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SERIES H: AUDIOVISUAL AND MULTIMEDIA SYSTEMS

Infrastructure of audiovisual services – Coding of moving video

Coding-independent code points for video signal type identification

Recommendation ITU-T H.273

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Recommendation ITU-T H.273

Coding-independent code points for video signal type identification

Summary

Recommendation ITU-T H.273 defines various code points and fields that establish properties of a video (or still image) representation and are independent of the compression encoding and bit rate. These properties may describe the appropriate interpretation of decoded data or may, similarly, describe the characteristics of such a signal before the signals compressed by an encoder that is suitable for compressing such an input signal. The text was developed as a twin text Recommendation corresponding to the video code points in ISO/IEC 23001-8:2016 and its Amendment 1 in collaboration with ISO/IEC JTC 1 SC 29/WG 11 (MPEG). It is published as technically aligned twin text by both organizations (ITU-T and ISO/IEC).

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Introduction

In a number of specifications, there is a need to identify some characteristics of video (or still image) media content that are logically independent of the compression format. These characteristics may include, for example, aspects that relate to the sourcing or presentation or the role of the video (or still image) media component. These characteristics have typically been documented by fields that take an encoded value or item selected from an enumerated list, herein called code points.

These code points are typically defined in the specification of compression formats to document these characteristics of the media. In past practice, the definition of these fields has been copied from standard to standard, sometimes with new values being added in later standards (and sometimes with later amendments specified to add new entries to existing standards).

This past practice has raised a number of issues, including the following.

1) A lack of a formal way to avoid conflicting assignments being made in different standards.

2) Having additional values defined in later specifications that may be practically used with older compression formats, but without clear formal applicability of these new values to older standards.

3) Any update or correction of code point semantics can incur significant effort to update all standards in which the code point is specified, instead of enabling a single central specification to apply across different referencing specifications.

4) The choice of reference for other specifications (such as container or delivery formats) not being obvious; wherein a formal reference to a compression format standard appears to favour that one format over others and also appears to preclude definitions defined in other compression format specifications.

5) Burdensome maintenance needs to ensure that a reference to material defined in a compression format specification is maintained appropriately over different revisions of the referenced format specification, as the content of a compression format specification may change over time and is ordinarily not intended as a point of reference for defining such code points.

This Specification provides a central definition of such code points for video and image applications to address these issues. This Specification can be used to provide universal descriptions to assist interpretation of video and image signals following decoding or to describe the properties of these signals before they are encoded.

Recommendation ITU-T H.273

Coding-independent code points for video signal type identification

1 Scope

This Recommendation | International Standard defines various code points and fields that establish properties of a video (or still image) representation and are independent of the compression encoding and bit rate. These properties may describe the appropriate interpretation of decoded data or may, similarly, describe the characteristics of such signal before the signal is compressed by an encoder that is suitable for compressing such an input signal.

2 Normative references

The following Recommendations and International Standards contain provisions which, through reference in this text, constitute provisions of this Recommendation | International Standard. At the time of publication, the editions indicated were valid. All Recommendations and Standards are subject to revision, and parties to agreements based on this Recommendation | International Standard are encouraged to investigate the possibility of applying the most recent edition of the Recommendations and Standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards. The Telecommunication Standardization Bureau of the ITU maintains a list of currently valid ITU-T Recommendations.

2.1 Identical Recommendations | International Standards

– None

2.2 Paired Recommendations | International Standards equivalent in technical content

– None

2.3 Additional references

– ISO 11664-1, *Colorimetry – Part 1: CIE standard colorimetric observers*.

3 Definitions

For the purposes of this Recommendation | International Standard, the following definitions apply.

3.1 **chroma**: Sample array or single sample representing one of the two colour difference signals related to the primary colours, represented by the symbols Cb and Cr.

NOTE – The term chroma is used rather than the term chrominance in order to avoid the implication of the use of linear light transfer characteristics that is often associated with the term chrominance.

3.2 **component**: Array or single sample from one of the three arrays (*luma* and two *chroma*) that compose a *picture* in 4:2:0, 4:2:2 or 4:4:4 colour format or the array or a single sample of the array that compose a *picture* in monochrome format.

3.3 **luma**: Sample array or single sample representing the monochrome signal related to the primary colours, represented by the symbol or subscript Y or L.

NOTE – The term luma is used rather than the term luminance in order to avoid the implication of the use of linear light transfer characteristics that is often associated with the term luminance. The symbol L is sometimes used instead of the symbol Y to avoid confusion with the symbol y as used for vertical location.

3.4 **picture**: An array of *luma* samples in monochrome format or an array of *luma* samples and two corresponding arrays of *chroma* samples in 4:2:0, 4:2:2 and 4:4:4 colour format.

3.5 **reserved**: Values of a particular code point that are for future use by ITU-T | ISO/IEC and shall not be used in identifiers conforming to this version of this Specification, but which may be used in a manner yet to be specified in some future extensions of this Specification by ITU-T | ISO/IEC.

3.6 **unspecified**: Values of a particular code point that have no specified meaning in this version of this Specification and will not have a specified meaning as an integral part of future versions of this Specification.

4 Abbreviations

For the purposes of this Recommendation | International Standard, the following abbreviations apply.

LSB	Least Significant Bit
MSB	Most Significant Bit
SAR	Sample Aspect Ratio

5 Conventions

NOTE – The mathematical operators used in this Specification are similar to those used in the C programming language. However, integer division and arithmetic shift operations are specifically defined. Numbering and counting conventions generally begin from 0.

5.1 Arithmetic operators

The following arithmetic operators are defined as follows:

+	Addition
−	Subtraction (as a two-argument operator) or negation (as a unary prefix operator)
*	Multiplication, including matrix multiplication
x^{y}	Exponentiation. Specifies x to the power of y. In other contexts, such notation is used for superscripting not intended for interpretation as exponentiation.
/	Integer division with truncation of the result toward zero. For example, 7 / 4 and (−7) / (−4) are truncated to 1 and (−7) / 4 and 7 / (−4) are truncated to −1.
÷	Used to denote division in mathematical equations where no truncation or rounding is intended
$\frac{x}{y}$	Used to denote division in mathematical equations where no truncation or rounding is intended
$\sum_{i=x}^{y} f(i)$	The summation of f(i) with i taking all integer values from x up to and including y
x % y	Modulus. Remainder of x divided by y, defined only for integers x and y with x >= 0 and y > 0.

5.2 Relational operators

The following relational operators are defined as follows:

>	Greater than
>=	Greater than or equal to
<	Less than
<=	Less than or equal to
= =	Equal to
!=	Not equal to

When a relational operator is applied to a code point or variable that has been assigned the value "na" (not applicable), the value "na" is treated as a distinct value for the code point or variable. The value "na" is considered not to be equal to any other value.

5.3 Bit-wise operators

The following bit-wise operators are defined as follows:

&	Bit-wise "and". When operating on integer arguments, operates on a two's complement representation of the integer value. When operating on a binary argument that contains fewer bits than another argument, the shorter argument is extended by adding more significant bits equal to 0.
|	Bit-wise "or". When operating on integer arguments, operates on a two's complement representation of the integer value. When operating on a binary argument that contains fewer bits than another argument, the shorter argument is extended by adding more significant bits equal to 0.
^	Bit-wise "exclusive or". When operating on integer arguments, operates on a two's complement representation of the integer value. When operating on a binary argument that contains fewer bits than another argument, the shorter argument is extended by adding more significant bits equal to 0.

x >> y Arithmetic right shift of a two's complement integer representation of x by y binary digits. This function is defined only for positive integer values of y. Bits shifted into the most significant bits (MSBs) as a result of the right shift have a value equal to the MSB of x prior to the shift operation.

x << y Arithmetic left shift of a two's complement integer representation of x by y binary digits. This function is defined only for positive integer values of y. Bits shifted into the least significant bits (LSBs) as a result of the left shift have a value equal to 0.

5.4 Mathematical functions

The following mathematical functions are defined as follows:

$$\text{Abs}(x) = \begin{cases} x & ; \quad x >= 0 \\ -x & ; \quad x < 0 \end{cases} \tag{1}$$

$$\text{Clip1}_Y(x) = \text{Clip3}(0, (1 << \text{BitDepth}_Y) - 1, x) \tag{2}$$

where BitDepth_Y is the representation bit depth of the corresponding luma colour component signal.

$$\text{Clip1}_C(x) = \text{Clip3}(0, (1 << \text{BitDepth}_C) - 1, x) \tag{3}$$

where BitDepth_C is the representation bit depth of the corresponding chroma colour component signal C. In general, BitDepth_C may be distinct for different chroma colour components signals C – e.g., for C corresponding to Cb or Cr.

$$\text{Clip3}(x, y, z) = \begin{cases} x & ; \quad z > x \\ y & ; \quad z > y \\ z & ; \quad \text{otherwise} \end{cases} \tag{4}$$

Floor(x) the largest integer less than or equal to x(5)

Ln(x) the natural logarithm of x (6)

Log10(x) the base-10 logarithm of x (7)

$$\text{Round}(x) = \text{Sign}(x) * \text{Floor}(\text{Abs}(x) + 0.5) \tag{8}$$

$$\text{Sign}(x) = \begin{cases} 1 & ; \quad x > 0 \\ 0 & ; \quad x == 0 \\ -1 & ; \quad x < 0 \end{cases} \tag{9}$$

$$\text{Sqrt}(x) = \sqrt{x} \tag{10}$$

6 Specified code points

This clause identifies the code points defined in this Specification, as listed in Table 1 with cross-references to the subclause in which each is specified.

Table 1 – List of code point definitions

Name	Abstract	Subclause
ColourPrimaries	Video colour primaries	8.1
TransferCharacteristics	Video colour transfer characteristics	8.2
MatrixCoefficients and VideoFullRangeFlag	Video matrix colour coefficients	8.3
VideoFramePackingType and QuincunxSamplingFlag	Video frame packing	8.4
PackedContentInterpretationType	Interpretation of packed video frames	8.5
SampleAspectRatio, SarWidth, SarHeight	Sample aspect ratio of video	8.6

7 Principles for definition and referencing of code points

7.1 Code point encoding and defaults

The code points defined herein may be specified as a value or a label of an enumerated list. The definition of their encoding and representation (e.g., as a binary number) is the responsibility of the specification using the code point, as is the identification of any applicable default value not specified herein. It is also possible for external specifications to use a mapping to values defined here, if they wish to preserve identical semantics, but different code point assignments.

Guidance is given for each code point as to a suitable type (e.g., unsigned integer) and a suitable value range (e.g., 0–63) for assistance in writing derived specifications. In some instances, default flag values are provided that are suggested to be inferred for code point parameters with associated flags that may not be explicitly signalled or specified in derived specifications.

7.2 Externally defined values

If the external specification permits values not defined by this Specification to be identified in the same field that carries values defined by this Specification, then that other specification must identify how values defined herein can be distinguished from values not defined herein.

7.3 Reference format

References to code points specified in this Specification should use only the code point name (i.e., a "Name" from Table 1) and specification title, and not use section numbers or any other "fragile" reference such as a table number. For example, for a hypothetical code point named "**ChocolateDensity**", a specification could refer to "**ChocolateDensity** as defined in Rec. ITU-T H.273 *Coding-independent code points for video signal type identification*".

8 Video code points

8.1 Colour primaries

Type: Unsigned integer, enumeration
Range: 0–255

ColourPrimaries indicates the chromaticity coordinates of the source colour primaries as specified in Table 2 in terms of the CIE 1931 definition of x and y as specified by ISO 11664-1.

An 8-bit field should be adequate for representation of the ColourPrimaries code point.

Table 2 – Interpretation of colour primaries (ColourPrimaries) value

Value	Colour primaries	Informative remarks
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.1361-0 conventional colour gamut system and extended colour gamut system (historical) IEC 61966-2-1 sRGB or sYCC IEC 61966-2-4 Society of Motion Picture and Television Engineers (MPTE) 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 color television* United States Federal Communications Commission (2003) *Title 47 Code of Federal Regulations* 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.601-7 625 Rec. ITU-R BT.1358-0 625 (historical) Rec. ITU-R BT.1700-0 625 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.601-7 525 Rec. ITU-R BT.1358-1 525 or 625 (historical) Rec. ITU-R BT.1700-0 NTSC SMPTE 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	SMPTE 240M (1999) (historical) (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.2100-0
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	SMPTE ST 428-1 (CIE 1931 XYZ as in ISO 11664-1)
11	primary x y green 0.265 0.690 blue 0.150 0.060 red 0.680 0.320 white 0.314 0.351	SMPTE RP 431-2 (2011)

Table 2 – Interpretation of colour primaries (ColourPrimaries) value

Value	Colour primaries	Informative remarks
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	SMPTE 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

8.2 Transfer characteristics

Type: Unsigned integer, enumeration
Range: 0–255

TransferCharacteristics, as specified in Table 3, either indicates the reference opto-electronic transfer characteristic function of the source picture as a function of a source input linear optical intensity input L_c with a nominal real-valued range of 0 to 1 or indicates the inverse of the reference electro-optical transfer characteristic function as a function of an output linear optical intensity L_o with a nominal real-valued range of 0 to 1. For interpretation of entries in Table 3 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 both value and slope at the value β. 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 TransferCharacteristics equal to 1, 6, 14 or 15, α has the value 1 + 5.5 * β = 1.099296826809442... and β has the value 0.018053968510807....

An 8-bit field should be adequate for representation of the TransferCharacteristics code point.

NOTE 1 – As indicated in Table 3, some values of TransferCharacteristics 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 (as could be indicated by TransferCharacteristics 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.1886-0.

NOTE 2 – Certain combinations of TransferCharacteristics, VideoFullRangeFlag, BitDepthY and BitDepthC may not be permitted.

Table 3 – Interpretation of transfer characteristics (TransferCharacteristics) value

Value	Transfer characteristics	Informative remarks
0	Reserved	For future use by ITU-T | ISO/IEC
1	$V = \alpha * L_c^{0.45} - (\alpha - 1)$ for $1 >= L_c >= \beta$ $V = 4.500 * L_c$ for $\beta > L_c >= 0$	Rec. ITU-R BT.709-6 Rec. ITU-R BT.1361-0 conventional colour gamut system (historical) (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

Table 3 – Interpretation of transfer characteristics (TransferCharacteristics) value

Value	Transfer characteristics		Informative remarks
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 color television* United States Federal Communications Commission (2003) *Title 47 Code of Federal Regulations* 73.682 (a) (20) Rec. ITU-R BT.1700-0 625 PAL and 625 SECAM
5	Assumed display gamma 2.8		Rec. ITU-R BT.470-6 System B, G (historical)
6	$V = \alpha * L_c^{0.45} - (\alpha - 1)$ $V = 4.500 * L_c$	for $1 >= L_c >= \beta$ for $\beta > L_c >= 0$	Rec. ITU-R BT.601-7 525 or 625 Rec. ITU-R BT.1358-1 525 or 625 (historical) Rec. ITU-R BT.1700-0 NTSC SMPTE 170M (2004) (functionally the same as the values 1, 14 and 15)
7	$V = \alpha * L_c^{0.45} - (\alpha - 1)$ $V = 4.0 * L_c$	for $1 >= L_c >= \beta$ for $\beta > L_c >= 0$	SMPTE 240M (1999) (historical)
8	$V = L_c$	for $1 > L_c >= 0$	Linear transfer characteristics
9	$V = 1.0 + \text{Log10}(L_c) \div 2$ $V = 0.0$	for $1 >= L_c >= 0.01$ for $0.01 > L_c >= 0$	Logarithmic transfer characteristic (100:1 range)
10	$V = 1.0 + \text{Log10}(L_c) \div 2.5$ $V = 0.0$	for $1 >= L_c >= \text{Sqrt}(10) \div 1000$ for $\text{Sqrt}(10) \div 1000 > L_c >= 0$	Logarithmic transfer characteristic (100 * Sqrt(10) : 1 range)
11	$V = \alpha * L_c^{0.45} - (\alpha - 1)$ $V = 4.500 * L_c$ $V = -\alpha * (-L_c)^{0.45} + (\alpha - 1)$	for $L_c >= \beta$ for $\beta > L_c > -\beta$ for $-\beta >= L_c$	IEC 61966-2-4
12	$V = \alpha * L_c^{0.45} - (\alpha - 1)$ $V = 4.500 * L_c$ $V = -(\alpha * (-4 * L_c)^{0.45} - (\alpha - 1)) \div 4$	for $1.33 > L_c >= \beta$ for $\beta > L_c >= -\gamma$ for $-\gamma >= L_c >= -0.25$	Rec. ITU-R BT.1361-0 extended colour gamut system (historical)
13	$V = \alpha * L_c^{(1 \div 2.4)} - (\alpha - 1)$ $V = 12.92 * L_c$	for $1 > L_c >= \beta$ for $\beta > L_c >= 0$	IEC 61966-2-1 sRGB or sYCC
14	$V = \alpha * L_c^{0.45} - (\alpha - 1)$ $V = 4.500 * L_c$	for $1 >= L_c >= \beta$ for $\beta > L_c >= 0$	Rec. ITU-R BT.2020-2 (10-bit system) (functionally the same as the values 1, 6 and 15)
15	$V = \alpha * L_c^{0.45} - (\alpha - 1)$ $V = 4.500 * L_c$	for $1 >= L_c >= \beta$ for $\beta > L_c >= 0$	Rec. ITU-R BT.2020-2 (12-bit system) (functionally the same as the values 1, 6 and 14)
16	$V = ((c_1 + c_2 * L_o^n) \div (1 + c_3 * L_o^n))^m$ $c_1 = c_3 - c_2 + 1 = 107 \div 128 = 0.8359375$ $c_2 = 2413 \div 128 = 18.8515625$ $c_3 = 2392 \div 128 = 18.6875$ $m = 2523 \div 32 = 78.84375$ $n = 653 \div 4096 = 0.1593017578125$ for which L_o equal to 1 for peak white is ordinarily intended to correspond to a reference output luminance level of 10 000 candelas per square metre	for all values of L_o	SMPTE ST 2084 for 10-, 12-, 14- and 16-bit systems Rec. ITU-R BT.2100-0 perceptual quantization (PQ) system

Table 3 – Interpretation of transfer characteristics (TransferCharacteristics) value

Value	Transfer characteristics		Informative remarks
17	$V = (48 * L_o \div 52.37)^{(1 \div 2.6)}$ for which L_o equal to 1 for peak white is ordinarily intended to correspond to a reference output luminance level of 48 candelas per square metre	for all values of L_o	SMPTE ST 428-1
18	$V = a * Ln(12 * L_c - b) + c$ $V = Sqrt(3) * L_c^{0.5}$ a = 0.17883277 b = 0.28466892 c = 0.55991073	for $1 >= L_c > 1 \div 12$ for $1 \div 12 >= L_c >= 0$	ARIB STD-B67 Rec. ITU-R BT.2100-0 hybrid log-gamma (HLG) system
19–255	Reserved		For future use by ITU-T | ISO/IEC

NOTE 3 – For TransferCharacteristics equal to 18, the equations given in Table 3 are normalized for a source input linear optical intensity L_c with a nominal real-valued range of 0 to 1. An alternative scaling that is mathematically equivalent is used in ARIB STD-B67 with the source input linear optical intensity having a nominal real-valued range of 0 to 12.

8.3 Matrix coefficients

Type: Unsigned integer, enumeration
Range: 0–255, plus associated flag

MatrixCoefficients describes the matrix coefficients used in deriving luma and chroma signals from the green, blue and red or X, Y and Z primaries, as specified in Table 4 and Equations 11 to 74.

A flag, VideoFullRangeFlag, may be supplied with this code point.

VideoFullRangeFlag specifies the scaling and offset values applied in association with the MatrixCoefficients. When not present or not specified, the value 0 for VideoFullRangeFlag would ordinarily be inferred as the default value for video imagery.

An 8-bit field should be adequate for representation of the MatrixCoefficients code point.

NOTE 1 – Certain values of MatrixCoefficients may be disallowed depending on the application and the characteristics and format of the signal, e.g., in regard to combinations of the chroma format sampling structure and the values of $BitDepth_Y$ and $BitDepth_C$.

The interpretation of MatrixCoefficients is specified by Equations 11 to 74. E_R, E_G and E_B are defined as "linear-domain" real-valued signals based on the indicated colour primaries (see 8.1) before applying the transfer characteristics (see 8.2).

NOTE 2 – For purposes of the YZX representation when MatrixCoefficients is equal to 0, the symbols R, G and B are substituted for X, Y and Z, respectively, in the following descriptions of Equations 11 to 13, Equations 14 to 16, Equations 20 to 22, and Equations 26 to 28.

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

– If MatrixCoefficients is not equal to 14, the signals E'_R, E'_G and E'_B are determined by application of the transfer characteristics function as follows:

$$E'_R = (E_R)' \tag{11}$$

$$E'_G = (E_G)' \tag{12}$$

$$E'_B = (E_B)' \tag{13}$$

In this case, the range of E'_R, E'_G and E'_B is specified as follows:

– If TransferCharacteristics 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.

– Otherwise (TransferCharacteristics is equal to 11 (IEC 61966-2-4) or 12 (Rec. ITU-R BT.1361-0 extended colour gamut system)), E'_R, E'_G and E'_B are real numbers with a larger range not specified in this Specification.

– Otherwise (MatrixCoefficients is equal to 14), the "linear-domain" real-valued signals E_L, E_M and E_S are determined as follows:

$$E_L = (1688 * E_R + 2146 * E_G + 262 * E_B) \div 4096 \quad (14)$$

$$E_M = (683 * E_R + 2951 * E_G + 462 * E_B) \div 4096 \quad (15)$$

$$E_S = (99 * E_R + 309 * E_G + 3688 * E_B) \div 4096 \quad (16)$$

In this case, the signals E'_L, E'_M and E'_S are determined by application of the transfer characteristics function as follows:

$$E'_L = (E_L)' \quad (17)$$

$$E'_M = (E_M)' \quad (18)$$

$$E'_S = (E_S)' \quad (19)$$

The interpretation of MatrixCoefficients is specified as follows.

- If VideoFullRangeFlag is equal to 0, the following applies:
  - If MatrixCoefficients is equal to 0 or 8, Equations 20 to 22 apply:

$$R = \text{Clip1}_Y((1 << (\text{BitDepth}_Y - 8)) * (219 * E'_R + 16)) \quad (20)$$

$$G = \text{Clip1}_Y((1 << (\text{BitDepth}_Y - 8)) * (219 * E'_G + 16)) \quad (21)$$

$$B = \text{Clip1}_Y((1 << (\text{BitDepth}_Y - 8)) * (219 * E'_B + 16)) \quad (22)$$

  - Otherwise, if MatrixCoefficients is equal to 1, 4, 5, 6, 7, 9, 10, 11, 12, 13 or 14, Equations 23 to 25 apply:

$$Y = \text{Clip1}_Y(\text{Round}((1 << (\text{BitDepth}_Y - 8)) * (219 * E'_Y + 16))) \quad (23)$$

$$Cb = \text{Clip1}_C(\text{Round}((1 << (\text{BitDepth}_C - 8)) * (224 * E'_{PB} + 128))) \quad (24)$$

$$Cr = \text{Clip1}_C(\text{Round}((1 << (\text{BitDepth}_C - 8)) * (224 * E'_{PR} + 128))) \quad (25)$$

  - Otherwise, if MatrixCoefficients is equal to 2, the interpretation of the MatrixCoefficients code point is unknown or is determined by the application.
  - Otherwise (MatrixCoefficients is not equal to 0, 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 or 14), the interpretation of the MatrixCoefficients code point is reserved for future definition by ITU-T | ISO/IEC.
- Otherwise (VideoFullRangeFlag is equal to 1), the following equations apply:
  - If MatrixCoefficients is equal to 0 or 8, Equations 26 to 28 apply:

$$R = \text{Clip1}_Y(((1 << \text{BitDepth}_Y) - 1) * E'_R) \quad (26)$$

$$G = \text{Clip1}_Y(((1 << \text{BitDepth}_Y) - 1) * E'_G) \quad (27)$$

$$B = \text{Clip1}_Y(((1 << \text{BitDepth}_Y) - 1) * E'_B) \quad (28)$$

  - Otherwise, if MatrixCoefficients is equal to 1, 4, 5, 6, 7, 9, 10, 11, 12, 13 or 14, Equations 29 to 31 apply:

$$Y = \text{Clip1}_Y(\text{Round}(((1 << \text{BitDepth}_Y) - 1) * E'_Y)) \quad (29)$$

$$Cb = \text{Clip1}_C(\text{Round}(((1 << \text{BitDepth}_C) - 1) * E'_{PB}) + (1 << (\text{BitDepth}_C - 1))) \quad (30)$$

$$Cr = \text{Clip1}_C(\text{Round}(((1 << \text{BitDepth}_C) - 1) * E'_{PR}) + (1 << (\text{BitDepth}_C - 1))) \quad (31)$$

  - Otherwise, if MatrixCoefficients is equal to 2, the interpretation of the MatrixCoefficients code point is unknown or is determined by the application.
  - Otherwise (MatrixCoefficients is not equal to 0, 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 or 14), the interpretation of the MatrixCoefficients code point is reserved for future definition by ITU-T | ISO/IEC.

When MatrixCoefficients is equal to 1, 4, 5, 6, 7, 9, 10, 11, 12 or 13, the constants K_B and K_R are specified as follows:

- If MatrixCoefficients is not equal to 12 or 13, the constants K_B and K_R are specified in Table 4.

– Otherwise (MatrixCoefficients is equal to 12 or 13), the constants K_R and K_B are computed as follows, using the chromaticity coordinates (x_R, y_R), (x_G, y_G), (x_B, y_B) and (x_W, y_W) specified in Table 2 for the ColourPrimaries code point for the red, green, blue and white colour primaries, respectively:

$$K_R = \frac{y_R * (x_W * (y_G * z_B - y_B * z_G) + y_W * (x_B * z_G - x_G * z_B) + z_W * (x_G * y_B - x_B * y_G))}{y_W * (x_R * (y_G * z_B - y_B * z_G) + x_G * (y_B * z_R - y_R * z_B) + x_B * (y_R * z_G - y_G * z_R))} \quad (32)$$

$$K_B = \frac{y_B * (x_W * (y_R * z_G - y_G * z_R) + y_W * (x_G * z_R - x_R * z_G) + z_W * (x_R * y_G - x_G * y_R))}{y_W * (x_R * (y_G * z_B - y_B * z_G) + x_G * (y_B * z_R - y_R * z_B) + x_B * (y_R * z_G - y_G * z_R))} \quad (33)$$

where the values of z_R, z_G, z_B and z_W, are given by:

$$z_R = 1 - (x_R + y_R) \quad (34)$$

$$z_G = 1 - (x_G + y_G) \quad (35)$$

$$z_B = 1 - (x_B + y_B) \quad (36)$$

$$z_W = 1 - (x_W + y_W) \quad (37)$$

The variables E'_Y, E'_{PB} and E'_{PR} (for MatrixCoefficients not equal to 0 or 8) or Y, Cb and Cr (for MatrixCoefficients equal to 0 or 8) are specified as follows.

– If MatrixCoefficients is not equal to 0, 8, 10, 11, 13 or 14, Equations 38 to 40 apply:

$$E'_Y = K_R * E'_R + (1 - K_R - K_B) * E'_G + K_B * E'_B \quad (38)$$

$$E'_{PB} = 0.5 * (E'_B - E'_Y) \div (1 - K_B) \quad (39)$$

$$E'_{PR} = 0.5 * (E'_R - E'_Y) \div (1 - K_R) \quad (40)$$

NOTE 3 – 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 TransferCharacteristics is not equal to 11 or 12, E'_Y is a real number with values in the range of 0 to 1. When TransferCharacteristics is not equal to 11 or 12, E'_{PB} and E'_{PR} are real numbers with values in the range of −0.5 to 0.5. When TransferCharacteristics is equal to 11 (IEC 61966-2-4) or 12 (Rec. ITU-R BT.1361-0 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 MatrixCoefficients is equal to 0, Equations 41 to 43 apply:

$$Y = \text{Round}(G) \quad (41)$$

$$Cb = \text{Round}(B) \quad (42)$$

$$Cr = \text{Round}(R) \quad (43)$$

– Otherwise, if MatrixCoefficients is equal to 8, the following applies:

  – If $BitDepth_C$ is equal to $BitDepth_Y$, Equations 44 to 46 apply:

$$Y = \text{Round}(0.5 * G + 0.25 * (R + B)) \quad (44)$$

$$Cb = \text{Round}(0.5 * G - 0.25 * (R + B)) + (1 << (BitDepth_C - 1)) \quad (45)$$

$$Cr = \text{Round}(0.5 * (R - B)) + (1 << (BitDepth_C - 1)) \quad (46)$$

NOTE 4 – For purposes of the YCgCo nomenclature used in Table 4, Cb and Cr of Equations 45 and 46 may be referred to as Cg and Co, respectively. The inverse conversion for Equations 44 to 46 should be computed as:

$$t = Y - (Cb - (1 << (BitDepth_C - 1))) \quad (47)$$

$$G = \text{Clip1}_Y(Y + (Cb - (1 << (BitDepth_C - 1)))) \quad (48)$$

$$B = \text{Clip1}_Y(t - (Cr - (1 << (BitDepth_C - 1)))) \quad (49)$$

$$R = \text{Clip1}_Y(t + (Cr - (1 << (BitDepth_C - 1)))) \quad (50)$$

  – Otherwise ($BitDepth_C$ is not equal to $BitDepth_Y$), Equations 51 to 54 apply:

$$Cr = \text{Round}(R) - \text{Round}(B) + (1 << (BitDepth_C - 1)) \quad (51)$$

$$t = Round(B) + ((Cr - (1 << (BitDepth_C - 1))) >> 1) \quad (52)$$

$$Cb = Round(G) - t + (1 << (BitDepth_C - 1)) \quad (53)$$

$$Y = t + ((Cb - (1 << (BitDepth_C - 1))) >> 1) \quad (54)$$

NOTE 5 – For purposes of the YCgCo nomenclature used in Table 4, Cb and Cr of Equations 53 and 51 may be referred to as Cg and Co, respectively. The inverse conversion for Equations 51 to 54 should be computed as:

$$t = Y - ((Cb - (1 << (BitDepth_C - 1))) >> 1) \quad (55)$$
$$G = Clip1_Y(t + (Cb - (1 << (BitDepth_C - 1)))) \quad (56)$$
$$B = Clip1_Y(t - ((Cr - (1 << (BitDepth_C - 1))) >> 1)) \quad (57)$$
$$R = Clip1_Y(B + (Cr - (1 << (BitDepth_C - 1)))) \quad (58)$$

– Otherwise, if MatrixCoefficients is equal to 10 or 13, the signal E'_Y is determined by application of the transfer characteristics function as follows and Equations 61 to 68 apply for specification of the signals E'_{PB} and E'_{PR}:

$$E_Y = K_R * E_R + (1 - K_R - K_B) * E_G + K_B * E_B \quad (59)$$

$$E'_Y = (E_Y)' \quad (60)$$

NOTE 6 – In this case, E_Y is defined from the "linear-domain" signals for E_R, E_G and E_B, prior to application of the transfer characteristics function, which is then applied to produce the signal E'_Y. E_Y and E'_Y are real values with the value 0 associated with nominal black and the value 1 associated with nominal white.

$$E'_{PB} = (E'_B - E'_Y) \div (2 * N_B) \quad \text{for } -N_B <= E'_B - E'_Y <= 0 \quad (61)$$

$$E'_{PB} = (E'_B - E'_Y) \div (2 * P_B) \quad \text{for } 0 < E'_B - E'_Y <= P_B \quad (62)$$

$$E'_{PR} = (E'_R - E'_Y) \div (2 * N_R) \quad \text{for } -N_R <= E'_R - E'_Y <= 0 \quad (63)$$

$$E'_{PR} = (E'_R - E'_Y) \div (2 * P_R) \quad \text{for } 0 < E'_R - E'_Y <= P_R \quad (64)$$

where the constants N_B, P_B, N_R and P_R are determined by application of the transfer characteristics function to expressions involving the constants K_B and K_R as follows:

$$N_B = (1 - K_B)' \quad (65)$$

$$P_B = 1 - (K_B)' \quad (66)$$

$$N_R = (1 - K_R)' \quad (67)$$

$$P_R = 1 - (K_R)' \quad (68)$$

– Otherwise, if MatrixCoefficients is equal to 11, Equations 69 to 71 apply:

$$E'_Y = E'_G \quad (69)$$

$$E'_{PB} = (0.986566 * E'_B - E'_Y) \div 2.0 \quad (70)$$

$$E'_{PR} = (E'_R - 0.991902 * E'_Y) \div 2.0 \quad (71)$$

NOTE 7 – In this case, for purposes of the $Y'D'_ZD'_X$ nomenclature used in Table 4, E'_{PB} may be referred to as D'_Z and E'_{PR} may be referred to as D'_X.

— Otherwise (MatrixCoefficients is equal to 14), Equations 72 to 74 apply:

$$E'_Y = 0.5 * (E'_L + E'_M) \quad (72)$$

$$E'_{PB} = (6610 * E'_L - 13613 * E'_M + 7003 * E'_S) \div 4096 \quad (73)$$

$$E'_{PR} = (17933 * E'_L - 17390 * E'_M - 543 * E'_S) \div 4096 \quad (74)$$

NOTE 8 – In this case, for purposes of the IC_TC_P nomenclature used in Table 4, E'_Y, E'_{PB} and E'_{PR} of Equations 72, 73 and 74 may be referred to as I, C_T and C_P, respectively.

Table 4 – Interpretation of matrix coefficients (MatrixCoefficients) value

Value	Matrix coefficients	Informative remarks
0	Identity	The identity matrix. Typically used for GBR (often referred to as RGB); however, may also be used for YZX (often referred to as XYZ); IEC 61966-2-1 sRGB SMPTE ST 428-1 See Equations 41 to 43
1	K_R = 0.2126; K_B = 0.0722	Rec. ITU-R BT.709-6 Rec. ITU-R BT.1361-0 conventional colour gamut system and extended colour gamut system (historical) IEC 61966-2-1 sYCC IEC 61966-2-4 $xvYCC_{709}$ SMPTE RP 177 (1993) Annex B See Equations 38 to 40
2	Unspecified	Image characteristics are unknown or are determined by the application
3	Reserved	For future use by ITU-T | ISO/IEC
4	K_R = 0.30; K_B = 0.11	United States Federal Communications Commission (2003) *Title 47 Code of Federal Regulations* 73.682 (a) (20) See Equations 38 to 40
5	K_R = 0.299; K_B = 0.114	Rec. ITU-R BT.470-6 System B, G (historical) Rec. ITU-R BT.601-7 625 Rec. ITU-R BT.1358-0 625 (historical) Rec. ITU-R BT.1700-0 625 PAL and 625 SECAM IEC 61966-2-4 $xvYCC_{601}$ (functionally the same as the value 6) See Equations 38 to 40
6	K_R = 0.299; K_B = 0.114	Rec. ITU-R BT.601-7 525 Rec. ITU-R BT.1358-1 525 or 625 (historical) Rec. ITU-R BT.1700-0 NTSC SMPTE 170M (2004) (functionally the same as the value 5) See Equations 38 to 40
7	K_R = 0.212; K_B = 0.087	SMPTE 240M (1999) (historical) See Equations 38 to 40
8	YCgCo	See Equations 44 to 58
9	K_R = 0.2627; K_B = 0.0593	Rec. ITU-R BT.2020-2 (non-constant luminance) Rec. ITU-R BT.2100-0 Y′ CbCr See Equations 38 to 40
10	K_R = 0.2627; K_B = 0.0593	Rec. ITU-R BT.2020-2 (constant luminance) See Equations 59 to 68
11	$Y'D'_ZD'_X$	SMPTE ST 2085 (2015) See Equations 69 to 71
12	See Equations 32 to 37	Chromaticity-derived non-constant luminance system See Equations 38 to 40
13	See Equations 32 to 37	Chromaticity-derived constant luminance system See Equations 59 to 68
14	IC_TC_P	Rec. ITU-R BT.2100-0 IC_TC_P See Equations 72 to 74
15–255	Reserved	For future use by ITU-T | ISO/IEC

8.4 Video frame packing type

Type: Unsigned integer, enumeration
Range: 0–15, plus associated flag

VideoFramePackingType indicates the type of packing arrangement used in video frames as specified in Table 5. A flag, QuincunxSamplingFlag, may be supplied with this code point.

QuincunxSamplingFlag indicates whether a quincunx sampling structure is used in the frame packed video representation. When not present or not specified, the value 0 for QuincunxSamplingFlag would ordinarily be inferred as the default value for packed video imagery.

Table 5 – Definition of VideoFramePackingType

Value	Interpretation
0	Each component plane of the decoded frames contains a "checkerboard" based interleaving of corresponding planes of two constituent frames as illustrated in Figure 1
1	Each component plane of the decoded frames contains a column based interleaving of corresponding planes of two constituent frames as illustrated in Figure 2
2	Each component plane of the decoded frames contains a row based interleaving of corresponding planes of two constituent frames as illustrated in Figure 3
3	Each component plane of the decoded frames contains a side-by-side packing arrangement of corresponding planes of two constituent frames as illustrated in Figure 4 and Figure 6
4	Each component plane of the decoded frames contains top-bottom packing arrangement of corresponding planes of two constituent frames as illustrated in Figure 5
5	The component planes of the decoded frames in output order form a temporal interleaving of alternating first and second constituent frames as illustrated in Figure 7
6	The decoded frame constitutes a complete 2D frame without any frame packing (see Note 4).

NOTE 1 – Figure 1 to Figure 6 provide typical examples of rearrangement and upconversion processing for various packing arrangement schemes. In Figure 1 to Figure 6, upconversion processing is performed on each constituent frame to produce frames having the same resolution as that of the decoded frame. An example of the upsampling method to be applied to a quincunx sampled frame as shown in Figure 1 or Figure 6 is to fill in missing positions with an average of the available spatially neighbouring samples (the average of the values of the available samples above, below, to the left and to the right of each sample to be generated). The actual upconversion process to be performed, if any, is outside the scope of this Specification.

NOTE 2 – A sample aspect ratio (SAR) should be signalled appropriately to describe the intended horizontal distance between the columns and the intended vertical distance between the rows of the luma sample array in the decoded frame. For the typical examples in Figure 1 to Figure 3 with an SAR of 1:1 for the upconverted colour plane, signalling an SAR of 1:1 is appropriate. For the typical examples in Figure 4 and Figure 6 with an SAR of 1:1 for the upconverted colour plane, signalling an SAR of 2:1 is appropriate. For the typical example in Figure 5 with an SAR of 1:1 for the upconverted colour plane, signalling an SAR of 1:2 is appropriate.

NOTE 3 – VideoFramePackingType equal to 5 describes a temporal interleaving process of different frames.

NOTE 4 – VideoFramePackingType equal to 6 is used to signal the presence of 2D content (that is not frame packed) in 3D services that use a mix of 2D and 3D content.

All other values of VideoFramePackingType are reserved for future use by ITU-T | ISO/IEC.

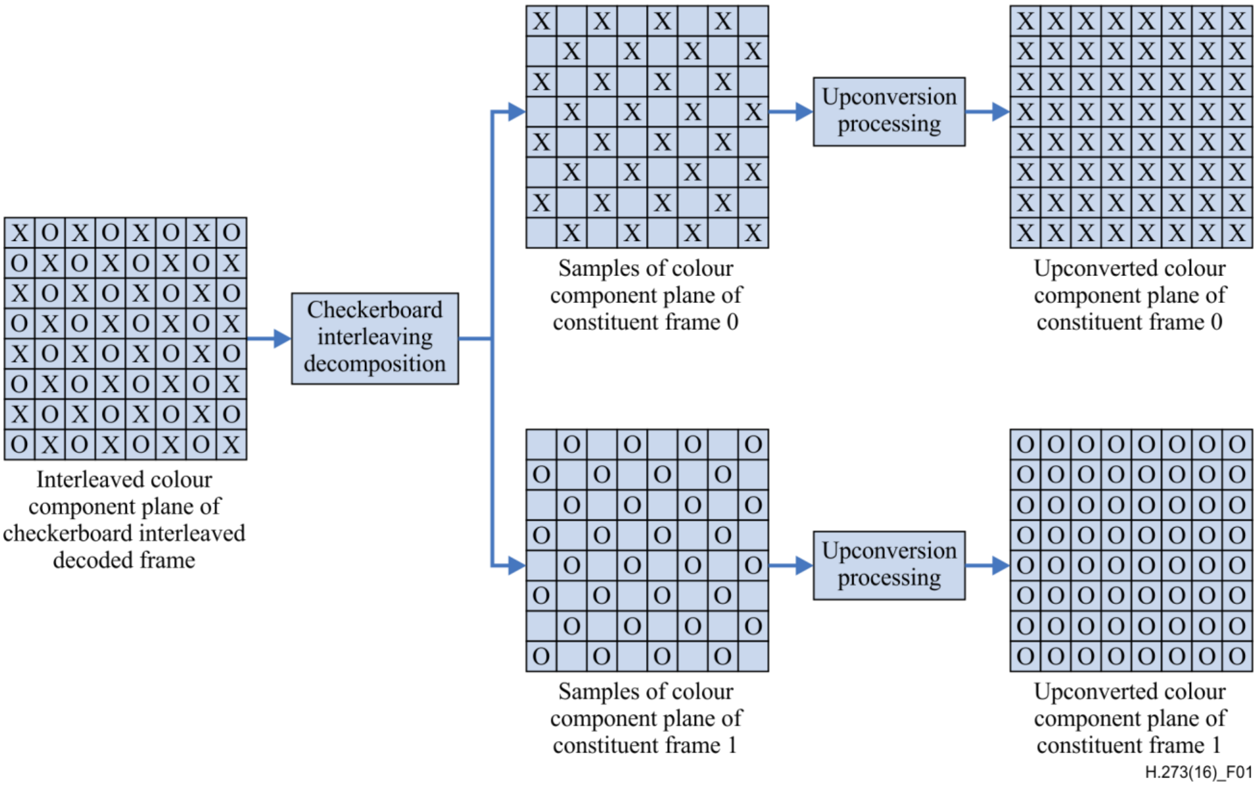

Figure 1 – Rearrangement and upconversion of checkerboard interleaving (VideoFramePackingType equal to 0)

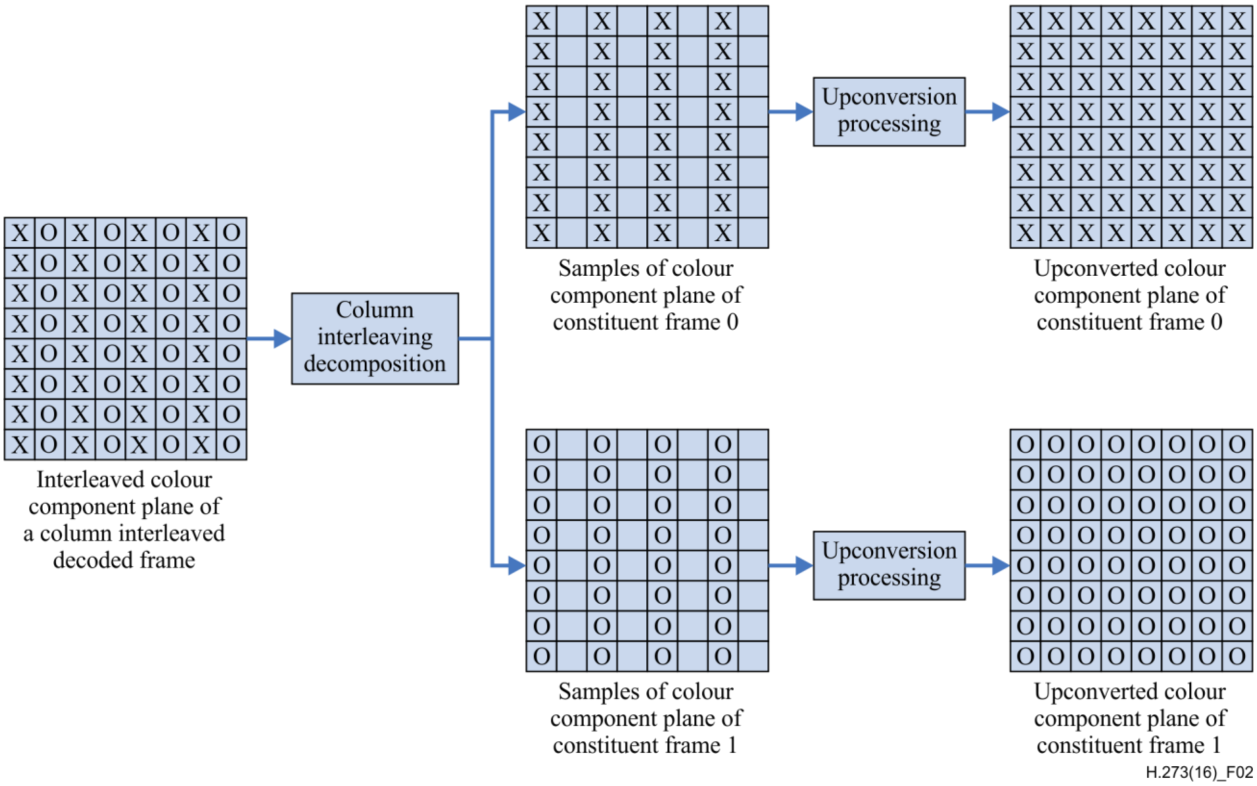

Figure 2 – Rearrangement and upconversion of column interleaving (VideoFramePackingType equal to 1 with QuincunxSamplingFlag equal to 0)

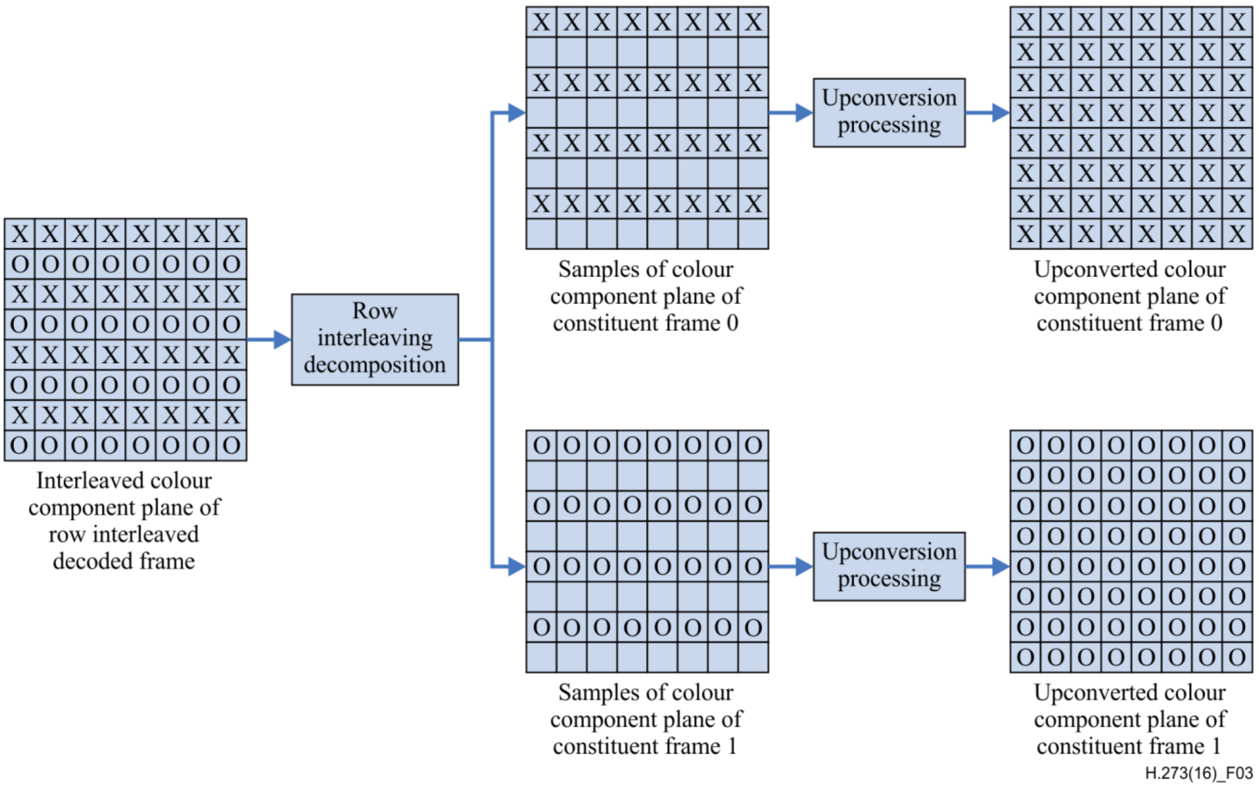

Figure 3 – Rearrangement and upconversion of row interleaving (VideoFramePackingType equal to 2 with QuincunxSamplingFlag equal to 0)

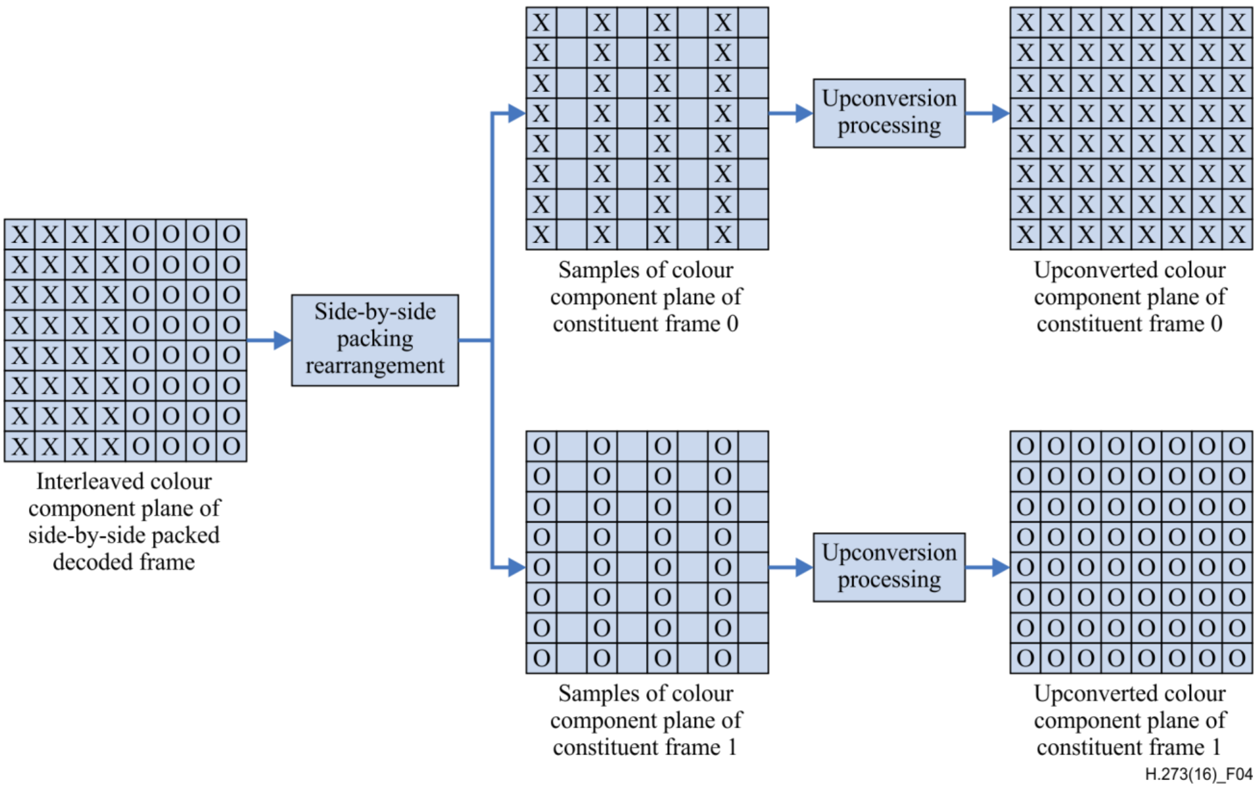

Figure 4 – Rearrangement and upconversion of side-by-side packing arrangement (VideoFramePackingType equal to 3 with QuincunxSamplingFlag equal to 0)

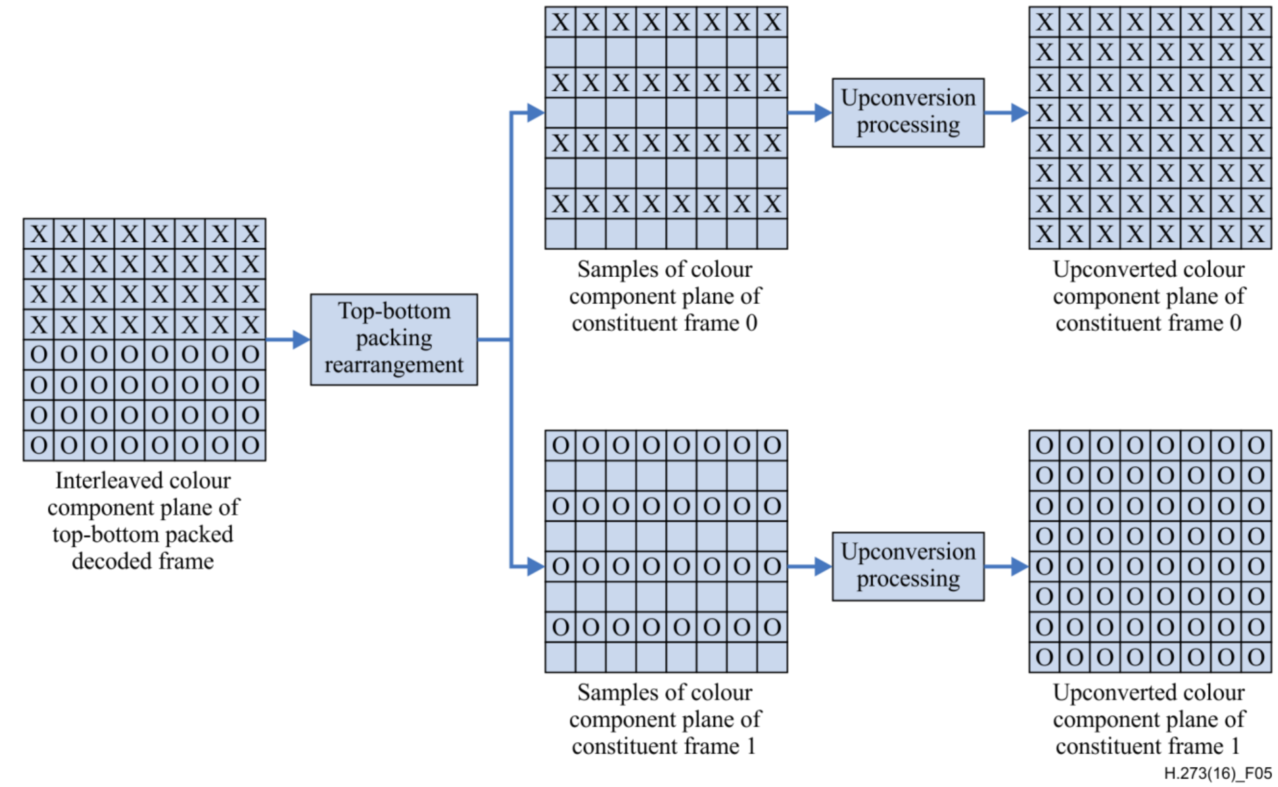

Figure 5 – Rearrangement and upconversion of top-bottom packing arrangement (VideoFramePackingType equal to 4 with QuincunxSamplingFlag equal to 0)

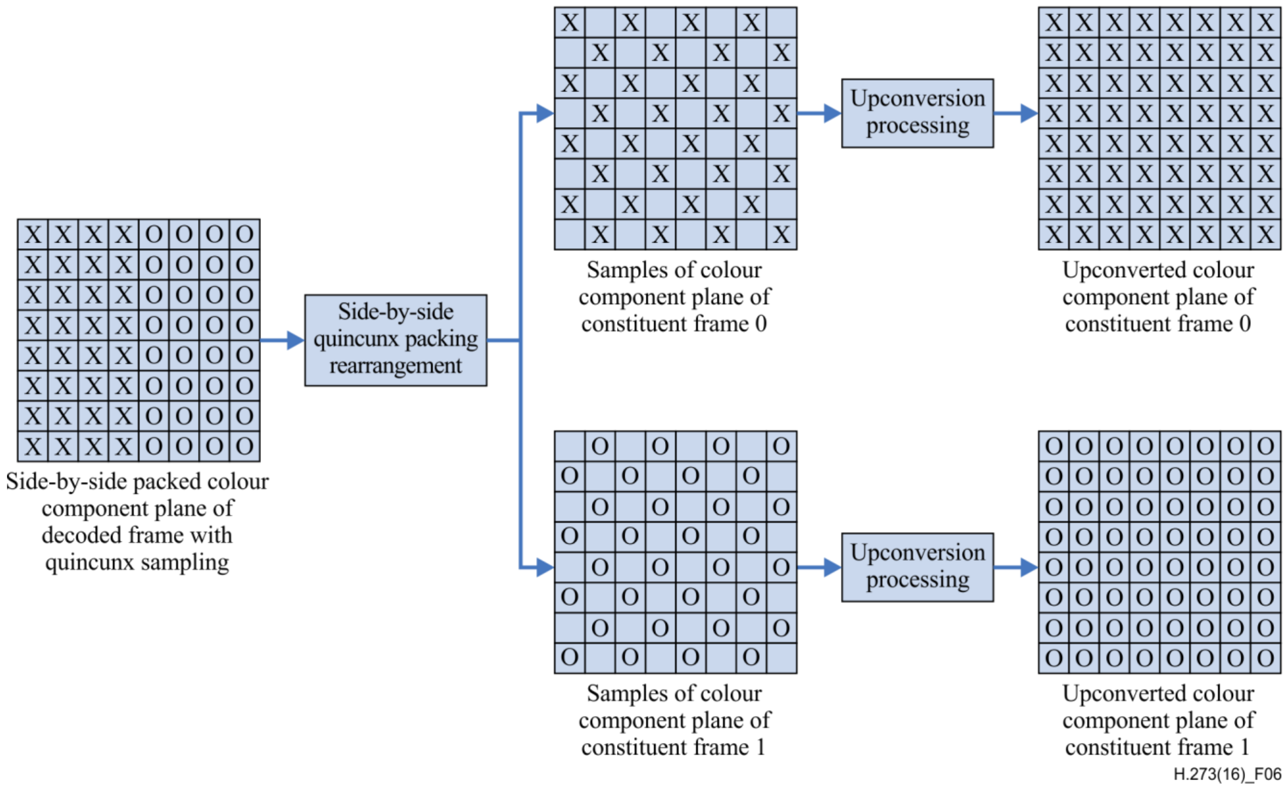

Figure 6 – Rearrangement and upconversion of side-by-side packing arrangement with quincunx sampling (VideoFramePackingType equal to 3 with QuincunxSamplingFlag equal to 1)

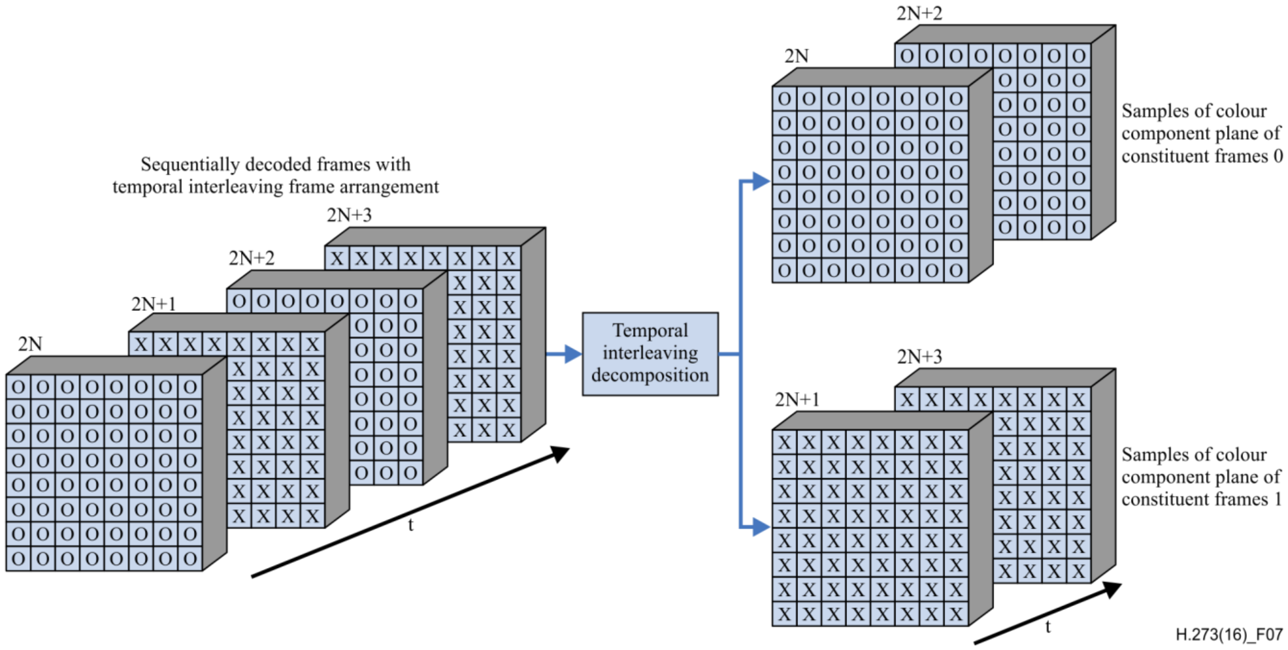

Figure 7 – Rearrangement of a temporal interleaving frame arrangement (VideoFramePackingType equal to 5)

8.5 Packed video content interpretation

Type: Unsigned integer, enumeration
Range: 0–15

PackedContentInterpretationType indicates the intended interpretation of the constituent frames as specified in Table 6. Values of PackedContentInterpretationType that do not appear in Table 6 are reserved for future specification by ITU-T | ISO/IEC.

NOTE 1 – All currently specified packed content interpretation types are for purposes relating to stereoscopic video imagery.

For each specified frame packing arrangement scheme, there are two constituent frames that are referred to as frame 0 and frame 1.

Table 6 – Definition of PackedContentInterpretationType

Value	Interpretation
0	Unspecified relationship between the frame packed constituent frames
1	Indicates that the two constituent frames form the left and right views of a stereo view scene, with frame 0 being associated with the left view and frame 1 being associated with the right view
2	Indicates that the two constituent frames form the right and left views of a stereo view scene, with frame 0 being associated with the right view and frame 1 being associated with the left view

NOTE 2 – The value 2 for PackedContentInterpretationType is not expected to be prevalent in industry use. However, the value was specified herein for purposes of completeness.

8.6 Sample aspect ratio indicator

Type: Unsigned integer, enumeration
Range: 0–255

SampleAspectRatio, when present and not equal to 255, indicates the value of the sample aspect ratio of the luma samples. Table 7 shows the meaning of the code. When SampleAspectRatio is not present or is equal to 255, the sample aspect ratio is indicated by SarWidth : SarHeight.

Table 7 – Meaning of sample aspect ratio indicator (SampleAspectRatio)

Value	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	SarWidth : SarHeight	

NOTE – For the examples in Table 7, 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 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 SampleAspectRatio 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.

When SampleAspectRatio is not present or is equal to 255, the following applies:

– If SarWidth and SarHeight are present and are not equal to 0, the values of SarWidth and SarHeight shall be relatively prime, and the following applies:
  – **SarWidth** indicates the horizontal size of the sample aspect ratio (in arbitrary units).
  – **SarHeight** indicates the vertical size of the sample aspect ratio (in the same arbitrary units as SarWidth).
– Otherwise, the sample aspect ratio shall be considered unspecified by this Specification.

When SampleAspectRatio is present and is not equal to 255, if SarWidth and SarHeight are present, their values shall be equal to the values specified in Table 7.

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