ i ]) specifies the maximum input bit rate of the i-th CPB.

**cpb\_size\_scale** (together with cpb\_size\_value\_minus1[ i ]) specifies the CPB size of the i-th CPB when the CPB operates at the access unit level.

**cpb\_size\_du\_scale** (together with cpb\_size\_du\_value\_minus1[ i ]) specifies the CPB size of the i-th CPB when the CPB operates at sub-picture level.

**initial\_cpb\_removal\_delay\_length\_minus1** plus 1 specifies the length, in bits, of the nal\_initial\_cpb\_removal\_delay[ i ], nal\_initial\_cpb\_removal\_offset[ i ], vcl\_initial\_cpb\_removal\_delay[ i ], and vcl\_initial\_cpb\_removal\_offset[ i ] syntax elements of the buffering period SEI message. When the initial\_cpb\_removal\_delay\_length\_minus1 syntax element is not present, it is inferred to be equal to 23.

**au\_cpb\_removal\_delay\_length\_minus1** plus 1 specifies the length, in bits, of the cpb\_delay\_offset syntax element in the buffering period SEI message and the au\_cpb\_removal\_delay\_minus1 syntax element in the picture timing SEI message. When the au\_cpb\_removal\_delay\_length\_minus1 syntax element is not present, it is inferred to be equal to 23.

**dpb\_output\_delay\_length\_minus1** plus 1 specifies the length, in bits, of the dpb\_delay\_offset syntax element in the buffering period SEI message and the pic\_dpb\_output\_delay syntax element in the picture timing SEI message. When the dpb\_output\_delay\_length\_minus1 syntax element is not present, it is inferred to be equal to 23.

**fixed\_pic\_rate\_general\_flag**[ i ] equal to 1 indicates that, when HighestTid is equal to i, the temporal distance between the HRD output times of consecutive pictures in output order is constrained as specified below. fixed\_pic\_rate\_general\_flag[ i ] equal to 0 indicates that this constraint may not apply.

When fixed\_pic\_rate\_general\_flag[ i ] is not present, it is inferred to be equal to 0.

**fixed\_pic\_rate\_within\_cvs\_flag**[ i ] equal to 1 indicates that, when HighestTid is equal to i, the temporal distance between the HRD output times of consecutive pictures in output order is constrained as specified below. fixed\_pic\_rate\_within\_cvs\_flag[ i ] equal to 0 indicates that this constraint may not apply.

When fixed\_pic\_rate\_general\_flag[ i ] is equal to 1, the value of fixed\_pic\_rate\_within\_cvs\_flag[ i ] is inferred to be equal to 1.

**elemental\_duration\_in\_tc\_minus1**[ i ] plus 1 (when present) specifies, when HighestTid is equal to i, the temporal distance, in clock ticks, between the elemental units that specify the HRD output times of consecutive pictures in output order as specified below. The value of elemental\_duration\_in\_tc\_minus1[ i ] shall be in the range of 0 to 2047, inclusive.

For each picture n that is output and not the last picture in the bitstream (in output order) that is output, the value of the variable DpbOutputElementalInterval[ n ] is specified by:

DpbOutputElementalInterval[ n ] = DpbOutputInterval[ n ]  DeltaToDivisor (E‑51)

where DpbOutputInterval[ n ] is specified in Equation C‑17 and DeltaToDivisor is specified in Table E‑6 based on the value of frame\_field\_info\_present\_flag and pic\_struct for the CVS containing picture n. Entries marked "-" in Table E‑6 indicate a lack of dependence of DeltaToDivisor on the corresponding syntax element.

When HighestTid is equal to i and fixed\_pic\_rate\_general\_flag[ i ] is equal to 1 for a CVS containing picture n, the value computed for DpbOutputElementalInterval[ n ] shall be equal to ClockTick \* ( elemental\_duration\_in\_tc\_minus1[ i ] + 1 ), wherein ClockTick is as specified in Equation C‑2 (using the value of ClockTick for the CVS containing picture n) when one of the following conditions is true for the following picture in output order nextPicInOutputOrder that is specified for use in Equation C‑17:

– picture nextPicInOutputOrder is in the same CVS as picture n.

– picture nextPicInOutputOrder is in a different CVS and fixed\_pic\_rate\_general\_flag[ i ] is equal to 1 in the CVS containing picture nextPicInOutputOrder, the value of ClockTick is the same for both CVSs, and the value of elemental\_duration\_in\_tc\_minus1[ i ] is the same for both CVSs.

When HighestTid is equal to i and fixed\_pic\_rate\_within\_cvs\_flag[ i ] is equal to 1 for a CVS containing picture n, the value computed for DpbOutputElementalInterval[ n ] shall be equal to ClockTick \* ( elemental\_duration\_in\_tc\_minus1[ i ] + 1 ), wherein ClockTick is as specified in Equation C‑2 (using the value of ClockTick for the CVS containing picture n) when the following picture in output order nextPicInOutputOrder that is specified for use in Equation C‑17 is in the same CVS as picture n.

Table E‑6 – Divisor for computation of DpbOutputElementalInterval[ n ]

|  |  |  |
| --- | --- | --- |
| **frame\_field\_info\_present\_flag** | **pic\_struct** | **DeltaToDivisor** |
| 0 | - | 1 |
| 1 | 1 | 1 |
| 1 | 2 | 1 |
| 1 | 0 | 2 |
| 1 | 3 | 2 |
| 1 | 4 | 2 |
| 1 | 5 | 3 |
| 1 | 6 | 3 |
| 1 | 7 | 2 |
| 1 | 8 | 3 |
| 1 | 9 | 1 |
| 1 | 10 | 1 |
| 1 | 11 | 1 |
| 1 | 12 | 1 |

**low\_delay\_hrd\_flag**[ i ] specifies the HRD operational mode, when HighestTid is equal to i, as specified in Annex C. When not present, the value of low\_delay\_hrd\_flag[ i ] is inferred to be equal to 0.

NOTE 3 – When low\_delay\_hrd\_flag[ i ] is equal to 1, "big pictures" that violate the nominal CPB removal times due to the number of bits used by an access unit are permitted. It is expected, but not required, that such "big pictures" occur only occasionally.

**cpb\_cnt\_minus1**[ i ] plus 1 specifies the number of alternative CPB specifications in the bitstream of the CVS when HighestTid is equal to i. The value of cpb\_cnt\_minus1[ i ] shall be in the range of 0 to 31, inclusive. When not present, the value of cpb\_cnt\_minus1[ i ] is inferred to be equal to 0.

* + 1. Sub-layer HRD parameters semantics

The variable CpbCnt is set equal to cpb\_cnt\_minus1[ subLayerId ].

**bit\_rate\_value\_minus1**[ i ] (together with bit\_rate\_scale) specifies the maximum input bit rate for the i-th CPB when the CPB operates at the access unit level. bit\_rate\_value\_minus1[ i ] shall be in the range of 0 to 232 − 2, inclusive. For any i > 0, bit\_rate\_value\_minus1[ i ] shall be greater than bit\_rate\_value\_minus1[ i − 1 ].

When SubPicHrdFlag is equal to 0, the bit rate in bits per second is given by:

BitRate[ i ] = ( bit\_rate\_value\_minus1[ i ] + 1 ) \* 2( 6 + bit\_rate\_scale ) (E‑52)

When SubPicHrdFlag is equal to 0 and the bit\_rate\_value\_minus1[ i ] syntax element is not present, the value of BitRate[ i ] is inferred to be equal to CpbBrVclFactor \* MaxBR for VCL HRD parameters and to be equal to CpbBrNalFactor \* MaxBR for NAL HRD parameters, where MaxBR, CpbBrVclFactor and CpbBrNalFactor are specified in subclause A.4.

**cpb\_size\_value\_minus1**[ i ] is used together with cpb\_size\_scale to specify the i-th CPB size when the CPB operates at the access unit level. cpb\_size\_value\_minus1[ i ] shall be in the range of 0 to 232 − 2, inclusive. For any i greater than 0, cpb\_size\_value\_minus1[ i ] shall be less than or equal to cpb\_size\_value\_minus1[ i − 1 ].

When SubPicHrdFlag is equal to 0, the CPB size in bits is given by:

CpbSize[ i ] = ( cpb\_size\_value\_minus1[ i ] + 1 ) \* 2( 4 + cpb\_size\_scale ) (E‑53)

When SubPicHrdFlag is equal to 0 and the cpb\_size\_value\_minus1[ i ] syntax element is not present, the value of CpbSize[ i ] is inferred to be equal to CpbBrVclFactor \* MaxCPB for VCL HRD parameters and to be equal to CpbBrNalFactor \* MaxCPB for NAL HRD parameters, where MaxCPB, CpbBrVclFactor and CpbBrNalFactor are specified in subclause A.4.

**cpb\_size\_du\_value\_minus1**[ i ] is used together with cpb\_size\_du\_scale to specify the i-th CPB size when the CPB operates at sub-picture level. cpb\_size\_du\_value\_minus1[ i ] shall be in the range of 0 to 232 − 2, inclusive. For any i greater than 0, cpb\_size\_du\_value\_minus1[ i ] shall be less than or equal to cpb\_size\_du\_value\_minus1[ i − 1 ].

When SubPicHrdFlag is equal to 1, the CPB size in bits is given by:

CpbSize[ i ] = ( cpb\_size\_du\_value\_minus1[ i ] + 1 ) \* 2( 4 + cpb\_size\_du\_scale ) (E‑54)

When SubPicHrdFlag is equal to 1 and the cpb\_size\_du\_value\_minus1[ i ] syntax element is not present, the value of CpbSize[ i ] is inferred to be equal to CpbBrVclFactor \* MaxCPB for VCL HRD parameters and to be equal to CpbBrNalFactor \* MaxCPB for NAL HRD parameters, where MaxCPB, CpbBrVclFactor and CpbBrNalFactor are specified in subclause A.4.

**bit\_rate\_du\_value\_minus1**[ i ] (together with bit\_rate\_scale) specifies the maximum input bit rate for the i-th CPB when the CPB operates at the sub-picture level. bit\_rate\_du\_value\_minus1[ i ] shall be in the range of 0 to 232 − 2, inclusive. For any i > 0, bit\_rate\_du\_value\_minus1[ i ] shall be greater than bit\_rate\_du\_value\_minus1[ i − 1 ].

When SubPicHrdFlag is equal to 1, the bit rate in bits per second is given by:

BitRate[ i ] = ( bit\_rate\_du\_value\_minus1[ i ] + 1 ) \* 2( 6 + bit\_rate\_scale ) (E‑55)

When SubPicHrdFlag is equal to 1 and the bit\_rate\_du\_value\_minus1[ i ] syntax element is not present, the value of BitRate[ i ] is inferred to be equal to CpbBrVclFactor \* MaxBR for VCL HRD parameters and to be equal to CpbBrNalFactor \* MaxBR for NAL HRD parameters, where MaxBR, CpbBrVclFactor and CpbBrNalFactor are specified in subclause A.4.

**cbr\_flag**[ i ] equal to 0 specifies that to decode this bitstream by the HRD using the i-th CPB specification, the hypothetical stream scheduler (HSS) operates in an intermittent bit rate mode. cbr\_flag[ i ] equal to 1 specifies that the HSS operates in a constant bit rate (CBR) mode. When not present, the value of cbr\_flag[ i ] is inferred to be equal to 0.

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